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Enclosure 26

Response to Request for Additional Information

Westinghouse Nuclear Fuel Columbia Site Evaluation Report March 1975 Section 5

SECTION 5.0

ENVIRONMENTAL EFFECTS OF ACCIDENTS

The impact on the off-site environment from postulated plant accidents which result in chemical and/or radiological effects is considered in this section.

Special design and operating precautions are taken to prevent the occurrence of these plant accidents. Hence they have a low probability of occurrence. These precautions have been successful, in that there have been no serious accidents to date that have had a significant off-site environmental effect.

The only radioactive material present at the NFCS fuel fabrication plant in unsealed container form is low enriched uranium* containing up to 4.15** percent by weight (w/o) of U-235. Because of the low specific activity of low enriched uranium (2.0 μCi per gram(1) for the maximum (4.15 w/o) U-235 enrichment) the radiological impact on the environment for any postulated accident within the fuel manufacturing plant or elsewhere on or off site should be very minor.

Accidents have been divided into three categories of severity. These include Category 1 (likely to happen), Category 2 (unlikely to happen) and Category 3 (incredible, design basis accidents [DBA]). For the meteorological dispersion of releases to the atmosphere, 50 percent confidence, short-term values of χ/Q (Table 2.6-2) have been assumed to apply. The specific use of 50 percent confidence meteorological dispersion factors in this evaluation as opposed to 95 percent confidence short-term dispersion factors used in usual safety analysis evaluations

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* Future plans for the NFCS include assembly of mixed oxide (UO_2 - PuO_2) fuel rods. This mixed oxide will have been hermetically sealed in tubular rods prior to delivery to NFCS for assembly into fuel assemblies.

** A maximum of 5.0 w/o U-235 was requested in an August 26, 1974 license renewal application. However, only one or two contracts with over 4.0 w/o U-235 will be processed at NFCS within the next 5 years. The present license(2) restricts the maximum enrichment to 4.15 w/o instead of 4.0 w/o to allow for manufacturing variations. Thus, 4.15 w/o enrichment will be considered the maximum enrichment in this analysis.

is consistent with the philosophy of making realistic rather than extreme-condition assumptions for assessing the environmental effects of accidents.

To provide an assessment of potential risks of accidents for light water reactor power plants (LWR), the AEC has suggested that the evaluation be based on nine accident classes, ranked in order of estimated severity.(2) The assumptions used should be more realistic than the conservative ones used in safety analysis evaluations.(3) This scheme for power reactors has been adapted for use in evaluating the environmental risk for potential accidents for a fuel fabrication plant, i.e., the NFCS, but the nine classes are reduced to only three. These include:

Category 1 Events

Category 1 events would include those plant accidents which would be most likely to occur in the course of plant operations. These accidents would have the least severe consequences of the three categories considered. Although some adverse on-site effects would be likely to occur as a result of these accidents, the effects on the off-site environment would be minimal and would not be likely to exceed those from normal effluent releases.

Category 2 Events

Category 2 events are incidents which may occur relatively infrequently during the operating life of the plant. These accidents could release amounts of uranium or harmful chemicals to the environment which would be several times those from normal effluent releases.

Category 3 Events

Category 3 events include postulated accidents which are not expected to occur during the life of the plant, but are considered because their consequences would include the potential for the release of significant

> amounts of radioactive or harmful chemical materials. Thus, they represent the limiting design conditions or design basis accidents. Category 3 events shall not cause a release of harmful material which could result in an undue risk to the public health and safety of the neighboring population.

The following sections outline the proposed release guides and the analytical methods and evaluations for radiological, transportation and nonradiological accident release conditions. The radiological dose model used in this analysis is described in Appendix 4.B.

5.1 RADIOLOGICAL ACCIDENT EVALUATION - ACCIDENT RELEASE GUIDES

Specific regulations covering accidental release guides are not available for uranium fuel fabrication plants. Thus, the following guides for accident conditions were selected for evaluation of the NFCS. For the most likely, Class 1 severity accidents, 10 CFR 20(1) guides for normal annual exposure of the general public in unrestricted areas will be assumed to apply, e.g., 3.0 rem to the bone and 1.5 rem to the lung and other organs.

Based on the amount of radionuclides equal to the time-integrated inhalable concentrations for 50 years of exposure to the airborne concentrations shown in Table II, Column 1 of the 10 CFR 20(1) and the ICRP dose model (Appendix 4.B), a lifetime dose commitment to the bone of approximately 150 rem from the short-term inhalation of soluble uranium and 75 rem to the lung from inhalation of insoluble uranium is obtained. In the absence of further guidance, these values are used in this report for the evaluation of the consequences of accidental releases of uranium for the less frequent but more severe Class 2 and Class 3 accidents. The guides for reactor siting,(4) i.e., 300 rem to the thyroid and 25 rem to the whole body, are used for the evaluation of accidental releases of other radioisotopes for criticality accidents. The radiological dose guides for accidental releases are summarized in Table 5.1-1.

Chemical toxicity guide value limits for Class 1 accident atmospheric contamination will also be based on 10 CFR 20(1) limits to the general population for soluble uranium in air utilizing the limiting concentration of 3 $\mu g/m^3$ (5) and an assumed breathing rate of 20 m^3/day. Thus, a daily limit of 0.06 mg U inhaled by the general public in unrestricted areas is found to apply in this case. Chemical toxicity guide value limits for Class 1 accident ground or surface water contamination are based on recommended concentration limits in drinking water of 4.0 mg/l U(6) (in soluble form) and an assumed water intake of 1.2 liter/day.

TABLE 5.1-1

RADIOLOGICAL DOSE RELEASE GUIDE

(Lifetime Dose to an Organ, rem*)

Accident Category	Description	Bone	Lung	Other Organs
1	Minor Faults and Operational Transients (Accidents of Moderate Frequency)	3.0	1.5	1.5
2	Infrequent Faults	150	75	1.5
3	Limiting Faults (Design Basis Accidents)	150	75	300 (Thyroid) 25 (Total Body)

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* The values for Conditions 1 and 2 are rem/year. The values for Category 3 are rem/occurrence.

The Class 2 and 3 accident chemical toxicity guide value limits for atmospheric contamination are based on ICRP(7) recommended limits for occupational workers of 2.5 mg/day inhaled.

Class 2 and 3 water ingestion guide value limits resulting from accidental contamination of ground or surface waters are based on recommended water quality criteria.(8) The uranyl ion is of concern in drinking water because of possible damage to kidneys. The threshold level of taste and the appearance of color due to the uranyl ion occur at about 10 mg/l which is much less than the safe level for ingestion of this ion insofar as adverse physiological effects are concerned. Although the Public Health Service adopted the limit of 5 mg/l for continuous intake, based on taste and color, in the present accident analysis the physiologically safe figure of 10 mg/l uranyl ions (equivalent to ∿ 8 mg/l uranium) was used. An assumed daily water intake of 1.2 liters with such a concentration of uranium results in a total daily ingestion limit of 10 mg U.

Release guides for chemical toxicity effects of uranium are summarized in Table 5.1-2.

5.1.1 RADIOLOGICAL ACCIDENT EVALUATION AT PRESENT OPERATING CAPACITY

This section presents evaluations of accidents which may involve both radiological and chemical uranium toxicity accident conditions for the present 400 MTU/yr capacity.

5.1.1.1 CATEGORY 1 TYPE ACCIDENTS WITHIN MANUFACTURING BUILDING

5.1.1.1.1 BREAK IN A TRANSFER LINE

Many minor accidents of this type have occurred. The worst such accident of this type occurred when a pneumatic transfer flex hose came loose from a flange on an enrichment blender, spilling about 27 kg of UO_2 powder on

TABLE 5.1-2

URANIUM CHEMICAL TOXICITY RELEASE GUIDE
AIR AND WATER INTAKE LIMITS FOR HUMANS
(mg/day)

Accident Category	Description	Air	Water
1	Minor Faults and Operational Transients (Accidents of Moderate Frequency)	0.06	5
2	Infrequent Faults	2.5	10
3	Limiting Faults (Design Basis Accidents)	2.5	10

the floor. Air samples taken in the vicinity of the accident indicated a maximum concentration of 8.5 x 10^{-10} μCi/ml or 8.5 times MPC for continuous occupational exposure. Since this is not excessively above MPC limits and was limited to a localized area for a relatively short time period and since this accidental release must still pass through a HEPA filter, the effects on the environment would be within the normal operational releases.

5.1.1.1.2 SOLUTION SPILL

Spills of solutions containing up to 4.15 percent enriched uranium have occurred within the plant. The average amount spilled is estimated to be about 200 ml while the maximum, worst case could not credibly exceed 38 liters. This type of spill would be quickly detected, isolated and contained. Although it might present some Health Physics problems for clean-up and decontamination, there would not be a measurable release to the environment.

5.1.1.1.3 SPILL FROM UO_2 POWDER LOADING

This type of accident has occurred several times, and it usually involves the dropping of the polyethylene containers used to store UO_2 powder. The worst recorded accident of this type occurred when a container slipped out of an operator's hand as he was loading it onto a storage cart. Approximately 14 kg of UO_2, about half that resulting from the worst case break in a transfer line discussed above, was spilled onto the floor. Thus, the consequences would be expected to be the same as for that case, i.e., no release above normal operational limits to the environment would be expected.

5.1.1.1.4 UF_6 RELEASE WITHIN THE PLANT VAPORIZOR AREA

All of the UF_6 releases within the plant to date have occurred as a result of leaks associated with connect and disconnect operations of the UF_6 cylinders. The typical release from these operations is estimated to be about 20 grams of uranium. At an average specific activity of 2.0 x 10^{-6} Ci/g for 4.15 w/o enriched U235, the total amount released to the UF_6 conversion area is 40 μCi. However, this accidental release is filtered by a HEPA filter which has an efficiency of 99.97 percent for liquid vapors or solid particles $\geq$0.3 μ in diameter.(10) Assuming that the above efficiency applies in the case of accidental UF_6 releases, then the release to the external environmental for releases of this magnitude would be only 0.013 μCi per occurrence. This short-term release could possibly cause an increase of about 50 percent in the normal average hourly release to the atmosphere, but a single occurrence would add only 4.4 x 10^{-5} mrem to the bone dose of an individual at the nearest site boundary or 1.5 X 10^{-8} of the annual release guide, assuming a soluble form of uranium.

The chemical effects to the kidney of an individual at nearest site boundary would also be negligible since only 1.0 x 10^{-9} g uranium per occurrence would be inhaled, amounting to only 1.7 x 10^{-5} of safe daily intake limits.

5.1.1.1.5 LOSS OF ELECTRIC POWER OR WATER SUPPLY

Electric power is purchased from the South Carolina Electric and Gas Company. A standby diesel generator system provides emergency power as required. One electric power failure has occurred over the life of the plant, and this resulted in a loss of power for an 8-hour period. No problems arose from this power failure since an orderly transition to diesel power followed by plant shutdown was accomplished. This would be the contingency plan in case of electric power failure. Thus, for any power failure, the plant would be transferred to diesel generator power, and an orderly shutdown with the emergency power would be carried out.

Water is supplied through the Columbia Municipal Supply water mains. If a water main break occurs such that the total plant water supply ceases, sufficient water is available through storage in the cooling systems to operate the plant for approximately 4 hours and to provide an orderly shutdown.

Two such water main breaks have occurred over the life of the plant. Both of these occurrences were handled by performing a normal shutdown with no consequent releases above normal limits to the environment.

Thus, radiological releases to the environment are not expected to be increased above normal values through either electrical or water loss.

5.1.1.1.6 SPILL OF RADIOACTIVE WASTES

Another accident which has occurred at the NFCS facility is a spill of radioactive wastes. The most severe accident of this type which has occurred at the plant was the result of losing a package of baled waste from a truck. Since each bale is restricted by DOT regulations to $\leq$ 45 grams of U-235 and if a maximum enrichment of 4.15 percent is assumed, the total uranium spilled amounts to 1080 grams. It is extremely unlikely that all of this uranium would be released to the area within the plant where the accident occurred unless this bale of waste also caught on fire. Assuming the latter condition to take place, and assuming an average specific activity of 2.0 μCi per gram of uranium, the total release to the plant area would be 2160 μCi.

If this accident occurred within the manufacturing area where HEPA filtration is utilized to reduce atmospheric releases, the resulting discharge to the external environment, assuming that the HEPA filter is 99.97 percent effective,$^{(5)}$ would be 0.7 μCi. The resulting dose rates from this type of accidental release would be 6.3 x 10^{-3} mrem to the lung (assuming insoluble uranium).

If this type of accident occurred in an area of the manufacturing building where HEPA filters are not being utilized (e.g., in the shipping dock area), the release to the atmosphere could be as much as 2160 μCi and the resulting dose from the short-term release, assuming a breathing rate of 3.5 x 10^{-4} m^3/sec would be 19 mrem to the lung.

The latter dose represents only 1.3 percent of the radiological dose guide value of 1.5 rem to the lung.

No evaluation of this same accident on the basis of chemical toxicity is performed because, for the postulated accident, the fire would convert any soluble uranium to the insoluble, biologically nontransportable UO_2 form.

5.1.1.1.7 LOCALIZED FIRE AND/OR EXPLOSION

Some small localized fires and minor explosions have occurred within the manufacturing building. The most prevalent cause of events of this type has been hydrogen "pops" (i.e., hydrogen-air reactions) which have resulted from insufficient purging of residual air pockets during calciner startups. The worst case accident in this category is represented by a bale of radioactive (uranium containing) waste catching on fire. This type of accident was already evaluated for the case of accidents involving a spill of radioactive wastes and thus will not be covered here.

5.1.1.1.8 FAILURE OF HVAC SYSTEM

Failure of the Heating, Ventilating and Air Conditioning System (HVAC), could cause some environmental problems within the plant which would require close surveillance by Health Physics and perhaps evacuation of certain plant areas and/or requirements for wearing face masks or artificial breathing apparatus. However, such conditions would not produce any additional hazard to the environment or to inhabitants outside the plant because, with the HVAC system shutdown, no radioactive effluents would be exhausted from the plant. Thus, the environmental effects of such an incident are expected to be no worse than, and probably less than, normal releases.

5.1.1.2 CATEGORY 1 TYPE ACCIDENTS EXTERNAL TO THE MANUFACTURING BUILDING

The most severe consequences from Category 1 Accidents would be expected to come from accidents which take place outside the manufacturing building since the advantages of building containment and air filtration are lacking in this case.

5.1.1.2.1 LEAK OF A UF_6 CONTAINER

Outside the fuel manufacturing building, a typical accident in this category might be the dropping of a cylinder of uranium hexafluoride (UF_6). These cylinders arrive by truck in their protective shipping containers. The shipping container is opened and the cylinder is transferred to a weighing and staging area, and then moved into the fuel building or onto an outdoor storage area. All precautions associated with moving high-pressure cylinders are observed, but it is possible that a cylinder might be dropped.

At no time is a cylinder more than 10 feet from an unyielding surface. Testing has shown that a 30-foot drop is necessary to cause a hairline crack(9) in the cylinder. Thus, no damage would be expected even if a drop did occur. If such a hairline crack did occur, it would not cause major leakage of UF_6 since it is a solid at ambient temperature (sublimes at 132°F) and therefore would evaporate out very slowly. Also, UF_6 reacts with atmospheric moisture to form uranyl fluoride (UO_2F_2), a nonvolatile solid. Thus, a slow leak is self-sealing.

If a cylinder were dropped, it would be checked for leakage, and corrective action would be taken immediately. A leaking cylinder would be taken immediately into the fuel building where the fumes would enter the scrubbed ventilation system. The cylinder contents would then be consumed in the manufacturing process as soon as possible.

The amount of UF_6 which could enter the environment from such an accident is too small to cause concern.

5.1.1.2.2 BREACH OF A UO_2 CONTAINER

UO_2 powder is shipped in two types of packages: Model BB-250-2 and Model LA-36 (Section 5.2). The maximum weights of the powder contained in these packages are 250 pounds (114 kg) and 79.2 pounds (36 kg), respectively. The composition is typically 2.8 w/o U-235 and 97.2 w/o U-238 with a maximum U-235 enrichment of 4.15 w/o.

There have been no accidents involving UO_2 containers to date. This accident is considered to be very unlikely and thus is evaluated in Category 2 rather than Category 1.

5.1.1.2.3 LEAK IN A LAGOON

A potential accident which could result in a measurable release of uranium to the environment is the result of a leak in a holding pond or lagoon. There are four lagoons which normally contain radioactive liquid effluent. The east, west, north and south lagoons contain 500, 1500, 90 and 90 thousand gallons of liquid effluent, respectively.

Historical records of minor leaks show that two such leaks have occurred. The first in January 1972 involved a leak from the west lagoon and the second in June 1973 involved a leak from the east lagoon.

The concentration level of gross alpha activity in these lagoons is monitored by taking a grab sample from a lagoon prior to releasing each batch to the Congaree River. The average monthly values for the period April 1973 through June 1974 show that the concentration levels in these lagoons generally average less than 10 percent of the MPC_w to the off-site environment with a maximum of 29 percent of MPC_w.

The choice of a leak rate which constitutes a "minor leak" in a lagoon is somewhat arbitrary since it depends on the ability to visually observe such a leak. This in turn will depend on where the leak occurs and other conditions such as existing water levels in the collection ditch. For the purposes of this evaluation, a leak rate equivalent to 20 percent of one of the smaller lagoons or 18,000 gallons per day is assumed. It is further postulated that the leak would be detected and corrected within 1 day. Also, to help detect such a leak, a monitor for pH is being installed with an instantaneous alarm. Such a monitor will detect leaks from the process liquid storage lagoons within a relatively short period after their initiation. Based on this leak rate and an assumed concentration in the leaking lagoon of 10 percent of MPC_w or 3.1×10^{-6} μCi/ml, the total amount of uranium activity reaching the environment would amount to 210 μCi or about 105 g of uranium, assuming a specific activity of 2.0 μCi/g uranium. Assuming that all of this activity is transported by flow through the drainage ditch over a period of 1 day to the upper part of Sunset Lake, the resulting average concentration of uranium activity in the lake would be 1.3×10^{-9} μCi/ml. This concentration amounts to only 0.0042 percent of MPC_w or about 2.5 percent of presently measured levels in the lake (Table 2.8-6). Such an extremely low uranium concentration would not result in any impact on the environment from either the radiological or chemical effects of the uranium.

5.1.1.3 CATEGORY 2 TYPE ACCIDENTS WITHIN THE MANUFACTURING BUILDING

5.1.1.3.1 CRACKED CALCINER TUBE

Certain accidents within the manufacturing building could release significant amounts of uranium to the external environment. An accident in this category which is postulated to occur is an explosion in the calciner which could cause a cracked calciner tube and subsequent uranium release to the off-site environment since the calciner combustion gas is not filtered. The atmosphere within the calciner tube is made up of hydrogen, ammonia, ammonium fluoride, steam and nitrogen. Air would be present only when the equipment has been shut down. When this atmosphere is kept at ≤ 7 percent oxygen with hydrogen, it is an inert atmosphere and no explosion can occur.

Pressure excursions have resulted because of hydrogen ignitions in the presence of air, and the pressure recorder has been driven off scale ($\geq$ 4.0 inches of water positive pressure) for an instant. Of the few ignitions resulting in explosive force, no damage has been experienced in the calciner itself.

For the purposes of this analysis, an accidental explosion in the calciner is postulated to take place and 50 pounds (23 kg) of uranium in the form of UO_2 are assumed to be released to the external environment through a cracked calciner tube and the unfiltered calciner exhaust system. Assuming a breathing rate of 3.5×10^{-4} m^3/sec and utilizing the dose model given in Appendix 4.B, the resulting dose is calculated to be 414 mrem to the lungs of an individual located at the nearest site boundary. This amounts to only 0.55 percent of the selected accident guide limit of 75 rem. No chemical toxicity effect is calculated since the uranium inhaled is in a biologically nontransportable form.

5.1.1.3.2 FAILURE OF A SINGLE FILTER IN A VENTILATION SYSTEM

The HEPA exhaust filters have two types of monitors to assess their capability. These include a differential pressure monitor across the filter and a monitor for the radioactive discharge concentrations. The filter is removed and exchanged for a new one when the differential pressure shows a decrease equivalent to 1.25 inches of water. The differential pressures are checked daily. Also, Health Physics monitors the air effluents from each exhaust filter and if the concentration of alpha activity leaving the exhaust filter shows any increase (caused by a leak), the filter system is repaired or exchanged. This detection system, however, has an inherent delay of about 48 hours resulting from the total elapsed time for sample collection, counting and reporting the data.

Based on the measured release rates of 5.3 μCi/week per section at a flow rate of 9×10^{10} ml/hr ($\sim$ 50,000 CFM) with the filter intact, the equivalent exhaust concentration is 3.5×10^{-13} μCi/ml (Table 3.3-3). Assuming that a filter is completely ineffective for a 48-hour period, and assuming that the filter when functioning properly is 99.97 percent effective in removing uranium activity,(10) then the release rate would increase a factor of 3300 to a concentration of 1.2×10^{-9} μCi/ml, or ∿ 12 times MPC_a for occupational workers. The total release to the atmosphere from this accident is thus estimated as 5000 μCi and the maximum resulting incremental dose to the off-site individual continuously inhaling the increased effluent concentration at a rate of 2.3×10^{-4} m^3/sec for the 48-hour period, assuming that the uranium is in an insoluble form, would be 30 mrem to the lung. If the uranium is in a soluble form, the comparable dose to the bone would be 11 mrem. These doses are approximately 0.04 percent and 0.007 percent of the guide value dose limits to the lung and bone of 75 and 150 rem, respectively. Also, the maximum concentration of uranium in the air at the site boundary location is only 7.5×10^{-5} g/m^3 which is approximately 6.0 percent of the safe chemical toxicity limit of 2.5 mg/day for the kidney. Thus, a filter failure for a 48-hour period as postulated would not result in any significant increase of uranium release or resulting dose effects.

5.1.1.3.3 RUPTURE OF A FUEL ROD

Loss of uranium from a ruptured UO_2 containing fuel rod is a very unlikely event. During 5 years of production at a process flow rate of ≈400 MTU/year, approximately 1,080,000 rods have been processed and only one rod rupture has occurred. However, recent fuel densification problems have required pressurizing the fuel rods and these pressurized rods may rupture at a lower temperature than was the case for rods handled previously. Hence, fuel rupture vs temperature tests were conducted to determine the temperature at which a rupture could take place and to determine the consequences, in terms of the amount of uranium released, of such a rupture.

These tests demonstrated that the temperature required to produce a ruptured rod ranged from 590°C to 641°C for the six rods tested. The total amount of UO_2 powder escaping was determined to be 237 mg of uranium ± 50 percent. Using the conservative, upper limit of error, the maximum loss of uranium is 356 mg of uranium for 6 rods, or about 60 mg per rod.

Thus, assuming a fire producing rod rupture caused by a heating incident, the total mass in the form of powder or vapor released would be expected to be 0.06 g of uranium. At a specific activity of 2.0 μCi/g, corresponding to maximum enrichment, this would amount to 0.12 μCi per incident. If this powder were all released through the HEPA filter system, assumed to be 99.97 percent efficient in removing uranium, the amount released to the atmosphere would be 3.6×10^{-5} μCi. The radiological dose and chemical toxicity effects from such a minor release would be negligible in comparison to normally occurring releases and thus will not be evaluated.

If mixed oxide (PuO_2 + UO_2) rods are handled within the manufacturing building as will be the case beginning about January 1976, the possibility exists for the release of small amounts of the mixed oxide to the environment through a fire producing rod rupture of the same type as discussed above for a UO_2 containing rod. Based on a maximum concentration amounting to 6.6 weight percent of plutonium in the UO_2 - PuO_2 mixture and assuming the same amount of mixed oxide powder is released as was the case for the UO_2 element described above, a maximum of 4.45 grams of plutonium powder could be made available for dispersion through the HEPA filtration system to the external atmosphere from a fire producing rod rupture. Using a specific activity of 0.268 Ci/g of plutonium alpha activity and 9.12 Ci/g of beta activity which is expected to be characteristic of the mixed oxide fuel material,(11) an assumed HEPA filter efficiency of 99.97 percent,(10) a breathing rate of 3.5×10^{-4} m^3/sec and lung dose conversion factors from Reference 12, the radiological dose to the nearest off-site resident from the plutonium dispersed in the atmosphere is estimated to be 12 mrem to the lung. This is only 0.016 percent of the guide value limit of 75 rem.

5.1.1.3.4 MASSIVE FAILURE OF A UF_6 CONTAINER

Another type of accident which could occur inside the manufacturing building is a massive failure of a UF_6 container. As noted previously, because of the way the UF_6 cylinders are handled and the containers are designed, it is very unlikely that such an accident would happen and no accidents of this type have occurred at NFCS to date.

Nevertheless, for this analysis, such an accident is postulated to occur.

Based on considerations detailed in WASH-1248(12) it is hypothesized that a 2.5-ton UF_6 cylinder has been overfilled with UF_6 or contaminated with some foreign gas or vapor such that overpressurization occurs upon heating. Approximately 700 kg of UF_6 are released in about 35 minutes, after which the contents of the cylinder cool to the solid state.(12) The uranium is assumed to be immediately airborne and dispersed through the exhaust and HEPA filtration system with 50 percent confidence meteorological dispersion to an individual located at the nearest site boundary. Assuming a HEPA filter efficiency of 99.97 percent and an inhalation rate of 3.5×10^{-4} m^3/sec, the total radiological doses are then calculated to be 2.6 mrem to lung and 1.0 mrem to bone. An additional degree of conservatism is added by assuming that the uranium is entirely in insoluble form for the lung dose calculation but in a soluble form for the dose evaluation of the bone dose. It is most likely that some fraction of the uranium would be in each form. Thus, the actual organ doses would be lower than indicated above. Even with this conservatism, the calculated doses are only 3.5×10^{-3} and 6.7×10^{-4} percent of their respective accident dose guide limit values for lung and bone.

The chemical toxicity caused by effects on the kidney was calculated to be 2.4×10^{-2} mg inhaled or about 1.0 percent of the guide value limit.

In addition to the conservatism in these accident calculations as noted above, there is additional conservatism included in the assumed intake.

As soon as UF_6 is vaporized in air, it forms UO_2F_2 and HF upon contact with the moisture in the atmosphere. The uranium released from this reaction would be in a soluble form. Hydrogen fluoride, in particular, is very irritating to the lungs and mucous membranes. Hence the natural reaction when exposed to this material is to hold one's breath and run from the cloud. Thus, it is extremely unlikely that any individual would inhale the cloud for more than a few minutes. Therefore, the actual expected exposure doses and chemical toxicity effects would be expected to be lower than those presented above.

5.1.1.4 CATEGORY 2 TYPE ACCIDENTS EXTERNAL TO THE MANUFACTURING BUILDING

5.1.1.4.1 COMPLETE FAILURE OF A UO_2 SHIPPING CONTAINER

If a complete failure of the larger of the two types of UO_2 shipping containers occurred external to the manufacturing building, 114 kg of UO_2 powder would be available for dispersion into the atmosphere. However, not all of this material would be airborne. For purposes of this analysis, 50 percent of the material is assumed to be airborne, although it is more likely that a lot less than this would be airborne before the accident would be observed and corrective measures to contain the spill were taken.

Based on 57 kg of airborne UO_2 and a specific activity for the uranium of 2.0 μCi/g, a total activity of 0.10 Ci is available for dispersion to the atmosphere. The resulting dose to the nearest off-site individual, assuming a breathing rate of 3.5×10^{-4} m^3/sec, was calculated to be 900 mrem to the lungs. This dose is only 1.2 percent of the accident dose guide value of 75 rem. No comparable effects from chemical toxicity are calculated since the UO_2 would be insoluble and biologically nontransportable.

5.1.1.4.2 BREACH OF A URANYL NITRATE CONTAINING DRUM

Uranyl nitrate, a liquid at ambient temperatures, is shipped in 55-gallon drums. These drums are unloaded to the pad storage area and, as use requires, are transferred to the manufacturing building via the dock entrance.

One accident has occurred to date which involved leakage of uranyl nitrate. This accident involved the leakage of 140 pounds (63.6 kg) of 3.1 w/o U-235 enriched uranyl nitrate solution to a drainage ditch which discharges into Sunset Lake. Based on an assumed leakage of 63.6 kg, an analyzed total uranium content of 0.086 g U per g of solution and a specific activity of the uranium of 1.6 μCi/g, this would amount to a total activity of 0.0088 Ci of soluble uranium discharged to the aquatic environment. Assuming that all of this activity is transported to Sunset Lake, and assuming complete mixing of the uranyl nitrate solution throughout the 43 million gallons of water in the upper portion of Sunset Lake, the average concentration in the lake would be 5.5×10^{-8} μCi/ml or approximately 0.18 percent of the maximum permissible concentration for off-site waters. This uranium concentration corresponds to 3.4×10^{-8} grams U/ml of water. If 1200 ml of this water were ingested each day by a human (which is not a feasible pathway), the annual radiological dose to the GI tract would be 1.5 mrem or 2×10^{-3} percent of the guide value and chemical toxicity would be only 0.41 percent of the guide value intake limit of 10 mg per day based on chemical toxicity considerations to humans. At this low concentration, there would not be any toxic effects to the aquatic biota.

Thus, an accident of this magnitude would not present any significant radiological impact since it is so far below the long-term safe limits for uranium concentration in the aquatic media.

5.1.1.4.3 MASSIVE FAILURE OF A LAGOON

Another potential accident which could have an adverse effect on the environment would be the result of a massive failure of a lagoon containing the radioactive process liquid. It is unlikely that this could occur since the holdup lagoons are lined with liner materials to prevent such an accident. However, a massive failure of the west lagoon did occur on October 20, 1971, and thus it is possible that this could occur again.

In the case of record, the total contents of the west lagoon (1.5 million gallons) were released to the upper part of Sunset Lake when the west wall of the lagoon collapsed. The gross alpha activity of the lagoon, however, was probably less than 10 percent of MPC, based on the grab sample monitoring data for April 1973 through June 1974. The 1974 data are more typical of 400 MTU operation than are the 1973 data and these data indicate an average of 10 percent of MPC. Using an assumed concentration of 10 percent of MPC_w or 3.1×10^{-6} μCi/ml for the lagoon water when the accident occurs, and assuming that all the 1.5 million gallons of process water discharges into the upper part of Sunset Lake which contains 43 million gallons of water, the average concentration in the lake after mixing would be 1.0×10^{-7} μCi/ml. This level should be mixed with the existing concentration. The existing concentration is taken to be 5.5×10^{-8} μCi/ml (Table 2.8-6) which represents the average measured value at the Causeway for 1973. The average concentration in the lake would then be 1.6×10^{-7} μCi/ml or 0.5 percent of the MPC_w to the off-site population. Such a low concentration would cause no environmental effects and could be discharged, after suitable monitored verification of the specific activity, to the Congaree River via Lower Sunset Lake and Mill Creek.

The total amount of uranium discharged through the drainage ditch to Sunset Lake for this accident amounts to 0.018 Ci or approximately 12,000 grams, based on an average specific activity of 1.45 μCi/g for 2.8 percent enriched uranium.

The resulting annual bone dose, if 1200 ml of water or 600 grams of fish were taken daily from Sunset Lake and ingested and the concentration were to remain at 1.6×10^{-7} μCi/ml for the full year, would be 7.8 mrem to the GI tract or 0.01 percent of the radiological release dose value guide. Actually, the lake could be flushed in about 3 days following the accident, assuming average flow rates exist in Mill Creek and creel census data show that no more than 140 g/day of fish are taken from the lake. Also, no drinking water is taken from Sunset Lake, and fishing would probably be temporarily discouraged following such an accident either by Health Physics posting the lake or because fish depart from the lake because of the chemical effects from the process waste discharge. Thus, the above evaluation is expected to be very conservative.

No radiological effects from this accidental discharge would be expected in the Congaree River downstream of the discharge from Mill Creek because the average concentration created by dilution in Sunset Lake is so low and because of the additional large dilution introduced by the Congaree River itself.

The chemical toxicity caused by uranium in upper Sunset Lake would also be very low since the 12,000 grams of uranium mixed in 43 million gallons (1.6×10^{11} ml) of water would give an average concentration of only 7.5×10^{-8} g/ml.

Compared to drinking water standards for humans, this would amount to only 0.9 percent of safe chemical toxicity limits to humans.

Thus this type of accident, should it occur again, would be expected to have no significant consequences on the environment.

5.1.1.5 CATEGORY 3 TYPE ACCIDENTS

5.1.1.5.1 CRITICALITY ACCIDENT

Nuclear criticality safety is based on a double contingency philosophy. Equipment design, system parameters and administrative procedures are such that two independent errors must occur to create an accidental critical excursion. Conservatism in the assumptions regarding operating conditions further increases the margin of safety. To the extent practicable, particularly when working with solutions, equipment is designed to be safe by geometry or with fixed nuclear poisons. A criticality accident has never occurred at NFCS, or for that matter, at any low enriched uranium fuel processing plant in the United States. Thus, the probability of such an accident is not subject to reliable quantitative prediction.(12)

However, for the purposes of this analysis, a release of 1.0×10^{18} fissions in a supercritical liquid system will be assumed. Only volatile fission products are considered to be released. The energy released by a criticality excursion is minimal and although the container in which the excursion occurs may be damaged, the building and filtration system will not be. A postulated 1×10^{18} fission excursion yield in U-235 would lead to the inventory of iodines and noble gases shown in Table 5.1-3. The activities shown in the table are the highest activities that would exist for each isotope at any time during the 630 seconds following the event (the approximate travel time for these gases to reach the site boundary). The iodine isotopic activity used to compute the off-site doses is reduced to 50 percent of the values given on the table to account for plateout on structures. No credit for holdup time in the plant is taken or for radioactive decay as the cloud moves off site. The filters are not considered effective for reducing the amount of iodines and noble gases released.

The equation used to compute the total body dose is $D = 0.25\ \Sigma Q_i \times E_i \times \chi/Q$ where E_i is the average gamma energy per disintegration (Table 5.1-3) and χ/Q is the cloud meteorological dispersion factor, sec/m^3, and Q_i is the isotopic yield, curies (Table 5.1-3). The thyroid inhalation dose is computed from $D = 3.5 \times 10^{-4} \times DCF \times Q_i \times \chi/Q$ where DCF is the dose conversion factor in rem/curie inhaled (Table 5.1-3). The breathing rate (m^3/sec) is 3.5×10^{-4} and the meteorology used is from Section 2.6. The site boundary doses are 0.14 rem from whole-body gamma exposure and 3.4 rem from thyroid irradiation through inhalation. These values are 1.1 percent and 0.56 percent of the dose limit guide values of 300 rem thyroid and 25 rem whole body.

5.1.1.5.2 SINTERING FURNACE EXPLOSION

The sintering furnaces are electrically heated with molybdenum heating elements. The hydrogen reducing gas is piped into the furnaces from storage tanks outside the manufacturing building to provide the reducing gas atmosphere.

All exit of H_2 gas is controlled by providing a natural gas curtain to limit entrance of air and to burn the H_2 escaping from the furnace.

If the H_2 pressure decreases low enough, the furnace automatically shifts to an inert N_2 atmosphere. The maximum pressure of the H_2 in the furnace is limited by venting.

TABLE 5.1-3

DATA FOR CRITICALITY DOSE CALCULATIONS

Isotope	Curies	Half-life	E Mev/dis	DOSE CONVERSION FACTOR* Thyroid (Rem/Ci)	DOSE CONVERSION FACTOR* Whole Body (Rem/Ci)
I-131	0.84	8.05 day	0.371	2.0×10^6	2.6×10^3
I-132	107.	2.3 hr	2.40	7.0×10^4	1.3×10^2
I-133	17.3	20.8 hr	0.477	5.0×10^5	5.7×10^3
I-134	465.	52.5 min	1.940	3.0×10^4	4.2×10^1
I-135	47.4	6.7 hr	1.78	2.0×10^5	2.9×10^2
Xe-133m	0.15	2.3 day	0.003	--	--
Xe-133	2.8	5.27 day	0.030	--	--
Xe-135m	38.7	15.3 min	0.422	--	--
Xe-135	24.9	9.2 hr	0.246	--	--
Xe-138	1050.	17.0 min.	2.870	--	--
Kr-85m	3.48	4.4 hr	0.151	--	--
Kr-85	3.8×10^{-5}	10.3 yr	0.002	--	--
Kr-87	100.	78. min	1.37	--	--
Kr-88	66.3	2.8 hr	1.74	--	--

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* Dose conversion factor for inhalation pathway

The entrance and exit doors of the furnace are also protected by a natural gas curtain and an automated pilot light ignition system for excess H_2 burn-off. The automated pilot system is activated by a thermocouple which controls the door opening. The limits of flammability of hydrogen-nitrogen-air mixtures have been determined.(13) The lower limit of flammability of hydrogen in air is ∿4 percent, while above ∿70 percent nitrogen, no hydrogen-nitrogen-air mixture is flammable. Hydrogen and nitrogen alone, in the absence of air, cannot combine in an exothermic reaction. For a range of between ∿4 percent to ∿8 percent hydrogen in air, the reaction is very slow and large temperatures and pressures are not reached. For a range of between ∿8 percent and ∿20 percent hydrogen, a deflagration can occur, but a detonation, with its associated high pressures, will not occur.

Thus, the precautionary steps which have been taken to ensure the plant safety include the following:

1. The furnace is purged with nitrogen prior to use.
2. A hydrogen pressure analyzer is utilized and below the minimum pressure set point, the introduction of inert nitrogen atmosphere is provided.
3. Excess H_2 is vented and burned.
4. Entrance and exit doors are protected by a natural gas curtain and an automated pilot light system.

Therefore, the possibility that an explosive mixture of hydrogen and air could be present in the furnace is extremely remote.

However, for purposes of this report, it is hypothesized that these controls fail and an explosion occurs in one of the furnaces. The explosive force would not be sufficient to destroy the furnace, but uranium could be blown out the ends.(12)

The furnace could contain up to 1125 pounds (510 kg) of UO_2 in the form of UO_2 pellets. It is assumed that all of this material is blown out and that the building air filter system remains intact.

Assuming a filter efficiency of 99.97 percent, the calculated atmospheric release to the external environment is 153 grams of UO_2 or 270 μCi. This is expected to be an overestimate of the UO_2 release since much of the UO_2 released in the postulated explosion would probably be in the form of pellets.

The calculated radiation dose to an individual located at the nearest site boundary, 1800 feet from the manufacturing building, would be only 2.4 mrem to the lungs. This is only 0.0032 percent of the radiological accident dose guide value of 75 rem to the lungs.

No comparable chemical toxicity effects are evaluated from these accidental conditions since the uranium would be in the insoluble, biologically nontransportable form.

5.1.1.5.3 CALCINER EXPLOSION

An explosion similar to that postulated for the sintering furnace could also take place in the calciner since, as was mentioned previously (Section 5.1.1.3.1), the calciner also contains hydrogen.

Safety features exist for the calciner similar those discussed above for the sintering furnace. Furthermore, the calciner contains less uranium. However, the calciner contains soluble as well as insoluble forms of uranium materials. Thus, this accident will also be evaluated.

The calciner is estimated to contain a maximum of 3.4 cubic feet of uranium dioxide (UO_2) at bulk density 1.9 g/cm^3 and 1.0 cubic foot of uranium diuranate, $(NH_4)_2\,U_2O_7$, also at bulk density 1.9 g/cm^3. Utilizing these values, a total inventory of 203 kg of uranium is calculated. This 203 kg is made up of approximately 20 percent by weight of the soluble (diuranate) form and 80 percent by weight of insoluble (dioxide) form.

It is postulated that all safety systems fail and all of the uranium contained in the furnace is blown out into the room. It is further assumed that the building air filter and ventilation system remains intact.

Assuming a filter efficiency of 99.97 percent, the release to the external environment would be 49 g of U in insoluble form and 12 g of U in soluble form. Assuming that all of the uranium is converted to the insoluble form (a conservative assumption), the lung dose is calculated to be 1.1 mrem and, utilizing the 12 g of soluble U released, the bone dose is calculated to be 0.08 mrem. These values are only 1.3×10^{-3} and 5.4×10^{-5} percent of the radiological guide values of 75 and 150 rem for doses to the lung and bone, respectively.

The chemical toxicity effect based on the 12 g of soluble U released is calculated to be 2.0×10^{-3} mg of U inhaled or equivalent to 0.08 percent of the chemical toxicity guide value of 2.5 mg/day.

5.1.1.5.4 FIRES

Precautions are taken to minimize the possibility of fires and to provide suitable fire extinguishing methods in case a fire should occur. For example, the storage of combustible materials is minimized in areas where fissile material is located. Water sprinklers are located in the store room where nonfissile material is located. Fire extinguishers are located strategically throughout the plant. These include three types: CO_2, dry powder and Metal-X. These fire extinguishers are checked monthly to assure that they are operational. A plant standby fire brigade is trained in the use of the fire fighting equipment and holds periodic drills which include practice on simulated fire emergencies which may arise in the plant.

Because of these precautions and contingency plans, no serious fires have occurred at the NFCS facility, and none are expected.

Nevertheless, for this analysis, a fire in a bank of HEPA filters on top of the manufacturing building is postulated.

5.1.1.5.5 FIRE IN A BANK OF HEPA FILTERS

The HEPA filters whose loss would cause the largest effect on the external environment would be those associated with the furnace exhausts since these filters control the largest single source of radioactive releases from normal operation at the NFCS facility (Table 4.2-1). These filters are located in the furnace filter house which is separately located on the roof of the manufacturing building. There are three sections horizontally adjacent to each other with each section containing three fans. Under normal operation, only one, or at most two, sections would be in operation at any one time. In the vertical direction, a pre-filter or "roughing" filter is mounted below each HEPA filter.

These filters are combustible and are housed in a wooden box. Thus, the accident which is postulated to occur is the complete burning of an operational set of filters with the release of all uranium activity which is contained in these filters. Based on the measured release rate of 10.6 μCi of uranium activity per week, an assumed HEPA filter efficiency of 99.97 percent and a maximum time between changes in filters of 26 weeks, the total activity accumulated in a set of filters is calculated to be 0.91 Ci. Assuming that all of this activity is released to the atmosphere outside the manufacturing building and utilizing a breathing rate of 3.5×10^{-4} m^3/sec in the dose model contained in Appendix 4.B, the maximum dose to an off-site individual would be 8.2 rem to the lung, assuming an insoluble form of uranium. This is 11 percent of the selected maximum guide value of 75 rem per event to the lung. Thus, this postulated accident, should it occur, would not be expected to result in any adverse radiological effects to humans or to the environment. No evaluation of this same accident on the basis of chemical toxicity is performed because, for the postulated accident, the fire would convert any soluble uranium to the insoluble, biologically nontransportable UO_2 form.

The values above are expected to be an overestimate of such an accident for the following reasons.

First, the maximum time for accumulation of activity was assumed. An average value one-half as large would be more likely.

Secondly, the release of uranium to the environment and subsequent airborne dispersion to the off-site environment has been assumed to be 100 percent effective, i.e., all of the uranium accumulated in the filters is dispersed to the environment. It is not likely that all of the uranium would become airborne even in the event of an extremely large fire. A better estimate would be that only 50 percent of the uranium activity would become airborne.

Thus it is most likely that the above values would be only 1/4 of the values given.

5.1.1.5.6 NATURAL EVENTS (FLOODS, HIGH WINDS, TORNADOES AND EARTHQUAKES)

Certain natural events could also result in contamination of the environment. These environmental effects, however, would not be expected to be as significant as the directly related environmental effects from natural causes. The probabilities of such events and the plant design features and contingency plans which would mitigate these effects are described below.

FLOODS

The probability of having a flood severe enough to cause releases of radioactivity and/or chemicals beyond the extent already analyzed is very slight. In Section 2.5, it is stated that the worst flood in 73 years is expected to result in water rising to 129 feet above sea level which is still some 13 feet below the manufacturing plant base elevation. It is possible that severe and persistent rains could wash out or cause overflow of the holdup lagoons. However, this type of accident has been analyzed for the largest lagoon, and if the contents of the other three lagoons were to be released to the environment also, it would not increase the total release of soluble uranium by more than 50 percent. Such a release would most likely be accompanied by a more than compensating dilution by the flood waters. Thus, no additional environmental effects would be expected beyond that already analyzed for the massive failure of a lagoon.

HIGH WINDS AND TORNADOES

Major hurricanes and tropical storms which have reached the Columbia area have an average frequency of ∿1 in 10 years with maximum winds up to 60 miles per hour. The facility is designed for wind loading of 20 pounds per square foot.

Other effects caused by high winds which could affect effluent releases include loss of parts of the ventilation system located on the roof of the manufacturing building. Although this could require shutdown of the plant, it would not produce any unevaluated environmental effects since loss of the ventilation system through a fire in a bank of filters would produce a more severe effect than would high winds. Fire would most likely assure the short-term and near total release of the uranium contained in the filters to the local environment while high winds would disperse this activity over a wide area, thus diluting the concentration in the near vicinity of the plant compared to the case of the fire.

Tornadoes have occurred in Richland County, South Carolina as noted in Section 2.6 over the period of 1953 to 1974 with an average frequency of about 0.5 per year. Since these effects are rather local, the probability of a tornado path touching the NFCS property is about one chance in 700 years. High winds and tornadoes could cause a failure in the power and water systems but these effects have already been evaluated as discussed previously.

EARTHQUAKES

From the history of earthquakes in South Carolina, it has been determined that the maximum earthquake in a period of some 150 years was the Charleston quakes of 1886 which had an intensity of VIII Modified Mercalli or 6 on the Richter Scale at Columbia. This magnitude is equivalent to a vertical ground acceleration of 0.15 g. It is most likely that such events could cause failure in water or power supplies and/or loss of ventilation systems but these effects have been considered as discussed previously.

Thus, severe acts of nature are not expected to result in any unevaluated radiological effects on the environment.

5.1.1.6 SUMMARY OF RADIOLOGICAL ACCIDENT IMPACT EVALUATION (400 MTU CAPACITY)

A summary of the accident impact evaluation is given in Table 5.1-4.

In Accident Category 1, the event which is evaluated to have the greatest effect on the environment and to humans results from a postulated spill of solid radioactive wastes combined with a fire. This accident results in an airborne concentration of uranium at the site boundary which is 1.3 percent of the radiological dose guide value for the lung, assuming that all of the uranium is converted to the insoluble oxide form. The accident with the next highest effect is a "minor" leak in a holding lagoon equivalent to 12.5 gallons per minute persisting undetected for a 24-hour period. This release to upper Sunset Lake results in uranium concentrations in that lake equivalent to only 4.2×10^{-3} and 1.6×10^{-2} percent of the radiological dose and chemical toxicity release guides (Tables 5.1-1 and 5.1-2, respectively).

The accident in Category 1 with the third largest effect is a UF_6 release in the vaporizer area. The UF_6 leak is calculated to result in a uranium concentration at site boundary which is 1.5×10^{-6} percent of the radiological dose guide and 1.7×10^{-3} percent of the chemical toxicity guide values. All other accidents in Category 1 are expected to be equal to or less than the allowable releases for normal operation. Thus, the consequences of the most frequent Category 1 type accidents are calculated to be so far below the safe guide limits that they are expected to result in negligible effects to off-site residents or transients.

TABLE 5.1-4

SUMMARY OF RADIOLOGICAL PLANT ACCIDENT EVALUATION
(400 MTU/YR CAPACITY)

(Percent of Accident Release Guides)

Accident Category	Accident Description	Radiological Dose (rem/occurrence)	Uranium Chemical Toxicity (mg/da)	Percent of Guide* Radiological	Percent of Guide* Chemical
INSIDE					
1	Break in Transfer Line	$\leq$ normal releases		$\leq$ normal releases	
1	Solution Spill	$\leq$ normal releases		$\leq$ normal releases	
1	UO_2 Powder Spill	$\leq$ normal releases		$\leq$ normal releases	
1	UF_6 Release within Vaporizer Area	4.4×10^{-8} (bone)	1×10^{-6} (kidney)	1.5×10^{-6} (bone)	1.7×10^{-3} (kidney)
1	Loss of Electric or Water Supply	$\leq$ normal releases		$\leq$ normal releases	
1	Spill of Radioactive Wastes	1.9×10^{-2} (lung)	--	1.3×10^{0} (lung)	--
1	Localized Fire and/or Explosion	1.9×10^{-2} (lung)	--	1.3×10^{0} (lung)	--
1	Failure of HVAC System	$\leq$ normal releases		$\leq$ normal releases	
OUTSIDE					
1	Leak of a UF_6 Container	$\leq$ normal releases		$\leq$ normal releases	
1	Leak in a Lagoon	6.3×10^{-5} (GI Tract)	8.0×10^{-4} (kidney)	4.2×10^{-3} (GI Tract)	1.6×10^{-2} (kidney)
INSIDE					
2	Cracked Calciner Tube	4.1×10^{-1} (lung)	--	5.5×10^{-1} (lung)	--
2	Failure of a Single HEPA Filter	3.0×10^{-2} (lung)	1.4×10^{-1} (kidney)	4.0×10^{-2} (lung)	5.8×10^{0} (kidney)
		1.1×10^{-2} (bone)	--	7.3×10^{-3} (bone)	--
2	Rupture of a UO_2 Fuel Rod	$\leq$ normal operation		$\leq$ normal operation	
2	Rupture of a Mixed Oxide Fuel Rod	1.2×10^{-2} (lung)	--	1.6×10^{-2} (lung)	--
2	Massive Failure of a UF_6 Shipping Container	2.6×10^{-3} (lung)	2.4×10^{-2} (kidney)	3.5×10^{-3} (lung)	1.0×10^{0} (kidney)
		1.0×10^{-3} (bone)	--	6.7×10^{-4} (bone)	--

(Continued)

TABLE 5.1-4 (Continued)

Accident Category	Accident Description	Radiological Dose (rem/occurrence)	Uranium Chemical Toxicity (mg/da)	Percent of Guide* Radiological	Percent of Guide* Chemical
OUTSIDE					
2	Complete Failure of UO_2 Shipping Container	9.0×10^{-1} (lung)	--	1.2×10^{0} (lung)	--
2	Breach of a Uranyl Nitrate Drum	1.5×10^{-3} (GI Tract)	4.1×10^{-2} (kidney)	2.0×10^{-3} (GI Tract)	4.1×10^{-1} (kidney)
2	Massive Failure of Lagoon	7.3×10^{-3} (GI Tract)	9.0×10^{-2}	1.1×10^{-2} (GI Tract)	9.0×10^{-1}
INSIDE					
3	Criticality	3.4×10^{0} (thyroid)	--	1.1×10^{0} (thyroid)	--
		1.4×10^{-1} (whole body)		5.6×10^{-1} (whole body)	
3	Sintering Furnace Explosion	2.4×10^{-3} (lung)	--	3.2×10^{-3} (lung)	--
3	Calciner Explosion	1.1×10^{-3} (lung)	2.0×10^{-3} (kidney)	1.3×10^{-3} (lung)	8.0×10^{-2} (kidney)
		8.[illegible] $\times 10^{-5}$ (bone)	--	5.4×10^{-5} (bone)	
3	Fires in Bank of Filters	8.2×10^{0} (lung)	--	1.1×10^{1} (lung)	--

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* See Table 5.1-1 for Radiological Dose Release Guide Values and Table 5.1-2 for Uranium Toxicity Release Guide Values.

In Accident Category 2, the accidents within the manufacturing building, which are evaluated to have the greatest effect to an individual located at the nearest site boundary, include a cracked calciner tube, failure of a single HEPA filter or a massive failure of a UF_6 container. These result in calculated radiological doses which are 0.55, 0.040 and 0.0035 percent of the Category 2 radiological dose guide limits, respectively. Additionally, the single HEPA filter failure and the massive failure of a UF_6 container are also calculated to result in inhaled concentrations of soluble U which are 5.8 and 1.0 percent, respectively, of the applicable chemical toxicity guide values.

Other accidents in Category 2 outside the manufacturing building which lead to fairly similar radiological and/or chemical toxicity effects include the complete failure of a UO_2 shipping container, breach of a uranyl nitrate drum and massive failure of a lagoon. For the latter two events, it is assumed that the uranium contamination all drains into upper Sunset Lake and is diluted there by the 43 million gallons of water contained therein. Since none of the Category 2 accident consequences exceed 10 percent of the guide value limits and since these accidents were evaluated using conservative and/or realistic parameters, and because such accidents would be expected to take place very infrequently, no measurable effect on individuals living in the vicinity of the plant from accidents of this type would be expected.

In Category 3, the events which would lead to the largest effects on an individual located at site boundary were postulated to be a criticality event or a fire in the bank of HEPA filters controlling the furnace exhausts. These two events, should they occur, would be expected to result in concentrations of airborne radioactive materials to the environment such that an individual located at the nearest site boundary would receive 1.1 and 11 percent of the radiological dose guide values, respectively. No effects from chemical toxicity would be expected to result from these accidents.

A calciner explosion, however, could result in an off-site individual receiving 0.0013 percent of the radiological dose guide for the lung and 0.08 percent of the chemical toxicity guide value based on effects to the kidney.

Thus these events, even if they should happen, would not be expected to result in measurable effects on residents or transients located nearby. Furthermore, as mentioned previously, Category 3 events would not be expected to happen during the life of the plant.

Thus, as can be seen from Table 5.1-4, all of the accidents evaluated are well within the accident release guidelines for present 400 MTU/yr operation. The effect on the accident evaluations of converting to 1600 MTU/yr is discussed in the following section.

5.1.2 EFFECT ON ACCIDENT IMPACT OF INCREASE IN PLANT PRODUCTION FROM 400 MTU/YR TO 1600 MTU/YR

The effect of expanding production from 400 MTU/yr (present capacity level) to 1600 MTU/yr for the evaluation of accidents in Severity Category 1 is judged to be very slight. Of all the accident types evaluated in this category, only the leak in a lagoon would be expected to increase by any significant amount. Since the evaluated consequences for this latter accident are low (0.004 percent and 0.016 percent of radiological and chemical accident release guides, respectively) the concentration and hence the resulting accident effects could increase by up to a factor of about 5000 before the guide values are exceeded. This is not likely to happen because of the combination of improved monitoring and chemical processing of the process liquids.

In Severity Category 2, only two of the accidents are expected to be affected by increased production. These include the failure of a single HEPA filter and the massive failure of a lagoon. If a single furnace exhaust filter were to fail at the 1600 MTU/yr operation level, the results of this accidental failure could be about a factor of two higher than at 400 MTU/yr because of the increased flow rate (Table 3.3-3). Thus, this accident could result in a radiological dose to the lung and bone of 0.08 and 0.015 percent of the guide value and in a chemical toxicity effect of 12 percent of the guide value.

Assuming that improved monitoring and chemical treatment methods are used on the process liquids so that the concentration of uranium in the holdup ponds will not exceed four times present values, a massive lagoon failure accident would be expected to result in 0.044 percent of the radiological dose guide to the GI tract and 3.6 percent of the chemical guide value to the kidney.

In Severity Category 3, the criticality and sintering furnace or calciner explosion accidents would be expected to result in no greater consequences for 1600 MTU/yr operation than for 400 MTU/yr operation, although the probability which is judged to be extremely low, could increase by the ratio of the production rates.

The effect of an accident involving a fire in a bank of HEPA filters could again increase by the ratio of mass flow rates, or by about a factor of 2. Thus, this accident could result in a radiological dose of 22 percent of the guide level for the lung.

No other unevaluated effects would be expected for the 1600 MTU/yr operation as compared with the 400 MTU/yr operation as discussed in Section 5.1.1.

5.1.3 REFERENCES

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5.2 TRANSPORTATION ACCIDENTS

5.2.1 GENERAL

This section provides a general analysis of the potential environmental impact resulting from the shipment of chemical and radioactive materials to and from the NFCS facility. The materials considered in this analysis include toxic chemicals and radioactive materials. The radioactive material shipments can be further subdivided into input fuel materials, fuel rods, final assemblies and radioactive wastes.

Previous records and projected requirements will serve as the basis for shipment quantities discussed in this analysis.

5.2.2 NONRADIOACTIVE CHEMICAL MATERIALS

Bulk tank truck shipments of anhydrous ammonia, aqueous ammonia, nitric acid, hydrofluoric acid, hydrated lime and sodium hydroxide solutions are received and utilized on-site.

The frequency of these shipments will be less than 25 per week for the 1600 MTU/yr capacity. These materials are all shipped in accordance with state and federal regulations. The probability of accident frequency is discussed in Section 5.2.3.6.

5.2.3 RADIOACTIVE MATERIALS

5.2.3.1 PRINCIPLES OF SAFETY IN TRANSPORT

Most shipments of radioactive materials move in routine commerce via conventional transportation equipment. Therefore, shipments are subject to the same transportation situation as nonradioactive cargo although a shipper may impose some conditions on his shipment, such as speed limitations, special routing or an escort to provide additional protection. In transport of radioactive material, safety depends primarily on the packaging. Packaging must meet applicable state and federal regulatory standards to prevent the loss or dispersion of the radioactive contents, ensure nuclear criticality safety and provide adequate heat dissipation under normal conditions of transport and under specified accident damage test conditions (i.e., design basis accident*). The contents of packages not designed to withstand accidents is limited; therefore, the risks from releases that could occur in an accident involving these packages are limited.

Protection against external radiation is provided by state and federal regulations regarding radiation levels on the outside of packages of radioactive materials and by storage array provisions. For example, the number of packages in a single vehicle or area is limited to control the external radiation level and to assure nuclear criticality safety.

5.2.3.2 SHIPPING CONTAINER DESIGN CRITERIA

Regulations governing the packaging and shipping of radioactive materials have been established by the AEC and the DOT.(1,2) These regulations are, to a large extent, based on the regulations for safe transport of radioactive materials of the International Atomic Energy Agency. The United States regulations, therefore, represent an international consensus on good practice.

Under existing AEC and DOT regulations, the package user must be approved and/or licensed to use a given package for shipments of radioactive material. These regulations are intended to assure that the package has the requisite integrity to meet all conditions which may be encountered during the course of transportation.

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* The "design basis accident" refers to that accident chosen as the most severe accident considered likely and used for the basis of the design of safe shipping containers licensed by the AEC and DOT for shipment of radioactive materials of the type discussed here.

It should be noted that the validity of this approach to safety is dependent on the assumption that packages are properly prepared for shipment, a point which has received increasing administrative attention.

5.2.3.3 SHIPPING CONTAINERS FOR NFCS USE

Shipping containers used at the Columbia Site consist of the following types:

1. Uranium oxide powder or pellet shipping containers
2. Uranyl nitrate material container
3. Uranium hexafluoride container
4. Fuel assembly shipping containers
5. Radioactive waste material shipping containers

Incoming uranium oxide powder (UO_2 and U_3O_8) in various enrichments up to 5 w/o U-235 can be shipped in any appropriate AEC and DOT approved containers. For purposes of this evaluation, however, only approved and licensed Westinghouse containers will be considered. These are the Models LA-36 and BB 250-2 containers.

The Model LA-36 container is made up of two 5-gallon open head pails with flange seal lids surrounded by approximately a 5.0-inch thickness of vermiculite contained within a 65-gallon 16-gauge steel-walled drum as shown in Figure 5.2-1.

The Model BB 250-2 container is a similar arrangement container with the same outer diameter and thickness of vermiculite packing but with two of the outer steel drums welded together to provide an overall minimum length of 74 inches compared to the 38-1/2-inch length for the Model LA-36. A sketch of the Model BB 250-2 container is shown in Figure 5.2-2. Both of the above containers are licensed under SNM-1107. Incoming shipments of uranium oxide powder are supplied approximately 60 percent by Model LA-36 containers and 40 percent by Model BB 250-2 containers.

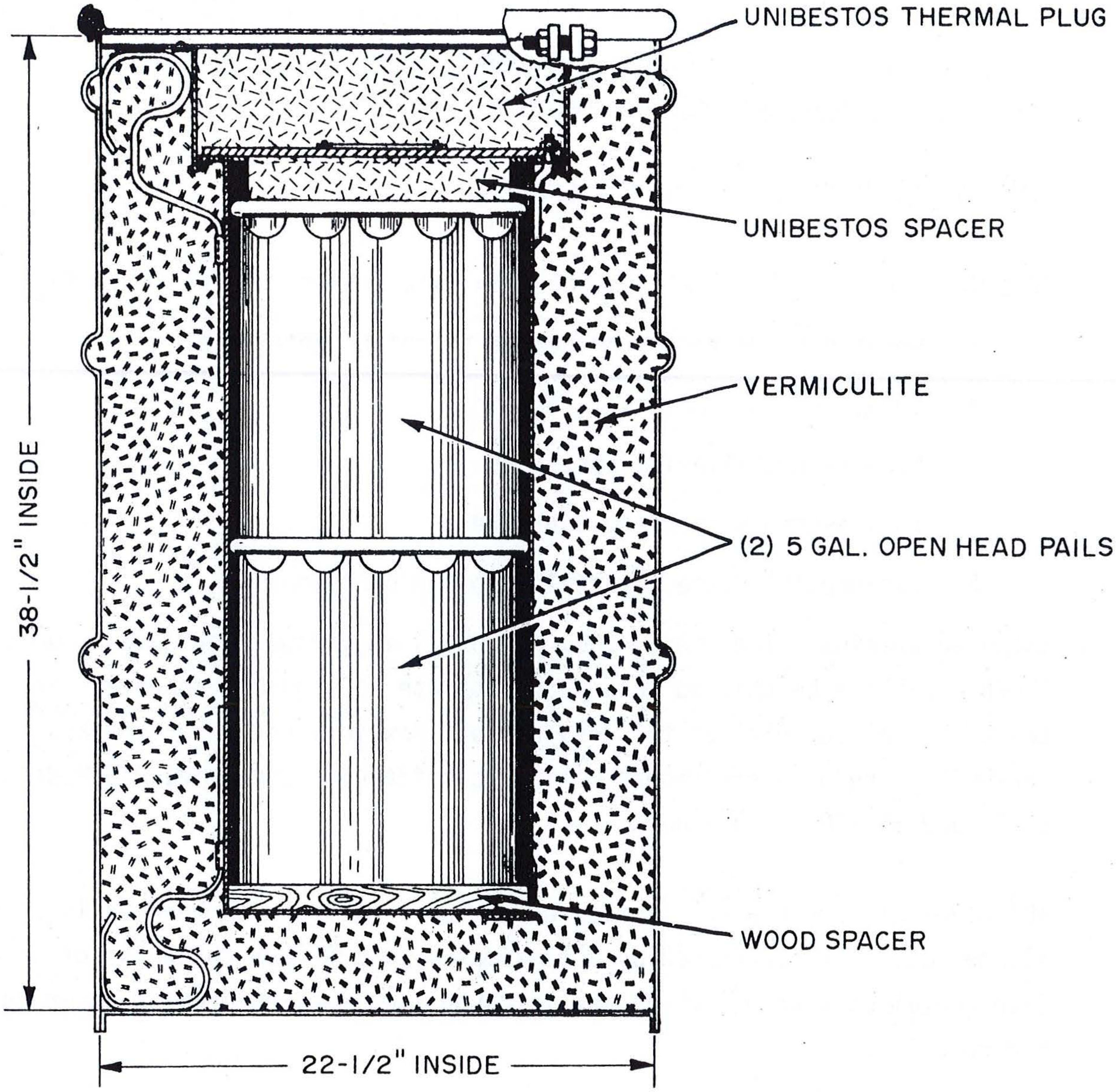

Figure 5.2-1. LA-36 UO_2 Powder Shipping Container Assembly

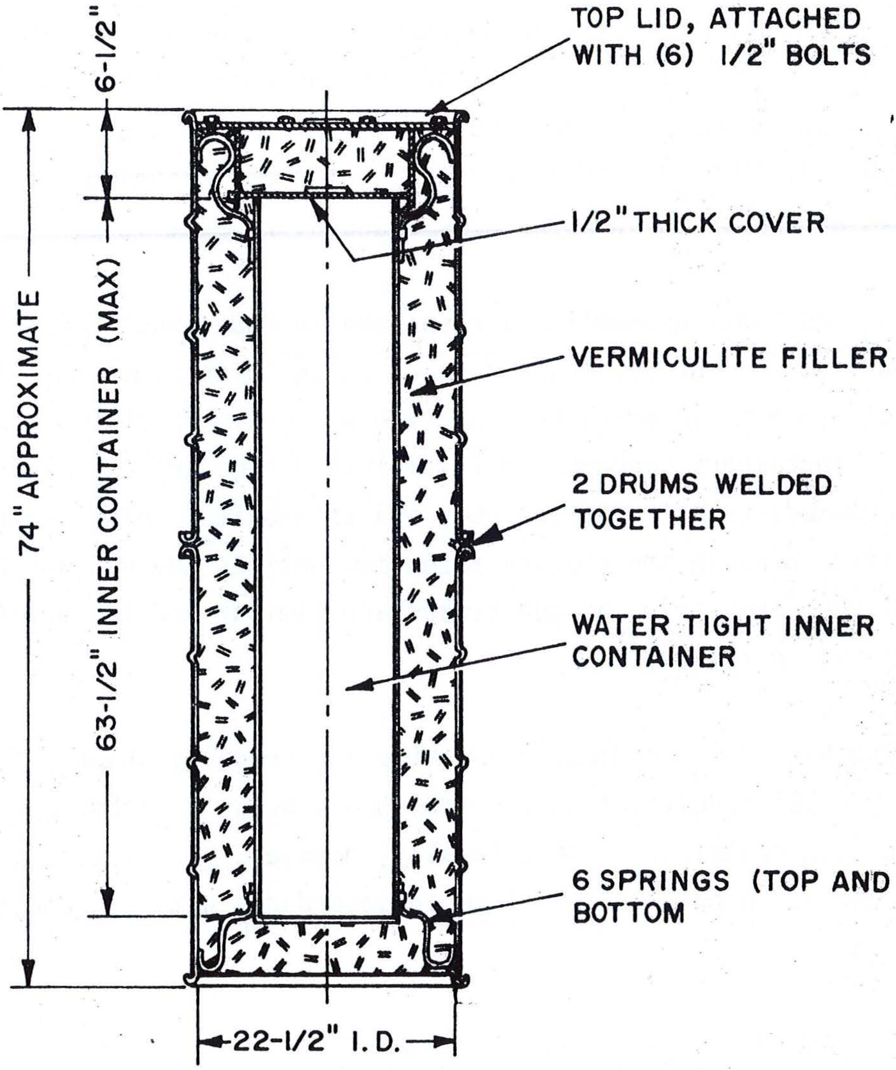

Figure 5.2-2. BB250-2 UO_2 Powder Shipping Container

Uranyl nitrate ($\leq$ 5g U-235/ℓ) solution is shipped in DOT specification containers equipped with DOT specification polyethylene liners.

Uranium hexafluoride (UF_6), a solid at ambient temperature, is shipped in Model OR-30(4) series shipping containers. Incoming UF_6 is shipped in Model 30A or 30B cylinders with overpack(3) as specified in DOT regulations. For the return of UF_6 containers, the heels with less than 25 lbs UF_6 remaining in each cylinder, may be shipped without overpack under DOT Special Permit SP-6273. Further details of these shipping containers and overpacks are provided in References 3 and 4, respectively.

Fuel rods and final assemblies are shipped in Model RCC, RCC-1 or RCC-2 shipping containers. The basic differences among these containers is in the length of elements accommodated and type of locking mechanisms. The RCC and RCC-2 containers accommodate 10-foot-long rods and assemblies while the RCC-1 accommodates 12-foot-long rods and assemblies. Also there are some minor differences in the closure mechanism between the RCC and RCC-2. Otherwise, all RCC-type shipping containers are similar and the general features are depicted in Figure 5.2-3.

Noncombustible, solid radioactive wastes are normally shipped for off-site disposal in DOT Specification 12B fiberboard boxes or other appropriate DOT specification containers. Occasionally, however, radioactively contaminated metal scrap is shipped in bulk form in accordance with all applicable DOT regulations.

5.2.3.4 TRANSPORTATION METHODS AND ROUTES

Most shipments of radioactive materials to and from NFCS are made by exclusive use trucks. Occasionally, shipments are made by air and water transportation means.

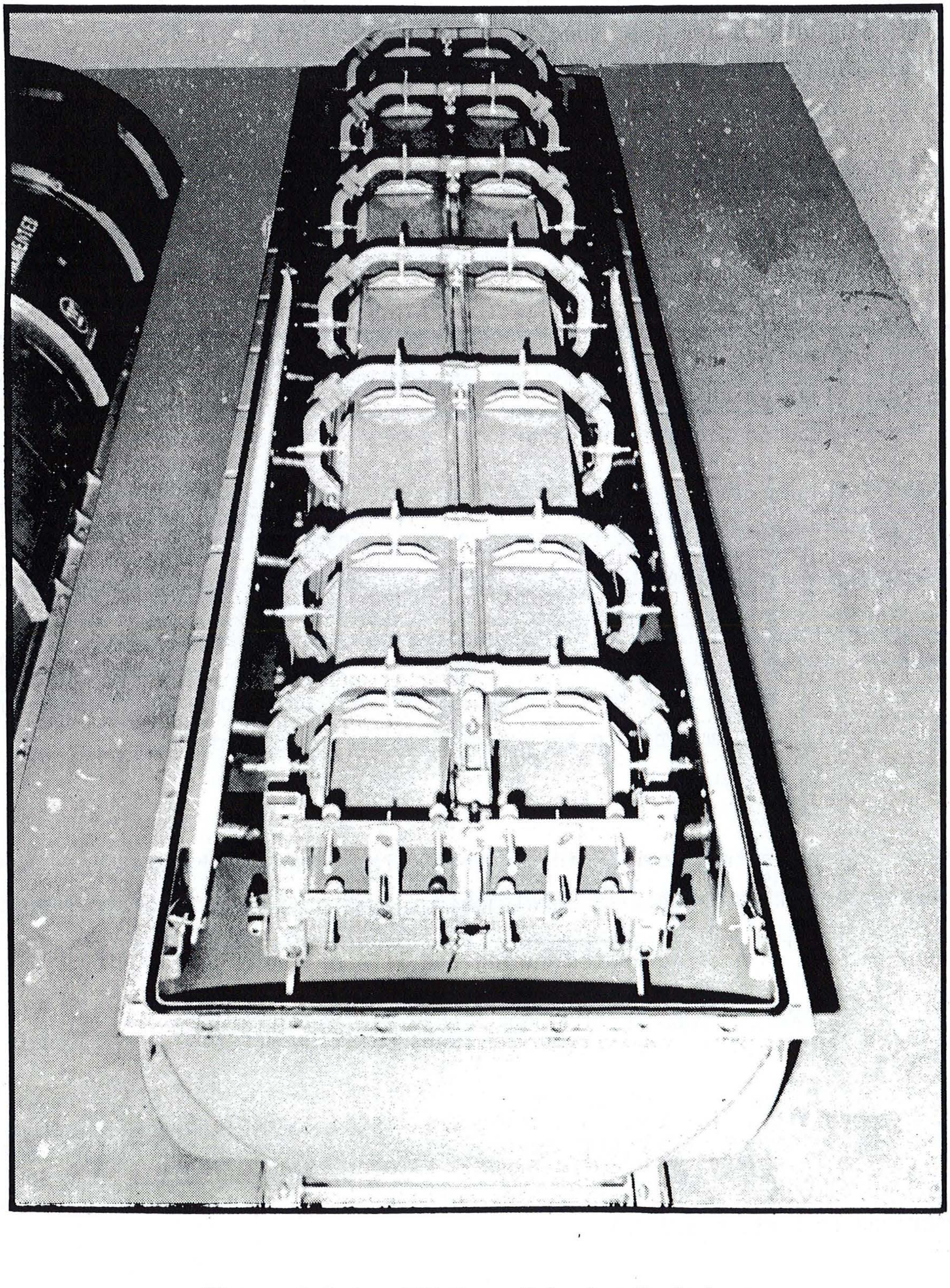

Figure 5.2-3. RCC Type Shipping Container

The quantities, routes and frequencies of radioactive materials shipments to and from the NFCS are described in detail in Section 4.2.1.4.

5.2.3.5 ACCIDENT CLASSES

Transportation accidents occur in a wide range of frequencies and severity. For purposes of this analysis, as in the case of plant accidents, transportation accidents will be divided into three classes of increasing severity but decreasing probability. Class 1 will include all transport accidents which are no more severe than the design basis accident. The few accidents in this class which have occurred on public transport of radioactive material presented no significant hazard.

Class 2 includes accidents in which several of the inner containers may be ruptured but no significant radioactive contamination is released to the environment. This type of accident could occur through a severe highway accident or upon unloading the radioactive shipment package. While this would not be expected to involve the general public significantly, it could present an important risk to the receiver or shipper. However, emergency plans have been formulated to handle this situation and minimize the exposure should it occur.

Class 3 includes transport accidents which are so severe that the accepted approach to package safety is invalidated. Such accidents occur so infrequently that none are expected during the life of the NFCS facility.

5.2.3.6 ESTIMATED PROBABILITIES FOR TRANSPORTATION ACCIDENTS

The probabilities for truck accidents are listed in Table 5.2-1.(5) The "moderate," "severe" and "extra severe" categories as given in Table 5.2-1 would be expected to roughly correspond to Severity Classes 1, 2 and 3 as described in Section 5.2.3.5.

TABLE 5.2-1

PROBABILITIES PER VEHICLE MILE FOR TRUCK ACCIDENTS OCCURRING IN VARIOUS ACCIDENT SEVERITY CATEGORIES(5)

Severity Category	Minor	Moderate	Severe	Extra Severe	Extreme
Probability per vehicle mile	$2.\text{x}10^{-6}$	$3.\text{x}10^{-7}$	$8.\text{x}10^{-9}$	$2\text{x}10^{-11}$	$1\text{x}10^{-13}$

Based on the above probabilities per vehicle mile and the shipping frequency and distance per shipment as given in Section 4.2.1.4, the overall probability in units of expected years between accidents was obtained as summarized in Table 5.2-2.

5.2.3.7 EFFECTS OF TRANSPORTATION ACCIDENTS

Considering that the expected frequency of serious accidents resulting from transportation of radioactive materials to and from the NFCS facility is less than one occurrence in 350 years (Table 5.2-2), it is very unlikely that any radioactive material would be dispersed to the environment as a result of NFCS operation.

In the event that a package of low specific activity material were in an accident, the low specific activity and the radiation levels associated with the materials limit the radiological impact from accidents involving these materials to negligible levels.(5)

The most likely type of accident is that involving the disablement of a truck without any of the contents of the radioactive shipment being released. Thus, the population exposure will be estimated for this case.

The maximum allowable dose rate from a radioactive shipment permitted by shipping regulations is 10 mrem/hr at 6 feet.(7) Assuming that fuel containment

TABLE 5.2-2

SUMMARY OF OVERALL ACCIDENT PROBABILITIES* FOR TRANSPORTATION OF RADIOACTIVE MATERIALS ASSOCIATED WITH NFCS OPERATION

Units - Expected Accident Frequency in Years for Class 2 and 3 Accidents

	Class 2 (Severe)		Class 3 (Extra Severe)	
Material Shipped	400 MTU/yr	1600 MTU/yr	400 MTU/yr	1600 MTU/yr
Uranium oxide (incoming)	6.0×10^5	3.0×10^5	2.5×10^8	1.3×10^8
Uranium oxide (outgoing)	1.2×10^4	3.0×10^3	5.0×10^6	1.3×10^6
Uranium Hexafluoride	2.7×10^3	6.8×10^2	1.0×10^6	2.5×10^5
Uranyl Nitrate	1.3×10^4	3.2×10^3	5.0×10^6	1.3×10^6
Fuel Assemblies	1.4×10^3	3.5×10^2	5.5×10^5	1.4×10^5
Uranyl Nitrate empty cylinders and heels	1.7×10^3	4.2×10^2	7.2×10^5	1.8×10^5
Uranium oxide pellets	1.8×10^5	9.0×10^4	7.0×10^7	3.5×10^7
Packaged waste	1.7×10^4	1.1×10^4	7.0×10^6	4.4×10^6
Mixed Oxide Fuel Assemblies**	---	4.8×10^4	---	1.4×10^7

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* Probabilities are given in units of years expected between accidents for events (Class 2 or 3) which could exceed the limits for which packaging is designed.

** Although incoming mixed oxide fuel rod shipments are expected during the 400 MTU/yr operation period, no fuel assembly shipments are expected during this period. Fuel assembly shipment accident probabilities during 1600 MTU/yr operation are based on an expected frequency of 4 per year and an average shipping distance of 870 miles. The probability of a transportation accident involving the incoming mixed oxide fuel rods is covered in the Westinghouse Cheswick Site Fuel Development Laboratories Environmental Report.(6)

has not been ruptured, that people have surrounded the truck at a distance of 50 feet, and that the dose rate falls off inversely as a function of distance from a shipping container, the dose rate at 50 feet would be 1.2 mrem/hr. While a circle with a 50-foot radius would accommodate approximately 154 people, additional people in outer rows would receive substantial shielding by those in the front row. If a person were to remain in the front row for a period of 2 hours, he would receive an exposure of 2.4 mrem or approximately 2 percent of the annual background dose for people in South Carolina. It is assumed that by the end of a 2-hour period the crowds would be dispersed by local authorities and thus would receive no further dose. Thus the total population exposure from this accident is estimated to be 0.37 person-rem and so the consequences of the first type of standard accident would be relatively minor.

Shipments of mixed oxide (PuO_2-UO_2) rods from the Cheswick Plutonium Fuel Development Laboratory in Cheswick, Pennsylvania (which are not expected to be initiated before January 1976) and of the mixed oxide fuel assemblies from NFCS to various nuclear power plants, involve slightly different considerations. Since the mixed oxide is a relatively high specific activity fuel material, additional precautions are taken in the packaging. Double containment is required for all mixed oxide materials. However, final designs for shipment containers of the rods and fuel assemblies have not been completed at this time. Such containers will meet all DOT and AEC requirements and are designed to prevent criticality under normal and hypothetical accident conditions. The pelletized form of the mixed oxide and its encapsulation help to ensure retention of the radioactive material even under hypothetical accident conditions. If in some extremely severe accidents some pellets are released from a package, the material should be in recoverable form. A pellet may be crushed or shattered but the particle sizes would fall predominantly in the non-respirable range. The particle size distribution would limit the area of contamination to the immediate vicinity of the ruptured package.

Based on the above considerations the impact on the environment from radiation or radioactive material release in transportation accidents involving mixed oxide fuel is considered negligible.(8)

5.2.4 REFERENCES

1. Title 10, Code of Federal Regulations, Part 71.
2. Title 49, Code of Federal Regulations, Parts 170 through 179.
3. Internal Memo. K-16-86, "Protective Packaging Overpack," Oak Ridge National Laboratory, Oak Ridge, Tennessee.
4. ORO-651, "UF_6 Handling and Container Design Criteria," Oak Ridge National Laboratory, Oak Ridge, Tennessee.
5. WASH-1248, "Environmental Survey of the Uranium Fuel Cycle," U. S. Atomic Energy Commission, Fuels and Materials Directorate of Licensing, April 1974, p. 20.
6. Westinghouse Cheswick Fuel Development Laboratories Environment Report, September 1974, Nuclear Fuel Division.
7. WASH-1238, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," Prepared by Directorate of Regulatory Standards, U. S. Atomic Energy Commission, December 1972.
8. WASH-1327, General Environmental Statement Mixed Oxide Fuel, Vol. 3, p. IV G49, Draft August 1974.

5.3 NONRADIOLOGICAL ACCIDENT EVALUATION

The most significant environmental problems that may occur at a low level enrichment nuclear fuel fabrication plant would most likely result from possible accidents associated with potentially harmful chemicals rather than from radioactive materials. Because of the low specific activity of uranium U-235 ($\leq$ 5.0 w/o), accidents which release chemicals would have, in most cases, a relatively greater environmental impact than from accidents associated with radioactivity which are described in Section 5.1. Thus, the NFCS can be considered in the same class as any other manufacturing plant in which significant quantities of nonradioactive chemicals are processed.

Potential environmental effects, both chemical and radiological from accidents involving uranium compounds were discussed in Section 5.1, Radiological Accident Evaluation, and will not be repeated in this section.

The chemicals presently stored on site are listed in Table 5.3-1 and estimated quantities for the 1600 MTU capacity are also included. Table 5.3-2 presents the types of chemical accidents that may occur from the most significant quantities of chemicals either stored on site or that are in some phase of plant processing. This table also lists the accident type, category, plant history and characterization of environmental effects in the event of an accident. The important chemical accidents would involve chemicals associated with uranium, anhydrous ammonia, aqueous ammonia, nitric acid and hydrogen.

A description and environmental effects of the various types of the chemical accidents that may occur at the NFCS are as follows.

5.3.1 CATEGORY TYPE 1 ACCIDENT WITHIN THE MANUFACTURING BUILDING

An accident of this type in the chemical processing area would be typified by minor liquid spills (i.e., 10 gallons or less) including acid, ammonium diuranate, uranyl nitrate and oil spills. A leak of this nature would be quickly detected by operators and corrective action (such as isolation of

TABLE 5.3-1

BULK CHEMICAL AND GAS STORAGE

	400 MTU/YR				ESTIMATED 1600 MTU/YR			
	Location	Total Gallons	Feet^3	Pounds	Gallons	Tank Size Gallons	Feet^3	Pounds
Liquid NH_4OH	Tank Farm	15,700			20,700	5,700		
Anhydrous Ammonia	"	30,000			60,000	18,000		
Nitric Acid (68%)	"	5,000			10,000	5,000		
Hydrogen (Liquid)	"	18,000	2,044,000		36,000	18,000	2,044,000	
Nitrogen (Liquid)	"	6,000	541,000		12,000	6,000	541,000	
Argon (Gas)	"	600	58,000		1,200	600	58,000	
Helium (Liquid)	"		138,000				276,000	
Uranium Hexafluoride	Outside Pad			550,000				1,100,000
Uranyl Nitrate (Liquid)	Inside Plant			25,000				80,000
Lime (CaO)	Waste Treat. Hopper			100,000				200,000
Zinc Stearate	Inside Plant			2,500				5,000
Miscellaneous								
Acetone	55 gal drums Oil House	825			1,650			
Sulfuric Acid (66 Baume + 45°)	55 gal drums Outside	770			1,540			
Nitric Acid (68%)	55 gal drums Outside	275			550			
Muriatic Acid (22% HCl)	55 gal drums Outside			800				1,000
Sodium Carbonate	Outside Tent			800				1,600
Caustic Soda (50% NaOH Solution)	Outside Tent 100 lb drums			500				1,000
Nickel Sulfate	Outside Tent			500				1,000

Note: Other small amounts of miscellaneous chemicals (500 lb or 55 gallons) are stored on plant site.

TABLE 5.3-2

TYPES OF CHEMICAL ACCIDENTS

	Category				Environmental Effect	
Outside	1	2	3	Plant History	Air	Water
Hydrogen Explosion	0	0	X	No record	X	X
Liquid Ammonia Tank Leak or Rupture	0	X	X	No record	X	X
Anhydrous Ammonia Tank Leak or Rupture	0	X	X	No record	X	X
Nitric Acid Tank Leak or Rupture	0	X	X	No record	X	X
UF_6 Cylinder Failure	0	0	X	No record	X	--
Lagoon Break	0	X	X	One major incident	--	X
Process Scrubber Failure	Z	0	0	No record	X	--
Inside						
UO_2 Dust Explosion (Fire)	0	0	X	No record	X	--
Hydrogen Explosion	0	0	X	No record	X	--
Liquid Spills	Z	0	0	Many (minor)	0	0

X - Significant emission possible

Z - Insignificant Emission

0 - Negligible or no significant emission

-- - No effect

the leaking line section) would be taken. The spilled liquids would be quickly cleaned up and transferred to appropriate waste containers or if appropriate, returned to the process for recovery. No floor drains are installed in the processing area of the main plant building and, therefore, there would be no release to the environment through either airborne or liquid pathways.

5.3.2 CATEGORY TYPE 1 ACCIDENT EXTERNAL TO THE MANUFACTURING BUILDING

Accidents of this type which are likely to happen during the life of the plant include minor process equipment leaks (50 gallons or less). Typical accidents of this type are leaks in pipes or tanks, overflowing tanks, ammonia still malfunction or slight oil leaks. A leak of this type would be located rapidly by operators and corrective action would be implemented.

Another possible accident of this type can result from the release of chemicals due to a leak in the liner of a waste holding pond. Details of such a leak that has occurred since the NFCS has been in operation are described in Section 5.1.1.2.3. In previous spills that occurred before improvements in the waste treatment process as required by the NPDES permit were implemented, chemical analysis of surface water indicated that fluoride concentrations increased from less than 1 mg/l for all sampling stations to 120 mg/l at the causeway station, to 108 mg/l at the spillway station and to 96 mg/l at the exit station. Ammonia concentrations increased from less than 1 mg/l to 40.1 mg/l at the causeway station. Such concentrations can be hazardous to aquatic life (Section 4.2.2.2.3, Effects on Surface Water Systems at the Westinghouse Property). However, these leaks occurred before inception of the NPDES permit program that resulted in improved waste treatment programs as described in Section 7.0 and therefore anticipated effects of future leaks should not be as great.

Also, improvements in the environmental monitoring program as described in Section 6.2 will lower the possibility of environmental hazards from such accidents.

5.3.3 CATEGORY TYPE 2 ACCIDENTS WITHIN THE MANUFACTURING BUILDING

In general, Category 2 accidents (leakages of approximately 50 gallons) are of greater magnitude than Category 1 but still could not result in releases that would be of concern to the external environment because of the reasons given for accidents of Category 1, as described in Section 5.1.3.1.

A greater environmental consideration must be given to the case when the water spray to the plant gaseous effluent scrubber fails. In this case ammonia and hydrogen fluoride would escape to the atmosphere unscrubbed. This could go undetected for a maximum of 8 hours since the scrubber is checked at least once each shift. This scrubber is 70-85 percent effective. Therefore, when discounting the scrubber efficiency, the maximum concentration of ammonia and hydrogen fluoride that would escape to the environmental atmosphere during a maximum of 8 hours would be 36.28 mg/m^3 and 107 $\mu g/m^3$, respectively (Section 4.2.2.1.3). Assuming 75 percent scrubber efficiency, for ammonia, such releases are below the OSHA standards. It is very possible that the strong odor of ammonia emitted during such an accident will alert operators to the possibility of such a water spray failure. Fluoride emissions are not regulated by federal or local agencies other than the South Carolina deposition standard of 0.3 $\mu g/cm^2$/month. Although the South Carolina deposition standard could be exceeded during such an accident, the maximum concentration of hydrogen fluoride emitted though these stacks will be below the TLV set by American Conference of Government and Industrial Hygienists. This recommended value is 3 ppm in air or 2 mg/m^3.(1) The recent TLV ammonia value of 18 mg/m^3 will be exceeded during an accidental period of 8 hours. In 1967 the TLV value was 35 mg/m^3.

It should be noted, that since the NFCS has been in operation, such an accident has not occurred (Table 5.3-2).

5.3.4 CATEGORY TYPE 2 ACCIDENTS EXTERNAL TO THE MANUFACTURING BUILDING

These types of accidents occurring in the chemical storage areas could result in complete or partial emptying of a storage tank. The releases would flow to the storm drainage ditch to the upper Sunset Lake where it would mix and flow into lower Sunset Lake, via a causeway. The lower Sunset Lake drains into Mills Creek which eventually enters the Congaree River via a meandering route of approximately 7 miles. Both Sunset Lakes are on Westinghouse property.

In the event of a major spill the upper lake can be closed off at the causeway and diluted by increasing the diverted flow of incoming Mill Creek water to the upper Sunset Lake. The continuous chemical monitoring and the prompt dilution of these waters can prevent significant liquid releases to offsite environment from occurring. As part of the plant improvement program protective dikes that would contain approximately 36,000 gallons in the event of complete tank failure will be placed around the chemical tank farm in 1975. The largest bulk storage tank is the anhydrous ammonia tank having a capacity of 18,000 gallons.

Once these dikes are installed there would not be a loss of liquid solution from the area.

Each of the bulk storage tanks are discussed in the following paragraphs on the basis of the largest size tank for each chemical listed in Table 5.3-1.

5.3.4.1 AQUEOUS AMMONIA TANK

Criticality, power failure, water failure and fire conditions are not applicable. A projectile from an adjacent explosion would puncture one of the largest ammonia tanks, 5700 gallons capacity and concentration of 27 percent, resulting in discharge of a portion of its contents to the drainage ditch.

Ammonium hydroxide is not very volatile and an airborne concentration of 1000 ppm at the area can be assumed. Using the aeolian dilution factor, χ/Q, of 4.8×10^{-4} sec/m^3 at 1800 feet (the nearest property boundary), the concentrations of ammonia at the nearest property boundary will be 0.48 ppm.

The effect of 5700 gallons of ammonium hydroxide of 27 percent entering the Upper Sunset Lake that has a capacity of 43 million gallons would be an increase of 36 mg/l of ammonium hydroxide. Such an increase would occur when complete mixing is accomplished. In a lake, mixing is usually slow, and therefore it is possible that ammonia concentration will be higher at the point where the spill enters the lake. Ammonium hydroxide is in equilibrium with ammonia. Under the lake conditions it appears that the concentration of undissociated ammonia will exceed the recommended surface water criteria of 0.5 mg/l (see Table 4.2-22 and discussion in Section 4.2.2.2.3).

Examination of Table 5.3-2 indicates that since the NFCS has been in operation, more than 5 years, there were no such accidents.

5.3.4.2 ANHYDROUS AMMONIA

The anhydrous ammonia storage is governed by OSHA rules No. 1910.111. Each vessel is not to be filled with more than 87.5 percent of capacity.

Water or power failure, criticality, and explosion will not result in release of anhydrous ammonia. The storage tanks are constructed of welded steel and are capable of withstanding high operating pressures. A release due to fire could occur. However, to reduce this possibility, pressure relief valves are installed to prevent overpressure in case of fire.

Exposure of the storage vessel to an intense fire would result in operation of the relief valves, designed to relieve overpressure. The release would cease as the fire is extinguished. Ammonia vapors could reach 50 percent concentration in the release area.

By utilizing an aeolian dilution factor (χ/Q of 4.8×10^{-4}) at 1800 feet, it is expected that the concentrations at the nearest site boundary would be less than 240 ppm. The recommended TLV is 50 ppm and 400 to 700 ppm for one hour would ordinarily have no permanent effect on man(2). Thus, the 240 ppm of ammonia that could be released as a result of such an accident are not anticipated to have a severe impact. Such an accident has not occurred at the NFCS plant to date (see Table 5.3-2).

5.3.4.3 NITRIC ACID

The nitric acid tanks (5000 gallons each and of a concentration of 68 percent) are stored in stainless steel tanks that are self contained. Power failure, water failure and fire will not cause a release. A projectile from an explosion could pierce the tank wall, resulting in release of all or part of the vessel's contents. The material would then drain into the storm ditch and eventually to Sunset Lake. Assuming that the complete content of one ruptured tank enters the Upper Sunset Lake and if complete mixing occurs, the nitrate ion concentration will increase in this lake by 78 mg/l. Since mixing is slow in lakes, the concentration at the entrance to the lake will be high enough to harm the aquatic community of the lake. Thus, preventative measures, such as construction of dikes beginning in 1975, will eliminate this environmental concern. Such an accident has not occured at the NFCS plant to date (see Table 5.3-2).

5.3.4.4 LAGOON

As discussed in Section 5.1.1.4.3, a massive failure in the west lagoon wall lining occurred on October 20, 1971 and cannot be discounted that it cannot credibly happen again. Approximately 1,500,000 gallons containing 62,500 pounds of NH_3 (5000 ppm NH_3), 18,800 pounds of fluoride (1500 ppm) and 125 pounds solids (0.010 mg/ml) were released in the incident to the upper Sunset Lake. The lake was held in a closed off condition from the lower Sunset Lake and samples were taken to determine the concentration of the lake. Corrective action was taken by diluting the upper Sunset Lake with increased inlet Mill Creek diverted water. The South Carolina Pollution Control Authority, South Carolina Division of Radiological Health, and the AEC were advised of the incident. Approximately 7 barrels, 55 gallons each, of fish, primarily carp, were killed.

Records of Section 2.7.2, Aquatic Ecology, indicate that the dissolved oxygen content is at times marginal for sustaining fish due to the nature of this kind of swampy lake water. The addition of the released chemicals was then probably more than sufficient to produce this fish kill.

Kills of this magnitude are highly improbable in the future since chemical concentrations in the lagoons have been reduced substantially through the use of more advanced waste treatment techniques. Since this massive failure, the lagoon walls have been redesigned to withstand the maximum hydrostatic stress pressure. Also, the NFCS is improving the chemical monitoring program as described in Section 6.2.2. These improvements will help detect such leaks sooner, so that appropriate measures can be taken promptly.

5.3.5 CATEGORY TYPE 3 ACCIDENTS

Accidents of this nature are catastrophic in magnitude and are not expected in the plant's lifetime. All of these are extremely unlikely and involve either container rupture, failure, explosion, fire, natural disaster, or an extremely improbable criticality type accident. Storage vessels are designed using good engineering practice and are filled according to safe operating procedures. To experience a rupture or failure, some unforeseen catastrophic disaster would have to occur or else all current safety systems would have to deteriorate simultaneously.

The Category 3 accident in the chemical storage area would release no more than the contents of a chemical storage tank or from a massive lagoon break. This type of release has been discussed in Section 5.1.1.4.3.

Another major accident could result from a hydrogen explosion. As a result of such an accident, tanks containing chemicals could be ruptured. Environmental hazards associated with such ruptures have been discussed in previous sections. To prevent such an accident the hydrogen gas tanks are stored and handled according to OSHA No. 1910.10 regulation and maintained according to procedures recommended by the Linde Division of the Union Carbide Company. As a result of these precautions and careful handling, no such accidents have occurred since this plant has been in operation, more than 5 years.

5.3.6 REFERENCES

1. American Conference of Government Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment, 1973.

2. Manufacturing Chemists' Association Inc., Chemical Safety Data Sheet SD-8, Properties and Essential Information for Safe Handling and Use of Ahydrous Ammonia, 1825 Connecticut Avenue, N. W., Washington 9, D.C., 1960.