On-Site Incineration of Basin F Liquids at the
Rocky Mountain Arsenal Superfund Site
Commerce City, Colorado

Incineration at the Rocky Mountain Arsenal Superfund Site Commerce City, Colorado

<table>
<tr><td>Site Name:
Rocky Mountain Arsenal Superfund Site</td><td rowspan="2">Contaminants:
Organochloric and organophosphoric pesticides and metals
• ardrin
• dieldrin
• vapona
• copper
• zinc
• arsenic</td><td>Period of Operation:
July 1993 - July 1995</td></tr>
<tr><td>Location:
Commerce City, Colorado</td><td>Cleanup Type:
Interim response</td></tr>
<tr><td>Vendor:
T-Thermal Sub-X® Liqui-Datur® Incinerator manufactured by T-Thermal Incorporated and cross-licensed by Nittetu Chemical Engineering, Limited</td><td rowspan="2">Technology:
On-Site SQI Incineration
• High-temperature oxidation in a down-fired, SQI
• High-energy venturi scrubber for particulate emission control
• Packed tower caustic scrubber for neutralization of exhaust gases
• Residuals transported to off-site handling facility</td><td>Cleanup Authority:
CERCLA and State: Colorado
• U.S. Army, PRP, and EPA enter into Federal Facilities Agreement 2/89 - includes 13 interim response actions
• ROD signed 12/9/96
• DoD Lead</td></tr>
<tr><td>SIC Code:
NA</td><td>Point of Contact:
Colonel Eugene H. Bishop
Program Manager
Rocky Mountain Arsenal
Commerce City, CO 80022-2180
(303) 289-0467 - Public Affairs Office
(303) 286-8032 - SQI Information Hotline</td></tr>
<tr><td>Waste Source:
Evaporation basin used to store manufacturing wastewaters</td><td colspan="2" rowspan="2">Type/Quantity of Media Treated:
Liquids
• 10.9 million gallons</td></tr>
<tr><td>Purpose/Significance of Application:
Innovative design used to capture metal particulates; 250,000 pounds of copper recovered and recycled</td></tr>
<tr><td colspan="3">Regulatory Requirements/Cleanup Goals:
• Destruction and Removal Efficiency (DRE) of 99.99% for all constituents of concern as required by Resource Conservation and Recovery Act (RCRA) incinerator regulations in 40 CFR part 264, subpart O</td></tr>
<tr><td colspan="3">Results:
Monitoring and trial burn data indicate that all DRE and emission standards have been met</td></tr>
</table>

Incineration at the Rocky Mountain Arsenal Superfund Site
Commerce City, Colorado

(Continued)

Description:
RMA was established in 1942 and historically has been used for manufacturing and demilitarizating chemical incendiary weapons. Portions of RMA were leased for the private production of agricultural chemicals including pesticides from 1947 to 1982. Between 1957 and 1982 an evaporation pond (Basin F) was used for disposal of various wastewaters from the site's manufacturing process and wastes from demilitarization activities.

The Army and the on-site chemical manufacturer were designated as responsible parties in a Federal Facilities Agreement (FFA) entered into in 1989. The FFA specified 13 interim response actions (IRAs), including the remediation of Basin F. A Record of Decision (ROD) for all operable units at the site was signed June 11, 1996.

The Army selected SQI to dispose of Basin F liquids. The SQI system included an atomizing liquid injection system; an incinerator chamber; a quench chamber; a spray dryer; a venturi scrubber for particulate matter control; a packed-tower scrubber for neutralization of off-gases; and a residuals handing facility.

Full-scale operation of the SQI began in July 1993, and incineration of approximately 10.9 million gallons of Basin F liquid was completed by July 1995. The SQI was decommissioned, dismantled, and sold for parts, per the FFA, upon completion of the project. All applicable and relevant or appropriate requirements were met throughout the project.

The actual cost for remediation of Basin F was approximately $93,000,000, including $14,800,000 in capital costs and $78,500,000 in operation and maintenance costs.

EXECUTIVE SUMMARY

This report presents cost and performance data for the application of on-site incineration at the Rocky Mountain Arsenal (RMA) Superfund Site near Commerce City, Colorado. An on-site submerged quench incinerator (SQI) was used from July 1993 through July 1995 to treat liquid wastes generated at RMA.

The primary contaminants of concern in the liquid waste included organochloric pesticides (including aldrin and dieldrin), organophosphoric pesticides (including vapona), and metals (including copper, lead, arsenic, and zinc).

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The Army and the on-site chemical manufacturer were designated as responsible parties in a Federal Facilities Agreement (FFA) entered into in 1989. The FFA specified 13 interim response actions (IRAs), including the remediation of Basin F. Standards for Basin F were established in a 1990 Final Decision Document (DD). These standards included treatment resulting in a 99.99% destruction and removal efficiency (DRE) of organic constituents. A Record of Decision (ROD) for all operable units at the site was signed June 11, 1996.

Remediation of Basin F was conducted in two parts. The first part consisted of removal and temporary storage of liquid, and removal and stockpiling of solids and sludges. The second part consisted of disposal of the stored liquid. The remainder of this document addresses the disposal of Basin F liquids, unless otherwise stated.

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Full-scale operation of the SQI began in July 1993, and incineration of approximately 10.9 million gallons of Basin F liquid was completed in July 1995. The SQI was decommissioned, dismantled, and sold for parts, per the FFA, upon completion of the project. All applicable and relevant or appropriate requirements (ARARs) were met throughout the project.

The actual cost for remediation of Basin F was approximately $93,000,000. This consisted of approximately $14,800,000 in capital costs and $78,500,000 in operating and maintenance costs.

SITE INFORMATION

Identifying Information

Rocky Mountain Arsenal Superfund Site
Commerce City, Colorado

CERCLIS #: NA

ROD and DD Date: A Decision Document for the Basin F IRA was issued May 1990. A single ROD for all on-site OUs, including Basin F, was signed June 11, 1996.

Treatment Application

Type of action: Interim response (on-site SQI incineration)

Period of full-scale incinerator operation: July 1993 through July 1995

Quantity of material treated during application: 10.9 million gallons of liquid hazardous waste

Background

Historical Activity that Generated Contamination at the Site: Manufacture and demilitarization of chemical munitions and manufacture of pesticides

Waste Management Practice that Contributed to Contamination: Disposal of manufacturing wastewater into an evaporation basin

Site History:

- RMA was established in 1942 for the manufacture of chemical and incendiary munitions as well as demilitarization of chemical munitions. Pesticides were manufactured at the site from 1947 through 1982.
- The RMA site is located on approximately 17,000 acres 10 miles northeast of metropolitan Denver, Colorado and directly east of Commerce City.
- From 1943 through 1950, stocks of Levinstein mustard gas were distilled, several million rounds of mustard-filled shells were demilitarized, and mortar rounds filled with smoke and high explosives were test-fired.
- In 1947, portions of RMA were leased for production of chlorobenzene, DDT, naphthalene, chlorine, and fuzed caustic.
- In 1951, another manufacturer assumed the lease and produced pesticides until 1982.
- Through 1956, waste streams from the above manufacturing operations were discharged to unlined evaporation basins (Basins A through E).
- In 1956, Basin F was designed and constructed as an evaporation basin to receive various manufacturing wastes. The basin had a surface area of 93 acres and a capacity of approximately 243 million gallons. The basin was constructed using an asphalt liner covered by a 1-foot layer of sand. Between August 1957 and December 1981, Basin F was the only evaporative wastewater disposal location in service at RMA.
- Basin F was located in the northeast section of RMA and was used to dispose of wastes containing organochloric and organophosphoric pesticides and various metals.

SITE INFORMATION (CONT.)

Background (Cont.)

- In 1986, the Department of Interior, the Department of Health and Human Services, the Department of Justice, and the U.S. EPA (EPA *et al.*,); and the potentially responsible parties (PRP) at the site agreed (via the Basin F Memorandum of Understanding) to undertake a removal action to address threats to human health and the environment posed by liquids and contaminated soils and sludges in Basin F. Part One of the removal action (completed in December 1988) included the removal of liquids from Basin F to storage tanks and a surface impoundment, and the removal of soil and sludge to a double-lined waste pile. Part Two included incineration of the Basin F liquid that was stored in the holding tanks and surface impoundment.

- In February 1989, EPA et al., and the PRPs entered into a FFA for all of RMA, including remediation of Basin F.

- In May 1990, the Army issued a Final Decision Document for Basin F Liquids which specified remediation via SQI with a venturi/packed-tower scrubber.

- Between July 1993 and July 1995, the SQI processed 10.9 million gallons of Basin F liquids, meeting the standards established in the FFA.

Regulatory Context: In February 1989, EPA et al., the Army and the second PRP entered into a FFA that stated RMA is subject to the cleanup standards in Section 121 of the Comprehensive Environments Response, Compensation, and Liability Act (CERCLA) and provisions of the National Contingency Plan for Oil and Hazardous Substances (NCP).

Remedy Selection: On-site submerged quench incineration (SQI) was selected as the remedy for Basin F liquids at RMA based on the results of feasibility studies, a preliminary risk assessment, and treatability studies (laboratory and pilot-scale testing); economic considerations; and input from the public.

Timeline

Table 1. Timeline

Date	Activity
1942	RMA established for manufacture and demilitarization of chemical and incendiary munitions.
1943 - 1950	Chemical munitions manufactured and demilitarized; explosives test-fired.
1947	Portions of RMA leased; manufacture of chlorobenzene, DDT, naphthalene, chlorine, and fuzed caustic begins.
1951 - 1982	PRP assumes lease and manufactures pesticides.
1957 - 1982	Basin F is used as an evaporation pond for various RMA manufacturing process discharges.
1986	U.S. Army, another PRP, and EPA et al., agree to Basin F Memorandum of Understanding, outlining Basin F IRA
July 1987	RMA placed on the NPL
May 1988 - December 1988	Part One of Basin F IRA conducted (removal and temporary storage of wastes).
September 1988	Part Two of Basin F IRA initiated (characterization of liquid waste, selection of treatment alternative, testing of treatment technology, design of treatment process).
February 1989	U.S. Army, another PRP, and EPA et al., enter into a FFA that includes 13 IRAs at RMA (including a two-part IRA for remediation for Basin F liquid, sludges, and soils).
December 1989	Final Treatment Assessment Report describing the preferred alternative for treatment of Basin F liquids.
May 1990	Final Decision Document for Basin F liquid treatment issued.

SITE INFORMATION (CONT.)

Table 1. Timeline

Date	Activity
September 1992	Trial Burn Plan submitted.
May 20-25, 1993	Two Mini-Burns conducted (to establish interim limits).
June 10-12, 1993	Trial Burn conducted.
July 1993 - July 1995	Full-scale operation of SQI conducted.
December 1993	Trial Burn Summary Report completed.
May 1996	SQI decommissioned, dismantled and sold for parts.

Site Logistics/Contacts

Site Management: DOD-Lead

Oversight: EPA with input from Colorado Department of Health, U.S. Fish and Wildlife Service, and Tri-County Health Department

Remedial Project Manager:
Laura Williams
U.S. EPA Region 8
999 18th Street, Suite 500
Denver, Colorado 80202
(303) 312-6660

U.S. Army Contact:
Colonel Eugene H. Bishop
Program Manager
Rocky Mountain Arsenal
Commerce City, CO 80022-2180
(303) 289-0467 - Public Affairs Office
(303) 286-8032 - SQI Information Hotline

Treatment System Vendor and Operator:
T-Thermal Sub-X® Liqui-Datur® Incinerator manufactured by T-Thermal Incorporated and cross-licensed by Nittetu Chemical Engineering, Limited

SQI system operated by Weston Inc.

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Liquid waste from pesticide manufacturing processes

Contaminant Characterization

Primary Contaminants: Organochloric and organophosphoric pesticides and metals in solution

- The contaminants of greatest concern include pesticides (aldrin, dieldrin, and vapona) and metals (copper, zinc, and arsenic).
- Several organochloric pesticides were detected, including vapona at a maximum concentration of 2.40 mg/L.
- Several organophosphoric pesticides were found at concentrations ranging from 0.11 to 0.89 mg/L.
- Several metals were detected, including copper, zinc, and arsenic at maximum concentrations of 210 mg/L, 0.95 mg/L, and 3.0 mg/L, respectively.

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

- The Basin F liquid was sampled and analyzed and determined to be corrosive, according to RCRA regulations in 40 CFR 261.22. The higher heating value of Basin F liquid was measured to be 37 BTU/lb.
- Specific gravity and pH of the liquid were measured to be 1.2 and 6.02, respectively.

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Submerged quench incineration system including:

- Atomizing liquid injection system
- Submerged quench incinerator
- Quench chamber
- Spray dryer

Supplemental Treatment Technology

Post treatment (air):

- High-energy venturi scrubber for particulate matter control
- Packed tower caustic scrubber for acid neutralization of the exhaust gases

System Description and Operation

- The incineration system at RMA consisted of high-temperature oxidation in a down-fired, SQI followed by a high-energy venturi scrubber for particulate emission control and a packed tower caustic scrubber for acid neutralization of the exhaust gases. A schematic of the incineration system is presented in Figure 1.
- During operations, liquid waste was fed to the flame zone of the down-fired incinerator through an atomizing spray nozzle. Molten salts (residuals from combustion) flowed down the sides of the incineration vessel and fell into a quench tank with water circulation. Combustion gases were bubbled through the quench tank and routed to the APCS. The quench tank liquid (brine), which contained dissolved salts and residual heavy metals, was transported first to the residuals storage facility and ultimately off-site where the metals were removed and recycled to a smelter.
- The APCS included of a mechanical venturi scrubber for removal of particulates in the off-gases from the quench tank. The APCS also included a caustic (packed) tower scrubber used as secondary treatment for the quench tank gases and primary treatment for the discharge air from the residuals handling facility. The packed-tower scrubber system consisted of an absorber section, a mist eliminator, and an exhaust stack.
- Combustion gases were drawn through the SQI and APCS by an induced-draft fan and were exhausted through a 30-meter reinforced, concrete stack. Typical exit gas velocity was 14.7 meters per second.
- The SQI was developed by T-Thermal, Inc. The SQI design operating parameters are presented in Table 2.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Table 2. Summary of Design Operating Parameters

Parameter	Value
Combustion chamber capacity	30 million BTU/hr
Gas temperature after quench	200°F
Residence time	2 seconds

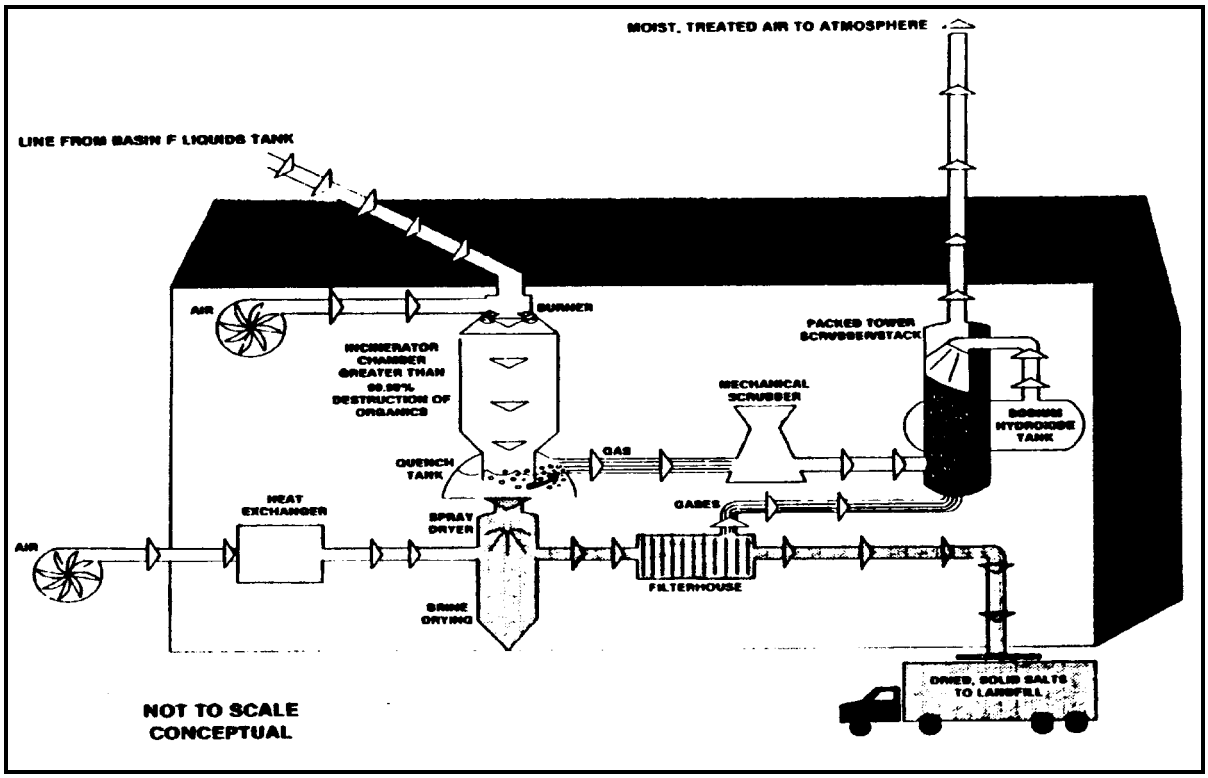

Figure 1. Conceptual Schematic of the Submerged Quench Incineration System
(prepared by Woodward-Clyde Consultants)

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

- The cleanup goals and standards specified in the FFA were consistent with the requirements in Section 121 of CERCLA and the provisions of the NCP.
- The maximum acceptable concentrations of contaminants corresponded to a 1×10^{-6} excess lifetime cancer risk and a hazard index of 1.00.
- The required DRE for POHCs was 99.99%.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance and Compliance

- Two mini-burns were conducted at RMA May 20 through May 25, 1993, and a full trial burn was conducted from June 10 through June 12, 1993. The burns were designed to operate the incineration system at conditions that would reflect worst- case destruction and removal of all constituents of concern. Monochlorobenzene and carbon tetrachloride were selected as POHCs for the trial burn at RMA. The POHC feed rate, stack gas emissions rate, and calculated DREs are shown in Table 3. Interim operating limits were then established based on results of the mini-burns. These interim limits were used until approval of final limits.
- The SQI operated within the operating limits established during the mini burns and trial burn, signifying that all emissions requirements were met or surpassed. Trial burn and interim operating parameters are shown in Table 4.

Table 3. Average Destruction and Removal Efficiencies from Trial Burn

POHC	Average POHC Feed Rate[a] (lbs/hr)	Average POHC Stack Gas Emissions Rate (lbs/hr)	DRE (%)
Monochlorobenzene	8.81	1.87×10^{-6}	>99.9990
Carbon Tetrachloride	8.12	2.91×10^{-6}	>99.9988

[a]Neither POHC was detected in the waste feed.

Table 4. Operating Parameters [4]

Parameter	Trial Burn[a,b]	Interim[c]
Waste Feed Rate	176 lb/min	< 166 lb/min
Emission Rate:		
Particulate - @7% O_2 - @12% CO_2	0.0214 grains/dscf 0.0320 grains/dscf	< 0.08 grains/dscf < 0.10 grains/dscf
HCl	0.2291 lb/hr	< 4 lb/hr
CO (HRA)	51.5 ppm	< 100 ppm
THC	8.25 ppm	NA
NO_x	131 ppm	NA
SO_2	55.6 ppm	NA
HCl	2.50 ppm	NA
Operating Conditions:		
Minimum SQI Chamber Temperature	1836°F	1825°F
Minimum Residence Time	2.72 sec	2.7 sec
Minimum Excess Oxygen	3.50%	3%

TREATMENT SYSTEM PERFORMANCE (CONT.)

Table 4. Operating Parameters [4]

Parameter	Trial Burn[a,b]	Interim[c]
Minimum Quench pH	5.12	4
Minimum Scrubber pH	5.76	5.25
Maximum Venturi Recycle Flow Rate	126.7 gal/min	100 gal/min
Maximum Venturi Differential Pressure	90 inches w.c.	80 inches w.c.
Maximum Liquid/Gas Ratio	11.1 gal/kcf	9.3 gal/kcf
Maximum Scrubber Recycle Rate	285.7 gal/min	270 gal/min
Natural Gas Flow Rate	438 scfm	NA
Total Combustion Air	7,107 scfm	NA
SQI Chamber Pressure	3.97 psig	NA

[a]Average measured value of three runs conducted at identical conditions during trail burn.
[b]one half the detection limit for individual non-detect results was used to determine the average values.
[c]Interim limits established during two "mini-burns" conducted May 20-25, 1993. These values were used as limits until approval of the limits proposed during the trial burn.

dscf - Dry standard cubic feet
HRA - Hourly rolling average
kcf - Thousand cubic feet
psig - Pounds per square inch, gauge
scfm - Standard cubic feet per minute
NA - Not available
w.c. - Water column

Performance Data Completeness

- Complete results of Basin F liquid testing can be found in the Summary Report for Incineration of Basin F Wastes [1] and the Trial Burn Summary Report [4].
- Complete risk assessment results can be found in the Final Human Health Risk Assessment [5].

Performance Data Quality

- According to site personnel, Quality Assurance and Quality Control (QA/QC) for all testing and associated analyses, evaluation of all data, and the complete decision making process was followed in accordance with the FFA.

TREATMENT SYSTEM COST

Procurement Process

- IT and Weston, Inc. were contracted to commission, test, and operate the SQI at the site.

Cost Data

- The total project cost of $93,337,779 was reported by Rocky Mountain Arsenal in terms of capital costs and operation and maintenance costs. The capital costs for the incineration system were $14,829,318 and operation and maintenance totaled $78,508,461. The total costs for thermal treatment were reported as $58,145,681. A total of 10.9 million gallons of liquid waste were incinerated. This corresponds to a total unit cost of $9 per gallon, and a unit cost for thermal treatment of $5 per gallon. Tables 5 and 6 show the operation and maintenance costs for incineration.

Table 5. Capital Costs

WBS Number		Description	Cost
331	01	Mobilization and preparatory work	$8,923,728
331	02	Monitoring, sampling, testing, and analysis	$3,505,590
331	03	Sitework	$2,400,000
		Total Capital Costs	*$14,829,318*

Table 6. Operation and Maintenance Costs

WBS Number		Description	Cost
342	14	Thermal Treatment (Incineration) which includes: • Equipment • Labor • Direct operating costs • Overhead	$58,145,681
342	18	Disposal	$18,936,616
342	22	General Requirements	$1,426,164
		Total Operation and Maintenance Costs	*$78,508,461*

Cost Data Quality

- Actual capital and operations and maintenance cost data are available from Rocky Mountain Arsenal.

OBSERVATIONS AND LESSONS LEARNED

Observations and Lessons Learned

- Unexpected weather conditions caused delays in the start-up of the incinerator. A heavy rainfall classified as a 25-year/24-hour event significantly increased the volume of liquid in the open holding pond just before the start of the project. This necessitated construction of a special double-lined holding pond for additional storage capacity. Additionally, a tornado touched down near the tanks and holding pond, requiring inspection and subsequent repair of equipment.

Public Involvement

- An extensive Community Relations program was developed in 1988 at RMA that addresses public concern relating to the entire site. This program included the establishment of an on-site information center, providing speakers for local clubs and organizations, attending conventions, public meetings, and open houses.

  A 24-hour telephone hotline was established and a monthly publication (the Rocky Mountain Arsenal SQI Update) was developed.

  In addition, a Restoration Advisory Board, including members of local governments and the public, was established to obtain input on the remedial approach from various parties.

  According to site personnel, these actions helped to alleviate public concern related to the on-site remediation action.

- The draining of liquid from Basin F and the subsequent drying of soils, sediments, and the Basin F liner was identified as a significant odor concern by nearby residents. Air purifiers were distributed to affected homes to help alleviate the odors. Toxicologists from various agencies identified the compounds causing the odors and determined that they did not present acute health effects.

REFERENCES

1. Summary Report for Incineration of Basin F Wastes at Rocky Mountain Arsenal, Volume 1; September 1988.

2. Final Decision Document for the Interim Response Action, Basin F Liquid Treatment, Rocky Mountain Arsenal, Volume I - Text; May 1990.

3. Interim Response Action, Basin F Liquid Incineration Project, Implementation Document, Volume I; January 1992.

4. Trial Burn Summary Report for the Interim Response Action, Basin F Submerged Quench Incineration Project, Volume I; December 1993.

5. Interim Response Action, Basin F Liquid Incineration Project, Final Human Health Risk Assessment, Volume I; March 1994.