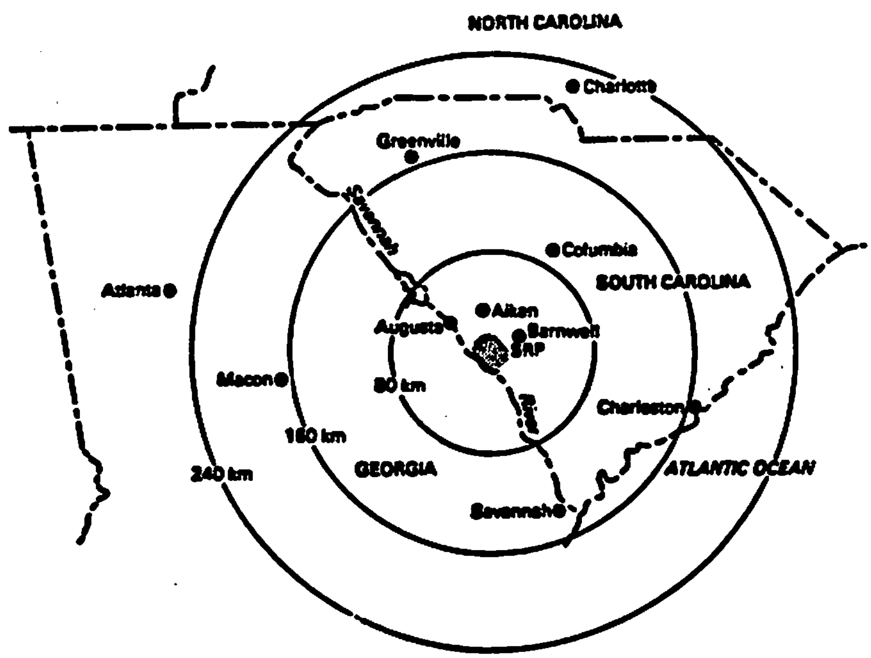
DEADLY CROP IN THE TANK FARM

An Assessment of the Management of High-Level
Radioactive Wastes in the Savannah River Plant
Tank Farm, Based on Official Documents



Arjun Makhijani, Ph.D.*
Robert Alvarez**
Brent Blackwelder, Ph.D.***

* Associate Professor, Capitol Institute of Technology
** Director, Nuclear Weapons and Power Project, Environmental Policy Institute
*** Vice-President, Environmental Policy Institute

Corrections were made to several pages, in January 2012.
Changes to pages 27 and 29 are described at http://www.ieer.org/errata.html.

TABLE OF CONTENTS

PREFACE

Although much attention over the past decade has been focused on accidental large-scale releases of radioactivity from commercial nuclear reactors, a similar potential exists at federal nuclear facilities. In recent years, the risks and consequences of major radiation accidents as well as the health and environmental effects from the routine operations of the facilities owned by the U.S. Department of Energy (DOE) have also become the subject of increasing concern. One principal reason is that the various DOE installations have now been operating for two to four decades, and the evidence of adverse health effects from exposure to radioactivity is now accumulating at an alarming rate. This applies to various exposed populations such as workers at DOE facilities, the veterans of atomic tests and the people who lived in the path of the fallout from these tests.

There also exists the potential for serious damage from large releases of radioactivity resulting from operating accidents or from events outside the control of DOE, such as earthquakes. Very large quantities of radionuclides in liquid form are present at some DOE facilities. In particular, the facilities at the Savannah River Plant in South Carolina and at Hanford in Washington state, contain very large quantities of radionuclides in liquid form, which are particularly dangerous because of their mobility. Large quantities of toxic non-radioactive wastes also exist at these sites. The terrible actuality of a massive accident involving nuclear high-level radioactive wastes has already been experienced in the Ural mountain region of the Soviet Union where U.S. intelligence sources and exiled Soviet scientists suggest an explosion in 1957 severely contaminated several hundred square miles and resulted in a major loss of life. A potential for similar explosive accidents or loss of containment from earthquakes also exists at the Savannah River Plant site.

The tragic accidental release of methyl isocyanate at a Union Carbide plant in Bhopal, India which killed more than 2,500 people and injured tens of thousands with long term effects underlines the need to pay much more attention to events which may have a small probability of occurring but which are disastrous if they do occur.

Initiated in 1981, this study is an independent evaluation of the management of the high-level radioactive wastes in the Tank Farm at the Savannah River Plant (SRP). These wastes come primarily from the manufacture of plutonium for nuclear warheads. Plutonium is produced in nuclear material production reactors and extracted at SRP's two reprocessing plants.

Our study is based upon that part of the official record which has been made public (some of it through Freedom of Information Act requests filed by the Environmental Policy Institute in 1981). In all over 14,000 summaries of reported accidents, worker exposures, spills, equipment failures and non-routine maintenance at the SRP Tank Farm were made available to us for analysis. However, a great deal more data, particularly technical monthly reports, and more detailed measurements of worker exposures and environmental contamination is still held secret by the U.S. Department of Energy and its contractor, E.I. du Pont de Nemours and Company. This secrecy, which we believe for the most part is not justified, means that limitations have been put on our research. Nonetheless, many conclusions emerge rather clearly, and we have tried to delineate these and other issues as best the available information permits.

The study comes not only in the context of a heightened concern about DOE nuclear facilities, but also at a time when the public and Congress are considering renewal of a federal law known as the Price/Anderson Act.

Enacted by the U.S. Congress in 1957, and renewed every ten years, the Price/Anderson Act is designed to deal with major nuclear accidents occurring at federal and civilian nuclear facilities. The principal mechanism in the law is a ceiling on the total limit of liability that private utilities and the federal government can bear. Under the law, some 280 DOE nuclear facilities are covered with the liability limit set at $500 million. DOE contractors are completely shielded from liabilities arising from a major nuclear accident. We hope that the data and analysis presented in this study will be a contribution to the public debate on this question which is not only important for our generation, but for future generations at well.

We would like to thank the people who reviewed our report and provided useful criticisms and comments. Dr. Peter Bickel, Professor of Statistics and Divisional Dean of the College of Arts and Sciences, University of California, Berkeley, reviewed statistical portions of the end of Chapter 3 and the portion of Chapter 5 dealing with calculations of failure probabilities and the statistical model used by DOE and DuPont for risk estimates. Robert Alexander, Chief of the Occupational Standards Branch of the Nuclear Regulatory Commission's Office of Research and his staff, reviewed Chapter 7 which deals with occupational exposures. Dr. Alice M. Stewart, MD, Senior Research Fellow at the University of Birmingham School of Social Medicine in England reviewed various epidemiological studies pertaining to the Savannah River Plant and offered advice on their interpretation. Dr. Karl Z. Morgan, former Director of Health Physics at Oak Ridge National Laboratory, reviewed Chapter 6 and 7. William Lawless, professor of Mathematics at Payne College, Augusta, Georgia, and former senior engineer for the Department of Energy at SRP, reviewed the entire report and made several helpful comments and criticisms. Yaaron Sternberg, Professor of Civil Engineering, University of Maryland, reviewed sections of Chapter 6 pertaining to hydrology at SRP. Bernd Franke, Senior Research Fellow at the Institute for Energy and Environmental Research in Heidelberg, West Germany, reviewed Chapter 6. Dr. Uta Boiket of the University of Bremen in West Germany also reviewed Chapter 6 and made comments on soil contamination. David Albright, research fellow at the Federation of American Scientists, reviewed portions of the Fault Tree Data Bank on occupational exposures and helped derive dose estimates for plutonium depositions. Dr. Roland Finston, Health Physics officer at Stanford University (California) provided advice on estimating cancer risks.

The conclusions and recommendations of this report are ours alone and not necessarily those of the reviewers.
Their comments were vital in improving the report and we are deeply indebted to them. We would also like to thank Jackie Williams and Diana Kohn, who helped type, edit and prepare the the report for publication.

Finally, we would like to express our thanks to the Mary Reynolds Babcock Foundation whose financial support made this report possible, and to Frances Close Hart who helped encourage its initiation and final completion.

Washington, D.C.
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Arjun Makhijani
Robert Alvarez
Brent Blackwelder

CHAPTER ONE
SUMMARY AND RECOMMENDATIONS

Eight hundred million curies of deadly high-level radioactive wastes are stored in the Savannah River Plant (SRP). Although 27 million gallons of these wastes constitute about one third of the total volume of military high-level radioactive wastes in the U.S., they contain about 78 percent of the total radioactivity in all U.S. military high-level wastes. SRP's high-level wastes pose a serious threat to the plant's workers, to the people who live in substantial portions of South Carolina and Georgia, to future generations and to the environment. The rates of radiation--related cancers among workers are already significantly higher than expected. The plant site borders the Savannah River and sits atop the Tuscaloosa aquifer, one of the most prolific and used sources of fresh water in the eastern United States. The 300 square mile site and the shallow aquifers above the Tuscaloosa are so severely contaminated that it is reasonable to conclude that it has been treated by the federal government as a national sacrifice area for the U.S. nuclear weapons program.

The high-level radioactive wastes which continue to build up at the Savannah River Plant result from the production of radionuclides for the U.S. nuclear weapons program. In particular most of the wastes come from the production of plutonium in nuclear reactors and the subsequent reprocessing of the reactor fuel rods in chemical separations plants. The SRP is owned by the U.S. Department of Energy (DOE) and operated under contract by E.I. du Pont de Nemours and Company (DuPont). Most of the major equipment--such as the reactors and reprocessing plants, as well as many of the tanks, date back to the 1950s. This is a field in which technological change and safety standards have changed rapidly. Yet in recent years the basic approach to waste management at the Savannah River Plant Tank Farm has changed but little. In fact, the operating record of the obsolete facility shows that its very design basis was faulty and dangerous.

There is also substantial evidence that these problems have been compounded by unsatisfactory management in many areas crucial to safety. Both DuPont and DOE appear to be more anxious to minimize any adverse consequences and thus allay public fears than to address operating problems and risks from accidents in a scientific and technically responsible manner.

We will summarize the issues discussed in detail in the main body of the report (where the references are provided) under the following four headings:

o Routine Environmental Contamination
o Accidents and Risks
o Worker Exposures and Cancer Risks
o Long-Term Waste Management

Routine Environmental Contamination

"...Severe contamination in the upper aquifer (at SRP) poses an imminent threat to a deeper aquifer that supplies drinking water to plant employees and off-site communities."
Environmental Protection Agency
October 1983

"...hazardous surface concentrations (of mercury) may exist well beyond the period over which land control can be anticipated and indeed may exist centuries or mellenia into the future..."
Internal Savannah River Laboratory Report.

The design of the Savannah River Plant assumed that radioactive wastes could be routinely discharged into the soil because the soil would trap them and prevent them from contaminating water supplies, particularly in the case of some of the more deadly materials like plutonium and cesium-137. Little thought appears to have been given to pollutants from non-radioactive toxic materials and less to interactions between the two kinds of pollution.

Time has shown both the design premise and the omissions to be serious errors. Radioactive materials and non-radioactive toxics have contaminated the shallow aquifers beneath SRP. Interaction between solvents and plutonium has caused it to migrate into the groundwater in twenty years - compared to a predicted time of hundreds of thousands of years. Despite repeated internal and external efforts to stop these dangerous and technically obsolete and erroneous practices. DuPont and DOE continue routine discharges of toxic materials into the soil.

If the SRP site is not to become a permanent national sacrifice area, a massive clean-up of the site will be required. DOE has estimated that the first seepage basin cleanup would require a billion dollars. Whether this will consist of something more than putting the toxic wastes in cardboard boxes and drums (until 1984 a common practice at SRP) remains to be seen.

The problem of clean-up is bound to be severely complicated by a lack of data and unreliability of such data as there is. In regard to non-radioactive toxic materials other than mercury, such as PCB's and organic solvents, hardly any data exist. Even the data on high-level waste contain serious uncertainties, notably in relation to plutonium content of the waste.

We have two widely differing estimates for plutonium in the high-level waste tanks. Data in DuPont Safety Analysis Report (issued in 1978) yields, an estimate of about 170 kilograms of plutonium containing 300,000 curies of radioactivity, for 1980. However, in 1980 DuPont supplies an estimate of 1 million curies of plutonium - about 400 kilograms - to the National Academy of Sciences. This enormous discrepancy, serious both for plutonium accounting from the security point of view, and for its potential environmental consequences, is unexplained at least in the public record.

Finally, despite the evidence, and the judgment of the Environmental Protection Agency, DOE and DuPont continue to operate the plant as if there is no danger to the deeper aquifers which are used by the public. Indeed, the official plans to start up the L-reactor to increase plutonium production call for considerably greater water use, which could further increase the likelihood of contamination of the vital Tuscaloosa aquifer.

Accidents and Risks

Some of the most technically difficult aspects of waste management at SRP have to do with the problems associated with accidents and risks to the public and to future generations. Both in relation to accidents that have occurred and the risks from potential accidents, DOE and DuPont discount as "insignificant" problems related to groundwater contamination, using scientifically flawed assumptions and methods. The data base has been arbitrarily kept and is of little statistical validity when it comes to some of the most crucial accidents.

Consider, for example, the question of hydrogen build-up in the high-level waste tanks. Hydrogen gas is generated in the tanks due to the action of radiation on hydrogen-containing chemical compounds in the waste. A build-up of hydrogen to high enough levels, due to partial or total failure of tank ventilation systems for example, could cause an explosion severe enough to destroy the tank and send millions of curies of radioactive waste spewing into the air and onto the land. Such an accident could cause up to 20,000 cancer cases in addition to genetic damage and other ill-health effects. In addition, a very large area of land would have to be written off essentially forever. It would also have unpredictable repercussions, possibly very severe, for groundwater contamination.

The DOE and DuPont approach to such accidents irresponsibly assumes that groundwater contamination can be ignored as "insignificant" because the soil will retain the radioactive wastes. This assumption has been shown to be invalid by SRP's own operating experience and has been criticized by the U.S. Geological Survey. DOE and DuPont also assume that water use patterns and many others factors will not change significantly for a hundred years or more. This is not merely arbitrary; it is contrary to evidence. Water use patterns have changed immensely in the past few decades with DOE and irrigation being major contributors to that change. Indeed, in other reports, DOE plans on continuing to contribute to significant increases in water use.

The data on hydrogen concentrations are also contradictory. A 1978 public Safety Analysis Report does not cite any explosion in the tanks resulting from a hydrogen build-up. The computerized Data Bank cites one explosion in Tank 6 due to a build-up of hydrogen to only 15% of the lower explosive limit-that is to an amount far less than the minimum required for an explosion, according to official estimate. As another example of defective data, the Data Bank records a maximum hydrogen conceration of 150% of the lower explosive limit in one instance. But the offical Safety Analysis Report implies a maximum of only 100%.

In other areas also data management has been poor. The evidence is that, tens of thousands of non-routine maintenance problems and equipment failures have been arbitrarily omitted from the record of data. In turn, this data has been used to estimate failure probabilities of components. This is only one example among many of serious deficiencies and omissions, all of which downplay systematically the risk from accidents to which the public is being exposed. As noted above, even the estimates of the inventory of plutonium in the waste appears to vary widely.

Besides the dangers from operating accidents and design and construction problems (for example, tank and pipe leaks), there is also the danger of earthquakes. SRP was not designed to withstand severe earthquakes. In the last few years, however, both the U.S. Geological Survey and the Nuclear Regulatory Commission have concluded that severe earthquakes, comparable to the one in Mexico City in 1985, cannot be ruled out. The Nuclear Regulatory Commission has criticized the SRP assumptions of moderate earthquakes at most, to "contain a strong element of speculation."

A severe earthquake could cause hundreds of millions of curies of radioactive wastes to contaminate the air, soil, and water of the area. Even using the non-conservative assumptions of DuPont and DOE, it would cause from 11,000 to 230,000 excess cancers and up to 2,500 genetic defects in future generations. The direct cost, moderately estimated, would be from $800 million to $14 billion - excluding the cost arising from writing off of large areas of land, from contamination of water supplies, from property, agricultural, and business losses.

Current law specifies maximum DOE liability as $500 million. DuPont is exempt from liability to the public in the event of accidents, earthquakes, and other catastrophic events. It exempts contractors from liabilities arising even from their own negligence.

Worker Exposures and Cancer Risks

Workers at SRP receive considerable doses of radiation just by being on the site because of routine emissions and radiation from site contamination. These doses averaged about 260 mrems per year - about 150% more than the doses received off-site from background sources. In addition, various types of work involve additional exposures.

Plant data show that the work in the reprocessing and waste management is especially hazardous in this regard. The greater dangers arise both from the nature of the work involving highly radioactive materials and from the design of the plant. The total recorded exposure to external radiation to workers from 1954-78 was 50,000 person-rem.* The waste and reprocessing area workers constitute one-third of the workforce but received more than half this dose.

The external radiation doses to SRP workers alone can be expected to cause between 16 and 330 excess cancers among SRP workers, with more than half of these expected among waste and reprocessing area workers. Already, there are definite indications at SRP and at other DOE owned nuclear facilities around the country that workers are contracting and dying from radiation related cancers. Some examples:

- At SRP, the incidence of myloid leukemia has been more than double the expected number (6 occurred versus less than 3 expected);
- At the DOE owned Oak Ridge Gaseous Diffusion Plant, a study found "excess deaths due to lung and brain cancers and respiratory disease..."

* When radiation doses are measured for large populations, the unit 'person-rem' is used. This is calculated by multiplying the total number of people exposed times their average dose in rems. Or, it can be the actual sum of all doses they receive.

- o A study of 2,509 DOE workers exposed to more than 5 rems between 1947 and 1978 showed a rate of cancer of the rectum at three times the national average among them.

The emergence of an alarming pattern of excess cancers has elicited a curious response from DuPont. An internal 1976 study by DuPont found "evidence...that lung cancer and leukemia were significantly increased..." among workers. Instead of publishing the study, DuPont attempted to erase the significance of its findings through statistical manipulations. Even an advisory committee to DOE found these manipulations "inappropriate," and recommended that the data be reanalyzed by a non-DOE/DuPont group.

The data themselves are not in good shape. One of the principal sources of data - the computerized Data Bank for accidents and non-routine maintenance - is missing thousands to tens of thousands of entries. Moreover, there is very little data on internal radiation exposure - through inhalation, ingestion and wounds. Most of the reported data is gathered by obsolete and discredited methods. This is a crucial area for evaluation of safety practices, and liability, since internal exposures are emerging as a principal cause of radiation related cancers. The records of DOE and the Defense Nuclear Agency (Department of Defense) are particularly poor in this regard.

Long-Term Problems

Little attention was paid to the problem of long-term waste management when the plant was designed. In the early years, it was simply assumed, without significant geologic or other systematic scientific investigation, that the wastes could be safely pumped into the bedrock underneath the plant site, and below the much used Tuscaloosa aquifer. Pending such long-term disposal, it was decided to store the wastes in carbon-steel tanks which were much cheaper than stainless steel tanks. However, this required the neutralization of the highly acidic wastes discharged from the SRP reprocessing plants, so that the acid would not corrode the carbon-steel. This created a much larger volume of waste, including sludge which is difficult to handle.

Eight of the first sixteen tanks developed leaks in the primary containment in about a decade. This has required much more handling and moving of the wastes than planned - which in turn causes - more equipment and process problems, worker exposures and environmental contamination.

The plan to dispose of the wastes into the bedrock under the plant has been abandoned in favor of solidifying the wastes by encapsulating them in glass. Solidification of the liquid wastes is urgently needed.

However, the current glassification plans, which are being implemented, face some serious problems.

The operating record does not bode well for the proposed waste vitrification facility at SRP called the Defense Waste Processing Facility. This will require much waste movement and remote operation. If heavy maintenance and repair are required, worker exposures may be increased. Further, there is no operating experience even at the pilot plant level for vitrification of radioactive sludge, which has been the source of considerable handling problems. Unanticipated breakdowns or failure of the plant to operate as predicted could result in costly delays in the implementation of long-term waste management, while at the same time leaving the wastes in the current dangerous liquid form.

DOE also plans to dump very large quantities of "low level" wastes, solidified in concrete, as part of its program. This will increase the radioactivity in the low-level burial grounds many fold. It almost certainly will contaminate the groundwater with very much larger quantities of radionuclides than are already present. In particular, it will increase plutonium-238 contamination by about 100 times, and that by iodine-129 and technicium-99 by several million times over the amounts that have been discharged already as "low-level" wastes into the seepage basins.

Moreover, two of the three sites picked by DOE, for the first repository for long-term disposal of high-level radioactive wastes have characteristics which may rapidly destroy glass.

At Hanford the relatively high water velocity in the repository could erode the glass much faster than required by current regulations. At the Nevada Test Site, low pressures could cause steam to form around the glass, with the same result. In either case, failure of the glass could cause large quantities of radioactive materials to be released into the environment.

For these reasons we recommend that solidification of the wastes by calcining to be done immediately and further generation of liquid high-level radioactive wastes be stopped pending pilot plant construction and resolution of other issues related to long-term management.

General Policy Recommendations

- The Department of Energy should not be allowed to continue to regulate itself or its contractors.
- Current limits on DOE liabilities under the Price/Anderson Act should be lifted. Further, DOE contractors should be held financially accountable for major accidents stemming from their negligence. Both would be great incentives for safety.
- Independent studies on various aspects of the plant such as health and safety decommissioning and long-term disposition of the site should be initiated. All documents relating to these matters should be made public.

Technical Recommendations

- The Savannah River Plant should be barred from producing any more high-level liquid radioactive waste until the long-term questions are satisfactorily resolved.
- Interim solidification, such as calcining of the existing high-level wastes (including sludge) should be done while setting up any pilot plant efforts for long-term management.
- Research and development of remote equipment and working methods to protect workers from radiation and other hazards should be broadened and intensified.
- The practice of using soil as a

disposal medium and surface and groundwater as transportation mediums of toxic materials (radioactive and non-radioactive) should be stopped. All the seepage basins should be shut down on an expedited basis. (Some are now due to be shut down in 1988.)

- An urgent program to clean up contaminated aquifers should be initiated.

CHAPTER 2
SITE CHARACTERISTICS

The Savannah River Plant near Aiken, South Carolina, occupies a nearly octagonal area of 200,646 acres or about 300 square miles on the coastal plain of South Carolina bordering the Savannah River. The tract extends over portions of Aiken, Barnwell and Allendale counties. (See Figure 2.1)

Owned by the Department of Energy and operated under contract by E.I. du Pont de Nemours and Company, the Savannah River Plant is the principal producer of radioisotopes (plutonium and tritium) for the nuclear weapons program. The plant site was picked in 1950 by the Atomic Energy Commission in the wake of the decision by President Truman to manufacture thermonuclear weapons.(1)

In December 1953, the first production reactor began operation and the following year the first warhead materials were chemically separated and sent off-site.

Currently, the Savannah River Plant operation employs about 8,000 workers and comprises five areas. They are:

Reactor or 100 Area

Since 1953 SRP has had five heavy water pressurized reactors operating over the following periods:

R-Reactor 12/1953 - 6/1964 (placed on standby)
P-Reactor 2/1954 - present
L-Reactor 7/1954 - 2/1968 (may be restarted)
K-Reactor 11/1954 - present
C-Reactor 3/1955 - present

The 100 Area reactors discharge radioactive and non-radioactive liquids into a series of seepage basins,(2) of which two are currently in operation.

Chemical Separations or 200 Area

Two spent reactor fuel reprocessing plants are in the 200 Area (F and H). Once spent fuel elements are chemically separated at the F and H facilities, low-concentration radioactive and non-radioactive waste products are discharged into a series of seepage basins. There are three in operation in the F Area and four in the H Area.(3) Other low-level and transuranic wastes are stored in shallow burial pits making-up about 195 acres known as the Burial Ground.(4) High-level wastes as well as some "Low Activity" wastes (See Chapter 3) from the reprocessing plants are stored in a series of tanks, known as the Tank Farm. There are 51 waste tanks in the 200 Area. The 200-Area also contains a tritium processing facility.

Fuel and Target Fabrication Facilities or 300 M Area

Uranium fuel elements for SRP's production reactors are fabricated at this site. This 300 M area contains one seepage basin which has received industrial solvents and uranium wastes.

A Heavy Water Extraction Plant or the 400 Area

This facility was started up in 1952 and has provided deuterium or heavy water which serves as the neutron moderator for the production reactors.

The Savannah River Laboratory or 700 Area

The Savannah River Laboratory has three test reactors and provides supportive research for the plant's activities. The laboratory also has four seepage basins which receive radioactive and non-radioactive wastes.(5)

CMX-TNX Area

This facility performs experimental research in support of the plant's operations and discharges radioactive and non-radioactive wastes into two seepage basins.

Proximity to Population Centers

Approximately 700,000 people live within a sixty-mile radius from the center of the Savannah River Plant. Major population centers near the plant include: Augusta, Georgia (20 miles northwest), Atlanta, Georgia (155 miles to the west and north), Columbia, South Carolina (65 miles northeast), and Savannah, Georgia (85 miles southeast). (See Figure 2.2)

Geology

About 80 percent of the SRP area lies in the Aiken Plateau, a level plain extensively eroded by surface streams with the remainder as alluvial terraces which are adjacent to the Savannah River. The plant complex itself ranges between 300 and 385 feet in elevation.(6)

The geologic profile of the SRP site consists of an overburden with an average thickness of 300 meters and consists of six layered unconsolidated sedimentary formations interbedded with thin layers of clay. (See Figure 2.3) The uppermost sediments comprise about 60 meters and contain the Hawthorne, Barnwell, McBean and Congaree formations. All except the Hawthorne yield water. Water in these shallow aquifers is recharged by the percolation of rainwater. It outcrops on the plant site. Discharges from these formations occur into plant streams or into the Savannah River.

Beneath these shallow formations are the Ellenton and Tuscaloosa formations. The two formations have a combined thickness of about 250 meters, and consist mainly of highly impermeable sands which yield large amounts of water of high quality. Beneath the Tuscaloosa and Ellenton formations is bedrock, which has been considered for many years as a potential storage area for SRP's high-level radioactive wastes.(7)

The Tuscaloosa and Ellenton formations are thought to be separate and distinct from each other. The recharge of these formations is about 18 miles north and east of the SRP site. They discharge into the Savannah River near Augusta, Georgia. Although nearby communities draw their water from these formations where they are closer to the surface, SRP withdraws the largest amounts for its purposes. In recent years, however. irrigation in the counties near SRP have been responnsible for significant withdrawals.

The deeper portions of the Tuscaloosa aquifer extend into Georgia, northern Florida and eastern Alabama. It is used extensively throughout the coastal plain for drinking, agricultural and industrial purposes. (see fig. 2.4)

The bedrock beneath the Tuscaloosa and Ellenton formations is composed of two substances, crystalline and triassic rock. The hydrogeology of the bedrock relative to the aquifers above has been studied extensively, but according to the National Academy of Sciences in 1981 "their relationships to the overlying aquifer are still not certain."(8)

Adding to the uncertainty are assumptions that the formations along the coastal plain may be vulnerable to major earthquakes of the magnitude of the Charleston earthquake of 1886 (Modified Mercali Scale X). SRP is considered to be in a seismic risk zone capable of experiencing major damage. (See Figure 2.5 An earthquake of lesser magnitude is capable of dramatically changing the hydrogeology of the area, as witnessed recently in Idaho.

Surface Hydrology

Six small streams on the plant site flow into the Savannah River to form the surface drainage system. Five streams flow diagonally across the area towards the southwest and are used to dispose of radioactive and non-radioactive discharges from SRP facilities. Since the surface of the SRP site gently slopes toward the sea, the five streams descend 100 to 200 feet before discharging into the Savannah River. Additionally there are over 50 artificial impoundments covering about 3000 acres, the largest of which is Par Pond (2700 acres). Water flowing to the Savannah River is held intermittently in marshes and over 200 naturally occurring basins known as "Carolina Bays." A large swamp borders the Savannah River as it runs past the plant site.

The Savannah River is used for fishing, boating and drinking. Approximately 70,000 people downstream from SRP rely on the river for drinking water.(9)

Climate and Meteorology

The climate in the vicinity of the Savannah River Plant is characterized as having mild winters and long summers with temperatures averaging 48 F in the winter and 85 F in the summer. The average annual humidity is 70%. Rainfall averages 47 inches a year.

Occasionally the area is subjected to severe storms in the forms of hurricanes and tornados.

References

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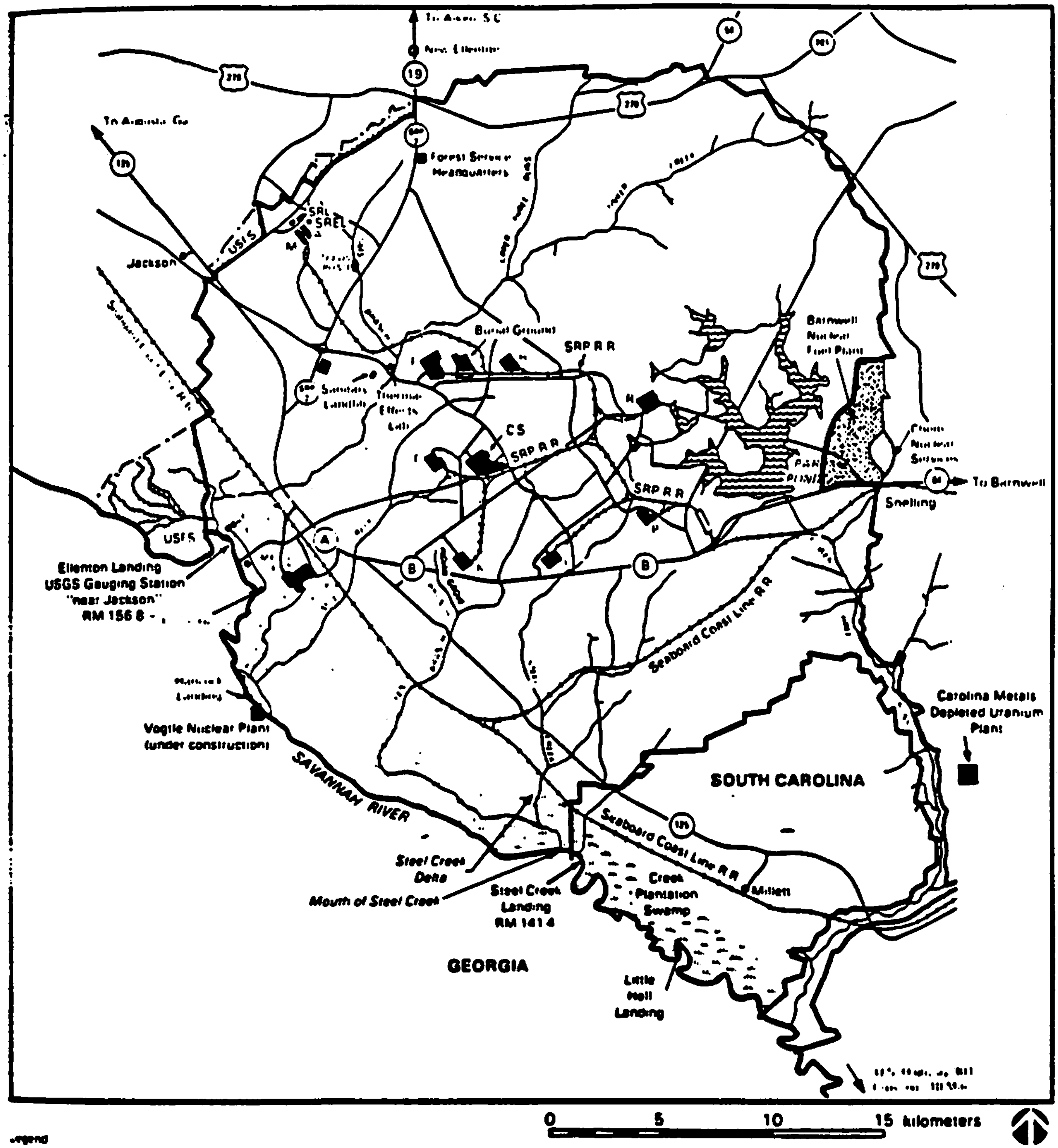
8. Ibid.
9. Op. Cit. Reference 6.



Legend

C K R L P Reactor Areas (C, P, K are operating) Road A = Highway 125
F, H Separations Areas
M Fuel and Target Fabrication
D Heavy Water Production
A Savannah River Laboratory and Administration Area
CS Central Shop
RM River Mile

FIGURE 2.1

Savannah River Plant site.

Source: DOE/EIS-0108b volI p.3.3

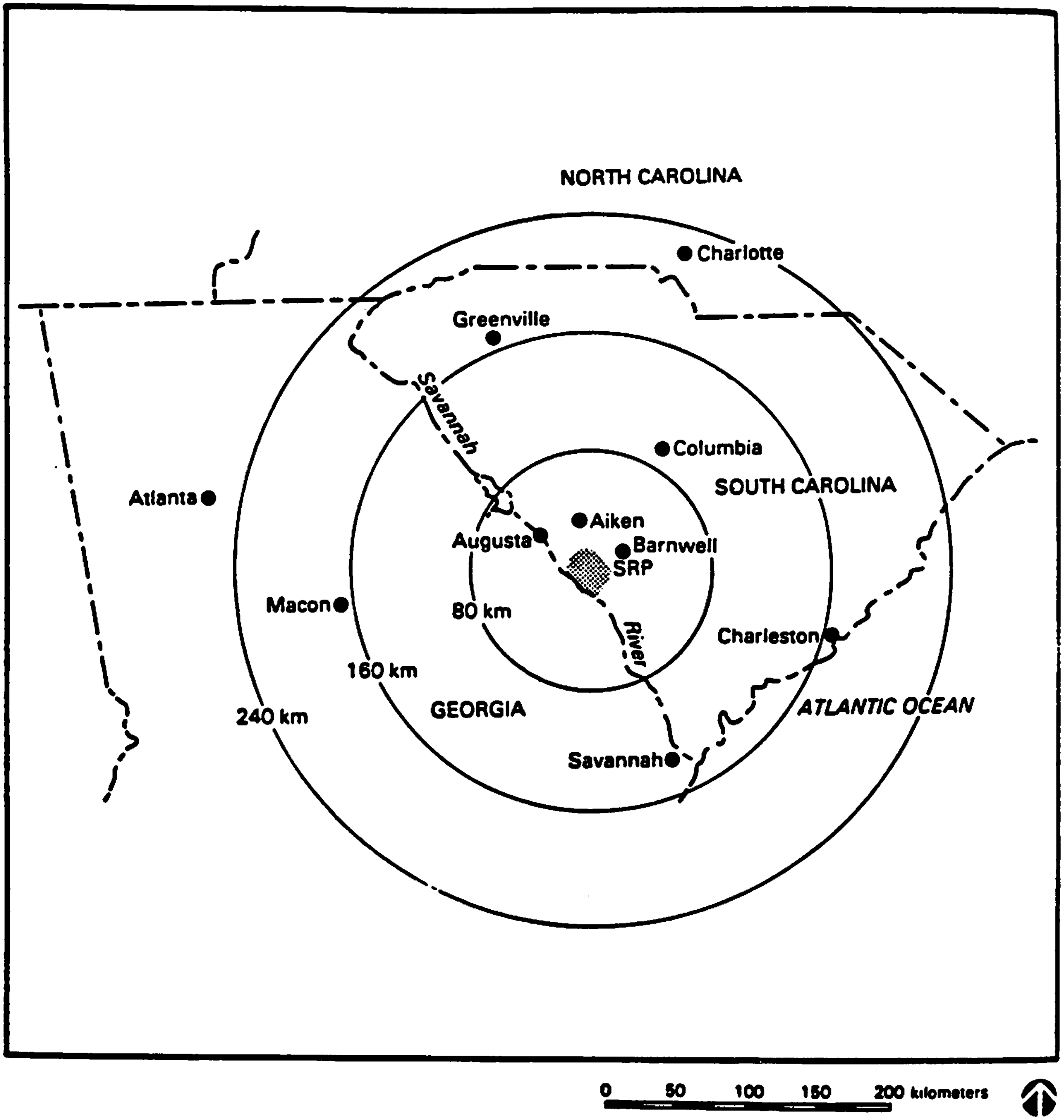
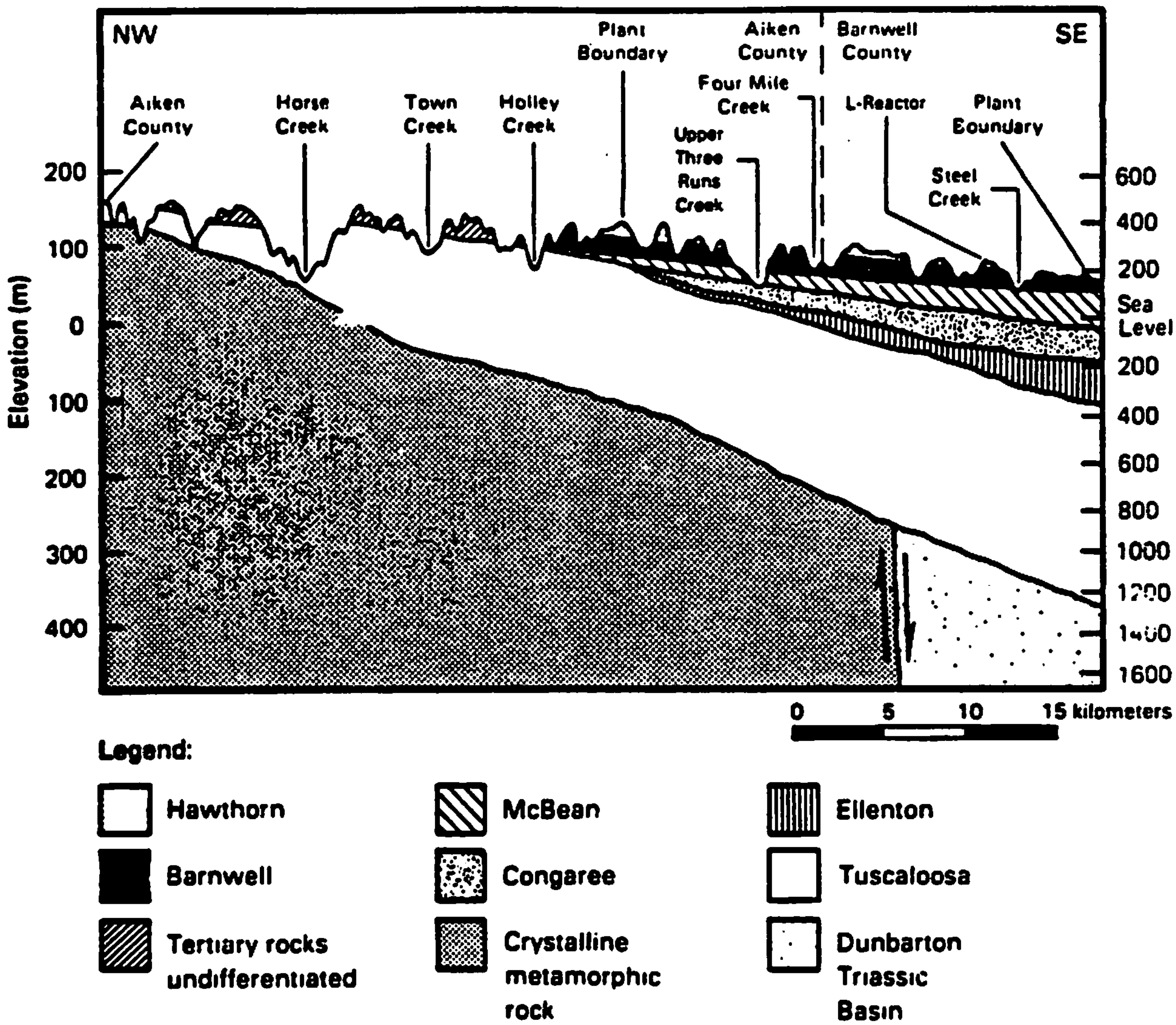


FIGURE 2.2

SRP location in relation to surrounding population centers.

Source: DOE/EIS-0108d volI p.3.2



Source Siple (1967)

FIGURE 2.3

Generalized northwest to southeast geologic profile across the Savannah River Plant.

Source: DOE/EIS-0108b volI p.3-14

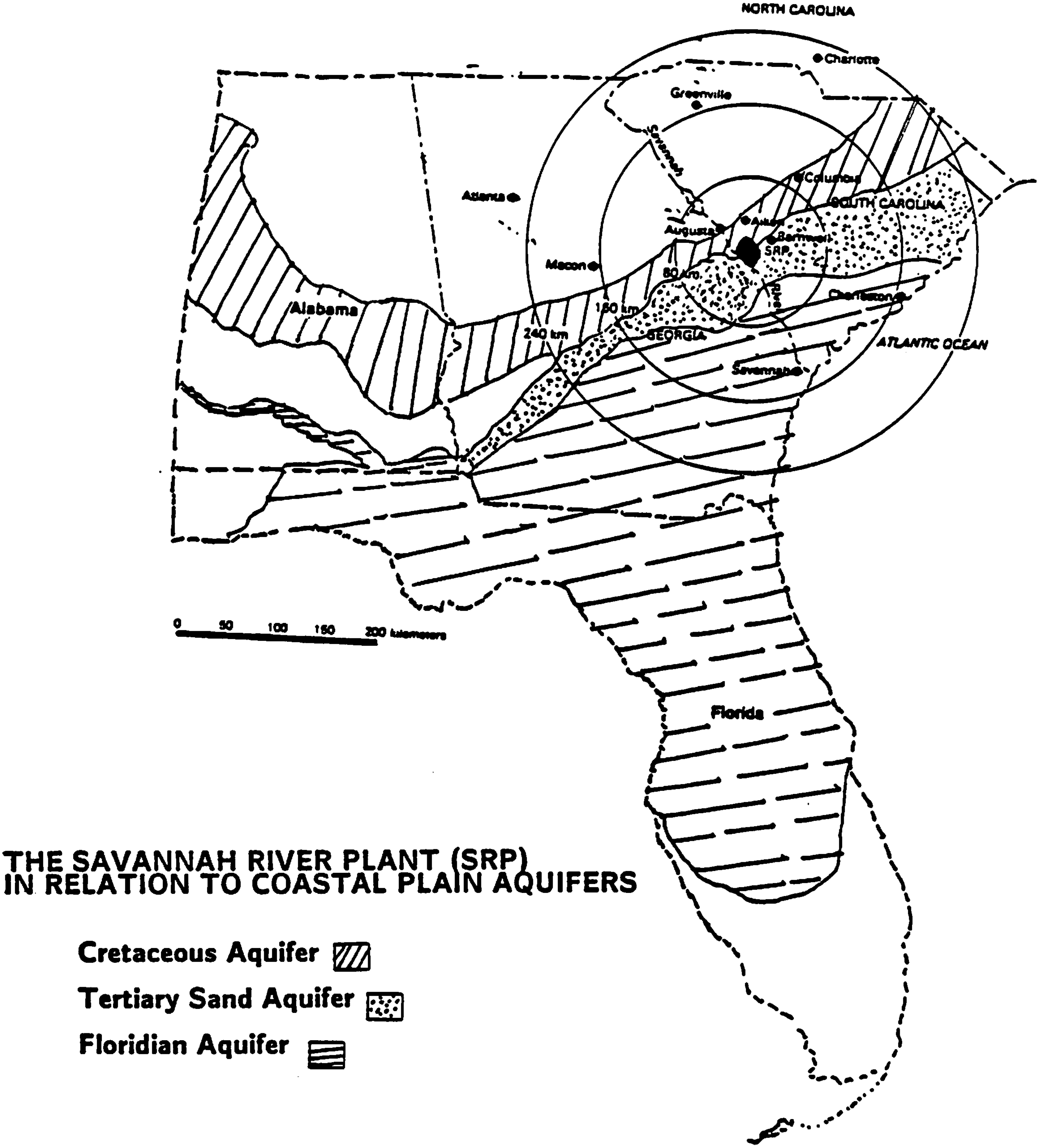
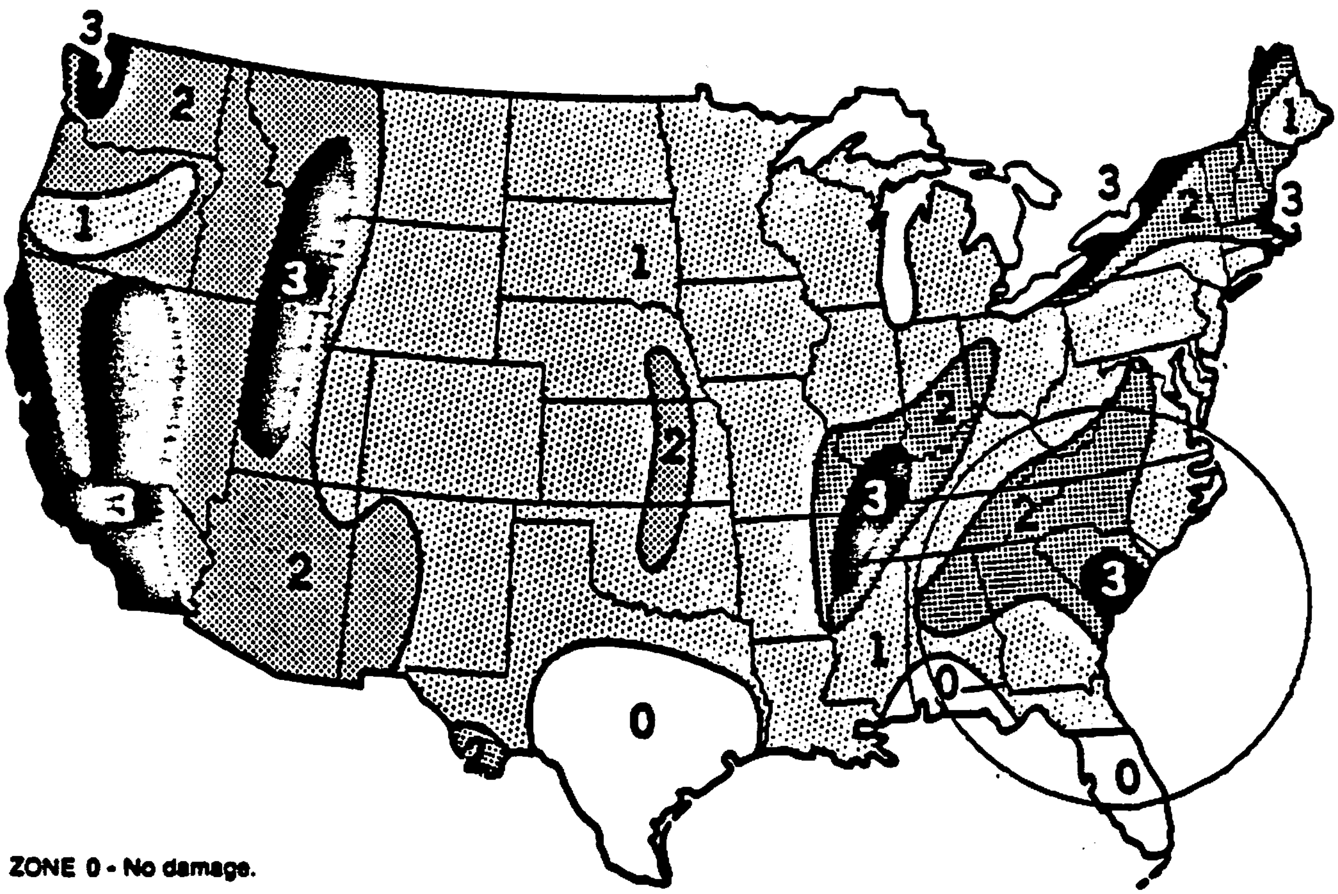


FIGURE 2.4

Sources: United States Geologic Survey Water Supply Paper 2275,
(National Water Summary 1984)

Draft Environmental Impact Statement L-Reactor Operation
Savannah River Plant, DOE/EIS-0108D

SEISMIC RISK MAP FOR THE UNITED STATES. *
The contiguous United States may be assigned to risk categories as indicated in the figure. These categories correspond to intensities on the Modified Mercalli Intensity Scale, as indicated. (Figure origin: "United States Earthquake, 1968," U.S. Department of Commerce, U.S. Coast and Geodetic Survey, 1970.)



ZONE 0 - No damage.

ZONE 1 - Minor damage: distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 seconds: corresponds to intensities V and VI of the M.M.* Scale.

ZONE 2 - Moderate damage: corresponds to intensity VII of the M.M.* Scale.

ZONE 3 - Major damage: corresponds to intensity VIII and higher of the M.M.* Scale.

FIGURE 2.5

* Source: Nero, A.V.,"A Guidebook to Nuclear Reactors," University of California Press (Berkeley and Los Angeles), 1979, Fig. 4-2, p. 57.

CHAPTER 3
INTRODUCTION TO THE TANK FARM OPERATION

The extraction of plutonium, and uranium from irradiated fuel rods results in large volumes of liquid wastes which contain the waste products from the fission of uranium-235 and plutonium. The wastes also inevitably contain some plutonium, uranium and neptunium since they cannot be completely extracted. These liquid wastes are highly radioactive and highly acidic. They are classified into "high-level waste" and "low-level" or "low activity wastes"* according to the amount of heat they produce per unit volume. The high-level wastes produce decay heat of 0.5 to 5 BTU/hr./gal.** The "low-activity" waste contains 3 to 5 orders of magnitude less fission products per unit volume than high-level waste. The variety of radioactive materials contained in each type of waste is the same and the handling of the wastes is similar except in two respects.

First, the high level waste must be allowed to decay for a year or more ("aging" of the waste) to decrease the radioactivity and heat content before further treatment. The "low activity" waste is not "aged." Second, "low activity" waste is stored in uncooled, single-wall tanks, while most high-level waste is stored in cooled, double-wall tanks. Figure 3.1 shows the treatment of wastes in the reprocessing "canyons" before discharge to the pipes that carry them to the tanks.

Large quantities of other radioactive wastes are generated at the Savannah River Plant. Principal among these is tritium which is released to the atmosphere, to the seepage basins, and to the Burial Ground.

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*The official papers and documents contain conflicting uses of the term "low-level" waste. In presentations to the National Academy of Sciences in 1969, "low-level" waste was defined as above. However, the report on waste management DPSTSA-200-3, of the E.I. du Pont de Nemours and Company, refers to "low-level liquid wastes" as those which are directly discarded to the environment. It refers to the dilute wastes from the secondary recovery cycles which are processed in the Tank Farm as "Low Activity Wastes". We will use the designation "low activity waste" in quotes in this report, for these latter wastes, and "low-level" wastes in quotes for liquid wastes discharged to the seepage basins or to other areas of the environment directly.

**One Btu, or British thermal unit, is the amount of heat required to raise the temperature of 1 pound of water by 1 degree Farenheit.

Figure 3.2 shows a schematic diagram of the handling of the high-level waste in the Tank Farm. The waste pipe ("header") carries the waste by gravity flow from the reprocessing area to a "diversion box." This contains the piping enabling the selection of the tank to which the waste is first routed. The routing of the waste has turned out to be a complicated and dangerous process, as we shall see. The selected tank is filled with the waste, which is known as "high heat waste" at this stage. It is allowed to "age" for at least one year in this tank. During this period the relatively short half-life radionuclides like zirconium-95 decay considerably. Also during this period most of the radionuclides, with the major exception of the cesium isotopes, settle to the bottom of the tank and form a fairly distinct layer of "sludge." This sludge contains from 80% of the zirconium-95 and ruthenium-106 to 98% of the strontium and plutonium isotopes. However, 95% of the cesium remains in the liquid above the sludge, known as "supernate" (supernatant liquid), or in the interstices in the sludge. (4)

The sludge is only 10% of the volume of the high-heat waste, but it generates 50% of the heat since it contains most of the radioactive materials. The radioactivity in the supernate consists primarily of radio-cesium. But there are also significant quantities of other very long-lived radionuclides, such as technicium--99 and iodine-129.

After this "aging" and settling process, the supernate is pumped out and sent to another tank. From there it is pumped to an evaporator where it is heated. The water in it evaporates and the vapor entrains some cesium isotopes with it. Most of this entrained cesium is removed in a zeolite ion-exchange column. Then the vapor (called "overheads") is condensed and sent to the seepage basin. These discharges to the seepage basin contain some long-lived radionuclides, including cesium-137 and cesium-135, as is discussed in Chapter 6. The evaporation process substantially reduces the volume of radioactive waste stored in the tanks.

The concentrated solution is sent to a tank for further settling, followed by further evaporation. The salts in the concentrate gradually precipitate out of it in the tanks where they form complex irregular structures. (5) The concentrate-containing tanks thus gradually become filled with salt. The radioactivity in these tanks consists mainly of cesium-137. Finally, when the zeolite in the cesium removal column is depleted, it is "dumped into the waste tank directly underneath it and replaced with a fresh charge." (6)

In summary, there are five kinds of high level radioactivity waste in the Tank Farm at the Savannah River Plant:

o "fresh" high heat waste, discharged from the reprocessing "canyons," being held for "aging";

o the sludge, which is about 10% of the total volume of wastes but contains most of accumulated radionuclides and generates 50% of the heat;

o the supernatant liquid in various stages of concentration containing principally cesium isotopes but also some quantities of other radionuclides;

- o the salt "cakes" which form in the concentrate holding as liquid is evaporated and the remainder becomes more concentrated with salts;

- o spent zeolite which has absorbed radiocesium from the evaporator overheads which is dumped into tanks directly beneath the cesium removal columns.

As of 1981 there were in all about 27.7 million gallons of high-level radioactive waste in the Tank Farm at the Savannah River Plant. (7) About 10% of this is in the form of sludge, about 25% is in the form of salt mounds, and the rest is in (low viscosity) liquid form. (See Table 3.1)

Tables 3.2 through 3.4 show estimates of the quantities of principal fission products, long-lived fission products and actinides like uranium and plutonium. There were according to one estimate a total of about 700 million curies in 1981. The estimate for the end of 1984 would be about 800 million curies extrapolated from an Oak Ridge National Laboratory estimate of 776 million curies through 1983.(8) Roughly half of this is in relatively long-lived radionuclides, principally cesium-137 and strontium-90.

The other radionuclides shown in Tables 3.3 and 3.4 are also of great concern, even though the amounts of radioactivity (compared to cesium-137 and strontium-90) are relatively small, because of their very long half-lives and, in many cases, their very high toxicity. Further, it takes a relatively large quantity of a radionuclide with a long half-life to yield 1 curie of radioactivity. Thus, the amount of stronium-90 in the tanks is about 1,100 kilograms which yields an activity of about 150 million curies. But only 3 curies of activity yields about the same weight of uranium-235.

There is some question as to the accuracy of these estimates since official data appear to yield substantially different values.

The estimates for the actinides like plutonium and americium in Table 3.4 above are based on figures drawn from an Energy Research and Development Administration report. This data yields a figure of about 300,000 curies for the plutonium-238 inventory for 1981. This is also the figure we get using the data from the 1978 DuPont Safety Analysis Report.(10) However, the data supplied by DuPont in 1980 to the National Academy of Sciences cites a total inventory of 1 million curies for 1981 or more than three times the above figure.(11)* These enormous

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*Average waste composition changes only very slowly so that the estimates based on 1978 compositions and 1981 compositions should be in close agreement, unless there was a major unreported discharge of plutonium between 1978 and 1981.

discrepancies can have serious implications for long-term waste management as well as for assessments of risks posed by the 200 Area Tank Farm operation in case of catastrophic events like hydrogren explosions or severe earthquakes. Table 3.5 summarizes its discrepancies for plutonium.

Most of the high-level waste is contained in cooled tanks which have a secondary containment partly or fully lined with steel.** Due to the requirements of waste processing and, as discussed below, due to problems with the tanks, the liquid waste and the sludge are moved from one tank to another. There is an extensive network of underground pipes in each area. The routing of waste between tanks is done through jumper changes in "diversion boxes." Some of the flow of the waste into the tanks is by gravity. The rest is accomplished with the use of pumps and steam jets.

Extensive instrumentation is necessary to keep track of the wastes, to detect leaks, contamination, etc. Instrumentation is also required to measure radiation levels and to estimate worker exposures and releases of radionuclides to the environment.

The following chapters provide a preliminary assessment of worker exposures, environmental contamination, technical problems and risks due to catastrophic accidents in the radioactive waste Tank Farm at the Savannah River Plant. Our assessment is based on the official documents of the Savannah River Plant, including the Fault Tree Data Bank(13) into which non-routine "occurrences" are logged in chronological order. The official record, at least that part of it which is public, is far from complete. It also suffers from a number of other deficiencies which are discussed below and in subsequent chapters. This report is, in many ways, also an assessment of that public official record.

The Fault Tree Data Bank, which is stored in a computer, is a principal source of official information in assessments of waste operations. It is used, for instance, by the Savannah River Plant management to estimate the probabilities of breakdowns or accidents and the risk to the public from such accidents. Yet it is sorely incomplete and uneven both with regard to the number of entries and the quality of the data. Sometimes it is also inconsistent with other official documents, even regarding major incidents.

From a statistical point of view, perhaps the most serious deficiency concerns the number of entries. Table 3.6 shows the number of entries in the Fault Tree Data Bank during various periods since the start-up of the Savannah River Plant in 1953. During the 1950s, there were on an average about 4 entries per year. During the 1960s, the figure jumped to about 55 per year. In the first half of the 1970s (1970-76) it was about 290 per year. Since 1977 there

**Type I and II tanks have a concrete outer shell lined with steel to a height of 5 feet of the tanks total height of about 25 feet. Type III tanks of later design have a secondary containment which is fully lined with steel. (12)

have been about 1800 entries per year -- about four hundred and fifty times the frequency during the 1950s.

Neither the Department of Energy (DOE) nor the management of the Savannah River Plant (E.I. du Pont de Nemours and Company) have claimed that the rapidly increasing frequency of entries corresponds to an increase in problems on the radioactive waste Tank Farm. Nor does the evidence available to us indicate that this is so. Thus we must infer that the increasing frequency of entries was the result not of technical factors but of periodic management decisions as to what was to be recorded.* This means that by the standards of 1977-82 (so far as the number of entries into the data base is concerned) tens of thousands of events involving equipment breakdowns, worker exposures, non-routine releases of radioactivity to the environment, etc. were not recorded.**

Moreover, the frequency and magnitude of the management changes in entry-making procedures does not lend confidence that all the events which need to be recorded are now being entered into the Data Bank. Even recently events of great importance, such as corrosion pitting in new tanks, have been omitted from the Data Bank (Chapter 5). We defer discussion on the quality of entries and documents to following chapters which deal with the specifics of the management of high level radioactive wastes on the Tank Farm.

The arbitrariness of the recording procedure until 1965 is revealed by the following entry dated August 24, 1965, in the Data Bank (Table II, Part II, entry 08-24-65H):

> *Prior to 1965, information on instrument failure, pump failure, leaks in the waste tank system are not recorded unless the individual occurrence is of particular interest.*

The official studies which we have examined do not set forth any criteria for which leaks and failures might be of "particular interest." From a technical and statistical standpoint, no failure can be so dismissed as being uninteresting. Indeed, sound estimation procedures of failure rates and hence of accident probabilities require the recording of *every* failure. Further, when data recording procedures are changed suddenly, corrections must be introduced in the prior data. We have not seen any discussion of such corrections in the official report.

Nor was the matter taken care of in 1965. The frequency of entries has continued to increase. The average for 1960-65 was about 32 entries per year, for 1966-69, 75 entries per year. As noted above this increased to 290 per year during 1970-76 and 1800 per year during 1977-82.

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*The probability that there was a purely fortuitous increase in the number of entries, related neither to technical factors nor to management decisions, is close to zero.

**If one assumes that there should have about 1800 entries per year in the pre-1977 period as there were during 1977-82, then we get an estimate of almost 40,000 abnormal events which were not recorded during 1953-76.

References

1. Management of Radioactive Wastes at the Savannah River Plant, Presentations made to the Committee on Radioactive Waste Management of the National Academy of Sciences at the Savannah River Plant, January 20 & 21, 1969. TID 26524, Reprinted 4/1/71; p. 32.
2. Ibid, p. 32, charts 2 and 3.
3. Energy Research and Development Administration, Waste Management Operations Savannah River Plant--Aiken, South Carolina. Final Environmental Impact Statement, ERDA-1537, National Technical Information Service, Springfield, Virginia, September 1977; p. II-65.
4. E.I. du Pont de Nemours and Company, Safety Analysis Report: Liquid Radioactive Waste Handling and Storage Facilities (200 Area) -- Savannah River, DPSTSA-200-3. Aiken, South Carolina, August 1978; p. 6-41.
5. Op. Cit. Ref. 1, pp. 35-7.
6. R.M. Girdler, Storage of Liquid Radioactive Wastes at the Savannah River Plant, E.I. du Pont de Nemours and Company, Aiken, South Carolina, July 1969; pp. 6-7.
7. National Research Council, Radioactive Waste Management at the Savannah River Plant - A Technical Review, Panel on Savannah River Wastes, National Academy Press, Washington, D.C., 1981; Table 1.
8. Oak Ridge National Laboratory, Spent Fuel and Radioactive Inventories, Projections, and Charactaeristics, U.S.D.O.E., report #DOE/RW-006. Washington, D.C., Sept. 1984; Fig. 2.20.
9. Op. cit. ref. 2.
10. Op. cit. ref. 4; Table 6-11.
11. Op. cit. ref. 7; Table 2.
12. Op. cit. ref. 6; pp. 3-6.
13. 200 Area Fault Tree Data Bank - F&H Area Waste Tank Farms, Savannah River Plant, computer printout of Data Bank provided by the Savannah River Plant management (DOE) to the Environmental Policy Institute in 1983 with entries dating from December 1953 to November 1982.

Table 3.1

Volumes of High Level Wastes Stored at SRP (Gallons), (1), (2), 1981

Waste Type	Type I,II	Type III	Total
Supernatant liquid	7,760,000	10,000,000	17,900,000
Crystalline salt	4,040,000	3,000,000	7,070,000
Sludge	2,630,000	180,000	2,810,000
TOTAL	14,400,000	13,300,000	27,700,000

Notes: 1. Source: National Research Council, Radioactive Waste Management at the Savannah River PLant - A Technical Review, National Academy Press, Washington, D.C., 1982.

2. All numbers rounded to 3 significant figures

Table 3.2

PRINCIPAL FISSION PRODUCTS (CURIE CONTENT) IN THE HIGH-LEVEL WASTES AT SRP

TOTAL QUANTITY AND RADIOACTIVITY ESTIMATES, 1981

Radionuclide	Half-Life(2) (years)	Average Activity in all High-Level wastes curies/liter	Specific Activity of nuclide(2) curies/grams	Total Quantity of Radio nuclide kilograms	Total Radio-activity of Radionuclide curies
1. Strontium-90	28	1.4	140	1,100	150,000,000
2. Ruthenium-106	1	0.1	2,500	4	10,000,000
3. Cesium-137	30	1.5	91	1,700	160,000,000
4. Cerium-144	0.78	1.3	3,100	44	140,000,000
5. Promethium-147	2.6[4]	0.98	~900	110	100,000,000
6. Samarium-151[5]	87	0.015	28	57	1,600,000
7. Radionuclides[6] with less than one-year half-life	<1	~1.5		~10	150,000,000
					700,000,000

Notes to Table 3.2

1. The total quantity of high-level wates as of 1981 was assumed to be 27.7 million gallons or 105 million liters. See Table 3.1 above.

2. Source: Ronnie D. Lipshutz, Radioactive Waste: Politics, Technology and Risk, Ballinger, Cambridge, Mass., 1980; Appendix A. Numbers preceeded by """are estimates from the graph in Appendix A (Figure A). Note that the half-lives cited in various sources differ somewhat.

3. Data on activity per liter of waste are from Table 6.11 of Dupont's Safety Analysis Report, DPSTSA 200-3, 1978.

4. Source: G. Friedlander et al. Nuclear and Radiochemistry, Wiley, N.Y., 1981; Appendix D.

5. The estimates for relatively short-lived radionuclides is a rough one, based on the charts of fresh waste in DuPont documents, adjusted for decay.

6. THe estimate for relatively short-lived radionuclides is a rough one, based on the charts of fresh waste in DuPont documents, adjusted for decay.

Table 3.3

LONG-LIVED FISSION PRODUCTS IN SRP HIGH-LEVEL WASTE ESTIMATE OF QUANTITY AND RADIOACTIVITY, 1981

Radionuclide	Half-life(1) Years	Average activity in sludge (2), (3) curies/liter	Specific activity(1) curies/gram	Total quantity of radio- kilograms	Total radio- nuclides(3) curies
1. Selenium-79	65,000	$3x10^{-5}$	~0.02[4]	~10	300
2. Zirconium-93	900,000	$2x10^{-4}$	0.0026	800	2,000
3. Technicium-99[5]	210,000	$1x10^{-3}$	0.017	600	10,000
4. Palladium-107	7,000,000	$1x10^{-6}$	~$1x10^{-4}$	100	10
5. Tin-126	100,000	$3x10^{-5}$	.01[4]	~ 30	300
6. Iodine-129	17,000,000	$2x10^{-6}$	$1.6x10^{-4}$	~10	20
7. Cesium-135[6]	2,000,000	$6x10^{-6}$ sludge; $1x10^{-5}$ supernate	$7.7x10^{-4}$	800	600

Notes to Table 3.3

1. Source: Ronnie D. Lipschutz, Radioactive Waste: Politics, Technology, and Risk, Ballinger, Cambridge, Mass., 1980; Appendix A.

2. Sludge consistutes about 10% of the wastes or about 10 million liters in 1981. The radionuclides in this table are located principally in the sludge except Cs-135 and possibly Tc-99 (see notes 5 and 6 below), so that an approximate estimate of the total can be obtained by multiplying the specific activity in the sludge with the total volume of sludge. Source: ERDA 77-42/1., Alternatives for Long-Term Management of Defense High-level Waste. Table III-4.

3. Rounded to one significant figure.

4. Estimated from Lipshutz, note 1 above, Figure A-1.

5. A considerable amount of technicium-99 is also contained in the salt-cake. This is indicated by levels of technicium-99 which are expected to be found after processing into "saltcrete". Source: DOE - EIS-0082, Final Environmental Impact Statement, Defense Waste Processing Facility, Feb., 1982.

6. Most of the cesium is in the supernate and salt-cake. Salt-cake content of Cs-135 estimated as follows:

In sludge Cs-135 = (6×10^{-6} curies/liter) x (10^{7} liters) = 60 curies

In supernate Cs-135 = (1×10^{-5} curies/liter) x (5×10^{7} liter) = 500 curies

Total Cs-135 is about 600 curies, excluding that present in salt-cake.

Table 3.4

ACTINIDES IN SRP HIGH-LEVEL WASTES:

AN ESTIMATE OF QUANTITY AND RADIOACTIVITY

	Radionuclide	Half-Life(1) Years	Average activity in sludge(2) curies/liter	Specific activity(1) Curies/gram	Quantity of radio-nuclide(3) kilograms	Total radio-activity(3) curies
1.	Uranium-233	160,000[4]	5.5×10^{-5}	~ 0.01	6	60
2.	Uranium-235	710,000,000	7.1×10^{-8}	2.2×10^{-6}	300	0.7
3.	Neptunium-237	2,100,000	1.0×10^{-6}	7×10^{-4}	60	10
4.	Uranium-238	4,510,000,000	1.7×10^{-6}	3×10^{-7}	60,000	20
5.	Plutonium-238	86	2.9×10^{-2}	17.5	20	300,000
6.	Plutonium-239	24,000	9.2×10^{-4}	.062	150	9,000
7.	Plutonium-240	6,600	1.7×10^{-4}	.23	7	2,000
8.	Plutonium-241	13	0.6×10^{-2}	114	0.5	60,000
9.	Americum-241	458	2.9×10^{-3}	32	0.9	30,000
10.	Plutonium-242	380,000	1.6×10^{-7}	3.8×10^{-3}	0.4	2
11.	Curium-244	18	3.4×10^{-3}	83	0.4	30,000
	TOTAL					~430,000

Notes to Table 3.4

1. Source: Ronnie D. Lipshutz, Radioactive Waste: Politics, Technology, and Risk, Ballinger, Cambridge, 1980; Appendix A.

2. Sludge is about 10% of the volume of high-level waste. The volume of sludge in 1981 was about 10 million liters. The radionuclides in this table are located principally in the sludge. An approximate estimate of the total quantity in curies of the radionuclide can be obtained by multiplying its activity per liter of sludge with the volume of sludge. The figures for average activity in SRP sludge are taken from ERDA 77-42/1X. Alternatives for Long-Term Management of High-Level Waste, Table III-4.

3. Rounded to one significant figure.

4. Source: G. Friedlander et al., Radiochemistry, Wiley, N.Y., 1981; p. 646.

Table 3.5

VARIOUS ESTIMATES OF PLUTONIUM-238 AND PLUTONIUM-239

INVENTORIES IN THE TANK FARM, 1981[1]

Item Source	Plutonium-238		Plutonium-239	
	curies	kilograms	curies	kilograms
1. DuPont-1978	300,000	17	8,000	130
2. NAS-1981	1,000,000	60	20,000	320

Notes: 1. Total quantity of high-level wastes in 1981 = 100 million liters.

2. Source: DuPont Safety Analysis Report, DPSTA 200-3, 1978, p.6.40. The table cites figure $3x10^{-3}$ curies/liter for plutonium-238 and $8x10^{-5}$ curies/liter for plutonium-239 as the average content in all the high-level wastes.

3. Data in the NAS report, Radioactive Waste Management at the Savannah River Plant, Washington, D.C., 1981, were supplied by DuPont .

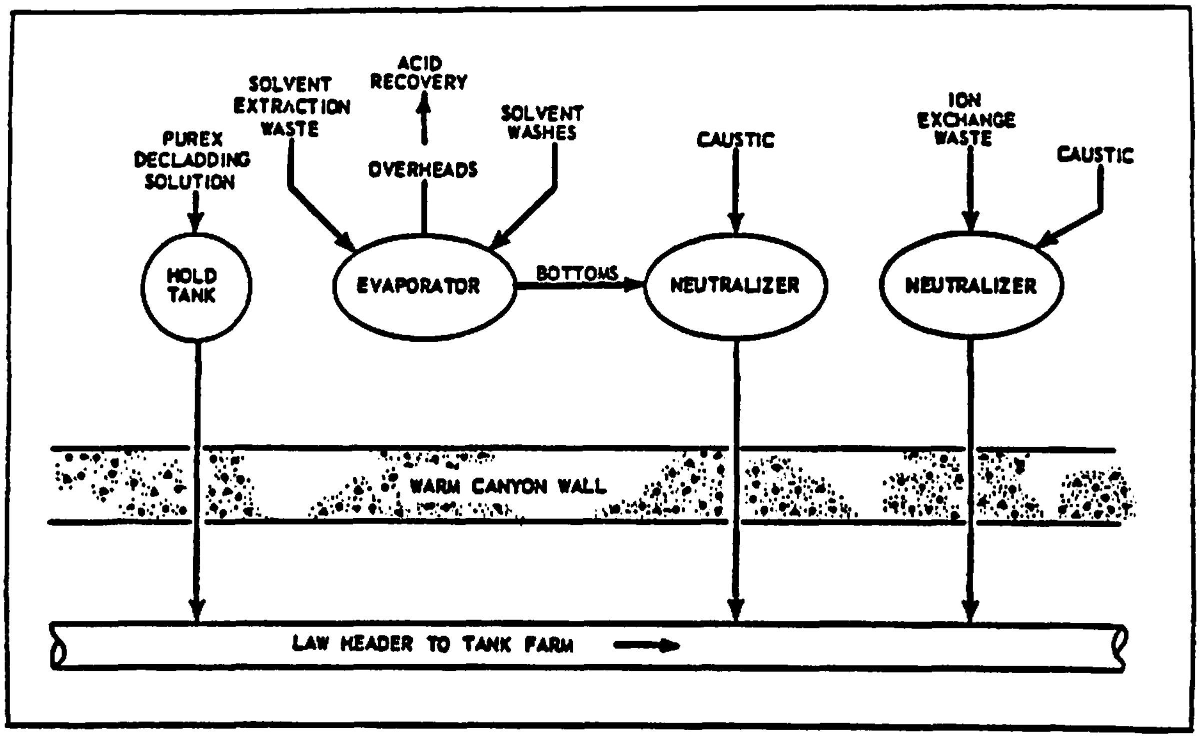
Table 3.6

FREQUENCY OF ENTRIES INTO THE FAULT TREE DATA BANK

Period	Average number of Entries per year
1953-1959	4
1960-65	32
1966-69	85
1970-76	290
1977-82	1,800

Source: 200 Area Fault Tree Data Bank - F & H Area Waste Tank Farm, Savannah River Plant, with entries from December 1953 to November 1982.

LOW ACTIVITY WASTE PROCESSING



HIGH ACTIVITY WASTE PROCESSING

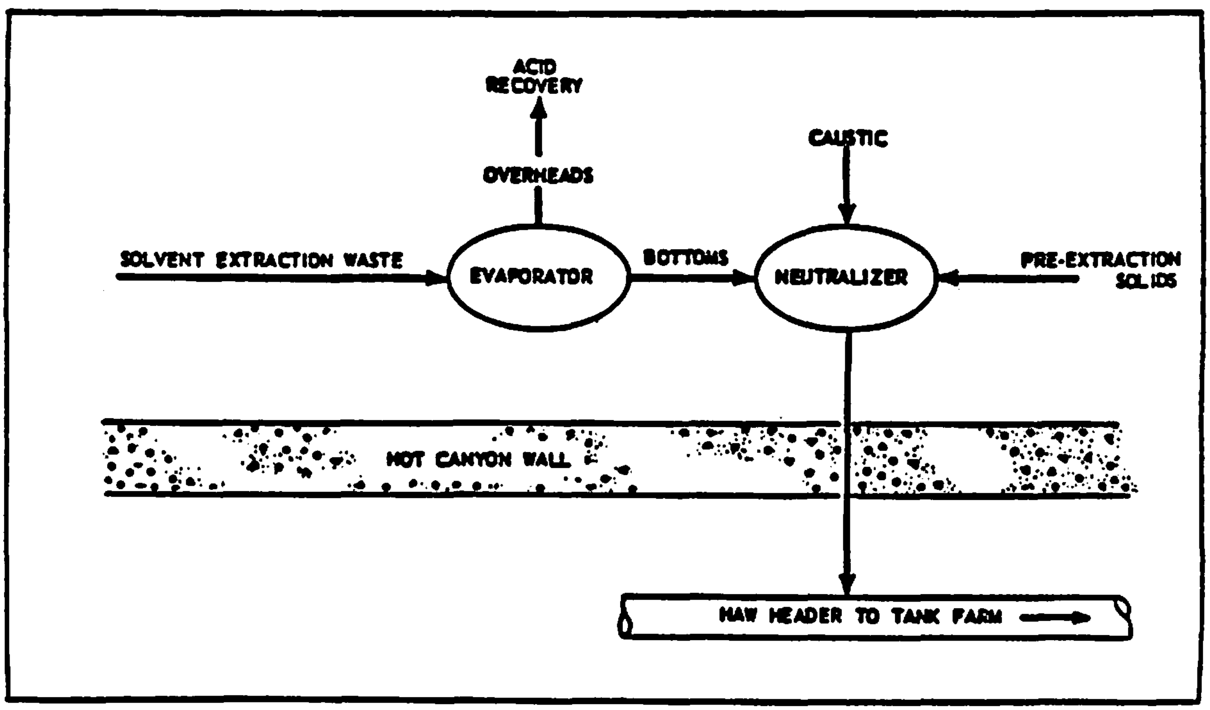


FIGURE 3.1

High Activity Waste (HAW) Processing in the Tank Farm

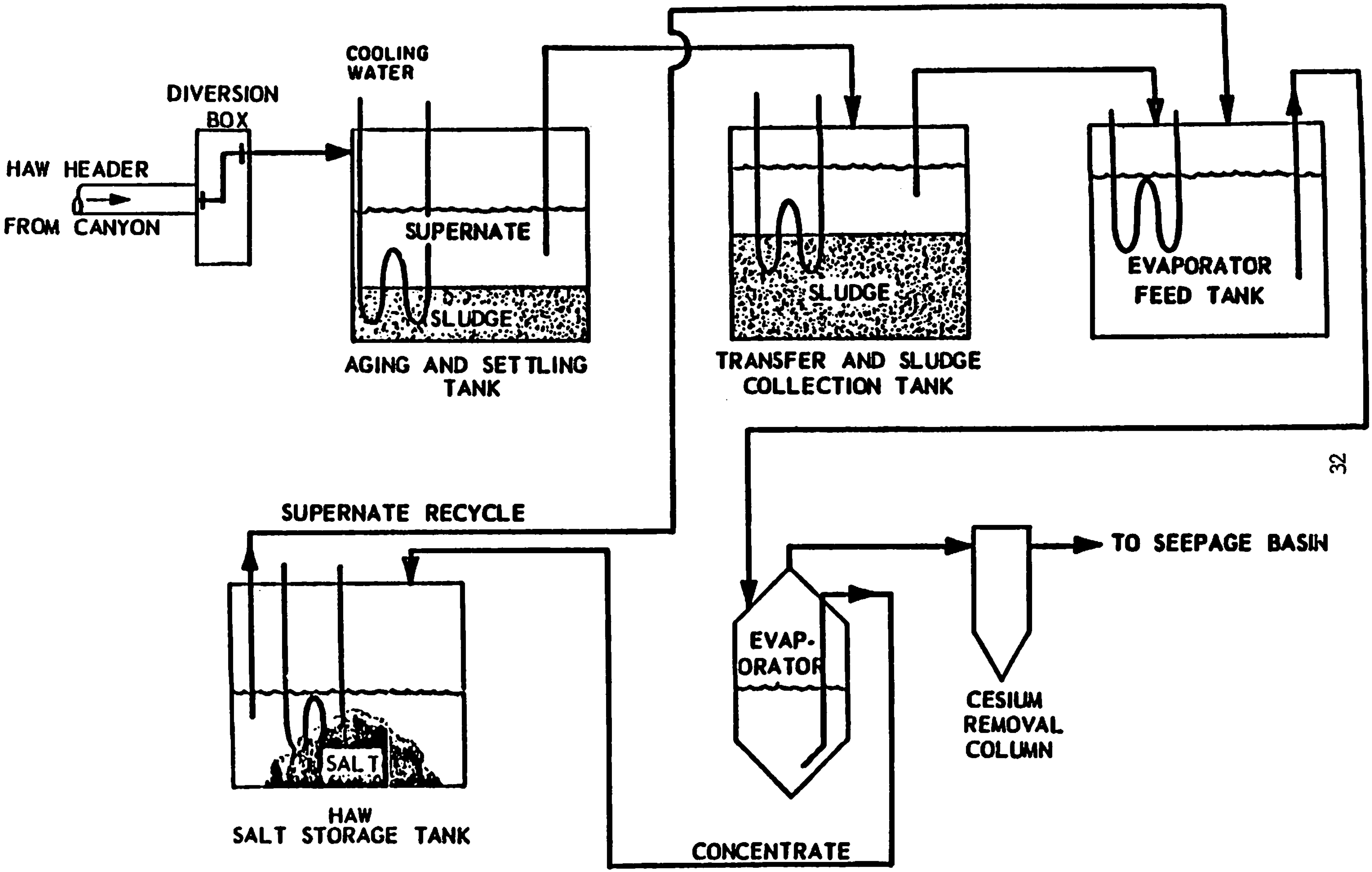


FIGURE 3.2

CHAPTER FOUR
TECHNICAL PROBLEMS

There has been a wide variety of technical problems at the Radioactive Waste Tank Farm since it began operation. In an industry not dealing with highly toxic, explosive and persistently radioactive materials, many of these problems, such as those with some measuring instruments or small pipe leaks, might be considered minor. However, in the context of management of a set of tanks containing about 800 million curies of radioactive waste which generate explosive gases, there are few, if any, problems that can be considered as minor. Moreover, the level of technology appears, in some instances, to be surprisingly primitive in situations where the price for this is often paid by increased risks of worker exposures and environmental contamination.

For example, one method of inspecting the high-level waste tanks is to open the "riser" covers (akin to manhole covers) and look in:

Inspection of equipment used for handling and storing radioactive waste is difficult because of radiation and contamination problems...
*Since 1959, the most important and recurrent waste tank inspections (other than routine surveillance) have been visual surveys in the annular space and, to a lesser extent, inside the primary tanks. Many such surveys...are made by direct observations through opened access risers and/or inspection holes in the roof, using either lowered incandescent lights or a mirror-directed sunbeam for illumination.**(1)

As many entries in the Data Bank indicate, when a tank riser is opened, fission products and plutonium rise up from the vapor space and contaminate the air.(2) In addition, some worker exposure is probably unavoidable as a result of such an inspection, though the Data Bank does not cite any.

A wide sampling of technical problems, which are usually some combination of equipment, operating and/or process problems, is given in Tables 3 through 11 of Part II. All these entries are based entirely on the Fault Tree Data Bank.

The premise on which the Radioactive Waste Tank Farm was built was starkly simple:

The high-level waste could be safely stored in tanks "until national policy and criteria can be agreed upon for the long-term storage of these wastes."(3)

No time period after which the tanks might become unsafe seems to have been specified. Hence a timetable for the

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*Other methods such as periscopic examination are also used for inspections emptying of the tanks and the initiation of a long-term management method seems not to have been part of the original design. The implicit conclusion must be that the Department of Energy (then the Atomic Energy Commission) and its contractor DuPont assumed that the wastes could be stored in tanks for an indefinite period.

This assumption was made explicit as recently as 1977 by DOE (then the Energy Research and Development Administration). This report explicitly considered continuing operation of the Tank Farm into the indefinite future, with the tanks being replaced every fifty years, as an alternative for long-term waste management.(4) (See Chapter 5 for further discussion on the assumed longevity of the tanks.)

This confidence in tank storage was accompanied by the premise that long-term management could be relatively easily accomplished by pumping the wastes directly into the bedrock beneath SRP. For about two decades this was an implicit premise in the design and operation of the Tank Farm.

But this original assumption of a quick, cheap and safe solution to long-term management has proved elusive. (see below.) Similarly, the operating history of the Tank Farm does not support the original premise that the wastes can be stored safely in tanks for an indefinite period -- even though this continues to be the official view of the operation. We cannot, of course, present a detailed assessment here. Our resources only permit a sketch , a preliminary overview of the technical issues as they relate to the operation of and to the long-term questions *posed* by the Waste Tank Farm.

We will discuss technical problems under two headlines:

- o Process and Operating Problems;
- o Equipment Problems.

This categorization, as any other, is to some extent an artificial aid to discussion since there is a considerable overlap and interrelationship between the two categories. For instance, equipment problems such as those with level measuring instruments or with pipe corrosion can lead to operating problems and accidents such as overfills and leaks. Similarly, process problems such as high sludge temperature can accelerate equipment problems such as tank stress-cracking.

Process and Operating Problems

The nature of the materials and of the reprocessing techniques at the Savannah River Plant meant that a large volume of high-level radioactive waste would be generated. It was decided to neutralize this acid waste with sodium hydroxide since the SRP management calculated that *"the storage of the wastes in alkaline solution [was the] most economical."(5)* This conclusion stems largely from the fact that acid waste must be handled with specially resistant equipment and stored in stainless steel tanks. Acid dissolves carbon steel. Neutralized waste does not do this, and it could thus be put in much cheaper carbon-steel tanks.

Unfortunately, the decision to neutralize the waste has had a number of severe impacts on the question of *long-term* waste management. As it turned out, even the near and medium term problems became so severe as to require substantial modifications in the process and in equipment design.

The problems stemmed from two sources -- first from the lack of a suitable long-term plan from waste management and second, from the characteristics of neutralized waste. No serious investigations for long-term storage appear to have been undertaken in the 1950s. It seems to have been simply assumed that pumping it underground would be the method of disposal. In the meantime, the volume of the waste kept increasing rapidly, in part because of the decision to neutralize the wastes -- a process which results in a considerable increase in waste volume.

In the absence of a long-term storage method which would empty the tanks and make room for newly generated waste there were two possibilities: construct a large number of new tanks or reduce the volume of the wastes. It was decided to rely primarily on reducing the waste volume by evaporation, and to build new tanks to accommodate added wastes and other problems.

There were other aspects to this decision. Many of the tanks had begun having significant problems within a few years of operation such as leaks and cracks in the primary steel containers and cooling coil leaks and failures. In addition, the sludge was getting hotter than anticipated, perhaps contributing to the problems. Thus, design for the new tanks

was modified to take into account Hanford experience which indicated that the sludge layer would become appreciably hotter than the supernate and also to allow for probable future waste concentration by evaporation. The design criteria were revised, therefore, to increase the allowable specific gravity of stored waste from 1.4 to 1.8 and to allow sludge temperatures up to 350 F.(6)

The leaks and cracks in many tanks and the evaporation of waste have together resulted in markedly increasing the handling and movement of the waste.

Each tank is sequentially made to handle various kinds of waste:

In general, the older tanks are put into salt storage service after prior service in the storage of new high activity waste. To form a firm foundation for this pile of salt, the sludge, resulting from the tank's prior use in high activity service must first be removed. This is done with high pressure jets and submerged pumps. All of the sludge not removed is being consolidated into a minimum number of tanks.(7)

These additions to the process have required additional equipment -- pumps, pipes, high pressure jets, etc. They have necessitated the use of single-wall uncooled tanks for holding high-level waste, whereas these tanks were originally "built to store waste containing very little radioactivity such as the solution obtained in removing aluminum jackets from fuel elements."(8) Much of this equipment, such as the pumps and jets, have been the source of considerable operating problems, accidents and breakdowns. The evaporators have also been the source of considerable operating problems.

These problems have in turn caused worker exposures and environmental contamination. For example, radiation exposure rates during replacement of an evaporator feed pump in November 1968 ranged up to 30,000 millirads/hour and the total exposure was estimated as 800 millirads. (See Summary Table 1) In another example, the total exposure during the excavation of the F area concentrate transfer system pump pit in October 1975 was 21.6 rem. (See Table 1, Part II, entry 07-75F) The following entry is an example of environmental contamination due to equipment problems:

02-29[sic]-61. Soil Contamination. [Plutonium] solutions have leaked from this panel 4 times in recent months by low level waste concentrate leaking through cell walls of the waste from evaporator. Soil removed; asphalt mostly replaced. (See Table 2, Part II)

It is also important to note that with three decades of operating experience, it has proven impossible to develop remote maintenance methods for many jobs essential to Waste Tank Farm operation, given the present level of resources devoted to it. Thus in November 1982, the plant management unsuccessfully attempted to use a shielded crane in order to change jumpers (pipe connections) in the concentrate transfer system, a dangerous operation that is frequently required to route waste:

Waste management and T & T using the shielded crane, attempted to change numerous jumpers in CTS [concentrate transfer system] cell but were unsuccessful due to crane failure or inability to see while moving equipment. The exposure dose rate in the cab remained less than 1 mr/hr and the radiation level over open cell was 2R/hr. T & T later made jumper changes encountering dose rates of up to 1.5R. The total estimated exposure involving 36 personnel entries was 1115 mr.

The successful development of adequately shielded equipment such as cabs could lower exposures substantially for operations which now require entry of personnel into extremely radioactive environments.

Many of the operating problems -- such as the plugging of jets and pipes, and pump failures as well as the failure to develop adequately shielded remote maintenance and operating procedures -- have a direct bearing on the prospects for long-term waste management in general and for vitrification in particular. (See below.)

There have been many other process and operating problems. A sampling of these is to be found in Summary Table 3, while a more extensive selection from the Data Bank is given in Tables 3 through 11 of Part II. For instance, summer lightning frequently causes loss of power. Usually, the emergency power takes over, but this has failed on occasion. Loss of power on July 31, 1972, caused a loss of make-up cooling water "for a short period of time" in some areas. (See Table 7, Part II)

Prolonged loss of cooling water to high level waste tanks could cause serious problems. The hotter wastes would come to a boil in about a week. An accident in December 1956 caused a loss of cooling water to Tank 12 for six days.

> *[This] resulted in waste temperatures that approached the boiling point and a visible discharge of condensing steam emerging from the fiberglass-packed vent filter, and release of less than 1 Ci of airborne activity. There was no appreciable spread of contamination beyond the immediate vicinity of the tanks.(9)*

Interestingly, this accident is not listed in the Fault Tree Data Bank. Rather an earlier less serious loss of cooling water for 2 days to Tank 3 in August 1956 is listed. (See Table 4, Part II)

As a final example, we consider the data of hydrogen formed by the action of radiation ("radiolysis") in the tanks. A substantial accumulation of hydrogen could result in a tank explosion. (See Table 5, Part II) The DuPont Safety Analysis Report on Waste Management states that on "one occasion...the hydrogen concentration in the vapor space of a waste tank reached the lower explosive limit" and that on all other occasions it has been below this limit. (10) However, the Data Bank entry dated 09-00-56 records a level well above this limit (Table 5, Part II): *"hydrogen content of the vapor space of Tank 9 150% of lower explosive limit."*

Besides this, the DuPont Safety Analysis Report does not mention any explosion in tanks resulting from hydrogen build-up. The Data Bank cites one such explosion in tank 6 due to a hydrogen concentration of only 15% of the lower explosive limit. The confused and contradictory data in the Safety Analysis Report and the Data bank does not permit us to arrive at any conclusions about these events, except that it shows the unreliability of the data and the public reports for even the most serious accidents that could happen in the Tank Farm operation.

Equipment Problems

Many operating problems have been rendered more severe by equipment problems. We have already mentioned the failure to develop adequately shielded remote work stations for many jobs. Further, process and operating problems such as those with failed pumps or plugged lines can be interpreted in some cases as those of equipment which is not fully suited to the materials, temperatures and radioactive conditions which are encountered on the Waste Tank Farm. Again, it is important to remember that it is the highly toxic and persistent nature of the radioactive materials which is a primary cause of many of these difficulties with instruments, pumps, jets, etc. A selection from the entries in the Data Bank is given in Tables 3 through 11 in

Part II. In this section we will concentrate on the problems related to the tanks *only*, since the questions of safety of worker and public exposures and long-term risk depend centrally on the integrity of the tanks.

There are four types of tanks on this Tank Farm. (See Figures 4.1 and 4.2) Type IV tanks are the single-walled, uncooled tanks which are used to feed the evaporator and for low-activity waste storage.(11) Types I, II and III are cooled tanks. Types I and II, the earlier designs for high-level wastes, have a secondary concrete containment with a partial steel lining for 5 feet of their approximately 25 foot height. They are sometimes known as "double-walled" tanks.(12) Type III tanks have a full-height secondary steel liner. There are 51 tanks in all: 16 of Types I and II, 27 of Type II and the rest of Type IV.

There have been several kinds of problems with the tanks. For instance, one major problem relates to cooling coil leaks. A large number of cooling coils on the first batch of 12 Type I tanks and the second batch of 4 Type II tanks leaked. The leaking coils had to be taken out of service, reducing the available cooling in the tanks. In some cases a large proportion of the cooling coils had to be blanked off because of leaks. Partly due to such leaks, some tanks are more hazardous than others for storing wastes. The cooling coil leaks have thus been one of the causes necessitating an increased number of transfers from one tank to another. Ironically, such transfers have sometimes created cooling coil leaks where none were previously evident, as was apparently the case in the transfer of sludge from Tank 11 during November 1969. (Table 4, Part II, H-area): "Tank 11 had 16 cooling coil leaks following sludge removal. None had been detected before sludge removal."

Cooling coil designs have been repeatedly modified. The initial design of Type III tanks called for removable cooling coils, but the later ones are being built with fixed coils as was the case with the design of the very first tanks.

Various incidents, some of frequent occurrence, have cast doubt on the integrity of both the primary and secondary containment of the tanks. In the leak from Tank 16 in 1960, discussed in Chapter 6, the liquid waste seemed to have escaped into the soil very soon after its level reached above the outer steel pan and came into contact with the concrete container. Other events, such as the escape of high heat waste from the concrete encasement of the pipe at Tank 8, also discussed in Chapter 6, also indicate that concrete is not an effective barrier to high-level wastes. The situation has been somewhat alleviated in this regard by the construction of full height steel liners in the secondary containment structure, but almost all the older tanks continue to be used and they contain large quantities of radioactivity.

Further evidence of the ineffectiveness of the secondary containment is provided by the frequency with which groundwater and rainwater flow into the annular space, sometimes in large quantities. For instance, several hundred gallons of water leaked into one of the newer tanks (Tank 40) in August 1982 due to inadequate sealing. The water carried some clay with it into the annulus. (See entry dated 08- -82 H-area in Table 3, Part II) Upon occasion, large quantities of rainwater have also entered the primary containment. For instance, 4,800 gallons of rainwater flowed into Tank 11 due to "excessive rainfall over a short period of time and failure to expedite repair of cracked risers immediately upon discovery." (H-area entry dated 08-18-82 in Table 3, Part II)

The primary steel containment has been subject to cracking and to leaks. Four of the first sixteen tanks had developed leaks by the late 1950s (13) and a total of nine by the mid-1970s. Some tanks have had extensive corrosion cracking. While the leaks from these cracks tend to get sealed with salt deposits in most cases, these deposits may not similarly keep the wastes confined in the event of mechanical stress, such as that from hydrogen explosions or earthquakes. The presence of many cracks and leaks in some tanks has possibly compromised their structural integrity. (See Chapter 5.)

The substantial redesign of the tanks after the experience with cracks and leaks in Type I and II tanks was supposed to have addressed these problems. The failures were investigated and as a "result of this investigation new cooled tanks were designed to eliminate the cracking problem and to obtain other advantages indicated desirable by experience to date."(14)

Unfortunately a large number of the new Type III tanks, at least fourteen of twenty-seven, were already compromised during construction by severe corrosion pitting. Such pitting was found on all fourteen tanks (Tank numbers 38 through 52) under construction during 1980 and 1981.(15) Yet the Data Bank contains only one entry regarding corrosion pitting in an H-area entry dated 02-04-81. (See Table 4, Part II).

Construction has completed over eight percent of measuring and mapping of pits in Tank 38. To date the deepest pit is 0.061. Inspection of the cleaned floor is revealing hundreds of shallow pits between 30 to 60 mil deep."

The deepest pit found in the tanks was 170 mils or about one-third the wall thickness. (16)

According to the testimony of William Lawless, a former Senior Engineer in Waste Management in the Department of Energy and stationed then at the Savannah River Plant. DuPont was aware that "corrosion pitting could penetrate the tanks in very short order." However, this "was not considered a problem at SRP for many reasons including the new design of these new Type III tanks...[and] also because of the construction quality assurance procedures that DuPont was using."(17)

This DuPont assessment was made in March 1980, six months prior to the discovery of the corrosion pitting. After the discovery of that pitting, according to Lawless, "DuPont felt that there should be no restrictions...[placed on] these tanks." A consulting firm, Arthur D. Little, Inc., hired to do an assessment of the problem, recommended that restrictions be placed on three tanks regarding the kind of wastes to be put in them.(18) The Department of Energy overruled these recommendations and certified them for unrestricted service.

Tank 38 was considered by all parties

to be sound. We understand that a few months after it was put into service, the primary containment leaked, possibly due to a welding problem.

<u>Long-Term Aspects</u>

The initial decision to neutralize the wastes and store them in relatively inexpensive carbon-steel tanks was made without much planning for the long-term consequences. Three factors appear to have been largely responsible for this:

o initial attention was focused mainly on production of plutonium, etc. without serious anticipation of possible domestic negative consequences;

o confidence that the tanks could hold the wastes for as long as necessary; and

o an assumption that a quick, cheap way would be found for long-term disposal.

Attention continues to be focused on the production aspects. However, the confidence regarding the long-term viability of the tanks and the quick availability of some other method has not been borne out by time.

Storage in tanks has faced a number of problems and cannot be a long-term option because of the severe dangers that this kind of storage poses in case of accidents or natural catastrophes. The numerous leaks which developed in the tanks in the first few years after they were built also pointed to the necessity of some other long-term management solution. For about two decades, the long-term approach which SRP management assumed would be viable, and the only one it considered in some detail, was direct disposal in bedrock.

Disposal of liquid high-level wastes in a deep rock formation beneath the SRP site was first proposed in 1951 by the Atomic Energy commission. Because this formation was located beneath two major aquifer systems, major concerns over this mode of disposal were soon raised. But it was not until 1955 that a Committee on Geological Aspects of Radioactive Waste Disposal of the National Academy of Science -- National Research Council (NAS-NRC) was convened to advise the Atomic Energy Commission on current and proposed geological disposal methods of radioactive wastes. In March 1960 the Committee reviewed the safety and feasibility of storing radioactive wastes beneath the SRP plant site and recommended that SRP proceed with test borings.

In December of 1962 the testing program for bedrock disposal at SRP was complete. The NAS-NRC Committee concluded that "storage of liquid radioactive wastes in excavated chambers was technically feasible."(19) Six months later, the NAS-NRC Committee concluded further that underground disposal at SRP was safer than storage in surface tanks. But they added a note of caution by pointing out that the test drilling at SRP may have "invalidated" some of their data because it disturbed groundwater flow. From 1964 and 1966 further tests were made.

By 1965 the NAS Committee membership changed, with only one member from the previous group remaining. In 1966 the majority of the newly reconstituted Committee opposed direct disposal in bedrock at SRP. They recommended that the entire program be discontinued on the grounds that *"...the placement of high-level wastes 500 to 1000 feet below a very prolific and much used aquifer is in its essence dangerous and certainly will lead to public controversy." The Committee also stated "...there is doubt that it will be possible to prove the safety of the proposed bedrock system for high-level liquid or soluble wastes."* Underscoring their opinion was the "unpredictable nature of groundwater flow through fractured rock." The minority view held that "work on bedrock disposal at SRP would be continued."(20)

The Atomic Energy Commission suppressed this study until 1970. Moreover, they ignored the majority opinion and proceeded along the same course set out in 1951. The NAS-NRC Committee went out of existence after submitting their report, and a new Committee was convened in 1972 with different members. This time, the Committee concluded that "...there is a reasonable prospect of achieving [adequate] protection by storing the waste in vaults in rocks underlying the Tuscaloosa formation beneath the Savannah River Plant site." However, the Committee felt that "...no reasonable amount of exploration from the land surface can conclusively demonstrate the safety of waste storage in deep vaults." The Committee then recommended that "an exploratory shaft be sunk and exploratory tunnels be driven into the rock selected."(21)

Plans for executing the NAS Committee's recommendations were blocked in 1972 by the Environmental Protection Agency (EPA) on the grounds that deep geological disposal of high-level waste was "environmentally unsound" and that for more than 20 years DOE had not studied any alternative.(22) EPA also cited the existence of faults in the rock formations beneath SRP which have the potential for movement -- threatening the integrity of a repository located in these formations.

Throughout the 1970s, the state of Georgia voiced strong opposition to the bedrock disposal option at SRP, particularly when Jimmy Carter was governor. In 1979, under President Carter's administration, the DOE in a decision on the final Environmental Impact Statement on the "Long-term Management of Defense High-Level Radioactive Wastes" at SRP, administratively foreclosed the option.(23) This, however, has not satisfied the current Georgia state government because they believe that DOE's decision is legally non-binding. Adding to Georgia's suspicions, the NAS released yet another report on disposal of high-level wastes at SRP in 1981, which endorsed (a) the drilling of an exploratory shaft for bedrock disposal; (b) the grouting of radioactive wastes into rock formations underneath SRP; (c) the direct disposal beneath the SRP site as a safe and cheaper option than putting the wastes in solid form and storing them at a repository off-site.(24)

<u>Defense Waste Processing Facility</u> *

While DOE and DuPont have not yet officially acknowledged the dangers of the direct disposal approach, they appear to have abandoned it in practice for the present in favor of encapsulating the wastes in glass (which is similar to the Pyrex kitchenware). This process, known as vitrification, is to be carried out in the Defense Waste

* The discussion, the data and quotes in it are based on D.O.E's final EIS for the project, unless otherwise stated (25).

Processing Facility now under construction at SRP. Most of the radionuclides will be encapsulated in glass. The rest of the waste will be in the form of a chemical salt solution. This is to be processed by evaporation and mixed with cement. The large radioactive cement blocks, called "saltcrete", are to be disposed of as "low-level" wastes in shallow unlined burial pits at the SRP site.

The production of glass is scheduled to begin in 1989. No schedule exists as yet for placing the glass in a repository, but it is reasonably certain that no repository will be in operation before 1998 -- the earliest date announced for repository opening by DOE-- since there have already been substantial delays in the repository program. Thus, the glass is to be stored at the Savannah River Plant for about a decade, and probably longer. DOE plans to dispose of the saltcrete in an "engineered low-level" waste burial site near the glassification plant.

Successful solidification of the wastes would be a step forward in protecting the public from accidents such as hydrogen explosions. It would also pose less immediate danger in case of earthquakes. However, we have serious reservations about the way in which this plan is being carried out, since there are a number of unresolved issues and problems relating to both the routine operation of the facility as well as to potential accidents. In addition, there are basic questions relating to the glass and saltcrete and the proposed disposal of saltcrete in the "low-level" waste burial ground.

The first, and perhaps most significant fact about routine operation of the vitrification plant, is to note that there is <u>no experience with such a facility even on a pilot plant basis, to say nothing of an actual, full-scale industrial basis.</u> In its Final Environment Impact Statement for the project, DOE summed up the vitrification experience at SRP as follows:

At SRL the borosilicate glass process is being successfully demonstrated on an engineering scale with simulated (non-radioactive) waste and tested on a laboratory scale with actual SRP waste. Physical property data have been obtained on full-size non-radioioactive forms and on small-scale forms made with actual waste.

In other words, individual full-size glass cylinders (0.61 meters diameter and 3 meters high) have been produced, but without radioactive wastes incorporated into them. The production of single glass cylinders without radioactive wastes is qualitatively different in major respects from a large-scale plant producing 500 canisters every year, each containing up to 200,000 curies of radioactivity. In fact, <u>many of the major features of radioactive waste processing that will be peculiar to the Defense Waste Processing Facility have never been operationally tested with actual radioactive materials for any significant length of time.</u> Further, the entire process has not been tested on an industrial scale, with the actual equipment even with simulated (non-radioactive) wastes. Nor has a pilot plant been built or operated. Thus, many critical pieces of equipment, such as the slurry-fed glass melter, have not been adequately tested under anticipated operating conditions. As a result, there is no direct body of experience which the management and workers of SRP can draw on with regard to the routine operating maintenance and repair problems that might arise once production begins.

The official assessments point to development of the technology outside the U.S. to shore up the credibility of glass as a suitable candidate and of the commerical feasibility of vitrification. Most of these countries have only paper plans or plants under consideration. The only factory of any significant size to have operated and produced radioactive glass is the plant at Marcoule in France, which has produced 75 canisters per year (1978-82 average), each about one-fourth the volume of the canister planned SRP. More significant than the difference in canister size and plant capacities are the following facts:

- o the physical-chemical nature of the high-level waste processed at Marcoule is basically different from that at SRP;
- o Marcoule has confronted some significant problems;
- o the "Castaing Report" commissioned by the government of France found glass to be unsuitable as a medium for long-term disposal of radioactive wastes (26).

The Department of Energy has explicitly admitted basic differences between the French AVM process and the one to be used at SRP. In response to a question from Congressperson Richard L. Ottinger, DOE Secretary Hodel noted that one reason for the rejection of the AVM process for SRP was:

> *[i] ncompatibility -- the AVM process uses a rotary calciner to dry the wastes. SRL [Savannah river Laboratory] evaluated rotary calcination for the DWPF [Defense Waste Processing Facility ad SRP] and found that the French process (which vitrifies acidic wastes) could not be applied directly to alkaline wastes at SRP. Sticking of the waste to the calciner, in particular, was a problem. (27)*

Thus, the only experience from an operating plant of substantial size is largely inapplicable to the plant at SRP because of the very nature of the wastes. The original decision to neutralize the acidic high-level wastes was made because it was cheaper to store alkaline rather than acidic wastes in tanks. Neutralized wastes have given rise to their own special set of problems, largely unanticipated. One of these is that almost all significant vitrification experience has been with acidic high-level wastes.

To proceed as hastily as is being done, without building a pilot plant, would be inadvisable for such an enormous and critical project, even if all the data from the indirect evidence was favorable. However, that is not the case as we have seen. The routine operations of the SRP Tank Farm have faced many serious problems arising from the design of the operation and the nature of the work. Much hands-on maintenance, repair, and replacement of equipment has been necessary, involving substantial worker exposures to radioactivity. Failure of pumps and the plugging of jets and other equipment essential for the transfer of high-level waste have been common in Tank Farm operations. Most repair and replacement and much maintenance has required "hands-on" work. Breakdowns in such essential equipment have therefore led to worker exposures and sometimes to lengthy shut-downs. It is particularly important to note that, after three decades of Tank Farm operation, DuPont and DOE have not been to able develop remote working methods for such routine work as jumper changes (required for the proper routing of waste).

The formation of the waste-glass mixture, the production of the canisters filled with radioactive glass and many of the other processes in the Defense Waste Processing Facility will be remotely controlled and operated. Under such conditions, maintenance, repair, and replacement of equipment and clean-up after accidents may pose even more serious problems than those which have been encountered so far in Tank Farm operation. For those reasons we have concluded that significant experience on a pilot plant basis for vitrifying sludge is necessary if serious maintenance problems are to be minimized in the operation of the Defense Waste Processing Facility. This conclusion is reinforced by the possibility of accidential contamination of the facility.

The Final Environmental Impact Statement of the Department of Energy for the project contains a list of the accidents "in which significant amounts of radioactive materials could be released into the environment. "The EIS briefly discusses events such as "spill from a slurry receipt tank" and "steam explosion in glass melter." However, only the consequence for immediate releases to the environment are discussed. The analysis is based on a number of assumptions, many of which do not derive from direct operating experience. It comes to the conclusion that radiation doses to the public would be small.

Since there is no significant operating experience, and since the public literature is meager -- the Appendix on Accidents in the Final EIS does not contain even one reference -- it is not possible for us to make an assessment of DOE's conclusions. However, we note that the approach to the analysis is similar to that which DOE and DuPont have used for analyzing the safety of the Tank Farm operation. As we will see in the next chapter, that approach is statistically and technically unsound.

DOE's analysis of accidents in the Final EIS omits any substantial discussion of what might become a critical problem for the continued operation of the plant, and hence for the future vitrification of the wastes and their placement in a repository. This is the problem of the effect of accidents, ranging from small spills to fires or explosions, on the operability of the plant itself. Failure of the plant to operate substantially as predicted would have substantial environmental and economic impacts, and possibly major health impacts as well.

DOE dismisses "minor incidents" out of hand:

> *Occasionally minor incidents will occur during plant operation because of operator error or failure of a plant component or system. Such events will result in the release of little or no radioactivity to the environment and are, therefore, not discussed in this report.*

In a similar vein, the consequences for operability of a major spill are discussed. In the event of a spill of 16,000 liters (more than 4,000 gallons) of highly radioactive sludge slurry onto the cell floor, the spilled material would be flushed into the sump with about 1000 L [liters] of water and then transferred through the dump system to a vessel for reprocessing . . . During the accident and subsequent transfer, aerosols from the evaporation of the spilled material would be carried through the canyon ventilation system."

There is no discussion of the effects of such a spill on the subsequent operation and maintenance of the plant.

One effect of this and other such spills would be to make the processing areas very radioactive. This would make any entry into the process area much more dangerous. Consequently, all maintenance, repair, and replacement requiring such entry by personnel would involve higher exposures and work under more hazardous conditions. It is possible that some of the accidents listed would seriously impair the maintainability, and hence the operability, of the plant.

There is another class of events that could seriously affect the operation of the vitrification plant which has apparently not been considered. This relates to the ability to produce consistently the kind of feed solutions and slurries that will be required for vitrification, without seriously impairing the integrity of the Tank Farm operation.

For instance, water and hot chemicals will be added to the sludge and the mixture agitated to produce a slurry-feed for the glass melter. As noted above such a process has been suspected to cause failures of several tank cooling coils on at least one occasion.

Failure of a large number of cooling coils in the new tanks would seriouly impair their ability to hold high-level wastes. The older tanks already have many leaking cooling coils, rendering them unfit for holding hot sludge.

Most of the older tanks also have leaks in the primary containment vessels which are currently plugged with salt which has crystallized on the cracks. Thus, the transfer of wastes from older tanks to newer ones and the preparation of feedstock for the vitrification plant could lead to serious problems, including leaks of radioactivity and impairment of Tank Farm operations.

These problems must be confronted in any effort to solidify the wastes. However, the likely intensity of the problems will depend on the demands of the specific solidification process and equipment. We do not know if these problems have been taken into account in the design details which are not public. Public documents, such as the Final EIS relating to the Defense Waste Processing Facility, do not deal with them substantially.

Saltcrete

The salt in the tanks is proposed to be dissolved and most of the cesium and strontium isotopoes are removed from it. The rest of the solution is to be mixed with cement and poured into trenches to set as concrete, called saltcrete. The saltcrete "monoliths" are to be formed in trenches about 10 meters below the soil surface. Each trench will be 20 feet deep by 21 feet wide by 52 feet long. This arrangement and the specification of the saltcrete are to conform to the Nuclear Regulatory Commission's criteria for "low- level" waste. The saltcrete burial ground will be treated as such.

The designation "low-level" waste does not apply to the overall radionuclide content of the wastes, but rather has been created as a catch-all category for wastes not falling into other categories. Ronnie Lipshutz has noted that these wastes were renamed "nonhigh level wastes" and were defined by the federal government to include any waste that is not high level and contains less than ten nanocuries of alpha activity per cubic foot. (28)

Thus, a sufficiently large dilution of radioactive waste would allow its redefinition as "low-level waste and hence permit its discharge into dumps from which the long-lived nuclides could pollute the soil and the groundwater. This appears to be the case with the proposed production of "saltcrete" in the Defense Waste Processing Facility.

Table 4-1 shows the quantities of some of the long-lived radionuclides which are to be disposed of in the new "low-level" waste burial ground to be built as a part of the Defense Waste Processing Facility. The cumulative quantities of some long-lived radionuclides at the end of the proposed 28-year operation of the plant will be very large, even after adjusting for radioactive decay. Roughly three million tons of "saltcrete" will be disposed off in the "low-level" dumps at SRP over 28 years. The cumulative amount of various radionuclides in this will be approximately: 30,000 curies of cesium-137, 50,000 curies of samarium-151 (half-life 90 years), 60,000 curies of technicium-99 (half-life 214,000 years), and 200 curies of iodine-129 (half-life of 16 million years). In addition, substantial quantities of alpha emitters like plutonium-238 and americium-241 will be discharged. Further, these alpha emitters do not decay into stable elements but generate other radioactive elements like uranium-234 and neptunium-237, some of which are even more long-lived.

In 1984 the DOE adopted a new internal nuclear waste management standard (DOE order 5820) which raised the control limit for alpha emitters in soil from 10 nanocuries per gram to 100 nanocuries per gram. This increase in alpha contaminated soil appears to be designed to accomodate the saltcrete process. Support for this relaxation in DOE's standard assumes that substances like plutonium can be compared to natural analogs(29) -- an approach not widely accepted in the industry.(30) In Chapter 6 we discuss how DuPont's soil transport models which support this increase in alpha emitters in soil has been invalidated by data from its own operating experience.

Saltcrete falls into the category of "low-level" waste only because of dilution. Very large quantities of it are to be produced -- 530 cubic meters per week, which is about 1 million cubic feet per year. The planned overall production in 28 years of almost 30 million cubic feet of "low-level" waste in the form of saltcrete alone is about double the volume which had accumulated in all six commerically operated low-level radioactive waste dumps in the U.S. combined. (31) It will be triple the cumulative "low-level" waste generated at SRP in its first 22 years of operation.

The total quantity of most long-lived radionuclides which have been discharged into the seepage basins in the first 30 years will pale by comparison with the planned discharges in the form of saltcrete. For example, the planned accumulated discharge of 30,000 curies (decay-corrected) of cesium-137 will be 100 times the accumulated decay corrected discharges of cesium 137 to the seepage basin until 1976. Similarly, the planned cumulative discharge of about 100 curies of plutonium-238 will be about 30 times the estimated accumulated dischanges to the seepage basins until 1976 of 3.4 curies. (See Chapter 6 for discussion of routine discharges.)

The situation with regard to technicium-99 and iodine-129 will be especially serious. The cumulative amounts discharged to the seepage basin until 1976 of these radionuclides was about one hundredth of a curie and 20 microcuries, respectively. The planned discharges in saltcrete will increase these figures by six million times for for technicium-99 and twenty million for iodine-129. There is no prospect that saltcrete can contain these long-lived elements for anything approaching their half-lives. Thus, much of the over 3 tons of technicium-99 and 12 tons of iodine-129 is likely to find its way into ground and surface waters from the "low-level" saltcrete burial site. They will then present a substantial hazard to people.

The "maximum permissible concentration" of iodine-129 in water is 50 nanocuries per cubic meter (about 0.2 billionths of a curie per gallon). This means that it would require about 5 billion gallons of water to dilute 1 curie of iodine-129 to the maximum permissible concentration (which will do some harm, particularly to children, even at those levels).

Thus, 200 curies of iodine-129 will require a dilution by 100 billion gallons to achieve the maximum permissible concentration for iodine-129. The final Environmental Assessment made by DOE for saltcrete considers only the effect of discharges of radionuclides with the Savannah River, where a large dilution can be assumed. As in the other assessments discussed in this report, the contamination of shallow aquifers is not given due importance and the possibility of the contamination of the much-used Tuscaloosa aquifer is not even seriously considered.

The present plans for disposal of large quantities of radionuclides in saltcrete are the combined result of inadequate technological development and inadequate efforts at using known technology. For example, in the case of technicium-99, the technology to recover it from the waste exists, as discussed in an official report on Hanford waste operations.(32) But DOE and DuPont do not plan to use it at SRP.

Mercury in saltcrete could also present problems. There are about 90 to 100 tons of mercury in high-level waste tanks at SRP. Present plans call for extraction and cleaning of this mercury for reuse, as part of the Defense Waste Processing Facility. On the order of one percent of this, or 1 ton, may be present in the saltcrete, due to imperfect recovery techniques. Yet the final EIS admits that studies of the leachability from saltcrete are still only in the "preliminary" stage.

In sum, the construction of a full-scale vitrification plant appears to be technically premature. It may even result in cosiderable delays in the vitrification of wastes if an accident irretrievably contaminates a vital section of the plant.

Our recommendations for solidification by calcining and construction of a pilot plant are aimed at achieving the relative safety that solidification of the wastes in the tanks will bring (particularly the sludge and supernates), and at the same time minimizing the risks of failure in the long run.

More time is also needed to select the best waste form for the repository site to be selected. The choice of borosilicate glass may turn out to be an unfortunate one. The controversy about choice of materials known as "waste forms" for waste solidification has had a long and complex history, which we will not go in to here. We only note here that it is by now well recognized that the choice of encapsulating material and the choice of the location of the geologic repository must be such that the two complement each other.

In December 1983, the Department of Energy announced three locations from which it will choose its first geologic repository.* They are:

o Hanford, Washington
o Nevada Test Site
o Deaf Smith County, Texas

Two of these three sites - Hanford and the Nevada Test Site - have characteristics which could result in the relatively rapid destruction of the glass and, hence, release of the wastes to the surrounding environment.

At Hanford, the relatively rapid velocity of the water in the aquifers which would soon saturate the repository could cause a relatively rapid erosion of the glass. (34)

At the Nevada Test Site, the relatively low pressure in the repository could cause water coming into contact with the hot glass to flash into steam. In experiments at the Argonne National Laboratory, researchers discovered that steam attacks glass and can cause its rapid disintegration.(36)

This mismatching of waste form to the repositories could result in violation of Nuclear Regulatory Commission regulations for long-term disposal at both these sites. These require that:

o the waste form remain almost completely intact for at least 300 years and up to 1,000 years;

o the rate of disintegration of the waste form should not exceed 1 part per 100,000 per year thereafter.

It is quite possible that in the case of glass one or both these requirements would not be met at Hanford and the Nevada Test Site. (We have not made an investigation of geologic questions relating to the Deaf Smith

*While the selection is formally only for civilian high-level wastes at this stage, military high-level wastes are likely to be put there also because of the cost of additional repositories and the political difficulty of finding a site. DOE has already filed one evaluation in which it claims a common civilian-military geologic repository would be cheaper. STET(33)

County site. We should note here, however, that the county is agriculturally very productive for which it depends on clean underground water supplies.)

This possible mismatching arose in part because of the haste with which both decisions were made, and the apparent lack of serious coordination between them. The initial repository selection documents do not examine in depth the question of waste form interaction with the specific sites selected for study as possible repositories.

The result of this haste is likely to be increased cost, higher worker exposures, and less long-term security from radioactivity for future generations. It would, in our opinion, be more prudent and conservative to proceed in the following manner:

o solidify the existing high-level wastes, including the sludge by calcining them;

o conduct appropriate pilot plant studies, including development of better worker protection measures, for waste encapsulation in glass and, possibly, other waste forms.

o stop the further production of liquid high-level radioactive wastes until the long-term questions are resolved.

The Department of Energy has opposed calcining on the grounds that this might be more costly and cause more worker exposures.* We believe this is a short-sighted view. Rushing in to full-scale vitrification without pilot plant experience is likely to cause many unanticipated problems and even breakdowns, which have not been factored into cost and exposure. There is at least some experience with calcining, which is also required, anyway, as part of the vitrification process. We believe that if risks and exposures to be minimized, it is more prudent to proceed carefully, and step by step, rather than rushing headlong into full-scale production without pilot-plant experience, as DOE and DuPont are now doing. These risks and exposures can be further minimized by stopping the production of high-level liquid radioactive wastes, pending the resolution of the long-term questions.

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TABLE 4-1

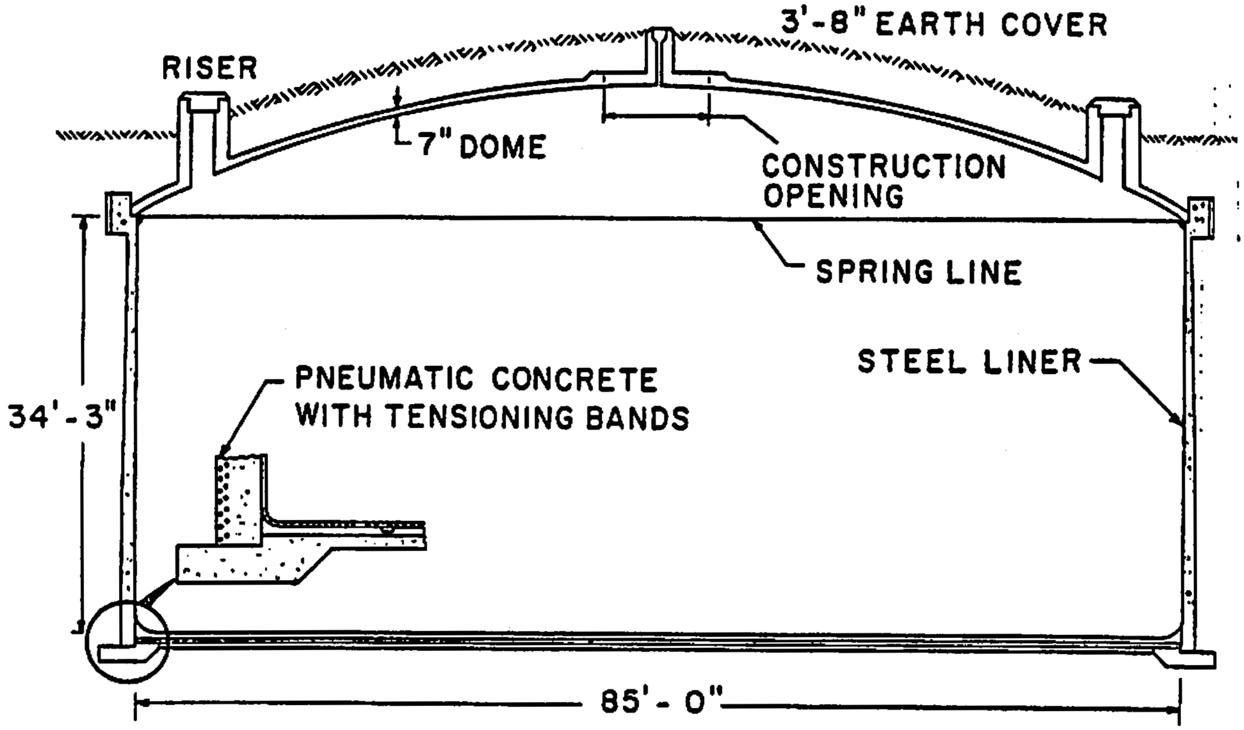
Planned Annual Discharges amd Cumulative Quantities of some Radionuclides in Saltcrete, Corrected for Radioactive Decay

Radionuclide		Half-life in years	Specific Content in Saltcrete nanocuries/gm	Cumulative Content Saltcrete after 28 Years
1.	Tritium	12.3	21	6,000
2.	Selenium-79	65,000	0.063	200
3.	Strontium-90	28.8	0.03	40
4.	Technecium-99	214,000	19	60,000
5.	Ruthenium-106	1.0	14	40,000
6.	Iodine-129	16,000,000	0.067	200
7.	Cesium-135	3,000,000	5.7×10^{-5}	0.2
8.	Cesium-137	30	15	30,000
9.	Samarium-151	90	20	50,000
10.	Plutonium-238	87.7	0.04	100
11.	Plutonium-241	14.4	0.03	10
12.	Americium-241	433	0.19	600

Source: DOE/EIS-0082

UNCOOLED WASTE STORAGE TANK

Prestressed Concrete Walls 1,300,000 Gallons



COOLED WASTE STORAGE TANK

Type I, Original 750,000 Gallons

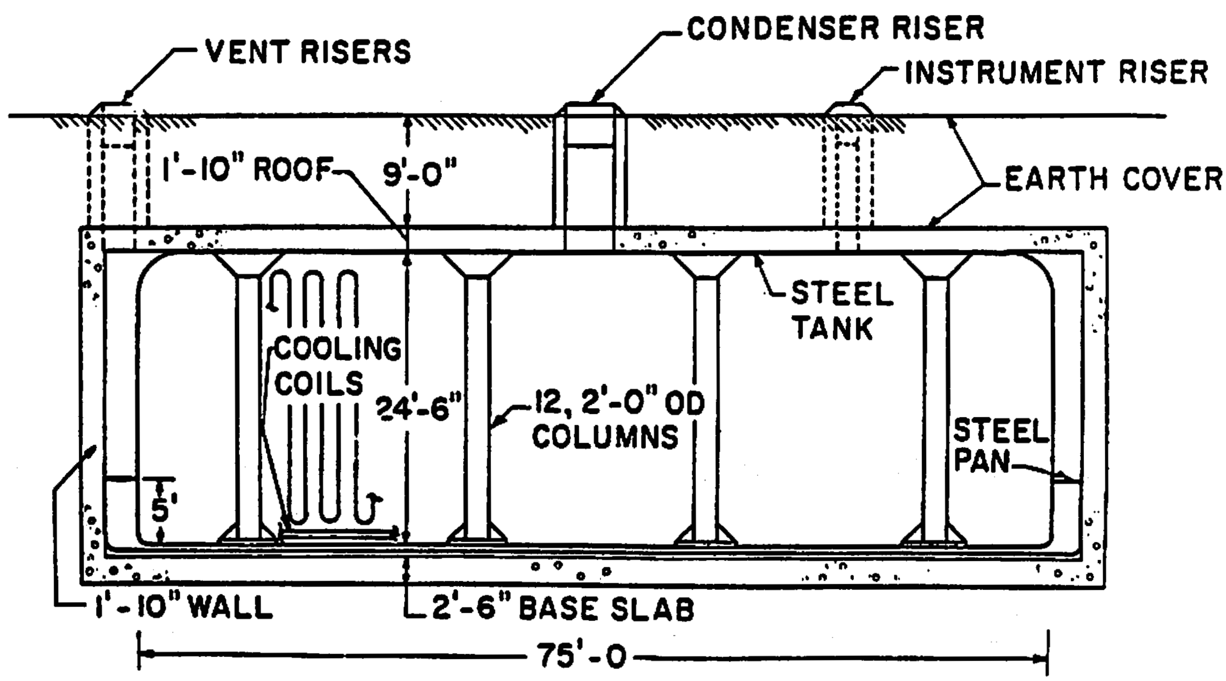
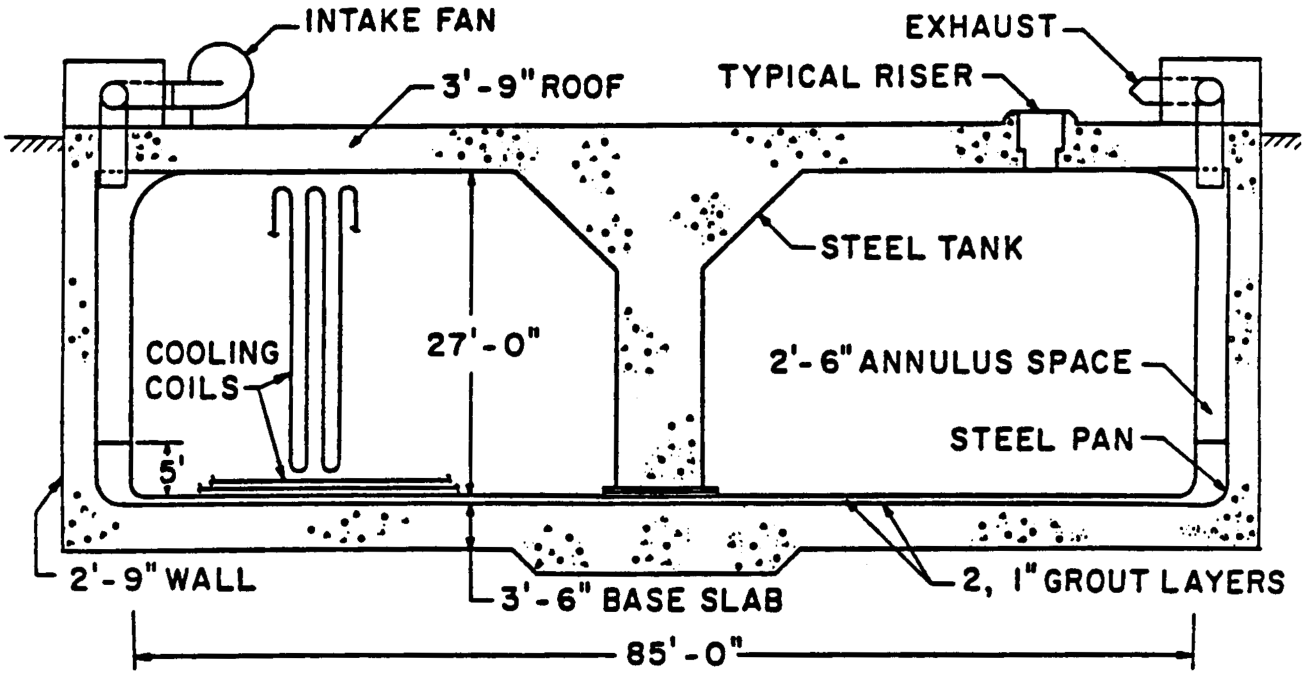


FIGURE 4.1

COOLED WASTE STORAGE TANK

Type II 1,030,000 Gallons



COOLED WASTE STORAGE TANK

Stress Relieved Primary Liner 1,300,000 Gallons

Type III

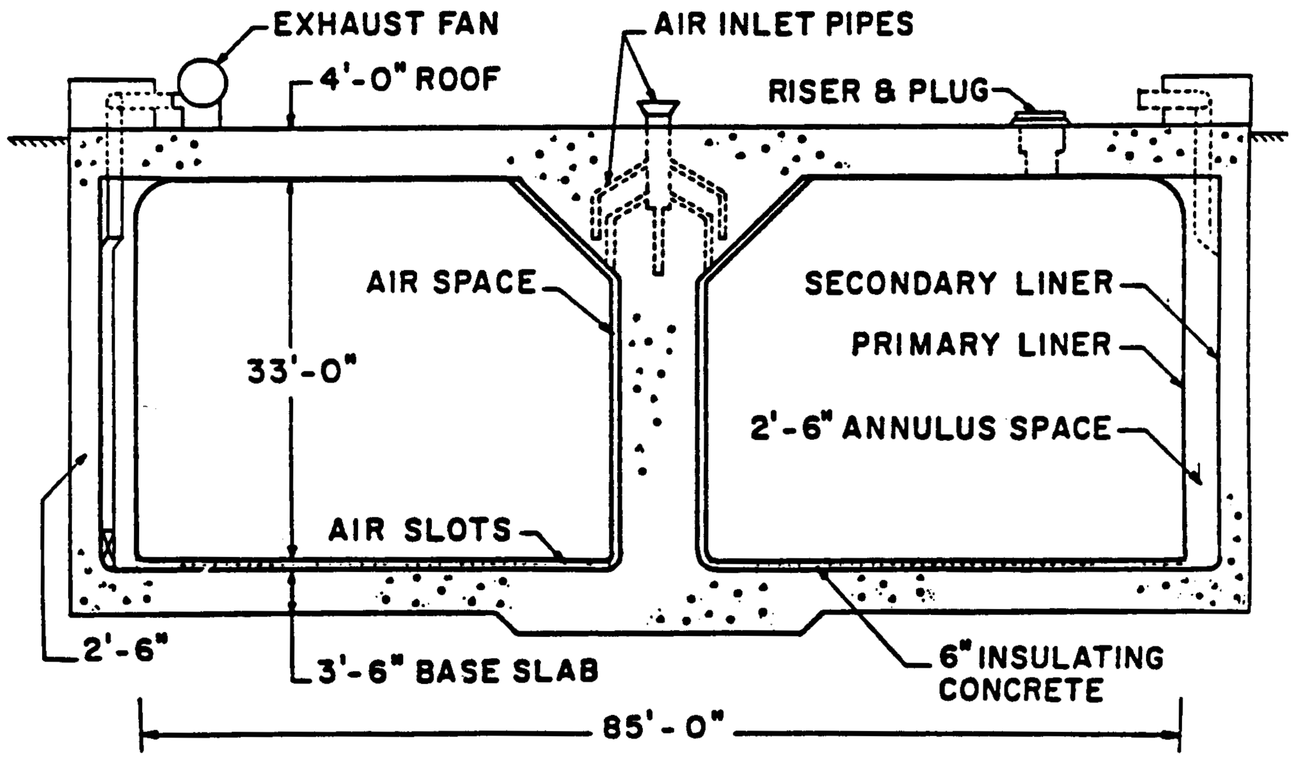


FIGURE 4.2

CHAPTER FIVE
CATASTROPHIC EVENTS

In a situation where 800 million curies of radionuclides, in mostly liquid and sludge form, are being held in tanks, there is the ever-present possibility that some event may precipitate a catastrophic release of radioactivity to the environment. There are three broad areas that must be addressed to assess the probabilities and consequences of such releases:

- analysis of possible equipment and process failures which could result in large releases - for example, tank leaks or hydrogen explosions in tanks;

- an assessment of the effects of events not caused by the Savannah River Plant but which could have a severe impact on its operation -- for instance, an earthquake:

- an assessment of the consequences of such accidents and releases once they do happen.

Both the Department of Energy and DuPont have produced reports on this subject. In 1977, the Energy Research and Development Administration presented calculations of risk to the public posed by the possibility of catastrophic events.(1) DuPont completed a Safety Analysis Report * in 1978 which is practically the same in regard to the risk calculations.(2) We will not analyses the results of their calculations but rather present a critique of the method and suggest more reasonable ways of approaching the problem.

The basic approach of DuPont and the Department of Energy is to calculate probabilities for events that might initiate or contribute to releases of radionuclides and then estimate the magnitude of the releases. The method is called "fault tree" analysis. The human consequences of these releases are then calculated by estimating how the radioactivity might reach people ("critical path") and how many cancers and genetic effects it might therefore cause. Both the calculations of the probabilities and the ways in which they are used are seriously defective. Some of the calculations of the consequences of releases fall into the realm of the absurd.

Process and Equipment Failures

The first step in the official risk assessment is to catalog events which might result in releases and to calculate their probabilities. For events related to the plant itself:

Probabilities for primary events of Tank Farm Fault Tree were obtained primarily from three sources:

- *"The SRL [Savannah River Laboratory] computer-stored data bank called 200 Area Fault Tree Data Storage and Retrieval System."*

*this report remained secret until 1982.

o *"WASH-1400, Appendix III, Failure Data."*

o *"Judgments by experienced Technical personnel of SRP and SRL[Savannah River Laboratory]."(3)*

The second of these three items has nothing directly to do with the Savannah River Plant Waste Tank Farm. WASH-1400 is a study entitled Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants published by the Energy Research and Development Administration in 1975. Apart from the considerable controversy surrounding this study, the fact of the matter is that commercial nuclear power plants do not have tanks full of reprocessed, neutralized, liquid high-level radioactive waste. Some of the same equipment used in commercial powe1 plants might be useo on the Tank Farm, but it is used under significantly different conditions. Thus, while it would be prudent to check on the performance and breakdown frequencies of such equipment under power plant conditions,* it is inappropriate to use such data as primary source for accident or breakdown probabilities for SRP's Waste Farm operations.

This leaves only one document as the source of data for the probability calculations -- The Fault Tree Data Bank. Statistical calculations based on this document will, general, be of dubious validity, to say the least.

Good statistical estimation requires a clear philosophy of data recording and a uniformity of recording data over periods comparable to or longer than the periods for which estimates are to be made. If there is any significant change in recording procedures, this should be clearly motivated and related to field conditions. Finally, when different recording procedures are used, a systematic attempt to bring all periods to a comparable statistical basis must be made. None of these criteria have been followed in the recording of the Fault Tree Data Bank.

We noted in Chapter 3 that the frequency of Data Bank entries have varied from 4 per year in the 1950s to about 1,800 per year in the late 1970s. Moreover, these changes in recordkeeping procedures seem to have been largely arbitrary and dictated by non-technical considerations. Many events of considerable significance such as tank leaks were explicitly not recorded since they were deemed not to be of "particular interest." The quality and consistency of the data also leave much to be desired (as we have discussed in Chapter 4). Statistical estimates based on such data are likely to have considerable margins of error.

Deficiencies of data when they relate to hundreds of pieces of equipment and process details, and which are of such enormous magnitude, cannot possibly be made up by technical judgment of a few experienced people. Further, primary reliance on Savannah River Plant employees' opinions to estimate the probabilities of failure contains inherent conflicts of interest. A finding of high failure probabilities would reflect unfavorably upon the

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*It would be interesting to know how the breakdown probabilities for Tank Farm equipment have been changed after the 1979 accident at the Three Mile Island nuclear power plant.

quality of the technical work and the inadequacy of corrective measures. It might also jeopardize the jobs of the very personnel making the estimates if there was a finding that the probabilities of serious damage to the public were large because such a finding might imply a lack of due care or responsibility. All of this would be true even if the management were committed to a scientific and thorough evaluation of the dangers of plant operation.

Judgment of technical personnel can, in general, only be a supplement to an evaluation based on reasonably comprehensive data. It cannot make up for lack of essential data.

This essential inadequacy of the data is compounded by the way in which the statistical estimates are used and presented. Given the defective data base, it would be more reasonable to calculate a range of failure rates. Instead, only one number, an average, is presented. It is then used as if it were utterly reliable. That is, the consequence is calculated using these average rates as if these rates are the actual failure rates -- with 100 percent certainty. In practice, there is some uncertainty associated with any estimate of failure rates. This will vary with the adequacy and amount of data, with the specific piece of equipment and with the probability model used. Sound statistical practice, particularly in the presence of inadequate data, is to estimate ranges for parameters using 95 percent, 99 percent or higher confidence limits. The higher limits would be used if consequences of misestimation are serious. The upper failure frequency, with the specified confidence limit, should form the basis of further estimation of consequences.

Thus, for example, if the recorded data yield any average failure rate for a piece of equipment of once a month, the confidence in that estimate could vary considerably. With excellent data -- that is, data covering many identical pieces of equipment, under the same operating conditions, uniformly recorded over periods of time much longer than the average time between failures -- we would be able to use a maximum failure rate of a few percent more than the average rate yielded by the data with a high confidence level. This might be the case with some estimates for equipment at the Tank Farm which have failure rates of once a year or greater, on the assumption that all such failures have been recorded for the six year period 1977-82. (However, as noted in Chapter 3, the frequency and nature of the recording changes does not lend itself to having a high confidence that all equipment failures and operating problems were recorded during this, or any, period.)

In the case of equipment such as tanks or evaporators for which the recorded failure rates are comparable to or smaller than once a year, the Data Bank provides an inadequate data base, particularly due to changes of recording procedures. Under such circumstances an estimate of failure rate in which one could have a high confidence might well be substantially larger than the estimate based on the recorded data, especially since many tank leaks have explicitly been excluded from the data base as discussed in Chapter 3. Consequently, improving the calculations by requiring high confidence levels in the estimates of failure rates of such equipment could well result in much higher estimates or risks compared to those given in the official publications. In addition, it is good statistical practice to estimate the variance, or spread of the quantity estimated around the average. For example, if the average interval between breakdowns of a pump is 60 days, then it is important to know whether most failures occur at or near the average of 60 days, or whether the average is composed of widely spread values, for example from 10 to 100 days. This practice also appears not to have been followed by DuPont and DOE.

For some events, such as those which are dependent on social factors, or for which requisite technical data are not available, there appears to be no statistical basis for the probability estimates. For example, DOE has considered the consequences of possible abandonment of the Tank Farm without the removal of the wastes in it. The basis of its assumption of a probability of one chance in one hundred thousand per year is the general assertion that the "waste tank farm is less likely to be abandoned than other engineered facilities that have been maintained for centuries such as dikes and aqueducts."(4) While some dikes and aqueducts have been maintained for centuries, many, perhaps the majority, have not. DOE does not cite any analysis of the matter, nor does it justify using a probability of abandonment that might be orders of magnitude lower than that for aqueducts and dikes. When probability assumptions are of the "hand-waving" variety, as appears to be the case with this example, it is meaningless to discuss improving them by the use of statistical techniques which can be applied to cases where some real data has been compiled.

The DOE and DuPont approach to evaluating probabilities of system failure is also defective. For instance, the probability of a waste tank explosion resulting in a collapse of the tank roof is estimated as follows:

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

o Failure of tank ventilation system.

o Failure of pressure alarm to detect ventilation failure or failure of operating personnel to heed the warning.

o Spark initiation in tank after explosive gases have been generated in the tank.

o Failure of procedural safeguards (in routine check of blower operation, routine measurement of hydrogen composition in gas space of waste tank, etc.) to detect and correct ventilation failure.

Based on estimates of the individual probabilities of these conditions, a hydrogen explosion is estimated to have a probability of approximately 1×10^{-3} *[one in 1,000] per year.*

The waste tank explosion postulated...involves failure and collapse of the tank roof. It is estimated that one tank explosion in 10 would result in such an extensive accident. The probability of the waste *tank explosion postulated for Incident 6 is therefore about 10^{-4} [one in 10,000] per year."(5)*

The use of average failure rates of components without attaching appropriate confidence limits will, in general, result in even more uncertain estimates of system failure probabilities. Put another way, in order to have a certain level of confidence in an estimate of the probability of system failure, the confidence limits failure estimates of critical system components or sub-systems must be greater. Thus, in the above example, to have a confidence level of 99% in the estimate of the probability of a tank explosion of one in a thousand per year, one must have practically perfect statistical estimates of component failure rates. Since the component estimates are themselves based on seriously defective data, or sometimes no actual data at all (as in the case of roof collapse) little statistical significance can be attached to system failure rates based on the methods used by DOE and DuPont.

There are some possible events for which no probabilities at all are calculated. Thus the possibility of a nuclear criticality in a tank is not considered because a "measurement, made in 1973 in the tank containing the most U-235, confirmed that the concentrations were all less than one-tenth of the level of concern. There is no known mechanism to concentrate and rearrange the Pu-239 or the U-235 in this manner."(6) It may, however, be too late to take corrective measures if some "unknown" mechanism brings about a criticality accident! Moreover, we noted in Chapter 3, that the 1978 DuPont estimates of plutonium in the tanks appear to be too low by a factor of 3, according to its own 1981 data. Another error like that and the requisite order of magnitude increase would be nearly present without help from unforeseen chemical or physical events!

Besides omitting the possibility of a criticality inside a tank, DOE and DuPont appear also to have ignored the possibility of a criticality following a breach of tank containment. The soil is known to concentrate plutonium and this might eventually produce a "nuclear excursion." Such a process of plutonium concentration almost produced a criticality accident at Hanford.(7) This omission is all the more strange when we consider that DOE (then ERDA) has explicitly considered the possibility of a criticality in the Burial Ground.(8)

The above discussion applies to problems with data and with its application to the estimation of the probability of events such as equipment or system failures. There also appear to be some problems with the statistical model into which these failure rates are incorporated to assess the expected number of failures over long periods of time. The model used is the Poisson distribution:

The time basis for probability used in this analysis is the hour. Mean failure rates were calculated in events per hour and were assumed to be constant over a time period of one hour. For all failure events encountered, the product of mean failure rate (λ) and time basis (t = 1 hr) is much less than 1, and therefore the general *expression for the probability of a failure in the next time period t, P(t) = 1-e(- λ t), reduces approximately to P(t) (events/hr) (1 hr) = λt . This expression was used in calculations throughout the analysis.*

This statement does not explicitly rule out the possibility that failure rates may vary with time. That is, as equipment grows older, the possibility of failure might increase, in some cases dramatically. However, in the application of the model, constant probabilities of occurrence appear to be used throughout to cover long periods of time. This might be adequate for equipment, such as reel tapes, which are frequently repaired and replaced, but it is not a reliable way to estimate risks involving long periods, particularly over periods which are comparable to or greater than the entire period of observation. This is especially crucial in estimating the probabilities of events relating to the integrity of the tanks.

DuPont estimates the frequency of tank failures to be 1 per 200 tank-years for Type I and II tanks and 1 per 17,000 tank-years for Type III tanks.(10) The latter figure means that one would expect one leak in 500 to 600 years in a Tank Farm consisting of 30 Type III tanks. The estimated frequency of failure of 1 in 17,000 tank-years is made on very inadequate data. Little confidence can be placed on it, particularly when we note that corrosion pitting has already occurred in 14 tanks during construction and that the primary containment of one tank has already leaked.

Earthquake Potential

In 1886 Charleston, South Carolina, experienced a severe earthquake, with an estimated intensity of X on the Modified Mercalli scale.* This earthquake had an intensity of VII to VIII in the SRP area, which is about 100 miles from Charleston. The earthquake was felt over a 2 million square mile area and caused damage as far away as Chicago, Illinois. This intensity of VII to VIII on the Modified Mercalli scale, with an acceleration of 0.26, is the design basis earthquake for SRP.

Until 1982, the U.S. Geological Survey (USGS) rated "the likelihood of a Charleston type event in other parts of the coastal plain and the Piedmont [as] very low." But the USGS altered its views dramatically in 1982. The Charleston region and elsewhere along the coastal plain indicated that "...the general geological structure of the Charleston region can be found at other locales within the eastern seaboard (Appalachian, Piedmont, Atlantic Coastal Plain, and Atlantic Continental Shelf)."(11) Furthermore, the USGS stated that "...the historical record is not, of itself, sufficient grounds for ruling out the occurrence in these other regions of strong seismic ground motions similar to those experienced near Charleston in 1886."(12) They advised the Nuclear Regulatory Commission (NRC) that the design basis for nuclear facilities should be determined on their revised assumption of a major earthquake

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*Modified Mercalli Earthquake Intensity Scale. Source DuPont Safety Analysis Report; Liquid Radioactive Waste Handling and Storage Facilities (200 Area), DPSTA 200-3 August 1978; p. 6-59.

occurring anywhere in the region including the SRP site.(13)

The Nuclear Regulatory Commission has taken the USGS seriously and has launched short and long-term probabilistic and deterministic studies. In explaining their research plan to the Commission, the NRC staff noted that "the November 18, 1982 letter from the USGS represents not so much a new understanding but rather a more explicit recognition of existing uncertainties with respect to the causative structure and mechanism of the 1886 Charleston earthquake." Put more simply, the confident pronouncement by various experts that "a major earthquake near SRP is improbable,"(14) is simply speculation, according to the NRC staff in 1982:

Many hypotheses have been proposed as to the locale in the eastern seaboard of future Charleston-size earthquakes. Some of these could be very restrictive in location while others would allow the earthquake to recur over very large areas. Presently, none of these hypotheses are definite and all contain strong elements of speculation.(15)

The NRC staff found "the primary problem with seismic hazard characterization of the eastern seaboard is that no causative mechanism for seismicity has been identified to date and no surface offset due to earthquakes are known." This means that the causes of the Charleston earthquake are not yet well understood.There are "literally thousands of crustal structures" known in the eastern seaboard, which if they were active, "could produce strong earthquakes. But none have been shown to have been active for the last 2 million years."(16) However, the difficulty is that evidence of past inactivity cannot be used for ruling out future large earthquakes -- hence the "strong elements of speculation" in any probability numbers.

Calculating the Consequences

Some of the most serious lapses in the analysis of risks lie in the calculations of the consequences of equipment or process failures or of events like earthquakes or hydrogen explosions. It is here, in their eagerness to prove that nothing could possibly happen to gravely endanger the public, that the Department of Energy and its contractor DuPont descend frequently into the realm of the incredible and the absurd.

The official reports present calculations relating to a couple of dozen "primary " events -- that is, initiating causes of releases of radionuclides. Our resources do not permit an evaluation of each one, but many of the more serious ones are similar since they involve ruptures of equipment containing large quantities of high-level waste. We will therefore concentrate on evaluating the official analysis of the consequences of earthquakes and of hydrogen explosions.

Table 5.1 summarizes the major effects of earthquakes of various intensities on Tank Farm operations as calculated by DuPont. For intensities VII or less on the Modified Mercalli scale, no damage or releases are assumed. An earthquake of intensity VII would cause difficulty in standing, plaster and tiles to fall, and furniture to break.(17) At least some of the calculations appear to be based on rather optimistic assumptions.

For example, the calculations assume that the cracks and corrosion of the tanks will not compromise the ability of the tanks to withstand a "design basis earthquake."(18) These calculations appear to rule out any brittle cracking of the tank walls even though this has been acknowledged as a possibility by both DuPont(19) and the Department of Energy.(20)

In earthquakes of intensity IX or greater, rupture of some waste tanks and piping, etc., is explicitly considered. The only two modes of release considered "significant" are those which result in direct release to the surface water or to the air. Thus, in the worst possible case of an intensity XII, where destruction would admittedly be total, the maximum possible release considered is 46 million curies to the surface water(21) which accounts for about less than one tenth of the total radionuclide content of the tanks (1977 inventory).

The consequences of releases into the soil and groundwater -- which would amount to about 500 million curies in the worst case (1977 inventory) -- are explicitly dismissed because "their consequences and risks are insignificant compared to those of release by the surface water and atmospheric pathway."

The major premises for such an assumption have already been proven wrong as we will discuss in Chapter 6. The waste is assumed to be immobilized in the soil, and if it does reach the water it is assumed to decay before it reaches the surface water, before anyone uses it. The possibilities of substantial changes in groundwater use, or in hydrology (known to be caused by severe earthquakes) are explicitly dismissed.

No synergistic interaction with events the earthquakes might cause elsewhere in the Savannah River Plant appears to have been considered. For instance, it is well known that the presence of organic compounds like tributyl phosphate in the soil can cause a tremendous acceleration of the migration of some radionuclides -- plutonium in particular. Tributyl phosphate , being the principal solvent used to separate plutonium and uranium from fission products, is present in large quantities at the plant. It is stored in tanks which would likely rupture in case of an earthquake. That would mean that vast areas of the soil on the site would have tributyl phosphate which would spread because of the heavy rainfall in the area. The effects of even so obvious a contingency on the contamination of groundwater seem not to have been considered.

The clear implication of the earthquake calculations is that the Department of Energy and DuPont do not consider soil and groundwater contamination to be serious matters in and of themselves (that is, except as they affect surface water). In that case, one wonders why they have not carried their argument to the logical conclusion: if soil and groundwater contamination pose "insignificant" risks, why have tanks at all? Why not just dig trenches, being careful to cover them with tarps (to prevent suspension of radionuclides), and discharge the wastes directly into them with hoses? It would be much cheaper -- and get rid of the problem of long-term management all in one stroke!

Equally egregious are some of the assumptions about restoration of plant operation. For instance, the calculations assume near total destruction (90%) in an earthquake of intensity XI. The result would undoubtedly be a plant site that would be extensively and intensely contaminated. We should note here that soil excavation work on a spill of 50 curies, which would be tiny compared to the consequences of an earthquake releases of hundreds of millions of curies (plus large quantities of other toxic materials), had to be stopped because radiation rates of 500 rads per hour were encountered. (F-Area entry dated 03-12-76. Table 1, Part II>) Ignoring its own records and experience, the management assumes that cooling water to tanks would be restored after 90 days.

How workers would be mobilized to work in an area which would be a veritable radioactive hell and which would have to be abandoned essentially forever, or how they would work to restore piping and power in such an environment, is not described in the official reports. Neither does the question of what use it would be to restore cooling water supply to tanks that no longer exist seem to have been addressed.

The absurdity of the calculations and the determination to show that there could be no serious harm even as a result of big earthquakes, can be further illustrated by the official conclusion that suspension of particles into the air would be one of the two most important sources of risk to the public. Thus, in an intensity IX earthquake a relative damage of just 25% to tanks containing about a million gallons each of waste is postulated. This would result in the suspension of about 1.5 gallons per tank in the air according to DuPont. (See Table 5.1). This is assumed to be the second most important source of radiation to people.

A closely related assumption is that only the present generation would be affected and that cancers would be practically the only effect. Doses to future generations appear to have been ignored. We do not know if cancer or other effects on fetuses have been considered.

The risk calculations also appear to omit the effects of non-radioactive toxic materials present in the tanks. For example, there were about 190,000 pounds of mercury in the tanks in 1975.(23) The risks and problems posed by the much smaller quantities of mercury in the seepage basin have been acknowledged both by the EPA and by DuPont researchers (see Chapter 6). Yet the risks posed by almost 100 tons of mercury in the tanks, particularly to ground water, seem to have been ignored.

The effects of the errors and defects in both the approach to and the details of the risk calculation is to yield probabilities in catastrophic events which are very small. When these are combined with the selective estimation of the consequences of radioactivity releases, the overall effect is to yield small risk or "dose" estimates. This is because "dose" estimates are calculated by multiplying the probability of events with the releases which are considered "significant."

Besides the serious deficiencies and errors in the analysis, this method of calculating risks of catastrophic events is not a well-considered one. It assumes that an event of a large probability with relatively small consequences is equivalent to an event of small probability with serious consequences.* The soundness, or lack thereof, of the procedure in evaluating risks can be illustrated by looking at it from the point of view of an insurance company or a bank. An insurance company with a thousand dollars in capital could write many times a thousand dollars of insurance provided that the maximum amount of any policy was small compared to the capital. A prudent insurer would not sell one policy for several million dollars if the ability to pay is a few thousand, even if the probability of having to pay on the policy was very small. This is because the consequence of the event, if it occurred, would be bankruptcy. The total amount of all outstanding policies can safely be higher than the capital only if each one is kept below it. Similarly banks generally do not make single loans which are larger than their invested capital, even though the cumulative amount of all loans is usually much larger. In fact, banks are required by law to keep the largest single loan to well below the capital invested.

Reducing damage from a catastrophe to an average risk is contrary to common sense. If one adopted this view, one might advise people to cross the street against "DON'T WALK" signals, if calculations showed it would save time on the average. Similarly, no healthy young parent would be advised to purchase life insurance because the return on investment is higher in a bank account on the average. We reject risk estimates based on statistical averages in such cases because average gains cannot compensate for the losses in the specific instances.

For this reason, an average measure of risk is not a very meaningful measure to be used for catastrophic events. For these, the consequences, once a precipitating cause of catastrophe has occurred, are more significant.* This procedure should not be applied to events that threatens substantial or complete destruction of large areas or numbers of people. For these kinds of cases, the calculations of risk must be based not only on expected probabilities of occurrence but also on the consequences if catastrophe strikes.

Thus, the seriously defective calculations of DuPont admit to a possible dose of 34 million person-rems as the result of an intensity XII earthquakes.(24) On the basis of dose-risk relationships established by various scientists and committees, a range of subsequent health effects can be estimated, though this range is substantial. (See Chapter 7 for

*This method is not peculiar to DuPont. It is used all too often by DOE and is widespread throughout the nuclear industry.

*In theoretical terms: one must not only consider the probability of the intersection of two events E1 and E2 given by the product of the probability of E1 with the conditional probability of E2 given E1, $(pr(E1 \cap E2) = pr(E1) \times pr(E2/E1))$. One must also consider the conditional probability, pr (E2/E1), by itself.

detailed discussion.) The 34 million person-rems estimated by DuPont to occur from the rupture of the high-level waste tanks at SRP could give rise to anywhere from 11,000 to 230,000 excess cancer cases.(25) These estimates are based on 1978 data presented by DuPont. Current inventories (1984) are about 30% higher. Moreover, we have discussed above that the quantities of plutonium and other actinides in the wastes could be several-fold higher than the 1978 DuPont data. The casualty estimates, even for the limited model used by DuPont, based on current inventory data would likely be still higher.

The calculations of risk of genetic harm also have a wide range. With the exception of cytogenic data from monkeys and humans, genetic risk estimates have been heavily dependent on extrapolations to humans from experimental rodent studies. These risks are expressed in terms of (a) first generation serious disorders, (b) cumulative genetic effects over time (equilibrium), and (c) effective years of life lost. Because of the major uncertainties in predicting generational effects from the initial radiation exposure of the parents, we cite low and high range estimates.

Thus, if a 34 million person-rem dose occurred in the vicinity of SRP from a major accident at the Tank Farm: (a) first generation genetic diseases could range from 200 to 2,500;(26) (b) cumulative effects over time could be 2000 to 37,000;(27) (c) effective years of life lost are estimated at 80,000 years in the first generation and about 460,000 years for all generations.(28)

Radiation geneticists assume that the bulk of adverse hereditary effects from radiation will occur during the first three generations or 90 years after the parents are first exposed.

In the case of a magnitude X earthquake, comparable to the 1886 Charleston earthquake, the consequences based on DuPont release estimates would be about 60% of the above figures.

These estimates are in no sense definitive. The large range of uncertainties are ample evidence of this fact. But for purposes of public health planning, such estimates help us to understand the general parameters of catastrophic risks and their possible effects on the society, as best we know them today.

It is even more difficult to assign monetary values to the health effects of radiation exposure from man-made sources. Nonetheless, we provide some rough minimal figures as supplementary indicators of the material consequences of dangerous activities. We have taken values from the scientific literature(29) on the societal costs of radiation exposure and have applied them to a catastrophic accident involving the high-level waste tanks at SRP. Assuming an inflation adjusted discount rate of 6% per year, the estimated excess cancer cases due to a 34 million person-rem dose could cost from $800 million to $ 14 billion. Adverse genetic effects, which include long term institutional care for first generation offspring damage could cost from $90 million to over $1 billion. These costs do not reflect property damage or loss.

Some accidents could also cause very large releases and damage.

Consider, for example, an explosion in a waste tank due to a build-up of hydrogen. Such a build-up due to the failure of ventilation systems in a tank. A severe explosion could cause the rupture of the tank and a roof collapse. We have cited above the official probability estimates for such an event, along with a discussion of their weakness. In the worst case officially postulated, an explosion could cause the release of about 7 million curies of radioactivity into the soil, water, and air.

The official calculation of the effects of such a release hae the same general defects as those discussed above for earthquakes. Even with the underestimation implicit in these estimates, a severe hydrogen explosion could result in sufficient radiation doses to cause from 1,000 to over 20,000 excess cancer cases, as well as hundreds or thousands of cases of diseases from genetic defects in future generations. The costs, excluding property losses and environmental damage, could range up to about $1.4 billion.

The inclusion of property losses, environmental damage, losses of agricultural land and crops would drive the total damage estimates considerably higher.

Accident Liability and Accountability

During the 1940s, it was recognized that certain federal nuclear facilities had the potential of causing catastrophic radiological accidents involving massive loss of life, serious injuries, and extensive property damage. Up until 1957, the federal nuclear weapons program had no limit on liability for catastrophic radiation accidents. Private contractors were also held accountable for accidents stemming from their negligence. In 1957, however, a system was created by law which set a limit on liability for accidents at 500 million dollars. Known as the Price/Anderson Act, this system was added to the 1954 Atomic Energy Act mainly as an incentive for private utilities to purchase nuclear power plants, who were fearful of liabilities which could bankrupt them. The act also covered federal nuclear facilities under section 170d.

The central feature of the act is a limit on the total aggregrate liability which arises from a major nuclear accident. Although the act has been changed over the years to increase coverage for nuclear power plant accidents, the limit on liability for Department of Energy facilities is set at the 1957 level of $500 million.

As it applies to DOE nuclear facilities, the Price/Anderson Act provides total indemnification for all government contractors regardless of contractor negligence. Currently there are over 100 DOE contracts with Price/Anderson protection, covering about 50 prime contractors and 70,000 subcontractors.(31) A total of 280 DOE facilities are covered under the Act.(32)

According to the Department of Energy:

> *essentially, the contract indemnity provides that, in the event of a nuclear incident, the contractor or any other person who may be liable would be indemnified by the DOE, up to the*

statutory, specified ceiling of $500 million, for any legal liability resulting from a covered nuclear incident arising out of or in connection with contractual activity.(33)

If an accident occurs and the limit on liability is exceeded, as would likely be the case if major ruptures occurred at SRP's high-level radioactive waste tanks, an act of Congress would be required to provide adequate compensation. Unfortunately, the speed by which the Congress has moved to provide even partial relief has been less than timely. For example, in 1947 a chemical explosion caused by the collision of two ships under government contracts killed 570 people and injured another 3,500 near Texas City, Texas. The entire Texas City dock was destroyed along with residences and industrial facilities causing property damages estimated at $80-$300 million. Eight years later Congress passed disaster relief awarding victims a mere $21 million in inflated 1955 dollars.(34)

Additionally, the act does not cover the cost borne by states and citizens in the case of an incident at a federal nuclear facility which requires a precautionary evacuation. Nor does it cover acts of sabotage or terrorism. High level radioactive waste repositories are also not covered under the Act.

The indemnification system for DOE nuclear contractors is such that contractors are not required to purchase private insurance since the government would have to pay the premiums. According to DOE, "our experience to date, of course, completely supports the prudence of the judgment to self-insure from the first dollar of the indemnity coverage."(35)

The enormity of the possible damage, as well as the lack of scientific soundness of the analysess of DOE and DuPont in their assessments of possible catastrophic events, leads us to conclude that making contractors accountable for major accidents stemming from their negligence would add a much needed incentive for safety. Further, the DOE liability should be made commensurate with the damage that would occur. This would be another built-in incentive for the federal government to meet "state-of-the-art" health and safety standards.

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22. Ibid., p. 6-62.
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Table 5.1

Estimated Earthquake Damage to Major Containment Systems.

Earthquake Intensity at SRP	
VII	None leading to release.
VIII	Covers of evaporator cells fall into cells and shielding blocks tip over. Pipes and evaporator pots are ruptured. Waste sprays out top of evaporator cells at 20 gpm for 10 minutes. 0.01% converted to 10m spray. The concrete shells of some waste tanks crack, but the steel liners remain intact. Soil liquefies in the H-Area tank farm and slumps away from 11 waste tanks built partially above the grade. Some transfer lines may also be uncovered. The transfer line from the H-Area CTS pump tank to the waste tanks fails and spills 50 gpm to the ground surface for five minutes.
IX	Normal and emergency electric power lost. 0.25 relative damage done to evaporator cells waste tanks and underground piping. Evaporator cells crack and pots rupture, spilling 0.25 of their contents to the ground surface (1500 L/evap). Roofs collapse on 0.25 of waste tanks splashing 57,000 L of supernate per tank to the ground surface, and atomizing 5.2 L of supernate per tank (<10m). Soil liquefies in the H-Area tank farm and slumps away from 11 waste tanks built partially above grade. The liners and concrete shells of the 11 tanks crack, releasing 0.25 of their contents. One-half of this leaks to the ground surface over a 24-hour period. The remainder seeps into the ground beneath the tanks. Cooling water 0.25 of waste tanks lost for two weeks. One of the three tanks that would boil with no cooling waste boils for one week.

Table 5.1 (continued)

X	Same damage as that estimated for a Class IX earthquake except relative damage to evaporator cells waste tanks, and underground piping is 0.6, and the cooling water outage to waste tanks is assumed to last 4 weeks. Two tanks boil for 3 weeks.
XI	Same damage as that estimated for a Class IX earthquake except relative damage to evaporator cells waste tanks, and underground piping is 0.9, and the cooling water outage to waste tanks is assumed to last 90 days. Three tanks boil for 83 days.
XII	Same damage as that estimated for a Class IX earthquake except relative damage to evaporator cells waste tanks, and underground piping is 100%, and the cooling water outage to waste tanks is assumed to last long enough for the three boiling waste tanks to evaporate to dryness. (approx 110 days).

Source: DuPont Safety Analysis Report, DPSTSA-200-3, Aiken, SC, August, 1978.

CHAPTER 6
ENVIRONMENTAL CONTAMINATION

There are four kinds of environmental contamination from radioactive and non-radioactive substances which occur at the Waste Tank Farm operation:

- routine discharges to the environment, notably of large quantities of contaminated liquids to the retention and seepage basins;
- releases due to improperly working equipment, such as air filters;
- accidental contamination, such as that from tank and pipe leaks;
- disposal or abandonment of contaminated materials and equipment used on the Tank Farm.

The Seepage Basins

The Savannah River Plant management allocates to each part of the operation "release guides" for routine radioactivity discharges to the environment. These are based on the nature of the specific part of the plant and on overall total release limits calculated to keep doses to the surrounding population below certain levels.

Legally the management is constrained to keep discharges of radioactivity so that the dose to an individual member of the public from its activities will not exceed 500 millirems per year.(1)

The permissible levels of discharges are calculated from the 500 millirem limit using a "dose-to-man" model. These limits are very large. They are shown in Table 6.1. Overall they allow releases of over a million curies per year, including 800,000 curies of tritium. Large releases of alpha emitters, like plutonium and uranium-235, are permitted. For instance, they allow the release of 600 curies of U-235 per year, which amounts to over 25 tons. These legally allowed limits, under which the Department of Energy and its contractor for the Savannah River Plant operate, allow public radiation exposures which are higher than those for commercial nuclear power plants by a factor of twenty.

In practice, the routine releases that have been documented so far are considerably below the limits shown in Table 6.1 for most radionuclides. However,these limits are applied to *"the point at which effluents pass the site boundary"* and not the more conservative EPA standard that places limits at the point of discharge onto the ground. In a previously secret report on the Savannah River Laboratory (SRL) seepage basins, it was noted that "most discharges would be above ERDAM -524 [DOE's] concentration guides," if limits were applied to the point of discharge.(2) The non-conservative practice of calculating release limits at the plant boundary has enabled the DOE and DuPont to develop operating release guides which are well below the "legal" limit in most cases. It has also made it impossible to assess the performance of these standards for individual facilities. Each area is allocated operating monthly release guides which may be exceeded if "required" by operations. They frequently are exceeded.

Liquid releases to the seepage basins make up the largest volumes of routine releases from the Waste Tank Farm. The operating release guides for some radionuclides from the F & H areas, which include the reprocessing plants and the tank farm, are shown in Table 6.2.

While these are considerably below the DOE's legal limits shown in Table 6.1, the releases from the other parts of the operation, notably the Burial Ground have been much higher than anticipated (see below). Further, the "dose-to-man" model used to translate releases of radionuclides to the environment into doses of radioactivity to people is a linear model whose inadequacies have been criticized by the Environmental Protection Agency.(3)

Many entries into the Data Bank show that the operating release guides to the seepage basins are frequently exceeded on a monthly basis, and sometimes on an annual basis as well. (See for example, the H area entry dated November 81, Table 2, Part II.)

Besides such routine releases, there have been releases due to operating problems in the plant. To prevent this radioactivity from going to the earthen seepage basins, lined retention basins have been built to which large volumes of liquids contaminated to a greater degree than usual are diverted. The retention basins hold some of the radionuclides instead of the seepage basins. This allows some of the shorter half-life radionuclides to decay before entering the soil and water, but it is not likely to have any significant effect on the longer lived isotopes like cesium-137 and strontium-90.

Routine releases to the seepage basins are not the only discharges of radionuclides from the Tank Farm. Improperly working equipment, such as air filters, contribute to plant radionuclide releases to the atmosphere.* The Data Bank contains a number of entries showing air filters working well below specification efficiency. This includes the HEPA (High Efficiency Particle Activity) filters which are installed on the waste tanks to filter out any radionuclides from the air in the primary tank and the annulus.** On one occasion two tanks were operated for five days without air filters. (See H area entry dated 09-05-80, Table 2, Part II.) We do not have estimates of the total radioactivity which has been released due to poor filter operation.

Similarly, there have been problems with radioactive cesium removal. On one recorded occasion cesium-137 was released because the cesium removal column was inadvertently bypassed for 11 hours (F area entry dated 1-15-65, Table 2, Part II): "Cs release. Cs columns inadvertently bypassed for 11 hours." No estimate of the quantity released is provided in the Data Bank entry.

There are some entries in the Data Bank whose environmental implications may be serious but which are not explained sufficiently. From the data given it is not possible to determine whether environmental contamination

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*Some of the radionuclides released to the seepage basins enter the atmosphere later by volatilization. This applies in particular to radioiodine and tritium. Some of these airborne releases come down with the rain in areas outside the plant.

**Air circulation in the annulus was provided after many tank leaks were discovered. It was found that dry air helped to deposit salt on the cracks which prevented most cracks from leaking further.

occurred. Perhaps most remarkable among these is an entry dated March 1981, (F area entry dated 03- -81, Table 2, Part II) which reads in full:

A valving error in JB-line resulted in a transfer of 494 grams of Pu [plutonium] into canyon tank 9.7. This solution was subsequently fed to the LAW [Low Activity Waste] evaporator and discarded.

There is no indication as to where this large quantity of plutonium was "discarded."

Finally, radionuclides, including plutonium, are released when tank risers (pipes) and other similar pieces of equipment are opened. The Data Bank has dozens of entries indicating such contamination during the two-year period 1976-77. Yet no environmental contamination data or worker exposure data are given. There is also no explanation of why these entries occur predominantly in this period in the H area. (See Tables 1 and 2, Part II, and Chapter 7.)

The importance of the seepage basins to environmental contamination lies in the fact that here the radionuclides come into direct contact with the soil and water. This nót only a means of routine contamination, but yields some important scientific data regarding the assumptions on which risk calculations are based.

On an average, about 30 million gallons of radioactive effluent is discharged annually onto the F & H area seepage basins. Thus, in all an estimated 2.5 billion gallons of contaminated liquids have been discharged during 1953-78.(4) The chemical composition of the effluent is highly variable. It has varied from highly acidic (pH = 0.6) to highly basic (pH = 13.2). Its content of salts, organic compounds and other materials is also highly variable since the water which is used to "clean-up" operating areas is, in part, collected and sent to the seepage basins.(5) Tables 6.3 and 6.4 show the discharges of radioactive and non-radioactive wastes to the seepage basins. By 1976 over half a million curies of radionuclides had been discharged to the seepage basins (decay-corrected figure). (See Table 6.3.) In terms of radioactivity, the principal component has been tritium, but large quantities by weight of their radionuclides have been discharged. Thus, while the total quantity of natural uranium (99.3% U-238 and 0.7% U-235) discharged up to 1976 was estimated at 13 curies (a small percentage of the total activity), it amounted to almost 40 tons of natural uranium by weight. This material will stay radioactive essentially forever, since the half life of U-235 is 710 million years and that of U-238 is 4.5 billion years.

Records pertaining to non-radioactive discharge are less complete, but DuPont has estimated that between 1954 and 1973 about 4,500 pounds of mercury were discharged into the F & H basins. The cumulative volume of nitrates from 1961 to 1970 was estimated at 5,260 tons.

(See Table 6.4) Large quantities of other chemicals are also routinely discharged.

Mercury poses significant problems. DOE has apparently only recently begun to consider it a serious environmental hazard at SRP. Generated as an impurity of sodium hydoxide and as a catalyst to dissolve spent fuel elements in SRP's reprocessing plants, the amounts of mercury discarded annually have varied widely, according to official documents. By the late 1970s a few studies had been done at SRP on the mercury problem. One report stated:

Long term behavior of non-radioactive mercury in soils of separations areas is lagely unknown and future environmental impacts are difficult to predict. [It also concluded that mercury]...in soil and groundwater may impose the most severe restrictions on future at the site...(6)

Additionally, very long-lived fission products have been discharged into the F & H seepage basins. They include zirconium-93 (950,000 years), cesium-135 (2.3 million years) and iodine-129 (16 million years). (See Table 6.5.) These very long-lived fission products were also not taken seriously until recently. A 1977 Savannah River Laboratory report states, "the amounts [of very long-lived fission products] expected to be present do not constitute a hazard." The study prefaces this claim by acknowledging that "only limited studies have been made of very long-lived fission products and available data is inadequate to estimate amounts in soil columns and groundwater."

It is the position of the Savannah River Plant management that SRP discharges will not result in serious consequences. Apart from the controversy regarding the dose calculations mentioned above, this position rests on several premises:

(a) ion-exchange will immobilize a number of radionuclides -- in particular plutonium in the soil so that they will never enter the groundwater;

(b) only strontium-90 and tritium will contaminate surface and groundwater in any significant quantities;

(c) groundwater contamination is by itself of no consequence and since there will be no contamination of deeper freshwater aquifers, the only "dose-to-man" path would be via surface water.

(d) decommissioning of waste facilities is a low priority because of favorable environmental conditions.

In the following discussion we show that there is sufficient data to throw doubt on the scientific validity of each of these assumptions. Indeed, some data indicates that they are invalid as general assumptions.

Researchers for the Savannah River Laboratory, in studies on waste discharges in the 200 Area, claim that only tritium and strontium-90 enter groundwater in appreciable quantities.(8) This is not reconciled with historical data regarding ground water contamination.

For some 30 years, radioactive and non-radioactive discharges at SRP have severely contaminated shallow aquifers beneath the plant. Moreover, in 1983 some of these contaminants were found in a deeper aquifer used for drinking water on-site.* Hundreds of wells have been drilled to measure and trace contaminants, particularly in the 200

*Lawless, W.F., "The Dupont Management of Savannah River Plant Radioactive Wastes: A Report to the U.S. House of Representatives. Committee on Energy and Commerce." Nov. 27, 1983.

Area where the largest discharges have occurred. However, only a limited amount of data is publicly available on the extent of groundwater contamination from the 200 Area operations.

There is general agreement regarding the contamination of groundwater by tritium and strontium-90. Substantial amounts have migrated to surface outcrops. As regards tritium, DOE (then AEC) stated:

Of the 420,000 Ci [curies] of tritium sent to the [seepage] basins through 1975, 100,000 Ci has migrated to Four Mile Creek. The remainder is in transit in the groundwater or has decayed (half-life 12.3 years) or evaporated from the surface of the basins.(9)

Similarly, a considerable portion of the seventy-six curies of strontium-90 discharged to the F and H area seepage basins until 1975 had reached the groundwater.* Nine curies of this had travelled to the surface outcrop at Four Mile Creek.(10)

Based on 1973 estimates, the average annual amounts which outcrop at surface streams are about 1.6 curies for strontium-90 and 11,000 curies for tritium. According to a DuPont analysis of seepage basins' operation:

The seepage basins in the separations areas have become the predominant source of strontium-90 release to the [Savannah] river.(11)

The flushing of strontium-90 and tritium into the groundwater system in the 200 Area has caused a steady build-up in the shallow aquifer in the form of radioactive underwater contaminant plumes. Groundwater inventories of tritium and strontium-90 in these plumes as observed in well readings are consistently in excess of concentration guides:

Concentration [of strontium-90] in groundwater near the separations are basins range from 47 to 1100 times the concentration guide in the F-Area...concentrations will not approach the concentration guide until several hundred years after basin decommissioning.(12)

According to a previously secret 1972 DuPont study of seepage basins, 44% and 59% of the tritium discharged, respectively, in the F & H basins will reach the Four mile Creek.(13) Only about 10% to 21% of the strontium-90 will be removed by decay in each area. These estimates of groundwater flush

*Note that the figure of 76 curies of strontium-90 discharged to the seepage basin 1975 cite by DOE does not match up with the DuPont figure of 65 curies to 1976 in Table 6.3 above.

rates are subject to wide uncertainties. For example, in 1974:

predicting future emergence of strontium-90 [from the H basins] in the creek is far more uncertain since the soil column between the basins and the creek is not near complete breakthrough and groundwater concentrations provide no indication where the strontium is.(14)

Similarly, tritium and strontium-90 have migrated with the groundwater underneath the 195-acre Burial Ground, where used contaminated equipment, contaminated mercury (until 1968), contaminated soil, etc. are put into 20-foot-wide by 20-foot deep trenches.

The tritium plume in the groundwater underneath the Burial Ground is so concentrated that according to William Lawless, a former DOE engineer, it "would give a dosage of about 18 rem/yr to anyone drinking well water from this area and exceeds the EPA drinking water standard by 3500 times and would not be safe for 100 years."(15) (See Figure 6.1.)*

There is also evidence of contamination of the groundwater with other radioactive and non-radioactive toxic materials. Previously secret reports covering pre-plant operations (1951-53) to the year 1963 (DPSP series)(16) show that groundwater contamination due to the F & H area seepage basins was quite severe, often exceeding maximum permissible concentrations for non-volatile beta-emitters and alpha-emmiters by factors ranging from 100 to 1000. (See figures 6.2 and 6.3.) Alpha contamination of groundwater near the F & H basins was often in excess of drinking water standards, sometimes by a factor of 1000 at depths of 23 feet and as far away as 46 feet from the basins.(17) During this same period, non-volatile beta-emitters (primarily radiocesium and radiostrontium) were measured in shallow aquifers at levels hundreds of times above pre-operation "background readings". Until 1956, certain alpha readings in water were referred to as "uranium or plutonium."(18) This description was dropped in later reports and statements were made that no plutonium was being detected in surface or groundwater. In spite of these facts DuPont researchers confidently state that "most of the plutonium is bound in the top few inches to one foot of seepage basin sediment." The researchers also stated that uranium "is barely detectable in groundwater separation areas."(19) This would imply that uranium migrates through the soil very slowly. However, uranium migration at SRP maybe comparable to the more rapid rate of strontium-90.(20) We have not independently researched this controversy, but it is potentially very important in view of the large quantities of uranium both in the seepage basins and in the tanks.

Cesium-137 has also reached the groundwater under the seepage basins

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*There are no drinking water wells from the shallow aquifers on the SRP site discussed here. We cite the drinking water standard in this and other cases as a reference standard only.

though ERDA claimed that the "concentration of 137-Cs in the groundwater in equilibrium with this soil is below the concentration guide given in ERDAM-0524."(21) Some of this cesium has migrated all the way to surface outcrops and is "detectable in Savannah River water by the routine monitoring program."(22)

The leakage of high-level wastes in 1960 containing plutonium directly into the groundwater has been documented by Savannah River Laboratory reports.(23) William Lawless, in suppressed appraisal reports written in 1982 and 1983 noted groundwater samples in the 200 Area indicating the presence of plutonium.(24)

The appraisal report related primarily to the Burial Ground which contained 400,000 curies of transuranic waste stored on pads, an estimated 4,000 curies of transuranics in cardboard boxes, between 1 million and 2 million curies of radiocobalt and between 14,000 and 20,000 curies of strontium-90 and cesium-137. In this report DuPont, in response to a DOE question, admitted the presence of plutonium in the groundwater:

> *Current plutonium levels in this groundwater are quite low and generally do not exceed drinking water standards. Only one well (G-21) in the area of the solvent spill exceeds [the] 5 pc/L [pico curies per liter] standard.(25)*

However, according to testimony by William Lawless, four wells out of forty had exceeded the drinking water standard for alpha-emitters (see below).

The Burial Ground has also had another source of plutonium dumped into it. In the early 1960s tributyl phosphate contaminated with plutonium was burned in open pans in the Burial Ground. The ashes were left on the soil surface and they were eventually washed into the trenches by rainwater.(26) This, together with the plutonium disposed of in the Burial Ground, have provided strong evidence of the migration of plutonium in the soil, particularly in the presence of organic solvents like tributyl phosphate. This is not only important of itself -- it is of basic significance to one of the major design premises of SRP.

It is one of the principal assumptions of the risk calculations that ion-exchange, that is, selective absorption of radionuclides in the soil, will prevent plutonium and other alpha-emitters from migrating through the soil site into the groundwater. This assumption, which often takes on dogmatic proportions in some public documents, is crucial to the rationalization of the prolonged operation of obsolete waste disposal practices at SRP -- long after they should have been discontinued.

The Savannah River Plant waste disposal system is based on the experience of the "semi-works," a prototype nuclear explosives production facility constructed in 1943 at Oak Ridge, Tennessee, and the Hanford Plutonium Works constructed near Richland, Washington, in 1943. SRP was the third and last plutonium production complex constructed and operated by DuPont for the federal government. The common denominator of these operations which justified their design basis was the presence of a large land base with abundant water supplies. These combined factors made a "buffer zone" whereby radioactive and non-radioactive chemicals discharged onto the environment would be diluted to "safe" levels at the plant boundary. At the same time, heavy industrial water demands could be satisifed.

The "buffer zone" concept assumed that, more often than not, the most dangerous waste products discharged into the environment could be absorbed indefintely in the soils. This assumption is not supported, even by DOE and DuPont data. First of all, the build-up of waste chemicals in soil has a finite absorption capacity. When that limit is reached, the molecular barriers are overcome and a "breakthrough" occurs. This has been observed with strontium-90 in the soil near the F & H area seepage basins.(27)

This "breakthrough" effect, as well as migration of radionuclides prior to "breakthrough," is enhanced by the presence of organic solvents such as tributyl phosphate in the soil. This has been demonstrated by events both at SRP and at other locations.

DOE has officially acknowledged that an accident involving a 40-gallon spill of contaminated solvent in 1962 and a leak of solvent from two storage tanks in 1968 (tributyl phosphate) contributed to the migration of plutonium as well as fission products into the groundwater over a 12-acre portion of the Burial Ground.(28) In fact, the solvent appears to have accelerated the movement of radionuclides to such an extent that DuPont has acknowledged that by 1981 "most of the released activity from the spilled solvent has already reached the water table."(30) This is a migration time of less than twenty years for plutonium. Yet, the official risk analyses deny the possibility of such migration in the case of accidents or other catastrophic events such as earthquakes. (See Chapter 5.)

The accelerated migration of plutonium in the presence of organic solvents has been observed at other locations and reported in the scientific literature.* For instance, Jess M. Clevelan and Terry F. Rees of the U.S. Geological Survey reported on a similar phenomenon at the nuclear waste dump at Maxey Flats, Kentucky.(29) Indeed, the U.S. Geological Survey has also warned against the generalization that the soil is always an effective barrier to radionuclide migration:

In some of the qualitative literature on waste disposal a pancealike aura surrounds the term "ion-exchange." In such literature it is implied that when all else fails ion-exchange processes will prevent movement of contaminants to points of water use.(31)

Changes in the rate of groundwater flow are another factor which could cause the acceleration of radionuclide movement. As documented below, DOE and DuPont explicitly assume in their evaluations of accidents and risks that groundwater flow patterns will not change. We have already mentioned the possibility of change in these patterns due to events such as earthquakes. (Chapter 5.) They may also change due to changes in patterns of usage of

* Soil Intrusion by "cleavage" from rainfall also can enhance vertical plutonium migration:

groundwater. Current groundwater flow rates are roughly 0.5 ft/day in the F area and 1 ft/day in the H area.(32) But DuPont has acknowledged that "water movement in the area is complex because sediments are not uniformly permeable."(33) Groundwater withdrawal, in the SRP area principally from the Tuscaloosa formation, is estimated to be 70 cubic meters per minute.(34) SRP is estimated to be pumping about 24.3 cubic meters/min. or roughly about one third of the total withdrawal.(35)

Major withdrawals of this magnitude can have the effect of changing the relationships between the aquifer systems, which in turn encourage contaminants under the 200 Area waste operations to migrate and possibly enter the deeper systems. Over the next few years, DOE plans to expand plutonium production at SRP which will increase withdrawals.(36) Moreover, in recent years off-site pumping of the Tuscaloosa for irrigation has increased rapidly near SRP in Allendale and Barnwell Counties.(37)

"If this trend, coupled with anticipated increases in groundwater use at the SRP facility continues," writes Dr. Yaron Sternberg, a University of Maryland hydrogeolosit, "the present head difference of about 12 feet at the L-Reactor may decrease and likely be reversed."(38)

In more general terms, the EPA has agreed with Sternberg that additional pumpage of groundwater by SRP"*could cause additional drawdown of the groundwater level beneath adjacent seepage basins, thereby increasing the tendency of contaminants to enter the groundwater and migrate."(39)*

DOE and DuPont claim that the deeper aquifers are protected from contaminants in the upper systems because of the "extensive upward vertical gradient between the Tuscaloosa and the Congaree."(40) This statement is not reconciled with their own data which shows that upward vertical gradients, on site, are being significantly reduced due to present withdrawals.(41) Pixie Newman, a University of Wisconsin hydrogeologist, has concluded that "pumpage in the H Area has reduced the vertical head difference between the Tuscaloosa and the Congaree to less than or equal to 0.6m (2.0 ft)."(42) Further, she found it conceivable that the "effects of additional L-Reactor pumpage may induce flow and spread contamination away from inactive as well as active waste site. There is little doubt that (expanded plutonium production) will accelerate contamination problems in the F & H areas (nitrates and mercury) and the M area (degreaser solvents)."(43)

The major source of evidence used by DOE/DuPont to suggest that contaminants in shallow formations will not enter the deeper systems is a map "constructed by subtracting two peizometric maps for which data are somewhat sparse."(44) The accuracy of this map is questionable since it is not based on data collected from several "nested" observation wells which measure pressure relationships at 2 or more depths within each hydrostratigraphic unit.

Moreover, this interpolated map does not factor in anticipated changes in water flow from increased groundwater pumping. In essence, DOE and DuPont assume that the hydrogeology of the aquifer systems underneath SRP will remain essentially unchanged indefinitely.

In addition to radionuclide contamination, there is also the problem of groundwater contamination by non-radioactive toxic materials such as mercury and PCB's, some of which are also contaminated with radioactive materials. On October 29, 1982, G.C. Halstad, Director of the Process and Weapons Division at SRP, indicated to G. Smithwick, Director of Environment, that SRP could not meet EPA's Interim Final Hazardous Waste Regulations because:

The seepage basin exceeds the allowable hazardous constitutent concentrations for many non-radioactive nuclides.

Liquid hazardous waste are stored below grade in the burial ground. Over ten tons of mercury are intimately mixed with the environment in the Burial Ground.

An inventory of the Hazardous non-radioactive nuclides in the Burial Ground is not possible; there are no records except in the case of mercury and PCB's (in recent years).(45)

Non-radioactive contaminants are present in significant amounts in groundwater beneath SRP's nuclear waste operations. Nitrates which constitute the largest single non-radioactive substance discharged into the F & H basins are found in groundwater and at surface stream outcrops far in excess of EPA standards. A 1977 Savannah River Lab report notes:

Nitrates have been detected in groundwater at seep lines at Four Miles Creek in Concentrations ranging from 7 to 30 times the EPA drinking water standard. The average concentration of nitrates in Four Mile Creek at Road A-7 was 3.1 Mg/l corresponding to a transport of 460 tons per year.(46)

Thus about 460 tons of nitrates are flushed by groundwater into surface streams annually. Lesser amounts of toxic mercury are present in groundwater beneath the SRP 200 Area. In 1974, DuPont researchers obtained soil samples from an H-area seepage basin which had temporarily dried up. They estimated that half of the mercury (assuming uniform distribution) was bound to the upper layers of the soil and the other half was leaching into the groundwater. If the remaining half continued to leach uniformly and if groundwater flow rates remained constant "in less than 200 years, concentrations of mercury would exceed the EPA drinking water standard."(47) In fact, a groundwater sample taken in 1982 in the vicinity of the Burial Ground was measured to have a level of mercury of 60% to 80% of EPA's drinking water standard. This mercury, as of 1977, *"is detectable in soil from a swampy outcrop along Four Mile Creek and bottom sediments and suspended solids from the creek show that some mercury from the H-area basins is migrating..."(48)*

DuPont has, in effect, acknowledged that mercury may pose one of the more serious long-term dangers. A Savannah River Lab has noted that:

hazardous surface concentrations [of mercury] may exist well beyond the period in which land control can be anticipated and indeed may exist centuries or mellenia into the future when soil erosion may expose mercury on the surface.(49)

Recent data analyzed by the EPA also underscores the groundwater contamination non-radioactive contaminants at SRP.

F & H area studies have shown that chemicals, e.g. mercury, 1-1-1 trichlorethyelene and chromium from the seepage basins have entered the shallow soil to outcrop zones...<u>this appears to demonstrate a method of discharging pollutants to a stream without a permit by using groundwater as a medium of transport</u>." (emphasis added)(50)

The EPA has concluded that "severe contamination in the upper aquifer poses an imminent threat to a deeper aquifer that supplies drinking water to plant employees and off-site communities."(51) Despite DuPont's claim that continued use is desirable" (52), by 1983, the EPA had also reached the following conclusions about the Burial Grounds:

*The present practice of disposing of low-level radioactive waste, in combination with chemical waste, into trenches and in the ground does not represent state-of-the-art technology and may violate RCRA [the Resource Conservation and Recovery Act] requirements. To increase the volume of waste which must be handled by this facility before the decommissioning plan has been developed, is out of logical phasing. Practically speaking, SRP needs to develop a proper disposal facility to handle present volumes of waste materials before any additional wastes are generated.(53)**

The AEC itself acknowledged some of these problems as long ago as 1971. Although it prefaced its recommendation with the claim that waste disposal in soil was a "well-established safe procedure," it issued a policy on the handling of low-level and intermediate liquid wastes which called for an end of "the use of natural-soil columns (by means of cribs, seepage ponds and further facilities..."(54)

The AEC further noted that:

there is an explicit assumption that the favorable environmental conditions will exist until the radioactivity

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**We understand that DOE and EPA have recently reached an agreement that DOE facilities will conform to the Resource Conservation and Recovery Act. How and when this will be done remains to be seen.*

in the soil decays to innocuous levels. Because of the long-term burden of control and surveillance inherent in the use of the technique that results in large local accumulations of radioactivity in soil, AEC sites are eliminating the routine use of surface and near surface techniques that depend on soil to remove radioactivity from liquid wastes...(55)

The AEC set a deadline to discontinue the use of seepage basins and other similar disposal methods by 1976.(56)

By September 1973, however, the AEC reversed itself and promulgated radioactive waste management standards(57) which in effect ignored their official conclusions of the year before and supported continued use of soil as a disposal medium for radioactive wastes. The standards also suggested that there be an "acceptable level" of radioactivity in soils. The level was not specified. A year later Savannah River Laboratory proposed using their current levels of radioactivity in seepage basin soils as the "acceptable" limit.(58) In the declassified 1977 report on SRP's seepage basins, it was noted that "most discharges" would be out of compliance with the standards if measurements of pollutants were made at the point of discharge.(59) It was perhaps with this in mind that the 1973 standards were modified to incorporate a "buffer zone" allowing measurements to be made at the site boundary instead.

By 1976, the year proposed by AEC to discontinue use of natural-soil columns, SRP had 15 seepage basins in active use with plans to significantly increase waste volumes over the next decade. The current schedule for the closure of some of SRP's seepage basins has been set for 1988.(60) No decommissioning plans exist for the Burial Ground.

Contamination Due to Accidents

The facts of groundwater contamination and the unexpectedly rapid migration of some pollutants are not only important in themselves. They are of central significance to the estimation of risk posed by the accidents and other catastrophes -- both those that have already occurred and those that might occur in the future.

Accidents in the course of operation have ranged from relatively small spills during maintenance work to large ones due to pipe and tank leaks. Tables 2 and 3 in Part II show the accidental releases that have been recorded in the Data Bank. For example, one accidental release was recorded on 02-05-69 in the H area as follows:

Release to environs, about 1 Ci, mostly Cs-137, to ground 30 feet southwest of Tank 9. Est. 0.50 is contaminated liquid flowed into storm drain and there to Four Mile Creek. Cause: failed copper pipe used back flush gravity drain...About 6 cubic yards of earth and asphalt surfacing, containing an estimated 0.5 curies was excavated and transported to the Burial Ground. Total personnel exposure was 5.8R.

A number of entries indicated serious accidental environmental contamination, but no details are given in the Data Bank, nor have we found reference to such events in other publications which we have examined. The entry dated "02/29/61" [sic], for instance, records that plutonium leaked into the soil and onto the asphalt around the evaporator four times in one month. No estimates of quantities are given. The soil was removed and, presumably, taken to the Burial Ground. Worker exposures are not cited. In another example the F area entry date 04/00/63 (see Table 2, Part II) records the contamination of 10,000 square feet of area downwind of the diversion box due to jumper changes. No estimates of quantity of contamination are given. Nor is there an explanation as to why these jumper changes, which are fairly frequent occurrences, resulted in such widespread contamination.

There have been a number of large, accidental releases of radioactivity. The following four have been at or near the waste tanks:

o Leaks from Tank 16 into surrounding soil and water during the 1960s (several H area entries, 1959 and 1960. Table 3, Part II.)(61)

o Overflow of Tank 8 due to instrument error resulting in soil and water contamination (F area entry dated 04-00-61. Table 3, Part II.)(62)

o A spill of "100 to 200" gallons of high level radioactive waste due to a plugged riser on Tank 9 (H area entry dated 05-01-67. Table 2, Part II.)(63)

o A leak resulted in the contamination of soil around Tank 3. (F area entries dated 08-21-75 to 08-25-75. Table 1, Part II.)

A summary of these incidents based on official descriptions is given in Table 6.6. In addition, a number of serious spills have occurred due to pipe failures:

o A leak in a flange in August 1962 contaminated 200 square feet of ground. (F area entry dated 08-13-62. Table 2, Part II.)

o A flexible hose ruptured in February 1967 causing a spill of 40 to 50 gallons of slurried radioactive sludge containing about 200 curies of radioactivity (H area entry dated 02-01-67. Table 2, Part II.)

o Chloride cracking of concentrate transfer system pump tank piping in June 1975 caused a spill containing roughly 100 curies of cesium-137;(64)

o A pipe failure due to corrosion resulted in the release of 500 gallons of radioactive salt solution into soil (H area entry dated 08-01-77. Table 2, Part II.)

Apart from the last incident, these spills have been discussed in various official documents which are public. We will therefore not discuss them in detail here. We will only comment on the adequacy or lack thereof of some of the official analyses. This enables us to assess the implications of the official position and of possible future spills in terms of their cumulative impact on long term contamination in the area of and around the Savannah River Plant.*

The first major leak to occur was in Tank 16 in September 1960**. Since it was preceded by a number of cracks in the primary tank, which were first observed in November 1959, it was perhaps the accidental release which was the most closely monitored of all of them. Yet a considerable uncertainty, of an order of magnitude or more, remains as to the quantity of radioactivity that was released to the soil and water. Since the bottom of Tank 16 is below the groundwater table it appears that some of the leaked radionuclides immediately entered the groundwater. The leak was first discovered by the detection of high-level waste in the water from a monitoring well near the tank. (See Table 3, Part II, H area entry dated 10-00-60.)

High-level waste began accumulating in the 5-foot high steel pan which lines the concrete secondary containment. The tank height is 27 feet. In September 1960 the level of waste rose above that of the liner and some waste leaked from the concrete containment, possibly from various joints. The total quantity of the leak from the primary tank into the annulus was 185,000 gallons.

The estimated 700 gallons of waste that exceeded the level of the steel annulus pan represents an upper limit of the amount that could have escaped from the tank into the ground. This amount of waste would contain 5,200 curies of radioisotopes. The actual amount of waste that reached the soil is not known, but for the waste to leak into the soil requires passage through a tortuous route and probably only a small fraction of the 700 gallons left the annulus.(66)

Even the figure of 700 gallons is subject to some uncertainty, since the height of the level of waste in the tank is the primary indicator of the quantity. The actual height at the maximum point used to derive the figure of 700 gallons is an inferred value, obtained by linear extrapolation of level measurements. Moreover, these level measurements are themselves subject to some uncertainty because of chronic problems with the main level measuring instrument (the "reel tape"). Yet the official report does not cite a range of possible values of height (and hence, quantity) but gives only one figure. There is at least one earlier account which indicates a loss of more than 700 gallons. J. Christl, in a 1969 presentation to the National Academy of Sciences, stated that *"inventory measurements indicated that as much as 1,000 gallons may have escaped the encasement."*(67) By 1980, the DuPont estimate given to a new National Academy

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*Technical issues relating to tank integrity have been covered in Chapter 4.

**This account is based on an evaluation of the Tank 16 leak by W.L. Poe of DuPont.(65)

of Sciences had decreased further to "about 100 liters" -- or 26 gallons.(68) This leaves almost one thousands gallons of waste unaccounted for.

The possibility of as much as 5000 curies of radionuclides, mainly radiocesium, getting into the groundwater should be an event of very serious concern whose long term consequences should be carefully evaluated. Yet both the content of the official evaluation of this incident, as of the others we have read, convey the impression that the management is certain that this matter will have no adverse effect on the public whatsoever. We have already discussed the assumptions regarding radionuclide transport and groundwater contamination on which such conclusions are based, and presented evidence to show that they are essentially erroneous. The following quote shows that such models, which have proved to be unreliable over the last three decades, are used to extrapolate over hundreds of years and even hundreds of thousands of years:

Calculations based on the measured groundwater flow velocities and estimated flow paths and the measured ion-exchange capabilities of the soil determined in laboratory samples indicate that the leading edge of the radionuclides should not reach the nearest creek and thus ultimately the populated area for $1x10^5$ to $8x10^5$ years. [At this point a footnote adds: "The range of times denotes the range of uncertainty in travel path to the creek."] Movement of the 'core' or central section of the radionuclides would be delayed and should require $2x10^5$ to $12x10^5$ years to reach the populated area. In any of these periods the radiocesium would have decayed, leaving harmless solutions of stable barium. The above calculations assume that climatic conditions, hydrology, and groundwater usage remain unchanged during the periods covered by the calculation. In times as long as hundreds of thousands of years, some of these conditions might change. If these conditions were assumed to remain unchanged for a hundred years or so and then the readioactivity from this leak was released to the creek by some mechanism or if the radioactivity moved at the same rate as groundwater (travel time 70-350 years), the concentration of radionuclides in the creek from this release would be below the concentration guide limit for cesium in drinking water.(69)

The second set of calculations involving hundreds of years is based entirely on arbitrary assumptions. The first set involving parameters determined from measurement involve projections of up to 1.2 million years and are on the face of it absurd. A mere glance at the history of the last one hundred years would alert anyone to the possibility that patterns of "ground water usage" might be subject to drastic change. In all cases attention is focused on travel time to the creek.

The focus on the pathway of surface water enables the further assumption of immense dilution by the creek and Savannah River waters. Thus, the possible doses appear small. The possibility of the contamination entering the Tuscaloosa aquifer was consistently dismissed. Thus, the implications of the known migration of radionuclides, particularly in the presence of solvents, and of groundwater use changes that are already occurring have not been examined.

DuPont has also issued a special report on the spill from Tank 8 around April 1961.(70) This spill apparently occurred when a faulty level reading (from a "reel tape") caused a tank overfill. The leak was not detected at the time. The Data Bank entry dated April 1961 does not mention a spill at all but explicitly states that the waste "showed up in the catch tank via [the] encasement drain system." (See Table 3, Part II, F area entry dated 04-00-61.)

The report of the incident states that about 15,500 gallons of high heat waste overflowed into the catch tank as a result of the overfill. This was detected on April 3, 1961, and corrective action taken by April 5. However, the "leakage from the fill-line encasement was not recognized at this time."(71) Apparently no steps to check for possible soil contamination were taken at the time, even though the high heat waste followed to the catch tank outside the primary steel pipe and through the concrete encasement (or jacket) covering it. This was in spite of the prior experience of leakage from the concrete secondary containment of Tank 16 (see above).

The investigations for a possible leak were begun only in 1973-74 when the "first indication of subsurface contamination" was discovered as a result of unrelated drilling of monitoring wells in the area. By that time it was impossible even to be sure that the radioactivity detected was a result of the 1961 overfill.(72)

The official report estimates that the contamination was probably the result of the April 1961 overfill and that the amount spilled was about 1540 gallons of high heat waste. This was estimated to contain anywhere from 25,600 curies to 260,200 curies, depending on assumptions about the composition of the waste. While much of this consisted of relatively short half-life cerium isotopes such as cerium-144, approximately 7000 to 20,000 curies consisted of longer lived isotopes like cesium-137 and strontium-90 and associated radionuclides that remain in the soil.(73)

From soil samples, the contamination was assessed to be localized. Radiation levels up to 300 rads per hour were measured within 17 feet of the soil surface (the top of the tank is 13 feet below the soil surface).(74) This spot is only around 30 feet above the maximum height of the water table around Tank 8.

As with the Tank 16 leak, the long-term calculations are exclusively oriented toward surface water outcrops. Even these concerns are effectively dismissed since travel time for strontium-90 and cesium-137 to the groundwater outcrops are claimed to be "on the order of several hundred thousand years" by which time they would have been rendered harmless by radioactive decay.(75)

Only plutonium-238 and -239 are recognized as possible long-term sources of contamination. The report's maximum estimate of plutonium in the spill was 1.8 curies. Here too, predictions are made for hundreds of thousands of years, along with arbitrary factors to account for uncertainties. Hundreds of thousands of years hence, we are told, "dispersion will have diluted the concentrations to below the 200 nCi/g [nanocuries per gram] limit for non-retrievable burial before any plutonium has migrated more than a few hundred feet from Tank 8."(76)

We have not examined any special reports on the other spills and leaks listed above which may have been prepared. However, neither the Environmental Impact Statement issued by the Energy Research and Development Administration in 1977,(77) nor the DuPont Safety Analysis Report written in 1978(78) mention the possibility of any serious adverse consequences from any of these accidents.

Some of the adverse consequences in terms of groundwater contamination have already happened. It was noted above that some of the Tank 16 leak has apparently directly entered the groundwater around the tank. In addition, the Data Bank indicates that large quantities of soil from some spills are excavated and taken to the Burial Ground. In the case of the extensive contamination around Tanks 16 and 8, the soil has been left in place. But in the case of the spill from Tank 9 and several of the spills from pipes, substantial quantities of each, containing hundreds of curies of cesium and other radioactive isotopes have been excavated and put in the Burial Ground.

The leakage of radioactivity from the Burial Ground into the groundwater has been established, as we noted above. It is not possible at present for us to estimate how much of this may have come from the contaminated soil from the Waste Tank Farm.

According to the testimony of William Lawless, who was a senior engineer in Waste Management at the Department of Energy based at the Savannah River Plant for six years:

those [monitoring] wells [at the Burial Ground] also...indicated that there was alpha nuclide migration. The alpha nuclide migration is important because it indicates that plutonium-239 and plutonium-238...which DuPont has constantly maintained cannot migrate were indeed migrating. In fact the...data that I had from the internal report indicated [that] four wells out of the forty had exceeded the drinking water standard for alpha radionuclides alone. [It was] as high as four times the standard in one instance.(79)

This record of a steadfast official denial of any possibility of significant radionuclide migration or harm to the public as a result of the accidents is based on a systematic refusal to take into account the large amount of evidence regarding groundwater contamination and radionuclide migration which already exists. This factual record is from the routine operations. We have documented in this chapter that DuPont and DOE, as well as other official bodies such as the U.S. Geological Survey and the Environmental Protection Agency, have acknowledged contaminations and unexpected migrations of radionuclides and other toxic materials.

No scientific assessment of the consequences of accidents or catastrophes such as earthquakes can be made wtihout systematically taking the evidence from routine operations into account. Far from attempting to do this the DOE and DuPont risk assessments discussed in Chapter 5 as well as the assessment of the accidents discussed above largely ignore this evidence. Thus, from a scientific point of view, these assessments are fundamentally flawed.

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73. Ibid., Table 3, p. 15.
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Table 6.1

ANNUAL RELEASE LIMITS FOR SRP OPERATION

Element	Release limit curies/yr	Element	Release limit curies/yr
tritium	800,000	iodine-131	300
sodium-24	100,000	cesium-134	100
		cesium-137	300
phosphorous-32	20	barium-140 + lanthanum-140	2,000
sulfur-35	10,000	calcium-141	10,000
chromium-51	80,000		
iron-59	100	cerium-144	1,000
cobalt-60	80	praesodymium-144	
zinc-65	200	promethium-147	20,000
strontium-89	600	thorium-232	200
strontium-90	50	uranium-233	300
tungsten-91	3,000	uranium-235	600
zirconium-95 + niobium	3,000	natural uranium	90
		neptunium-237	200
ruthenium-103	8,000	neptunium-239	50,000
ruthenium-106 + rhodium-106	1,000	plutonium-238	400
		plutonium-239	400

Source: Management of Radioactive Wastes at the Savannah River Plant. presentations made to the Committee on Radioactive Waste Management of the National Academy of Sciences at the Savannah River Plant, Jan 20 & 21, 1969; p.11.

Table 6.2

Release Guides for Seperations Areas, 1978 (Curies/Year)

Element	Release Guide to Seepage basins	Release Guide to atmosphere	Total
tritium	39,000	75,000	114,000
krypton-85	-	950,000	950,000
strontium-89	0.7	-	0.7
strontium-90	0.8	-	0.8
iodine-131	1.5	0.5	2.0
cesium-134	1.4	.0005	1.4
cesium-135	10.0	.003	10.0
uranium-235+ uranium-238	-	0.01	0.01
plutonium-238 plutonium-239		0.001	0.001

TABLE 6.3

INVENTORY OF RADIOACTIVITY TO SEEPAGE BASINS THROUGH 1976

Radionuclide	Curies
tritium	524,000
strontium-90	65
cesium-137	276
natural uranium	13
thorium-232	0.2
plutonium-238	3.4
plutonium-239	7.4
curium-244	0.14
Alpha - unidentified(2)	4.2
Beta - unidentified(2)	171
Short-lived(3)	38

Notes:

1. Decay corrected. Does not include 100-R basins.
2. Not corrected for decay.
3. Half-lives more than 1 year but less than 6 years.

Source: Marter W.L., "New Criteria for seepage basin use" DPST-77-444,Sep 1977. p.g.

TABLE 6.4

NON-RADIOACTIVE RELEASES OF MERCURY & NITRATES TO SEPARATIONS AREA BASINS - CUMULATIVE TO 1975

Basins	Mercury pounds	Nitrates tons
CMX-TMX	64	-
200-F	850	2,950
200-H	3,650	2,670
TOTAL	4,564	5,620

Source:
From: Marter, W.L., "New Criteria for seepage basin use". DPST-77-444. p. 12

Table 6.5

VERY LONG-LIVED FISSION PRODUCTS IN SEPERATIONS SEEPAGE BASINS (ESTIMATED)

Radionuclide	Half-Life Years	Fission Yield %	Total in F and H Ci
selenium-79	6.5×10^4	0.06	3.6×10^{-4}
zirconium-93	9.5×10^5	6.4	2.6×10^{-3}
technicium-99	2.1×10^5	6.1	1.1×10^{-2}
palladium-107	6.5×10^5	0.2	1.2×10^{-5}
tin-126	$\sim 10^5$	0.05	2.0×10^{-4}
iodine-129	1.6×10^7	0.9	2.2×10^{-5}
cesium-135	2.3×10^6	6.7	1.1×10^{-3}
		Total	1.5×10^{-2}

Source: Marter, W.L., "New Criteria for seepage basin use." DPST-77-444. p. 11.

Table 6.6

ACCIDENTS AT OR NEAR HIGH-LEVEL WASTE TANKS INVOLVING RADIONUCLIDE SPILLS

Location	Entry Date	Volume gallons	Radioactivity curies	Official Cause
Tank 16	Nov 1959	Max 700	Max 5200	primary leak to annulus
Tank 8	April 1961	1500*	7000 to 20,000	reel tape error, overflow of tank; discovered in 1973-74
Tank 9	May 1967	100-200	1500-2000 (90% Cs-137)	2' riser plugged with salt causing tank overflow
Tank 3	Aug 1975	?	50*** (mainly Cs-137)	suckback and leak in steam supply
H-Area	Aug 1977	400	500 (mainly Cs-137)	pipe corrosion

* High heat waste

** Estimate of what was in the soil around tank as of 1976

*** Soil radiation level of 500R/hr; soil removal had to be stopped because of high levels.

TABLE 6.7

ACCIDENTS AT OR NEAR HIGH-LEVEL WASTE TANKS INVOLVING RADIONUCLIDE SPILLS

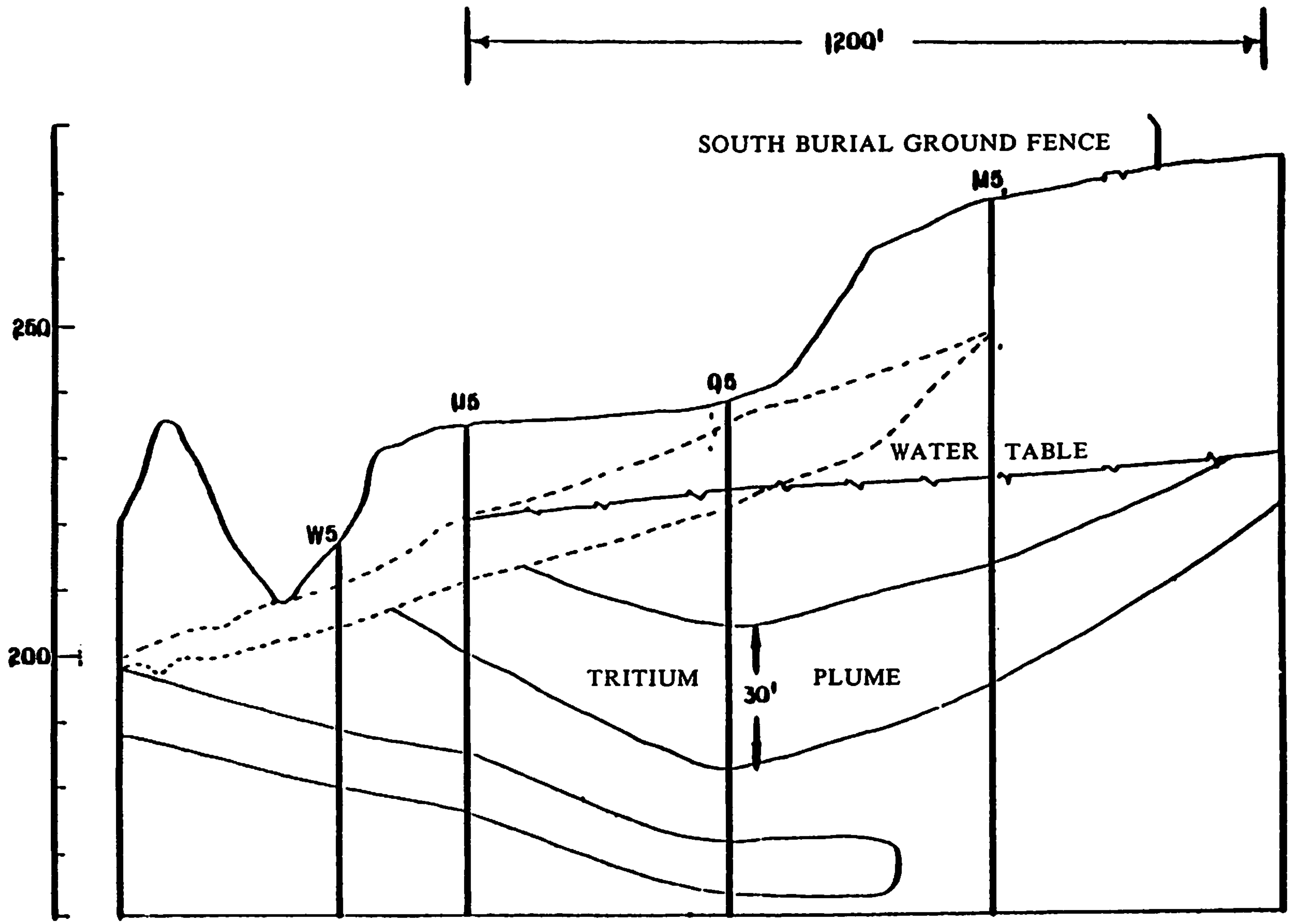
Location	Entry Date	Volume gallons	Radioactivity curies	Official Cause
Tank 16	Nov. 1959	Max. 700	Max. 5200	primary leak to annulus
Tank 8	April 1961	1500*	7000 to 20,000	reel tape error, overflow of tank discovered in 1973-74)
Tank 9	May 1967	100-200	1500-2000 (90% Cs-137)	2' riser plugged with salt causing tank
Tank 3	Aug. 1975	?	50 *** (mainly Cs-137)	suckback and leak in steam supply
H-Area	Aug. 1977	400	500 (mainly Cs-137)	pipe corrosion

*High heat waste

**Estimate of what was in the soil around tank as of 1976

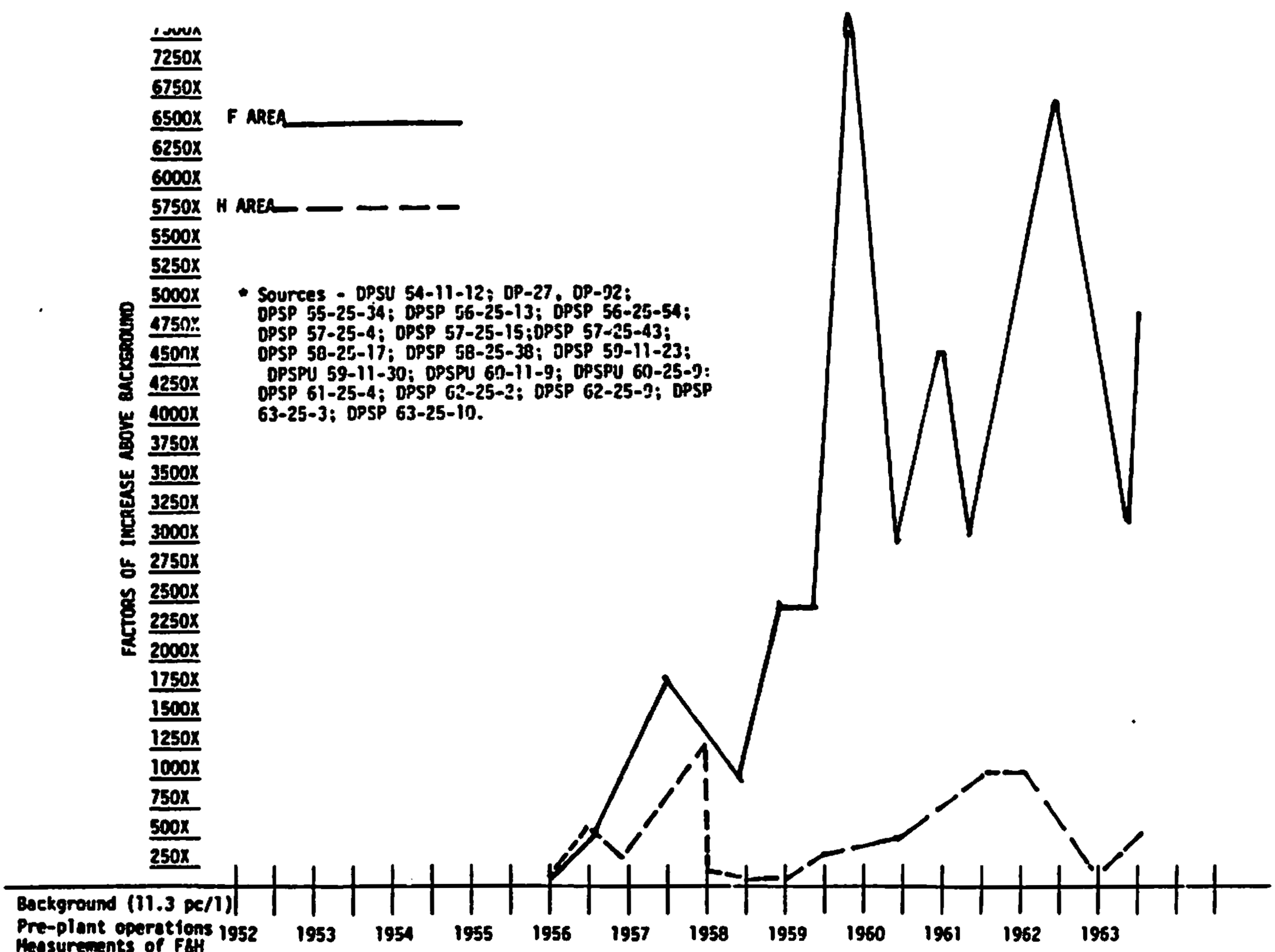
***Soil radiation level of 500R/hr; soil removal had to be stopped because of high levels.

FIGURE 6.1 643-G FLOW PATH CROSS SECTION



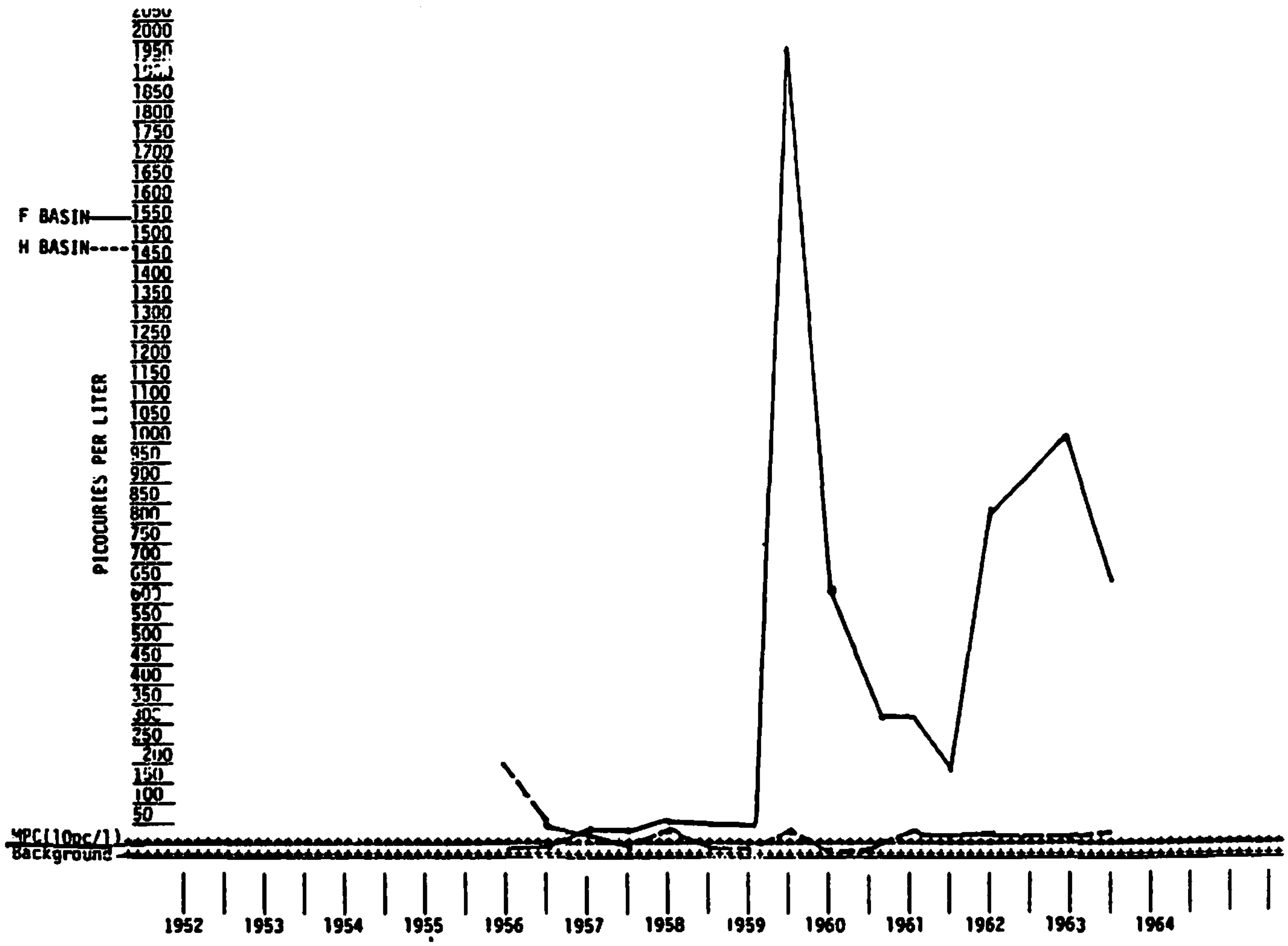
Source: Fenimore, J.W., DPST-82-725

FIGURE 6.2



GROUNDWATER CONTAMINATION BY NON-VOLATILE BETA EMITTERS IN THE 200 AREA F&H SEEPAGE BASIN WELLS BY ORDERS OF MAGNITUDE ABOVE PRE-OPERATIONS BACKGROUND READINGS*

FIGURE 6.3



GROUNDWATER CONTAMINATION BY ALPHA EMITTERS IN THE 200 AREA FAll SEEPAGE BASIN WELLS (SEMI-ANNUAL AVERAGES)

CHAPTER 7
WORKER EXPOSURES

There are over 8,000 workers at the Savannah River Plant. All workers, including the ones involved in waste management, are subject to some routine exposure to radioactivity as a result of plant operations, of routine radionuclide discharges to the environment, and of any increase in background radioactivity levels resulting from a build-up of contamination on the site. For instance, "background" radiation levels in SRP's 200 area between 1954 and 1969 gave an average cumulative dose of 3,896 mrems, or about 260 mrems a year. This is about 2-1/2 times the normal background levels for an off-site area.(1) In addition, they are also subject to the danger of exposures of two other kinds.

- Exposures which are an inevitable, and sometimes a routine consequence, of the specific nature of the work;
- Exposures as a result of accidents.

It is not uncommon for large numbers of construction workers at SRP to be recruited for manual clean-up of highly contaminated areas caused by accidents.* For the workers involved in the operation of the Tank Farm, it is difficult to draw a distinction between "routine," "non-routine" and "accidental" exposures since much of their "routine" work consists of dealing with "non-routine" matters such as repair, or checking, or replacement of malfunctioning equipment. In addition, these workers are also involved in the work resulting from accidents, for example, excavation of contaminated soil. During the course of such work, they are exposed to the dangers of accidents which can result in external exposures and internal exposures, as through inhalation of radionuclides.

Table I in Part II lists most of the entries relating to worker exposures found in the 200 Area Fault Tree Data Bank. The rest are to be found in Table 2, Part II. (See Introduction to Part II.)

We have mentioned the general problem of the uneven number of entries in the Data Bank. This applies in particular to worker exposures. There are about 300 entries where worker exposures are specifically mentioned. Three-fourths of these entries are for the six-year period 1977-82, and only about 70 are for the period 1953-76. Assuming that the recording frequency during 1977-82 expresses a management decision rather than increasing numbers of worker exposures (see Chapter 3), we can estimate that there are roughly 1000 occurrences involving exposures of the type entered into the Data Bank during 1977-82 which have been omitted from it for the earlier period as the result of varying management decisions about what was to be entered regarding worker exposures.

A large fraction of the 14,000

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*Between Nov. 1970 & Feb. 1971, 850 people were involved in a manual clean-up of the K-reactor process room where a reactor source rod burst open.

entries into the Data Bank either describe people working in radioactive environments and with radioactive system components, or imply such work by describing equipment problems. Yet worker exposures are mentioned only in about 300 instances -- or about 2% of the total entries. For example, problems with the reel tape, an instrument which measures the liquid level of radioactive waste in a tank, have been frequent. Reel tapes have required frequent repair and adjustment. They are quite radioactive since the tapes and probes come into direct contact with the liquid waste and with the radioactive vapors above the liquid. Yet an entry such as "Repaired Tk.29 reel tape. 8-4 [shift]"(2) gives no indication of any worker exposures whatsoever.

It is possible that worker exposures in some such instances might be small or even less than measurable. It is not likely, however, that most of the work involving intensely radioactive environments or components would not result in measurable worker exposures.

For instance, problems with evaporator feed pumps and concentrate transfer system (C.T.S.) pumps have been fairly frequent. The H area entry of March 1975 records radiation exposure rates of up to 10 R/hr during an evaporator pump replacement, and a total exposure of 0.8 rem to 9 people. Similarly an F area entry dated 09-26-74 records an exposure of 1.4 rem to 14 people during feed pump replacement and notes that the entire "evaporator feed pump job" during 1-1-74 to 09-26-74 caused a total exposure of 11.4 rem. (See Table 1, Part II.) Yet there are several entries which imply or mention changes of or repairs to radioactive pumps but which do not mention any worker exposures. They are quoted below in their entirety (Table 8, Part II):

1. 02-27-67, F area:
   "242-F Evaporator Feed pump failure"

2. 11-30-67, F area:
   "C.T.S. pump failed"

3. 01-00-68, F area:
   "Pump failure, after 40 days of service in tank loop of CTS. This is the 4th failure in 9 months."

4. 06-00-68, H area:
   "Pump failure. CTS tank loop pump failed and was replaced E M unit - bearing an EM unit packed with special grease."

Omissions of exposure data are only a part of the problem with the Data Bank. Many of the approximately 300 Data Bank entries which do mention worker exposures are unsatisfactory in a number of respects. These qualitative deficiencies can be broadly categorized as those relating to external and to internal exposure data.

As regards external exposures, most of the entries do not give the actual measured exposure or even an estimated exposure. They simply cite the fact of contamination or give expousre rates or radiation rates. Thus, data regarding the number of workers involved in the work or the duration of the work, which would enable an estimation of the total dose, are often left out. Here are some examples:

1. 04-00-67, H area:

"Released waste. During repairs to an evaporator can valve a leak caused extensive contamination." (from Table 2, Part II)

2. "People that were contaminated B.G. [Burial Ground] went home at 7:00 p.m. 4-12 [shift]."

3. 05-29-81, H area:
"Installed draw-off valve in C-2 riser on Tk-3.6. Radiation level over open hole was 100 rads/40R/hr. at 30 cms."

The largest radiation rate in the Data Bank was 500 R/hr encountered by workers excavating contaminated soil around Tank 3. (See Table 1, H area entry dated 03-12-76.)

For the entries which do record worker exposures to external radiation, the amounts range from doses of a few tens of millirems to ten or more rems. These are collective doses to all workers participating in a particular job. Some examples from Table 1, Part I, follow:

1. 01-00-75, F area:
"14 R received by personnel installing new feed systems in 242-F."

2. 07-00-71, F area:
"Total of 3.4R were obtained by personnel while tightening packing glands on 3 valves in the feedpump. Exposure resulted from high radiation levels in feedpump enclosure."

3. 06-00-82, F area:
"Excavation around tanks 17 and 18 to install foundations for salt removal equipment. Body dose rates to 100 mr/hr. Total exposure 515 mr. for 28 people."

4. 01-00-81, H area:
"Exposure rates to 30 rads/hr/2r/hr were encountered to remove a wire that had become wrapped around a sludge probe in Tank 15. Total exposure to remove the wire was 435 mrems."

5. 04-27-81, H area:
"Transfer jets screen plugged exposure rates during removal to 10R/hr. Total exposure to 27 workers was 3.2 R."

The largest single exposure of more than 14 rems is mentioned in an H area entry of November 1968:

"Film badge of sep[arations] dept. supv. indicated skin exposure of 14,590 mrads during Oct. exceeding AEC manual quarterly standard of 10 rem. The exposure pro[bably] occurred when the employee removed two acme nuts from a 241.H waste transfer pump in railroad tunnel airlock. See special hazards investigation 266."(Table 1, Part II).

Most of the entries in the Data Bank involving worker exposures record such cases of exposure to external, primarily gamma, radiation. There are also many entries which record contamination of clothing and skin through accidental contact with radioactive materials. For example, one worker's left hand was contaminated to 100 mrad/hr during the removal of a specific gravity dip tube from Tank 13. A second worker's wrist was contaminated to 40,000 c/m beta-gamma in the same accident (see Table 1, Part II, H area entry dated 03-28-80.)

Finally, there is the question of internal exposures -- that is, exposures which result from the incorporation of radionuclides into the body by inhalation, ingestion or through cuts. The Data Bank records very few cases of internal exposures. None of these contain estimates of lifetime exposures resulting from radionuclide incorporation. In fact, most of the data is in a form which does not allow such dose reconstruction. For example, much of the monitoring for inhalation is from nasal smears and urine samples. However, this data is not reliable enough to estimate lifetime dose commitment, which is a crucial indicator of the probability of radiation-induced diseases and problems.

According to research performed at DOE's Hanford operations, internal plutonium contamination estimates derived from urine samples in the best of circumstances were questionable.(3) An evaluation of Hanford workers with internal plutonium exposures showed that curves describing urinary excretion data for plutonium vary by individuals.(4) Therefore, any dose reconstruction drawn from excretion data may be unreliable, particularly if only one measurement was performed (as appears to be the case). In addition, the Data Bank does not state how long after the exposure the urine sample was taken, which will heighten the unreliability of the dose reconstruction.

Estimating inhalation doses from nasal contamination is also unreliable. A nasal smear does not measure the extent of the contamination, even within the nose. Only large particles are deposited in the nose, while small ones pass through to the lungs.(5) The nasal smears only demonstrate that the person may have inhaled plutonium. The measurements cannot be used to reconstruct the amount of plutonium that reached the lungs without some information about the particle size distribution.

We have performed an illustrative calculation for one case in which body counter data are provided in the Data Bank. (Body counters can be a more reliable means of determinig internal radionuclide burden, if the time and circumstances of contamination are accurately known, and if contamination is sufficiently large to be reliably detected by the available counters.) The H area entry dated 08-23-72 (see Table 1, Part II) gives a chest activity measurement of 33 nanocuries. We assume that it is a plutonium count, since it follows a measurement of plutonium in the urine. The accident report does not state when the chest measurement was performed. Therefore, it is difficult to determine the amount of plutonium that remains in the lung. We will assume that the measurement was performed soon after the accidental exposure. Therefore, any plutonium deposited into the pulmonary region of the lungs was still there.(6)

Since the plutonium is contained in waste from reprocessing, the most likely chemical form is plutonium nitrate.

The Data Bank does not give the particle sizes that were inhaled. Consequently, the plutonium particles are assumed to have an activity median aerodynamic diameter (AMAD) of one micron. This is a default value recommended by the International

Commission on Radiation Protection if no particle size distribution is given.

Since plutonium nitrate is more soluable than some other forms, various authorities(7)(8) have estimated that the amount of plutonium inhaled would be two to four times the amount of plutonium measured. For this case it would mean an estimate of 66 to 132 nanocuries inhaled by the worker.

Using dose conversion factors prepared at Oak Ridge National Laboratory, Table 7.1 presents selected organ doses (actually organ committed dose equivalents). The marrow dose below is sufficient (according to a survey by Mancuso, Stewart and Kneale of Hanford workers) to more than double the risk of this worker contracting a blood-related cancer.(9)

Another accident report (H area, date 02-28-74) records inhalation of cesium-137 and ruthenium-106 by two maintenance workers during an accidental spraying of one pint of contaminated liquid. The chest counts on one worker were: Cs-137: 262 nanocuries, and Ru-106: 43 nanocuries. For the second worker the count was Cs-137: 64 nanocuries.

There are only a handful of entries in the Data Book with body counter measurements which enable internal dose reconstruction. We do not know if documents not yet made public contain more extensive data. Of course, without more data we cannot know if the above calculations are representative of the dose commitments to workers from radionuclide inhalations. But they do illustrate the dangers workers face in the course of their duties from suspended radioactive particles.

In general, when equipment such as tanks or evaporators containing high level wastes are opened, we can expect some contamination of the surrounding air. There are many entries in the Data Bank which show the presence of plutonium as well as fission products in the air around the working areas when tank risers are opened. For reasons we do not know, such Data Bank entries were made mainly in the H area and primarily during 1976 and 1977. There is no apparent reason why such contamination would not have occurred in the years before or since, or why the entries were concentrated in the H area. It is possible that H-area management may have made a decision in 1976 to record such measurements, but that this was rescinded within a year or two.

The presence of radionuclides in the air in the working areas during certain kinds of work increases the possibility of inhalation of radioactive particles. We understand that protective equipment is normally worn during such jobs. However, without detailed information on the characteristics of the equipment, or its maintenance and condition, and on the size distribution of the suspended radioactive particles, we are not in a position to estimate the internal dose that might result from working in such conditions.

The evidence in the Data Bank is so fragmentary and qualitatively uneven that, taken by itself, it does not allow us to reach general conclusions about worker exposures. It does document many specific cases of worker exposures, both internal and external, and the conditions under which those exposures occur. Moreover, we are in a position to complement these specifics with some broad evidence regarding radiation exposures and hazards of contracting radiation-related diseases at SRP and other DOE facilities.

An official estimate of whole-body radiation accumulated between 1954 and 1978 by monitored SRP workers ia approximately 50,000 person-rems.(10) About one-third of these workers performed duties in the 200 Area of SRP involving processing and storage of radioactive and other toxic wastes. These 200 Area workers received over half the total accumulated dose.(11)

Savannah River Plant workers handling nuclear wastes bear higher risks of contracting radiation-induced cancer due to their higher exposures. Yet these risks have not yet been ascertained by independent epidemiological studies. In the absence of such studies, we can estimate expected health effects among SRP workers on the basis of their accumulated collective dose and risk estimates derived from studies of other exposed human populations. However, there are considerable uncertainties associated with such estimates.

One of the main uncertainties in radiation-cancer risk estimates relates to the questions now being raised about the Japanese A-bomb survivor study -- the principal scientific reference used by standard-setting agencies. Current revisions in radiation doses, cancer incidence and non-cancer effects data on the A-bomb survivors have made all present official cancer risk estimates tenuous at best.

Given these and other uncertainties (discussed below), it is more appropriate to evaluate radiation-induced cancers in the context of a range of risks. Based on the authorities citied above, we estimate that the 1954-78 collective occupational radiation dose of 50,000 person-rems can be expected to result in between 16 and 330 excess cancer cases. Over half of these cancer cases are expected to occur among workers who handle radioactive wastes.(12)

This is only a partial picture of the risk since it doesn't factor in exposures to internal organs from inhalation and ingestion. The above mentioned risk only pertains to external penetrating radiation.

The paucity of data regarding internal exposures is not unique to SRP. Indeed, it may be said to be typical. For instance, there is very little public data on internal exposures relating to the nuclear weapons testing program. This was recently documented as regards to the Bikini tests in 1946 by the revelations in the papers of the late Col. Stafford L. Warren, a principal medical officer of the Manhattan Project and the Chief of the Radiological Safety section at Operation Crossroads -- as the 1946 Bikini tests were called.(13) This relative neglect of internal exposures is a very serious lacuna in the data because a large body of medical evidence is beginning to emerge that such exposures play a principal role in causing radiation-related diseases.

So far as SRP workers are concerned one important piece of evidence is an unpublished DuPont study written in 1976. (14) The researchers found "evidence...that lung cancer and leukemia were significantly increased" when SRP workers were compared with other DuPont employees and the general public. A total of eleven cases of leukemia were found among about 5,000 SRP employees who were on the job up to 1974. Nine cases were found among wage employees when 2 cases were expected. Of these, six were myeloid leukemias, when 2.86 was the expected number of cases. Myeloid leukemia is generally recognized as being caused by ionizing radiation. In October 1983, this data was reanalyzed by DuPont in a way which erased the statistical significance of the previously observed positive findings. DuPont's revised analysis was deemed "inappropriate" by a DOE advisory committee reviewing the study. The committee also recommended this data be reanalyzed by a non-DOE/DuPont group.(15)

Additionally, the health risks of SRP workers cannot be evaluated in a vacuum. For example, the cancer findings among workers at the Hanford facility in Washington state have great relevance to SRP. Hanford was constructed and initially operated by DuPont for the U.S. government in 1943, ten years before SRP began operations. Like SRP, Hanford produced plutonium and processed enormous quantities of radioactive wastes. In 1974, excess cancer deaths were discovered by the Washington Public Health Department among Hanford workers. In 1977, DOE researchers published findings that bone-marrow, pancreatic and lung cancers were linked to radiation exposure levels 10 to 20 times below those considered "acceptable" under current federal standards.(16)

Since that time, researchers at the Oak Ridge Associated Universities (ORAU) and Los Alamos National Laboratory under contract to DOE have discovered the following additional evidence of excess cancer deaths among employees at DOE facilities:

o Workers at the Oak Ridge National Laboratory, according to an ORAU Project summary, show a 49% excess of leukemia when compared to the general public. The summary states, **"leukemia mortality did demonstrate a gradient with increasing radiation dose, but was associated with long-term employment in maintenance and engineering jobs."**(17)

o In a "nested case-control" study of cancer deaths among workers exposed to ionizing radiation at ORNL it was found that **"significant excess risk was found for workers in maintenance/construction and janitor/laborer job title groups."**(18)

o Data on employees who worked at the Oak Ridge Y-12 Tennessee Eastman facility between 1943 and 1947 show **"significant excess deaths from lung cancer when compared to U.S. white male rates."** A follow-up report states, **"relative risk was found to increase with increasing of lung dose even after controlling for age, smoking status and other work place exposures."**(19)

o A mortality study of workers at the Y-12 weapons plant operated by Union Carbide Corp. (until 1983) has found **"excess deaths for cancer of lung, brain, and CNS [central nervous system], Hodgkin's disease, other lymphatic tissue."** Brain tumors among Y-12 workers, was reported by

Dr. C.C. Lushbaugh at an "in-house" meeting of DOE researchers to be 100% to over 400% in excess of what is expected in the general public.(20)

o An epidemiologic study of deaths among workers employed at the Oak Ridge Gaseous Diffusion Plant, demonstrated "excess deaths due to lung and brain cancers and respiratory disease..." Enrichment workers exposed to nickel powder show "excess deaths from cancers of the buccal cavity and pharynx..."(21)

o A 117% excess of deaths from brain tumors has been found among 7,112 workers at DOE's Rocky Flats facility near Denver, Co.(22)

o At DOE's uranium processing plant in Fernald, Ohio, ORAU researchers report that "after taking age at diagnosis and age at hire into account there is an association between exposure to uranium and the development of non-malignant respiratory disease..." Furthermore, "digestive cancers show a 36% excess..."(23)

o Deaths from malignant skin cancers among workers at DOE's Lawrence-Livermore Laboratory was found to be three times the national average.(24)

o A study of 2,529 DOE workers who were reported to receive over 5 rems between 1947 and 1978 shows a "significantly elevated" excess for cancer of the rectum -- 3 times the national average.(25)

There is a definite and alarming industry-wide pattern here. The workers in the 200 Area of the Savannah River Plant form a part of it. For many of them internal and external exposures may be a cause of the radiation-related diseases which they have or might contract. The uneven quality of the data on external radiation, the serious lack of data on internal exposures, the use of obsolete and misleading methods for many of the measurements of internal exposures as have been made does not speak well of the attitude of DOE and DuPont toward the health and safety of the workers. We recommend a complete disclosure of data relating to worker exposures, and of the dose and cancer risk estimation methods.

Measures also need to be taken to reduce worker exposures. As has been discussed in chapter 4, remote shielded cabs have not yet been successfully been developed for many operations in very radioactive environments. There have probably been many improvements in operating procedures over the years. But the frequency with which non-routine maintenance is required and the persistence of problems such as plugging of pipes, faulty reel tapes, and pump failures leads one to suspect that any such improvement in operating procedures may have been offset by the larger quantity of wastes (in terms of radionuclide content) and the increasingly radioactive environment in

Table 7.1

ORGAN	Range of Dose equivalents from Plutonium Nitrate (rem)
Red Marrow	48-96
Bone Surface	600-1200
Lungs	4-8

which the workers must do their jobs. In other words, until a more definitive analysis can be made based on more quantitative data than we now have, it will remain an open question whether the "learning curve" has resulted in any decreases in exposures, or whether these have actually stayed the same or even increased over the years.

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19. Cookfair, D.L. et al., "Lung Cancers Among Workers at a Uranium Processing Plant", in: Proceedings of the 16th Mid-year Topical Meeting of the Health Physics Society -- Epidemiology Applied to Health Physics, Albuquerque, N.M., Jan. 9-13, 1983.

20. Op. Cit. Ref. 17 and Lushbaugh, C.C. et al., DOE Epidemiology Contractors Workshop, Program and Working Papers, April 13-14, 1983. U.S. Department of Energy, Office of Health and Environmental Research, p. 17.

21. Op. Cit. Ref. 17, p. 2-5, 2-7.

22. Op. Cit. Ref. 20 (see statement of G.L. Voelz et al., p. 5).

23. Op. Cit. Ref. 17, p. 2-12.

24. Op. Cit. Ref. 20 (see statement of G.L. Voelz et al., p. 4).

25. Op. Cit. Ref. 17, p. 5-1.

end

INTRODUCTION PART II

The tables on worker exposures, environmental contamination, technical problems and accidents have been compiled from the "200 Area Fault Free Data Bank - F and H Area Waste Tank Farms - a computer listing of such occurrences obtained by the Environmental Policy Institute through the Freedom of Information Act. This listing comprises about 700 pages of computer print-out in which there are about 14,000 entries. Each entry is a summary of some problem in the Radioactive Waste Tank Farm - whether this be a "non-routine maintenance" of an instrument or a major radioactive waste spill or worker exposure.

The record comprising the "Fault Tree Data Base" is very uneven both in quantity and quality of entries, as is discussed in Part I. The frequency of entries increased from about 4 per year during 1953-59 to about 1800 per year during 1977-82. The variation in the frequency of entries bears no apparent relation to the frequency of problems. Rather the range of problems and method of reporting seem to have changed. While the range of problems reported on has become much wider, the quality of entries has not improved. In some cases, it has tended to deteriorate. For example, there are many entries during 1980 which simply state "non-routine maintenance" on such-an-such piece of equipment, without even a brief statement of the problem or the nature of the corrective action. Further, as noted in Part I, there are instances when important problems have been left out of the Data Bank even after 1977.

The Data Bank entries are divided into two chronological sets, one each for the F and H areas. The earliest entry is dated December 20, 1953, and the latest was on November 30, 1982. We have chosen to group the entries into eleven tables based on the following problem areas:

- **Worker Exposures**
- **Environmental Contamination**
- **Tank Leaks and Overflows**
- **Tank System Failures and Problems**
- **Explosions: Potential and Actual**
- **Equipment Plugging**
- **Power Supply Failures**
- **Pump Failures**
- **Instrument Problems**
- **Miscellaneous Leaks**
- **Miscellaneous**

Each table is organized chronologically with one set of entries each for the F and H areas. The first two tables, "Worker Exposures" and "Environmental Contamination" contain every explicitly recorded entry on such exposure or contamination in the Data Bank. The entries are not repeated, however, so that there are many entries in the "Worker Exposures" table which also deal with environmental contamination and vice-versa. This non-repetition of entries that apply to more than one category applies to all the tables. Our resources did not permit a fully cross-referenced compilation, which might provide further useful insights.

The remaining tables, ie., Tables 3 through 11, contain selected entries whose purpose is to illustrate typical and frequent problems as well as to record the range of problems encountered. Frequent problems, such as plugging of certain equipment, or failure of cooling coils are noted in parenthetical comments. All our comments are given in parenthesis. The text of the description, when in quotation marks is directly from the Data Bank entry; when not in quotation marks it is a summary of the Data Bank entries. Our clarification inside quotation marks are inside square brackets.

TABLE 1

WORKER EXPOSURES

DATE AND AREA	DESCRIPTION AND COMMENTS
02-00-60F	Skin and clothing contamination - 2 people - safety violation.
06- -64F	"A transfer jet was moved from Tank No. 19 and installed in Tank No. 20 Body exposure rates to 1 R/hr. were experienced. Contamination to 1R/hr. was released inside the windbreak protected job site when liquid leaked from the jet dip tribe during removal."
02-10-66F	Leak in diversion box. Radiation level increased to 25 R/hr. Body exposure rate 5R/hr. Adjacent ground areas contaminated to 320 M/Rad/hr at 2 ubcges,
02- -68F	Failed tank 18 evaporator feed pump. "Body exposures ranging to 30 R/hr. at 18 inches" during replacement. Asphalt also contaminated to 5 rads/hr at 5 inches. "Total estimated personnel exposure was 0.8 R."
09-30-69F	Cooling water contaminated. Faulty valve and leaking tube bundle 1.5 curies of Cs-137 released to seepage basin. "Estimated 2.6 R exposure" to workers during "clean up."
11- -70F	6 workers - nasal and skin contamination during removal of defective reel tape. (Reel tape problems are frequent.)
06- -71F	Skin contamination to wrist. Gloves not taped to coveralls.
07- -71F	Total of 3.4 R worker exposure "while lightening packing glands." "Exposure resulted from high irradiation levels in feed pump enclosure."
11-20-72F	Exposure during removal of a valve. "Nasal contamination 400 to 70,00 Dis/m. beta gamma," 4 people. "Hands, face and personal items contaminated to 2000 c/m beta-gamma. Bioassay - 13 NCi, Cs-137/1.5 L. Body count = 84 NCi Ru-106, 368 NCi Cs-137."
04-00-73F	"242-F. Personnel received 13 R total exposure." (No explanation given.)
09- -73F	High radiation levels near vent filter up to 30 R/hr @ 1 inch. Replacement cased estimated 3.5 R exposure.
05-00-74F	"Exhaust filter; Radiation drain build-up of radioactivity on the original exhaust filter for tanks 18 & 20 resulted in exposure dose rates to 3 m/hr in the control room and lunch room."
05-00-74F	(The entry just above appears to have been repeated by mistake.)
05-08-74F	Reel tape replacement, "Max exposure was 30/30 mrads/mr/hr. at 12 inches."
08-21-74F	Jumper problems on Concentrate Transfer System Tank. Exposed at top of open riser 2000 mrads/2000 mr/hr.

DATE AND AREA	DESCRIPTION AND COMMENTS
09-26-74F	1.4 R total estimated exposure to 14 people during feed pump replacement. Total 1-1-74 to 09-26-74 exposure due to "evaporator feed pump job" above is 11.5 R
01- -75F	"14 R received by personnel installing new feed system in 242F."
02-03-75F	1 worker 4,000 c/m beta-gamma on shorts, 30,000 c/m on coveralls. "His flash suit pants had a hole."
05-07-75F	Steam condensate leak repair. "Exposure rate 500/500 mrads/mr/hr. at 12 inches from spool piece."
06- -75F	2R exposure during 2 replacements of evaporator feed pump.
06-26-75F	3.8 R due to concentrate tank lines being uncovered.
07- -75F	1 R during concentrate transfer system inspection and excavation. 2-5 R/hr at 18 inches.
08-15-75F	3.7 R during removal and shipment of 18 jumpers. "6.8 R during removal of CTS tank from pit. 10 R/hr. @ 15 ft."
08-21-75F	"Contaminated soil encounted [sic] during excavation around Riser 6 Tank 3. 350 R/hr @ 1 inch from steam supply line to the jet in Tank 3. Probably the result of suckback and leak. Soil contained about 50 Ci 137-Cs."
08-22-75F	"CTS Pit - Waste management began steam cleaning inside the CTS pit. Work was stopped when steam vapor was observed seeping thru cracks in the hut. Sample taken outside the hut read less than 1×10^{-9} micro ci FP/cc and 5.0×10^{-12} micro ci PW [sic]/cc on initial count."
10- -75F	Total exposure at CTS pump pit excavation to date 21.6 R
12-15-75F	Low activity waste transfer to 241-F. "Got gassed out several times."
02- -76F	10 R/hr radiation level @ 2" during removal of piping. (Worker exposure not given.)
03-12-76F	"Radiation rate 10R/hr close to Riser 6, Tank 3 during contaminated soil removal. Soil to 500 rads/200 R/hr at 2 inches. 100 cu. ft. contained 8-1/2 Ci of 137-Cs. Excavation stopped."
08-13-76F	1.5 R during evaporator feed pump replacement. Pump had leaked.
02-17-77F	Change trailer floor and bench contaminated. Up to 150 c/m beta-gamma. "Successfully deconned."
06-03-77F	Tank 7 feed pump leak repair. Safety violation. 2 workers. One had about 1000 d/m beta/gamma in nostrils.
09-22-77F	0.7 R during valve repair tank 31.
10- -77F	3.3 R exposure during repair of pump to tank 7 evaporator.

DATE AND AREA	DESCRIPTION AND COMMENTS
11-30-77F	30 c/m on control room floor and 50 c/m on lunch room floor found. Cleared. (No estimates of worker exposures. No data on possible sources of contamination.)
01- -78F	Filter replacement. "ETE [Estimated Total Exposure] = 3.2 R."
06-12-78F	Dip leg of transfer jet replacement "stopped when exposure rates increased to 30 R/hr. at 2 ft. of the dip leg." (Total worker exposure not given.)
06-15-77F	Workers rubber shoe came off. Personal shoe contaminated through cloth cover to 40,000 c/m beta-gamma. Working in hut on Tank 34.
10-07-78F	2 contaminated hard hats found in regulated locker area of control room.
10-16-78F	"Breathing air compressor shut down by waste management. Puff workers using [it] had to evacuate maintenance area. "No communication between groups. No audible alarm."
02- -79F	3 workers exposed to CTS loop. No badges. Exposure estimated 65 mr. Cause accidental removal of a fence.
03-08-79F	"Employee scratched the back of his left hand [during]...CTS live work. No beta-gamma or alpha contamination."
03-14-79F	"Construction worker got 8,000 c/m beta gamma on gloves. Worked in a 241-F regulated area without health physics coverage."
04-16-79F	"People that were contaminated B.G. went home at 7 p.m. 4-12 [shift]" (No further explanation.)
10-23-79F	Construction worker hands contaminated: "2,000 c/m beta-gamma on palm and back of his left hand, 200 c/m beta-gamma on back of his right hand."
02-29-80F	"Unauthorized line break on an evaporator process line." 100 ml liquid contaminated 1.5 sq. ft. area in gang valve house to 500 mr/hr. at 3 feet. One mechanic hands contaminated to 35 mr/hr., gloves and coveralls to 6,000 c/m. Two mechanics had nasal smears of 300 d/m and 275 d/m. Suckback in the line had occurred."
03-04-80F	241-F. Worker had 1000 c/m gamma on right palm and 600 c/m beta on left palm.
03-09-80F	Draining and drying of probes in LDB's which had ½" liquid in them. "No smearable contamination."
04- -80F	"A dip tube had to be mined loose from approximately 12 feet of salt in Tank No. 19. Total estimated exposure for 36 people was 1.2 R."
04-07-80F	"Two construction carpenters entered a barricaded excavation adjacent to F area diversion box No. 2 whitle waste was being transferred through lines exposed by excavation. The carpenters received 230 and 160 mr respectively."

DATE AND AREA	DESCRIPTION AND COMMENTS
04-21-80F	Tank 33: liquid radiationg 500 mrad/hr. at 5 cms spilled onto ground. 3,000 to 80,000 c/m in a 6 sq. ft. area. 3 workers had skin contamination to 60,000 c/m beta-gamma.
04-21-80F	"Hard hats in change and trialer floor smearing 8,000 c/m."
04-23-80F	Tank 33: Repairs to hut. 2 men got 30 mr. "The top of the tank, out approx. 2 m from the hut, was found contaminated to a max of 40,000 c/m beta-gamma at 2.5 cm. transferable."
04-28-80F	"A juno with 200 mrads/hr. of smearable beta-gamma was left in seat of [pick-up truck]. Seat and floor board contaminated to 30,000 c/m. Health physics inspector contaminated the seat of his personal trousers to 2,000 c/m."
07-11-80F	Worker had 1,000 c/m to 2,000 on both shoes and 1,000 c/m on bottom of left sock. Had been working on tank 20.
08- -80F	"Fiberglass filter for Tank No. 1 removed." It contained estimated 0.8 Ci activity. "Total estimated worker exposure for 65 employees was 2155 mr."
12-12-80F	"Employee reported to medical this a.m. with a slight wound on the back of her left hand that she said she received at DB-1 on 12-4-80."
12-20-80F	"Worker removed his plastic suit top at bottom of DB-1 due to the hoses being tangled. Nasal smears taken were less ms."
01-06-81F	Tank 18 transfer jet repair. Dose rate: "250/250 mrads/mr/hr. at 30 cms."
02-24-81F	Tank 25: Repairs. "Exposure dose rate to 350 mrad/350 mr/hr."
03-16-81F	HEPA filters changed. "T&T operator had 2000 c/m beta on his throat area." "North HEPA DOP tested 99.94%.."
04-10-81F	Ph-12 alkaline solution ("inhibited water") sprayed into hut and on workers during probe of Tank 2.
05-19-81F	"As sampler was pulled from tank 1 it brought with it discarded steel tapes from the tank interior. Liquid on the tapes contaminated the wrists and nasal passages of the foreman" because he "grabbed the steel tape, broke it into [sic] and pushed it back in hole before h.p. could stop him. Skin: 5 mrads/hr. beta-gamma at 5 cm. on right wrist; 60,000 c/m beta-gamma on left wrist. Nasal contamination 590 d/m beta-gamma."
05-27-81F	Mechanic changing feed pump. Tank 7, had 2 pairs coveralls on mask. 20,000 c/m beta-gamma on right sleeve of inner coveralls and 2,000 c/m on skin on underside of right forearm.
06-01-81F	Removal and shortening of transfer jet. 06-01-81; 3R to 19 men. Again 6-14-81. 1.7R for 16 men. One worker had 1,000 c/m beta-gamma on left forearm. Causes: repair to jet; pluggage; leak in diversion box; inspection. Dose rate: 50/mr/hr.
07- -81F	Lead Liner was inserted in riser #3. Radiation level over riser reduced from 15 R/hr to 2.5 R/hr. Estimated total exposure to 12 workers: 565 mr.

DATE AND AREA	DESCRIPTION AND COMMENTS
07-20-81F	Worker contaminated his left shoe to 1,000 c/m by stepping out of shoe cover at hut of Tank 26.
07-21-81F	Clean-out port to Diversion Box 5. "Water and salt backed out line and contaminated employee." Rubber gloves 150 mr/hr. at 8 cm., left cover was 10 mr/hr. at 8 cm. Left shoe (personal) 7,000 c/m beta-gamma. Cause: apparently a plugged line.
07-25-81F	Same clean-out. Worker contaminated to 2,000 c/m above port #15 after liquid sprayed from line.
12-21-81F	Tank purge HEPA filters fail. Estimated release to atmosphere: 10 micro-curies of fission products. Total exposure of 2 rads to 20 persons.
01-28-82F	Further repairs tank 28 jet. "Body dose rates ranged to 8 r/hr. at 45 cms of open riser...Employee knelt on damp cardboard." He had right knee: 3,000 c/m beta-gamma; left knee: 1,000 c/m beta-gamma; another had 2,000 c/m beta-gamma on right knee. Backflush valve installed in Tank 25. "Total exposure to 5 men was 100 mr." Leak repair concentrate transfer system pit. "Total exposure to 15 men was 720 mr."
03-18-82F	Work on failed sump jet steam line. "Total exposure to 4 people was 85 mr."
03-21-82F	Extensive work on transfer jets to replace gaskets, flush and align jet. "Body dose rates ranged to 8 R/hr. at 45 cm. above open riser. Total estimated exposure involving 30 people was 3,000 mr."
04-13-82F	Blow back of water from "catheter line": [used to unplug pipes] at Tank 25. "Contamination to 500 mr/hr. at 8 cm....inside the enclosure on the outer SWP clothing of the operator.
05-03-82F	Interarea pump pit repairs. "Total exposure for 17 people was 580 mr."
05-03-82F	Tank #27 transfer jet leak. Jet raised 3 times to regasket it. "Body dose rate was 2 R/hr at 0.5 meter above open riser...Total exposure was 1,025 mr. for 6 people."
05-11-82F	Power outage to Tank 33 and 44 ventilation system. During survey of vapor space skin contamination to foreman: left ear, 600 c/m (beta-gamma); hair, 2,000 c/m; inside both forearms, 20,000 c/m; and left side of abdomen, 600 c/m. Personal clothing was contaminated up to 10 mrad at contact.... Foreman's car and a personal wash cloth at the foreman's home were also contaminated. The foreman proceeded without monitoring as required. Blame partly laid to "insufficient training." (In spite of extensive body contamination, the report of the incident found "no nasal contamination or body assimilation.")
05-12-82F	Hydrogen survey tanks 33 and 34. Foreman had "skin contamination to 20,000 c/m beta-gamma — deconned to no detectable. Her clothing and personal items — several were contaminated to 25,000 c/m beta-gamma probe." A Health Physics department truck "contaminated to 100 c/m beta-gamma smearable and probed at 8,000 c/m. Hot smear probing 280 mr/hr at 5 cms was found in the truck."

06- -82F	New CTS ventilation system construction. "Body dose rates ranged to 20 mr/hr. The total estimated dose was 560 mr for 43 people.
06- -82F	Excavation around tanks 17 and 18 "to install foundations for salt removal equipment. Body dose rates ranged to 100 mr/hr. The total estimated dose was 515 mr for 28 people."
06-09-82F	Installation of pump tank transfer jet. "Total exposure was 80 mr for four people."
06-10-82F	"Construction concrete worker probing from 2,000 c/m to 6,000 c/m all over his person...May have had radioactive injection. Determined he had received an injection of thallium given by doctor."
07- -82F	Installation of new CTS ventilation system. "Body dose rates ranged to 50 mr/hr in the trenches. The total estimated expousre involving 201 personnel was 3565 mr."
07-13-82F	Concentrate Transfer System vent line construction. CTS just entered for work. "Total exposure for seven people was 550 mr."
08- -82F	CTS vent system construction. Body dose rates to 40 mr/hr. Total estimated dose to 158 people: 2030mr.
08- -82F	Tank #26 feed pump change. Dose rates to 2.5 r/hr. at 0.5 meters above open riser. "Total estimated exposure to four people was 165 mr."
08- -82F	Leaking evaporator condenser replaced. Dose rates to 1 r/hr. Total estimated dose to 30 workers was 635 mr.
08-24-82F	Replacement of failed pump in the concentrate transfer system. Total exposure for 9 workers: 340 mr.
08-25-82F	CTS pit reentered to check recirculation pump. 435 mr to 11 workers.
09- -82F	Check out of CTS vent system. 900 mr to 24 workers.
09- -82F	Tank #3 repairs. Dose rates to 1-5 r/hr at 50 cm above open riser. Estimated exposure to 40 people: 895 mr.
09-12-82F	2F Evaporator work. Exposure to 20 people: 400 mrem.
09-17-82F	Tank #33 transfer jet repairs. Total exposure of 865 mr to 7 people.
09-29-82F	CTS vent system modifications. 50 mr total exposure to 4 people.
10- -82F	Installation of asphalt on tanks 1,2,3,4. Body dose rates ranged to 100 mr/hr at 60 cm above tank tops. Total dose to 135 people estimated 1,390 mr.
10- -82F	"Installed a pump insert plug in the dome riser" at Tank #17. Dose rates to 800 mr/hr at 45 cm of riser top. Total estimated exposure to 8 people: 140 mr.
10- -82F	Diversion box FDB-4 entered twice for inspection and repair of leak. Total estimated exposure to 15 people: 560 mr. Dose rates ranged to 500 mr/hr at 1 meter above open box.

DATE AND AREA	DESCRIPTION AND COMMENTS
10-15-82F	FDB-4 entered again to verify valve operation. Total exposure to 7 people was 470 mr.
11- -82F	Replacement of leaking nozzle gaskets on Tank 26. Body dose rates to 8 R/hr. at 0.5 meters above open riser. Total estimated exposure to 12 people: 2465 mr. 1 worker knelt on wet lead shielding contaminating his right knee to 4,500 c/m. Decontaminated.
11-19-82F	CTS vent system check out preparation. Total exposure for 5 people: 135 mr.
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
02-15-61H	Raising of thermocouple were from annulus plug on Tank 16 caused contamination of 2 workers "up to 6,000 c/m" and equipment contaminated up "to 15 r/hr. on a riser plug." "Approved procedures" not followed.
09-21-65H	Suck back, ascribed to leaking valve. Contaminated control room to 5 mr/hr.
08-31-66H	"241-H tank 21. High exposure" to seven workers. Exposure levels to 7 r/hr. "without H.P. [health physics] monitoring the max expose was 565 mr." Exposure was during excavation of a trench over waste tank 24.
09-00-66H	"Radiation exposure. See SHI 243."
11- -68H	"Film badge of sep. dept. supv. indicated skin exposure of 14,590 mrads during Oct. exceeding AEC manual quarterly standard of 10 rem. The exposure prob[ably] occured when the employee removed two acme nuts from a 241-H waste transfer pump in railroad tunnel airlock. See special hazards investigation 266."
11-15-68H	Worker contaminated hands to 150 mr/hr. at 3 inches while attempting repairs [to evaporator] without proper protection equipment.
01-00-69H	"Exposure rates to 20 rads/hr" during removal of transfer jet from tank 14.
03-00-69H	Nasal contamination of worker during work on Tank 15 removal of reel tape to 30,000 c/m beta-gamma and face and hair contamination of 10,000 c/m. "Apparently occured during removal of protective equipment at end of job."
04-00-69H	Removal of slurry pumps and equipment from Tank 14. Exposure rates to 10 rads/hr. "Estimated exposure to personnel was 9 rad."
10-16-69H	"8 construction men and 1 HP inspector received nasal contamiantion during change of four slurry pumps from tank 11. Contamination levels were 530 to 43,500 d/m beta-gamma."
06-12-72H	"Undetected leak resulted in airborne contamination to personnel and equipment. 3 employees nasal contamiantion to 7,200 c/m beta-gamma. A vehicle and pavement around DB-2 contaminated."

DATE AND AREA	DESCRIPTION AND COMMENTS
08-23-72H	Worker exposure during grinding of contaminated piping. 4 workers had contamination to 1,500 d/m beta-gamma. "One construction personnel received an assimilation. Bioassay = 0.65 d/m 1.5L, chest - 33 NCI."
02-28-74H	1 pint of contaminated liquid sprayed from a leak. "Grating of the catwalk around the evaporator cell was contaminated to 8 Rads/hr...2 maintenance mechanics were contaminated by falling droplets. Nasal contamination up to 1,345 d/m beta-gamma. Body contamination 300 mr/hr at 2" from arm, 1st mech. bioassay = 12 NCI; Cs-137/ 1.5L Chest count = 262 NCI; Cs-137, 43 NCI Ru-106. Body burden (1% MPBB). 2nd mech. bioassay = 64 NCI, Cs-137/1.5L Rec'd (2% MPBB)."
06-26-74H	Student contaminated right hand to max. of 1,500 c/m beta-gammå.
07-02-74H	Jumper repairs DB-4. Liquid flooded bottom of box.
07-11-74H	Worker's "dosimeter was off scale at conclusion of job. His film badge was pulled and this revealed he had accumulated 590 mrads/590 mr."
08-00-74H	Radiation rates to 40 R/hr. above open riser, Tank 29. Personnel exposure rates to 3 R/hr. "Transferable contamination to 2.E06 d/m foot square alpha and 40,000 c/m foot square beta-gamma within plastic hut."
01- -75H	"Exposure rates to 400 mr/hr to construction personnel during live connections between Tank 13 and evaporator."
03- -75H	Failed evaporator feed pump. Exposure rates to 10 R/hr. Total exposure to 9 people 0.8R.
09- -75H	CTS leak detection system installation, exposure rates to 100 mr/hr. Total exposure to date 4R.
11-28-75H	CTS leak repair. Radiation exposure rate 3 R/hr. at 3 ft. above all. 4.8 R personnel exposure during inspection and leak repair.
12-15-75H	"Tank 15 - outside coveralls contaminated 6,00 c/m beta-gamma. No alpha on upper right leg." Student given used coveralls.
01-07-76H	Valve replaced. Maintenance mechanic's coveralls contaminated to 20,000 c/m beta-gamma at 1 with 3,000 d/m alpha. Air sample at hut door outside, during the job "revealed 1-75 x 10^{-9} microci FP/cc and 153 x 10^{-12} microci Pu/cc in air."
03-04-76H	CTS tank drawoff pump replaced. Exposure rate to 500 mr/hr. Pump radiated 25 rad/hr. at 2 inches.
03-24-76H	Technical engineer contaminated personal shoes to "1,500 c/-beta-gamma" by stepping on ledge of tank 31 to remove thermocouple.
04- -76H	Tank 31 HEPA filter replacement. Dose rates to 20 Rads/10R/hr at 2 inches and 1-5 R/hr at 2 feet.

DATE AND AREA	DESCRIPTION AND COMMENTS
04-27-76H	Evaporator cell: Air sample taken during jumper change: 0.44×10^{-9} micro Ci FP/cc and 40.6×10^{-12} micro Ci Pu/cc.
05-30-76H	Steam leak into Tank 22 sump. Air sample taken 10 ft. east of hut downwind measured 0.18×10^{-9} microcuries FP/cc of air.
07-11-76H	Hosed salt deposits in feed pump cell will water. Body exposure rate of 200 mrads/100 rm/hr at 2 ft. from hole. "No spread of contamination" from hosing.
08- -76H	Cesium removal column replaced. Exposure rates 700 mr/hr. 60 cm. over open riser and 100 mr/hr at 0.5 from the column.
08-16-76H	Pump pit No. 3. 3 workers contaminated clothes up to 40,000 c/m. 1 had 1,000 c/m on hair over right ear. Nasal smears for foreman 242 c/m to 300 c/m. Air samples: 10.66×10^{-9} microCi FP/cc and 47.7×10^{-12} microCi Pu/cc. Similar levels of air contamination on 08-17-76.
08-24-76H 09-10-76H	Hard hats at 241-H contaminated "up to 18 c/m beta-gamma, no alpha." Survey on 09-10-76 revealed hard hats contaminated up to 670 c, beta-gamma.
09-07-76H 09-17-76H 09-22-76H 09-23-76H 10-14-76H 10-15-76H 11-10-76H	Tank 31. Air samples during equipment removal: 86×10^{-9} microCi FP/cc and 400×10^{-12} microCi Pu/cc. Exposure rates to 150 rads/80 R/hr flush with open tank risers. Somewhat lower levels in air on 09-23-76 and again on 10-14-76. 1.9×10^{-9} microCi FP/cc and 40.5×10^{-12} microCi Pu/cc at Tank 13 on 11-10-76.
11-12-76H 11-19-76H 12-03-76H 03-08-77H 04-20-77H 04-26-77H 05-26-77H 09-07-77H	Tank 13 drill motor repairs. Air activity 3 meters east of hut at HEPA exhaust $.16 \times 10^{-9}$ microCi, FP/cc and 56×10^{-12} microCi Pu/cc. Similar levels on 11-19-76 when all covers removed in CTS. Again at Tank 13 on 12-03-76. Entry into Diversion Box 1 on 03-28-77. 90.1×10^{-12} microCi Pu/cc. Similar level during survey of Tank 16 for maintenance on 04-26-77. Similar level during removal of jumper DB-2. DB-1 work. Installation of "U" jumper. 49×10^{-9} microCi FP/cc and 18.3×10^{-12} microCi Pu/cc.
12-10-76H	Tank 13. Workers hoses contaminated to 7,000 c/m beta-gamma.
01-17-77H	"attempted decontamination" of ball value radiating 1,000 rad/hr at 58 cm.
02-01-77H	Tank 29. Liquid spill during repairs. Exposure rates 150 rads/100 R/hr. at 5 cms. "Personal shoes" contaminated.
02-07-77H	Tank 29 repairs. Total exposure 1,800 mr.
02-22-77H	"Contaminated water [5,000 c/m/ml, beta-gamma] bubbled from ground at Tank 13 during hydrostatic testing of a line, faulty weld. Exposure rates to 1 R/hr at 30 cm." Total exposure 2.6R.
05- -77H	"High personnel exposures to T&T workers on hot job."

DATE AND AREA	DESCRIPTION AND COMMENTS
05-03-77H	"New pumphouse - high activity was recorded in control room at 7:00 pm... 1/1mrad/mr/hr. gen. area."
05-17-77H	DB-5 repairs. "Exposure rate (hand rate also) was 20 rads/.2R/hr. at 5 cm. nozzle to regasket."
06-01-77H	Tank 16 maintenance. "Jet radiated 50 rads/4 R/hr at 5 cm."
09-15-77H	Removal of valve in Tank 31. "Radiation level flush with open hole 50 rads/hr. 15R/hr." DB-4. Gasket replacement. Body exposures rates to 8 rads/3R/hr. at 45 cm.
02-09-77H	Evaporator cell: Plugged vent and transfer line. Exposure rate 25R/hr. at 3 cm. "Repair personnel got about 2R."
02-15-78H	Liquid leak from evaporator cell. Exposure rates to 50 R/hr at 1 inch.
04-02-78H	"Repairs to valve on evaporator feed pump in Tank 13." Total exposure 0.8 R.
05-01-78H	Replaced gaskets in CTS pit. Total exposure to 8 people: 950 mr.
05-19-78H	Repairs to CTS draw-off pump. 4,000/200 mrad/mr at 18 inches. 3 days to repair.
07- -78H	Removal of CTS agitator. Total exposure 1 R.
07-16-78H	Up to 15,000 c/m on personal shoes of worker, probably while taking a reading at P-Trap riser #8.
08- -78H	Unplugging of vent line from 242-H evaporator. Total exposure to 15 workers: 800 mr.
08-03-78H	"Construction pipe fitter, to 8,000 c/m beta-gamma at 3 cms. on chest (small area)." Clothes also contaminated. "An open bag containing used regulated clothing was found radiating 20,000 c/m beta-gamma at 3 cms."
09-18-78H	Worker had 7,000 c/m "on his neck in one small spot."
02-05-79H	"Employees burned eyes while watching welding operation..."
02-15-79H	Worker contaminatead right index finger and left hand to max of 30,000 c/m while handling bottles of contaminated mercury.
03-02-79H	2 workers contaminated personal clothing and shoes up to 30,000 c/m while working at Tank 16.
04-17-79H	281-8H. Miscellaneous basin maintenance. "One employee's results was 620 mrems/620 mrems. The other employee's results was 825 mrems/825 mrems.
05-03-79H	Survey prior to repair of bad valve. Radiation rates over open hole of 1000 mr/hr beta-gamma and 1000 mr/hr gamma.

DATE AND AREA	DESCRIPTION AND COMMENTS
06-04-79H	Leak in evaporator bottom line. "100 workers accumulated 4750 rems." [This might be an error. The figure intended is probably 4750 mrems.]
12-05-79H	"CTS area - employee contaminated the front of his shirt and pants to 2,000 c/m beta-gamma."
01-02-80H	Soil near 502 line measured 1 rad/hr at 5 cm. Two workers contaminated their shoes to 1,000 c/m beta-gamma due to contaminated soil.
01-25-80H	Tank 16. Tape taping worker's gloves to coveralls came loose. Right forearm contaminated 20,000 c/m, left forearm to 40,000 c/m.
01-27-80H	Regulated hard-hat found contaminated to a max. of 200 c/m beta-gamma during weekly routine check.
02-07-80H	Worker's palm and forefinger contaminated to 10,000 c/m beta-gamma while sampling Tank 31.
03-28-80H	Removal of specific gravity dip tube from Tank 13. One worker's left hand contaminated to 100 mrad/hr. at 5 cm; right hand to 40,000 c/m beta-gamma. Second worker's wrist to 40,000 c/m beta-gamma.
04- -80H	6 sq. ft. area contaminated while removing dip tubes. 3 construction workers received up to 60,000 c/m contamination on skin during cleanup.
04- -80H	Installation of new line at evaporator. Total exposure of 1,100 mr to 30 people.
04-10-80H	Inside of vehicle cab found contaminated to 20,000 c/m beta-gamma during a survey.
05-10-80H	"Extensive decontamination of salt and gravel on top of Tank No. 13 was performed." Source of contamination apparently a crack in reel jet pill box. Total exposure to 11 people to remove tar and gravel: 140 mr.
05-30-80H	Work on air compressor. Exposure rate 10 mrad/10 mr/hr.
06-19-80H	CTS area - workers' shoes contaminated from 800 c/m up to 8,000 c/m beta-gamma. One worker "stepped in water that came up over his workshoes."
09-08-80H	Dismantled purge blower. Exposure rate "10/10 mrad/mr/hr gen. area."
10-02-80H	Repaired leaking jumper connector at 242-H evaporator. "Body dose rate flush with open cell was 2,000/1500 mrad/mr/hr. 3 shifts.
10-10-80H	Removal of faulty feed pump (Tank 13) and its transport. Exposure rates to 3 R/hr. Reinstallation exposure rate 8,000/mrads/3,000 mr/hr.
12-03-80H	Check on feed probe on Tank 13. Worker's personal jacket contaminated to "15,000 c/m beta-gamma (no alpha)."
01- -81H	"Exposure rates to 30 rads/hr.2R/hr were encountered to remove a wire that had become wrapped around a sludge probe" in Tank 15. Total estimated exposure to remove wire: 435 mrems.

DATE AND AREA	DESCRIPTION AND COMMENTS
01-11-81H	Accidental pressurization of riser on Tank 31 during work. 10 sq. ft. area contaminated. Worker's clothing and shoes contaminated from 2,000 c/m to 35,000 c/m beta-gamma.
01-20-81H	Entry into Diversion Box 4 for repairs: worker contaminated shoe covers and clothing to 20,000 c/m beta-gamma.
02-07-81H	Loop line to CTS and Tank 29 pluggage and malfunction. Repair causes exposure of 2,220 mrem. Total to 17 persons. Exposure rates to 8R/hr.
02-09-81H	Worker's clothes, including insulated underwear contaminated to 3,000 c/m beta-gamma while welding.
02-12-81H	By-pass valve cracked due to freezing and contaminated tank top and ground. Worker without protective clothing contaminated shoes and trousers to 1000 c/m and hand to 200 c/m.
02-16-81H	CTS line radiating 80 R/hr uncovered late Friday night. Measurement taken on Monday.
02-21-81H	Safety showers at evaporator replaced. General area dose rate 10 mrads/ 10 mr/hr.
03-20-81H	"T&T rigger's exposure of 1,145 mr exceeded exposure guide of 600 mr for month. He was changing jumpers in Diversion Box 4. Failure to communicate was principal cause."
04- -81H	Excavations for concrete pad at riser 3. Total exposure to 11 persons: 310 mrem.
04-02-81H	Workers from "Puritan Janitorial Service" exposed to ammonia vapor.
04-14-81H	Construction worker at Tank 15: gloves contaminated to 40,000 c/m and tarp over riser and plastic on floor to 60,000 c/m beta-gamma.
04-27-81H	Transfer jet screen plugged. Removal exposure rates to 10 R/hr. at 30 cm. Total exposure 3.2 R to 27 workers.
05- -81H	Removal of obsolete equipment from insider riser 6, tank 9. 40 workers accumulated 3.7 R exposure.
05-22-81H	Failed draw-off valve removed from Tank 36. Total exposure over 2-day job to 7 workers was 190 mr.
05-29-81H 06-01-81H	Installation of Thermocouple on valve riser C-2, Tank 36.
07- -81H	Removal and regasketting and reinstallation of jumpers in DB-6. 37 workers total exposure: 4.6 R.
07- -81H	Riser plug removals. Exposure rates to 1.5 R/hr. Total estimated exposure to 37 workers: 2265 mr.
07-04-81H	Change of bad gasket on trasnfer jet, Tank 36. "WM and T&T changed gasket on transfer jet at C-1 riser using a radiation dose rate of 5 rads/4 R/ hr at 0.5 m from connector. Radiation level at top of riser was 20 rads/ 15 rads/hr."

DATE AND AREA	DESCRIPTION AND COMMENTS
07-13-81H	"Employee inadvertently contaminated his personal clothing [to 6,000 c/m beta-gamma] after removing a rope [safety belt rope] from an open bag in the 242 supply room."
07-17-81H	Riser jet put on truck for disposal leaked. Both shoes of worker on truck contaminated to 80,000 c/m beta-gamma.
07-22-81H	"Construction boilermaker and laborer incurred skin contamination while handling a portable hand saw which was contaminated. The laborer also sustained nasal contamination."
08- -81H	Continuation of work on transfer piping installation. 43 workers exposed to a total of 1405 mr.
08- -81H	Installation of new nozzles in DB-6. Total exposure to 31 workers: 1885 mr.
08-14-81H	"Employee contaminated himself and clothing when he removed drain plug rod...at the CTS pit. Procedures not followed."
08-24-81H	T&T rigger contaminated arms and clothes up to 20,000 c/m after handling used tag line.
09-02-81H	Construction pipefitter handled contaminated welding lead. Right hand contaminated. Some area at 20 mrads/hr.
09-07-81H	Failed recirculation pump. "1035 mr for 11 men."
09-21-81H	Radiation survey inside transition box showed max. radiation level of 300 R/hr at 3 inches.
09-24-81H	Installation of new steam line. Dose rate 70 mrads/70 mr/hr. in the "general area."
09-25-81H	4 ball valves in CTS cell rebuilt. Exposure rates to 1R/hr. Total exposure to 13 people: 750 mr.
09-28-81H	Repaires to valve jumper, CTS pit. Exposure rates 500 mr/hr. at 30 cms. from jumper and 1R/hr over open cell. Total estimated exposure: 315 mr. Reentry into cell on 09-29-81. Total exposure to 6 people: 180 mr.
09-29-81H	"CTS pit - E&I, WMO, and T&T attempted to repair the automatic valve using a dose rate of 500 mr/hr."
09-29-81H	Worker contaminated hands and clothes up to 4,000 c/m.
09-30-81H	New thermocouple installed "using a dose rate of 100 mr/hr."
10- -81H	Jumper placed in burial box. Total exposure to 14 people: 2340 mr.
10- -81H	Installation of jumper in DB-2. Total exposure of 8 people: 775 mr.
10- -81H	Replacement of failed transfer pump and other repairs in CTS pit. Total exposure to 62 people: 2400 mr.

DATE AND AREA	DESCRIPTION AND COMMENTS
10- -81H	"Repair a bent nozzle inside the cell. The total exposure to (involving 70 construction, waste management, and T&T personnel) was 3900 mr."
10-04-81H	"Employee contaminated his right shoe to 2500 c/m beta-gamma while working in 281-8F retention basin."
10-09-81H	"Flush water jockey pump down..." Dose rates: up to 2,000 mrads/200 mr/hr at 30 cms.
10-12-81H	Worker knelt in contaminated water on cell covers. Right knee: 10,000 c/m beta-gamma.
10-16-81H	Replacement of contaminated filter on experimental gas sampler. Worker's hand and clothes contamianted to 70,000 c/m beta-gamma. "No nasal contamination or body assimilation."
11- -81H	Tank 13 feed pump work. Total exposure to 38 workers: 1495 mr. CTS work: Exposure to 18 workers: 1990 mr.
11- -81H	Installation of new jumper for DB-4, DB-6 transfer system. Total estimated 11 workers: 640 mr.
11- -81H	Work for start-up of evaporator. Total exposure to about 20 workers: 950 mr.
11-23-81H	Installation to replace failed feed pump. Exposure to 21 workers: 1245 mr. Decontamination and repair of another feed pump. "Total exposure to 40 men...was 33,000 mrad and 2,000 mr."
12- -81H	Installation to replace failed feed pump. Exposure rate to 2000 mrads/ 100 mr/hr at 0.5 m from pump. Total estimated exposure to 32 people: 1245 mr.
12-03-81H	Tank 31 - Worker contaminated right shoe to 3000 c/m beta-gamma, less than 500 d/m alpha.
12-17-81H	Changes in DB-7. Total exposure to 9 workers, 70 mr.
12-18-81H	Tank 38: lengthening of transfer jet. Total exposure to 5 workers: 570 mr.
12-21-81H	Diversion Box 1. Jumper changes. Total exposure to 8 men was 1,030 mr.
12-22-81H	Work in "HPT-3" mainly on transfer jet. Total exposure to 13 men: 980 mr.
01- -82H	Installation of new jet C-1 riser. Radiation level at top of open riser up to 20R/hr. Total estimated dose to 5 workers: 605 mrem.
01- -82H	Tank 13. Removal and installation of pump. Total of 4 entries needed to complete the job. Radiation exposure rates to 9R/hr. Total estimated dose to 29 people: 1560 mrem. [Same item appears to have been entered on 01-02-82H with exposure of 1420 mrem to 15 people??]
01-05-81H	Diversion Box 2 jumper changes. "Total exposure to 11 men was 1,160 mr."
01-06-82H	Replaced stator on recirculation pump motor. Total exposure to 15 workers: 1,240 mr.

DATE AND AREA	DESCRIPTION AND COMMENTS
01-06-82H	CTS pit - transport of contaminated metal angle riser. 3 workers' coveralls, gloves contaminated from 10,000 c/m beta-gamma to 100 mr/hr at 5 cms. Pick-up truck contaminated to 10,000 c/m beta-gamma.
01-25-82H	"Waste header tie-in. HP [Health Physics] started to set a rate for construction and found liquid dripping from canyon encasement rain line. The radiation rate was 60 rads/20 R at 18 inches from liquid...Approximately 5 gallons had drained into sump."
01-25-82H	Lift jumper vent line repaired "using a dose rate of 1000 mrads/200 mr/hr. at 0.5 meters from jumper."
01-28-82H	High radiation rate in Diversion Box #5 flug box - 200 rad/15 R/hr due to a leak. Total exposure to 3 workers: 350 mr.
01-29-82H	Work on jumpers - total exposure to 12 workers: 895 mr.
02- -82H	"Construction completed tie-in of the new jacketed waste headers. Problems were encountered when liquid radiating up to 150 rads/hr dripped from several of the headers."
02- -82H	Tank 13 failed feed pump. Exposure rates to 3R/hr above open riser. Total estimated exposure to 10 workers: 1035 mr.
02-07-82H	Tank 31 work. Total exposure to 3 workers: 155 mr.
03- -82H	"Construction chipped through four feet of concrete on top of Tank 38" to weld cooling weater line to tank primary. Radiation levels up to 600 mr/hr. at 5 cms. from tank top. Total estimated exposure to 24 workers: 920 mr.
03-31-82H	Diversion box 7 repairs. Total exposure to 27 workers: 4,370 mr.
04- -82H	Preparation for installation of jet for Tank 9. Total estimated exposure to 17 people: 1030 mr.
04-02-82H	Work in DB-5 "Radiation levels were reduced from 40 rads/2H[sic]/hr to 10 rads/1R/hr at 5 cms. Radiation dose rate of 2,000 mrads/200 mr/hr at 0.5 m was established..."Total estimated exposure to 7 workers: 215 mr.
04-02-82H	Diversion box #5 hose installation. "Job was stopped when outer pair of coveralls were contaminated to 15 mrads/hr at 2 inches."
04-05-82H	"DB-5 - WMO installed a flush valve on nozzle no. 9 flush valve using a dose rate of 3000 mrads/300 mr/hr. Estimated total exposure: 110 mr."
04-07-82H	Entry unto DB-2: jumper change. Total exposure to 7 men was 610 mr.
04-27-82H	CTS - removal of radioactive materials for burial. Broken jumper radiated 4000 mrads/300 mr/hr at 5 cms.
04-29-82H	Entered CTS pit for inspection of pump. [Exposure rate or total exposure not given.]

DATE AND AREA	DESCRIPTION AND COMMENTS
05- -82H	Failed feed pump decontaminated from 20 rads/1R/hr. at 30 cm to 1000 mrad/ 100 mr/hr at 30 cm. Total exposure to 17 workers: 555 mr.
05- -82H	Miscellaneous maintenance in CTS cell during April and May. Total exposure to 33 workers: 1,605 mr.
05- -82H	"Dry airborne waste contaminated 9 personnel and a 2500 sq. ft. area south of Tank 16 during removal of a recirculation jet." Improper equipment and procedure. Skin contamination up to 40,000 c/m beta-gamma. Nasal up to 700 c/m beta-gamma.
05-17-82H	"Construction began repair of leak...using dose rates to 100 mr/hr at 0.5 m.
05-18-82H	CTS work on drop valve in Tank 36. Total exposure to 3 workers: 220 mr.
05-19-82H	2 entries work on drop valve tank 37 "using a dose rate of 300 mr/hr at 0.5 from edge of riser (at tank level). Radiation level incrased to 50 R/ hr. over open riser when valve was removed." Total exposure to 4 men was 165 mr.
05-21-82H	Severe right forearm laceration during work in repair cell (299-H). Survey revealed, "Metal plate causing injury: 2,000 c/m less than 500 d/m alpha; cut area of plastic suit 45,000 c/m is 50 d/m alpha...employee's arm less than 10 c/m beta-gamma, less than 10 d/m alpha; and a blood smear less than 20 c/m beta-gamma, less than 10 d/m. [The last figure is apparently an alpha count but this is not stated.]
05-28-82H	Puncture wound on finger to maintenance mechanic. Cut area of finger contaminated to 1000 c/m beta-gamma.
06- -82H	Leaking transfer jet, Tank 24 mechanic had puncture wound: 1000 c/m on excised. Estimated total exposure: 240 mr.
06- -82H	Tank 41 gravity line plugged. Catherization required. Total exposure to 4 workers: 50 mr.
06- -82H	Unsuccessful attempt to install sump jet. DB-6. Total estimated exposure for 11 people: 580 mr. "The radiation level increased to 2500 mr/hr over the open cell. A dose rate of 500 mr/hr was established for the job."
07- -82H	Regasketing of Tank 37 CTS spool piece. Total exposure to 14 workers: 2165 mr
07- -82H	Regasketing of Tank 37 CTS spool piece. Max. radiation level 30 R/hr. Used an exposure date rate 500 mr/hr. at 1 m. from outside edge of riser. Estimated total exposure to 6 people: 910 mr.
07-13-82H	Work procedure violation. Maintenance mechanic received facial and hair contamination of 700 c/m beta-gamma.
07-19-82H	Entry to evaporator cell. Total exposure to 6 workers: 60 mr.
07-21-82H	Tank 38 transfer jet adjustment. Leak check. Total exposure to 7 workers: 145 mr. Again on 07-26-82. Exposure: 95 mr to 5 workers.

DATE AND AREA	DESCRIPTION AND COMMENTS
07-22-82H	Removal of sump jet from DB-6. Total exposure to 5 workers: 75 mr.
08- -82H	Worker contaminated soles of personal shoes to 200 mrads/hr by stepping on a piece of contaminated plastic on Tank 35. Monitor house floor contaminated up to 4,000 c/m; sample truck cab floor to 40,000 c/m and tank top up to 200 mrad/hr.
08- -82H	Tank 35. Worker contaminated personal shoes to 200 mrad/hr by stepping on contaminated plastic. Sample truck cab contaminated up to 40,000 c/m beta-gamma, and top of Tank 35 up to 200 mrad/hr. (This entry appears to have been repeated in somewhat different from on 08-20-82H.)
08-05-82H	DB-6. Sump jet installation. Total exposure to 4 workers: 90 mr.
08-06-82H	Pump replacement. Total exposure to 4 workers: 140 mr.
09- -82H	Removal of clean out port #3. 24 persons received a total of 980 mr.
09- -82H	Decontamination of Tank 13 in prepration for off plant vendor work to repair cracks. Total exposure to 19 people: 1560 mr. Continuation in Octobeer: Total exposure to 28 people: 1435 mr.
11- -82H	Unsuccessful attempts to change jumpers remotely in CTS cell using shielded crane. Exposure rate in cab of shielded crane 1 mr/hr compared to 2R/hr over open cell. Later hands-on change gave 1115 mr over 30 personnel entries, and further work gave estimated 900 mr over 50 personnel entries.

TABLE 2

ENVIRONMENTAL CONTAMINATION

DATE AMD AREA	DESCRIPTION AND COMMENTS
03-00-60F	1800 square yard area around diversion box contaminated with particulates.
02-29-61F	Plutonium leaked from evaporator to ground 4 times in "recent months."
08-13-62F	Flange leak between tanks 18 and 19. Radiation rates 4 to 10 R/hr at 4 inches., 186 cu-yds of soil and asphalt excavated. [Worker exposure not cited.]
04-00-63F	10,000 square feet area downwind of diversion box contaminated "due to jumper changes."
11-18-64F	Column feed pump shut off for shows. Radiocesium released to seepage basin.
01-15-65F	"Cesium release - Cs columns inadvertently bypassed for 11 hours."
02-03-66F	Radioactivity by-passed exhaust filter during sludge transfer. "Nearby area: contaminated."
05-13-66F	"Cesium 137. Continuing problems with high Cs"
04-00-67F	"Suckback through steamline." 60 R/hr at gang valve area. "Gang valve replaced and area decontaminated."
02-15-68F	Pump gasket ruptured. Area contaminated.
09- -68F	4.03 curies Cs released to seepage basin. Monthly guide of 2.5 curies exceeded, during August 30 - Sept. 5 releases.
12-00-70F	"Difficulty in meeting guides" for alpha release to seepage basins due to high alpha activity in Savannah River Laboratory waste.
08-00-71F	Leaking feed pump flush line caused ground contamination. 100 R/hr. on line insulation and 15 R/hr. on adjacent ground. 80,000 c/m released to Four Mile Creek after rain.
05-02-73F	Discharge of near boiling concentrate to Tank 34. Result: flashing of vapor and discharge of airborne activity from cracks in concrete and riser covers - 20 R/hr.
08-00-73F	Increase of Cs to Four Mile Creek - "Surface contamination in waste tank farm—storm sewer—rainfall??"
03-00-74F	Well FTF7, minor contamination has been found in groundwater of this well, new waste tanks 3 & 5 in F area, since last October, shortly after the wells were drilled." Cause of contamination unknown.

DATE AND AREA	DESCRIPTION AND COMMENTS
04- -74F	10 cubic yards contaminated asphalt removed. [Source of contamination not stated.]
04-05-74F 04-23-74F	"Contamination. Contaminated water was found between CTS pit liner and concrete encasement at 242-F. 300 mrad/hr at 2 inch." The liquid which was subsequently pumped out was found to have radioactivity levels of 7.07 x 10^{+7} d/m/ml cesium-137 and 7.04 x 10^{+5} d/m/ml Cs-134.
05-00-74F	Ru-106 contamination found in monitoring well FTF-6. Pumping continued throughout June 1974.
06- -74F	Top of Tank 29 contaminated.
06-05-74F	1.0 x 10^{-8} microcuries/cc of air released during jumper change in diversion box 1. Worker has nasal contamination of 8200 dis/mn beta-gamma was not wearing "respirator protection." 3 others and 1 pickup also contaminated.
07-16-74F	242F: Exhaust air ("airout") 24 hr. count of plutonium was 4.1 x 10^{-2} microcurie/cc. Fission products: 6 x 10^{-9} microcurie/cc during jumper removal work.
09- -74F	"Steam vapors and minor contamination escaped through HEPA filter on exhaust from Tanks 18 and 20."
09-05-74F	Contamination escapes Tank 18-20 filters. Filters replaced. Tank 20 samples: "62,000 cm beta-gamma 3.1 x 10^{-8} microcuries FP/cc" and "96 cm alpha, 4.8 x 10^{-12} microCi Pu/cc."
04-09-75F	"242-F. The storm sewer monitors alarmed...point 4 which monitors tanks 17-20 went off scale. Special water samples pulled were < than m.s. [less than measurable]." [Cause of alarm appears not to have been found.]
08-25-75F	500 R/hr in dry wells adjacent to Tank 3. "Contamination within 4 ft. of riser and 208 ft. deep."
09- -75F	Sr-90 to seepage basins above guide.
10- -75F	Asphalt near Tank 8 contaminated. Operator error.
06-16-76F	Concentrate Transfer System. Air Activity-fisson products. 166 x 10^{-9} microCi/cc.
05- -77F	"A HEPA filter installed downstream of Tank 7 fiberglas [sic] filter after release of 137 Cs to environment.
07- -77F	High activity waste evaporator "continued deterioration." Release of Ru-102 to seepage basin "exceeded monthly guide in June."

DATE AND AREA	DESCRIPTION AND COMMENTS
01-16-78F	Tank 7 filter leak contaminates road and platform. Operating error - portable filter left running over the weekend.
05-11-78F	"Filter tested 99.50% Tank 8 tea pot. HP [Health Physics] suspected leak."
05-24-78F	Wrong valve opened on evaporator. Alarm ignored. Road contaminated. 250 mr/hr at 5 cms; 20,000 c/m beta-gamma at 3 cm and "less than 500 d/m alpha."
02-26-79F	"The canyon diverted segregated on 281-8F...due to alpha contamination 11 d/m/ml."
03-06-79F	221-F canyon diverted segregated cooling water to 281-8F basin - alpha contamination 24.8 d/m/ml at water monitor.
03-07-79F	Contamination leaked from plastic construction hut to ground outside. "40 square feet contaminated to 60,000 c/m."
03-13-79F	Leak in a "loop line" during modifications. Construction hut floor contaminated to 3500 c/m beta-gamma.
03-16-79F	"radiation reading(s) in trench from DB-5...are 3R/hr. at 3 cm. south end, 1R (at 1 foot) at east end of the line, and 15-30 mr. at south end of trench."
03-27-79F	Tank #20 west riser radiating at 1 R/hr at 5 cm.
04-02-79F	HEPA filters on DB-5 leaking. Test efficiency 99.25%
04-04-79F	Water diverted "due to 13.4 d/m alpha, 180 d/m beta-gamma."
04-18-79F	"281-5 segregated cooling water diverted at 10:10 p.m. Initial contamination 200,000 d/m." Water diverted again at 3:30 pm. To 8F due to contamination of 20 d/m/ml beta-gamma.
05-13-79F	"Got alarm on DRB-5 high air activity. H.P. checked and O.K. now." [Not clear whether this was an instrument problem or leakage of radioactivity or both.]
06-06-79F	Leak from concrete encased line. Soil samples "showed 100 c/m beta-gamma and less than 10 c/m alpha transferable contamination."
07-13-79F	Segregated cooling water diverted to seepage basin due to beta-gamma and alpha contamination.
08-16-79F	"Caved in [depression] area of berm on cast side of 242-F evaporator" had radiation reading of 4 R/hr. in depression and 40 mr/hr at 60 cm above depression.
09-13-79F	"281-6 high activity alarm went off."...Diverted to 281-8. Counts were about 400 d/m/ml.

DATE AND AREA	DESCRIPTION AND COMMENTS
01-29-80F	Construction breached tank 2 positive pressure and "caused tank air to flow from the tank 2 riser 2 opening. No consequence occured, but the incident resulted because the job was not reviewed by HP and operations as required by procedure."
02-11-80F	"While digging holes for streamline poles" the soil was found to have activity of 2,000 c/m near seepage basin line near road C.
03-03-80F	Diversion box #1 opened for a leak check. Dose rate 20 R/hr at 60 cm. After remote flushing, dose rate 5 R/hr. Job stopped "due to high winds that spread contamination outside the windbreak for a distance of 30 ft." Cause: leaking jumper.
04-18-80F	"Trebler line - at 15 feet below p-30 manhole. Water seeping out berm was detected that probed 1 to 4,000 c/hr. beta-gamma."
05-16-80F	30 cc of contaminated liquid released due to operating errors during work on Tank 25 to remove pluggage. Radiation was 500 mr at 5 cm."
07-08-80F	Tank 18. Condensate leaked from HEPA filter at temporary exhaust system. 5 square feet area contaminated to 15,000 c/m beta-gamma.
07-25-80F	"Water leaking around segregated water; some at P-3 manhole. Each probed 6,000 c/m beta-gamma.
07-26-80F	"During excavation for new tank" dirt under road found radioactive to 4,000 c/pm.
08-26-80F	"Contaminated zeolite "inadvertently released."
09-17-80F	Contaminated Zeolite again released out to top of Tank 27 in attempt to clear a plugged line.
12-03-80F	Filter change on tanks 18 and 20. "Max rate 30 mr/hr." 20 gallons water drained into plastic pages "with small amounts escaped to asphalt."
12-08-80F	"During startup, about 115 grams of uranium fromk the uranium cycle were lost to DW waste stream when mixer-settler D was operated 20 minutes with failed impellers. [Also see, DPSPU-80 272-238; SI-80-12-153.)"
03- -81F	"A valving error in JB-line resulted in a transfer of 494 grams Pu into canyon tank 9.7. This solution was subsequently fed to the Law [low activity waste] evaporator and discarded."
04-14-81F	3 gallons of flush water and zeolite contaminated platform and tank top. "Decontamination will require about 10 man-days."
04-29-81F	"Segregated C.W. from 22-F is still diverted to 281-8F." Readings inlet: 209 d/m/ml; outlet: 227 d/m/ml.
05-13-81F	Accidental fire in a "waste box stored in the windbreak." Box radiated 5 mrads/hr and ashes smeared 10,000 beta-gamma."

DATE AND AREA	DESCRIPTION AND COMMENTS
06- -81F	Release of Sr-90 and Ru-106 "exceeded the prorated monthly guide" in April 200-F. Release of other beta-gamma also exceeded monthly release guide in April. Several causes.
06-08-81F	"Pumping from F-area retention basin to seepage basin was discontinued due to high seepage basin level. Acid has been added to seepage basin to aid in seepage process.
06-09-81F	High activity in circulated cooling water at 281-4F (561 d/m/ml beta-gamma). Evaporator 1 shut down.
06-22-81F	1.3 million gallons cooling water collected in 8F basin. Samples "analyzed less than 50 d/m/ml. Pumping from 8F to seepage basins in progress. Seepage basins are ninety-two percent filled."
06-23-81F	Segregated cooling water with up to 700 d/m/ml diverted to 281-8F from canyon.
06-23-81F	"DOP Test results - Tanks 18 exhaust greater than 99.97% efficient. Tanks 17 and 19 exhaust 99.90% efficient." Cause of low efficiency at 17 and 19: inleakage of air at blower (06-25-81 entry). Increased efficiency to 99.60% by 06-29-81. Increased to 99.8% by 07-07-81.
07-19-81F	"Building 221-F circulating cooling water was diverted once and the segregated cooling water diverted four times to the 281-8F retention basin due to contamination from conyon equipment during July." Levels of radioactivity in samples from 30 d/m/ml to 150 d/m/ml.
08-03-81F	"281-6F was diverted to 281-8F. ..281-6F samples 182 to 362 d/m/ml."
08-10-81F	"Segregated cooling water was again diverted to 281-F on August 7, 12, 17, 19, 21, and 27. [Contamination to 104 d/m/ml.]"
08-11-81F	Canyon diverted water to 281-8F. Sample reading 2150 d/m/ beta-gamma.
09-01-81F	"241-F-T&T completed removal of contaminated asphalt in front of Tank No. 26 and by west side of Tank No. 27."
10- -81F	Release of several beta-gamma emitters including Sr-90 and Cs-137 and alpha emitters exceeded monthly guide. "Source of release was 211-F building segregated cooling water contaminated by leaks."
10-16-81F	Low level waste trailer leaked liquid "probing 8000 c/m to 10,000 c/m beta-gamma. 30 gallons of low level waste backed...out the roadway and into an adjacent drainage ditch."
11- -81F	"Releases of Ru-103 and Ru-106 to F area seepage during July exceeded monthly guide." Cause: tube leak in building 221-F evaporator re boiler. Releases for other beta-gamma and alpha emitters also exceeded guide. Same cause.
11- -81F	"The combined 200-F and H releases to Four Mile Creek of Sr-89, Sr-90, Cs-134 Cs-137 and other beta-gamma emitters exceeded the monthly and annual guides in September."

DATE AND AREA	DESCRIPTION AND COMMENTS
11-21-81F	Radioactivity release to air saturated HEPA filters. Air filter counter 20,000 c/m.
12- -81F	Monthly release guides again exceeded for several beta-gamma emitters in October. Annual guides again exceeded for several beta-gamma emitters in October. Annual guides for several radionuclides "had already been exceeded."
12-04-81F	"5000 gals chromated water was lost from system and diverted to the retention basin."
12-23-81F	"Cesium removal column hopper overflowed. "Less than 500 d/m alpha smearable and less than 1000 c/m beta-gamma smearable."
12-26-81F	Radiation from riser opening 100 mr/hr. Rainwater leaking into annulus.
01- -82F	"Four transfers totalling 36,000 gallons from catch tank to Tank 7" in January 82. Contamination levels from $6.05 \times 10^{+4}$ d/m/ml (last transfer) $2.48 \times 10^{+8}$ d/m/ml (first transfer). Heavy rain caused water leakage into transfer line encasement.
01- -82F	Monthly release guide for several radionuclides exceeded in November 1981.
02- -82F	"7500 gallons of water contaminated to $1.5 \times 10^{+5}$ d/m/ml beta-gamma was transferred from F-area catch tank to Tank 7." Cause: "unusually heavy rains."
02- -82F	Monthly releases for a number of beta-gamma emitters exceeded release guides to seepage basins and to Four-Mile Creek in December 81. They "had already exceeded the annual guide."
02-01-82F	"Leak in No. 3 valve house. Smears showed 3500 c/m beta-gamma in drain."
02-21-82F	Radioactive liquid "came out of gang valve" accidentally while flushing. "Radiation 5 mrad/5 mr and floor under gang valve where it leaked was 15,000 beta-gamma."
02-24-82F	87,000 gallons of segregated cooling water diverted in February. [Radioactivity levels not cited.]
03-01-82F	Tank #7 HEPA filter tested 99.5% efficient.
03-25-82F	Failure of cooling coil on neutralization tank 12.1. Tank vessel replaced. 1.63 million gallons diverted. ".08 total beta-gamma Ci."
03-26-82F	"Canyon is draining 281-5F basin to 281-8F basin. Total gallons to be drained - 380,000. Contamination was 164 d/m/ml."
04-15-82F	281-8F retention basin, 530 gallons of slightly contaminated water. 5 d/m/ml beta-gamma, was pumped to Four Mile Creek."
04-22-82F	"Canyon diverted segregated cooling water to 281-8F...2,000 d/m/ml alpha."

DATE AND AREA	DESCRIPTION AND COMMENTS
04-28-82F	Tank #17 HEPA filter tested only 99.6% efficient.
05-17-82F	Changed hose from interarea pump pit leaked water radiating 1000 mr/hr. on top of cell cover.
05-17-82F	Regulated tools taken to truck. 9 square feet of truck bed contaminated to "15,000 c/m...beta-gamma fixed and 125 c/m beta-gamma transferable."
06- -82F	Zr-95 and Ru-103 releases to seepage basin exceeded monthly guide in April "due to decreased recycle of acid recovery unit." Zr-95 also exceeded in May for the same reason [entry date 07- -82F].
06- -82F	1.36 million gallons of cooling water containing about 24 millicuries transferred from the retention basins to seepage basin "677,000 gallons of slightly contaminated water transferred to creek releasing approximately 9 millicuries."
07- -82F	720,000 gallons rainwater transferred from retention basin to Four Mile Creek on July 13 and 15. Estimated activity released. 4.21 millicuries beta-gamma and 0.82 millicuries alpha.
07- -82F	Sr-89, 90 and other beta-gamma releases in May exceeded monthly guide to the Creek. May release of Sr-89,90 was 35 curies compared to monthly guide of 2.916 curies.
07-26-82F	HEPA filter test results: Tank No. 1 - 99.92%; #2 - 99.35%; #3 - 99.80%; #4 greater than 99.97%; #8 - 99.93%.
08- -82F	June Sr-89.90 release to creek 3.12 mCi [Monthly guide stated as 2.916 curies in previous (July) entry and 2.916 millicuries in this entry.]
09- -82F	241-F, Tank #33. "Breakthrough of the tank purge exhaust system HEPA filter caused an atmospheric release of an estimated 325 microcuries of Cs-137." Filters replaced.
11- -82F	P-30 A manhole plugged and overflowed while pumping salt and sand from 281-8F retention basin. 2000 sq. ft. contaminated from 4,000 c/m to 15,000 c/m. "Contaminated soil was removed and the area returned to normal on 11/4/82."
11- -82F	200 sq. ft. asphalt and soil to a depth of 4 to 6 inches removed - contaminated by leak. "Radiation level reduced ferom 1.5 R/hr to 200 mr/hr at 5 cm." Body exposure dose rates to 1 R/hr. Total worker exposure to 27 workers estimated at 940 mr.
11-03-82F	2000 sq. ft. ground area contaminated from 4,000 c/m to 5,000 c/m. Process sewer plugged from silt and mud being removed from 281-8F retention basin. "The potential existed for a larger quantity of radioisotopes to be released to area if the overflow had not been detected."

F AREA LISTING COMPLETE

DATE AND AREA	DESCRIPTION AND COMMENTS
	H AREA LISTING BEGINS
04-00-58H	"241-H, Tank 9. Concern for several airborne contamination if dehumidification system is not equipped with filtering device and a more annulus flushing.
01-00-59H	"Ground water leak contaminates diversion box. Groundwater leak into catch tank at 300 gallons a day since 11/57."
05- -60H	"H-canyon jumpers shipped to burial ground. 5 R/hr at 1 ft. from box. Maximum contamination 60,000 c/m beta-gamma."
10-00-60H	"High activity waste was detected in water discharged from a well around Tank 16."
03-00-66H	"About 4 curies of Cs-137 was released to segregated water while unplugging waste evaporator bottoms discharge line." "Sent flow to 281-3 retention basin for 7 hours. There was no release to 4 Mile Creek."
12-00-66H	"Leak - environmental contamination. Liquid backed up the water flush line and leaked out ground and pavement near the backflush riser at Tank 24."
02-01-67H	Leak of high level waste due to rupture of flexible pipe. "50 gallons of slurry contaminated approximately 1000 square feet of the ground surface and equipment." Ground contaminated to 200 mrad/hr. at 6 inches was temporarily covered with earth and sprayed with asphalt to immobolize the activity. 2 workers had "slight nasal contamination" but bioassay was "negative."
04-00-67H	"Released waste. During repairs to an evaporator gang valve a leak caused extensive contamination." No further information.
04-10-67H	"Contamination of ground area" during resin removal from cesium removal column. 1 gallon contaminated water fell on ground.
05-01-67H	"An estimated 100-200 gallons of highly radioactive liquid waste containing 1500-2000 Ci (90% Cs-137), overflowed from riser 6 of waste tank 9 in 241-H. Crystalized salts plugged the 2 foot diameter riser causing waste to overflow the riser. The waste flowed across the ground following the grade to the lip of an open storm sewer." 1200 sq. ft. of earth and asphalt had "radiation intensities to 100 R/hr at 1 ft. The storm sewer effluent was impounded within a few hours by constructing a dam near the sewer outfall. The impounded water was pumped to 281-3H retention basin (3 ci) and the seepage basin (4 Ci). The storm sewer was subsequently flushed with clean water. Flow of water was discontinued through the most highly contaminated portion of natural stream bed at the sewer outfall and downstream of the temporary impoundment dam. Some of the waste escaped into Four Mile Creek and as of May 29, 16.62, 9.32 and 0.47 curies had passed sample points at Road 4, C and A respectively." No release detected in Savannah River. Ground covered with earth to "immobolize radiation." About 150 cubic yards containing an estimated 1200 curies taken and buried in burial ground. "Rainwater caused overflow of small dam at sewer." NOTE: Uncertainty about quantity of leakage and escaped activity.
07-00-67H	"Cs releases from the 5/67 tank 9 incident in the Four Mile Creek are tabulated as of 7/24/67 - see DPSP 67-1-7, on page 405."

DATE AND AREA	DESCRIPTION AND COMMENTS
07-24-67H	"Cesium released to Four Mile Creek as of July 24 was measured as follows. 26.7, 16.1 and 0.9 total curies passing sample point at Roads 4, C and A respectively."
02-05-69H	"About 1 Ci" Cs-137 released to ground near tank 9. Estimated 0.5 Ci flowed into Four Mile Creek. 6 cu. yds. of earth and asphalt containing 0.5 Ci removed to burial ground. Total worker exposure was 5.8 R.
12-22-69H	"Poor performance" of zeolite column is causing Cs-137 to be released to seepage basin. [Quantity and period not cited.]
01-00-71H	Radiation from tank 32 vent continues to increase. Magnitude not cited.
12- -71H	0.2 m Ci to storm sewer. 200 sq. ft. asphalt "contaminated 1000 c/m beta-gamma at 1 inch. 100 gallons process liquid overflowed from E.P. 4 and 5 overheads." Further overflow recorded 12-09-71. Samples from sewer outfall were 20 d/m/ml.
01- -72H	Tank 29 HEPA filter "efficiency less than the required 99.9%.
08-00-73H	"Contaminated water from water addition system under tank 16 pumped to seepage basin."
09-28-73H	"An estimated 2 gallons of contaminated liquid spilled...during attempts to remove salt blockage...between Tank 29 and the CTS system. A 5 foot by 20 foot area was contaminated to 500 mr/hr. at 3 feet above the asphalt." Rain storm fed activity into sewer "which was diverted to the seepage basins." Estimated release to the plant streams of Cs-137 is 20 microcuries and 200 microcuries to the seepage basin. "Personnel received an estimated 1.8 R exposure during cleanup operations."
11-00-73H	Leak and subsequent rain contaminated 600 sq. ft. to 1 rad/hr at 2 inches of ground deposited from the top of Tank 13.
04-00-74H	Evaporator concrete pad "highly contaminated and an additional 300 feet square ground was contaminated with low level radiation."
05-08-74H	"Trebler sample [routine] off at 10 am, counted 38,348 d/m/ml beta-gamma and 96 d/m/ml alpha [119,000 gallons]. Total release calculated 8 curies gross beta-gamma and 0.019 curies gross alpha."
06-11-74H	"Air sample at piping from catch tank...Sample calclulation] 48.5 x 10^{-9} microcuries Pu/cc and 11.044 x 10^{-12} microcuries Pu/cc.
06-24-74H	Tank 29 water valve contaminated - "3000 mrad/hr at 2 inch beta-gamma. Valve connection radiating 40 rads/10R/hr. at 3 inches...Air sample taken downwind at approximately 10 feet; 2^{-6} x 10^{-10} microCi FP/cc and 64 x 10^{-12} microcuries Pu/cc of air..."
08-16-74H	Tank 23 dip tube left in a trailer overnight before shipment to burial ground. Contaminated shoes and trousers of 6 workers and 35 sq. ft. of asphalt.

DATE AND AREA	DESCRIPTION AND COMMENTS
08-28-74H	Liquid spilled on hut floor during reel tape change. Tanks 9 and 12. Radiation to 25 rads/hr at 2 inches.
10- -74H	Monthly release of Cs-134 to streams exceeded guide of 8.33 mci for Sept. due to "runoff water from waste tank farms." [Indicated a high level of contamination of the soil in the waste tank areas.]
11-06-74H	"Transfer between Tank 29 to 21 gassed out today. Steam visible... ground area at filter radiating 120 mrad/hr. C. at 1 inch..."
11- -74H	About 130 gallons of liquid waste "generated in RBOF" containing 1.9 micro curies/gallon Cs-137 sent to seepage basin. Total radioactivity discharged about 0.6 Ci.
11-11-74H	907-4H and Water monitor alarmed. "Water samples indicated up to 99 d/m/ml beta-gamma."
12- -74F	"Sightglass on cesium removal column froze and burst." Four gallons evap[orator] overheads spilled on top of Tank 9. "Less than 2,500 d/m gamma." No further details are given.
07-25-75H 08-06-75H	"Tank 31 and 32 - the following filters were leaking: Tank No. 31 "A" filter on condensate exhaust (99.92%). Tank No. 32 purge filter (inlet) (95.00%)." [95% efficiency have meant large releases of radioactivity into the air. No figures cited.] Efficiency stated at 95% during 08-06-75 report in spite of filter change on 8/1/75. Tank 16 annulus filter efficiency 97.60%.
08-12-75H	"907-3H monitor - water diverted." Calculated 1028 d/m/ml beta-gamma.
08-14-75H	Leaking process line. "Contamination 1000 mrad/600mr hr. 25 R/hr at 2 inches from recycle line jacket." Ground contaminated.
08-19-75H	"904-48G - Sample calculation 1067 d/m/ml beta-gamma F-11 d/m/ml alpha on routine sample...Source of activity appears to be Tank 23 material."
09- -75H	Cs-137 contaminated water 34 gallons to 56 d/m/ml pumped from leak detection sumps of Tanks 21, 22 and 24.
09-11-75H	
09-11-75H	Tank 11. 2 leaking HEPA filters replaced.
09-12-75H	Tank 16 annulus exhaust filters leaking and found installed backwards. Filters changed.
10- -75H	Exhaust filters for Tanks 29 and 31 changed. Old filters radiating 1-5 RH 10R at 3 inches.
10-09-75H	"Tanks 21 and 22 - purge inlet filters...were 98.50% efficient and... for Tanks 23 and 24, 99.80% efficient."
10-27-75H	"CTS - liquid detector alarmed..." samples was "less 1000 c/m beta-gamma and less 500 d/m alpha."

DATE AND AREA	DESCRIPTION AND COMMENTS
11- -75H	Ladder contaminated to 20,000 c/m fixed beta-gamma put in clean scrap and sent to salvage yard. [Apparent safety violation.]
11-14-75H	"Overflow of 242-H concentrate pump tank to sump. 50 gallon of very dilute waste. 13 Ci of 137cs. Failure to follow approved procedures and false liquid level readings."
01- -76H	1975 annual release guide of 4 Ci for Cs-137 exceeded. Total 1975 release 6.22 curies. 2.25 Ci released in December 75. Cause believed to be loosening of sediment in line between H area and seepage basin.
03-03-76H	"907-2H...water diverted." Samples up to 125 d/m/ml.
03-15-76H	907-5H water diverted to retention basin. 666 d/m beta-gamma and 3 d/m/ml alpha in water sample.
05-04-76H 05-06-76H	Low efficiency for HEPA filters on tanks 9, 12 and 16.
06-01-76H 06-16-76H 06-28-76H	Tank 29. Air sample 15 feet downwind 3.05×10^{-9} microCi FP/cc and 75×10^{-12} microCi Pu/cc duirng change of demister. Similar levels (1.6×10^{-9} and $12^{-9} \times 10^{-12}$ respectively) downwind of annulus plug on tank 16. 11×10^{-12} microcuries Pu/cc near Tank 16 on 06-28-76.
07-06-76H	14×10^{-12} microCi Pu/cc in air during work in diversion box 2.
09-29-76H	"19,500 gallons (0.01 Ci) waste tank cooling water leaked under road... Circumferential break [in the pipe] due to heavy loads on road."
12-17-76H 01-04-77H	"Filter tested 90.00%. New construction. Location not specified." 96.00% on 01-04-77H.
01-26-77H	Line or jet pluggage. Ground contaminated up to 1 R/hr. Ten pairs of shoes contaminated 15,000 c/m, 3 vehicles had contamination -- "all decontaminated."
03-16-77H	Liquid spill in diversion box 2. Dose rate increased from 1-5 R/hr. to 30 R/hr. Air sample 3 meters downwind showed 8×10^{-9} microCi FP/cc. Total worker exposure 0.5R.
04-18-77H	Purge filter on Tank 31 tested only 90.00% efficient.
05-01-77H	"The 221-H circulating water has been increasing in alpha activity. If it continues the C.W. will have to be diverted to seepage. The 5:30 sample had 8 c/m alpha."
05-03-77H	Tank 29 filter tested 90.80%. Tank 24: 99.29%.
06-09-77H	Tank 29 filter tested 99.80%. "Replaced because of high radiation."

DATE AND AREA	DESCRIPTION AND COMMENTS
06-15-77H	Similar changes on same day on other Tank 29 and Tank 31 filters. But poor efficiencies seen again on 06-15-77. (99.50 to 99.88%) and 06-20-77.
08-01-77H	"Liquid high level waste leaked from transfer line as waste was pumped from Tank 16 annulus to tank 14. Line thought to be acketed was in fact unjacketed 2-inch carbon steel with no waterproofing. Presence of jacket never confirmed. No prints available. Tech. std. violation. About 400 gallons of salt solution and about 500 Ci Cs-137 leaked into earthen berm over line. Pipe failed from corrosion."
08-01-77H 08-10-77H	Radiation rates to 15 rads/10R/hr. at 5 cm. during start of clean-up and up to 40 rads/30R/hr. after pipe and some dirt removed. [entry of 08-10-77] Pipe and some soil slipped to 643-6. Air samples: 2.5×10^{-9} micro Ci FP/cc and 7.8×10^{-12} microCi Pu/cc.
09-07-77H	221-H cooling water diverted to 281-8H "when alpha contamination was detected (max. of 190 d/m/ml)." After 4 hours alpha was 3 to 11 d/m.
10-04-77H	Tank 35 intake filter 99.60%. Tank 37 intake filter 97.50%.
10-10-77H	Valve stuck open on waste evaporator overheads tank. 0.34 Ci of Cs-137 sent to seepage basin.
11-07-77H	Warners pond area bushes showed contamination to 6000 c/m beta-gamma.
12-02-77H	Water monitor-3H. "Beta-gamma 28 c/m/ml = 235 d/m/ml - 1.0×10^{-4} microCi/ml."
03-08-78H	Water leaking out of seepage basin line. Extent of contamination, if any, not given.
07-19-78H	Tank #13 top contaminated up to 1R/hr during HEPA filter installation. "Soil moved to burial ground."
08-16-78H	"Misvalving released 2-3 Ci of Cs-137 to H seepage basin [about one-third of annual guide] in one week."
09-08-78H	"904-8G...trebler sample calculated 65,000 [d/m/ml. 1.42 curie based on 128,400 gallons released." Composition of release given.
09-21-78H	Pluggage of cooling water line to high level waste neutralization tank and cooling coil leak. "134,000 d/m/ml beta-gamma and 443 d/m/ml alpha measured at 281-4H monitor house." Diverted to 281-8H retension basin: "This incident put 1.7 million gallon of water containing 30 curies in retention basin 281-8H, capacity is 5.2 million gallon. Twice water overflowed a manhole in route to the seepage. The overflow and other water discharged per procedure to Four Mile Creek released 11.5 MCi."
09-25-78H	Diversion box overflowed while diverting water to 281-1. Soil leading to ditch at Warner's pond contaminated to 40,000 c/m beta-gamma. [NOTE: repair work given to contractor (data book entry dated 10-10-78).]
05-23-78H	281-8H: contaminated soil from around this basin being sent to burial ground. 17 truckloads to date.

DATE AND AREA	DESCRIPTION AND COMMENTS
07-29-79H	"Environmental well pump is leaking and flowing between tanks 15 and 16. Analyzed 15 d/m/ml beta-gamma and 0 d/m alpha."
09-07-79H	Waste leaked into pit during repairs. Exposure rate event from 600 mr/hr. to 3 R/hr. Total exposure not given.
09-17-79H	Leak due to corroded pipes - they were improperly fabricated. Earth contaminated to 3000 mrad/hr at 2 inches.
11-05-79H	Cesium removal column. Valve leaked and an "area approx. 10 feet long [contaminated] to 15,000 c/m beta-gamma."
03-07-80H	Spill over top of pan being transported to burial ground contaminated 2 areas, including one near building 643-G receiving area to 2000 c/m.
03-17-80H	Waste truck mishandling resulted in spill on top of tank 21 contaminating ground up to 20,000 c/m beta-gamma.
04-30-80H	Old CTS ventilation system - filter accidentally separated from housing during removal. Plastic under filter contaminated to 400 mr/hr transferable.
09-05-80H	"The new purge ventilation system for tanks 23 and 24 was placed in service without a HEPA filter and operated from September 5 - September 10."
09-10-80H	"Changed air sample for tanker [?] 23 and 24 exhaust. 4.1×10^{-12} microCi Pu/cc air, 10 ft. south of tanks 23 and 24 exhaust filter."
12- -80H	"Exposure rates to 2 R/hr. were encountered during removal of a concrete pill box from Tank 9. The soil underneath the pill box is contaminated and will be removed at a later time." Soil removed in 01-81. 7.5 cubic yards contained 115 curies. Taken to burial ground.
01-06-81H	"Charging hopper of cesium removal column backed up overflowing onto ground and asphalt which were contaminated to 40,000 c/m beta-gamma at 9 inches."
01-14-81H	"Water coming from tank no. 14 and running across road smeared less than 1000 c/m beta gamma and less than 500 d/m alpha."
01-16-81H	Sand and asphalt around riser 4, Tank 15 contaminated to 5 rads/hr at 8 cm. Removed.
02-05-81H	Leak in line during welding work. [Tanke 14.] "Swipe indicated 30 mrads/ hr. Area was covered with plastic."
02-12-81H	Tank 29 drop valve. "100 mrad smearable, 500 mr probe at 3 inches on the ground...600 c/m to 100 mrad. Ground is iced and also the liquid at tank. Employee had 200 c/m on his hand, it cleaned up. He had 1000 c/m on right pants knee...contaminated asphalt removed 2/22."
03-17-81H	Tank 24 HEPA filter 99.92% efficient.
03-30-81H	Segregated cooling water [sample 289 d/m/ml beta-gamma] diverted to 281-8H. [Quantity not stated.]

DATE AND AREA	DESCRIPTION AND COMMENTS
04-20-81H	"Liquid was found coming out of the air vent to the draw-off valve Tank 31, liquid was smearing to 1000 mr.
05-05-81H	Segregated cooling water sent to seepage basin "for 3 days...as a result of high activity." Cause, quantities, sample measurements not given.
06- -81H	0.294 Ci of Ci-144 released to seepage basin during 4/81, compared to "monthly guide" of 0.125 Ci.
06-25-81H	Liquid, up to 400 mrad smearable, found on top of riser 3, tank 13.
08-06-81H	"Tank 13 - HEPA radiation level remains the same the slight [2 R/hr. at 8 cms. and 10 m/hr. at rope.]
09-01-81H	Liquid leak onto riser and tank area, Tank #13. "Maximum smearable 60,000 c/m beta-gamma, less than 500 d/m alpha detected liquid."
09-26-81H	Ground under leaking CRC column filter "radiates to 10,000 c/m."
10-14-81H	"Overflow from cesium removal column due to wear on valve no. 32, teflon seats worn due to zeolite particles. Potential for serious release. 32 sq. ft. of ground and hopper contaminated to 200 mrad/hr...1/2 gallon."
10-28-81H	DB-4 hut area: 1 sq. ft. soil contaminated to 15 mrads/hr.
11- -81H 01- -82H	August releases of Ci-144 and tritium to seepage basin exceeded monthly guide. Tritium exceeded guide in July as well. "The year-to-date release of Ci-144 [1.701 curies] has exceeded the annual guides of 1.5 curies." "Sr-90 release has exceeded...the annual guide of 0.600 curies." Ci-144 increased to 2.005 Ci by November.
12- -81H	15,100 gallons of contaminated water to seepage basin in 3 transfers. "One transfer of 6,500 gallons measured 3,070 d/m/ml, exceeding the limit."
12-01-81H	Fire burned 3000 square feet bank near 241-H.
01- -82H	5700 gallons contaminated water, 3250 d/m/ml beta-gamma and 1 d/m/ml alpha sent to seepage basin in the month. Activity exceeded release limit of 1500 d/m/ml, but was "only 2% of the monthly discharge."
01- -82H	3.5 million gallons of retention basin water released to creek from December 29 to January 5. "A sample measured 100 d/m/ml beta-gamma. 5.6 millicuries is estimated to have been released during the transfer of the last 50,000 gallons."
03-18-82H	Top of tank 13 and 1000 square feet asphalt contaminated to 10,000 c/m beta-gamma smearable. Leak due to possible crack between pill box and encasement.
05- -82H	Spill during removal of mixing jet from tank #16. 2500 square feet contaminated up to 20 mrads/hr. Workers had skin and personal clothing contamination up to 40,000 c/m beta-gamma. 3 workers nasal contamination - max. was 722 d/m beta-gamma. All persons skin decontaminated using soap and water.

DATE AND AREA	DESCRIPTION AND COMMENTS
05-12-84H 06- -82H	"Decontamination of ground area continues around tanks 15 and 16H. Roadway of tanks decontaminated from 30,000 c/m to 2,400 c/m." Work completed in June.
06- -82H	Total of 10.1 million gallons of mud and water transferred from retention basin to seepage basin over 2 months. "No annual release guides were exceeded as a result of the cleaning." One transfer, 662,000 gallons also made to creek. "Activity...was less than minimum sensitivity of the monitors."
06- -82H	Transfer of about 12,000 gallons from catch tank to seepage basin. Activity average about 1100 c/m beta-gamma and less than 1 d/m/ml alpha. Total activity released 0.02 Ci.
06- -82H	March releases to H area seepage: Sr-90: 0.150 Ci. Pu-247: 0.142 Ci.
06-14-82H	600-800 gallons evaporator overheads spilled to ground from seepage basin manhole. "The release to ground was 0.5 percent of the annual guide to plant streams from F and H areas. The contamination was actually carried to the retention basin via the storm sewer system."
08- -82H	11,700 gallons water contaminated to about 450 d/m/ml [0.009 Ci] released to seepage basin.
08-19-82H	50 squre feet ground area contaminated to 20,000 c/m beta-gamma during transfer to seepage basin.
10- -82H	"Beginning in August, radioactivity up to 27,000 c/m has been detected intermittently in air exhausted from the annuli of Tanks 29 and 31." Normal activity is 100-700 c/m.
10- -82H	Release to seepage basin in Agusut exceeded monthly guide: Sr-90: 0.190 Ci released [guide 0.083 Ci].
10- -82H	H area outfall-52 - soil contaminated to 12,000 c/m beta-gamma excavated to improve drainage.

TABLE 3

TANK LEAKS AND OVERFLOWS

DATE AND AREA	DESCRIPTION AND COMMENTS
04-00-61F	Tank 8 overflow. Reel tape error. Contamination of 2-2 R/hr at 2" found in well on 10-9-74 possibly from this spill.
02-00-69F	Tank 1 leak. [No details given.]
08-12-73F	Leakage of groundwater to 241-F catch tank.
03-15-74F	Tank 18 overflow. Increased pressure caused overflow from riser. [Environmental contamination not discussed.]
06-19-74F	Catch tank overfill. Instrument problems.
12- -74F	Miscellaneous serious problems with tanks 4, 8, 15, 29, 31 ranging from build up of salt to reel tape malfunction. "Tank 8 drove uncontrollably on 2 occasions."
04-17-74F	4,000 c/m in Tank 7 dehumidification exhaust dust. Source unknown. Mainly Cs-137.
06-30-75F	Waste solution sprayed as mist onto top pf riser cover of Tank 19.
09-06-75F	Tank 19 - cracks in riser contaminate soil - 500 mrads/hr.
09-06-75F	Rain leaks into annulus of Tanks 1, 4, 5, 33, 34. [Frequent occurrence.]
11- -76F	2230 gallon groundwater in leakage to catch Tank.
12-11-76F	67,000 gallon rain to waste tanks. Operating error during construction. Tank 7 above mx. operating level and 4.2 below max. fill limit.
03-08-77F	Crack in tank sealer. "Steam and condensate seeping out." Tank No. 6. 10,000 c/m beta-gamma; 4,000 d/min. alpha.
05-29-77F	Tank 7 feed pump packing leak. 1,500 mrad/200 mr/hr at 5 cm.
02-09-78F	"Solution backup flush water tank overflow and it reads from 7 to 25 rads/hr."
07-25-79F	Lightning struck surge tank level instrument. Tank overflowed to chromate water tank. Chromate water tank full because the pump is inoperable."
12-24-79F	"Underground water leak between Tank 2 and 4."
01-04-80F	Condensate leaking from bottom hole at Tank 27 filter encasement. Condensate drain valve cracked. Liquid reading 20 mrads/hr at 5 cms.
05-22-80F	5600 lb. of 51% nitric acid overflowed tank 35 and went to seepage basin. Cause: valve leak.

DATE AND AREA	DESCRIPTION AND COMMENTS
01-07-81F	Tank 14: Small crack found. Sealed itself after "a very small leak occurred." "Tank 14 has a history of inactive leak sites, and this additional crack does not significantly change the tank integrity."
06-20-81F	Nozzle 6 leaking. Stopped transfer from Tank 26 to Tank 47. Extent of contamination, if any, not cited.
07-21-82F	241-F - Tank #26. Line leaking - "probed 45 mrad/5 mr/hr. at 5 cms and smeared 30,000 c/m beta-gamma and less than 5oo d/m alpha."
08- -82F	Rainwater in leakage into annulus of tanks 40H and 47F. "The leaking penetration on tank 40 was found when a cooling water line near the penetration ruptured."
08- -82F	"The catch tank collected...6,044 gallons of ground water that leaked into the encasements. 408 gallons were collected in the previous report period.
10-02-82F	High level waste required more sodium hydroxide for neutralization than tank 12.1 could hold. 300 lbs. of solution overflowed onto cell floor.

F AREA LISTING COMPLETE

H AREA LISTING BEGINS

05-27-59H	"Tank 14 leaking." [No further information.]
07-10-59H	"Tank 10 leaking - this is the third apparent leak in H area waste tank farm. Tank 9 and 14 are also leaking."
11-00-59H	"241-H leak. Waste detected in annular space of tank 16." No measurements of activity in or near annulus given.
03-00-60H	"241-H leak. Tank 14."
07-00-60H	"Leaking tank. Tanks 14 and 16."
09-08-60H	"Tank 16. Waste leaking into annulus at rate of 0.2 inch increase/hour."
10-00-60H	"241-H leak. High activity waste was detected in water discharged from a well around Tank 16." No measurements given. Test north of tank also showed activity. Also activity beneath contructions pad. [Entries 11-07-60 and 12-01-60.]
06-17-61H	"Tank 16. Many leaks observed...in annulus space."
06-22-61H	"Tank 9. About 850 gallons waste leaked into annulus in a week. Total about 5000 gallons."
9-19-61H	"Tank 10. Leak into annulus - solids have been visible for 2 years."

DATE AND AREA	DESCRIPTION AND COMMENTS
01-31-67H	Waste tank 10 - high pressure water flange leak. Leak developed "while line was under 2000 lbs. of pressure. Potential danger to personnel."
01- -71H	"Increase of 84 inches noted in tank 21 leak detention sump." Max. activity "200 c/m/ml gross beta-gamma and 29 counts Cs-137. Source of activity unknown."
03-00-71H 04-00-71H	Tank 21 sump leak 36 gallons/day. Cause unknown. Activity about 30 c/m/ml. Pump out continues for months.
04-00-73H	Tank 21 contaminated water accumulates in bottom leak detention sump. Many tanks have this problem in the H-area.
07-00-73H	"Unexplained increase in Tank 10 liquid level." In August same for Tank 9.
09-00-73H	"Evidence of leakage of groundwater in...Tank 24."
04-01-80H	Underground water leak into annulus of Tank 11.
01- -82H	New leak found in Tank 14 - "inactive." "About 40 other leak sites have been previously detected in Tank 14."
06- -82H	Several hundred gallons water in leakage tank 40 annulus. Inadequate sealing. Water carried some clay into annulus.
09-18-82H	4800 gallons rainwater entered tank 11H through inadequate seals to tank risers...A means existed for uncontrolled water addition to tank. Causes: heavy rain plus failure to repair cracks soon enough.
10- -82H	4600 gallons rainwater into Tank 11 through riser #1.

TABLE 4

TANK SYSTEM FAILURES AND PROBLEMS

DATE AND AREA	DESCRIPTION AND COMMENTS
08-00-56F	Cooling water to tank 3 shut off for 2 days due to "operating error."
12-01-64F	Error shut off cooling water for "several hours."
01-28-69F	Cooling water contaminated to 80,000 cts./m/ml due to operating error.
03-21-69F	Tank 7. "Half of cooling coil orifices plugged."
12- -74F	64 leaks total in cooling coils of Tanks 1, 2, 3, 8, 9, 10, 11, and 14 - presumably for 1974.
10- -75F	Waste tank cooling water contaminated due to leaks. 4500 d/m/ml of Cs-137.
09-19-79F	Failure of refractory band on new tank (#26) before radioactive service. Corrosion caused by heating caused high carbon steel to crack.
10-16-79F	"Reheat box on Tank 7 drain line increased in radiation to 25 R/hr at drain line." After flushing radiation reading down to 1 R/hr.
01-10-80F 01-11-80F	Several unexplained entries called "non-routine maintenance" on various tanks. [Many similar entries thereafter also.]
01-21-80F	Sample taken six months prior to entry date "was outside technical standard limits for the prevention of nitrate-induced stress corrosion cracking."
04-06-80F	Vent line on cesium removal column radiated at 2500 mr/hr at 5 cms. "Vamp on Tank 19 alarmed."
05-17-80F	"Flush tank L.L. [low level] is acting crazy, it has filled to overflow at anything from 20 to 60%."
08- -80F	"Alpha activity in process vessel vent discharge to sand filters increased sporadically up to 20 times normal. Air sparge on Tank 16.1-2 prior to sampling of frame waste recovery product resulted in high alpha activity."
10-14-80F	Radiation filed at monitor on tank 26 was 4 R/hr. Cause: "probably leaking automatic valve."
05-26-81F	Tank 2. Two shaft sections of a probe disengaged. One 10 ft. section left in tank.
05-27-81F	14' long 160 lb. probe and shaft "uncoupled and fell into waste Safety champ failed.
07-01-81F	43' long dip tube (600 lbs.) fell 6 feet to bottom of tank 19.

DATE AND AREA	DESCRIPTION AND COMMENTS
02- -82F	Fission product decay heat in Tank 32 increased to 20% limit due to receipt of fresh waste - i.e. to 37 x 10^{-6} Btn/hr.
05-13-82F	Tank 38 containing 19,000 gallons of waste "was outside technical standards for inhibitors." ["Inhibitors" inhibit tank corrosion from unneutralized high level waste.]
08- -82F	Tank #27 cesium removal column (CRC) pluggage. Dead algae apparently present at inlet seem to be the cause. [CRC pluggage fairly frequent.]
09-15-82F	"Unplanned transfer of Pu solution to canyon tank 9.7, due to defective valve handle installation. 46 grams of Pu accidentally transferred. Tank 9.7 contents recycled through canyon second Pu cycle."
09-24-82F	100 grams Pu again accidnetally transferred to canyon tank 9.7 due to improper valving. Tank contents again recycled through second Pu cycle.

F AREA LISTING COMPLETE

H AREA LISTING BEGINS

DATE AND AREA	DESCRIPTION AND COMMENTS
02-00-58H	"Outside air purged hot jet line and got 200 mpc. Tank 9 annulus flushed and transfer line was 4.5 R/hr with 1/4 inch lead shield. Concluded they should have flushed with water somehow."
05-00-58H	Tanks 10,11, 12 gamma radiation: max. measurements 306 R/hr at 1 foot, 1.5 R/hr at 2 feet and 1240 l/hr at 1 foot respectively.
05-01-61H	"Corrosion pitting to 5 mils observed" on tanks 21 and 22.
12-22-66H	"Radiation. 5 R/hr. From unshielded feed line from tank 23."
01-22-69H	Tank 10 cooling coil leaking.
01-23-69H	Tank 14 cooling coil leaking.
06-00-69H	3 cooling coil leaks in one month. Tank 10 on 5-30-69; Tank 14 coil #10 on 6-1-69 and Tank 14, coil #4 on 6-15-69. Coils blanked off. [Cooling coil leaks frequent.]
07-00-69H	"241-H, Tank 9. Exterior wall of the tank 9 reel jet riser was contaminated to 30 rads/hr. at 3 inches. Jet discharge line inside riser had failed.
09-25-69H	"Cracked refractory line of new tank. Affected tanks 29 through 32."
11-00-69H	16 coil leaks in Tank 11 coils between 10-28-69 and 11-23-69 following sludge removal. "No coil leaks had previously been observed in this tank."
02-00-70H	11th leak in Tank 10 cooling coils. [Total no. of coils = 35.] Two more failed by 04-00-70. Two more failed during 06-00-70. Total number of failures by 05-00-72 was 19.

DATE AND AREA	DESCRIPTION AND COMMENTS
10- -72H	Tank 32 temperature rise. Unexplained. Increased cooling reduced temperature but "sludge temperature remained at approximately 99° C."
12-27-72H 12-27-73H	Almost same entry as for 12-27-73 of 14,000 gallons waste siphoning into annulus of Tank 14. Siphon broke. [Could be a coincidence or duplicate entry with wrong date. Annulus alarm was ignored for several hours.]
07-26-74H	5000 gallons of high level waste supernate containing up to 5000 Ci, Cs-137 inadvertently transferred to low level waste receiving tank.
04- -75H	"Tank 15 smear samples taken with wet cotton swipes on the pan floor disclosed contaminated much higher than found...in 1973." Actual values not given.
10-12-79H	Tanke 36 annulus: Air sample showed 746 c/m beta-gamma and 1202 c/m alpha. Alarm did not indicate high activity.
04- -80H	Tank 16. 100 gallons of sludge at the bottom of tank.
11- -80H 12- -80H	Temperature of cooling water for Tank 16 found higher than standard due to faulty air lock and heat exchanger.
01-31-81H	Valving error. High heat waste sent to wrong tank.
02-04-81H	"Construction has completed over eighty percent of measuring and mapping of pits in Tank 38. To date the deepest pit is 0.061. Inspection of the clearing floor is revealing hundreds of shallow pits between 30 to 60 mills deep."
09-10-81H	Unsealed cooling coil penetration, Tank 38. This "allowed contaminated air to be drawn from the primary tank vapor space into the annulus."
12-02-81H	Tank 32 annulus fan shut down during core drilling. "The WMO self imposed limit of 115 C on bottom temperature was exceeded due to loss of cooling air flow."
02-05-82H	"A back-up system has been provided for annulus air exhaust from Tank 32H ...to prevent possible hardening of sludge onto the tank bottom upon interruption of cooling effect of airflow through the air slots under the primary tank."
02-11-82H	Erroneous transfer of 18,000 gallons of concentrate supernate between tanks.
04-21-82H	Radioactive waste accidentally sucked back into unshielded above ground piping. Radiation rates were 4 R/hr at 5 cm. between tank top and manual sparger valves...
07- -82H	$7\frac{1}{2}$ inch crack observed in Tank 16 primary wall. Longest previous observed crack was 6 inches.
07-20-81	"Uninhibited seal water" supplied to Tank 41 for 1 month in place of standard due to failure of automatic chemical addition system.

TABLE 5

EXPLOSIONS: POTENTIAL AND ACTUAL
(due to build up of hydrogen, ammonia, organic compounds)

DATE AND AREA	DESCRIPTION AND COMMENTS
06-00-60F	Hydrogen in Tank #8
04-00-61F	Hydrogen build-up to 95% of lower explosive limit - fan failure on tank 5 and 8. [NOTE: All percentages below refer to lower explosive limit.]
05-07-62F	Hydrogen to 20%. Fan not started.
07-31-62F	Hydrogen to 30%.
08-29-62F	Hydrogen to 80% in Tank 4; 45% in Tank 8; and 20% in Tank 3. To 100% in Tank 2 during scheduled power outage. Operating error.
05-08-64F	Tank #1 H2 would read "100% in 2-4 day" without ventilation. [Comment only.]
12-12-65F	Organic solvent "degration" - fumes and smoke.
10-03-66F	"Hydrogen explosion." H2 to 15% in 11½ hours. Vent blower off for 19 hrs. [Possibly an erroneous entry. Intent might have been to write possible explosion. Hydrogen explosions not mentioned in any other report.]
08-30-68F	H2 to 5-15%. "Temporary blowers being used."
06-26-70F	H2 to 12%. Failure to turn on hydrogen purge blower.
01-16-76F	H2 to 10% in riser #7 of Tank 8.
01-18-76F	H2 to 10% in Tank 18 vapor space.
08-05-76F	Ammonia from added ammonia nitrate evolves in Tanks 4 and 17.
08-07-76F	NH3 to 8%.
06- -77F	140 ppm ammonia in Tank 7 air exhaust.
12-11-77F	Tank 8 explosimeter readings, presumably hydrogen: "4 pm = 7%; 6 pm = 6%; 8 pm = 4%; 10 pm = 3%. No smoke. Still smells same."
02- -78F	Ammonia at Tank 4 purge exhaust 1000 ppm during transfer of flush solution from 221-F.
12-05-78F	Tank 8 purge had 2000 ppm ammonia 12-8 shift.
12-05-78F	Tank 8 purge exhaust had 1000 ppm ammonia 8-4 shift.
12-06-78F	Tank 8 purge exhaust had 3000 ppm ammonia 12-8 shift.
07-06-82F	"241-F PP No. 2 and 3 purge exhaust" ...ammonia 1500 ppm.

DATE AND AREA	DESCRIPTION AND COMMENTS
	F AREA LISTING COMPLETE
	H AREA LISTING BEGINS
06-00-56H	Hydrogen in vapor space of Tank 9 to 150%. (No forced ventilation.)
07-00-60H	H2 build-up to 40% in the air space above Tanks 14 and 16."
08-00-60H	Tank 14 H2 to 30%. Blower found off.
12-26-61H	Tank 15. H2 to 10%.
02-07-62H	"Tank 14. Leak of 25 gallon per day essentially self sealed."
02-21-62H	"Tank 16. 26 previously undetected leaks seen through hole 42."
08-25-64H	Tank 21, Hydrogen to 5%
06-18-70H	"On 3-26-70 firecracker-like detonations occured during the removal, regasketing and reinstallation of the 242H evaporator...The potential problem from explosive compounds was emphasized when Tank 21 jet pill box was entered ...several cap-pistol pops with puffs of smoke occured on the skinless steel floor under the operators rubber overshoes." Further information in DPSP 70-1-6, pages 68-69.
08-00-70H 09-00-70H	Silver compounds may be responsible for detonations.
07-00-71H	H2 to 5% in Tank 11.
01-00-71H	"Tank 32 hydrogen build-up." In leakage of air also indicated.
07-16-77H	H2 to 37%. Tank 11.
07-28-77H	"Tank 15 - 4% hydrogen detected today on weekly routine."
08-09-77H	Tank 8 - 8% H2.
12-15-77H	"Tank 35 - 350 ppm ammonia."
12-31-77H 01-02-78H 01-04-78H	"First transfer from canyon to Tank 22 containing ammonia was started at 6:15 a.m." NH3 rose from 25 ppm to 450 ppm. "Next check due at 11 a.m." 650 ppm at 10:30 p.m. On January 2, 1978, HN3 reached more than 1000 ppm. Not this is an intentional transfer. Purpose not stated. 1000 ppm on 01-04-78.
02-14-82H	"...hydrogen was coming out of tank [32] at 10% on explosimeter scale."

TABLE 6

EQUIPMENT PLUGGING

DATE AND AREA	DESCRIPTION AND COMMENTS
04-00-61F	Evaporator line plugged: contamination
04-11-61F	Evaporator line plugged - waste accumulated in cell. "Radiation was 5R outside cell wall."
07-06-64F	Leak due to jet pluggage. Beta-gamma contamination to 80,000 C/M
02-16-67F	Evaporator bottoms line plugged. [Frequent occurrence.]
04-25-67F	Concentrate transfer system (CTS) loop pump plugged. [Plugging equipment such as pumps and pipes common in this system.]
10-14-68F	Steam vent lift line plugged. [Frequent problem.]
11-00-69F	"4 major line plugs" in one month.
07-20-78F	Lift dropvalve plugged. Evaporator down 12 hours. [Life line problems particualrly plugging common.]
08-17-78F	Extensive pluggage in recirculation pump, 301 line to Tank 34 D/O valve and instruments.
03-16-79F	"some" pluggage in high level waste header #1. Removed with heated water.
02-04-80F	Vent line plugged. [Frequent problem.] Evaporator down due to this and other problems.
03-04-80F	Both F-area evaporators down due to line pluggage and valve problems.
08-05-81F	"Evaporator down 299.5 hours. Primarily caused by plugging of both loop and vent lines..." and some other factors.
11-12-81F	"CRC is plugged." Even extensive efforts to unplug it were not successful as per entry of 11-14-81.
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
03-15-68H	"242-H evaporator. Persistent plugging."
05-23-68H	"Cs column. Plugging problems."
06-10-68H	"242-H evaporator. Bottoms line plugged due to electrical power failure."

DATE AND AREA	DESCRIPTION AND COMMENTS
09- -73H	"242-H Evaporator. 67.5 hours downtime due to pluggage of Tank 29 draw-off valve and tank loop line."
01-07-74H	During unplugging of CTS tank level instrument, the tank overflowered 2000 gallons to the sump. "Sump contents returned to the system and the cell floor flushed."
08-00-74H	Unsuccessful attempt to unplug high level waste header by jetting hot 25% sodium hydroxide.
08-23-77H	Transfer jet to Tank 31 plugged. "Could not be removed, stuck in salt. Mining tool made of Al dissolved when lowered into tank, liquid backed up contaminated Al tubing and contaminated hut"...Worker exposure not given.
10-17-80H	"Pluggage of lift line of evaporator. Attempts to catheter were unsuccessful because the lift pumper connector block was not properly designed. Pluggage was removed using caustic and acid."

TABLE 7

POWER SUPPLY FAILURES

DATE AND AREA	DESCRIPTION AND COMMENTS
12-20-53F, 04-04-54F 07-10-56F, 07-13-56F 07-07-57F, 07-27-57F 07-31-59F, 07-25-60F 08-08-60F, 08-14-60F 08-06-62F, 08-07-62F 06-11-63F, 07-29-64F 05-28-65F, 07-08-65F 07-17-68F, 08-18-68F 05-25-69F, 04-05-71F 07-02-71F, 07-27-71F 08-04-71F, 08-31-81F 02-20-73F, 06- -73F 06-18-73F, 08- -73F 11- -73F, 06-17-75F 07-18-75F, 01-29-77F 09-16-77F, 07-09-78F 06-30-79F, 08-11-79F 08-12-79F, 08-27-79F	Both complete and partial failures noted. Data on standby power not given as a rule. Most power failures occur during summer storms. Durations vary froma few minutes to several hours. Lightning is the most common problem. Some examples include:
02-20-73F	Outage due to operator error.
06-17-75F	Emergency generator did not start; then started and then failed after "several hours."
02-29-77F	Emergency generator failed during routine 30 minute weekly test.
09-16-77F	Diesel generator failed to start during test.
06-30-79F	Electrical power from substation during storm. Emergency power [apparently] shorted out. No power for 10 hours in portions of area.
08-11-79F	Power completely out, including emergency power (briefly). Emergency supply stuck on. "Emergency feed breaker was smoking again."
09-08-81F	Emergency generator failed to start due to failure of breaker and compressor motor. Normal power failed due to electrical storm. Emergency power failed. Two apparently independent reasons. Evaporator instrumentation also lost. [Total down time or consequences not cited.]
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
07-31-72H	Total loss of power to wells 44, 45 and 48 and waste management substation 254-14: Loss of process cooling water make up to 241, 242, and 285-H "for a short period of time."

DATE AND AREA	DESCRIPTION AND COMMENTS
06-15-75H	Lightning. Main power down. Emergency on. Some emergency switch gear instruments and controls damaged by lightning.
09-03-78H	Main power down due to lightning. One emergency generator failed to start. 3 segregation valves failed to close. Also much equipment, including emergency power related equipment, damaged.

TABLE 8

PUMP FAILURES

DATE AND AREA	DESCRIPTION AND COMMENTS
03-02-64F	Feed pump motor burn out [fairly common].
02-27-67F	Evaporator feed pump failure. [Frequent pump failures.]
01- -68F	Concentrate transfer system pump failure - 4th time in 9 months.
02-00-68F	Flash tank pump "inadvertently left off." 8 to 12 feet water accumulated in evaporator cell.
07-00-68F	Tank loop pump bearing failure - 5th in 4 months. No definite solution to problem.
10-00-68F	13 day evaporator outage due to repeated pump failures.
01- -71F	Jacuzzi: feed pump failed, [frequent occurence], motor bad leaking packing.
04- -72F	Evaporator down 39 hours due for replacement of feed pump control valve. Extensive valve problems in evaporator pumping area.
05-10-79F	Concentrate Transfer System pump failed. Evaporator shut down.
07-17-79F	Lightning struck near west pump house "knocking out power to all c.w. pumps" 2 blown fuses. Emergency power circuit was open [apparently due to ligntning]. Possible common made failure.
01-25-80F	"Evaporator feed pump failed."
07-06-80F	Tank 26 feed pump failed, 242-16F. Evaporator down 334 hours, caused by motor winding short circuit.
03-05-82F	Tank #26 feed pump failed March 5 after 1 year of operation. New pump failed in 6 days. Both due to short circuits in motor. "4r/hr at 0.5 meter above open riser hole."
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
10-00-68H	Failed transfer pump being reconditioned for use. [These pumps are radioactive.]
01-26-81H	"Evaporator-replaced chems pump — 40 mrad/40/hr general area." Nature of problem and total exposure not given.
08-05-81H	Evaporator 1-H: down 357.5 hours "primarily due to a failed CTS recirculating pump." Down again for 1 month (09-20-81 entry) due to pump failure.

TABLE 9

INSTRUMENT PROBLEMS

DATE AND AREA	DESCRIPTION AND COMMENTS
01-17-63F	"Extensive troubles: due to water and oil in instrument airlines.
03-25-65F	Tank 7. "Necklace Alarm from heavy rains. Alarm disconnected."
07-16-65F	Instrument air lost [Frequent air compressor problems.]
08-10-65F	Entire alarm system inoperative.
09-03-68F	"Mass spec. and explosimeter readings on H2 in tanks differ up to one decade."
01- -71F	Tank 3 reel tape assembly failed. [Very frequent problems with reel tapes.]
11-00-72F	"Reel tape reads erroneously when it comes into contact with salt."
05-01-74F	"Serious problems" on new reel tapes for several tanks - "May hinder reliability in the future."
06- -74F	Erroneous annulus alarm during heavy rain occur "very frequently."
10-07-75F	High Activity alarm goes off. Apparently a false alarm. [Frequent occurence.]
10-30-75F	"241-F South vamp is out of order." [Frequent problems with Vamp.]
11-06-75F	On Tank 5, Vamp gave false alarm. Unplugged.
07-06-76F	New solid state temperature recorders' performance "very poor."
07-03-76F	Storm sewer radiation alarm. Activity less than "MS." Frequent.
08-26-76F	South vamp monitor out. Fail safe light is out 5 days.
05-05-77F	F area evaporator start-up. Several instrument failures due to freezing.
07- -77F	Lightning damaged circuits in evaporator alarm system. Repan - 48 hours.
08-02-77F	"Left palm on hand and shoe monitor will not respond to source." [Very frequent problem with these gauges.]
10-26-78F	"Victoreen defective on 907-3F water monitor." [Frequent problems with victoreen.]
11-09-78F	Reel for Tank 7 dropped. 4 shifts to replace tape and problem. No exposures given.
01-18-79F	"Hand and foot counter in 242-F control room repaired."

DATE AND AREA	DESCRIPTION AND COMMENTS
05-17-79F	"Storm water monitor not operating."
05-31-79F	"Amplifers for radiation monitor...was returned to normal service."
06-20-79F	"Tank 37 annulus alarm. No apparent cause, probably instruments."
06-25-79F	A number of switches on a monitor shorted to ground. Probably lightning.
11-21-79F	"Tank 28 hydrogen analyzes is out of service."
05-29-80F	"Hydrogen analyser for Tanks 44-47 need more work [repairing]." [Frequent problems with and repairs needed for hydrogen analysers. Many entries beginning 1978, 1979.
08-08-80F	"Instrument power is off at 641-F [lightning]."
10- -80F	Faulty measurement causes high level waste emitting 14R/hr to be put in high level waste dumpster.
12-27-80F	Water in instrument airline freezing and stopping air flow. Annulus fans 1 to 3 and 33 and 34 went off 3 times during the day as a result.
06-07-81F	"Vamp alarmed at Tank 18 at 10:30 a.m. No unusual radiation.
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
09-00-59H	Accidental transfer of acidic waste to Tank 16 because Tank 12.1 (acid waste tank) sampler was out of order.
08-04-62H	"Rain caused tank 15 annulus alarm. Cause not determined before alarm ceased."
06-27-69H	Faulty reel tape. [Frequent problems with reel tapes in H area as well.]
05-25-74H	Alarms inoperable during power outage. "600 gallons of desalt-descale flush water overflowed the CTS pump tank...."
01-13-77H	"907-4H and 907-3H monitors giving much trouble. Getting hi-activity alarms due to spiking victoreen."
07-14-77H	Tank 35 and DB6. Air monitors did not respond to beta-gamma source during test.
08-10-78H	Vamp at Tank 37 would not alarm at 100 mr/hr. [This instrument needs frequent attention.]

TABLE 10

MISCELLANEOUS LEAKS

DATE AND AREA	DESCRIPTION AND COMMENTS
06-26-64F	Tank 7-18 transfer line leak: 40 R/hr. on unshielded portion.
07-14-64F	"Contamination line leak during test...spread contamination."
01- -68F	Valve leak. 60 R/hr at 1 inch on top of riser. Tank #19.
01-24-69F	"Heat exchanger. Leaking badly."
09-00-70F	"Custom designed valves at end of the jumpers leaking profusely."
09- -72F	Leak at valve "due to severely corroded valve plugs."
09-00-73F	Contaminated water in leak detection sump. [Fairly frequent.]
07- -75F	Chloride causes chipping of concrete of 2 waste liners. [Chloride cracking caused such severe problems that pipes with such coatings had to be taken out of service.]
10-10-77F	Steam line leak. "Very badly" corroded. [Steam line leaks frequently.]
08-03-79F	Leaking relief valve on Tank 34 Chromate cooling water piping.
09- -79F	Leak in piping occured in July between diversion boxes 5 and 6 and pump pits 2 and 3.
11-01-79F	Evaporator 242-F down 129 hr. due to leaking gaskets and replacement of pump motor starter.
02-28-79F	"Catch tank collected 4800 gallons of groundwater that leaked into the concrete encasement." A jumper leak was found though it tested leak-free on 1/24/80.
03-13-80F	Heavy rainfall flooded excavated trenches and cracked stainless steel liner of concentrate transfer system pump pit. This "constituted a loss of secondary containment for the CTS pump pit."
01-26-81F	"Water dripping from steam line to evaporator in cell sump." Water reading 43,000 c/m.
09-25-81F	"Waste line carbon steel jackets have suffered corrosion and one had $\frac{1}{2}$ inch diameter hole in it. This is a breach of secondary containment protection required for SRP operations. The defective lines were replaced. Radiation was reduced from 1 R/hr at 5 cm to 100 mr/hr at 5 cm."
08- -82F	20,000 gallons of chromate cooling water leaked from pipe serving tanks 9-16. Leak apparently began July 9 and continued at 30-40 gallons per hour until repaired on July 29. [Chromate water losses are frequent.] 12,000 gallons lost again on 08-09-82 due to 360 break in pipe serving tanks 29-32.

DATE AND AREA	DESCRIPTION AND COMMENTS
	F AREA LISTING ENDS
	H AREA LISTING BEGINS
05-00-70H	"Substantial leakage...in the 241-H heat exchanger...The five leaking tubes were plugged."
02-25-76H	Leaking valve inside pill box. Radiation levels up to 20 R/hr. at 2 inches of water flush line.
01-21-78H	"Repaired many leaks in 3H water monitor. The cabinet handle broke off."
02-08-78H	40 yard section of process sewer line to seepage basin caved in, caustic soda passed through pipe. "No release of radioactive material."
10-17-79H	Leak in or near preheater. Concrete pad under preheater radiated to 50 R/hr.

TABLE 11

MISCELLANEOUS

TYPE OF OCCURRENCE	DATE AND AREA	DESCRIPTION AND COMMENTS
GRASS FIRE	06-29-59F	"Welding sparks caused dry grass to burn. Bucket brigade."
GRASS FIRE	09-08-60F	Fire due to welding sparks. Dry chemical used to put it out.
VALVE FAILURES	11-03-61F	Solenoid valve failure admitted compressed air into evaporator, emptying it.
VALVE PROBLEM	12-00-64F	Valving error not discovered for 12 hours.
WASTE UNACCOUNTED FOR	08-18-65F	8,000 gallons of waste were unaccounted for in 5 days.
ELECTRICAL SHORT CIRCUIT	11-28-66F	Cell spray of radioactive liquid shorted out electrical equipment.
SALT LOAD	11-00-67F	Concern about salt load on cooling coils. "Thought to be safe."
ZEOLITE LOSS	08-25-69F	Zeolite from Cs removal column lost in "gross" quantity.
PLUGGED SEWER	07-00-71F	Could cause sewer water to flush into some tanks.
SNOW	02-12-73F	"All operations shut down. Snow."
STEAM OUTAGE	01- -74F	Area steam outage - 14.5 hrs. for evaporator.
GENERAL EVAPORATOR	03-01-74F	242-F evaporator down 70% of the month. Pump and instrument failures improper operation during operating period with high activity in the overhead stream.
VACUUM PUMP INLET CONTAMINATED	07-25-75F	Irregular maintenance procedure.
CONCENTRATE TRANSFER SYSTEM VESSEL FAILURE	08-14-75F	"Vessel radiated a maximum of 320 R/hr at side."
TANK ROOF LOADING	02-10-77F	18,000 lb. concrete cask placed on top of tank 3 without checking if loading acceptable. "Inadequate communications." No collapse.
FIRE ON CONSTRUCTION SITE	03-12-77F	Fire near tank construction. Probably cause: cigarette.
WASTE UNACCOUNTED FOR	04-12-77F	900 gallons waste from conyon unaccounted for due to various problems. Transfer of waste from "canyon" to Tank Farm.

TYPE OF OCCURRENCE	DATE AND AREA	DESCRIPTION AND COMMENTS
GANG VALVE PROBLEMS	10-03-77F	[Frequent.]
HIGH WIND	01-25-78F	Earth collapse during excavation exposed 25' section of concentrate transfer pipe. CTS line sagged 6" and broke a 2" domestic water line.
EXCAVATION ACCIDENT	10-17-78F	Breathing air line broken by heavy equipment during excavation.
EXCAVATION ACCIDENT	10-24-78F	1" water line broken by excavating equipment.
CONSTRUCTION ACCIDENT	11-22-78F	"Construction truck driver backed over probe pipe to the Jacket South of tank 33."
EXCAVATION ACCIDENT	11-27-78F	Excavation accidentally unearthed a 20' section of concentrate transfer line. "Soil under CTS collapsed allowing the CTS to sag about 10 inches. SI-78-12-138."
BURNED OUT MOTOR	12-28-78F	Burned out motor on gate valve to creek removed but not replaced for 10 days.
INADEQUATE WASTE NEUTRALIZATION	03-15-79F	High activity waste sent to tanks without adequate neutralization, in violation of the technical standards.
ASPHALT CAVING IN	08-06-79F	"Asphalt is caving in at LDB 122 Tank 25."
PLASTIC COVERING CAVES	11-02-79F	"Construction plastic covering over the end of core pipe gave way" allowing rainwater to flood several leak detection boxes.
SHOWER FLOODS BUILDING	12-01-79F	"Somebody left the shower running in the ladies change room in the new building and flooded the building."
EVAPORATOR FAILURE	08-13-80F	242-F, evaporator #1 down. Evaporator put into service in 1969. Cause: Bundle tube failure. "There have now been 4 evaporator failures. 2 were in 242-F and 2 in 242-H. Service life has been 7-11 years between failures."
SUCK BACK TO GANG VALVE	01-02-81F	Improper air blow leads to suckback of contaminated solution into gang valve discharge piping. "Radiation was 10 rads/10 R/hr. at 3 cms. on lower lance line in gang valve house."
COMPUTER PROBLEMS	02- -81F 03- -81F	"Waste PHA out of service for several weeks with an inoperable floppy disk unit." "Approximately 6 hrs. downline experienced on the sample PHA."
CONTAMINATED WHEELS	07-08-82F	Rear wheels of trailer loaded with high level waste fell off. Radiation dose rate 10 rmems/hr at 3 feet from end of tank.

TYPE OF OCCURRENCE	DATE AND AREA	DESCRIPTION AND COMMENTS
ACCIDENTAL CHEMICAL	07-26-82F	"Engineer inadvertently discharged the halon fire suppressor system in the F area No. 2 evaporator control room." 4 people had to evacuate the building.
	F AREA LISTING ENDS	
	H AREA LISTING BEGINS	
INLEAKAGE OF RAINWATER	05-00-65H	Pump pit #1 - 10 feet of water; pump tank had 4½ feet of water. Leakage of rainwater into operating areas was frequent.
PROBLEMS NOT RECORDED	08-24-65H	"Prior to 8-24-65 information on instrument failure, pump failure, leaks in the waste tank system are not recorded unless the individual occurrence [sic] of particular interest.
NEW PIT CONTAMINATION	02-13-80H	"New CTS pit - during air blowing of line, nozzle #24 leaked water contaminating wall to 1500 c/m and the floor to 3000 c/m beta-gamma."
FAILED VALVE DIAPHRAM	07-09-80H	Failed diaphram on CTS valve. Radiation rate: 12 rad/ 2R/hr. "flush with open riser."
CONTAMINATED MOTOR	08-05-80H	"Evaporator burped at about 9:00 pm, setting off Vamps on Tank 21 and CRC pump. Tank 5,500 mr/hr at 8 cms. and CRC tank 4,500 mr/hr at 8 cms."
CERIUM WINDOW SHATTERED	01-04-82H	"15 psig argon gas was applied to the annulus of the repair cell shielded window [299-H] with the annulus vent valve closed. The pressure shattered a cerium glass section of the window."
VITRIFIED CLAY LINE	03-12-82H	"The vitrified clay pipe seepage basin line in the H-area is being replaced with a new polyetheylene line."
MOTOR ROTATING BACKWARDS	04-29-82H	Recirculating pump motor rotating backwards. Switched electrical connections.
WASTE BOX FIRE	06-24-82H	"A waste box and its contents were ignited after coming in contact with hot metal slag in the 22-H warm sample isle. An explosion could have occurred along with the personnel injury due to the fire."

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INSTITUTE

218 D Street, S.E., Washington, D.C. 20003