From [illegible] A. Gibson, Jr.
AT PADUCAH

707697

Date of Issue: July 26, 1983 KY/L-1213

ASSESSMENT OF CONSOLIDATED UF_6 RELEASE STUDIES

D. E. Boyd

Goodyear Atomic Corporation
PORTSMOUTH GASEOUS DIFFUSION PLANT

C. G. Jones

Union Carbide Corporation, Nuclear Division
OAK RIDGE GASEOUS DIFFUSION PLANT

CONTACTED → S. F. Seltzer

Union Carbide Corporation, Nuclear Division
PADUCAH GASEOUS DIFFUSION PLANT

REPOSITORY OAK RIDGE/ENERGY SYSTEMS/K-25
COLLECTION ANALYTICAL SERVICES DIV.
BOX No.
FOLDER

A-00103
Human Subjects Project

1025595

10401

I. Executive Summary

The technical work addressed in this report had its origin in the technical support effort provided for the proposed packed-bed scrubber for the "Add-On" GDP at Portsmouth and a growing concern over the sites' ability to contain and predict the off-site impact of UF_6 releases. Early on the technical community agreed that scrubber studies would be conducted at Paducah and UF_6 knockdown work at Portsmouth. As a result of the SAR effort and dispersion modeling studies conducted by Battelle Laboratories, Columbus, Ohio, the need for data on the basic chemistry and physics of the interaction of UF_6 with atmospheric moisture was recognized. This assignment was directed to Oak Ridge, also in 1980. Prior to the consolidation effort of 1980, project action plans and objectives were developed with modest interaction between sites. Since that time, the Environmental, Health, and Safety TPMT has insured against duplication of technical effort and provided project guidance on a limited scale. The authors recognize the wealth of information available in topically related technical reports. This report addresses the work in progress or initiated after the consolidation effort of 1980. The following project objectives (and their respective status) have evolved for the three sites.

(E,H, and S)

and without a directed set of objectives from management

1. ~~Paducah~~ PGDP

   1a. Objective: Characterize the performance of selected aqueous scrubbers in simultaneously removing UF_6 and its hydrolysis products from gaseous streams

   2a. Status: A novel multichambered scrubber was found to remove both uranium and gaseous fluorides at greater than 99% efficiency under optimal conditions.

2. ~~Portsmouth~~ GAT

   2a. Objective: Determine the feasibility of various knockdown techniques for containing UF_6 releases in feed, withdrawal, transfer and sampling areas. Characterization of the reaction between UF_6 and atmospheric moisture and evaluation of the [illegible] ?

   2b. Status: Scoping type studies have identified electrostatic precipitation as the most effective means of particle knockdown.

1025596

[redacted]

3. ~~Oak Ridge~~ ORGDP

3a. Objective: Determine (1) the physical and chemical characteristics of UF_6 hydrolysis products, (2) the mechanism of the hydrolysis reaction and the species and lifetime of the intermediates, (3) the morphology, change in morphology, and the rate of morphology change over a range of ~~meteorological~~ meteorological conditions.

3b. Status: These objectives have been met over a range of release rate, quantity of UF_6 released, humidity and UF_6 temperature have been characterized as a function of the conditions, as has the change in morphology after release and the settling time of the cloud.

Insert 1

Major efforts have gone into the study of various types of UF_6 releases, their plausibility and consequences. These UF_6 release scenarios may be categorized as to those inside of structures and those in the open. The release of UF_6 vapor in an autoclave (estimated at about 80 lb/min through a broken valve or pigtail) is considered a maximum credible occurence. Scrubbers tested under these release conditions have proven capable of >99% removal efficiency for UF_6 and its hydrolysis products and returning visibility in the area to a level where emergency efforts can commence. The desired concentration of uranium and HF in the scrubber effluent and the degree of operational flexibility desired by operating groups would constitute the primary objective for which scrubber design would be chosen for low assay areas. If the decision is made to deploy scrubbers for this application, additional scrubbers studies could be considered to minimize the quantity of scrubber solution generated in the event of such a release. With studies in progress, the chosen scrubber design could also be challenged by higher inlet uranium concentrations and very low humidity conditions. Any future scrubber work would require extensive renovation/upgrading of Paducah's test facility. Severe equipment restrictions would be needed to adapt the scrubber concept for use in high assay areas. Although not evaluated to the extent of scrubbers, the feasibility of electrostatic filters has been demonstrated at Portsmouth. Additional testing would be needed to optimize operating parameters for containment applications.

The most serious and credible types of releases defined by SAR work are those involving liquid filled cylinders. A major scenario for the release of liquid UF_6 inside a building, such as a ruptured cylinder in a

GENERAL DESIGN AND COMPUTATION SHEET

UNION CARBIDE CORPORATION • NUCLEAR DIVISION

JOB	DATE	SHEET of
ESO NO.	COMPUTED	CHECKED BY

Insert 1

2A.

These objectives have been met over a number of release conditions where total UF_6 released, humidity, temperature of UF_6 at release, and release rate have been varied. The morphology of the UO_2F_2 formed has been characterized as a function of the conditions as has the change in morphology after release as the settling time of the cloud.

1025598

feed facility, indicates that while the likelihood of occurrence is small the potential impact to on- and off-site personnel is great. Scrubbers are capable of significantly reducing the impact of this event.

For outside liquid releases, much can be learned from the release experienced at the French Comurhex facility in July 1977. Upon breaking the valve (6 o'clock position) of a 7 ton cylinder (environmental conditions of 79°F, wind speed 20 mph) at the threads, liquid UF_6 spilled to the ground, with subsequent formation of a lingering dense cloud, for 15 minutes before a wooden plug could be inserted to stop the leak. The use of water spray was attempted for release control but seemed detrimental to the effort. A blanket of carbon dioxide was effective in knocking down the cloud, limiting access of atmospheric moisture to the UF_6, and permitting access to the area. Comparing these results to the worst case scenario involving a 14-ton cylinder points to a significant concern over the control of an actual release and the time span involved. The dense cloud limiting visibility and continued release and reaction of UF_6 points to the need for an acceptable means of cloud knockdown and reaction control for spilled material. This same concern over the availability of efficient methods to deal with outside releases of liquid UF_6, was voiced as the first priority concern by Operations Division personnel when interviewed prior to preparation of this report. It is recommended that in addition to continued support of those release projects already budgeted and in progress at Portsmouth and Oak Ridge that funding and priority be provided to develop a set of "second generation" techniques to handle outside releases of liquid UF_6.

II. Response to Directed Questions - The following responses were prepared by the individual site members to the EH&S TPMT. These responses are directed toward the questions posed earlier by Donnolley.[20] The questions addressed are as follows:

1. What were the original objectives?
2. Have the original objectives been met?
3. Are the original objectives appropriate in today's atmosphere?
4. Has the work significantly affected our ability to respond to a UF_6 release?
5. Has the work significantly increased our understanding of the mechanisms of UF_6 cloud behavior and knockdown?
6. What additional work is desirable?

The site project objectives and their status are presented in greater detail in the Appendix.

A. PGDP

1. The objective of the first phase of the scrubber effort at Paducah was to characterize the performance of selected aqueous scrubbers: of the following types.

   a. Wetted Fiber Pad (WFP)
   b. Single-Stage Water Spray Chamber (SSW)
   c. Novel Multichambered Scrubber (MCS)
   d. Conventional Nozzleless Venturi Scrubber (NVS)

   The characterization involved ~~in~~ simultaneously removing UF_6, UO_2F_2, and HF from gaseous streams. A second phase of testing grew from the high removal efficiencies seen for the MCS system and the need to test a Conventional Nozzleless Venturi Scrubber (NVS). Second phase objectives included optimization of water consumption for the MCS, and evaluation of both systems (MCS and NVS) over a wide range of UF_6 concentrations including insufficient moisture for complete UF_6 hydrolysis. + others as typically

   A second supportive area of study centered on the identification of a suitable electrolyte and sampling technique for UO_2F_2 particle size analysis by Coulter Counter methods.

2. These objectives have been met with the scrubber studies completed in Sept. 1981. The MCS system was found to remove both uranium and gaseous fluorides at greater than 99% efficiency at optimum conditions. Attempts to reduce water consumption below a weight ratio of 1.8 kilograms per kilogram incoming air resulted in lowered efficiencies especially at very dry ambient conditions. The NVS system provided removal efficiencies (96.4% to 99.7%) slightly lower than that of the MCS. The MCS system proved to be less sensitive to changes in release conditions in that there is less flexibility for making operational adjustments. Performance for the WFP was much lower for uranium and gaseous fluorides with removal efficiencies ranging from 69% to 98%. Application of the WFP system is thus marginal. Testing of the SSW system was terminated due to extremely poor performance as evidenced by penetration of the spray curtain and downstream deposition of UO_2F_2.

Suitable electrolyte systems for UO_2F_2 particle size analysis were identified as LiI/Isopropanol and $LiBF_2$/Isopropanol. A major improvement in sample preparation was found to be collection of the sample on a filter media followed by ultrasonic dispersion in the electrolyte.

3. The basic understanding of the capabilities of the various scrubber systems will stand as excellent core information. These studies provide confidence that off-the-shelf scrubber designs remove particulate uranium at the same efficiency as other potential particulate pollutants. Should deployment of scrubber systems for GDP application be considered, a particular design can be chosen with confidence depending upon the required exhaust uranium concentration desired and the operational flexibility/sensitivity desired by the operating groups.

4. The work performed at Paducah, as defined by its objectives, was intended to enhance the capability of a GDP to respond to a UF_6 release through the use of scrubber systems. Since scrubber deployment is not currently considered, the value of the scrubber effort is purely in its potential application.

5. The objectives of the scrubber studies conducted at Paducah did not address these issues. which objectives?

6. Additional scrubber studies can be justified if a decision is reached to deploy scrubber systems for GDP application. The final testing considerations are 1) possible recycle of scrubbing solutions to minimize the volume of liquid subsequently requiring treatment 2) extension of the studies to higher levels of uranium concentration. The potential value of solution recycle rests in the reduction of waste solution treatment and solid waste disposal costs. These potential savings would be considered in light of the projected infrequent use of the scrubbers and the known costs required to renovate/modify the scrubber test facility and conduct the required tests. As part of these studies the proposed scrubber design should be challenged by higher incoming uranium concentrations to simulate more adverse release conditions.

B. ~~Portsmouth~~ GAT

1. In response to recommendations resulting from containment problems and the increased emphasis in containment for employee and public safety, knockdown studies were initiated at Portsmouth. The objective of this work was to determine the feasibility of various knockdown techniques for containing releases in feed, withdrawal, transfer, and sampling areas. Associated with this effort were the tasks of characterizing the reaction between UF_6 and atmospheric moisture and evaluating environmental variables of UF_6 cloud formation and ultimate fate. Due to delays in obtaining the environmental chamber and changes in personnel, this work was not started until 1978 and was completed in 1981. Current studies include activities in two areas. One deals with UF_6 containment with the objective of developing techniques for mitigating, controlling, or eliminating existing or postulated credible accident hazards to plant personnel and/or public safety resulting from failure of plant components containing UF_6. The record deals with UF_6 release plume studies with the objective of providing assistance on plume tracking, analysis, and knockdown to the DOE/French information exchange team primarily using the environmental chamber.

2. Within the scope of the original objective to determine the feasibility of various knockdown techniques, the objective has been met as electrostatic concepts utilizing a charged stream of dry air were identified as the most effective. The associated task of characterizing the reaction between UF_6 and atmospheric moisture was consolidated to ORGDP and the task of evaluating environmental variables of UF_6 cloud formation and ultimate fate was partially completed at Portsmouth with the remainder of this effort being conducted at ORGDP. At Portsmouth, no association between settled UO_2F_2 cloud particle sizes and temperature or humidity effects in the range encountered in GDP operations was observed. The majority of particles analyzed were in the 0.5-3μ range. In spite of the high density of UO_2F_2 particulate material, UF_6 hydrolysis clouds were observed to rise followed by diffusion. Turbulence was observed to shorten settling time by enhancing agglomeration; however, this would not be expected in open air environments where current UF_6 containment studies have dealt with evaluating commercial electrostatic air filters

with reductions of 97% in airborne particulate concentrations being achieved. A rain simulation test has indicated little change in the airborne uranium content. Future activities in this project are to provide technical support and test environments for the development of fail-safe rehearse alarm systems for cascade buildings and auxiliary facilities. UF_6 release plume studies are being conducted to provide cloud settling rate data and establish means of seeing UF_6 hydrolysis cloud growth, movement, and dissipation.

3. Yes, Since information about various knockdown techniques is essential for a feasibility study dealing with improved containment in areas with higher potential for failure of UF_6 containing equipment. Objectives of current UF_6 containment and release plume studies reflect near term concerns and are revised as needed to respond to changes in anticipated needs.

4. As defined by the objectives, the UF_6 containment work at Portsmouth was intended to evaluate the feasibility of various knockdown techniques for containing releases. At this time, electrostatic concepts identified by this work are only candidates unique for future application in the GDPs.

5. Cloud behavior and the feasibility of various knockdown techniques, as defined by the objectives, are well understood for controlled environments. This information is applicable to small process areas where release clouds could be contained and knockdown techniques, as tested, utilized. Current UF_6 release plume studies are providing information which should enhance our understanding of cloud behavior in open field situations.

6. Additional electrostatic filtering could be justified if a decision for deployment of to install knockdown facilities such as electrostatic filters for GDP applications is made. Final testing would be needed to establish optimum operating conditions, nuclear safety parameters, uranium recovery techniques, and other operational considerations.

C. ORGDP

1. The original objective was to formulate a model that would accurately describe a UF_6 release given the meteorological conditions, the amount of releases of UF_6, and affected terrain. This model incorporated the various heats of reaction, association, and phase change. To supply emperical information to meet the needs of the model and to better understand UF_6 releases, experimental work was performed at Portsmouth and ORGDP to determine (a) both the physical and chemical characteristics of hydrolysis products, (b) the mechanism of the hydrolysis reaction and species and lifetime of intermediates, (c) and the morphology, the change in morphology, and the rate of that change for a wide range of meteorological and total UF_6 released conditions.

2. These objectives have been met over a number of release conditions where total UF_6 released, humidity, temperature of UF_6 at release, and release rate were varied. The morphology of the UO_2F_2 formed has been characterized as a function of the conditions, as has the change in morphology after release and the settling time of the cloud. Intermediates between UF_6 and UO_2F_2 have not been observed under normal release conditions and their lifetimes are considered to be very short. The HF formed appears to weakly adduct to the UO_2F_2, but is easily displaced by H_2O. The amount of hydration also is a variable yielding a large number of different $UO_2F_2 \times H_2O$ hydrates. A large effort was made to characterize the $UO_2F_2 \times H_2O$ formed, and to better understand the problems associated with its quantitative determination. The extent of hydration of HF and the onset of condensation as a function of HF and H_2O concentrations was determined.

3. Yes, since the basic information about cloud makeup is essential to the understanding of cloud behavior and fallout.

4. Outside of considering several remote sensing techniques to follow a release, particularly after dispersion has rendered it invisible, no response has been considered other than the currently in place actions to ensure the safety of plant personnel.

5. Understanding of cloud behavior in a controlled environment is well understood. Much less is known about cloud behavior in the ambience. But cloud behavior is dependent upon the characteristics of the aerosol particles comprising the cloud, thus a better understanding of cloud behavior in the ambience exists when wind and dilution are considered.

actual evrionment?

6. More experimentation is needed to evaluate the early stages of aerosol particle formation and the effects of environment on that formation. In addition, conditions approaching ambient need to be tested to better determine how our current results minimize an ambient release.

III. Summary

The project objectives for the UF_6 release work performed at Paducah, Portsmouth, and Oak Ridge are completed or currently in progress. These studies have been coordinated by the EH&S TPMT since 1980 to prevent duplication of technical efforts. It is desirable to continue the plume cloud studies in progress at Portsmouth and the studies under way at Oak Ridge. Further scrubber/electrostatic filtering studies are not warranted unless a decision favoring their deployment is made. Additional scrubber studies would require extensive upgrading of Paducah's scrubber facility and an assessment of the resulting treatment/disposal requirements. Use of electrostatic filtering technology would require additional study to move beyond the feasibility stage and establish optimum operating conditions, nuclear safety parameters, uranium recovery techniques and other operational considerations.

Operations personnel were interviewed prior to preparation of this report to define their priority of needs concerning release technology studies. Technical support was requested in the following areas.

1. Advanced technologies/procedures for handling liquid release of UF_6.

2. Training and equipment to make use of the plume dispersion model and topographical overlays in determining the off-site impact of UF_6 releases.

3. Updating the existing UF_6 outleakage detection systems.

4. Determination of means for egress from facilities under release conditions where visibility is impaired.

It is felt ~~that in~~ these areas ~~can the great~~ actions can test strides be taken to reduce the risk to on- and off-site personnel as well as the environment.

1025606

1025601

APPENDIX

This Appendix has been provided in order that a more extensive listing by site of the individual projects and their objectives and status can be examined. An attempt was not made to judge either the statistical design of the studies or the quality of the work performed. Rather the data and conclusions provided by the authors are taken at face value.

TABLE 1 PGDP

Title/Document	Objectives	Status/Results
Evaluation of Aqueous Scrubbers for Removal of UF_6 Hydrolysis Products. (KY/L-713, Part 1)	Characterize the performance of aqueous scrubbers: 1. Wetted fiber pad (WFP) 2. Single-Stage water spray chamber (SSW) 3. Novel multichambered device (MCS) in simultaneously removing UF_6, UO_2F_2, and HF from gaseous streams	1. Performance (removal efficiency) of the WFP varied from 69% to 98% and makes its application marginal. Inlet uranium concentrations for the trials ranged from 5000 mg U/m^3 to 16,000 mg U/m^3. 2. The SSW was the poorest performer studies were terminated due to penetration of the spray curtain and downstream deposition of UO_2F_2. 3. The MCS performs comparable (79.9% removal) for UF_6 systems as for other contaminants. ? 1a. Inlet uranium concentration for trials where injector gas was air was 8400 mg U/m^3 to 42,000 mg U/m^3. 1b. Inlet uranium concentration range for trials where injector-gas was steam 9200 mg U/m^3 to 37,000 mg U/m^3. 4. Over the relative humidity range of 15% to 70%, uranium removal was not found to be a function of relative humidity.
Advanced Aqueous Scrubber Studies (KY/L-1110, Part 9)	1. For the MCS: a. Test removal efficiencies over a wider rang of inlet UF_6 concentrations including insufficient moisture for complete UF_6 hydrolysis. b. Optimize water consumption at atomizer chamber. c. Determine removal efficiency as a function of particle size.	1a. Removal efficiencies remained above 99% for uranium and gaseous fluorides at optimum conditions. Concentrations for these tests ranged from 2660 mg U/m^3 to 61,400 mg U/m^3. 1b. Reduction of water consumption below a weight ratio of 1.8 kilograms per kilogram inlet air resulted in lowered efficiencies. 1c. Insufficient data generated. Based on manufacturers projections & efficiencies seen a particle size of 3μ was projected. question where from

APPENDIX

TABLE 1 PADUCAH (CONTINUED)

Title/Document	Objectives	Status/Results
	d. Investigate possible efficiency losses at low inlet UF_6 concentrations.	1d.
	2. Evaluate a conventional nozzleless venturi scrubber (NVS).	2. The conventional nozzleless venturi scrubber provided removal efficiencies (96.4% to 99.7%) slightly lower than that of the MCS for uranium and gaseous fluorides. Selection for making operating adjustments (ie fine tuning) were not as great as for the MCS. These tests included uranium concentrations of 3150 mg U/m^2 44,700 mg U/m^3.
UO_2F_2 Particle Size Analysis by Coulter Counter Method (KY/L-725)	1. Identification of a suitable electrolyte for UO_2F_2 particle size analysis by Coulter Counter Model Tall.	1a. Suitable electrolytes were found to be LiI/Isopropanol and $LiBF_4$ isopropanol can be used with 50/μ operature tube.
	2. Determine feasibility and workability of particle size analysis of UO_2F_2 in the 1 ? to 1/μ range by the Coulter Counter Model Tall using identified electrolyte.	1b. Exclusion of water from the electrolyte system is essential.
0.1		1c. Solubility of UO_2F_2 in these electrolytes is low and only of concern for 1/μ particles.
	3. Determine suitable sampling technique for collecting samples of UO_2F_2 particles from an air stream such that particle sizes are not altered and solubility problems are not encountered.	2a. UO_2F_2 particle size ranged from 0.8/μ to 40/μ.
		2b. Predominance of particles in the 0.8/μ to 2.5/μ range.
		2c. Reduction of instrument noise can be achieved be the placement of shielding around the sample beaker.
		2d. Additional study is needed to improve techniques for sealing sample beaker from humidity during analysis.
		3. Samples should be taken on filter media and then dispersed ultrasonically in electrolyte.

1025608

APPENDIX

TABLE 1 PORTSMOUTH

Title/Document	Objectives	Status/Results
UF_6 Containment Studies (GAT-T-3124, Part 6) (Mar. 1982)	1. Characterize the reaction between UF_6 and atmospheric moisture. 2. Evaluate environmental variables of UF_6 cloud formation and ultimate cloud fate. 3. Evaluate use of water, steam, CaO_2, Freon, air jet, boric acid, and air on UF_6 cloud knockdown and localization.	1. Effort consolidated to ORGDP 2a. No association between UO_2F_2 cloud particle size distribution and temperature of humidity effects in range encountered in GDP operations. Majority of cloud particles in 0.5 - 0.3 μm range. Conclusions are for settled particles and many not apply to airborne particles. 2b. Turbulence in chambers may shorten settling time by enhancing agglomenation. Opposite may occur in open field with cloud distribution. 2c. In spite of higher sensity of UO_2F_2 particulate matter, UF_6 release hydroloysis cloud immediately rises to ceiling of chamber followed by diffusion to fill chamber. 3. Reproducible UF_6 release cloud knockdown demonstrated (clear chamber in 5 minutes) with electrostatic-changed stream of dry air. Undisturbed cloud required 12-16 hours to settle.
Positive UF_6 Containment (520 Subdivision Project Status File) (Thru May 1983) and (GAT-T-3124, Parts 1,4, 5,6,7,8,10,&12) (FY-1982)	1. Develop techniques for mitigating, controlling, or eliminating existing or postulated credible accident hazards to plant personnel and/or public safety resulting from failure of plant components containing UF_6.	1. In progress - Reasibility of commercial electrostatic air filter demonstrated. Proposal use would be centralized location with ducting to remove contaminated air from anticipated release areas. 1a. Material balance indicated 40-60% of release recovery with 80-97% accounted for. 1b. Indicated 96.8% reductions in measurable particulate UO_2F_2 in air returned to chamber. Rain tests indicate little change in airborne U content.

1025609

APPENDIX

TABLE 1 PORTSMOUTH (CONTINUED)

Title/Document	Objectives	Status/Results
UF_6 Containment Studies UF_6 Release Plume Studies (520 Subdivision Project Status File) (Thru May 1983)	1. Provide assistance on plume tracking, analysis and knockdown to DOE/French information exchange team primarily using the environmental chamber. 1a. Determine cloud settling rates. 1b. Establish means of seeing UF_6 hydrolysis cloud growth, movement, and dissipation.	1. In progress 1a. Differential sampling point, vertical profile sampler and timed dropout samples collected. No significant concentration difference encountered through one foot differential sampler. Vertical profile sampler indicated gradual overall diminishing concentration at all levels. Timed dropout sampler indicated 0.17 in./min settling rate. 1b. Ultraviolet, thermographic, and optical methods, tried in chamber were unsuccessful. Ultrasonic reflection and possible forward looking infrared scanner will be tried to track cloud.
	2. Characterize solid products produced when UF_6 is released into air at specified relative humidities.	2a. UF_6 release experiments performed in small, static chambers at controlled atmospheric conditions; release chambers up to 8 cu. ft. in volume, UF_6 release of 5 to 230 mg. RH of 2 to 100%. 2b. Solid produced were collected and characterized by: electron microscopy, x-ray diffraction, laser light scattering, and cascade impactor using mass measurements. 3. Various morphologies and several compounds were observed to be dependent upon conditions of release. The particle size and degree of agglomeration were dependent on the relative humidity of the air and the temperature of the UF_6 at time of release.

1025610

APPENDIX

TABLE 1 ORGDP

Title/Document	Objectives	Status/Results
	Characterize solid products produced when UF_6 is released into air at specified relative humidities	1. UF_6 release experiments performed in small, static chambers at controlled atmospheric conditions; release chambers up to 8 cu. ft. in volume, UF_6 release of 5 to 230 mg. RH of 2 to 100%. 2. Solid produced were collected and characterized by: electron microscopy, x-ray diffraction, laser light scattering, and cascade impactor using mass measurements. 3. Various morphologies and several compounds were observed dependent upon conditions of release. The particle size and degree of agglomeration were dependent on the relative humidity of the air and the temperature of the UF_6 at time of release.

1025611

BIBLIOGRAPHY

1. W. H. McCulla, Determination of the Rate of HF Hydration and the Effects of HF on Moisture Condensation, K/PS-155, Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, April 30, 1982.

2. P. W. Pickrell, Characterization of the Solid, Airborne Materials Created by the Interaction of UF_6 with Atmospheric Moisture in a Contained Volume, KP/S-144, Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, April 30, 1982.

3. H. Conley and M. G. Otey, UO_2F_2 Particle Size Analysis by Coulter Counter Method, KY-725, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, March 12, 1982. UNCLASSIFIED.

4. L. V. Gibson, PGDP Technical Services Division Technical Activities Report, "Aqueous Scrubber Technology for UF_6 Containment", KY/L-1110, Part 9, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, September 1981, pp 59-69. SECRET.

5. L. V. Gibson, An Evaluation of Aqueous Scrubbers for Removal of UF_6 Hydrolysis Products, KY-713, Part 1, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, January 30, 1981. UNCLASSIFIED.

6. L. V. Gibson, Summary of previous UF_6 Behavior Experiments at Paducah, KY/L-1089, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, October 18, 1980. UNCLASSIFIED.

7. M. B. Fortune and G. T. Hull, Implementation Status of Three-Plant UF_6 Cylinder Handling Committee Recommendations at the PGDP, Paducah Gaseous Diffusion Plant Report, June 9, 1980. UNCLASSIFIED.

8. P. W. Pickrell, Characterization of the Solid Product(s) Formed When UF_6 is Released into Ambient Air in a Contained Volume (U), K/ET-503, Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, May 7, 1980. UNCLASSIFIED.

9. L. V. Gibson, Gaseous Scrubbers for UF_6 Removal, KY/L-1009, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, October 22, 1979. UNCLASSIFIED.

1025612

10. T. J. Mayo, The Application of the Gaussian Plume Equation to UF_6 Releases, KY/L-824, Union Carbide Corporation, Nuclear Division, Paducah Gaseous Diffusion Plant, April 15, 1976. UNCLASSIFIED.

11. E. O. Sternberg, Oak Ridge Gaseous Diffusion Plant Safety Studies, K/D-5050, Part 2, UF_6 Handling Facilities, Union Carbide Corporation, Nuclear Division Oak Ridge Gaseous Diffusion Plant, December 1, 1981. OFFICAL USE ONLY.

12. E. R. Johnson, Preliminary Safety Analysis Report for Improved UF_6 Containment, KY/G-371, Rev. 2, Union Carbide Corporation, Nuclear Division Paducah Gaseous Diffusion Plant, March 31, 1981. OFFICAL USE ONLY.

13. G. L. Williams, Methods for Containing A Uranium Hexafluoride Release: A Survey of the Literature, GAT-T-2318, Goodyear Atomic Corporation, Piketon, Ohio March 12, 1975. CONFIDENTIAL.

14. C. J. Lux, UF_6 Containment Studies: Controlled Releases in GAT Environmental Chamber, GAT-T-3007, Goodyear Atomic Corporation, May 27, 1980. UNCLASSIFIED.

15. Preliminary Safety Analysis Report Improved UF_6 Containment Project No. 82-OR-18, GAT-973, Rev. 1, Safety Analysis Department, Goodyear Atomic Corporation, April, 1981. UNCLASSIFIED.

16. Miculs, II UF_6 Containment and Recovery, Goodyear Atomic Corporation, October 1970, GAT-T-2316. CONFIDENTIAL.

17. C. J. Lux, Outline Summary of Completed On-Going and Proposed Capabilities/Studies in Support of Plume Model Verification, GAT-521-83-95, Interdepartmental Correspondence to V. S. Emler, Goodyear Atomic Corporation, May 23, 1983. UNCLASSIFIED.

18. C. J. Lux, Feature Article in Technical Monthly Activities Report, UF_6 Release Studies Under Controlled Conditions, GAT-T-3124, Part 6, Portsmouth Gaseous Diffusion Plant, Goodyear Atomic Corporation, March 1982. SECRET.

19. C. J. Lux, Summary of Agents and Procedures Evaluated in UF_6 Release Cloud Knockdown Studies, GAT-T-3207, Goodyear Atomic Corporation, January 27, 1983.