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Report to the Chairman, Environment, Energy, and Natural Resources Subcommittee, Committee on Government Operations, House of Representatives

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NUCLEAR ENERGY

Consequences of Explosion of Hanford's Single-Shell Tanks Are Understated

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Resources, Community, and
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October 10, 1990

The Honorable Mike Synar
Chairman, Environment, Energy,
and Natural Resources Subcommittee
Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

On December 8, 1989, you asked us to review the Department of Energy's (DOE) efforts to identify a solution for disposing of the high-level waste stored in underground tanks at its Hanford Site near Richland, Washington. As part of this review, we evaluated the work that has been done by DOE Richland and its contractors to understand and resolve questions concerning the stability of ferrocyanide—a potentially explosive material found in significant concentrations in 22 of the 149 single-shell storage tanks. Because our evaluation raised serious questions about the potential consequences of such an explosion, this report addresses the potential for an explosion. Our report on the remainder of your request will be issued in the near future.

Results in Brief

The consequences of an explosion in an underground waste storage tank containing ferrocyanide would be more severe than reported by DOE in the 1987 Hanford Site environmental impact statement (EIS). The EIS stated that an explosion in a tank containing ferrocyanide would create enough energy to release radioactive material to the atmosphere through ventilation openings (filters), exposing persons off-site to radiation doses equivalent to what they would receive from natural and man-made radiation sources.[1]

Although studies performed by DOE as early as 1984 and more recently by other experts, including the Defense Nuclear Facilities Safety Board, indicate that the probability of a ferrocyanide-caused explosion is low, this conclusion is based on limited information on the conditions of the waste in the tanks containing ferrocyanide. Our review of the work performed by DOE contractors indicates that, although the probability of an explosion may in fact be low, not enough is known about the waste in the single-shell tanks to definitely rule out the possibility of a spontaneous explosion.

[1] The average U.S. citizen receives about 0.38 rem per year from natural and man-made sources.

If an explosion did occur, our review indicates that it would be a major accident, with potentially more damaging effects than those described in the Hanford EIS, including contamination of large areas within and possibly beyond the Hanford Site boundaries, in addition to the human health effects. The force of this explosion would blow a large hole in the tank top and its overburden of earth. The radioactive material ejected from the tank could expose persons to radiation levels higher than reported in the EIS. Because limited data are available, the exact exposure levels are uncertain. The potential does exist, however, that, if an explosion occurs, off-site radiation exposure could rise to levels with potentially significant radiation-induced cancer consequences.

As a result of our discussions with DOE Richland, the Director, DOE Office of Environmental Restoration and Waste Management, appointed a team of independent DOE experts (referred to as the "Ad Hoc Task Force") to review our calculations of the potential radiation exposure. This Task Force, which reported its findings on September 20, 1990, agreed with our assessment that the respirable fraction of radioactive particles produced by the explosion would be higher than that used in the 1987 EIS, but stated that additional studies are needed to determine the potential radiation dose. The Task Force made numerous recommendations to DOE for additional studies to develop more precise information for resolving the ferrocyanide issue.

Background

The Hanford Site, located on the Columbia River in southeastern Washington State, is operated by the Westinghouse Hanford Company for DOE. Constructed in 1943, this major DOE defense facility, among other activities, reprocesses spent reactor fuel to recover the plutonium. This process produces a large volume of highly radioactive, heat-producing liquid wastes. Underground waste storage tanks were built to temporarily store this waste until a more permanent disposal solution could be found.

The first underground storage tanks consisted of a carbon-steel liner surrounded by reinforced concrete. Later, double-shell tanks—that is, a carbon-steel tank within a carbon-steel liner surrounded by reinforced concrete—were built. Over the years, 149 single-shell and 28 double-shell storage tanks, located within 12 to 22 miles of the Hanford boundaries, have been constructed. To control corrosion of the carbon steel tanks, sodium hydroxide is used to neutralize the acidic liquid wastes. A major waste component produced as a result of this neutralization is sodium nitrate.

Over the years, DOE devised various waste reduction procedures to minimize the number of storage tanks required. One of these procedures involved precipitating out the heat-producing, hazardous, and relatively long-lived radioactive isotope cesium-137 so that the remaining liquid could be pumped out of the tanks and sent to underground seepage structures. From 1954 to 1957, DOE used sodium and potassium ferrocyanide and nickel sulfate to precipitate out the cesium-137. According to DOE, this process caused various ferrocyanide precipitates to settle to the bottom of the tank, including cesium nickel ferrocyanide. The ferrocyanide precipitates are potentially hazardous because of the explosion danger, especially those containing the heat-producing cesium nickel ferrocyanide.

While DOE has documented some concern about ferrocyanide reactions in earlier reports, in 1983, its concern was renewed by studies assessing waste tank disposal options. As a result, DOE's Pacific Northwest Laboratory (PNL) carried out a preliminary literature evaluation of the potential hazard involved. The PNL 1984 report, summarizing the results of this evaluation, pointed out that (1) up to 140 metric tons (154 tons) of cyanide are contained in at least 14 single-shell tanks[2] with as much as 30 metric tons in 1 tank and 15 metric tons in another and (2) at high temperature, ferrocyanides could react with nitrates and release large amounts of heat and, if the reaction is very rapid, the result will be an explosion.[3] The report further presented a worse-case scenario, which it characterized as highly improbable, in which ferrocyanide reacting with sodium nitrate would produce an explosion equivalent to 36 tons of TNT.

In DOE's 1987 environmental impact statement (EIS) for the Hanford high-level waste, DOE evaluated the environmental, safety, and health effects of various high-level waste disposal options.[4] As part of this evaluation, DOE considered a ferrocyanide explosion to be an Upper Bound, or worst case, accident during disposal of the Hanford high-level waste. The EIS stated that this worst case accident would have "sufficient energy to breach the filters [ventilation openings] on the tank and release radionuclides as aerosols directly to the atmosphere." Although

[2]As of September 1990, DOE had identified 22 single-shell tanks containing significant concentrations of ferrocyanide.

[3]L.L. Burger, Complexant Stability Investigation Task I—Ferrocyanide Solids, Pacific Northwest Laboratory, PNL-5441 (Nov. 1984, released Aug. 1989).

[4]Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Department of Energy, DOE/EIS-0113 (Hanford Site Richland, Wash.: Dec. 1987).

the EIS did not address the on-site consequences of a ferrocyanide explosion, it did report that persons off-site would be exposed to radiation doses approximately equivalent to natural and man-made radiation sources.[5]

DOE Has Insufficient Information for Judging the Probability of a Ferrocyanide Explosion

Although DOE has concluded that an explosion in a tank containing ferrocyanide is highly unlikely, this conclusion is based on many uncertainties, including the composition of the waste material stored in the tanks. According to DOE, little is known about the precise contents of the tanks containing ferrocyanide. During the time that ferrocyanide was used, waste streams to and from the tanks were sampled and analyzed for limited constituents for purposes considered important at the time. But the available historical records are not adequate for determining the concentrations of the various waste constituents. Thus, it is difficult to estimate precisely the character of the wastes contained in the tanks without extensively sampling tank contents.

PNL's November 1984 report, which was not publicly released until the summer of 1989, concluded that not enough was known about the conditions in the tanks to state that the hazard of a potentially violent reaction did not exist. The report described many unknown circumstances that could affect the stability of the ferrocyanide precipitates and made several recommendations to resolve the uncertainties concerning tank temperatures and the amounts and concentrations of ferrocyanide available in the tanks. (App. I lists each of the recommendations and the actions taken to respond to them.)

In response to concerns initially surfaced in the 1984 DOE report, Westinghouse Hanford Company analyzed available information for those tanks suspected of containing ferrocyanide. A Westinghouse internal memorandum, dated March 2, 1989, reported Westinghouse's evaluation of the tank conditions that might affect ferrocyanide nitrate reactions and identified those tanks believed to have the highest potential for a ferrocyanide explosion. On the basis of studies performed to date, DOE believes that an explosion in a ferrocyanide tank is highly unlikely.

Our review of the work performed by the Westinghouse Hanford Company and PNL indicates that, although the probability of an explosion may in fact be low, not enough is known about the waste in the single-

[5]Until recently, DOE did not consider, in an EIS, the on-site consequences in assessing the health and safety impacts of its actions.

shell tanks to rule out the possibility of a spontaneous explosion. Specifically, the work does not adequately resolve questions concerning two of the key factors affecting the stability of the ferrocyanide precipitates—the temperature of the waste and the identity, amounts, geometry, and concentrations of the ferrocyanide precipitates.

The 1989 Westinghouse memorandum compared the temperatures measured in the tanks containing ferrocyanide with the temperatures required to initiate a ferrocyanide reaction and noted a large safety margin between the two temperatures. (According to DOE's independent team of experts, the highest temperature measured in a tank containing ferrocyanide was 135° Fahrenheit (F), whereas, the lowest temperature at which a reaction has been observed in the laboratory is 446° F.) In addition, the Westinghouse memorandum noted that concerns about temperature increases after all of the pumpable liquid had been removed were not supported by experience to date because there have been no apparent subsequent temperature increases in the ferrocyanide tanks that have been pumped.

We question the temperatures used to support this argument because the temperatures are measured only along one vertical line, sometimes near the edge, in each tank. Consequently, there are no records of temperatures at other points in tanks that are 75 feet in diameter and 30 feet deep. Therefore, the cyanides, which contain the heat-producing isotope cesium-137 may be generating local hot spots elsewhere in the tank away from the thermocouple string. Further, although hot spots may not have developed yet, they could appear, as moisture in the tanks continues to evaporate and the ferrocyanide material becomes dry. If, in fact, the situation is changing with time at some localized hot spots in the tanks, an explosion may still be possible even after all these years.

Westinghouse officials told us that additional temperature monitors will be installed in several locations within at least one tank containing ferrocyanide to determine if any localized hot spots exist. According to these officials, the results of this effort will then be evaluated to determine whether or not additional temperature probes need to be installed in other tanks containing ferrocyanide.

With respect to the second key factor, DOE's measurements of the explosive properties of the ferrocyanides have been limited almost entirely to cesium nickel ferrocyanide. However, our calculations indicate that only a tiny fraction of the ferrocyanide material in the tanks is cesium nickel ferrocyanide. Almost all is an unknown combination of other metal ions with the ferrocyanide. The temperatures which may cause an explosion of these materials may be different from those of the cesium nickel ferrocyanide. In fact, some limited experimental work by PNL in 1988 using potassium ferrocyanide indicated that such differences do exist.

Westinghouse representatives told us that they have discussed internally the need to examine how other materials might combine with ferrocyanide and how that might affect transition temperatures. They said that studies which will provide answers to those questions are planned but not yet scheduled. They explained that DOE's Los Alamos National Laboratory is conducting large-scale explosion testing for PNL to determine the explosive behavior of a large sample of cesium nickel ferrocyanide and nitrate/nitrite.

During the past year, the Defense Nuclear Facilities Safety Board, DOE's Advisory Committee on Nuclear Facility Safety, the State of Washington Department of Ecology, and others have reviewed the storage situation at the Hanford Site, concentrating primarily on the probability of an explosion. Although each group concluded that the probability of an explosion in any tank containing ferrocyanide was low, each identified problems similar to ours with respect to the lack of precise information about the waste material in the single-shell tanks and recommended that additional studies be undertaken.

In response to recommendations made by the Safety Board on March 27, 1990, DOE developed a plan to study possible chemical reactions that could cause heat generation in the single-shell tanks and to improve its temperature measurements in those tanks containing ferrocyanide. In addition, DOE plans to test the radiation stability of ferrocyanide precipitates and the energetics of ferrocyanide reactions beginning in fiscal year 1991. Following these actions, DOE will determine the need for additional action as recommended by the Safety Board.

Potential Consequences of a Ferrocyanide Explosion Have Been Understated

The Hanford EIS stated that an explosion in a tank containing ferrocyanide would create sufficient energy to release radioactive material to the atmosphere through ventilation openings (filters), exposing persons off-site to radiation doses from all exposure pathways (air, soil, water, and food) approximately equivalent to what they would receive from natural and man-made radiation sources. However, this conclusion was based on the assumption that the cesium would be evenly distributed throughout the tank waste.

We believe, however, that the cesium is more likely to be concentrated in the explosive material (that is, the ferrocyanide precipitates). We believe this because the ferrocyanide was added to the waste to bind with and precipitate out the cesium-137. If the cesium-137 is concentrated in the explosive material, our calculations indicate that a ferrocyanide-caused explosion would result in a higher level of radioactivity in the small radioactive particles being dispersed, increasing the dose that people might inhale to levels higher than the EIS indicated. Further, the force of this explosion would blow a large hole in the tank top and its overburden of earth. To the extent that the ferrocyanide is located under other waste in the tank, much of the waste would be blown out of the tank along with the gaseous products of the reaction. Among these products would be radioactive strontium-90 and cesium-137. (Strontium-90 is another highly radioactive element contained in the tanks.) Such an explosion would be a major accident, with potentially more damaging effects than those described in the Hanford EIS, including contamination of large areas within and possibly beyond the Hanford Site boundaries, in addition to the human health effects.

Because limited data are available, no one knows how much of the cesium-137 would be ejected as respirable particles. However, the greater the concentration of cesium-137 in the explosive material, the more likely it will be that a greater fraction will be in the form of respirable particles. For illustrative purposes, if one were to assume that about 5 percent of the concentrated cesium-137 becomes airborne as respirable particles, our calculations indicate that an explosion could produce radiation levels significantly higher than natural radiation sources. Off-site exposure from cesium-137 and strontium-90, for example, could be as high as, but likely will be less than, 7.3 rems.[6] For perspective, at the highest potentially estimated dose level of 7.3 rems, tables prepared by the National Research Council would indicate that approximately 1 additional person out of every 160 exposed to this dose could die from radiation-induced cancer over an extended period of years.[7]

It should be noted that our off-site exposure calculation does not consider exposure pathways other than the inhalation pathway. For

[6]This represents the equivalent whole-body 70-year committed dose (that is, the dose resulting from inhaling radioactive particles which deposit radioactivity in the body that continues to emit radiation to the body for 70 years).

[7]Derived from table 4-2, Health Effects of Exposure to Low Levels of Ionizing Radiation. BEIR V. Committee on the Biological Effects of Ionizing Radiations, Board on Radiation Effects, Research Commission on Life Sciences, National Research Council, pp. 172 and 173.

example, these figures do not include the external dose that someone would receive from the passing radioactive cloud, the dose delivered by the radioactivity after it is deposited on the ground, or the dose ingested through food and liquids.

Westinghouse Hanford and PNL officials agreed with our determination that the force of such an explosion would blow a large hole in the tank top and the earth overburden and our determination that the radiation doses may be higher than those presented in the 1987 Hanford EIS. They believe, however, that additional definitive, relevant experimental data must be obtained before accurate values for the radiation doses can be determined.

Agency Actions

As a result of our discussion with DOE Richland on August 22, 1990, the Director, DOE Office of Environmental Restoration and Waste Management, appointed a team of independent DOE experts on August 24, 1990, to review our calculations of the potential radiation exposure. This DOE Ad Hoc Task Force, which reported its findings on September 20, 1990, agreed with us that the cesium would be concentrated in the explosive material and that the respirable fraction of radioactive particles produced by the explosion would be higher than that used in the 1987 EIS. However, the Task Force commented that no data are available to accurately quantify the potential inhalation dose and that additional factors, such as how much of the ferrocyanide would participate in the explosion, need to be addressed to determine the dose.

The Ad Hoc Task Force report, dated September 20, 1990, recommended to DOE that additional studies be performed to provide information on the following:

- The potential for a ferrocyanide explosion.
- The conditions in the tanks most likely to initiate such an explosion.
- The potential consequences of such an accident. (The specific recommendations can be found in app. II.)

On September 26, 1990, the DOE High-Level Radioactive Waste (HLW) Tanks Task Force, the HLW Tanks Advisory Panel, and the Westinghouse Ferrocyanide Response Task Team considered the Ad Hoc Task Force recommendations in formulating a program to address the ferrocyanide issue.[8] On October 3, 1990, the Director, DOE Office of Environmental Restoration and Waste Management, requested that the Richland Operations Office submit an integrated conceptual plan to address the ferrocyanide issues by October 15, 1990. The DOE Richland Operations Office was also requested to (1) carefully review the on-going and planned programs to address high-level waste tanks' safety basis and issues and make necessary revisions to be consistent with the high priority assigned to tank safety and (2) identify how the Ad Hoc Task Force recommendations have been incorporated in DOE Richland's program planning.

Conclusions

The consequences of an explosion in an underground waste storage tank containing ferrocyanide would be more severe than reported by DOE in the 1987 Hanford EIS. Because so little is known about the waste in the ferrocyanide tanks, the probability of such an explosion is unknown.

DOE's planned course of action, as identified in its response to the Defense Nuclear Facilities Safety Board, if carried out, would provide much needed data. However, the additional studies recommended by DOE's Ad Hoc Task Force should be implemented by DOE Richland Operations Office so that sufficient information can become available to determine more precisely the probability of a ferrocyanide explosion and the potential consequences of such an event.

Recommendations

We recommend that the Secretary of Energy direct the DOE Richland Operations Office to implement the recommendations made by the DOE Ad Hoc Task Force on September 20, 1990.

Agency Comments and Our Response

As requested by your office, we did not obtain official DOE comments on this report. However, we discussed the facts presented in the report and our detailed calculations with DOE program and contractor officials. DOE generally concurred with the facts. An independent task force established by DOE also agreed with our analyses that the potential consequences of a ferrocyanide explosion would be greater than reported in

[8] According to DOE, the High-Level Waste Tank Task Force, established on Sept. 6, 1990, is to identify and address safety issues related to high-level waste tanks at all DOE sites, whereas, the Westinghouse Ferrocyanide Response Task Team will only address issues relating to Hanford ferrocyanide tanks. The High-Level Waste Tanks Advisory Panel will advise DOE on issues related to safe and efficient operations of high-level waste tanks at DOE facilities.

the Hanford EIS and recommended additional studies to resolve the current uncertainties.

We performed our review between February and September 1990 in accordance with generally accepted government auditing standards. Technical assistance in performing this review was provided by Dr. George W. Hinman, D.Sc. Dr. Hinman, currently Director, Office of Applied Energy Studies at Washington State University, has worked 40 years in the nuclear energy field in industry, government, and academia.

To assess the potential threat of a ferrocyanide explosion in the tanks, Dr. Hinman reviewed available studies concerning various aspects of the ferrocyanide situation and made independent calculations of the possible consequences of a ferrocyanide-caused explosion. To verify the accuracy of his work, his calculations were reviewed by Westinghouse Hanford, PNL, and an independent task force established by the Director, DOE Office of Environmental Restoration and Waste Management.

We also discussed our work with DOE-Richland and Washington, D.C., officials. However, as you requested, we did not obtain formal agency comments on this report.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will provide copies to DOE and other interested parties upon request.

This report was prepared under the direction of Victor S. Rezendes, Director of Energy Issues (202) 275-1441. Other contributors to this report are listed in appendix III.

Sincerely yours,

J. Dexter Peach
Assistant Comptroller General

Contents

Abbreviations

DOE	Department of Energy
EIS	Environmental Impact Statement
GAO	General Accounting Office
HLW	High-Level Waste
PNL	Pacific Northwest Laboratories

Pacific Northwest Laboratories' Evaluation of Potential Ferrocyanide Explosion

In 1984, Pacific Northwest Laboratories (PNL) carried out a preliminary evaluation of the potential hazard associated with ferrocyanides combined with nitrates in the single-shell storage tanks. The report, entitled Complexant Stability Investigation Task I—Ferrocyanide Solids by L.L. Burger, PNL-5441, was prepared in November 1984 but was not released until the summer of 1989. The following summarizes the recommendations made in that report and the work that has been done to date.

1. "Obtain and analyze the available information on tank histories for those tanks known to have held $Fe(CN)_6^{4-}$ in large quantities at one time."

An internal Westinghouse Hanford Company memorandum, dated March 2, 1989, addressed the ferrocyanide tank data. This memorandum reported Westinghouse's evaluation of the tank conditions that might affect ferrocyanide-nitrate reactions, and identified those tanks believed to have the highest potential for a ferrocyanide reaction.

The report identified the factors that might affect a ferrocyanide reaction as the temperature of the solids; the amounts and concentrations of ferrocyanide and oxidants (nitrates/nitrites); and the presence of catalysts, diluents, and moisture.

2. "Conduct radiolysis tests under simulated tank conditions to determine the rate of disappearance of CN^- and to identify the radiolysis products. The radiolysis tests should be conducted both with aqueous phase present and on settled sludges alone."

A study of this kind was issued in 1985. A preparation of cesium nickel ferrocyanide was irradiated under a sodium nitrate solution to $2.1 \times 10^{+8}$ rad using Cobalt-60 gamma ray radiation. There was negligible decomposition of the cesium nickel ferrocyanide at least in the form of soluble products.

The experimenters tentatively concluded that little or no degradation of the cesium nickel ferrocyanide had occurred as a result of radiolysis. They recommended that further analyses be done on the irradiated material to be sure there were no insoluble reaction products, since they had tested only for products released into solution. They also recommended that further irradiations be done under basic rather than the neutral or slightly acidic conditions they had used, because the stored wastes are expected to be basic (alkaline).

A PNL official told us in May 1990 that the question of decomposition remains unresolved. Apparently, the experiments were terminated before definitive results could be obtained.

3. "Determine the kinetic parameters of the CN^- and NO_3^- reaction by both experiment and calculation. The effect of inert materials is especially important and must be included in these studies. The information obtained from these studies would allow realistic conclusions to be made regarding the potential for rapid exothermic reactions in waste tanks containing ferrocyanide solids. In addition, the conditions for potentially hazardous reactions would be known and could be precluded by tank management practices."

PNL researchers conducted a short series of experiments during the summer and early fall of 1988 on the reactions of ferrocyanides with air, sodium nitrate, sodium nitrite, and a synthetic waste mixture. The onset of reactions was measured in three ways. Two methods measured all reactions of the ferrocyanide and one measured small explosions.

The temperatures at which reactions started ranged from 400°Fahrenheit (F) to as much as 990° F. The lowest temperature reactions occurred between the ferrocyanide and a 50-50 mixture of sodium nitrate and sodium nitrite, a low melting mixture (eutectic) that may be present in the tank wastes.

In the small-scale explosion tests, ferrocyanide reactions started at about 620° F with the 50-50 mixture. An actual explosion did not occur until the temperature reached 680° F with sodium nitrate, 660° F with sodium nitrite, and 645° F with the 50-50 mixture.

Adding inert material raised the temperature at which an explosion occurred. With a mixture intended to simulate tank composition, the ignition was at about 750° F.

The work in 1988 was funded only for a very brief time at the end of a fiscal year and not enough funding or time was allowed to do a definitive project. As a result, this investigation did not include the possible effects of initiators or catalysts. The presence of diluents in the ferrocyanide layers, if any, was also not determined.

A May 1989 safety study test plan described work (involving PNL, Westinghouse Hanford Company, and Los Alamos National Laboratories) which is now scheduled for completion in February 1991. A PNL official told us that some of the laboratory work already is complete and that some catalysts, notably nickel, iron, and EDTA, lower the exothermic and explosive temperatures by 10° to 25° F. That official told us that work concerning the important question of the kinetics of the ferrocyanide reaction still was not done and was not definitely scheduled to be done so far as he knew.

4. "Obtain tank samples and conduct chemical analyses for soluble and insoluble cyanides, cyanate, nitrate, fission products, and water content."

During 1986, a sampling program was carried out to obtain cores from two of the tanks (101-TY and 103-TY) which may contain ferrocyanides. However, the analyses of these cores apparently did not include tests for cyanides or cyanate. In 1988, cores from these two tanks were analyzed for cyanide, which was found to be present largely in insoluble form. However the identity of the cyanide precipitates involved was not established.

The 1989 Westinghouse memorandum noted that the ferrocyanide was expected to be in the lower depths of the waste in any tanks where unpumpable liquid remained. In this position, the moisture reduces the probability of a reaction because it removes heat from the reactive material. The memorandum also noted that the ferrocyanide was probably concentrated in thin layers in the tank solids. It stated that although concentrations could be determined by taking core samples and analyzing them, this procedure would be costly and time consuming, and instead undiluted ferrocyanide would be used in experiments by PNL.

Apparently, there are no cores available from any other ferrocyanide tanks. All of these tanks are scheduled for eventual sampling and analysis as part of the current waste characterization study.

5. "Obtain the temperature profile of the tanks to give information on temperature maxima and on possible layering of solids."

The 1989 Westinghouse memorandum compared the temperatures measured in the tanks with the temperatures required to initiate the ferrocyanide reaction and noted the large safety margin. The memorandum also noted that concerns about temperature increases after stabilization were not supported by experience to date because there had been no apparent increase in temperature due to pumping liquid out of the tanks.

6. "Obtain and analyze the gamma profile to provide information on temperature maxima and on possible layering of solids."

No gamma profile has been taken.

MEMORANDUM

20 September 1990

CC: Steve Cowan, EM-30
John Wagner, DOE-RL
Gary Bracken, DOE-RL

To: John Tseng
Office of Environmental Restoration and Waste Management

From: Tom Kress, Oak Ridge National Laboratory TSK
Kamal Bandyopadhyay, Brookhaven National Laboratory KKB
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RISK OF A FERROCYANIDE EXPLOSION IN THE HANFORD WASTE TANK FARM

Introduction

Certain single-shell tanks in the Hanford waste tank farms contain large quantities of ferrocyanide (Borsheim and Kirch). This ferrocyanide may contribute to the formation of chemical mixtures that are explosive at elevated temperatures (Burger and Scheele, 1990). A ferrocyanide explosion is considered to be the Upper Bound accident during disposal of Hanford High-Level Wastes (J. Mishima et al.). The report by Mishima et al. is the basis for the dose calculations shown in the Environmental Impact Statement (EIS) for disposal of Hanford Wastes.

During a recent audit, the General Accounting Office (GAO) expressed concern regarding the EIS dose calculations. A GAO consultant, George W. Hinman, calculated that the offsite dose from a ferrocyanide explosion could be up to two orders of magnitude higher than that shown in the EIS (Hinman).

The DOE Office of Environmental Restoration and Waste Management formed a task team to investigate this concern. The team consisted of the authors of this memo. The charter of the task team was 1) to review Hinman's calculations and explain the differences between his calculations and those in the EIS, 2) to make a qualitative judgement as to which calculations were most appropriate, and 3) to recommend a program for handling the ferrocyanide safety issue.

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The task team conducted its review on 28-29 August 1990. The team reviewed pertinent documents and interviewed key personnel at DOE-Richland, Westinghouse Hanford Company (WHC), and Pacific Northwest Laboratories (PNL). The team did not have the opportunity to interview Hinman.

Summary

Hinman calculated a higher offsite dose than the EIS because he assumed that a higher fraction (0.1 to 1.0) of the Cs-137 is carried into the air as fine, respirable particles. The EIS assumed only a small respirable fraction for both Cs-137 and Sr-90, namely 0.000005. With the higher Cs-137 fraction assumed by Hinman, Cs-137 became the dominant contributor to radiation dose. The EIS analysis showed Sr-90 as the primary dose contributor, with a committed dose two orders of magnitude less than the dose calculated by Hinman.

The task team agrees with Hinman that the respirable fraction of Cs-137 is likely to be higher than assumed in the EIS because much of the Cs-137 in these tanks is in intimate contact with the explosive. But the team cannot recommend what fraction should be used because it is not aware of any data that bears on the issue. There are a number of factors that will tend to attenuate the dispersion of respirable aerosols that were not considered in the EIS analysis or in Hinman's analysis.

The team believes that the risk of a ferrocyanide explosion is low. In experimental work at PNL, the lowest temperature at which an exothermic reaction has been observed is 446 degrees F (Burger and Scheele, 1990). The highest temperature currently measured in a tank containing ferrocyanide is 135 degrees F (Borsheim and Kirch). The team recognizes that neither of these temperatures can be considered limiting values, and the team recommends that further work continue to define the limiting temperatures more accurately. But, considering the margin between these two temperatures, the team believes the probability of an explosion is low enough that the risk (probability times consequence) is low. However, the team has no basis at this time to quantify the probability.

Therefore, the task team recommends that near-term efforts emphasize determining the probability of an explosion. The team recommends several key elements that should be included in this

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program. The team also recommends that better information be obtained on the fraction of respirable aerosols following a ferrocyanide explosion.

Finally, the task team recommends that plans be developed expeditiously for final disposal of these wastes.

Recommendations

A summary of the task team's recommendations follows. Each of these recommendations is discussed in more detail in the body of the report.

- Near term efforts should be concentrated on experiments and investigations to 1) determine the maximum temperature in a single-shell tank and 2) the detonation temperature of ferrocyanide mixtures that could credibly occur in a tank. The goal should be to define the probability of an explosion.
- The tanks of concern should be sampled to better characterize the wastes. Sample data is needed for several reasons: 1) to determine credible ferrocyanide mixtures, which is needed to estimate the minimum ignition temperature, 2) to determine physical properties of the waste that will help in estimating maximum temperatures in the waste, and 3) to guide experiments on aerosol generation.
- Studies underway on the initiating mechanisms for an explosion (e.g. spark, impact) should be continued.
- The possible formation of "hot spots" should be studied with the objective of defining the probability of hot spot temperatures approaching the exothermic reaction temperatures of ferrocyanide mixtures.
- Studies should be conducted to determine if any other chemicals might form in the tanks that could cause exothermic reactions or explosions at temperatures lower than required for ferrocyanide reactions.
- Temperature monitoring techniques and/or equipment need to be improved to reduce scatter and eliminate spurious readings.
- A formal action plan is needed for cases when the measured temperature in a ferrocyanide tank increases.

[Technical material on this page and the following pages of this letter has been deleted by GAO.]

- Explosion tests should be performed to measure the aerosol fraction, using simulated wastes on a scale basis.
- Long-term plans should be developed expeditiously for final disposal of these wastes.

Major Contributors to This Report

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