Evaluation of Risks Associated with Potential Metal Recycling of Uranium Hexafluoride Samples

Prepared for

Westinghouse Electric Company, LLC
Columbia Fuel Fabrication Facility
Columbia, SC

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ACRONYMS AND ABBREVIATIONS

ac	acre
atm	atmosphere
ADU	ammonium diuranate
AIHA	American Industrial Hygiene Association
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
Bq	Becquerel
^{o}C	degrees Celsius
CEDE	committed effective dose equivalent
CFFF	Columbia Fuel Fabrication Facility
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
cm^3	cubic centimeter
CRG	Carolinas Recycling Group
DCF	dose conversion factor
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERPG	emergency response planning guidelines
ºF	degrees Fahrenheit
ft	feet
ft^3	cubic feet
g	gram
gal	gallon (U.S.)
ha	hectare
HF	hydrogen fluoride
hr	hour
in.	inch
kg	kilogram
km	kilometer
L	liter
LLC	Limited Liability Company
μCi	microcurie
μg	microgram
m	meter
m^2	square meters
mg/m^3	milligrams per cubic meter

ACRONYMS AND ABBREVIATIONS (Cont'd)

mi	statute mile(s)
mil	milliliter
mPa	megapascal
mrem	millirem
NWS	National Weather Service
NRC	U.S. Nuclear Regulatory Commission
Pa	pascal
pCi	picocurie
psi	pounds per square inch
s	second
SC	South Carolina
SC-DHEC	South Carolina Department of Health and Environmental Control
SNM	special nuclear material
TtNUS	Tetra Tech NUS, Incorporated
^{235}U	uranium-235
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
WEC	Westinghouse Electric Company LLC
WMI	Waste Management, Incorporated
yr	year

UNITS CONVERSION FACTORS

Length

1 centimeter (cm) = 0.3937 inch	1 inch = 2.54 cm
1 centimeter = 0.03281 foot (ft)	1 foot = 30.48 cm
1 meter (m) = 3.281 feet	1 ft = 0.3048 m
1 meter = 0.0006214 mile (mi)	1 mi = 1609 km
1 kilometer (km) = 0.6214 mile	1 mi = 1.609 km

Area

1 square centimeter (cm^2) = 0.1550 square inch (in^2)	1 in^2 = 6.452 cm^2
1 square meter (m^2) = 10.76 square feet (ft^2)	1 ft^2 = 0.09294 m^2
1 square kilometer (km^2) = 0.3861 square mile (mi^2)	1 mi^2 = 2.590 km^2
1 hectare (ha) = 2.4710 acres (ac)	1 ac = 0.4047 ha
	1 ac = 43560 ft^2
1 hectare (ha) = 10,000 square meters (m^2)	1 ft^2 = 0.00002296 ac

Volume

1 cubic centimeter (cm^3) = 0.0610 cubic inch (in^3)	1 in^3 = 16.39 cm^3
1 cubic meter (m^3) = 35.31 cubic feet (ft^3)	1 ft^3 = 0.02832 m^3
1 cubic meter (m^3) = 1.308 cubic yards (yd^3)	1 yd^3 = 0.7646 m^3
1 liter (L) = 1.057 quarts (qt)	1 qt = 0.9463 L
1 liter = 0.2642 gallon (gal)	1 gal = 3.785 L

Mass

1 kilogram (kg) = 2.205 pounds (lb)	1 lb = 0.4536 kg
1 metric ton (mt) = 1.102 tons	1 ton = 0.9072 mt

Pressure

1 pascal (Pa) = 1 newton/m^2	1 atm = 0.101 MPa
1 pascal = 1.451×10^{-4} lb/in^2 (psi)	1 atm = 14.8 psi

Radiation

1 becquerel (Bq) = 1 disintegration /s	
1 becquerel = 2.703×10^{-11} curies (Ci)	1 Ci = 3.70×10^{10} Bq
1 sievert (Sv) = 100 rem	1 rem = 0.01 Sv

1.0 INTRODUCTION

The Westinghouse Electric Company, LLC (WEC) operates the Columbia Fuel Fabrication Facility (CFFF) to fabricate low-enriched uranium fuel assemblies for commercial light-water nuclear reactors. The CFFF is approximetly 13 km (8 mi) southeast of Columbia, SC in Richland County. The facility has been in operation from 1969 to the present. The fabrication process involves the chemical conversion of uranium hexafluoride (UF_6) to uranium dioxide (UO_2) using the Ammonium Diuranante (ADU) Process. The uranium dioxide is formed into ceramic fuel pellets which are used in the nuclear fuel assembly. In accordance with Title 10, Code of Federal Regulations, Part 70 (10 CFR 70), WEC operates CFFF under Special Nuclear Material License 1107 (SNM-1107) issued by the U.S. Nuclear Regulatory Commission (NRC).

As part of CFFF operations, samples of UF_6 contained in P-10 sample tubes are analyzed for uranium isotopic content. During preparation of receipt transaction documentation on February 12, 2008, WEC personnel discovered that laboratory analysis results for two shipping containers, each with eight, P-10 sample tubes could not be located. Investigating further, the sample tubes and shipping containers could not be located in the laboratory or on site.

The two shipping containers consist of 25.9 L (6.85-gal) galvanized buckets, painted blue with a rim-sealed top. The P-10 sample tubes are fabricated from flurothene and are sealed with monel fittings. Within each bucket, the eight, P-10 sample tubes are packed in polystyrene “peanuts”. There is approximately 100 grams (g) of UF_6 containing 64 g uranium at an average enrichment of 4.95 percent uranium-235 (^{235}U) in each of the two shipping containers. The 100 g of UF_6 is evenly distributed in the eight P-10 sample tubes in the bucket. The total uranium amount of 128 g has a radioactivity content of 409.4 microcuries (μCi).

WEC notified the NRC of the event on the day it was discovered, and NRC included the event in the Current Event Notification Report for February 15, 2008 (NRC 2008). WEC also discussed the matter with the South Carolina Department of Health and Environmental Control (SC-DHEC) and Richland County.

Subsequently, WEC asked Tetra Tech NUS, Incorporated (TtNUS) to perform an independent assessment of the potential risks associated with the long term disposal of the UF_6 samples at a landfill location in Richland County Landfill operated by Waste Management, Incorporated (WMI) in Elgin, SC. (TtNUS 2008). After further discussions with WEC, SC-DHEC asked WEC to evaluate the risks associated with the potential for inadvertent disposal of the two buckets and UF_6 sample tubes through scrap metal pickup at CFFF and disposal of the scrap metal through a metal recycle facility.

At the request of WEC, TtNUS performed an independent assessment of the potential risks associated with the potential metal recycling of the UF_6 samples. This report documents the TtNUS risk assessment. Section 2.0 presents a summary of the assessment, with details of the study presented in subsequent sections. Section 3.0 presents additional background information to provide a basis for the assessment. Section 4.0 describes the assessment methodology. Section 5.0 presents the results and conclusions of the study. Section 6.0 presents a list of cited references.

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2.0 SUMMARY

Based on an evaluation of information on the operations associated with scrap metal handling, transfer, shredding, and smelting, the most likely release location involving the UF_6 sample tubes would be at the Carolinas Recycling Facility near Spartanburg, SC. Due to potential temperatures involved in the shredding operation, the original solid UF_6 would be expected to sublime into vapor form. When released to the atmosphere, gaseous UF_6 combines with humidity to form particulate uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF), both of which are soluble and toxic. The reaction is fast and is dependent on the availability of water vapor. Upon escape, the UF_6 gas could interact with metals, yielding among other reaction products metal fluorides and hydrogen. Since the total quantity of UF_6 is only 200 g, the amount of reaction products would not be large in any case.

In developing release scenarios for this report, TtNUS has assumed total release of the UF_6 as a sublimed vapor. This approach will bound estimates of the potential exposure to radiation and hazardous material. Rather than total release, it is more likely that only a fractional release to the atmosphere would occur and any remaining UF_6 would be tied up in bulk reaction products of a limited volume (e.g., on the order of 1 m^3 [35 ft^3]). Consideration of a metal smelting scenario, in which the UF_6 remained with the metal stream and not sublime up to the point of smelting, would likely lead to lower exposures. The heated plume and stack release would lead to greater dispersion. Given that smelting takes place in a reducing atmosphere, it would be unlikely that any released UF_6 reaction products would end up in an oxide form.

In evaluating the potential hazards associated with the UF_6 sample vials, TtNUS evaluated the potential radiation doses and concentrations of hazardous material. Two exposure scenarios were examined: 1) a maximum exposure scenario, and 2) a nominal exposure scenario.

The U.S. Environmental Protection Agency's (EPA) CAP-88 model was used in evaluating the maximum exposure scenario. In this approach, all the radioactivity in the UF_6 samples of 409.4 μCi is assumed to be released at ground level under restrictive meteorological conditions that lead to the highest concentrations. The results indicated that the radiation dose associated with the maximum exposure scenario is 5.5 millirem [mrem]/yr at 100 m and 0.96 mrem/yr at 250 m. This can be compared to background radiation levels of nominally 300 mrem/yr and the EPA annual dose criterion of 100 mrem/yr to members of the public from all human-related sources.

The estimated maximum exposure over a period of 1 hour to UF_6 is 0.32 mg/m^3 at 100 m and 0.055 mg/m^3 at 250 m. Assuming the concentrations occurred only during a plume passage time of 100 s, the estimated concentrations would be 11.6 mg/m^3 at 100 m and 2.0 mg/m^3 at 250 m.

The American Industrial Hygiene Association (AIHA) has developed emergency response planning guidelines (ERPGs) for acute exposures at three different levels of severity. These guidelines represent concentrations for exposure of the general population for up to 1 hour associated with effects expected to be mild or transient (ERPG-1), irreversible or serious (ERPG-2), and potentially life-threatening (ERPG-3). ERPG values for UF_6 are as follows:

- ERPG-1: 5.0 mg/m^3
- ERPG-2: 15.0 mg/m^3
- ERPG-3: 30.0 mg/m^3

The results indicate that the concentrations would be below the ERPG-1 values at 100 m for a 1 hr reference exposure period. The concentrations during a 100 s plume passage period would be below the ERPG-2 value at 100 m.

The nominal exposure scenario considers the range of meteorological conditions affecting atmospheric transport and dispersion. The results for the Spartanburg site are slightly lower than the Columbia site, indicating more dilution at the former site. The results for radiation dose and UF_6 concentrations versus downwind distance for the nominal exposure scenario are about 5 percent of those values for the maximum exposure scenario.

As an extension of the maximum exposure scenario, the potential for direct contact with the UF_6 has been considered. The material is corrosive, and harmful by inhalation, ingestion or skin absorption. The effects of exposure may be delayed. Should a worker come into direct contact with the UF_6 sample tubes, and be subject to a skin exposure, there is potential for an acid burn, which is treatable with calcium gluconate.

Given the assumptions regarding the potential metal recycling of the UF_6 sample tubes, TtNUS concludes that the potential radiation and chemical exposure risks posed by the UF_6 sample tubes are small when compared to exposure and natural background radiation levels.

3.0 BACKGROUND INFORMATION

This section presents background information on the physical and chemical properties of uranium hexafluoride (UF_6) (Section 3.1); protection guidelines for radiation and hazardous material exposures (Section 3.2); the UF_6 shipping containers and P-10 sample tubes (Section 3.3); scrap metal pickup and metal recycling (Section 3.4); and the potential long-term fate of UF_6 (Section 3.5).

3.1 Uranium Hexafluoride

Information on UF_6 is summarized below with respect to its physical and chemical properties, and potential health effects associated with radiation and chemical exposure (based in part on ANL 2008).

3.1.1 Physical Properties

The mass density of solid UF_6 at 20°C (68°F) is 5.1 g/cm^3 and its molecular weight is 352 g/mole. At ambient conditions UF_6 is a volatile, white, crystalline solid. Solid UF_6 is readily transformed into the gaseous or liquid states by the application of heat. The phase diagram covering the range of conditions usually encountered in working with UF_6 is presented in Figure 3-1. It shows the correlation of pressure and temperature with the physical state of UF_6. The vapor pressure above the solid reaches 0.1 mPa (1 atm) at 56°C (133°F), the sublimation temperature. The triple point occurs at a pressure of 0.15 mPa (1.5 atm) and a temperature of 64°C (147°F). These are the only conditions at which all three states (solid, liquid and gas) can exist in equilibrium. If the temperature or pressure is greater than at the triple point, there will only be gas or liquid. Only the gaseous phase exists above 230°C (446°F), the critical temperature, at which the critical pressure is 4.61 mPa (45.5 atm). The vapor pressure above the solid reaches 0.1 mPa (1 atm) at 56°C (133°F), the sublimation temperature.

3.1.2 Chemical Properties

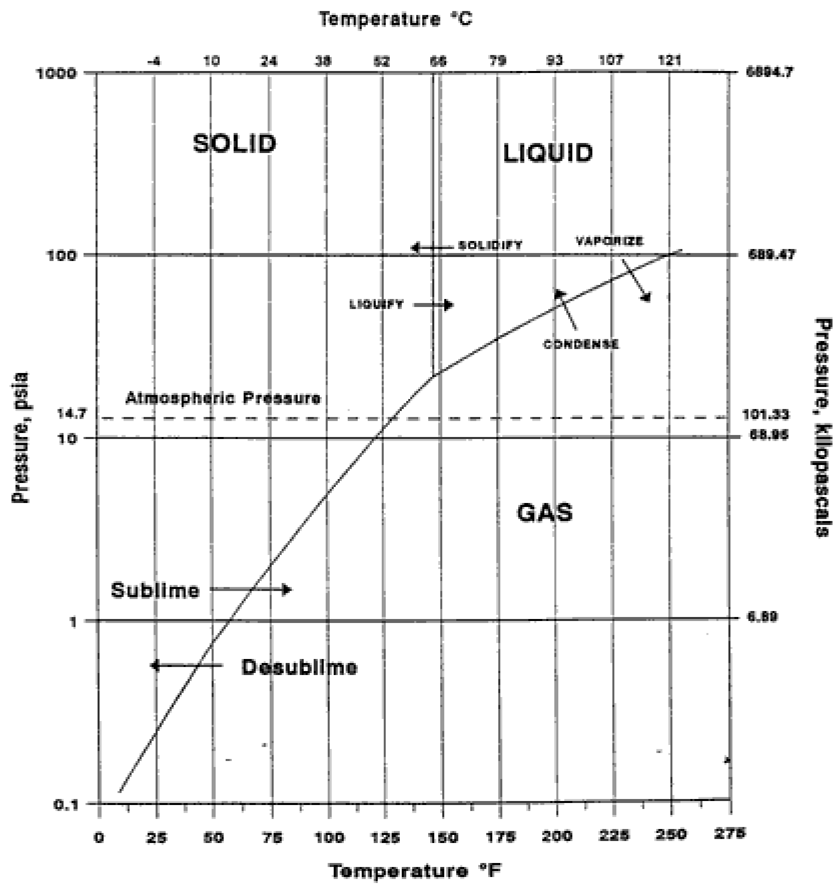
Uranium hexafluoride (UF_6) does not react with oxygen, nitrogen, carbon dioxide, or dry air. UF_6 is hygroscopic (i.e., moisture-retaining) and, in contact with water (H_2O), will decompose immediately into the soluble reaction products of uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF), both of which are water soluble. UF_6 is essentially inert to clean aluminum, steel, Monel, nickel, aluminum, bronze, copper, and Teflon.

When released to the atmosphere, gaseous UF_6 combines with humidity to form particulate UO_2F_2 and HF fumes. The reaction is fast and is dependent on the availability of water vapor.

In a fire, the reaction of UF_6 with water is accelerated because of the increased UF_6 vapor pressure and the water vapor formed in combustion of organic materials or hydrocarbons. Reaction of liquid UF_6 with hydrocarbon vapors is vigorous in flames, with formation of UF_4 and low-molecular-weight fluorinated compounds. More heat is generally released in these hydrocarbon interactions with UF_6 than in the corresponding reactions of hydrocarbons with oxygen.

3.1.3 Health Hazards

Uranium hexafluoride (UF_6) and related compounds have radiological and chemical characteristics that pose potential health risks. The uranium content is radioactive, with a



Source: ANL 2008

Figure 3-1 Phase Diagram for UF_6.

specific activity dependent on the percent enrichment of uranium-235 (^{235}U), exposure to which could result in a radiation dose. If UF_6 is released to the atmosphere, the UO_2F_2 and HF formed by reaction with moisture in the air can be chemically toxic. Uranium is a heavy metal that, in addition to being radioactive, can have toxic chemical effects (primarily on the kidneys) if it enters the bloodstream by means of ingestion or inhalation. HF is a corrosive gas that can damage the lungs if inhaled at high enough concentrations.

3.2 Protection Guidelines for Radiation and Hazardous Material Exposures

Exposure to ionizing radiation is characterized in terms of radiation dose, reported in units of millirem (mrem) in this report. The U.S. Environmental Protection Agency (EPA) has established radiation protection guidelines for members of the public such that radiation doses from all sources should be below 100 mrem/yr. For sites contaminated with radioactive materials that result in radiation doses greater than 100 mrem/yr, site cleanup criterion call for cleanup to as low as reasonable achievable (ALARA). In application of this criterion, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) take this ALARA level to be 25 mrem/yr above background radiation levels.

When exposure to UF_6 is considered from a chemical toxicity viewpoint, the American Industrial Hygiene Association (AIHA) has developed emergency response planning guidelines (ERPGs) for acute exposures at three different levels of severity. These guidelines represent concentrations for exposure of the general population for up to 1 hour associated with effects expected to be mild or transient (ERPG-1), irreversible or serious (ERPG-2), and potentially life-threatening (ERPG-3). ERPG values for UF_6 are as follows:

- ERPG-1: 5.0 mg/m^3
- ERPG-2: 15.0 mg/m^3
- ERPG-3: 30.0 mg/m^3

3.3 Shipping Containers and P-10 Sample Tubes

The P-10 tubes are constructed of flurothene (tri-fluoro-chloro-ethylene [TFCE]), as shown in Figure 3-2. The tubes are nominally 8 cm (3.1 in.) long (10 cm [3.9 in.] with the monel closure), 1.25 cm (0.49 in.) outer diameter, and 0.85 cm (0.33 in.) inside diameter. The volume of the tube is 4 cm^3.

The usual complement of eight (8) P-10 tubes has each tube individually heat-sealed into a pocket of a heavyweight (approximately 0.01 cm [0.004 in. or 4 mil]) polyethylene envelope. The envelope is rolled, wrapped in bubble wrap, and surrounded with polystyrene "peanuts" within a 25.9 L (6.85 gal) (30.5 cm diameter x 35.6 cm deep [12 in. x 14 in.]), 25 gauge, steel bucket. The bucket has a ring clamp lid closure and is painted blue.

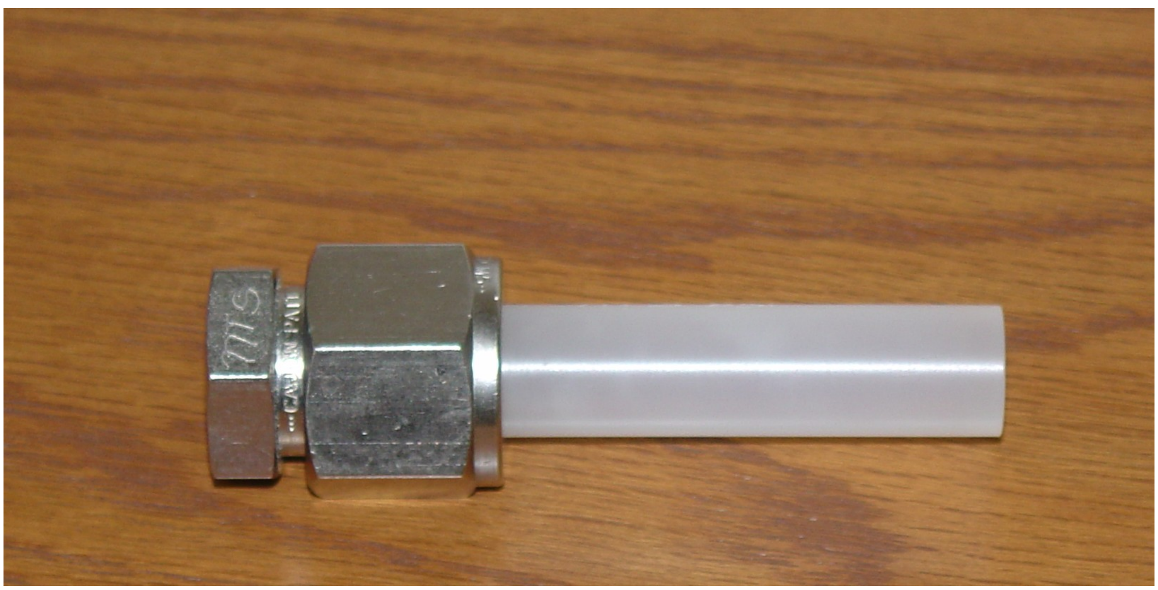


Figure 3-2 P-10 Sample Tube

There is approximately 100 g of UF_6 containing 64 g uranium at an average enrichment of 4.95 percent uranium-235 (^{235}U) in each of the two shipping containers. The 100 g of UF_6 is evenly distributed in the eight P-10 sample tubes in the bucket. The total uranium amount of 128 g has a radioactivity content of 409.4 microcuries (μCi). The isotopic composition of the UF_6 is presented in Table 3-1.

Table 3-1

Isotopic Composition of UF_6 Samples

Radionuclide	Specific Activity, μ Ci/g [a]	Total Activity, μ Ci [b]
U-234	2.767	354.2
U-235	0.106	13.6
U-236	0.002	0.256
U-238	0.323	41.3
	Total	409.4

a. μ Ci/g - microcurie/gram

b. Total activity = specific activity x 128 g uranium total

3.4 Scrap Metal Pickup and Metal Recycling

As part of CFFF operations, WEC has a Recycle Bin in which material destined for off-site recycle is placed. WEC contracts with a scrap metal dealer who brings in an empty bin and picks up the full bin. This scenario consists of placement of the two buckets containing the UF_6 sample tubes in the Recycle Bin, which is hauled off-site to a metal recycling facility. The normal bin pickup and recycle process involves first transporting the bin to the Columbia Recycling Center located on the south side of Columbia, SC and operated by the Carolinas Recycling Group (CRG). At this location, the bin is dumped and the unsorted recycle material is transferred to a larger truck. The larger truck then transports the material to a CRG metal shredding facility located in Lyman, SC, which is near Spartanburg, SC.

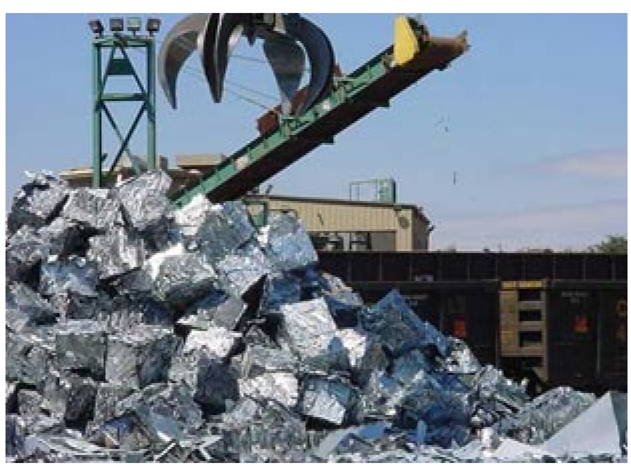
Operations at a typical metal shredding facility are shown in Figure 3-3 (CRG 2008). There is an incoming storage pile area where the material is initially dumped. Then the material is picked up for input into the shredding facility. The shredding process involves multiple operations, in which material is received, conveyed, shredded and separated. The actual shredding and separation process is enclosed, and pneumatic conveying systems employ cyclone separators to collect non-metal material. The input material is a mixed nature (e.g., metal, glass and paper) and is shredded into pieces no larger than nominally 8 cm (3 in.) in size. Separation of metal from non-metal material is accomplished by air streams that entrain the lighter density material. Following separation of shredded metal by type and quality, the sorted metal is picked up and transported to a variety of locations for smelting. The latter pickup, transport and smelting is undertaken by any one of a number of CRG customers.

3.5 Potential Fate of UF_6

In evaluating the potential fate of the UF_6 samples, the various mechanical operations need to be considered with regard to response of the samples to the types of mechanical environments involved. The transfer operations at the Columbia Recycle Center would likely cause minimal damage to the samples. The sample tubes are small, and would have been surrounded by the polystyrene "peanuts". The Recycle Bin from CFFF is initially dumped near a larger pile of recycle material. The material in the pile could range in size, for example, from small discarded items to items possibly as large as a refrigerator. Although some crushing takes place in the

Source: CRG 2008.

Figure 5-3   Typical Metal Recycling Facility Equipment and Operations (Page 1 of 2)



Source: CRG 2008.

Figure 5-3 Typical Metal Recycling Facility Equipment and Operations (Page 2 of 2)

pile and during transfer to the larger truck, significant crushing to the point of failing for the sample tubes is unlikely. Furthermore, in the unlikely situation where sampling tube failure would occur, only a few sampling tubes would be affected.

The more likely release condition would occur at the metal shredding facility near Spartanburg, SC. In those operations, TtNUS assumes that all sample tubes are breached and the lighter, flurothene tubing with UF_6 in solid form pneumatically separated from the metal stream. The monel end cap would go with the metal stream, and the cap could have a portion of the tube attached. It becomes a matter of the net mass density of the object whether the pneumatic separation system picks up the item and separates it from the metal stream.

As noted in Section 3.1.1, the vapor pressure above the solid reaches 0.1 mPa (1 atm) at 56°C (133°F), the sublimation temperature (analogous to the boiling point of a liquid, where the vapor pressure reaches the same value). In an open atmosphere, at lower temperatures, however, significant sublimation would still take place (in a manner analogous to evaporation of a liquid at temperatures below the boiling point). Prior to the shredding operation, it is unlikely that the sample tubes would experience a temperature of 56°C (133°F). During the shredding operation, temperatures could likely exceed this temperature, since the shredding is mechanically intense. Thus, one could envision that the failed tubes would release UF_6 as a vapor. Should intact or failed tubes be separated from the metal stream with the UF_6 still remaining in solid form, they would end up in the cyclone separator. The material in the cyclone separator ends up as bulk debris and dust-like material that is used as recycled material in some form.

Based on the information provided above, and given the lack of details on the actual response of the sample tubes to the shredding operation, one could hypothesize using the Maximum Entropy Principle, that the available UF_6 could be found distributed with equal likelihood in every identified state (i.e., the atmosphere, the material collected in the cyclone separated, and the metal stream). Any UF_6 on surfaces in contact with the atmosphere would either react with the surfaces or sublime as a vapor.

As noted in Section 3.1.1, when released to the atmosphere, gaseous UF_6 combines with humidity to form particulate UO_2F_2 and HF fumes. The reaction is fast and is dependent on the availability of water vapor. Upon escape, the UF_6 gas could interact with metals, yielding among other reaction products metal fluorides and hydrogen. Following deposition of material in the plume, contact of HF with soil in the form of silicon dioxide (SiO_2, quartz sand) would lead to silicon fluoride salts and water. Since the total quantity of UF_6 is only 200 g, the amount of reaction products would not be large in any case.

In developing release scenarios for this report, TtNUS has assumed total release of the UF_6 as a sublimed vapor. Upon release, the vapor UF_6 combines with humidity to form particulate UO_2F_2 and HF fumes, which are transported downwind. This approach will bound estimates of the potential exposure to radiation and hazardous material. Rather than total release, it is more likely that only a fractional release to the atmosphere would occur and any remaining UF_6 tied up in bulk reaction products of a limited volume (e.g., on the order of 1 m^3 [35 ft^3]). Consideration of a metal smelting scenario, in which the UF_6 remained with the metal stream and not sublime up to the point of smelting, would likely lead to lower exposures. The heated plume and stack release would lead to greater dispersion. Given that smelting takes place in a reducing atmosphere, it would be unlikely that any released UF_6 reaction products would end up in an oxide form.

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4.0 ASSESSMENT METHODOLOGY

In evaluating the potential hazards associated with the UF_6 sample vials, TtNUS evaluated the potential radiation doses and concentrations of hazardous material. As noted in Section 3.5, it that assumed total release of the UF_6 as a sublimed vapor during the metal shredding operation. Upon release, the vapor UF_6 combines with humidity to form particulate UO_2F_2 and HF fumes, which are transported downwind. Two exposure scenarios are examined: 1) a maximum exposure scenario, and 2) a nominal exposure scenario.

In evaluating the maximum exposure scenario, the entire radioactivity in the UF_6 samples of 409.4 μCi is assumed to be released at ground level under restrictive meteorological conditions that lead to the highest concentrations. Those conditions are assumed to be an F atmospheric stability class with a wind speed of 2 m/s (6.6 ft/s). The U.S. Environmental Protection Agency's (EPA) code CAP-88, Version 2.1 was used in estimating the concentrations at selected downwind distances (EPA 2008). The internal dose conversion factors (DCFs) used in this assessment are those from Federal Guidance 11 (EPA 1988). The dose conversion factors are a function of the solubility class of the chemical compound and the particle size. Since gaseous UF_6 is expected to combine with humidity to form particulate UO_2F_2 and HF fumes, which are soluble, TtNUS selected a D solubility class and a 1 micrometer (μm) particle size for the DCFs.

From a chemical exposure viewpoint, the exposure concentrations of UF_6 can be estimated in a manner consistent with that for the radiation doses by using the normalized time-integrated concentrations, X/Q, values generated as part of the CAP-88 runs. The X/Q value can be interpreted as a time-integrated dilution factor per unit release.

The nominal exposure scenario considers the range of meteorological conditions affecting atmospheric transport and dispersion. For this scenario, five years of National Weather Service (NWS) data (1988 to 1992) from the Greenville-Spartanburg, SC Airport were used to evaluate the mean X/Q value. For completeness, one could hypothesize a release at the Columbia Recyling Center although no mechanism is postulated that would result in that scerario. This site was also considered in the same manner, except that NWS data for Columbia, SC were used.

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5.0 RESULTS AND CONCLUSIONS

Section 3.0 outlined the approaches TtNUS took in evaluating the potential hazards associated with the UF_6 sample vials. The results of this evaluation are presented below.

5.1 Maximum Exposure Scenarios

In evaluating the maximum exposure scenario, the entire radioactivity in the UF_6 samples of 409.4 μCi is assumed to be released at ground level under restrictive meteorological conditions that lead to the highest concentrations. The results of the CAP-88 runs are presented in Table 5-1 in terms of the committed effective dose equivalent (CEDE) versus downwind distance and the associated normalized time-integrated air concentration, χ/Q.

Table 5-1

Radiation Doses for Maximum Exposure Scenario

Downwind Distance, m	Dose, mrem/yr	χ/Q, s/m^3
100	5.53×10^{0}	5.80×10^{-3}
250	9.61×10^{-1}	9.96×10^{-4}
500	2.56×10^{-1}	2.61×10^{-4}
750	1.19×10^{-1}	1.19×10^{-4}
1000	6.88×10^{-2}	6.79×10^{-5}

Based on these results the radiation dose associated with the maximum exposure scenario is 5.5 mrem/yr at 100 m and 0.96 mrem/yr at 250 m. This can be compared to background radiation levels of nominally 300 mrem/yr and the EPA annual dose criterion of 100 mrem/yr to members of the public from all human-related sources.

From a chemical exposure viewpoint, the exposure concentrations of UF_6 can be estimated in a manner consistent with that for the radiation doses by using the χ/Q values in Table 5-2. Assuming a release of 200 g of UF_6, and assuming a time integration of 1 hr (3,600 s) corresponding to the AIHA reference exposure period, the estimated concentrations at the downwind distances of interest are presented in Table 5-2. Estimates are also provided for a total plume passage time of 100 s.

The estimated maximum exposure over a period of 1 hour to UF_6 is 0.32 mg/m^3 at 100 m and 0.055 mg/m^3 at 250 m. Assuming the concentrations occurred only during a plume passage time of 100 s, the estimated concentrations would be 11.6 mg/m^3 at 100 m and 2.0 mg/m^3 at 250 m. These concentrations can be compared with the 1 hr ERPG values for UF_6 which are as follows:

- ERPG-1: 5.0 mg/m^3
- ERPG-2: 15.0 mg/m^3
- ERPG-3: 30.0 mg/m^3

Table 5-2

UF_6 Concentrations for Maximum Exposure Scenario

Downwind Distance, m	χ/Q, s/m^3	UF_6 Concentration, mg/m^3 [a]	
		1 hr[a]	100 s[b]
100	5.80×10^{-3}	3.22×10^{-1}	1.16×10^{1}
250	9.96×10^{-4}	5.53×10^{-2}	1.99×10^{0}
500	2.61×10^{-4}	1.45×10^{-2}	5.22×10^{-1}
750	1.19×10^{-4}	6.61×10^{-3}	2.38×10^{-1}
1000	6.79×10^{-5}	3.77×10^{-3}	1.36×10^{-1}

a. UF_6 concentration = (200 g) (χ/Q, s/m^3) (10^3 mg/g) / (3600 s)
b. UF_6 concentration = (200 g) (χ/Q, s/m^3) (10^3 mg/g) / (100 s)

The results indicate that the concentrations would be below the ERPG-1 values at 100 m for a 1 hr reference exposure period. The concentrations during a 100 s plume passage period would be below the ERPG-2 value at 100 m.

As an extension of the maximum exposure scenario, the potential for direct contact with the UF_6 has been considered. Themmaterial is corrosive, and harmful by inhalation, ingestion or skin absorption. The effects of exposure may be delayed. Should a worker come into direct contact with the UF_6 sample tubes, and be subject to a skin exposure, there is potential for an acid burn, which is treatable with calcium gluconate.

5.2 Nominal Exposure Scenario

The results of the nominal exposure scenario based on the mean χ/Q values are summarized in Tables 5-2 and 5-3. Table 5-2 presents the radiation doses versus downwind distance, and Table 5-3 presents analogous information for the UF_6 concentrations when considered as a hazardous chemical material. The results for the Spartanburg site are slightly lower than the Columbia site, indicating more dilution at the former site. The results for radiation dose and UF_6 concentrations versus downwind distance for the nominal exposure scenario are about 5 percent of those values for the maximum exposure scenario.

5.3 Conclusions

Given the assumptions regarding the potential metal recycling of the UF_6 sample tubes, the potential radiation and chemical exposure risks posed by the UF_6 sample tubes are small when compared to natural background radiation levels.

Table 5-3

Radiation Doses and UF_6 Concentrations for Nominal Exposure Scenario

Downwind Distance, m	Dose, mrem	Mean Χ /Q, s/m^{3} [a]	UF_6 Concentration, mg/m^{3} [b]	
			1 hr[a]	100 s[c]
Spartanburg, SC Site				
100	2.63×10^{-1}	2.76×10^{-4}	1.53×10^{-2}	5.51×10^{-1}
250	4.55×10^{-2}	4.72×10^{-5}	2.62×10^{-3}	9.44×10^{-2}
500	1.21×10^{-2}	1.23×10^{-5}	6.84×10^{-3}	2.46×10^{-2}
750	5.61×10^{-3}	5.61×10^{-6}	3.12×10^{-4}	1.12×10^{-2}
1000	3.25×10^{-3}	3.21×10^{-6}	1.78×10^{-4}	6.41×10^{-3}
Columbia, SC Site				
100	2.93×10^{-1}	3.08×10^{-4}	1.71×10^{-2}	6.15×10^{-1}
250	5.00×10^{-2}	5.18×10^{-5}	2.88×10^{-3}	1.04×10^{-1}
500	1.31×10^{-2}	1.33×10^{-5}	7.40×10^{-4}	2.66×10^{-2}
750	6.01×10^{-3}	6.01×10^{-6}	3.34×10^{-4}	1.20×10^{-2}
1000	3.45×10^{-3}	3.41×10^{-6}	1.89×10^{-4}	6.82×10^{-3}

a. Mean Χ /Q, applicable for any arbitrary direction.
a. UF_6 concentration = (200 g) (Χ /Q, s/m^{3}) (10^{3} mg/g) / (3600 s)
b. UF_6 concentration = (200 g) (Χ /Q, s/m^{3}) (10^{3} mg/g) / (100 s)

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