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Project Swiftsure Final Report: Destruction of Chemical Agent Waste at Defence Research Establishment Suffield

PREPARED FOR:

Research and Development Branch
Department of National Defence
Ottawa, Canada

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MAY 1995

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Project Swiftsure Final Report

SUFFIELD SPECIAL PUBLICATION NO. 170

DESTRUCTION OF CHEMICAL AGENT WASTE AT DEFENCE RESEARCH ESTABLISHMENT SUFFIELD

prepared for:
Research And Development Branch
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John M. McAndless
Project Manager

EXECUTIVE SUMMARY

Project Swiftsure describes a Department of National Defence (DND) project undertaken at the Defence Research Establishment Suffield (DRES) to dispose of old chemical warfare agent waste stored on the DRES Experimental Proving Ground (EPG). DRES is located at the Canadian Forces Base (CFB) Suffield, approximately 50 kilometres northwest of the city of Medicine Hat, Alberta.

This project was created in response to an independent study which reviewed all aspects of the DND chemical and biological defence research and training programs. In 1989, the Minister of National Defence directed DRES to accelerate and complete by 1992 the chemical agent disposal programs which had been on-going at CFB Suffield since the end of World War II. This directive was based on the rationale that continued storage of agents represented an unacceptable risk and that Canadian initiatives at the United Nations Conference on Disarmament remained compromised while the agents existed.

The agent waste inventory, which had been sorted previously and stored at remote, protected sites on the EPG, included mustard (12 tonnes), lewisite (2.5 tonnes), nerve agents (0.3 tonnes) and contaminated scrap metal (400 tonnes). An on-site disposal operation was selected by DRES as this provided maximum safety and environmental protection compared to either permanent storage or transportation of agents off-site for commercial disposal. Chemical neutralization and incineration technologies was chosen to destroy the waste inventory.

The nerve agents were destroyed by chemical neutralization in early 1989 using DRES resources and expertise. The remaining agent stockpile and contaminated scrap, as well as the secondary waste remaining from the nerve agent neutralization program, were destroyed in 1991 by Chem- Security Ltd., a hazardous waste disposal firm, under the terms of a $14 million contract. A commercial transportable incinerator was purchased by DND and operated by Chem-Security Ltd. to destroy mustard agent and neutralized nerve agent waste and to thermally decontaminate the scrap metal. The lewisite was destroyed using transportable chemical neutralization equipment, with the resulting arsenic byproducts stabilized in concrete and landfilled. The thermally decontaminated scrap metal was sold to private industry where it was melted in a foundry for recycling as metal feedstock .

During 1990 and prior to commencing agent destruction operations under contract, Chem-Security Ltd. and Western Research prepared a comprehensive Environmental Protection Plan which was reviewed by DND, federal and provincial environmental departments, and the district public. An extensive public consultation program was implemented to ensure the district communities were fully informed of project aims and approaches. This program included a series of open public meetings, community information newsletters,

news releases, site visits and tours offered to the public and media, and the provision of informational brochures. A key element in this program was the formation of a volunteer citizens' advisory committee. In addition to being the primary liaison between DRES and the general public during subsequent destruction operations, the committee contributed to the overall success of the project through their input during the planning and operational phases. The committee proved effective for maintaining dialogue, dealing with the technical issues and representing their community interests.

Prior to processing mustard and contaminated scrap material, the incinerator underwent a series of trial burns in early 1991 to demonstrate that project limits established by Environment Canada for stack emissions and ambient air quality could be met. In many cases, these limits were more strict than current regulatory standards. The incinerator proved capable of burning mustard at greater than 99.9999% destruction and removal efficiency under operational conditions. A feature unique to Project Swiftsure was the manner in which the mustard was processed. During cooler weather, mustard was transferred and frozen into incinerable cardboard boxes which served as packaging material for the agent, as well as for shredded contaminated scrap and agent-filled ordnance items. The boxes were processed in batches through the incinerator solids waste feed system. This method of packaging, handling and processing mustard greatly reduced potential risks of agent spills or fugitive emissions from the destruction process.

To verify operations were carried out safely with minimal environmental impact, an extensive environmental monitoring program was carried out by DRES, Chem-Security Ltd., and an independent contractor hired to conduct air quality surveys around the incinerator facility and in district communities. The incinerator itself was equipped with a sophisticated continuous stack emissions monitoring system which provided instantaneous data on the performance of the incinerator. The independent contractor employed a mobile monitoring laboratory which provided air quality data on a continuous basis. During agent incineration, the environmental monitoring program demonstrated that all project limits were successfully met and that there were no risks to public health and safety nor environmental impacts. The destruction of the agent waste inventory was completed by the end of 1991 and the incinerator was decommissioned in preparation for its removal from CFB Suffield.

The sale and removal of the incinerator, as promised by DND, remained a public issue until the end of March 1992. A delay arose when the United Nations expressed an early interest in having the equipment donated to support a UN- supervised chemical agent destruction project in Iraq. No firm commitment arose from this interest and the incinerator was eventually sold to private industry and removed from CFB Suffield by August 1992.

Project Swiftsure was a unique undertaking in Canada to destroy chemical warfare agent waste in a safe, environmentally-responsible manner. This project represented the second successful example of a DND waste destruction activity involving full public participation, the first being the PCB destruction program at Goose Bay, Labrador.

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CHAPTERS I & II

INTRODUCTION AND OVERVIEW

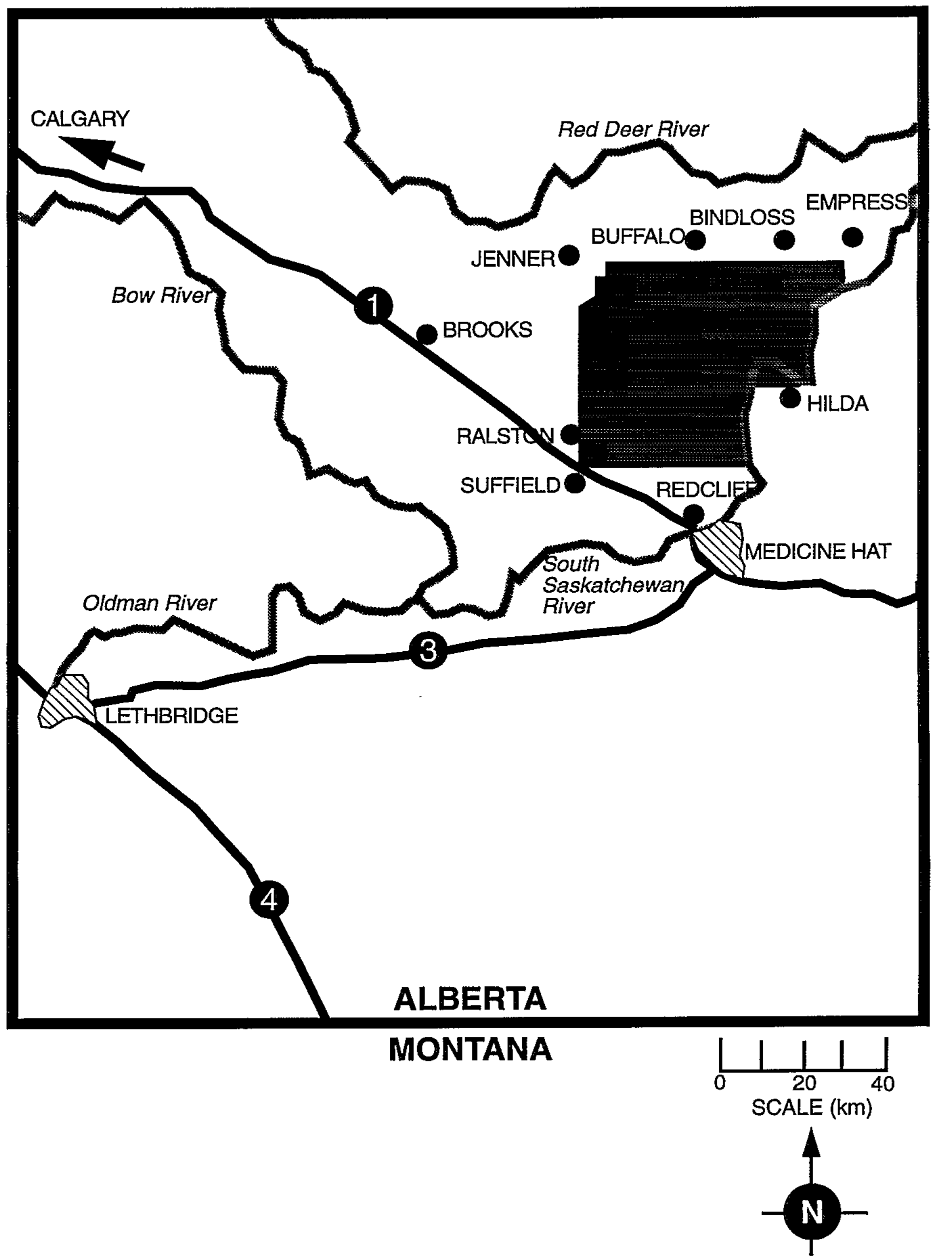
1.0 INTRODUCTION

The Department of National Defence (DND) recently completed a three- year project at the Defence Research Establishment Suffield (DRES) to safely destroy old chemical warfare agent waste which had been stored for many years on the DRES Experimental Proving Ground range. This project, codenamed Swiftsure, was the culmination of numerous range clean-up and chemical agent disposal programs which have been on-going at DRES since World War II. Such disposal programs previously had been carried out in-house; in the present case, the chemical agent waste was destroyed with a combination of chemical neutralization and incineration technologies using both in-house and contracted resources. Project Swiftsure represents the second successful example of a DND waste destruction project involving public participation, the first being the destruction of PCBs stored at Goose Bay, Labrador [1]. During Swiftsure, a strong public consultation program was instrumental in overcoming initial controversy and gaining acceptance for the project goals, the selection and use of agent destruction technologies and for the environmental monitoring programs which were implemented.

1.1 Project Location

DRES is located at the Canadian Forces Base (CFB) Suffield, approximately 50 km northwest of the city of Medicine Hat, Alberta, as shown in Figure 1.1. The Base features a 2600 square kilometre federal land reserve known as the Suffield Military Range which is used primarily for mechanized training exercises conducted by the Canadian Forces and the British Army Training Unit Suffield (BATUS). The Experimental Proving Ground (EPG), located in the southern portion of the Range, encompasses an area of approximately 495 square kilometres which is dedicated to field trials in support of DRES research and development programs.

Figure 1.1



Regional Location of Project Swiftsure

1.2 Barton Report

The initial planning for Project Swiftsure was triggered in July 1988 when DND announced that an independent review would be conducted of chemical and biological research, development, and training programs within the Department and the Canadian Forces. This action was prompted, in part, by public concern which had arisen over open-air tests conducted earlier at DRES which had involved chemical agents. The public required assurance that such testing presented no health or environmental risks and that Canadian policy [2] had not changed regarding a defensive-only capability with respect to chemical and biological warfare agents.

The review was conducted by William H. Barton, Chairman of the Board of Directors for the Canadian Institute for International Peace and Security, and included visits to the appropriate Defence Research Establishments and Canadian Forces training units. Mr. Barton presented his report [3] to the Minister of National Defence on December 31, 1988. The report concluded that all DND research, development and training activities in chemical and biological defence remained strictly defensive in nature and that the program was conducted in a professional manner which posed no threat to public safety or the environment.

With respect to DRES, the report noted that a residual stockpile of aged chemical warfare agents and contaminated scrap material remained stored on the EPG from previous disposal operations started after World War II. The agent stockpile (estimated at 18 tonnes) was in excess of that needed to maintain the current defensive research and development program. The stockpile included nerve agents, mustard and lewisite.

In response to the Barton Report, the Honourable Perrin Beatty, the incumbent Minister of National Defence, directed [4] that DRES accelerate and complete the on-going agent disposal program by 1992. The directive stated that the nerve agent stocks were to be neutralized as soon as possible, with the destruction of the neutralized residues and other chemical agents to commence only after adequate public consultation and environmental assessments had been completed.

The rationale for implementing this directive was as follows:

- continued storage of the chemical agents represented an unacceptable safety and environmental risk;
- Canadian initiatives at the United Nations Conference On Disarmament, especially those related to the Chemical Weapons Convention, remained compromised while the agents existed;
- technology was available which could be used for the safe destruction of the DRES waste;
- DND intended to comply with the intent and spirit of Canadian environmental legislation, and
- DND intended to further demonstrate its commitment to environmental protection management.

2.0 PROJECT OVERVIEW

2.1 Project Name

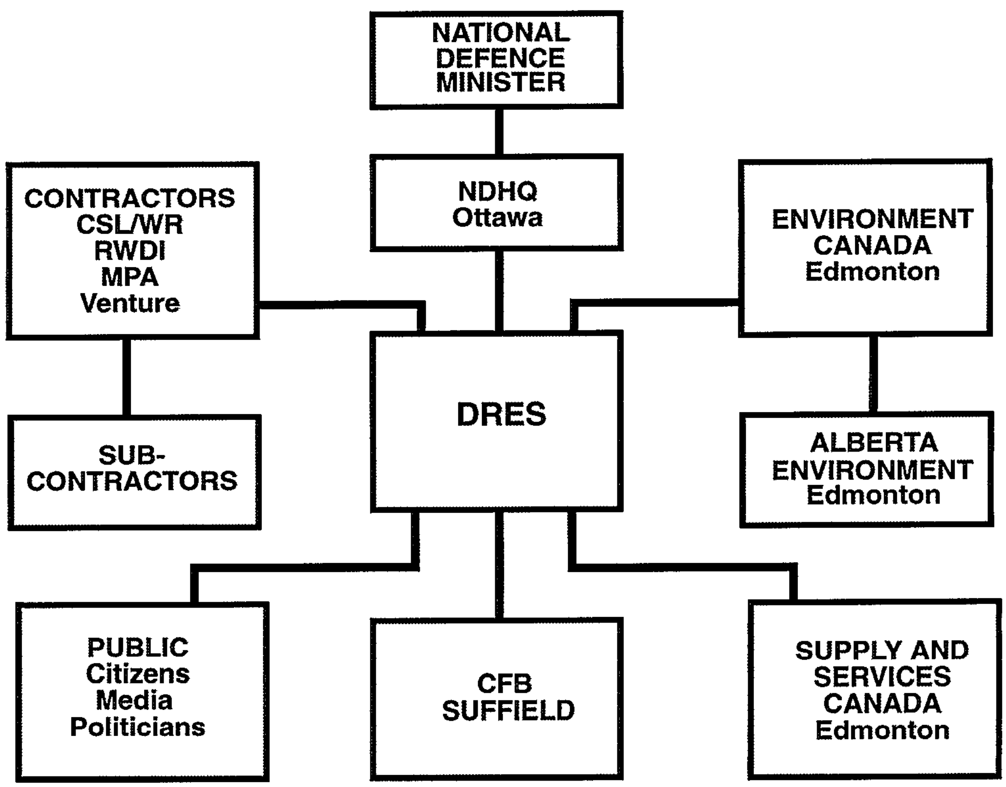
The name Swiftsure was chosen to reflect the project aim, viz: to quickly, but more importantly, to safely destroy the chemical agent waste in an environmentally-responsible manner within the time frame mandated by DND.

2.2 Agency Participation

The general organization for Project Swiftsure is illustrated in Figure 2.1. Several different agencies, government departments, contractors, consultants and citizen groups participated in project activities. Overall responsibility for the project was vested with the Chief of Research and Development (CRAD) organization at National Defence Headquarters, Ottawa. CRAD is responsible for the strategic planning, implementation, and conduct of research and development programs to support DND requirements, as well as for the operation of five Defence Research Establishments (including DRES) nationwide. The day-to-day responsibility for managing technical and contractual matters with respect to agent destruction activities was vested with DRES.

The key agencies involved in Project Swiftsure were as follows:

Figure 2.1



General Organization Chart For Project Swiftsure

2.2.1 Department of National Defence

- CRAD/Head Research and Development Technical Services:- Project Swiftsure Director;
- Director of Procurement Supply Communications and Electronics (DPSCE)/Ottawa:- project funding and financial control;
- Director Conservation and Environment[1] (DCE)/Ottawa:- DND policy on environmental protection management;
- Director General Information[2] (DG Info)/Ottawa:- assistance in developing and implementing the public consultation program;
- DRES/Medicine Hat:- Project Swiftsure Manager and operational staff.

2.2.2 Supply and Services Canada

- Science Procurement Branch/Edmonton:-contract preparation, negotiations and management;
- Crown Assets Distribution Centre/Edmonton:-sale and removal of the incinerator equipment upon project completion.

2.2.3 Regulatory Agencies

- Environment Canada/Edmonton:- federal regulatory environmental standards and monitoring requirements, and liaison with the provincial environment agency;
- Alberta Environment/Edmonton:-provincial regulatory requirements.

2.2.4 Contractors

- Western Research Partnership/ Calgary:- the prime contractor for carrying out the destruction of the DRES chemical agent waste. The partnership consisted of two companies, Chem-Security Ltd. (CSL), who supplied and operated incineration and chemical neutralization technologies, and Western Research Ltd., who performed stack sampling and environmental monitoring activities during incineration operations. Both are part of the BOVAR group of companies. The contractor was supported by Can-Tox Inc., toxicological consultants,Oakville, Ontario during preparation of the project Environmental Protection Plan (EPP);

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[1] This organization is now known as the Director General Environment (DGE).
[2] DG Info is now known as Director General Public Affairs (DGPA).

- Rowan Williams Davies Irwin Inc. (RWDI)/Guelph:- independent air monitoring program. RWDI sub-contracted with Canadian Environmental Monitoring Ltd., Calgary, to supply and operate mobile monitoring equipment in support of this program.
- Shred-Tech Ltd./Cambridge:-development and construction of a transportable scrap metal shredder;
- Maureen Payne Associates/Venture Communications Ltd./ Calgary:- public consultation program support;
- Brian Stuckert, Seacor Environmental Engineering/Calgary:- independent technical consultant for a citizens' advisory committee (see below).

2.2.5 Citizens' Committee

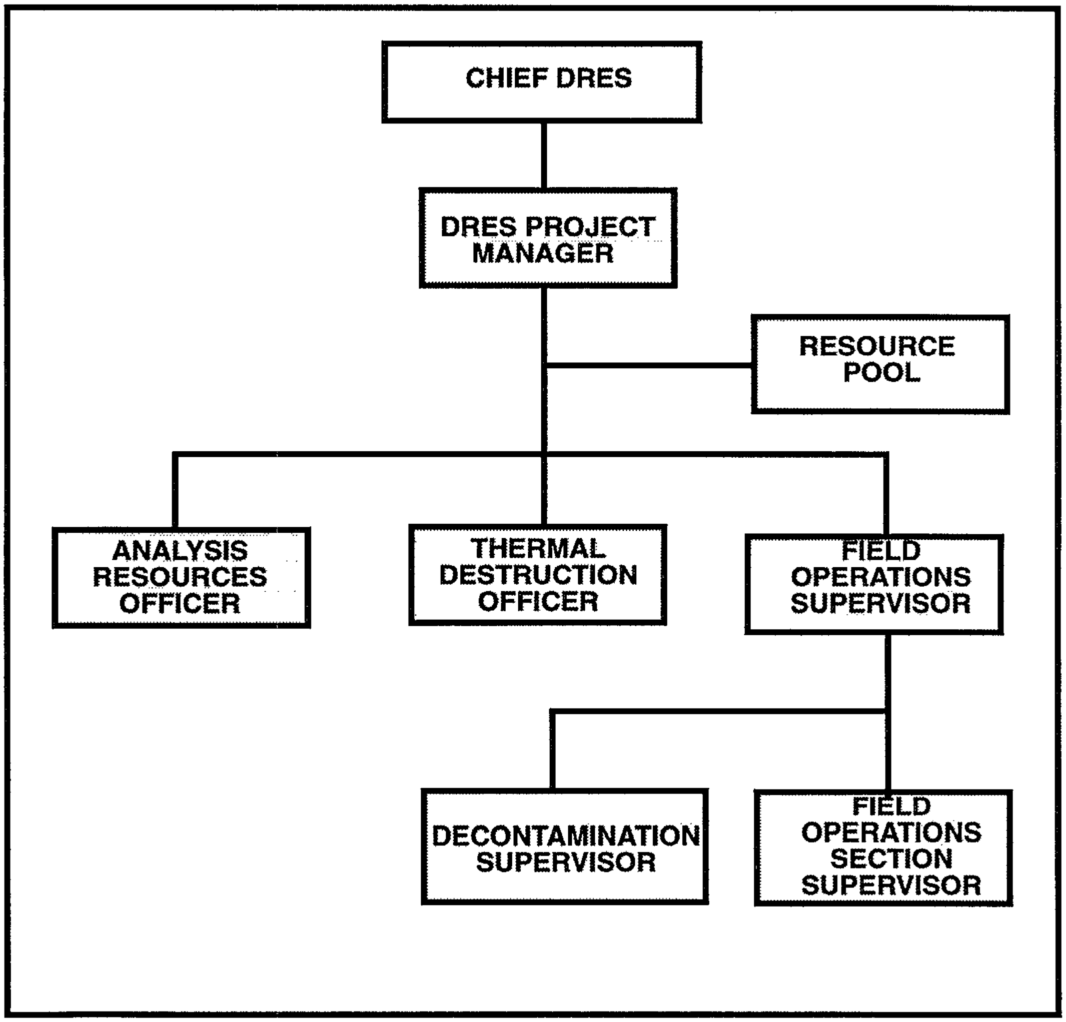
- Citizens' Environmental Protection Committee (CEPC):- a citizens group representing the general public in district communities, liaison with the project proponents.

2.3 Internal Roles

The high profile of the project dictated that effective, rapid communications be maintained amongst the various government departments, agencies and staffs involved. To this end, DND developed a simple matrix organization which gave key staff sufficient authority to quickly exercise decisions with a minimum of bureaucracy. The key positions included the Project Director, who reported directly to Associate CRAD at National Defence Headquarters, and the Project Manager who reported directly to the Project Director and to the Chief, Defence Research Establishment Suffield. The duties and responsibilities assigned to these two positions are given in Annex A.

The matrix organization set up at DRES for Project Swiftsure is shown in Figure 2.2. At any given time, up to 26 DRES employees were involved in various aspects of the project.

Figure 2.2



DRES Matrix Organization For Project Swiftsure

2.4 Previous Disposal Operations

During World War II, the DRES EPG was used extensively for the testing of protective equipment and training of personnel for the potential advent of chemical warfare [3]. Following the war, Canada's production stocks of chemical agents, primarily mustard (bis-2-chloroethyl sulphide), were shipped to DRES for safe storage and eventual disposal. Other agent stocks were obtained from allied nations after the war in order to continue the development of protective equipment and defensive procedures. This work was carried out in response to the continued threat of chemical warfare from potential adversaries such as the Warsaw Pact nations.

DRES has previously carried out several programs to dispose of unneeded chemical agent stocks. For example [5,6], over 700 tonnes of bulk mustard were destroyed in the mid- 1970's, using a special hydrolysis facility constructed for this purpose. Other disposal methods have included chemical neutralization, explosive detonation and open-pit burning of hazardous items at remote field sites on the EPG. All disposal operations were conducted and supervised by experienced DRES personnel under specific conditions which called for maximum safety. Most operations involved relatively small amounts of material in order to minimize and localize any environmental impact.

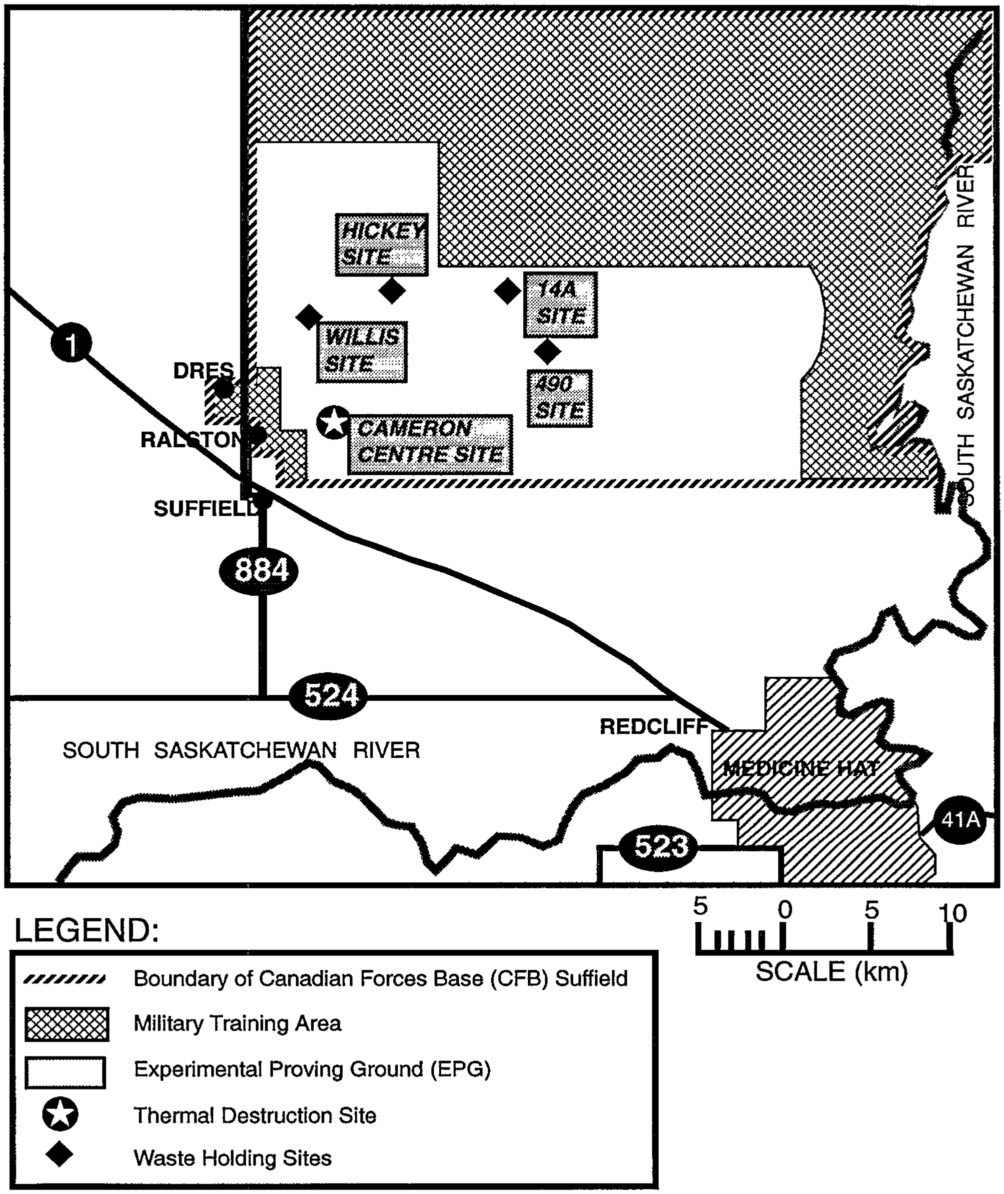
Prior to Project Swiftsure, all chemical agent materials awaiting final disposal had been collected and consolidated at three protected sites on the EPG. These sites are shown in Figure 2.3. The Willis Centre Site was used to temporarily store waste generated during Project Swiftsure nerve agent destruction operations.

2.5 Waste Inventory

A wide variety of chemical agent material was stored at the EPG sites. The waste inventory included bulk chemical agents, contaminated drums, scrap metal fragments and a variety of chemical-filled ordnance, tanks, cans and other containers. Some ordnance items were known to contain explosives as well as chemical fills. Many items were empty but were potentially contaminated with chemical agents that had penetrated the metal during long-term storage. In addition, many of the drums and ordnance contained an intractable sludge of aged mustard agent. Most of the drums, along with some ordnance, were piled in crude, open pits which made it impossible to count and weigh such items accurately; therefore, estimates were used for inventory purposes. The original estimate for the Project Swiftsure chemical agent waste inventory is given in Table 2.1. The amounts listed were assumed to have a 10% variability.

Chemical agents in bulk storage were located at the Hickey Storage Site and included mustard (3 tonnes), lewisite (2-chlorovinyl-dichloroarsine, 2.5 tonnes) and nerve agents in the G- and V-classes (0.3 tonnes). The physical and physiological properties of the chemical agents are described in Annex B.

Figure 2.3



Project Swiftsure Site Location

The nerve agents were stored in non-explosive containers, primarily in 105-mm and 155-mm artillery shells located inside a concrete bunker on the site (Figure 2.4). Some of the containers were stored outside on a wooden rack (Figure 2.5). A one-ton container of GA (tabun) was located near the site perimeter fence. A total nerve agent weight of 1.1 tonnes was estimated for reporting purposes [3] by assuming all containers were full. This approach was taken in anticipation of public reaction to disclosure of the nerve agent stocks as well as to ensure that a revised, larger estimate would not be required as the project proceeded. The original nerve agent inventory was, in fact, overestimated; during disposal operations many of the agent containers were found to be empty or only partially full.

All of the lewisite was stored in two one-ton containers located outdoors near the Hickey Storage Site perimeter (Figure 2.6). Bulk mustard was stored in four other one-ton containers at this same location.

Aged and decomposed forms of mustard (9 tonnes) were found in a variety of ordnance and spray tanks stored at the 14 Alpha Site. Examples included aerial spray bombs ("Flying Cows", Figure 2.7) and Livens mortars (Figure 2.8). A number of (potentially) explosive, chemical-filled items were also stored at this site, including captured World War II German munitions (Figure 2.9), US and UK mortars and several types of large aircraft bombs (Figure 2.10).

The 490 Site was used for the open storage of contaminated scrap material. The scrap (approximately 400 tonnes) consisted mainly of several thousand 210 L drums contaminated with mustard residues and which were stored in four separate pits; one example of a scrap storage pit is shown in Figure 2.11. The scrap also included numerous (presumably) empty ordnance casings as well as eleven, unserviceable vehicles such as fuel bowsers, tanker trailers and trucks which had been used in previous disposal operations. These vehicles (see Figure 2.12) were contaminated with mustard or mustard hydrolysate (thiodiglycol) residues. One of the vehicles (tanker trailer) contained a full load of solidified mustard hydrolysate salts.

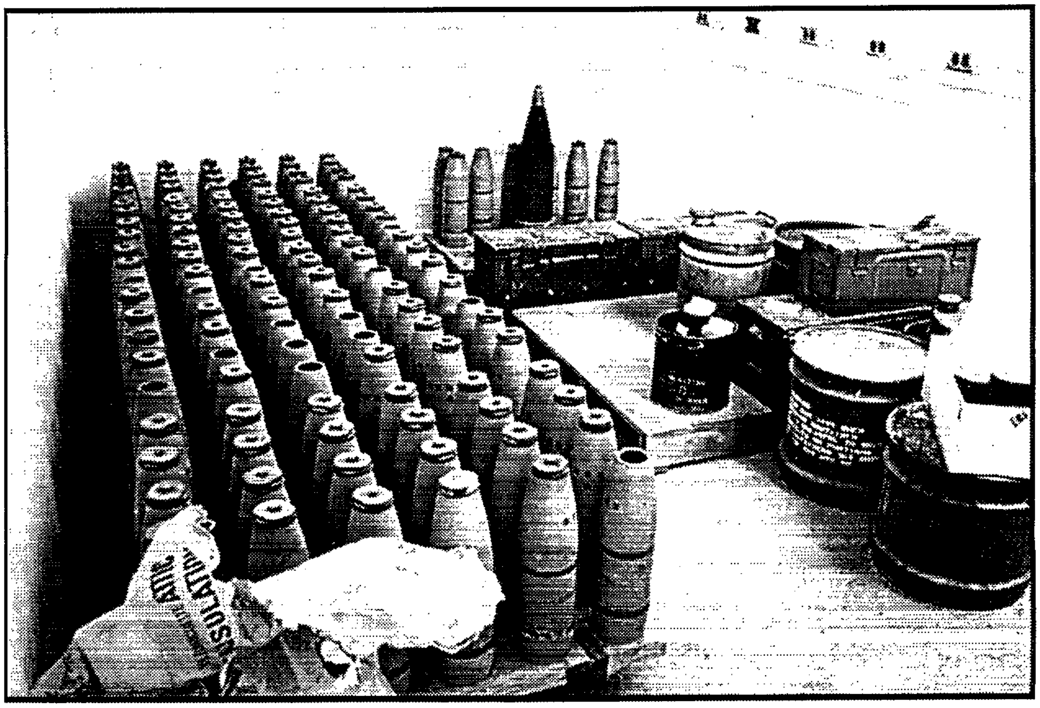
Table 2.1

PROJECT SWIFTSURE ORIGINAL WASTE INVENTORY ESTIMATE[1]

MATERIAL	DESCRIPTION	AMOUNT (Tonnes)
Contaminated Scrap	empty drums empty ordnance vehicles (x11) miscellaneous	250[2]
Mustard Agent[3]	ton containers (x4) ordnance drums spray tanks	12
Lewisite Agent	ton containers (x2)	2.5
Nerve Agent[4]	non-explosive ordnance ton container (x1) miscellaneous containers	1.1[5]
Non-Hazardous Scrap	vehicle parts storage containers miscellaneous scrap commercial solvents[6]	40

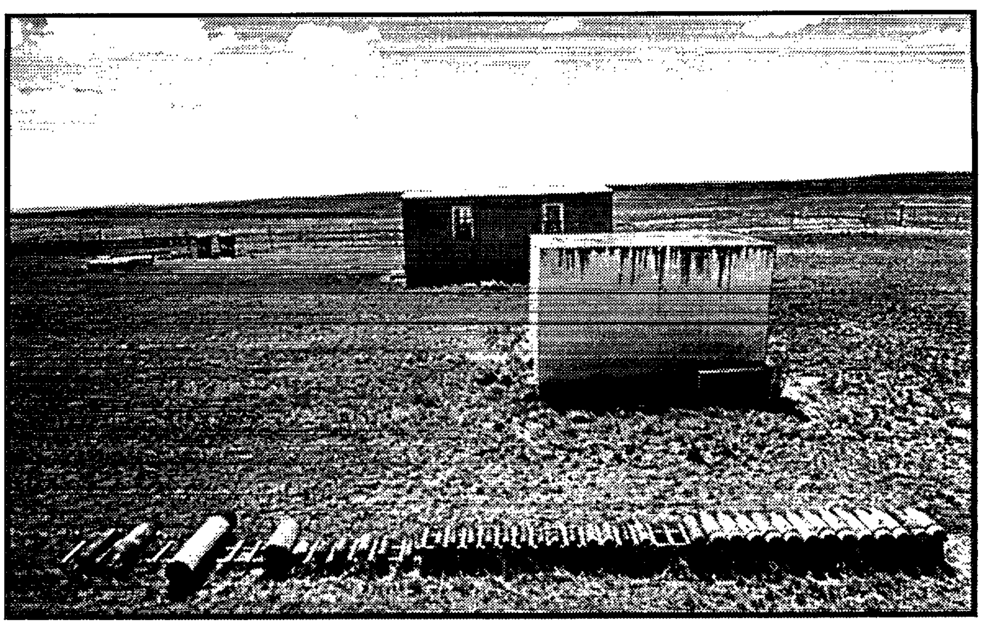
1 The original estimate was assumed to have a variability of ±10%
2 After processing, the weight of the scrap inventory was found to be approximately 400 tonnes.
3 Mustard inventory in liquid and semi-solid (thickened or aged) form.
4 G-agents, VX and experimental V-agent formulations.
5 All nerve agent containers were assumed to be full for reporting purposes.
6 Triethyl- and tributyl-phosphate, 10 x 210 L drums.

Figure 2.4



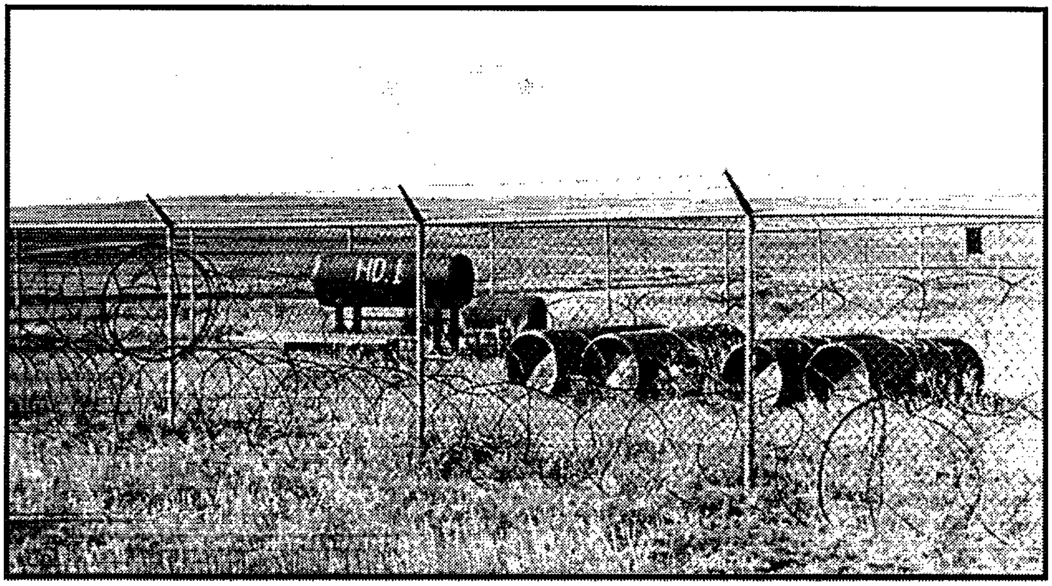
Hickey Storage Site Bunker (Nerve Agent Storage)

Figure 2.5



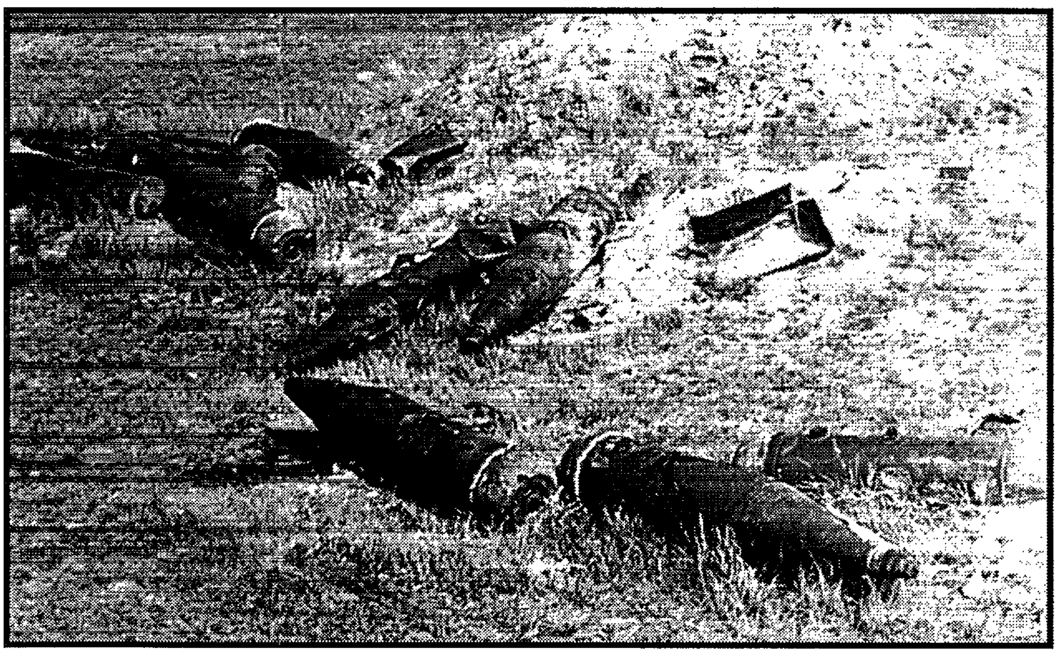
Outside Storage Rack At Hickey Storage Site

Figure 2.6



One-Ton Bulk Agent Containers (Hickey Storage Site)

Figure 2.7



Flying Cow Bombs (14A Site)

2.6 Disposal Options

Certain types of disposal activities previously carried out by DRES, such as open-pit burning, were deemed unlikely to meet the stringent emission requirements imposed on commercial disposal operations by legislation such as the Canadian Environmental Protection Act [7] and Alberta Hazardous Chemicals Act [8].

A number of options were considered for the disposal of the Project Swiftsure inventory. These included:

- maintaining the agent waste in permanent storage with continuous monitoring to ensure safety;
- removing the agent waste to a commercial hazardous waste disposal facility for destruction;
- conducting an on-site disposal operation using DRES resources and facilities;
- conducting an on-site disposal operation using contracted resources.

The permanent storage option was rejected as this did not eliminate the risks associated with storing chemical agents, nor did it meet the requirements of the ministerial directive issued in response to the Barton Report. Moreover, it was considered unacceptable to store agents in excess of the small amounts needed for the defensive research and development program conducted within the Defence Sciences Division at DRES.

The high degree of risk from accidents and expected public concern associated with an off-site transportation and disposal program rendered the removal option unacceptable. Aside from this, there are no commercial facilities in Canada licensed and equipped to properly dispose of chemical warfare agents. US sites such as the Chemical Agent Munitions Disposal System (CAMDS) facility at Tooele, Utah or the Johnston Atoll Chemical Agent Disposal System (JACADS) in the South Pacific do not accept inventory from foreign nations. Finally, policy statements regarding Project Swiftsure (see Section 2.14, Project Policy) precluded the removal of waste inventory from CFB Suffield.

It was concluded that an on-site operation was the best approach to minimize risk to personnel, the public, and the environment. In considering whether to carry out the operation with in-house or contracted resources, the following points were considered:

- DRES personnel were experienced in the proper and safe destruction of extremely toxic nerve agents. A destruction program using available DRES resources could accommodate the relatively small size of the nerve agent stockpile;
- DRES expertise and personnel were available to dispose of explosive items using well-established techniques developed in-house;
- While DRES had appropriate expertise to chemically destroy mustard and lewisite, the stockpiles were too large to be destroyed

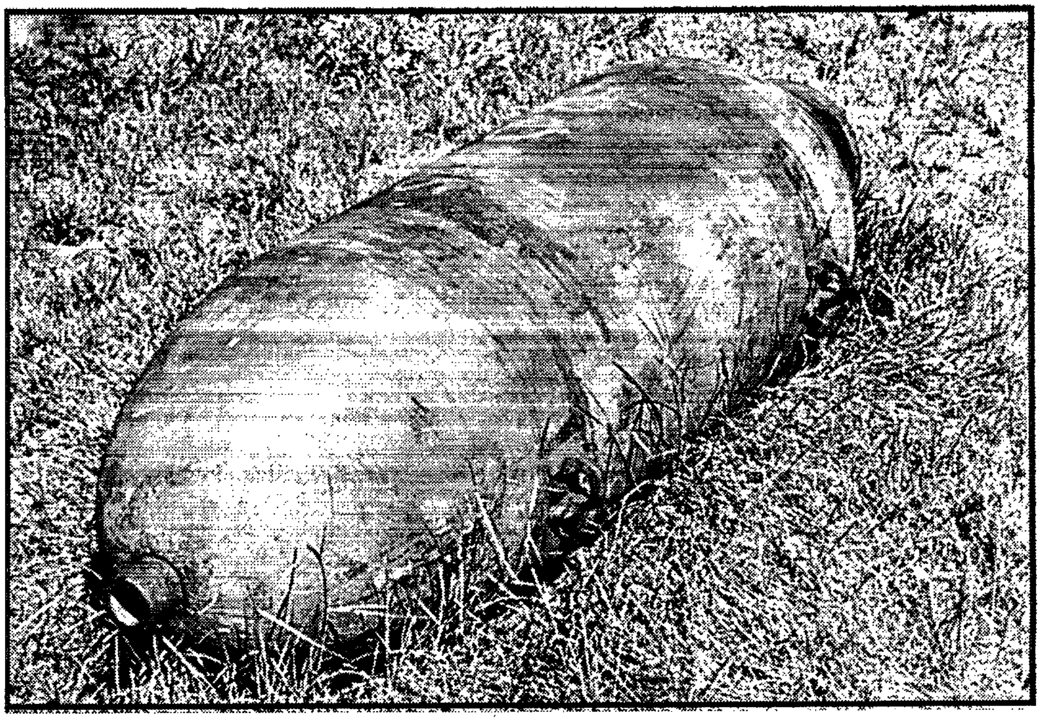
Figure 2.8

Livens Mortars (Processed Examples)

Figure 2.9

Examples Of German Ordnance (14A Site)

Figure 2.10

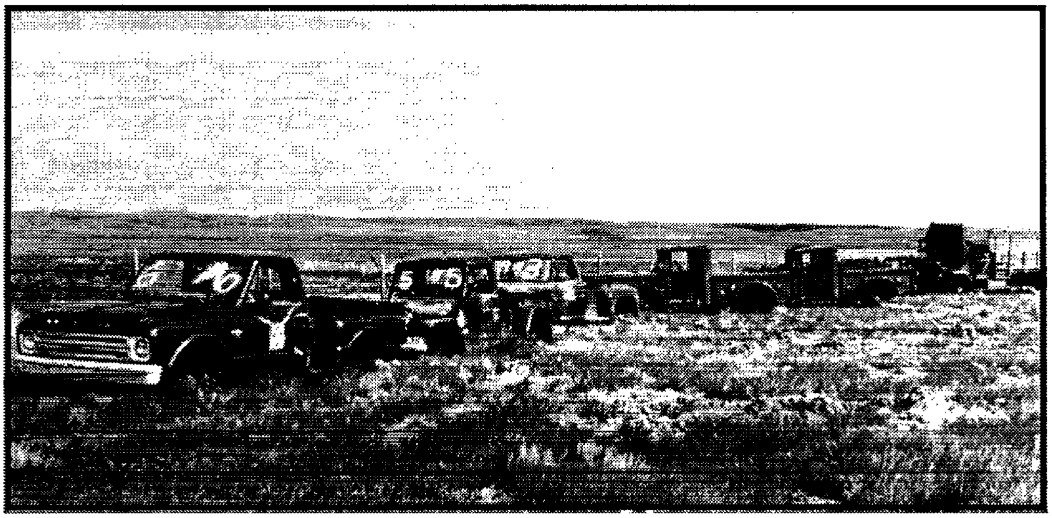


Aircraft Bomb Example (14A Site)

Figure 2.11

Drum Storage Pits (490 Site)

Figure 2.12



Contaminated Vehicles (490 Site)

in-house in a timely fashion. Some of the mustard was in a form which precluded destruction by chemical neutralization;

- The large stockpile of contaminated scrap required some form of thermal treatment to render it clean, using technology, e.g. incineration, which was not available at DRES or could be readily acquired off-the-shelf.

Therefore, the overall approach chosen for Project Swiftsure was to conduct destruction operations on-site using both in-house and contracted resources. That is, DRES assumed responsibility for destroying the nerve agent stockpile and any explosive items, while a contract to a hazardous waste disposal firm or firms) would be let to destroy the remaining chemical agent waste inventory.

2.7 Destruction Technology And Method Selection

It was recognized that available, proven destruction methods and technology were required for the project, given the short time frame and the need to meet high standards for safety and environmental protection. In addition, it was considered essential to use proven methods in order to gain public acceptance for Project Swiftsure. Chemical neutralization and incineration currently are the only two proven methods for large-scale chemical agent destruction [9,10]: thus, these methods were selected to treat the agent waste inventory.

A variety of promising alternative methods for chemical agent destruction [11,12], e.g. bioremediation or pressurized steam, were examined and rejected as such methods have yet to be proven viable on a large scale or were not applicable to the waste inventory on-hand.

The initial plan called for destroying the chemical agents to the fullest extent possible using chemical neutralization, with high temperature incineration to be used to treat other waste material such as contaminated scrap metal and empty containers. Most of the mustard contained in non-explosive ordnance was in a thickened or deteriorated state which effectively precluded its removal and destruction by chemical means. Therefore, the only practical option for this form of mustard was to destroy it in small batches by direct incineration of the ordnance.

Although effective in destroying chemical agents, neutralization and incineration generate secondary waste products which eventually must be disposed of. For example [10,12], large scale chemical agent neutralization can produce approximately 6 kg of detoxified waste for every 1 kg of agent treated. Incinerating 1 kg of agent can produce approximately 2 kg of process residues, including ash and scrubber system salt solutions. For Project Swiftsure, it was decided to incinerate the secondary waste resulting from chemical neutralization, where possible, to reduce the amount of process residue requiring final disposal.

Finally, for explosive ordnance and the contaminated vehicles, DRES employed approved in-house methods to safely destroy or dispose of individual items on a case-by-case basis.

2.8 Destruction Sites Selection

The Willis Centre site, located approximately 4 km from DRES, was chosen for conducting nerve agent destruction operations. This developed site housed a small field laboratory (Figure 2.13) which had been used previously for small-scale agent destruction operations. The laboratory (Building 214) was equipped with a fume hood which incorporated a charcoal filter element to prevent fugitive emissions. The housing for the filter element was located on the roof of the building. To support the destruction operations, a mobile decontamination trailer and meteorology trailer were positioned near the laboratory.

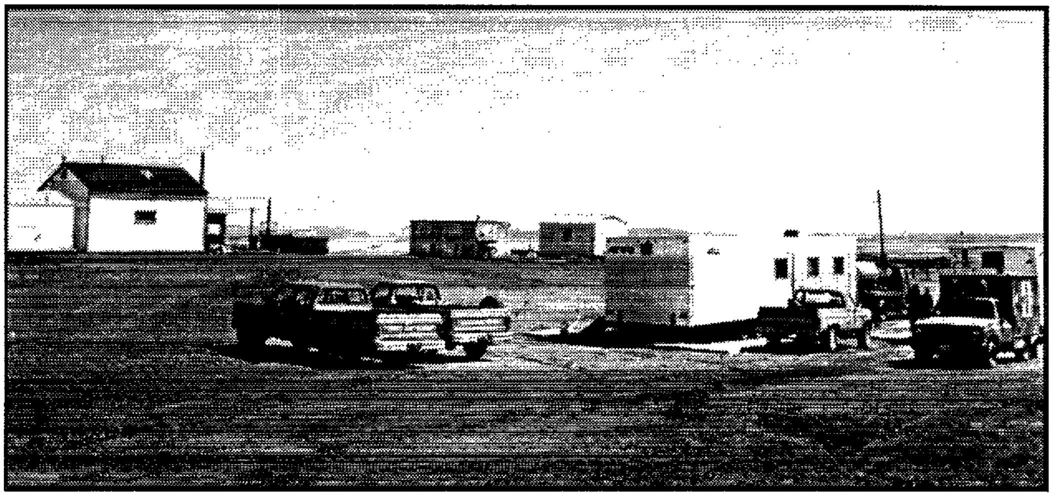
Several locations on the DRES EPG were examined for siting the Project Swiftsure incineration operations. Site selection criteria included the following:

- favourable environmental factors related to soil, hydrogeology and groundwater characteristics;
- ready access to support services such as medical and fire-fighting;
- developed infrastructure including utilities, road access and security fencing;
- minimal requirement to construct or relocate support facilities at the site;
- safety distance associated with potential worst-case accident scenarios not to extend beyond the boundaries of the DRES EPG.

Moreover, DRES considered it important to demonstrate confidence in the safety of the incineration process. Therefore, sites located closer to DRES were given preference over sites located further away on the EPG.

The Cameron Centre, located approximately 3.5 km from DRES, was eventually chosen as the most suitable site for incineration operations. This well-developed site, which is occupied daily by DRES staff to support field programs, met all selection criteria. A lined effluent lagoon, deemed suitable for containing incinerator scrubber system discharge and for evaporating water back to atmosphere, was available. A natural gas well and electrical utilities were also available to support operations. An overhead view of the Cameron Centre prior to the start of Project Swiftsure is shown in Figure 2.14. Site characteristics [13,14,15] are listed in Table 2.2.

Figure 2.13



Willis Centre Site (Nerve Agent Destruction)

2.9 Environmental Impact Assessment

Certain chemical agent destruction operations had potential to produce impacts on the surrounding environment. For example, both the chemical neutralization and incineration processes could produce emissions to the atmosphere. Spills or accidents occurring during the handling and transport of agents could create emissions or ground contamination. No environmental impact was expected from the nerve agent destruction program as operations would take place in a laboratory designed to prevent fugitive emissions and to contain small spills. As required by the Canadian Environmental Assessment Review Process (EARP) [16] and in accordance with DND policy on environmental protection management [17], an initial screening was conducted during project planning to examine potential health, safety and environmental impacts from the proposed waste destruction operations as well as facilities construction activities. This screening [18], which was registered with the Federal Environmental Assessment Review Office, Ottawa, in January 1990, concluded that any potential adverse health, safety and environmental impacts from Project Swiftsure activities could be mitigated with known technology and waste management practices. Normally, such an assessment decision is sufficient to gain Departmental approval to proceed with a project without need for further study. However, because of anticipated public interest in Project Swiftsure, DRES required that the contractor supplying and operating the destruction technology prepare a comprehensive Environmental Protection Plan (EPP). Furthermore, this EPP was developed with public and regulatory agency input and was accepted by all stakeholders involved prior to carrying out waste destruction operations under contract.

Figure 2.14

Overhead View Of Cameron Centre Prior To Project Swiftsure

Table 2.2

CAMERON CENTRE SITE CHARACTERISTICS

CRITERIA	DESCRIPTION
Land Usage	DND federal land reserve for military training and defence R/D programs
Population Setback	Direct distance from nearest populations DRES 3.5 km Ralston 3.5 km Suffield 5 km
Topography and Terrain	Flat, short-grass prairie, no surface water
Soil	Chernozemic, alkaline clay loam
Hydrogeology	Groundwater depth: 43 m quality: poor (alkaline/mineralized) Soil hydraulic conductivity: $<10^{-5}$ cm/second
Infrastructure	Utilities available: Natural gas Electrical Groundwater well Buildings: B60 Decontamination Centre B57 Engineering/Storage B59 Storage Graded gravel/hardpan access roads Site perimeter security fence
Site Access	Restricted access through EPG range control. Area patrolled by military on a continuous basis
Support Services	Firefighting and medical support located 4 km away by road (CFB Suffield). DRES support staff available (Building 60)
Additional Features	Bermed and lined lagoon, capacity: 1.4×10^6 L water Constructed fire-guards around site perimeter

2.10 Environmental Monitoring

Project Swiftsure operations were restricted to specific sites on the DRES EPG (Figure 2.3). In general, the area involved is well-characterized [13] and may be described as flat, arid, featureless short-grass prairie terrain which exhibits minimal sensitive environmental components; i.e. an area ideal for carrying out hazardous waste disposal operations. Thus, monitoring programs were directed primarily towards measuring airborne emissions to confirm the safety and environmental impact from incinerator and chemical neutralization operations. The incinerator wastewater (scrubber effluent) discharged to the Cameron Centre lagoon was also measured for organic and metal content to ensure water quality standards set for the project were met.

Project limits were established by Environment Canada for incinerator stack emissions and ambient air quality, as listed in Tables 2.3 and 2.4, respectively. The limits were, in many cases, guidelines which were more stringent than current regulatory standards. No standards exist in Canada with respect to mustard emissions: therefore, the guidelines applied to the US chemical demilitarization program [19] were established for Project Swiftsure. The limits set for the scrubber effluent are listed in Table 2.5. These latter standards were similar to those used for drinking water, in spite of the fact the effluent was discharged to a lagoon specially designed to contain hazardous fluids.

An extensive monitoring program was implemented which involved both retrospective sampling/analysis as well as real-time, fixed and mobile detection equipment (see Chapter VIII). Monitoring results were forwarded periodically to the federal and provincial environmental agencies for review. These agencies opted to forego their own monitoring in view of the on-going project monitoring program.

2.11 Public Consultation

The need for a strong public consultation program was identified early during project planning. For example, the project was expected to generate public concern primarily for the following reasons:

- dangerous chemical warfare agents were to be handled, transported (on the DRES EPG) and processed;
- an incinerator would be used to destroy agent waste, and
- the Federal government (National Defence) was the project proponent.

Table 2.3

PROJECT SWIFTSURE INCINERATOR EMISSIONS LIMITS

PARAMETER	CONCENTRATION LIMIT [1] (mg/m^3) STACK EMISSIONS
Particulates	20
Sulphur Dioxide	250
Nitrogen Dioxide	300
Hydrogen Chloride	75
Carbon Monoxide	57
Total Hydrocarbons	45
Mustard	0.03
Trace Metals:	
arsenic	1
copper	5
lead	5
Dioxins/Furans[2]	12×10^{-6}

1 Concentrations at standard conditions of 25°C and 101.3 kPa with stack emissions corrected to 11% oxygen on a dry gas basis.

2 Dioxin and furan congener concentrations are converted to a toxic equivalent concentration relative to 2,3,7,8- tetrachlorodibenzodioxin (T4CDD).

Table 2.4

AMBIENT AIR QUALITY LIMITS FOR PROJECT SWIFTSURE

PARAMETER	CONCENTRATION LIMIT[1] (mg/m³)	(ppm)[2]	AVERAGING PERIOD[3]
Particulates[4]	0.10	-	24-hour
	0.06	-	annual
Sulphur Dioxide[4]	0.45	0.17	1-hour
	0.15	0.06	24-hour
	0.03	0.01	annual
Nitrogen Dioxide[4]	0.40	0.21	1-hour
	0.20	0.11	24-hour
	0.06	0.03	annual
Hydrogen Chloride[5]	0.10	0.066	1-hour
Carbon Monoxide[4]	15.0	13.0	1-hour
	6.0	5.2	8-hour
Mustard[6]	0.003	0.00045	8-hour
	0.0001	0.000015	72-hour

1 Concentrations are at standard conditions of 25°C and 101.3 kPa.

2 Parts per million (by volume).

3 Time period over which ambient air quality measurements are averaged.

4 Based on Alberta Clean Air (Maximum Levels) Regulation 218/75.

5 Based on Alberta Environment Guidelines (1983).

6 Long-term exposure limits recommended by United States Department of Health and Human Services for protection of workers (8-hour average) and the general public (72-hour average).

Table 2.5

WASTEWATER DISCHARGE LIMITS FOR PROJECT SWIFTSURE

PARAMETER	CONCENTRATION LIMIT (mg/L)
Arsenic	0.1
Copper	0.1
Lead	0.1
Mustard or Organic Products	0[1]

1 Free of organic material to the detection limit of the laboratory analysis equipment (<0.1 mg/L).

The main goals of the program were to inform the interested public of the project, to solicit input during planning and EPP development, and to maintain a dialogue with the public as the project proceeded.

A variety of consultation techniques were employed under this program including public meetings and open houses held in district communities, small group meetings and site visits held at DRES, media presentations, distribution of information brochures and newsletters, a toll-free information "hotline" and the formation of a volunteer citizens' advisory committee.

2.12 Scheduling

Project Swiftsure was divided into five distinct phases based on the requirement to use both in-house and contracted resources. The following summarizes the major activities which were carried out during each phase:

2.12.1 Phase I: (Project Planning) Sept-Dec 1988

- a complete computer-based chemical agent waste inventory was developed;
- a project concept plan was submitted for Departmental approval;
- discussions were initiated with Environment Canada and Alberta Environment on regulatory requirements;
- methods for chemical agent destruction were reviewed, and
- project cost estimates were prepared for funding approval.

2.12.2 Phase II:
(DRES Operations and Contract Development)1989

- nerve agent stocks were destroyed by chemical neutralization using DRES facilities and resources;
- an initial environmental screening was completed for the project;
- the site for incinerator operations was selected;
- contract specifications were prepared and a Request For Proposal for the destruction of the remaining chemical agent waste inventory was issued;
- contracts were awarded for the development, construction and delivery of a transportable metal shredding system to process contaminated scrap;
- bids were reviewed and a contract awarded to supply and operate chemical neutralization and incineration technologies, and
- the public consultation program was developed.

2.12.3 Phase III: (Public Study of Project Plans) 1990

- a contractor-prepared Environmental Protection Plan (EPP) was developed for review by regulatory agencies and the public prior to commencing destruction operations;
- the public consultation program and public participation in the EPP development were initiated;
- bids were reviewed and a contract was awarded to conduct an independent environmental monitoring program;
- the revised EPP was completed for acceptance by Environment Canada and approval by DND.

2.12.4 Phase IV: (Contracted Destruction Operations) 1991

- support facilities were constructed and the incinerator system was installed;
- the incinerator system was commissioned and trial burns completed for approval by Environment Canada;
- a transportable system for chemical neutralization of lewisite was constructed and delivered;
- lewisite stocks were neutralized, final waste products were stabilized and landfilled;
- mustard, scrap metal and neutralized nerve agent solution were packaged and incinerated and the contaminated scrap vehicles were thermally-treated *in-situ;*
- the public consultation program was continued;
- the independent environmental monitoring program was conducted;
- options were assessed for removal of the incinerator system at project completion;
- site clean-up and demobilization of contractor-owned equipment was completed;
- the incinerator equipment was prepared for removal.

2.12.5 Phase V: (Decommissioning) Jan-Aug 1992

- the incinerator removal option was selected;
- offers to purchase were prepared to sell the incinerator to private industry;
- incinerator removal and site restoration were completed;
- the public consultation program was completed.

2.13 Approval Milestones

Within the project schedule, several key milestones were established. In general, these were related to obtaining approvals before commencing certain operations:

- Concept Plan Approval:- DRES prepared a plan which described the overall approach to meeting the ministerial direction for conducting chemical warfare agent destruction in a safe, environmentally-sound manner, including methods to be employed by DRES personnel for destruction of nerve agent stocks on a first priority basis. This plan was approved by National Defence Headquarters.
- Environmental Impact Assessments:- an initial environmental screening, as described above, was carried out as part of the concept plan approval process. Before starting disposal operations, the contractor prepared an Environmental Protection Plan [13] for review and approval by the public and government agencies involved.
- Trial Burn Protocol:- as part of the incinerator commissioning activity, CSL prepared a document which described tests to demonstrate that incinerator emissions could meet the standards set for the project. This document was approved by Environment Canada before starting trial burns.
- Trial Burn Reports:- the results of incinerator tests conducted in accordance with the Trial Burn Protocol were reviewed and approved by Environment Canada before commencing full-scale waste incineration. In the interim, the contractor was permitted to process lightly-contaminated scrap metal.

2.14 Policy

In general, Project Swiftsure was conducted in accordance with DND policy regarding safety and environmental protection management, as well as the Canadian Environmental Protection Act and all applicable federal and provincial regulations regarding the transportation and disposal of hazardous materials. Although this was a federal project carried out on DND property, a philosophy was adopted to utilize the most stringent of either provincial (Alberta) or federal regulations, where applicable.

During planning for Project Swiftsure, Departmental policy was established to restrict disposal operations to those wastes listed as official inventory in the Environmental Protection Plan and in the contract awarded to Western Research Partnership. No waste of any kind was imported into the project for destruction.

During the initial public meetings, DRES informed the public that transporting chemical agent waste from DRES to a commercial hazardous waste processing facility such as the Alberta Special Waste Treatment Centre, Swan Hills, was an unacceptable option. Nonetheless, the Alberta Minister of Environment issued a policy statement [20] to the provincial legislature which prohibited the removal of chemical agent material or project-related final waste products for disposal off-site.

Early plans for Project Swiftsure included a proposal for retaining the incinerator technology on-site after project completion. The intention was to periodically incinerate general waste produced by CFB Suffield operations under the terms of a standing offer contract. However, the public became concerned regarding the possibility that the base might become a regional centre for the destruction of hazardous waste imported from other locations. To provide assurance that this was not the case, the incumbent Minister of National Defence (the Hon. William McKnight) issued a public statement [21] that the incinerator would be dismantled and removed from DND property at CFB Suffield following completion of project operations.

2.15 Concept Of Operations

An operating concept was developed to ensure maximum safety and protection for personnel working at the Project Swiftsure sites. By extension, this concept applied to the general public, even though project operations were carried out at considerable distance from the communities surrounding the DRES EPG. At the same time, protection of the environment was maximized by employing best-available destruction and monitoring technology during the destruction operations. The operating concept embodied some of the following principles:

- All operations were carried out in accordance with DND policy, CFB Suffield standing orders, DRES EPG Range Safety and local standing orders designed to protect the health and safety of workers;
- DRES personnel with expertise in agent properties, ordnance characteristics, decontamination techniques, protective clothing systems and emergency response capabilities worked closely with contractor personnel whenever possible. This was particularly important for field operations conducted at the waste storage sites on the DRES EPG. All operations involving nerve agents, potentially-explosive items or the use of explosive materials were conducted by trained DRES staff only;
- Transportation of chemical agent material on the DRES EPG was minimized and carried out in accordance with the Transportation Of Dangerous Goods Act (TDGA) [22]. For example, contaminated material was transported from storage sites to the incinerator facility in special incinerable boxes which were packed within a sealed overpack metal container, where necessary. All waste shipments were scheduled and escorted by trained personnel and vehi-

cles equipped to deal with accidental spills.

- Handling and processing of bulk chemical agents was carried out during winter months when cooler temperatures prevailed. For example, mustard freezes below 10°C which substantially reduces the possibility of agent emissions and improves safety during packaging, transportation and storage of this agent.
- Packaging of contaminated materials at the field storage sites was conducted before transportation to minimize contamination spread to other locations;
- Canadian Forces Individual Protective Equipment (IPE), rated for protection against chemical agent exposure, was employed by both DRES and contractor personnel during the handling and processing of chemical agents and agent- contaminated material;
- Bulk chemical neutralization reactions were carried out in buildings or special facilities equipped to prevent fugitive agent vapour emissions to the atmosphere;
- During waste incineration, continuous ("real time") monitoring equipment was employed to verify that incinerator emissions and ambient air quality limits set for the project were met.

Whenever possible, waste processing activities were recorded using portable video cameras for ready reference during the course of the project. Scheduled weekly meetings were held between DRES and contractor staff for troubleshooting purposes and to maintain constant communication regarding project activities.

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CHAPTER III

PROJECT PLANNING AND DEVELOPMENT

3.0 PROJECT PLANNING AND DEVELOPMENT

The formal planning for Project Swiftsure began in September 1988 and continued throughout the year. Goals for this phase included the following:

- assess chemical agent destruction technologies employed by other nations;
- produce a more definitive waste inventory list;
- develop a concept plan and procedures for disposal of the agent waste;
- determine regulatory and financial requirements.

3.1 International Agent Destruction Programs

Prior to finalizing the concept plan for Project Swiftsure, the Project Manager and key DRES staff visited defence facilities in other countries to examine first-hand applicable chemical agent destruction methods and technologies. Facilities visited included:

- Chemical Biological Defence Establishment (CBDE), Porton Down, UK.
- Wehrwissenschaftlichen Dienstelle der Bundeswehr (WWD), ABC-Schutz, Munster, Germany
- US Army Chemical Agent Munitions Disposal System (CAMDS), Tooele Army Depot, Tooele, Utah.

CBDE Porton Down was the central site for destruction of UK stocks of mustard during the 1970s, using incineration as the prime destruction process [23]. Small quantities of agents recovered from old munitions which are found in the public domain, e.g. during excavation and construction work, continue to be thermally destroyed in the CBDE hazardous waste incinerator. The incineration plant is devoted primarily to the destruction of waste laboratory chemicals arising from research and development programs at CBDE. Several specialized techniques are employed for the remote opening of explosive, chemical-filled munitions, e.g. compressed air guns and explosive cutting charges.

The UK nerve agent stockpile was destroyed in 1967-68 by alkaline hydrolysis at the Chemical Defence Establishment Nancekuke, an agent production facility located on the South West coast. Salt solutions which resulted from the destruction process were free of anticholinesterase activity and met regulatory requirements for direct discharge to the coastal waters.

The German Nuclear-Biological-Chemical Defence Establishment (WWD), located at Munster, is a storage and disposal site for a variety of old chemical munitions found on Establishment property and in the public domain [24]. During World War II, WWD was a test site which included chemical agent production and filling facilities. A complete chemical demilitarization program is now operated at WWD. Activities under this program include reconnaissance, locating and unearthing chemical munitions, removal and transportation of munitions to Munster, storage, remotely-operated disassembly and separation of munition components and destruction of agent fills. All types of chemical agents, including arsenicals, are thermally destroyed in a large, specially-designed two-chamber incinerator [25]. Agent material and non-explosive chemical munitions are packaged in incinerable plastic containers and batch-loaded into the incinerator on heat-resistant carts. Agents are vaporized in the first chamber at approximately 300°C; the vapours are directed to the second chamber where thermal destruction occurs at approximately 1200°C. The heat-treated, empty munition casings are then removed from the first chamber and disposed of as metal scrap.

The US Army CAMDS facility, located at Tooele Army Depot near Salt Lake City, is a highly integrated and automated system for the remote disassembly of US chemical ordnance and the destruction of components (explosives, chemical agent fills, packaging materials, etc.) using high temperature incineration. Approximately 42% of the US chemical agent stockpile is stored at the Tooele Depot [26,27] and includes various munition types such as rockets, bombs, land mines, spray tanks, cartridges, projectiles and bulk containers filled with nerve agents (GB, VX) or mustard.

CAMDS incorporates four incinerators, each dedicated to a particular waste stream, *viz*: a liquid incinerator for agent fills, an explosives incinerator for energetic materials, a deactivation furnace for thermal treatment of metal parts and a dunnage incinerator for packing materials and other solid wastes. The CAMDS facility is considered the prototype for the Johnston Atoll Chemical Agent Disposal System (JACADS), a full-scale agent destruction facility [28] located in the South Pacific which is undergoing commissioning tests.

3.2 Initial Waste Inventory Survey

An initial survey of the agent-related waste was conducted by DRES during development of the project concept plan and contract work statements. A wide variety of ordnance and other items, including bombs, artillery shells, mortars, drums and other special containers were found at the EPG sites. Many items were poorly characterized with respect to explosive or chemical fills. Some technical information was available which described, for example, ordnance internal firing mechanisms and designated fills; however, the origin and history of many of the items was not documented.

For concept plan development and inventory control, individual items were numbered, where possible. Identification numbers were incorporated into a locally-developed, "cradle-to-grave" data base which was employed to locate and track items during storage, transportation and disposal operations. Ordnance items which had been numbered previously were re-assigned the same numbers. Where possible, items were numbered *in situ* using red spray paint. Photographs were taken of individual items, storage areas and general site conditions for reference purposes.

3.2.1 490 Site

A schematic of the 490 Site, including the inner fenced area, is shown in Figure 3.1. Most of the project waste inventory located at this site consisted of several thousand 210 L drums. These drums, most of which contained mustard sludges, were largely intact and had been piled in four crude open pits (see example, Figure 2.11). In the 1970s, mustard contained in these drums had been transferred into large underground concrete vaults in preparation for mustard hydrolysis operations [5]. Some of the drums had been unearthed previously from other EPG landfills and consolidated at the 490 drum pits. The pits also contained a variety of ordnance such as aircraft bombs, presumably non-explosive and empty.

The depth and extent of the drum pits could not be determined with certainty from visual inspection or from available historical documentation. Likewise, it was not feasible nor desirable to individually number drums for tracking purposes.

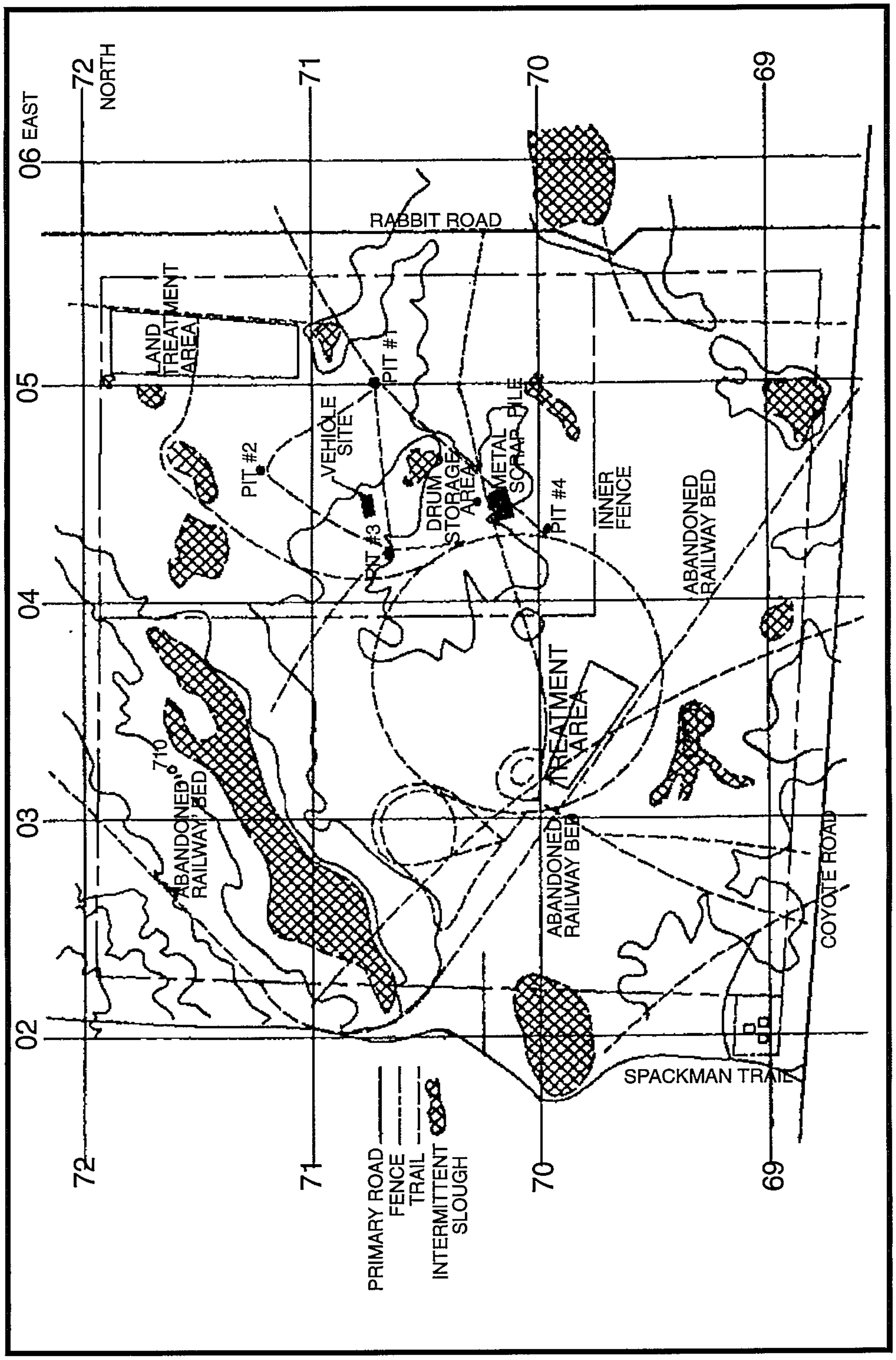
Table 3.1

INVENTORY ESTIMATE FOR 490 SITE

ITEM DESCRIPTION	NUMBER	COMMENTS
Miscellaneous Scrap	-	Large surface pile containing an estimated 150 tonnes of metal,glass, wood and rubber scrap
Drums	3600[1]	Contaminated with mustard residues
Aircraft Bombs	13	Empty, no contamination
Ton Containers	10	Empty, no contamination
Spray Tanks	3	Mustard fill
Livens Mortars	4	Mustard fill
25-pounder Shell	5	Suspected mustard fill
Hydrolysis Vat	1	Used during 1970s mustard destruction project
Vehicles	11	Utility trucks, tankers and fuel bowsers used during field trials and 1970s mustard destruction project

1 Estimated number of drums contained in 4 separate pits.

Figure 3.1



490 Site Schematic

The 490 Site also contained a large surface pile of miscellaneous scrap consisting of metal, glass and wooden items, such as explosively punctured one-ton containers, ordnance fragments, used and damaged rocket bodies, pipes, metal sheeting, experimental equipment, appliances, glass jars, etc. As with the drum piles, it was not considered feasible to number the miscellaneous waste for inventory purposes.

During the summer of 1989, the surface pile was inspected, sorted and rendered explosive-free by Canadian Forces explosive ordnance disposal (EOD) personnel wearing chemical protective clothing. Small scrap items of similar type were packaged in sturdy cardboard containers ("tri-walls") for further processing. Explosive items found were removed to a remote area of the 490 Site and detonated under controlled conditions.

Eleven unserviceable vehicles which had been used in previous disposal operations or field experiments were located at the 490 Site. These vehicles were included in the project inventory for disposal. Also included was a large steel tank in which mustard hydrolysis reactions had been carried out during previous large-scale mustard destruction operations.

The overall philosophy adopted for the 490 Site waste was to assume all scrap materials, including the vehicles, were contaminated with chemical agent residues. Thus, all such scrap required thermal treatment to render the material safe for disposal.

The original estimate of waste inventory at the 490 Site is given in Table 3.1.

3.2.2 14 Alpha Site

A schematic of the 14A Site is shown in Figure 3.2. A large variety of ordnance was scattered over the site, either in groups of similar type or as individual items. Typical items included aircraft bombs (115-2000 pound classes), 4.2-inch mortars, Livens mortars, artillery shells (e.g. 25-pounders), German bombs (e.g. KC-250) and German projectiles (e.g. 150-mm GR19 rockets). The site also contained experimental items such as pressure cylinders and approximately 100 partially-buried chemical spray bombs. These "Flying Cows" (see Figure 2.7) required unearthing before processing could commence. Many of the items were of international origin and had been collected following various training exercises or field trials during and after World War II. As shown by the examples in Figure 3.3, some of the items were badly damaged and corroded, exposing chemical agent fills to the atmosphere. The waste inventory stored at the 14A Site is listed in Table 3.2.

Although many items displayed standard military markings, it was not certain from available documentation whether specific items contained explosives or what type of chemical fill was used. In general, most of the items were believed to contain mustard or mustard formulations. Many of the non-explosive items were determined to be empty from their weights or visual inspection (holes). A few drums suspected of containing thickened mustard or arsenical agents were also stored at the 14A Site, along with a small scrap pile consisting of broken ordnance parts and metal fragments.

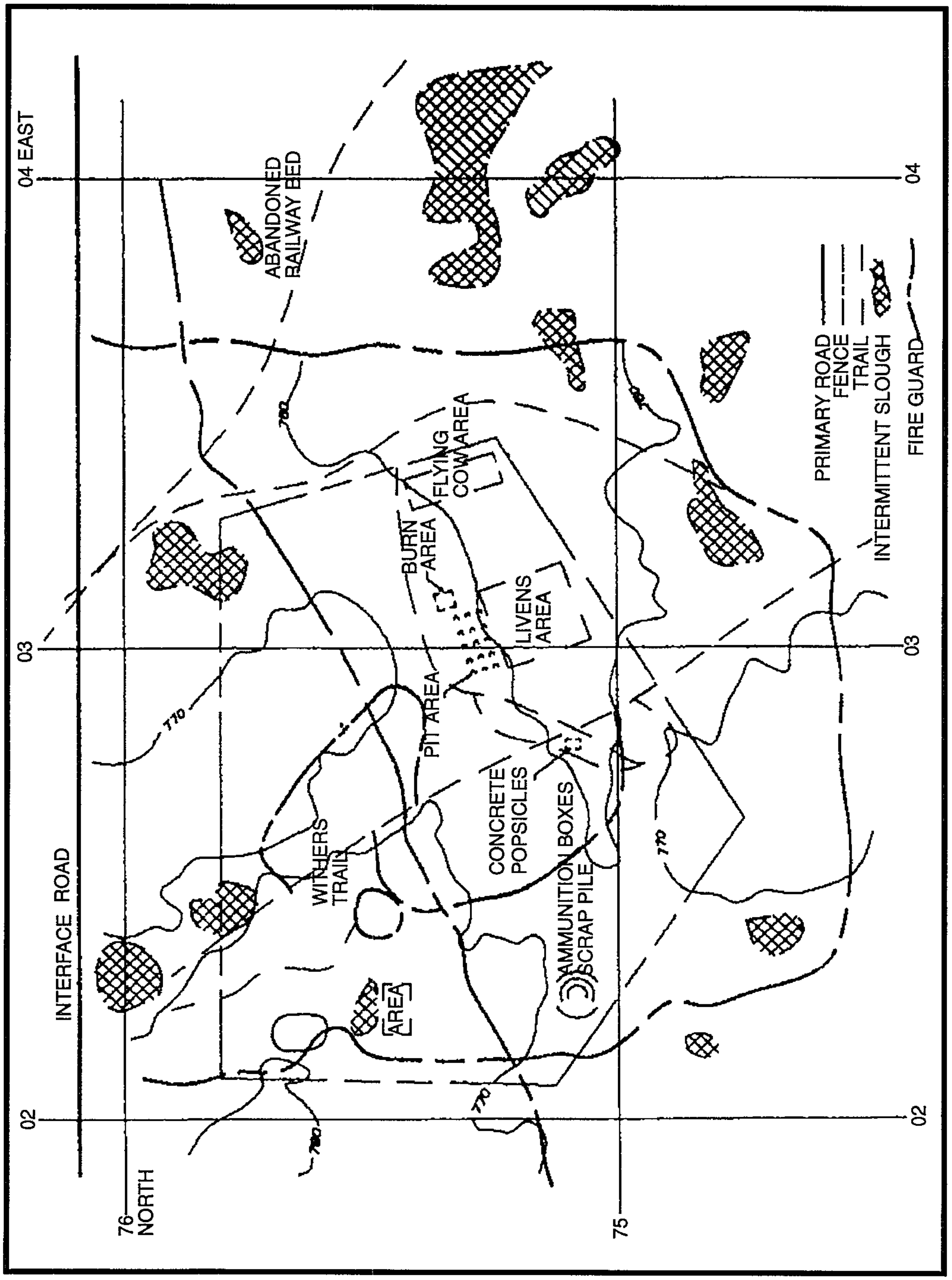
Table 3.2

14 ALPHA SITE WASTE INVENTORY

ITEM	NUMBER OF ITEMS MUSTARD FILL	EMPTY[1]	OTHER FILL[2]
Livens Mortar	33	1385	-
Flying Cow	42	59	-
5.5-inch Projectile	79	233	-
4.2-inch Mortar	19	55	1 - WP 4 - CNS
25-pounder Shell	1	33	-
Drums:			
210L	1	4	1 - CSA 1- PCyA 4 - PCA
75L	-	1	1 - PCA
20L	-	17	-
Cylinder	5	41	1 - PGN 1 - CHL
Aircraft Bombs:			
2000-pound	-	-	1-HCN
1000-pound	-	2	-
250-pound	-	5	-
150-pound	-	3	-
115-pound	4	-	-
German Ordnance:			
150 mm Rocket	3	1	2-H/Arsinol 1 - HN3
Aircraft Bomb KC250	-	13	1 - G/CN
Aircraft Bomb KC125	-	1	-
150-mm Projectile	-	1	-
105-mm Projectile	-	-	2-H/Arsinol 1-HN3
101-mm Projectile	1	-	-
75-mm Projectile	-	1	1-HE
Misc. Containers	-	9	10 - BBC

1 Assumed contaminated with mustard or other agent residues.
2 Other agent fills include: WP - white phosphorus; CNS - tear gas; CSA - chlorosulphonic acid; PCyA - phenylcyano arsine; PCA - phenylchloro arsine; PGN - phosgene; CHL - chlorine; HCN - hydrogen cyanide; H/Arsinol - mustard/phenylchloro arsine mixture; HN3 - nitrogen mustard; G/CN - G-agent/tear gas mixture; HE - explosives; BBC - bromobenzyl cyanide.

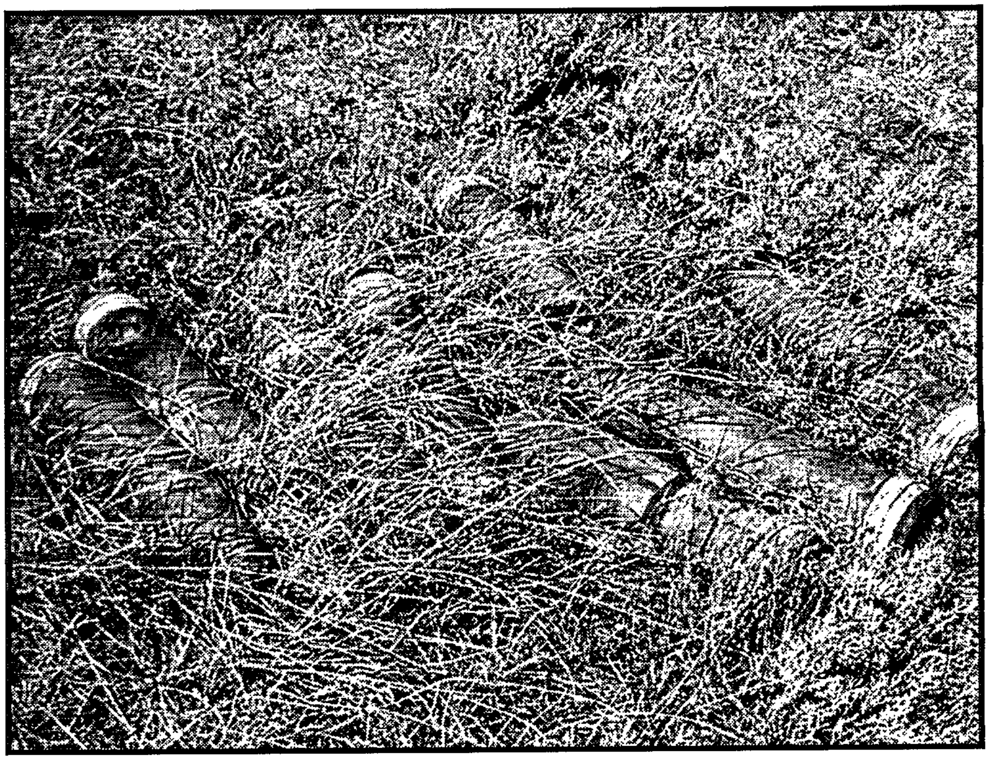
Figure 3.2



14 Alpha Site Schematic

All items at this site except the scrap fragments were assigned a project inventory number for record-keeping purposes. Many of the 14A items were considered extremely dangerous; therefore, it was considered essential to examine these by remote means for explosives content before further handling and processing. Many items required sampling to determine the exact nature of their chemical fills.

Figure 3.3



Corroded Artillery Shells Located at the 14A Site

3.2.3 Hickey Storage Site

This site was a small, securely fenced area which contained all the bulk chemical warfare agents slated for disposal. Seven one-ton containers were stored near the perimeter fence, four of which contained mustard while two others were filled with lewisite (see Figure 2.6). An unspecified amount of the nerve agent GA (tabun) was contained in the remaining ton container. These standard bulk agent containers were in good condition (not leaking) and were fitted with valves to permit the liquid contents to be withdrawn. In the past, small quantities of agent had been removed from these containers and used in support of DRES research and development programs, e.g. to study the long-term aging and decomposition of mustard and lewisite.

As previously described, all remaining nerve agent stocks, including

GA (tabun), GB (sarin), VX and experimental agent formulations (e.g. VE, VM), were stored inside a concrete bunker (Figure 2.4) or on a wooden rack immediately outside (Figure 2.5). Other types of ordnance or heavy-walled cylinders stored outside the bunker also contained nerve agent fills. All items at this site had been numbered previously. In addition, most items had been drilled and plugged to permit agent samples to be withdrawn for analysis.

A number of the nerve agent containers were believed to be empty based upon their weights. However, for estimating purposes, all nerve agent containers were assumed to be full, yielding a total stockpile of 1.1 tonnes. All containers, with the possible exception of one 155-mm artillery shell, were in good condition. A second 155-mm artillery shell located in the concrete bunker was equipped with a fuse mechanism, although records indicated this shell was non-explosive and did not contain a nerve agent fill. The waste inventory stored at the Hickey Storage site is listed in Table 3.3.

3.3 Previous Destruction Methods Used at DRES

DRES had previously used chemical neutralization, explosive demolition, weathering and open-pit burning carried out at remote locations on the EPG to destroy unwanted chemical agent waste and contaminated material. For example, explosive shaped-cutting charges were used to open explosive and/or chemical ordnance, allowing the contents to flow onto decontaminant-soaked ground. For mustard fills, the ensuing oxidation reaction would often cause the liquid agent to ignite and burn. Items ruptured in this fashion were allowed to weather for prolonged periods and then consigned to a scrap metal pile on the EPG.

For corroded, mustard-filled items (e.g. 1940-vintage “Flying Cows”), one or more items were placed inside a specially constructed burning tank. Shaped cutting charges were then placed on the items, aviation fuel added to the tank and the charges detonated. The ensuing fire consumed the agent fill as well as thermally treating the metal casings, rendering them safe for storage as scrap.

Field operations were usually carried out during cooler weather while mustard fills were frozen solid. This prevented leakage from corroded items and provided the personnel involved with an extra degree of safety against agent exposure.

DRES previously employed chemical neutralization as the prime means of destroying bulk agent. For example [5,6], the large-scale mustard destruction carried out in the mid-1970s involved reaction with calcium oxide (lime) in water in a specially-constructed facility. The hydrolysate salts (calcium chloride, calcium thiodiglycolate) were either sprayed on the ground to decompose naturally (“land-farming”) or incinerated in a liquid incinerator. This latter method proved ineffective due to the low thermal properties and resulting high solids content of the aqueous hydrolysate solution. Nerve agents were destroyed effectively by reaction with e.g. 10% potassium hydroxide in methanol solution. This basic hydrolysis method successfully destroys all classes of nerve agents as well as mustard [29]. The resulting detoxified agent solution subsequently was poured into a shallow pit and allowed to evaporate. The original agent container was filled with potassium hydroxide/methanol for several hours, emptied, then broken open with an explosive charge and allowed to weather for some time before consigned to a scrap metal pile.

Table 3.3

HICKEY STORAGE SITE WASTE INVENTORY LIST

AGENT MATERIAL	CONTAINER	NUMBER OF CONTAINERS
Mustard	Ton Container	4
	4.2-inch Mortar	11
Lewisite	Ton Container	2
Nerve Agent GA	Ton Container	1
	155-mm Shell	14
	Bottle/Can	3
Nerve Agent GB	105-mm Shell	150
Nerve Agent VX	Cylinder	5
	Bottle/Can	3
Experimental V-Agents	Bottle/Can	50
	Vial	1
	25-pounder Shell	10
Known Empty	Cylinder	3
	25-pounder Shell	5
	105-mm Shell	1
	155-mm Shell	2
	4.2-inch Mortar	1

A favourable aspect of the previous disposal methods was the high degree of safety afforded the personnel involved. For example, explosive cutting was carried out remotely at a distance sufficient to protect against fragments, liquid and vapour hazards. Only one item at a time was opened in this manner; this combined with the large size of the DRES EPG provided safety in terms of downwind vapour hazards. For dangerous items suspected or known to be explosive, the remotely-activated cutting charge would cause such items to detonate (self-destruct).

3.4 Concept Plan

The Project Swiftsure concept plan embodied the philosophy of using methods and technology to meet current safety and environmental protection regulations which would be imposed on any waste disposal operation, whether on federal property or not. In the Fall 1988, DRES prepared and submitted the plan to National Defence Headquarters, Ottawa, for approval and to provide information on funding requirements to support the forthcoming disposal activities. Following DND approval in November 1988, a summary of this plan was prepared and submitted to Environment Canada in January 1989 for review and discussion purposes.

The plan proposed a system in which both chemical neutralization and incineration were used in order to accommodate the variety of waste awaiting disposal. In particular, neutralization was to be used to the fullest extent possible to destroy chemical agent fills in various containers while incineration was to be used to destroy secondary waste generated by the neutralization process and to thermally treat scrap metal and emptied containers. The proposed waste disposal system is shown schematically in Figure 3.4. Although the system incorporated two incinerators, it was expected that one general purpose incinerator (e.g. a rotary kiln) would meet all requirements.

The principal elements of the waste disposal system are described below. In general, the proposed system could dispose of all of the waste inventory by direct incineration or a combination of chemical neutralization and incineration with the following few exceptions:

- explosive devices and/or explosive chemical-filled munitions;
- fragile or large bulk agent containers.

For these cases, alternative methods (see Critical Alternative Methods, below) which maximized safety and minimized environmental impact would be employed, including transferring agent contents to safe containers, using container reinforcement/over-packing or using controlled explosive demolition. For thickened mustard and/or decomposed mustard in an intractable form, chemical neutralization was not feasible; therefore, direct incineration was the destruction method of choice in this case.

3.4.1 Identification and Screening

These operations were carried out at the waste storage sites and involved visual inspection, numbering and photographing items. Piles of scrap material were photographed as part of the general view of the storage site, rather than attempting to number scrap items individually. A small, vehicle-mounted X-ray machine was used to survey interior components of certain items where doubt existed as to their explosive or chemical nature. The X-ray equipment, which incorporated a portable, remote-sensing head, was powered by a portable generator which accompanied the vehicle. Items identified as explosive were disposed of using alternative destruction methods (e.g. explosive demolition, shaped charge fuse-cutting) and, unless certified as being free-from-explosives, were not processed through the disposal system.

3.4.2 Waste Transport and Storage

Items to be transported from storage sites to selected disposal sites included:

- empty containers, shredded scrap, miscellaneous waste;
- agent-filled containers; and
- containers filled with used neutralization (decontamination) solution.

Large metal containers, similar to those used commercially for securing hazardous waste, were proposed for transport of agent-related inventory. These containers are designed to prevent the transport vehicles from becoming contaminated by the waste. The containers may also serve as temporary storage for material delivered to a disposal site for processing. The overall plan called for the waste to be prepared and packaged to the fullest extent possible at the EPG storage sites, transported according to a pre-arranged schedule only as required, and stored at the disposal site in amounts sufficient to sustain a few days of continuous processing.

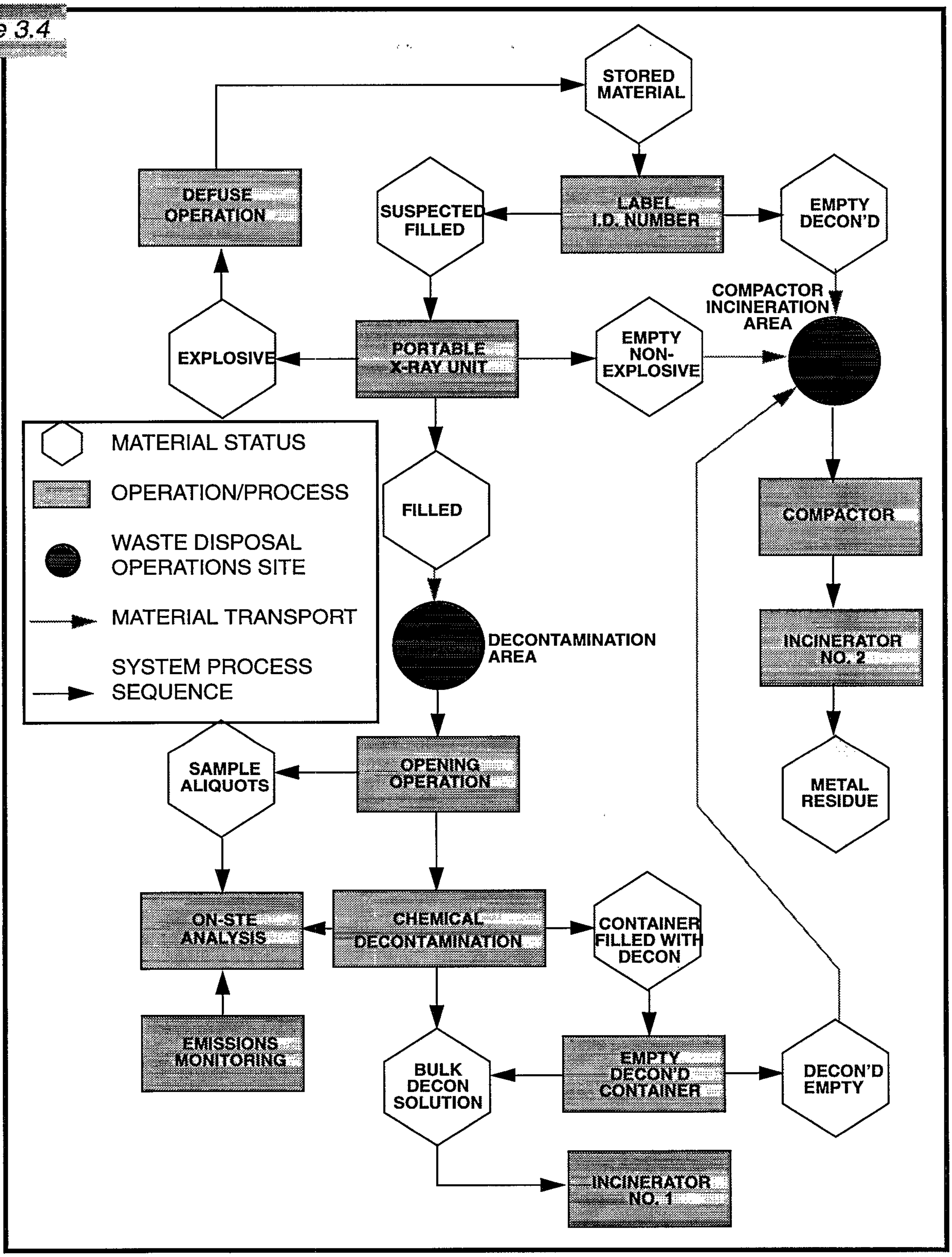
3.4.3 Opening and Chemical Neutralization Operations

The container opening operation represented the most potentially hazardous component of the waste disposal system in terms of personnel safety and environmental impact. Except when using explosive perforating or cutting charges (see below) or draining one-ton cylinders of mustard or lewisite, all opening operations were carried out inside the Willis Centre laboratory where small amounts of agent vapour, if released, were trapped in a fume hood/charcoal filtration system.

The purpose of opening chemical-filled items was to:

- where necessary, acquire samples of the container fill for identification purposes;
- remove liquid fills into neutralizing (decontaminating) solution and to add decontaminant to the container to neutralize toxic residues;
- provide a pressure-relief opening for those containers to be directly incinerated (mustard fills only).

Figure 3.4



Schematic Of Proposed Agent Waste Disposal System

In general, four methods were considered for opening containers, depending on the container type, its physical condition, and whether the presence of explosives was a possibility. These methods included:

- ❖ using a special drill press and containment tank system similar in concept to the US Munition Decontamination Unit/Drill Table [30];
- ❖ direct manual opening of container closures (which were not rusted shut) to allow container contents to drain into a containment vessel filled with neutralizing solution;
- ❖ using small, remotely-activated perforating charges to hole containers while submerged in neutralizing solution inside a special reinforced tank (see Priority Disposal below), and
- ❖ employing explosive perforating or cutting charges *in situ* to hole items deemed too dangerous to handle or transport (e.g. explosive munitions) or items not amenable to the other proposed opening methods (e.g. large, empty containers and drums).

Other methods examined included the use of suitably-contained powered cutting saws, hydraulically-driven metal punches and water-jet cutting equipment; however, the necessary equipment was not immediately available or required extensive modifications in order to meet project requirements.

In general, the concept plan called for DRES staff with appropriate expertise to conduct all opening operations to avoid potential safety problems which could arise with inexperienced contractor personnel.

3.4.4 Analysis

A fully-equipped laboratory located in close proximity to chemical neutralization and incineration operations was recommended to provide timely feed-back on the performance of the disposal system. The purpose of the laboratory was to:

- ❖ identify the main chemical agent(s) and ingredients of containers with unknown contents for destruction method selection and record-keeping purposes;
- ❖ analyze air samples collected near chemical neutralization and incineration operations to verify compliance with emission and air quality standards set for the project with respect to chemical warfare agents;
- ❖ analyze neutralized agent solutions where necessary to verify completeness of agent destruction, and
- ❖ perform special analyses of materials such as lagoon water, soil, metals etc. to determine extent of contamination with chemical agents, if any.

Initially, it was proposed that the agent analysis laboratory be located on-site with the neutralization and incineration operations. However, the DRES Central Laboratory located nearby at CFB Suffield was used eventually for this purpose as the necessary expertise was resident there, well- established protocols for the transportation of toxic samples to the laboratory from EPG locations existed, and the transportation time (e.g. minutes) was not significant compared to the overall analysis and reporting time (e.g. hours). During incineration operations, Chem-Security Ltd. established an on-site laboratory to deal with routine analyses as well as some chemical agent identifications as part of the contractual requirements to monitor incinerator system performance.

3.4.5 Compaction/Shredding

Many of the containers and scrap metal pieces were expected to be too large for direct introduction into the supplied incinerator technology. Normally, incinerators designed to handle large quantities of solid wastes have an integrated compaction or shredding system to volume reduce the waste stream and increase through-put. However, to maximize safety with respect to processing chemical warfare agent-filled items, it was decided to volume reduce scrap metal and other large inventory items at the storage sites rather than risk contaminating the incinerator facility through potential malfunction of the integrated compaction system. This decision also enabled a wider range of incinerator technologies to be considered for the project.

A requirement was identified for a self-contained, transportable or mobile shredding system which would be positioned at the storage sites to shred drums and scrap metal, and which could be relatively simple compared to a unit integrated with the incinerator. In addition to the safety advantages, transportation of packaged bulk shredded material was considered more efficient in terms of delivered weight and number of trips required compared to transporting empty containers such as drums.

3.4.6 Incineration

Two distinct types of waste in the project inventory were to be thermally treated or destroyed:

- contaminated scrap metal and metal containers (suitably volume reduced when required), and
- organic liquids, solutions (aqueous and organic) and solids (organic and inorganic).

A single incinerator capable of processing both types of waste was preferred in order to streamline the disposal process and reduce capital cost, labour and operating expenses.

The extent of thermal destruction required normally depends on the type of waste being incinerated. For example [31], most municipal wastes are burned to achieve a destruction and removal efficiency (DRE) of 99.99%, whereas hazardous wastes such as polychlorinated biphenyls (PCBs) or wastes considered carcinogenic, teratogenic or mutagenic must be destroyed with a DRE of 99.9999%. As shown in Table 3.4, the incineration of chemical warfare agents must achieve an even higher DRE [27,32]. For Project Swiftsure, the nerve agent stockpile was to be destroyed by chemical neutralization; therefore, the only applicable incineration standard was that for mustard.

Table 3.4

HAZARDOUS WASTE INCINERATION DESTRUCTION AND REMOVAL EFFICIENCY (DRE) REQUIREMENTS

MATERIAL	EMISSION LIMIT (mg/m^3)	REQUIRED DRE[1] (%)
Municipal Solid Waste	-	99.99
PCBs[2]	12×10^{-6}	99.9999
Mustard Agent (H)	0.03	99.99995
Nerve Agent GB	0.0003	99.999999
Nerve Agent VX	0.00003	99.9999999

1 Destruction and Removal Efficiency (%) = 1 -{(Q x [M]q)/[M]i} x 100
where:
Q = incinerator stack gas flow rate (m^3/hour)
[M]q = concentration of material in stack gas (mg/m^3)
[M]i = material feed rate into incinerator (mg/hour)

2 Polychlorinated biphenyls. Polychlorinated dioxin and furan combustion products can be formed during PCB incineration. Emission limits are set with respect to 2,3,7,8- tetrachloro-p-dibenzodioxin toxic equivalent concentrations.

Generally, incinerators capable of attaining the high DRE required for hazardous waste destruction are modular in nature and incorporate three main components: a primary combustion chamber (furnace), a secondary combustion chamber and a pollution abatement system. The furnace can be designed to accept both solid and liquid feedstock and typically operates at approximately 1000^{o}C with a solids residence time of 30 minutes (batch mode). The secondary combustion chamber completes the oxidation of the combustion gases from the furnace and typically operates at approximately 1250^{o}C with a gas residence time of about 2 seconds. The pollution abatement system removes acid gases and particulates generated in the combustion process and normally consists of a quench system to lower combustion gas temperature, a packed tower or scrubber to neutralize acid gases and remove particulate matter, and a stack for releasing the scrubbed process air to atmosphere.

A preliminary survey showed that a wide variety of incinerator equipment was available which potentially could be used for the destruction of chemical agent waste [31,33,34]. Although special incinerators had been designed for the destruction of the US stockpile of agent-filled munitions [27,28], it was expected that commercial incinerator equipment would meet Project Swiftsure requirements.

3.4.7 Critical Alternative Methods

The concept plan noted that explosive munitions (with or without a chemical fill) and large or fragile containers which could not be handled or transported safely would require disposal *in situ* using specially-developed methods. Inventory items requiring such treatment were few in number and DRES staff with appropriate expertise were available to dispose of such items using well-developed techniques. Typical items included:

- High explosive munitions without chemical fill: -these munitions are extremely dangerous to handle, especially when in damaged or rusted condition, and must be destroyed by EOD experts. Provided sufficient open space is available (as is the case on the DRES EPG), the munition is detonated by activating a second explosive charge placed close by. In some cases, the item may be rendered inoperative and opened by using explosive shaped charges. When ruptured, the fragments and explosive material may be incinerated directly as the uncontained explosive will burn in a non-destructive fashion.
- Bursting munitions with chemical fill: -For items which cannot be safely defused by EOD experts, precisely-aligned explosive cutting charges which are remotely-activated are used to rapidly cut off the fuse and deactivate the firing mechanism. This approach has a high success rate at DRES. The item is covered with a reinforced metal container and sandbagged to contain munition fragments should it function during the fuse-cutting event. Release of agent vapour is certain should the device function; therefore, downwind safety distances are established for each operation to accommodate "worst-case" scenarios (i.e. instantaneous release of the entire fill as vapour). After weathering, contaminated metal fragments and the containment box are sprayed with decontaminant and then incinerated. When the fusing mechanism is successfully cut off, the explosive material can be removed from the burster tube and the item subsequently treated as a non-explosive agent container.
- Large containers with chemical fill: -The fill is drained slowly in batches through tubing into a smaller container filled with neutralizing solution. The emptied large container is filled with neutralizing solution to destroy residual agent before the container is fragmented e.g. using explosive charges. In some cases, containers may be perforated with explosive charges, methanol added and the fluid ignited to provide a thermal treatment prior to final disassembly.

3.4.8 Emissions Monitoring

As noted in the project concept plan and in the initial environmental screening document [18], operations such as waste packaging, transportation and storage, container opening, chemical neutralization and incineration had potential for producing atmospheric emissions which could potentially impact on worker safety and the environment. Thus, an emissions monitoring program was essential to verify that destruction operations were in compliance with the standards set for the project (see Tables 2.3 - 2.5) as well as to provide a record of the performance attained during the project for future reference.

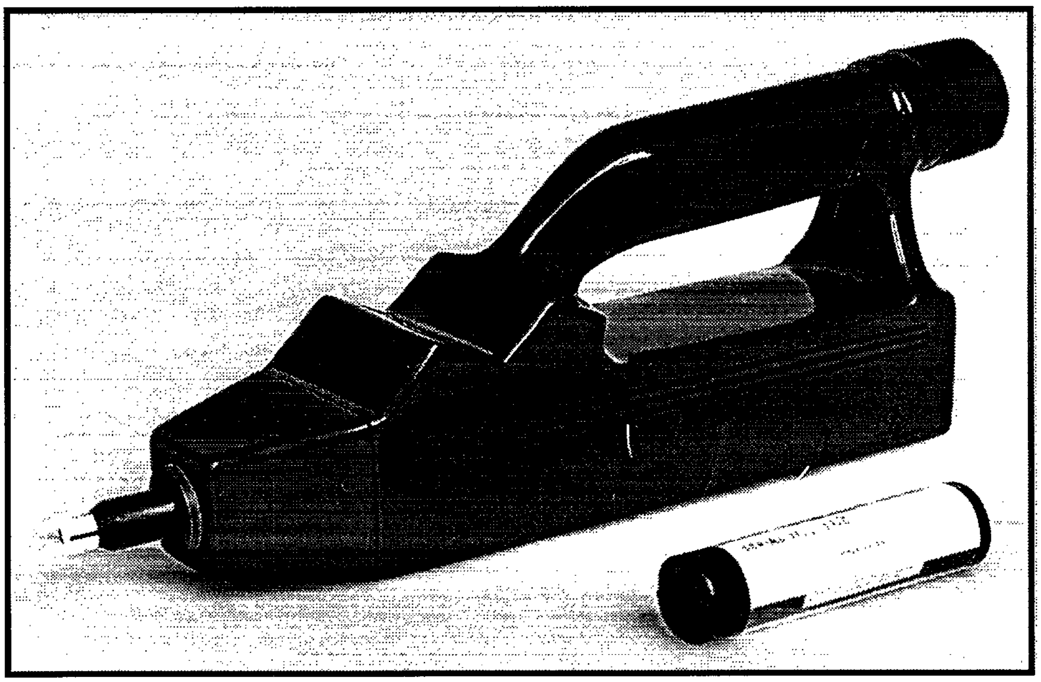
For commercial equipment such as the incinerator(s), the associated contract required the supplier to provide best-available technology to monitor specified stack emissions containing typical combustion gases such as sulphur dioxide, carbon monoxide, particulates, and oxides of nitrogen. In the case of chemical agent monitoring, portable Chemical Agent Monitors (CAMs) were expected to provide a qualitative capability in detecting fugitive agent emissions from storage sites, neutralization facilities, field operations and around the incinerator site. CAM is a miniature ion-mobility spectrometer which has been specifically designed for military use in detection of mustard and nerve agent vapours. An example of a CAM is shown in Figure 3.5. The device may be operated continuously for several hours on its self-contained battery power supply. Through a mode selection switch, CAM responds either to the presence of mustard or nerve agents; a liquid crystal display provides a qualitative read-out (in "bars") which relates to the concentration of agent vapour present. The device is sensitive to agent vapour concentrations at levels below that which may cause physiological harm in humans during short term exposures. The CAM response is logarithmic, with the 1-8 "bar" read-out representing agent vapour concentrations which cover the range from approximately 0.001 mg/m^3 to several hundred mg/m^3. To complement the use of CAMs, real-time monitoring instruments such as long-path infrared analyzers (MIRANs) and retrospective sampling and analysis equipment such as the DRES Minitube Air Sampling System were to be deployed to provide quantitative data on airborne agent emissions.

3.5 Meetings With Environmental Agencies

Scheduled quarterly meetings, which involved DRES, DND representatives and officials from Environment Canada (Western Region) and Alberta Environment, commenced in the Fall of 1988. As shown by the summary in Table 3.5, meetings were usually held in Edmonton, with special meetings held occasionally at DRES. Initially, the purpose was to introduce the DND concept plan for destruction of chemical agent waste, set up a communications protocol and points-of-contact amongst the organizations involved, and determine environmental regulatory requirements which would apply to Project Swiftsure. During project planning, the meetings also served to define requirements for environmental assessments and monitoring, to discuss project status, public consultation initiatives and to cover outstanding technical and contractual issues from the perspective of the environment agencies. Environment Canada officials visited DRES on two occasions to view the waste inventory first-hand and discuss regulatory requirements with project officials and prospective contractors.

Following award of the disposal contract to Western Research Partnership, company officials were invited to attend meetings where the development of the Environmental Protection Plan and requirements for documenting incinerator trial burns and monitoring programs were discussed. No official meetings were held during the operational phases of Project Swiftsure as the information needs of Environment Canada and Alberta Environment were met through the submission of reports and data supplied by DRES on behalf of the contractors and public groups involved.

Figure 3.5



Portable Chemical Agent Monitor (CAM)

Table 3.5

FORMAL MEETINGS HELD WITH ENVIRONMENTAL AGENCIES

DATE	AGENCIES REPRESENTED	LOCATION	AGENDA
27 Sept 88	National Defence Environment Canada Alberta Environment	Edmonton	Initial contacts
10 April 89	National Defence Environment Canada Alberta Environment SSC[1]	Edmonton	Concept Plan review Contracts
7 June 89	National Defence Environment Canada SSC	DRES	Site visits Project updates
July 89	National Defence Environment Canada SSC	DRES	Project updates Bidders conference Public consultation
24 Jan 90	National Defence Environment Canada Alberta Environment CSL/WR[2]	Edmonton	Project updates EPP development Public consultation
5 April 90	National Defence Environment Canada Alberta Environment CSL/WR	Edmonton	EPP review mechanism Project policy
28 Aug 90	National Defence Environment Canada Health and Welfare CSL/WR	Edmonton	Final EPP review and acceptance protocol

1 Supply and Services Canada, Western and Northern Region, Edmonton.
2 Chem-Security Ltd. and Western Research, Project Swiftsure Contractors.

A modus operandi and policy evolved as a result of the meetings, as follows:

- As Project Swiftsure was a federal undertaking, Environment Canada was designated the lead agency for project- specific environmental matters. In practice, DND liaised directly with Environment Canada who acted on behalf of Alberta Environment rather than reporting to an all-agency formal Steering Committee;
- The waste destruction operations carried out under contract were constrained to processing only those wastes described in the Barton Report. No waste was imported into the project from other DND bases, other locations in Canada or elsewhere.
- With respect to provincial or federal environmental standards, the most stringent standards were applied to the project (see Tables 2.3, 2.4 and 2.5). The designated waste was treated to the fullest extent possible to render it non-hazardous according to existing guidelines and regulations;
- A public consultation program was required. This program was developed under contract and managed using professional communication consultants;
- The incinerator was not formally licensed by the environment agencies, as Project Swiftsure was a one-time-only activity. Instead, the agencies reviewed trial burn data to ensure emission standards were met, then DND advised the contractor to proceed with incineration operations after the data proved satisfactory;
- The potential impact of incinerator emissions on ambient air quality was monitored by a contractor operating independently of the incinerator contractor;

Several changes were made in the Project Swiftsure concept plan as a result of the meetings with the environment agencies. For example, an initial proposal to dispose of final waste products at commercial facilities was later rejected during contract development in favour of conducting a complete on-site disposal operation [35]. This was later reinforced by statements issued by the Alberta Minister of Environment to the Alberta legislature [20], viz: that the project must take place entirely on DND property and that transportation of project-related wastes off-site would not be permitted. Originally, DRES planned to purchase and retain chemical neutralization and incineration technology supplied under the waste disposal contract, to be used for such purposes as destroying waste laboratory chemicals and general waste from DRES R/D programs, as required. To assure Alberta Environment that DRES would not become a regional centre for disposing of hazardous waste (in direct competition with the Alberta Special Waste Treatment Centre, Swan Hills), DND stated formally to Environment Canada that Project Swiftsure incinerator or chemical neutralization facilities would not be used to process waste of any kind from external sources [35]. This position was further modified as a result of public information meetings held on Project Swiftsure (see Chapter IX: Project Swiftsure Public Consultation). The final policy called for the incinerator equipment to be dismantled and removed from CFB Suffield upon completion of the project [13,21,36].

3.6 Project Funding Requirements

The initial cost estimate for Project Swiftsure based on the requirements given in the conceptual plan was $10 million. This estimate included major sub-programs such as equipment purchases, public consultation, and contracts as shown in Table 3.6. Starting with latter part of 1988, the funding was divided into fiscal year allotments with funding requirements scheduled to terminate on 31 March 1992, i.e. the end of Fiscal Year (FY) 91/92.

Requirements for extra personnel resources ranging up to 9 person-years (PYs) were also estimated. The PY allotments were to be obtained from CRAD resources.

In accordance with Departmental procedure, a funding proposal for consideration by the Program Change Board (PCB) was prepared on a fast-track basis and submitted to the Board by the Project Director under Assistant Deputy Minister Materiel signature. Project Swiftsure was categorized as an Operations and Maintenance (O&M) activity and funding approved, giving due consideration to the fact that the agent destruction had been given ministerial direction and priority. Overall financial and procurement management for the project was assigned to the Director General Procurement and Supply (DG Proc S) with the Directorate of Procurement Supply Communications and Electronics (DPSCE) designated as the responsible agency for day-to-day financial matters, including the raising and controlling of funds to support project requirements. Both organizations report to the Chief of Supply under the Assistant Deputy Minister Materiel.

DPSCE raised several financial encumbrances for project management, operations, temporary duty and contracts which were authorized for use by the Project Director and Project Manager as required to support project activities.

Table 3.6

PROJECT SWIFTSURE ORIGINAL COST ESTIMATE[1,2] ($K)

ITEM	FISCAL YEAR 88/89	89/90	90/91	91/92
Equipment Procurement Project Management	650	450	2550	-
Destruction Operations (Contract)	-	500	3100	300
Environmental Protection Plan	-	100	-	-
Public Consultation (Contract)	-	100	100	-
Air Quality Monitoring (Contract)	-	-	100	-
Soil Survey	-	150	150	-
Site Preparation	-	150	600	-
TOTALS:	**650**	**2450**	**6600**	**300**

1 Cost Estimate prepared in 1988. $K = $1000.
2 Estimates prepared based on the assumption that destruction operations would be completed in mid-1991.

CHAPTER IV

DRES OPERATIONS AND CONTRACT DEVELOPMENT

4.0 DRES OPERATIONS AND CONTRACT DEVELOPMENT

This phase Project Swiftsure, which was carried out during 1989, included the following major activities:

- The destruction of nerve agent stocks and miscellaneous agents on a priority basis by DRES staff ;
- The preparation of appropriate Request For Proposals for contracted support services;
- Contract awards to develop and provide a transportable metal shredding system and to provide technology and resources to dispose of the remaining agent waste inventory.
- Development of the public consultation program (see Chapter IX).
- Completion of the initial environmental screening [18] for the project based on the concept plan and approaches which had been developed earlier (see Sections 2.9 and 3.4).

4.1 Nerve Agent Destruction

Immediately following disclosure of the nerve agent inventory in the Barton Report, the Hickey Storage Site was guarded on a 24-hour basis to prevent possible unauthorized removal of items (e.g. by terrorist organizations). The security was maintained until all inventory at this site had been removed for processing.

The nerve agents were destroyed on a first-priority basis in accordance with the project concept plan. Operations started in January 1989 and were completed in May 1989. The Willis Centre field laboratory (Building 214) was used for the destruction of the nerve agent inventory. Non-explosive agent-filled artillery shells, as well as the GA ton-container, were transferred from the Hickey Storage Site to the Willis Centre as required using well-established DRES procedures for hazardous material transport on the EPG [37]. Generally, the amount of inventory transferred on each occasion could be readily processed during a six hour working shift; this avoided the need to provide overnight security for unprocessed items at the Willis Centre. The one-ton container did not require special precautions for secure storage.

Two different methods were developed concurrently for processing the artillery shells, *viz:* drilling and draining or explosive perforation. The latter method was developed as an expedient alternative for use in cases where poorly-characterized or potentially explosive agent-filled containers were encountered.

4.1.1 Shell Perforating Method

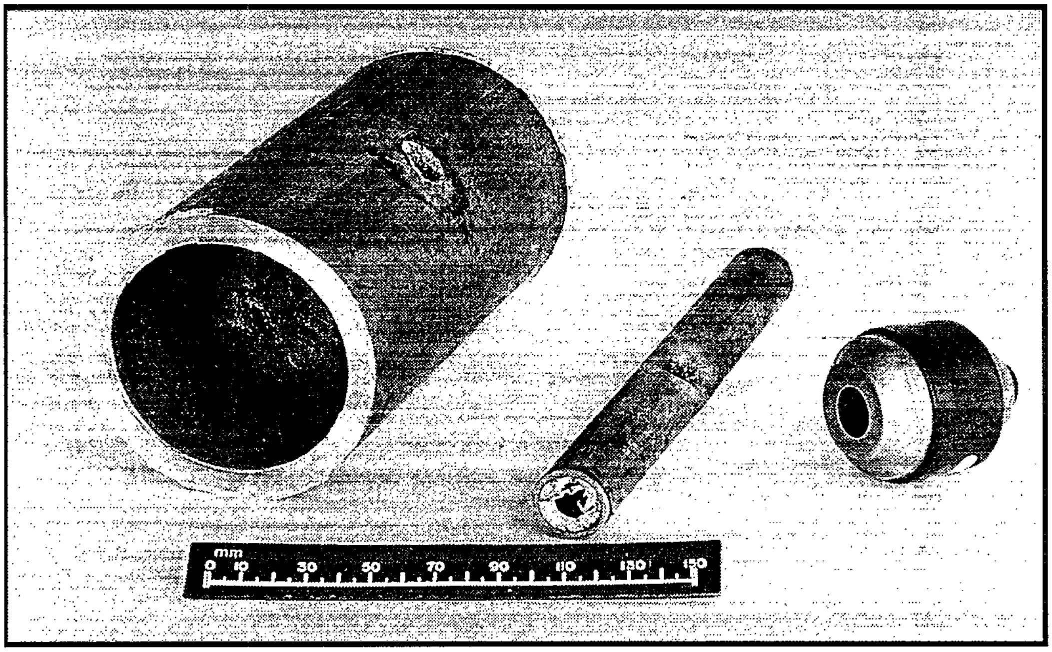
This method involved both chemical neutralization and thermal treatment to completely destroy agent fills and ensure the emptied shells were safe to handle for final disposal.

Remotely-activated shaped perforating charges were used to open items contained in a special reinforced tank while the items were immersed in a solution of 10% (w/v) potassium hydroxide (KOH) in methanol. This solution rapidly and effectively converts methyl phosphonate nerve agents in the G- and V-classes to methyl phosphonate methyl esters which subsequently undergo hydrolysis to methyl phosphonic acids salts. Shaped charges suitable for this application are well- proven, reliable and inexpensive devices used extensively in the oil industry for perforating underground well casings. An example is the Jet Research Centre 4-inch GSC 19.5 Gram shaped charge (Figure 4.1) which will successfully perforate 105- and 155-mm artillery shells.

The equipment used for the shell perforating method consisted of two reinforced tanks connected by piping through a trailer-mounted pump, as shown schematically in Figure 4.2. Each tank ("Kimbell Cooker") was fitted with a small air inlet pipe and exhaust stack. Up to six shells at a time were mounted in a special rack (Figure 4.3), perforating charges taped to the upper recessed holders in the rack and the entire assembly inserted into brackets in one of the tanks which was filled with approximately 200 L of 10% (w/v) KOH in methanol. Enough solution was added so as to immerse the shells while the perforating charges remained in the immediate air space above the shells. The tank was then closed and the perforating charges activated remotely using electrical detonator wire. Small cylindrical sections of solid steel stock placed in the rack underneath the shells prevented the perforating jets from rupturing the bottom of the tank. The perforating action is illustrated in Figure 4.4, using high speed photography. Here, a plastic tank filled with water and a pipe section of the same diameter, thickness and hardness as a 155-mm artillery shell are used to demonstrate the process. Examples of perforated shells are shown in Figure 4.5

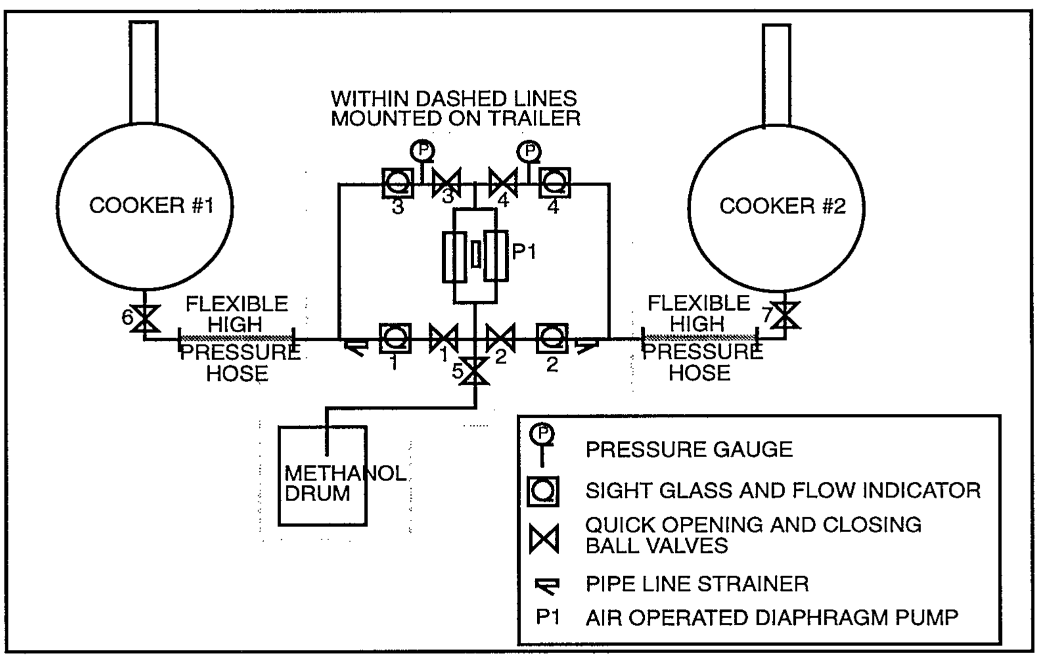
Occasionally, the methanol solution ignited when the charges were functioned but combustion would cease immediately due to lack of oxygen within the tank. The agent fill drained from the perforated shells by gravity (accelerated by density differences between the fill and methanol solution) while simultaneously undergoing chemical reaction with the caustic alcohol solution. After approximately one hour, the used reactant solution was pumped to the second tank and fresh methanol introduced into the first tank to just cover the perforated shells. The methanol was then ignited using a secondary ignition source installed in the tank while combustion was sustained and controlled by a small air blower connected by flexible ducting to the tank inlet pipe. The shells were thus thermally treated at approximately 700 ^{o}C for up to three hours to effectively decontaminated the metal. This treatment exceeded the United States Army 5X thermal decontamination standard (approx. 550^{o}C for 15 minutes) for agent-contaminated metal. The shell casings were then removed as clean scrap metal for final disposal.

Figure 4.1



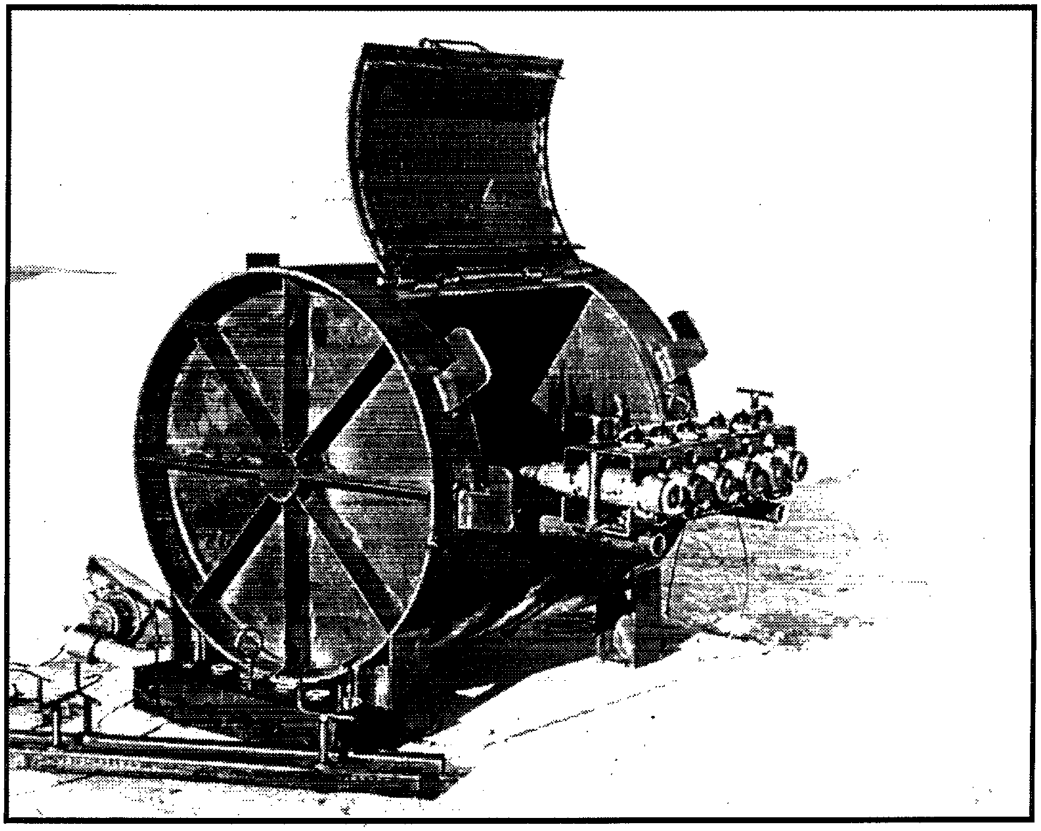
Shaped Charge Used For Perforating Artillery Shells

Figure 4.2



Schematic of "Kimbell Cooker" Apparatus

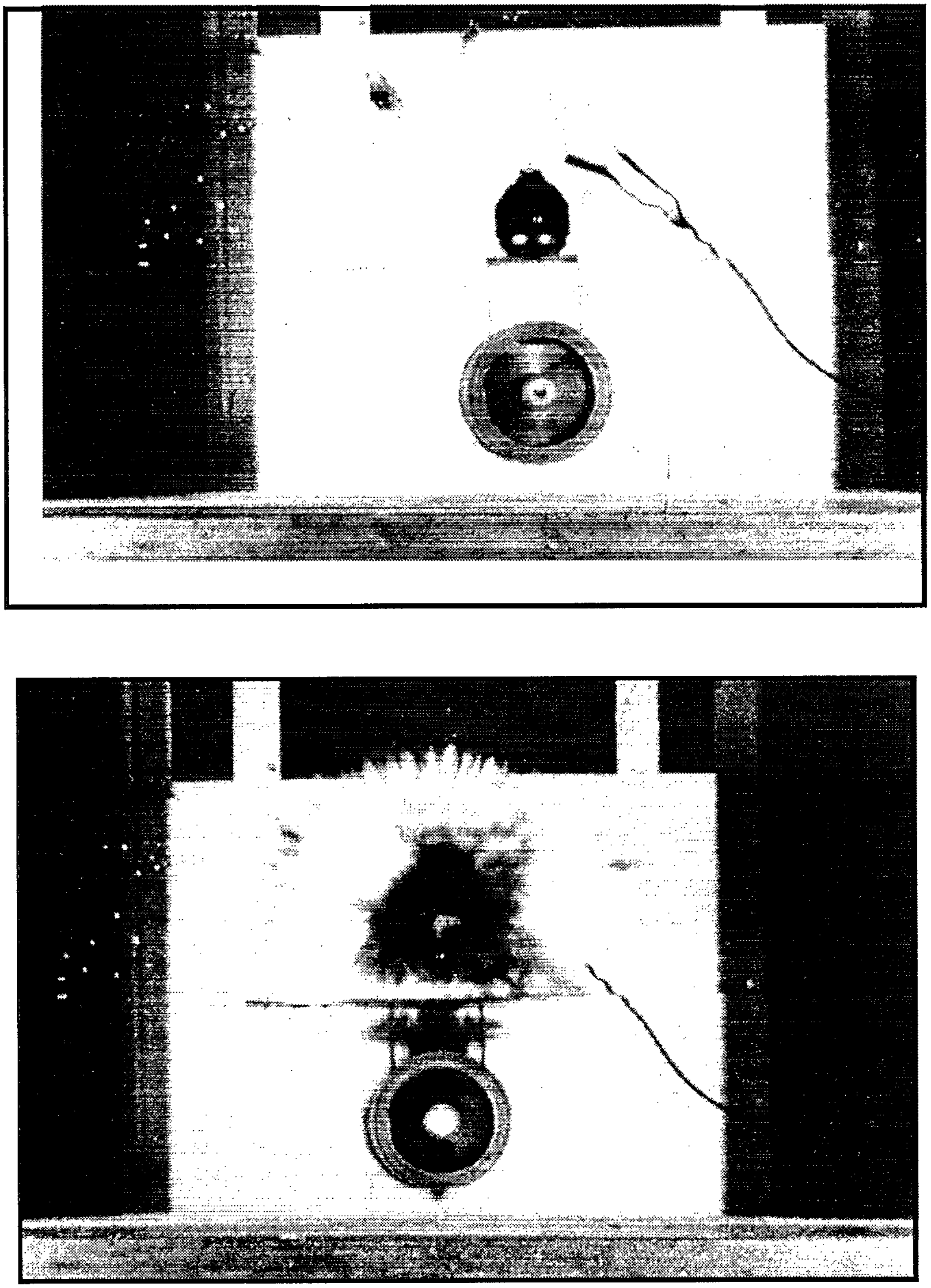
Figure 4.3



Racked Artillery Shells For Placing In
The Containment Tank

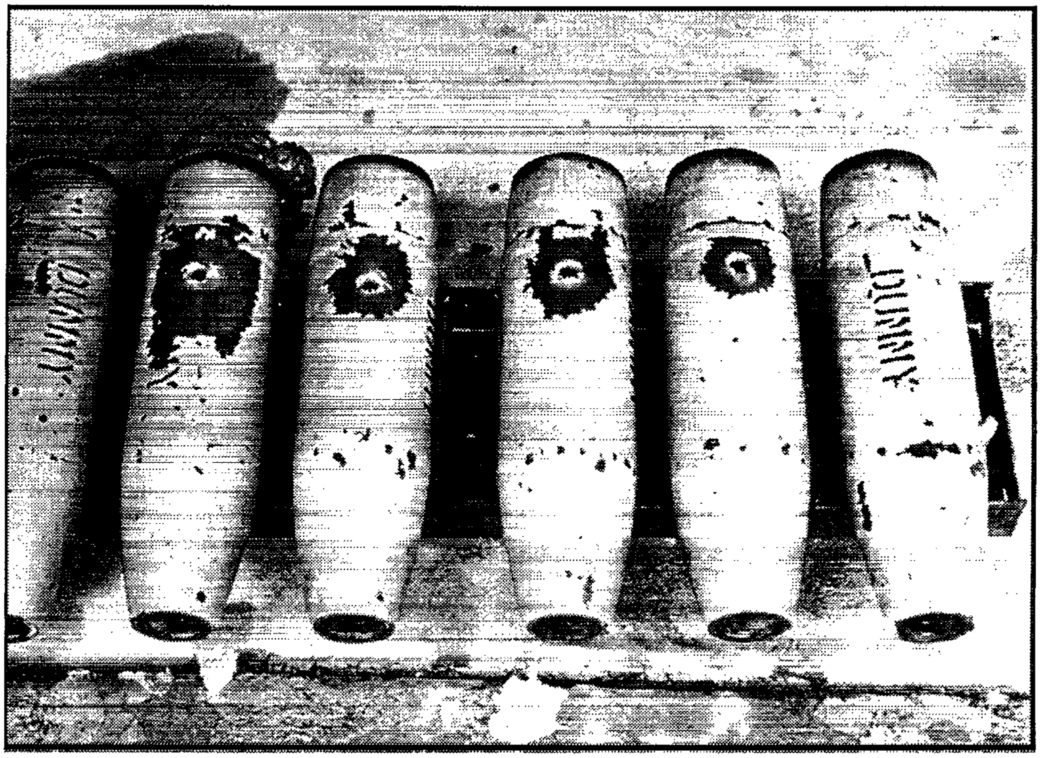
During methanol combustion in the first tank, another six shells were loaded into the second tank containing the used reactant solution and the perforation, draining and neutralization processes repeated. The used reactant solution was re-pumped to the first tank after the thermally treated shells had been removed, methanol added to the second tank and the thermal treatment completed on the second batch of shells. This procedure could be repeated several times before the large excess of potassium hydroxide in the reactant solution was expended. Up to 36 shells may be processed daily using this technology. With the exception of loading shells into the tank, placing the shaped charges and removing the thermally-treated shells, all operations are carried out remotely, thus increasing the inherent safety of the destruction operation. For example, should a poorly-characterized shell explode due to e.g. internal gas pressure, the force of the explosion is contained within the closed tank. A high explosive detonation (unlikely in the case of the project inventory) would probably destroy the tank and its contents.

Figure 4.4



Shell Perforation Sequence Shown By High Speed Photography

Figure 4.5



Examples of Perforated Artillery Shells

All operations with the tank system were performed outdoors where methanol combustion products are emitted directly to the atmosphere. These products are mainly carbon dioxide and water vapour. Extremely small quantities of phosphorus pentoxide and oxides of nitrogen would be expected from the combustion of trace surface contaminants or the organic salts produced during the neutralization process.

Tests with this system were completed using shells filled with methyl salicylate. This "worst-case" simulant was chosen as it hydrolysed relatively slowly in KOH/methanol and could be detected easily with portable Chemical Agent Monitors (CAMs). CAMs were used to provide a qualitative assessment of the efficiency of the combined neutralization/combustion process by monitoring the tank stack effluent during methanol combustion as well as the internal air space of the perforated shells following the thermal treatment. No methyl salicylate was detected by such monitoring (CAM detection level $< 0.01\ mg/m^3$ for methyl salicylate).

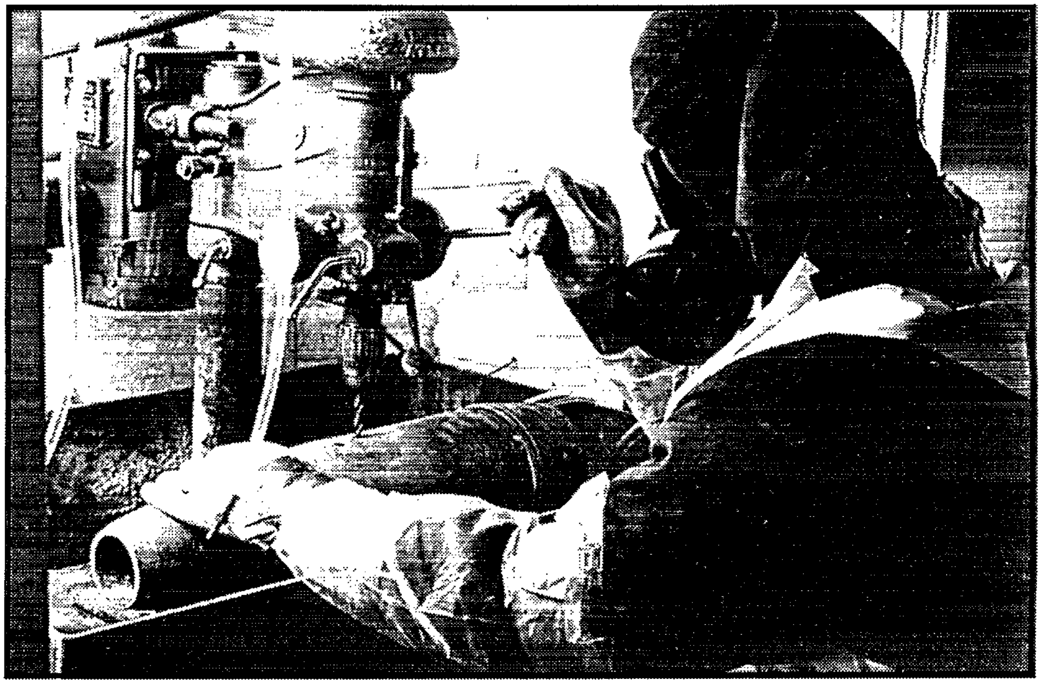
Further development and testing of the shaped-charge perforating method using nerve agent-filled shells was not pursued as all available inventory was processed in the interim using the drill and drain method.

4.1.2 Drill and Drain Method

The entire nerve agent stockpile (305 kg), consisting of tabun (GA), sarin (GB), VX and experimental V-agent formulations was processed using a DRES-developed drill and drain apparatus (Figure 4.6). This operation was conducted in the field laboratory fume hood which incorporated a charcoal filter assembly on the exterior exhaust duct (Figure 4.7). On average, two personnel (drill operator and safety back-up) could daily process approximately 20 items each containing 2-3 kg agent using this apparatus. Operations were carried out on a periodic, scheduled basis when weather permitted. Other personnel on-site to support operations and provide emergency response capability included a meteorologist, trial safety officer, chemical safety specialist, medical specialist and ambulance driver. All personnel who worked within the laboratory or handled inventory items wore the Canadian Forces NBC Protective Ensemble which was rated for protection against nerve agents.

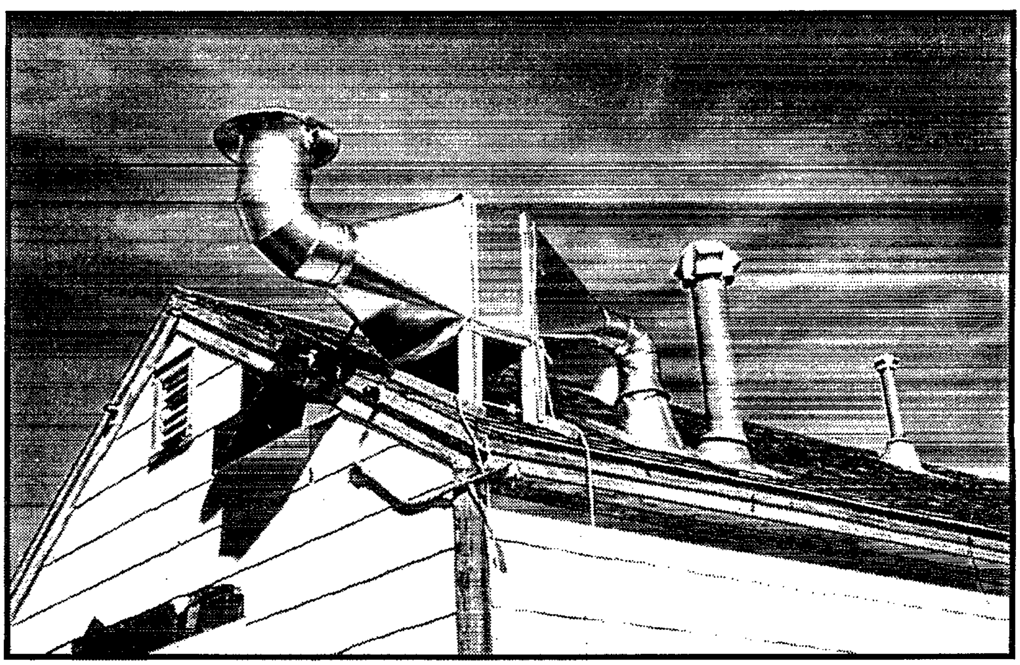
Although the drilling operation was conducted as safely as possible, this operation was inherently hazardous as the drill operator was in close proximity to the item as it was being opened. Thus, all precautions were taken beforehand to ensure items were well-characterized (e.g. contained no explosives). In most cases this included X-raying the items. To guard against the possibility of splashing from items that may have developed internal pressure after many years of storage, personnel wore the NBC Protective Ensemble with additional plastic coverings while the drilling itself was performed slowly and carefully. To process the one-ton GA container, the side wall of the laboratory building was removed temporarily to allow the container to be mounted inside on a wooden pedestal. The container was then slowly drained in separate batches through a tube immersed into a closed vat containing potassium hydroxide/methanol solution.

Figure 4.6



Drill and Drain Apparatus For Nerve Agent Destruction

Figure 4.7



Charcoal Filter Housing Mounted On Roof Of Willis Centre Laboratory

Examples of the small containers and artillery shells which were processed are shown in Figure 4.8. Containers were carefully opened by either removing available plugs or manually drilled open and the contents drained into a tray filled with 20% (w/v) potassium hydroxide in methanol. A number of small glass vials containing used nerve agent analytical standards were also destroyed by immersing the vials in the solution and breaking them with tongs. Drained containers were rinsed by pumping in fresh solution to destroy residual agent contamination. All used solutions and rinsings were then bulked and stored in a 4000 L plastic tank (Figure 4.9) located outside of the laboratory building. The nerve agent destruction process generated approximately 1500 L of waste solution which contained methanol, potassium salts (cyanide, fluoride, phosphates), methyl phosphonate esters and organic sulphide compounds. To reduce flammability and complete the hydrolysis process, this solution was diluted with water to 3500 L total volume and stored for a year while awaiting final destruction by incineration.

The rinsed containers were thermally treated by methanol combustion using the reinforced tanks designed for shell perforation operations (see Section 4.1.1). In this manner, the containers were rendered safe for further handling and processing by incineration along with other scrap metal inventory. The drained GA ton-container was partially filled with fresh neutralizing solution to destroy agent residues, then removed outdoors to a cleared area. After a week, the container was drained, explosively perforated on the top-side with large shaped charges, then partially filled with methanol. The methanol was ignited with a secondary charge and allowed to burn inside the container. This form of thermal treatment rendered the container safe for further handling. The container was eventually cut into small pieces with explosive cutting charges and the fragments incinerated along with other scrap metal inventory.

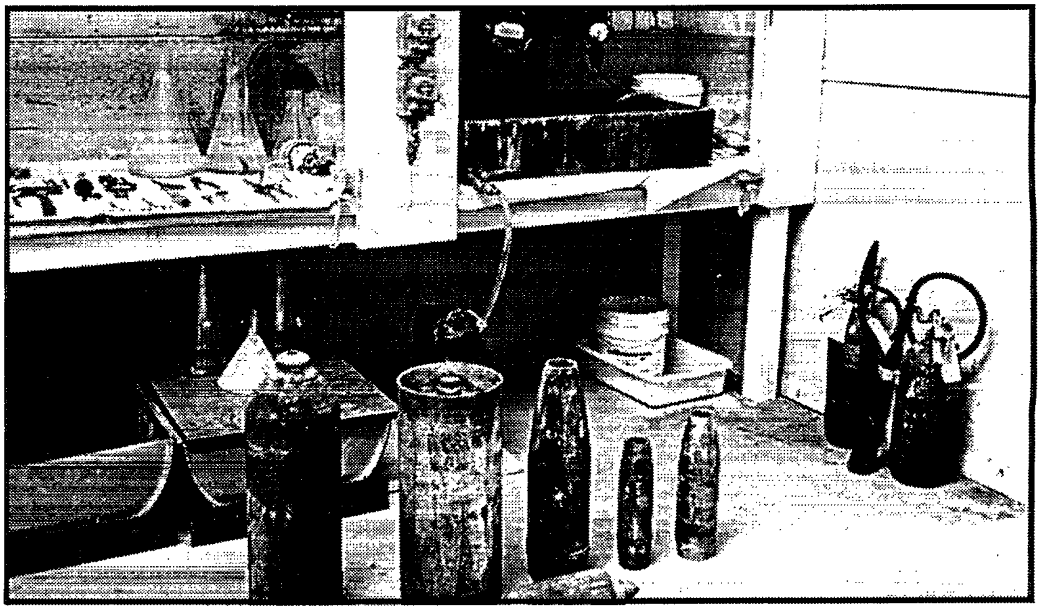
The progress of the nerve agent destruction operation over the entire program is illustrated in Figure 4.10. In general, the rate of destruction increased as experience was gained with the drill and drain method and larger items such as the ton container were processed. The "theoretical destruction rate", based on the original assumption that all the containers were full (total 1.1 tonnes of nerve agent), is shown for comparison.

4.2 Monitoring Activities

Hand-held CAMs and two portable long-path infrared analyzers (MIRAN 1As) which were mounted inside the laboratory were used to monitor for agent emissions during drill-and-drain operations. The MIRANs were calibrated by injecting standard solutions of GA, GB and VX in acetone into a closed-loop calibration system supplied with the instruments. One MIRAN was used to continuously monitor for background concentrations of agent vapour in the laboratory while the probe of the second instrument was placed near the fume hood opening to detect any fugitive vapour emissions from the drilling apparatus. Periodically, a CAM was taken onto the roof of the laboratory building and used to check the fume hood exhaust filter element for any agent "breakthrough" during drilling operations. The nerve agent detection limit of the instruments was approximately 0.05 mg/m^3.

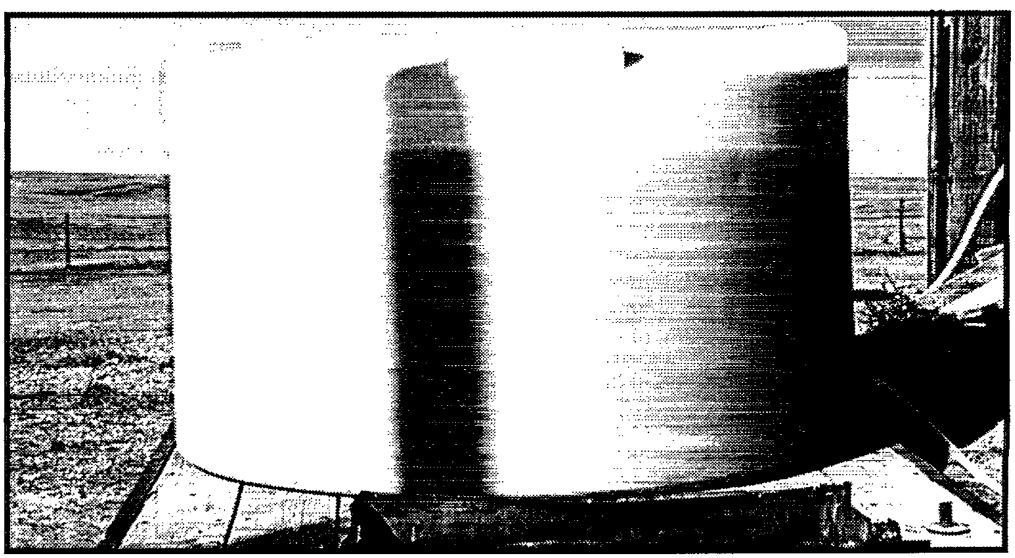
While drilling and draining containers, no nerve agent emissions were detected outside of the fume hood in the laboratory or downstream of the charcoal filter element. CAMs held close to the drill bit would respond occasionally as the drill penetrated into an item. Following the nerve agent destruction program, the fume hood filter elements were removed, packaged and incinerated in the Project Swiftsure incinerator.

Figure 4.8



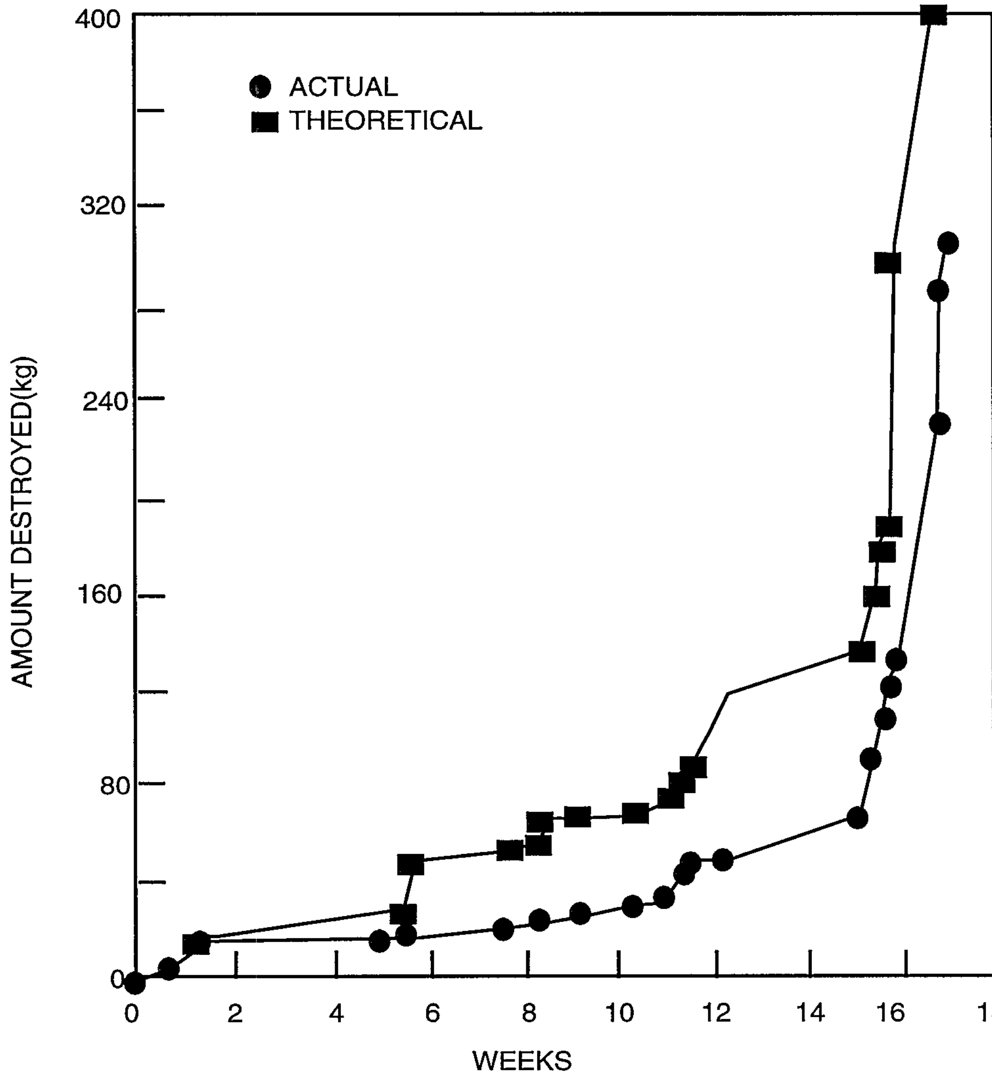
Examples of Processed Nerve Agent Containers

Figure 4.9



Bulk Storage Tank For Neutralized Nerve Agent Solution

Figure 4.10



Progress Chart for Nerve Agent Destruction Program

4.3 Destruction Of Miscellaneous Agents

The 14A Site contained small numbers of items with chemical fills other than mustard, as shown in Table 3.2. These items were destroyed or processed using the following critical alternative methods (see Section 3.4.7):

- Items containing white phosphorus, high explosives, tear gas and agent/tear gas mixtures, chlorine, and phosgene were explosively destroyed *in situ* one at a time;
- Containers with bromobenzyl cyanide (BBC) were emptied into methanol. This solution was then used as a combustion fuel to thermally treat the emptied containers using the "Kimbell Cooker" apparatus (see Section 4.1.1);
- A large 2000-lb aircraft bomb suspected of containing hydrogen cyanide was carefully drilled open *in situ* using a portable pneumatic drill. After venting slowly to atmosphere, the bomb was then explosively destroyed;
- Drums containing chlorosulphonic acid (empty) and arsenical agents were retained for eventual disposal by stabilization in concrete and landfilling.
- German ordnance containing nitrogen mustard or mustard/arsenical fills were explosively perforated under cold conditions, packaged and incinerated as per mustard-filled ordnance.

4.4 Contract Bidding Process

Prior to Project Swiftsure, Canadian private industry had no previous experience in carrying out chemical warfare agent destruction. A few firms were indirectly involved in facilities design and environmental monitoring programs during the mid-1970s mustard hydrolysis project. Therefore, before completing a formal Request For Proposal (RFP), DRES contacted several hazardous waste management and disposal companies to determine their interest in bidding on a project involving the destruction of chemical warfare agents. Surprisingly, considerable interest was expressed in the project; four companies submitted unsolicited "pre-proposals" to DRES which outlined general approaches and technology for an agent destruction program. In all, 24 companies which had expressed interest were included on the formal bidders list developed by Supply and Services Canada (SSC).

On 28 June 1989, an RFP entitled "Disposal Of Hazardous Material Held On The DRES Experimental Proving Ground", SSC File No. XSG89-00043-(601)/A, was issued to potential bidders with a closing date of 30 August 1989. The RFP Statement of Work (SOW), which incorporated many of the technical elements of the DRES project concept plan, had previously been reviewed by DND, SSC and Environment Canada officials. The SOW provided the necessary technical information to enable the bidders to develop their approaches to the project and outlined means by which the client Department (DND) would be protected against cost overruns and operational deficiencies. The Statement of Work included descriptions of the following:

- Scope of work for the providing and operating a hazardous waste disposal system.
- A detailed description of the agent-related waste inventory;
- Specifics of the type of work to be carried out at waste storage sites and destruction sites, including site preparation, waste preparation activities, transportation aspects, neutralization and incineration operations and demobilization activities;
- Emission standards and process monitoring, sampling and analysis requirements;
- Development of an Environmental Protection Plan (see Chapter V);
- Reporting and documentation requirements;
- Scheduling of project activities and approval requirements;
- Support services provided by the contractor and by DRES;
- Contractor liabilities and responsibilities, and
- Project management including control and supervision of resources.

In response to the RFP, bidders were required to submit to SSC a Technical Proposal, a Management Proposal, as well as a separate Cost Proposal. This latter Proposal was reviewed only after the evaluation of the Technical and Management Proposals had been completed. A bidders conference and site tour was held at DRES on 12-13 July 1989 which was attended by managers and technical specialists from 11 firms and representatives from DND, SSC and Environment Canada who were in attendance to field questions. The project emission and air quality limits were confirmed by Environment Canada at this time. Questions raised by firms during the conference and in subsequent written correspondence were recorded along with the answers provided. Formal letters were issued by SSC to all bidders on 24 July, 15 August and 24 August 1989 which collated all questions and answers and provided clarification statements or supplementary information related to the RFP.

Formal bids were submitted from 4 firms in response to the RFP:

- Allure Industries Corporation (Vancouver, B.C.)
- Ogden Environmental Services (Toronto, Ontario/San Diego, California)
- O.H. Materials of Canada Ltd. (Oakville, Ontario)
- Western Research Partnership (Calgary, Alberta).

The bids were evaluated at DRES during 11-13 September 1989 using rating criteria set out in the RFP. To be accepted, bids were required to meet all specified mandatory requirements and achieve a minimum rating of 75% in each of several sections in the Technical and Management proposals. The lowest-priced, acceptable bid was then selected for contract award. National Defence Headquarters Directorates (CRAD and DPSCE), SSC/Edmonton and DRES provided members for the review committee. Copies of the bids were sent also to Environment Canada (Edmonton) officials who evaluated specific-sections with respect to environmental protection matters.

One of the submitted bids failed to meet technical requirements and was removed from further consideration. Of the three remaining responsive bids, the review committee recommended that a contract be awarded to Western Research Partnership. DND accepted this recommendation and requested SSC to proceed. Following contract negotiations which took place during October and November 1989, Western Research Partnership (Chem-Security Ltd./Western Research) was awarded SSC Contract No. W8464-9-KA02/01-XSG in the amount of $13,592,605.00 on 28 December 1989. The value of the contract itself exceeded the original estimate for Project Swiftsure; therefore, DND supplied additional funding from Department operations and maintenance budgets to cover the cost of this contract.

4.5 Operations Schedule

The original schedule proposed by Western Research Partnership for Project Swiftsure is shown in Figure 4.11. The schedule embodied the following key elements:

- Preliminary and final versions of the Environmental Protection Plan (EPP) would be prepared during the first half of 1990 concurrent with design work on the equipment and facilities to be supplied. The EPP was scheduled for approval at the end of June 1990;
- Following EPP approval, equipment would be delivered and buildings erected during late summer and Fall of 1990 (3.5 months);
- The incinerator and flue gas scrubbing equipment would be commissioned and performance-tested during the winter of 1990/1991;
- Chem-Security Ltd. (CSL) would commence field operations such as screening, classification, shredding, and packaging of waste at storage sites during the summer of 1990. Neutralization operations were scheduled for the cooler months of fall and winter 1990/1991;
- Following approval of performance test results (trial burns) of the incinerator and flue gas scrubbing equipment, routine waste incineration operations would begin during 1991 (7 months);
- Incineration would be completed in mid-1991 followed by a two-week period where contractor-owned equipment would be decontaminated, dismantled and removed.

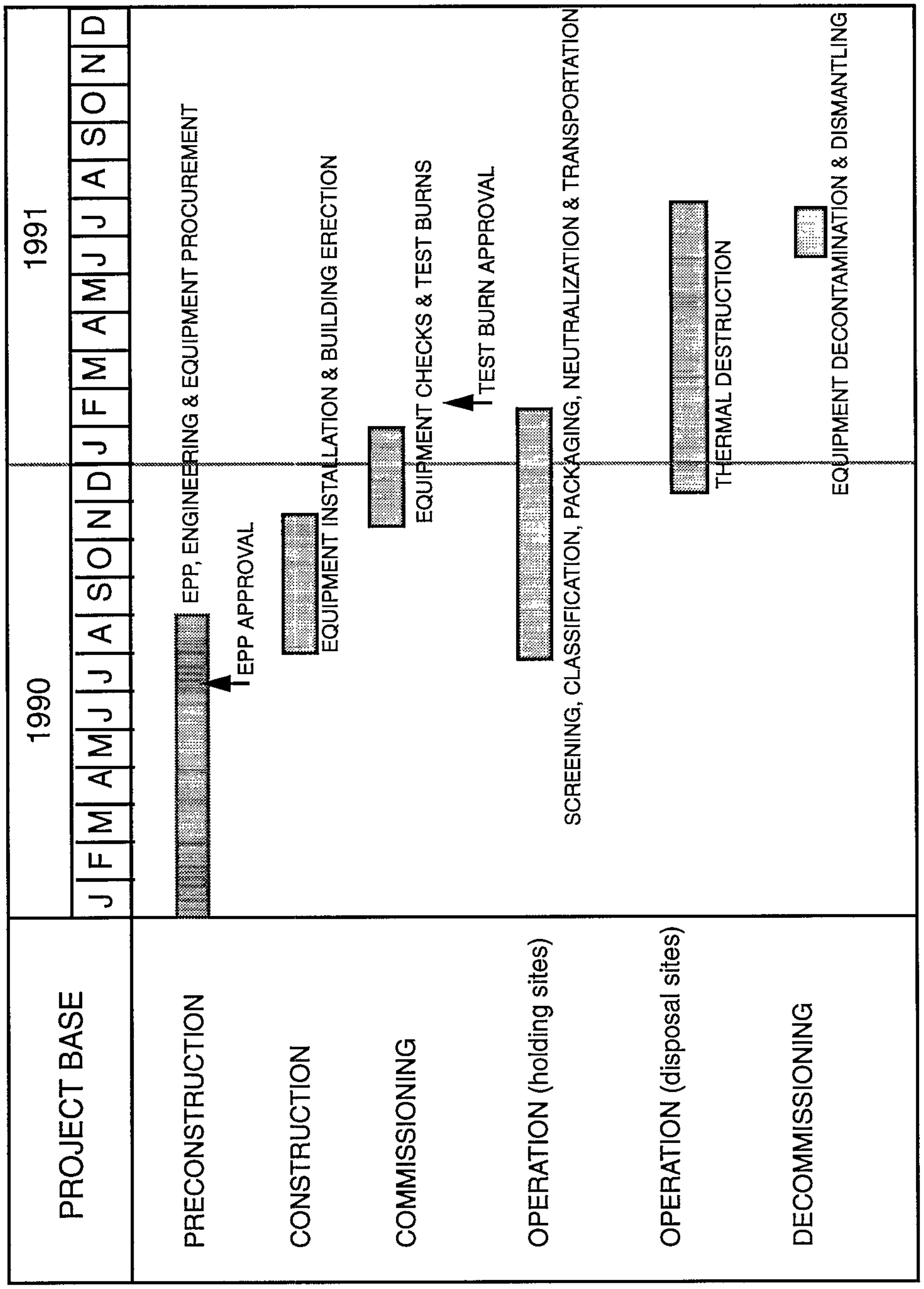
4.6 Aproval Process For Incinerator Operation

Project Swiftsure was conducted entirely on DND land and thus was not subject to the usual provincial requirements for the siting, licensing and operation of an incinerator facility.

During meetings between National Defence, Environment Canada, and Alberta Environment (see Section 3.5), a project-specific approval process was developed for the operation of the incinerator. This included the following;

- Prior to delivering and installing the incinerator, the project Environmental Protection Plan required acceptance by the environmental agencies and the general public as well as approval by DND;

Figure 4.11



Western Research Partnership Schedule For Agent Waste Destruction

- ❖ The incinerator would be tested in accordance with a trial burn protocol prepared by Western Research Partnership. The protocol document required acceptance by Environment Canada and Alberta Environment before conducting trial burns;
- ❖ Agent material or heavily-contaminated items would not be incinerated until the trial burn results were accepted by Environment Canada. In the interim, non-hazardous or lightly-contaminated scrap material could be processed provided emission standards set for the project were met.

4.7 Transportable Shredder System

As described in the concept plan (See Section 3.4.5), a transportable, self-contained shredding system was required which could volume reduce the scrap waste inventory at the EPG storage sites for batch loading into the Project Swiftsure incinerator. Much of the project inventory consisted of light-walled containers such as empty drums; therefore shredding, as opposed to compaction, was considered more practical in terms of safety (i.e., avoid entrained contamination) and for providing an appropriate feedstock for the incinerator.

DRES conducted an initial survey which indicated that, although suitable permanently-installed shredding equipment was available in commercial scrap yards or in waste processing plants, no equivalent mobile systems were then available, except for scrap automobile compactors. Thus, Shred-Tech Ltd, Cambridge, Ontario was awarded SSC Contract W7702-8-RO68/01-XSG in January 1989 to examine the feasibility of developing a transportable system based on the company's proven, low-speed metal shredding units. Based on this feasibility study and preliminary designs submitted to DND, the company was awarded a second contract (SSC W7702-8-R075/01-XSG) in the same month to produce a transportable drum and scrap metal shredder utilizing the Shred-Tech ST-400 hydraulic shredder mounted on a 40-foot tri-axle trailer. The total value of the two contracts was approximately $0.75 million.

4.7.1 Description

The transportable shredder, designated the ST-400-H-SP Mobile Shredding Station, is shown in Figures 4.12 (schematic form) and 4.13. The major components of the system are as follows:

Shredder:

- ❖ The ST-400 Shredder is powered by two hydraulic motors which counter-rotate two hexagonal shafts, each equipped with 24 hardened steel knives which intermesh with the opposite shaft knives. Each knife has three hooks to engage the material for shredding. Two shaft speeds may be utilized; a lower-torque 23 rpm speed for normal shredding operations or a higher-torque 10 rpm speed for shredding heavier material. Maximum torque developed at 23 and 10 rpm is 89,000 and 130,000 ft.lbs, respectively. Physical parameters for the shredder sub-components are listed in Table 4.1.

Power Plant/Hydraulic System:

- A Caterpillar Model 3408TA diesel engine developing 475 bhp at 1800 rpm is the primary power source for the shredder system. This engine engages the hydraulic system through a PD 450 Cotta Transmission pump drive unit at a 1:1 conversion ratio. Two Hagglunds-Denison hydraulic pumps coupled to this transmission provide the primary pumping source for the hydraulic system. The hydraulic fluid is delivered to various sub-systems through secondary pumps and motors from a 300 gallon (US) reservoir. Descriptions and performance characteristics of these hydraulic components are given in Table 4.2.

Conveyors:

- The horizontal-mount primary discharge conveyor is located directly beneath the ST-400 Shredder. The conveyor, 6 ft. wide by 5.5 ft. long, utilizes a roughened neoprene rubber belt mounted on 6-inch diameter steel rollers. The belt is driven by a 5 hp hydraulic motor coupled to the conveyor hydraulic pump. A one-foot high sidewall is mounted on either side of the belt to prevent spillage of shredded material. The material is discharged to a 6 ft. wide by 10 ft. long side-mounted conveyor which utilizes a similar neoprene belt, side-wall and hydraulic motor as the primary conveyor. The side-mount conveyor belt also has 2-inch high rubber cleats to prevent material back-slip. The conveyor assembly is hinged to permit stowage and has a winch-controlled assembly which enables the conveyor to be set at different inclines for discharging material into e.g. truck dump boxes or storage bins.

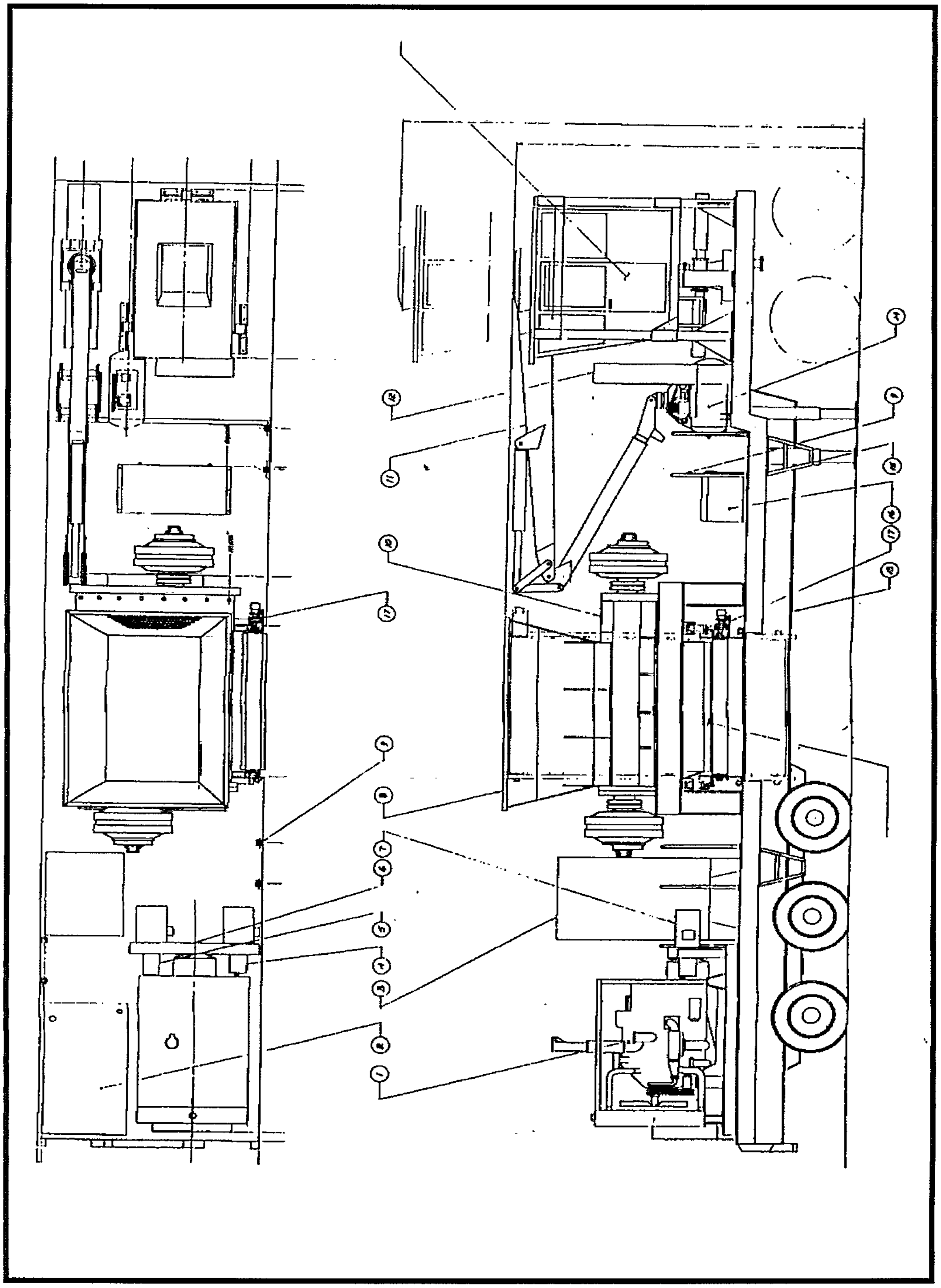
Crane:

- The transportable shredder incorporates a deck-mounted, high-duty cycle crane with a special jaw design (drum grapple) which permits drums lying at different angles to be picked-up and delivered to the shredder hopper. The crane has a maximum reach of 25 feet with a pulling force and lifting capacity at full extension of approximately 3 tonnes and 0.8 tonnes, respectively. An electromechanical detente system prevents the crane from rotating into contact with the operators cabin. The drum grapple is capable of picking up two drums at a time if the drums are positioned side-by-side.

Operators Cabin:

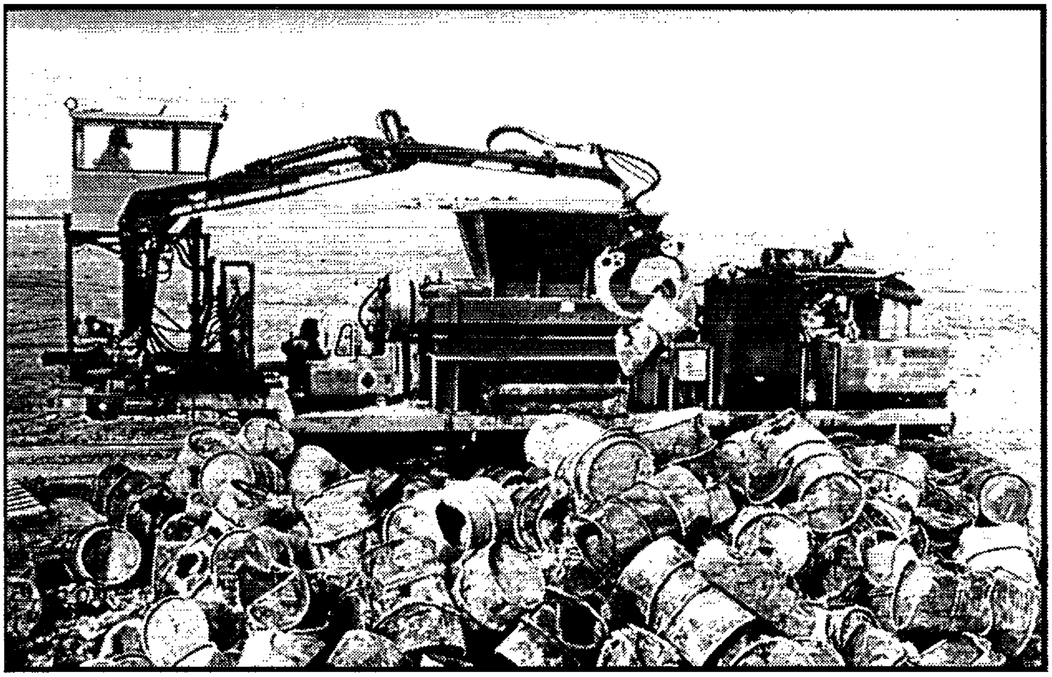
- An enclosed operator's cab, complete with heating and air conditioning, enables the system to be operated under all weather conditions. The cab is mounted on a six-stage telescoping hydraulic piston which can raise the cab approximately 6.5 feet above the trailer deck to provide the operator with an unobstructed view of the shredder hopper and the shaft-mounted knife blades. The cab is

Figure 4.12



ST-400-SP-H Mobile Shredding Station Schematic

Figure 4.13



Shredder In Operation at 490 Site Drum Pile

equipped with a swivel seat, joystick controls and control panel which are designed to make the shredder system simple and straight-forward to operate.

Table 4.1

PHYSICAL PARAMETERS FOR ST-400 SHREDDER SUB-COMPONENTS

COMPONENT	PHYSICAL DESCRIPTION
Knives (x48)	width: 2.75 inches diameter: 22.75 inches
Shafts (x2)	length: 122 inches weight: 5,000 lbs center distance: 17 inches
Cutting Chamber	75 x 42 inches
Hopper	opening: 78 x 96 inches height: 48 inches
Shredder Stand	length: 120 inches width: 67 inches height: 40 inches
Shredder System	total weight: 38,000 lbs

Table 4.2

SHREDDING SYSTEM HYDRAULIC COMPONENTS

COMPONENT	DESCRIPTION
Hagglunds-Denison MA 283 Hydraulic Motor (x2)	displacement: 1084 cu.in./rev maximum speed: 42 rpm maximum power: 575 hp maximum pressure: 5000 psi flow (42 rpm): 197 gal/min weight: 1350 lbs
Hagglunds-Denison P14P M2 Pump (x2)	displacement: 14 cu.in./rev maximum speed: 2400 rpm maximum power: 350 hp maximum pressure: 5000 psi flow (2400 rpm): 145 gal/min weight: 300 lbs

4.7.2 Operation

System operation, including operation of the drum shredder, crane, conveyor belts, cab position and trailer levelling jacks is controlled through the use of a program logic controller sub-system. A full range of sensors monitor engine status, hydraulic components and shredder performance. A special control feature automatically lowers rotational speed of the shredder shafts when a difficult-to-shred item is encountered. This feature maintains a constant torque while ensuring the engine's capabilities are not exceeded. When an item which cannot be shredded is encountered, the shredder shafts automatically reverse direction to disengage the item.

4.7.3 Shredder Modifications

The Mobile Shredding Station was delivered to DRES in August 1989. Several design improvements and modifications were made to the system as a result of preliminary tests and subsequent field operations, as follows:

- Electric immersion heaters were incorporated into the engine radiator and shredder hydraulic fluid reservoir to improve starting and operating performance under cold winter conditions. When required, the immersion heaters were powered by a portable gasoline-powered generator;
- Motions of the crane caused excessive trailer deck sway. This problem was rectified by attaching a set of manually-operated hydraulic stabilizers to the sides of the trailer frame;
- Crane motions also caused buckling of the deck plates under the crane mount. A more robust deck mount was constructed which eliminated this problem;
- The original side-mounted conveyor belt was found to be susceptible to improper tracking. The belt material itself was found to wear rapidly when in contact with shredded metal. The original conveyor was modified to incorporate a positive tracking, sprocket-driven belt drive and the neoprene belt was replaced by a polyethylene belt containing cleats and sidewalls.

4.8 EPG Soil and Groundwater Surveys

Over the years, DRES has completed several surveys of EPG buildings and sites where chemical agent waste disposal activities had been carried out to assess the extent of known or potential contamination. In 1985, the Royal Military College (RMC), Kingston, Ontario, carried out environmental investigations under contract at three discontinued chemical waste disposal sites to determine whether site-specific remedial action was required. These investigations found no evidence of wide-spread chemical contamination in collected groundwater or soil samples, with the exception of tributyl phosphate, a non-toxic chemical agent simulant, which was found near the limit of detection (0.5 ppm) at shallow depths in several boreholes [38].

In 1989-1990 and in conjunction with Project Swifsure, RMC undertook a further detailed study at the 490 Site to characterize the soil types present and to determine the extent of soil contamination in and around the drum storage pits, at nearby field trial layouts, and at the mustard hydrolysate "land farming" area which was created in the mid-1970s. RMC used an on-site mobile laboratory to support this study; the laboratory provided the necessary resources and capability to analyze soils and groundwater for chemical warfare agents and their degradation products.

Except for highly localized mustard surface contamination within the drum pits, no mustard, mustard hydrolysis products (e.g. thiodiglycol) or other chemical agents were found in soil or groundwater samples collected within the 490 Site. The local soil type, which is similar to soil found throughout the EPG [13,14], possessed a high clay content and was alkaline in nature; these characteristics mitigate against agent migration through the soil and enhance the rate of mustard hydrolysis in the environment. The localized mustard contamination within the pits was remediated by spreading lime on the soil surface and adding fresh soil to fill in the pits after the drums had been removed and processed during Project Swiftsure.

Project Swiftsure Final Report

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CHAPTER V

ENVIRONMENTAL PROTECTION PLAN AND PUBLIC INPUT

5.0 ENVIRONMENTAL PROTECTION PLAN PLAN AND PUBLIC INPUT

5.1 Overview

DRES completed an initial environmental screening for Project Swiftsure in 1989. Based on this screening, it was concluded that the project could proceed as all potential environmental impacts resulting from project-related activities could be eliminated or mitigated with known technology, procedures and environmental management practices [18]. However, in anticipation of public interest, DND decided to carry out a further assessment involving public participation in order to provide the necessary assurance that safety and environmental protection measures were being incorporated during project planning and implementation. That is, a detailed assessment similar to the Initial Environmental Evaluation which is normally carried out as part of the second stage of the Environmental Assessment Review Process [16] was implemented for Project Swiftsure.

The detailed assessment took the form of an Environmental Protection Plan (EPP) which was prepared by Western Research Partnership under the terms of their contract for review by National Defence, Health and Welfare Canada, Environment Canada and Alberta Environment officials. A first draft of this document, which was completed in March 1990, covered some of the issues raised by the public at several open information meetings held in district communities in February 1990 (See Chapter IX: Project Swiftsure Public Consultation). A revised version [13] of the EPP was produced in May 1990 and distributed to district community libraries to allow public access to the document prior to holding a second series of open meetings in July - August 1990. The original distribution of the EPP is summarized in Table 5.1. The document consisted of two volumes: Volume I (Environmental Protection Plan For Disposal Of Hazardous Waste At The Defence Research Establishment Suffield) which described the plans, technologies, and protective measures to be employed, and Volume II (Appendices) which collated newspaper articles, news releases, reference letters and DND policy documents.

The EPP was filed with Environment Canada on 14 June 1990 with copies forwarded to Alberta Environment, Health and Welfare Canada, and National Defence as well as to an independent consultant working on behalf of a citizens advisory committee (see Chapter IX: Project Swiftsure Public Consultation). These agencies reviewed the EPP and provided written input before, during and after the July-August 1990 public meetings. Subsequently, a third Volume of the EPP was produced (Volume III, Supplementary Information) which addressed all of the issues raised by the public and the reviewing agencies and described the project modifications which would be implemented. The entire EPP in three volumes was accepted by the reviewing agencies [39] and approved by National Defence in September 1990 [40]. The Supplementary Information volume was distributed as before to complete the EPP documentation. DND then provided written authorization [13,40] for Western Research Partnership to proceed with installing the equipment to be used for chemical agent destruction.

Table 5.1

ENVIRONMENTAL PROTECTION PLAN EXTERNAL DISTRIBUTION

RECIPIENT	COPIES	DATE FORWARDED 1990 EPP	DATE FORWARDED 1990 SUPPLEMENT
NDHQ Project Director	2	13 June	1 October[1]
NDHQ/DSIS[2]	1	14 June	12 October
Calto Industries	1	14 June	17 October
Environment Canada[3]	5	11 June	12 October
Alberta Environment	5	11 June	12 October
Citizens' Committee	6	15 June	17 October
Mayor of Medicine Hat	1	14 June	11 October
Mayor of Brooks	1	14 June	11 October
Medicine Hat College	2	29 June	12 October
Venture Communications	1	21 June	17 October
SE Alberta Health Unit	1	1 August	11 October
Big Country Health Unit	1	27 July	12 October
District Libraries			
Medicine Hat	3	15 June	11 October
Brooks	1	29 June	11 October
Bow Island	1	29 June	11 October
Redcliff	1	29 June	12 October
Ralston/Suffield	2	29 June	11 October
Irvine	1	28 June	12 October

1 The EPP including the Supplementary Information Volume was approved by the Project Director on 24 September 1990 for public distribution.

2 Defence Scientific Information Services, National Defence Headquarters, Ottawa.

3 Environment Canada requested three additional copies of the EPP (Volumes I and II). These were forwarded on 29 June 1990.

5.2 EPP Outline

The EPP focused on the approaches, equipment and procedures to be used by Western Research Partnership in eliminating or mitigating any environmental and health risks associated with the installation and operation of the agent waste destruction system. As well as describing the project history, scope and approaches, the EPP addressed the following specific topics:

- potential public health risks and environmental impacts which might arise off DND property from the agent destruction site (Cameron Centre) and storage sites were evaluated. In general, there were no “worst-case” scenarios which could affect the public in the vicinity of the Experimental Proving Ground under the proposed operating plan;
- emergency response and destruction site safety plans were described, including communications plans, responsibilities and terms of reference for emergency response personnel;
- potential health/safety risks and environmental impacts on EPG sites from operation of the agent destruction system were identified;
- specific technologies and procedures employed to prevent or miti gate identified potential impacts were described;
- monitoring programs and technologies for verifying compliance with project-related emission standards were described, including stack monitoring, ambient air quality monitoring, destruction site air monitoring, water sampling and, where necessary, soil sampling.
- public consultation programs were outlined, including means to keep the public informed as well as to receive public input during operations.

The EPP also described the local EPG environment where Project Swiftsure was to be conducted, the incinerator technology and other equipment to be used to prepare, process and destroy the waste inventory and general environmental protection and safety measures. Some of these latter measures included:

- scheduling agent processing (other than incineration)for the winter months;
- using protective clothing and containment systems at the waste storage sites and during transportation of wastes to the incinerator site;
- designing the incinerator stack to maximize emissions dispersion,
- continuous monitoring of process parameters, stack emissions and ambient air quality.

5.3 Review Process

Several different agencies as well as the public were involved in the review of the EPP. Government agency review was coordinated through the Western and Northern Region office of Environment Canada, in Edmonton. Staff of Environment Canada, Health and Welfare Canada and Alberta Environment provided written comments and recommendations to DRES. These inputs were then considered and appropriate written responses supplied to the coordinating department for further examination. Ultimately, on behalf of National Defence, DRES received letters of acceptance from the reviewing agencies through Environment Canada [39] stating that the review had been completed and that the agencies were satisfied that all issues had been fully addressed.

The issues raised, comments, recommendations and responses, including the final acceptance letters were collated and included in the Supplementary Information volume of the revised EPP [13].

The public review process was formally initiated with a presentation of the EPP to a citizens' advisory committee meeting on 20 June 1990 (see Chapter 9: Project Swiftsure Public Consultation). This process included an independent review of the EPP which was completed on behalf of the citizens advisory committee by Mr Brian Stuckert, Calto Industries Inc. A report [41] by the independent consultant was issued in August 1990. Specifically, this report covered the following areas:

- ❖ The EPP was examined to ensure sufficient information had been provided to fully describe potential safety and environmental impacts;
- ❖ Proposed incinerator emission standards were assessed for protec tion of human health and wildlife near the selected incinerator site as well as in district communities;
- ❖ The emissions dispersion model used was assessed for adequacy;
- ❖ The proposed technology options, site selection and processes employed were assessed with respect to providing maximum safety and minimal environmental impact;
- ❖ The proposed health, safety and emergency response plans were reviewed;

The citizens' group consultant also attended the public EPP review meetings to assess public response and issues of concern. Prior to completing his report, Mr Stuckert posed interim questions and received comments from an independent toxicologist (Dr. Bob Rogers). The consultant's Final Report was also included in the EPP Supplementary Information volume.

5.4 Amendments

Several important modifications to Project Swiftsure and the EPP resulted from reviews by the government agencies, the citizens' committee, and the general public. Where applicable, the Western Research Partnership contract for the agent destruction operations was amended to be consistent with the EPP changes. The key modifications were as follows (see Section 7.2.5 for other amendments):

5.4.1 Lewisite Destruction Process

In the original plan, lewisite was to be converted to arsenic salts by chemical neutralization followed by incinerating the neutralizing solution and salts to destroy organic chemical impurities. Arsenic-containing incinerator ash and scrubber fluid were to be collected and stabilized in concrete for final disposal. This approach raised concerns regarding the potential for arsenic emissions from the incineration process as well as with the overall efficiency of this combined process.

In the interim, preliminary tests were conducted by Chem-Security Ltd. which suggested that the lewisite neutralization process was highly efficient in destroying organic compounds. Therefore, the need for incineration to ensure complete destruction of lewisite was contraindicated. The modified project plan called for lewisite to be chemically neutralized with the collected arsenate salts and neutralizing solution immediately stabilized in concrete without any incineration.

5.4.2 Use Of Explosive Cutting Charges

A modified procedure was developed to eliminate the requirement to cut open drums containing thickened or aged mustard using explosive cutting charges. Instead, the drums were to be placed in a catch pan and opened with a pneumatic drum deheader tool which did not generate any heat or fragments. As an extra precaution against vapour emissions, these operations were to be carried out in cooler temperatures (0^oC - 5^oC) when mustard was frozen solid.

5.4.3 Hydrogeology and Soil Survey

Well water from several EPG Siteshad previously been analyzed to confirm that the area groundwater was not contaminated with chemical warfare agents and/or degradation products. Plans were modified to implement a new hydrogeological evaluation and soil survey near the waste holding sites during the course of Project Swiftsure (see Section 4.8). Remediation efforts would be undertaken in the event groundwater or soil contamination was found.

5.4.4 Incinerator Removal

The original concept plan developed by DRES called for retaining the incinerator at CFB Suffield to process site-generated waste on a periodic basis. As a result of concerns raised at open meetings, the Minister of National Defence issued a public statement [36] which required the Department to dismantle and remove the incinerator from CFB Suffield upon completion of Project Swiftsure.

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CHAPTER VI

INCINERATOR INSTALLATION AND TESTING

6.0 INCINERATOR INSTALLATION AND TESTING

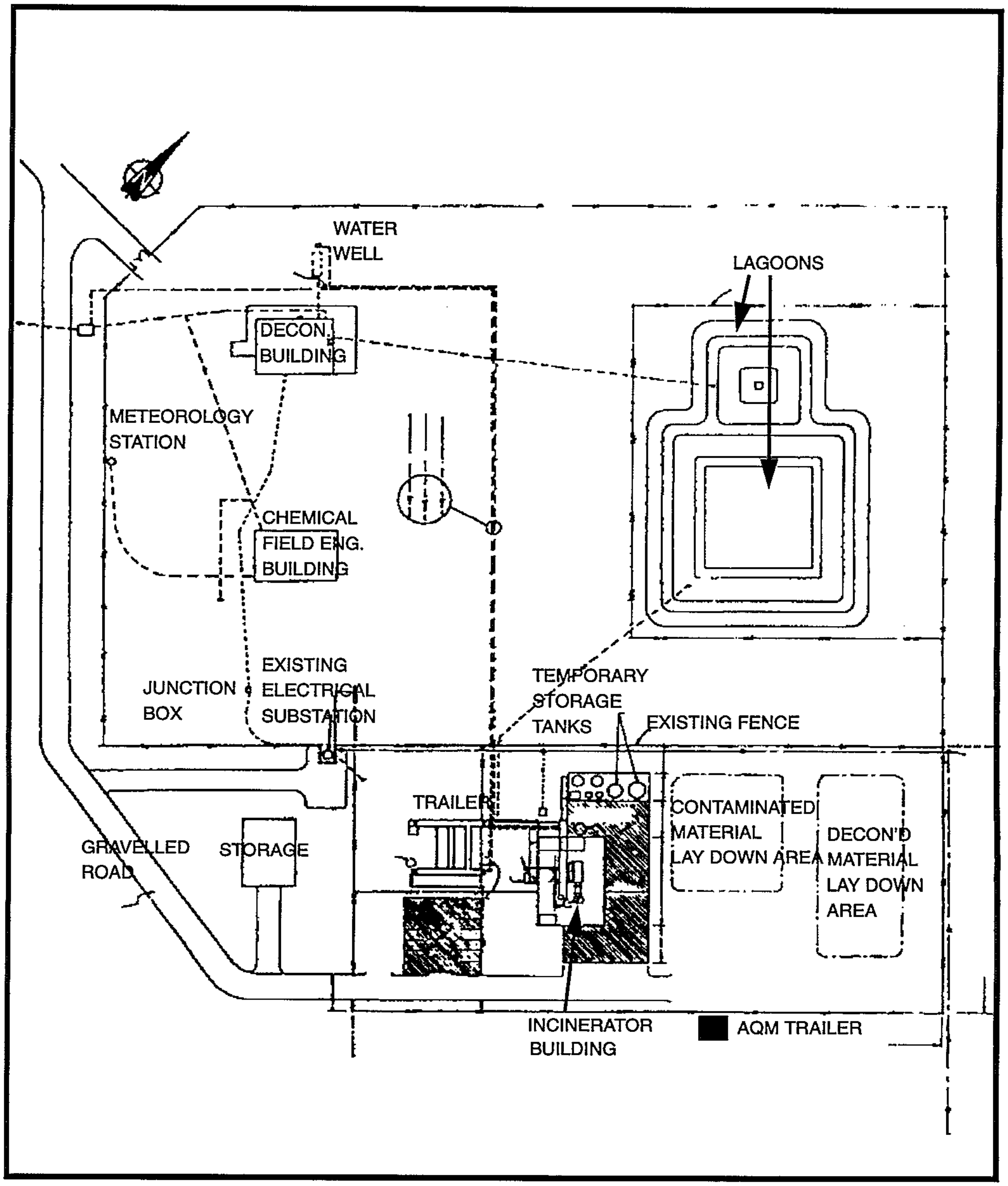
6.1 Overview

Following DND approval of the Project Swiftsure Environmental Protection Plan in September 1990, Chem-Security Ltd. was authorized to begin the necessary construction and installation of the incinerator facility at the Cameron Centre. This was followed by commissioning tests to ensure the mechanical and electrical integrity of the equipment and the preparation of a Trial Burn protocol document for review by Environment Canada. In accordance with the project approval process (see Section 2.13: Approval Milestones), CSL was allowed to proceed with trial burns of the incinerator following approval of the protocol document by Environment Canada. The results of the trial burn program, which was carried out in accordance with the approved protocol, required acceptance by Environment Canada before DND authorized CSL to proceed with full-scale agent destruction operations.

6.2 Construction and Incineration Installation

During the Spring of 1990, DRES and CSL representatives inspected the Cameron Centre site to prepare a Siting Plan for approval by National Defence Headquarters. An area immediately south-east of the existing Cameron Centre boundary fence was selected for the construction of the necessary facilities to support incineration operations. A site schematic, as originally proposed by Western Research Partnership in their contract bid, was amended to reflect the current survey and changes made in the project plans as a result of the EPP review. A schematic of the site layout approved in September 1990 by local authorities at CFB Suffield and by National Defence Headquarters is shown in in Figure 6.1. This schematic shows the location of existing Cameron Centre facilities as well as the proposed facilities which were installed under contract. Contractor facilities included a thermal destruction building to house the incinerator, four trailers to house administration, laboratory, decontamination and maintenance functions (see below), as well as separate areas for storage tanks, and the temporary storage of waste inventory and processed final waste products.

Figure 6.1



Cameron Centre Site Schematic For Project Swiftsure

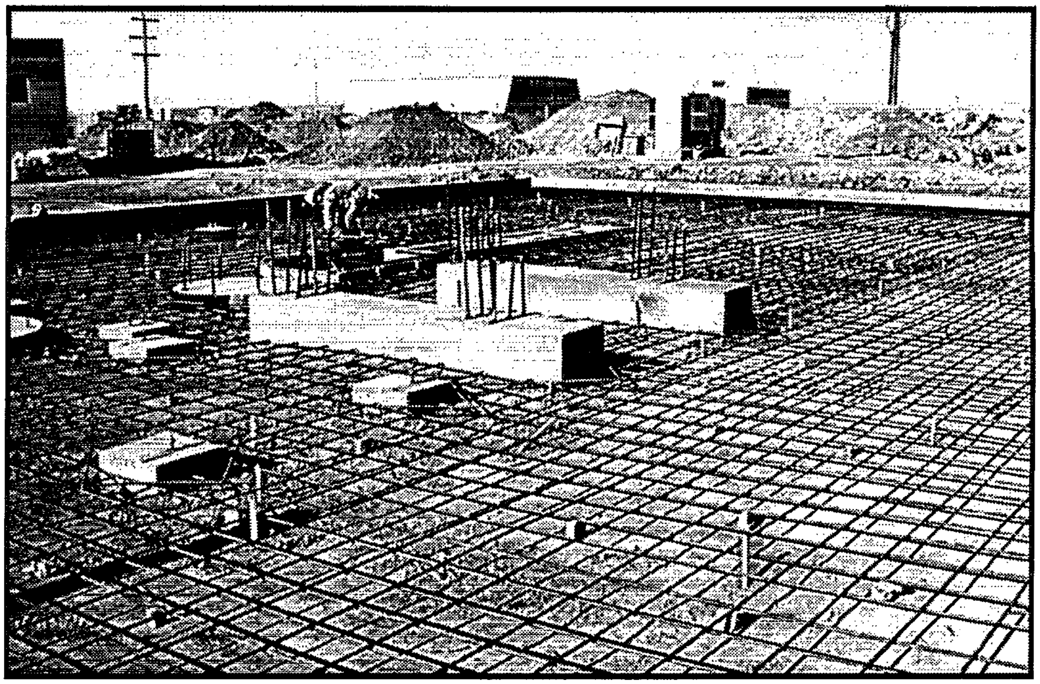
Construction of the thermal destruction building foundation (Figure 6.2) started immediately following approval of the project EPP in September 1990 and after DRES personnel had completed a standard inspection of the proposed site for items such as unexploded ordnance. Transportable incinerator components such as the rotary kiln, secondary combustion chamber and scrubber system were brought to the site and assembled on the concrete foundation, as shown in Figures 6.3 and 6.4. The building was then erected around the assembled components (Figures 6.5 and 6.6) and the necessary mechanical and electrical subsystems installed. The completed thermal destruction building is shown in Figure 6.7

An Air Quality Monitoring (AQM) trailer (Figure 6.8) operated by Western Research was also installed near the incinerator building (see Figure 6.1, Site Schematic). The location chosen for this trailer was based on downwind dispersion modelling predictions as described in the EPP [13]. The AQM trailer was immediately commissioned and began collecting background air quality data for comparison to data obtained later during incinerator operations.

Other trailers which were installed by Chem-Security Ltd. to support the forthcoming incineration operations included:

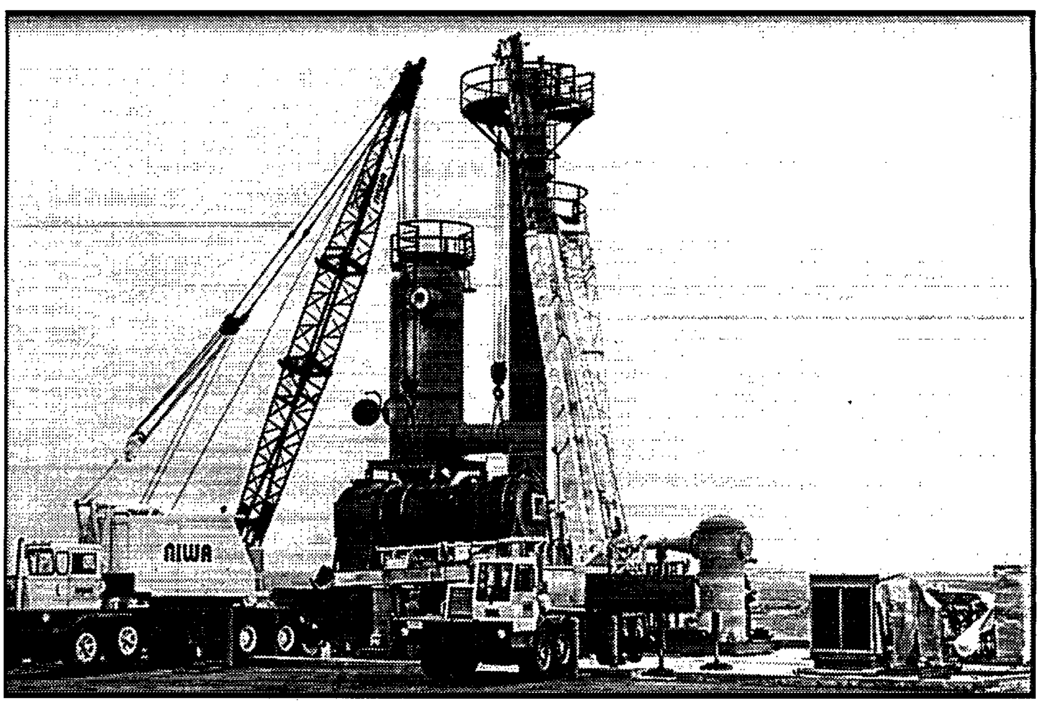
- ❖ An Administration Trailer which contained a small general office, conference room, washroom facilities and an individual office for the CSL Site Superintendent. This trailer also served as the security control point for personnel entering and leaving the contractor's work areas at the Cameron Centre. All visitors and workers were required to sign a log book which enabled a record to be kept of personnel who were on-site at any given time;
- ❖ A Decontamination Trailer where CSL personnel could don, doff and store protective clothing and personal clothing during work shifts. This trailer served as the entry and exit point for workers assigned to operate the incinerator and process waste in the nearby incinerator building;
- ❖ A fully-equipped Laboratory Trailer where samples acquired from various operations, processes and environmental monitoring programs could be screened and analyzed for chemical agent content. Included in the laboratory equipment were two gas chromatographs equipped with either flame ionization or flame photometric detectors. One gas chromatograph was equipped with a Minitube thermal desorption unit so that air samples collected by the AQM trailer using the DRES-developed Minitube Air Sampling System could be analyzed directly. For the duration of incinerator operations, the laboratory was staffed by two analysts from Western Research;
- ❖ A general purpose trailer which served as a workshop, equipment storage and clothes/equipment washing facility.

Figure 6.2



Thermal Destruction Building Foundation

Figure 6.3

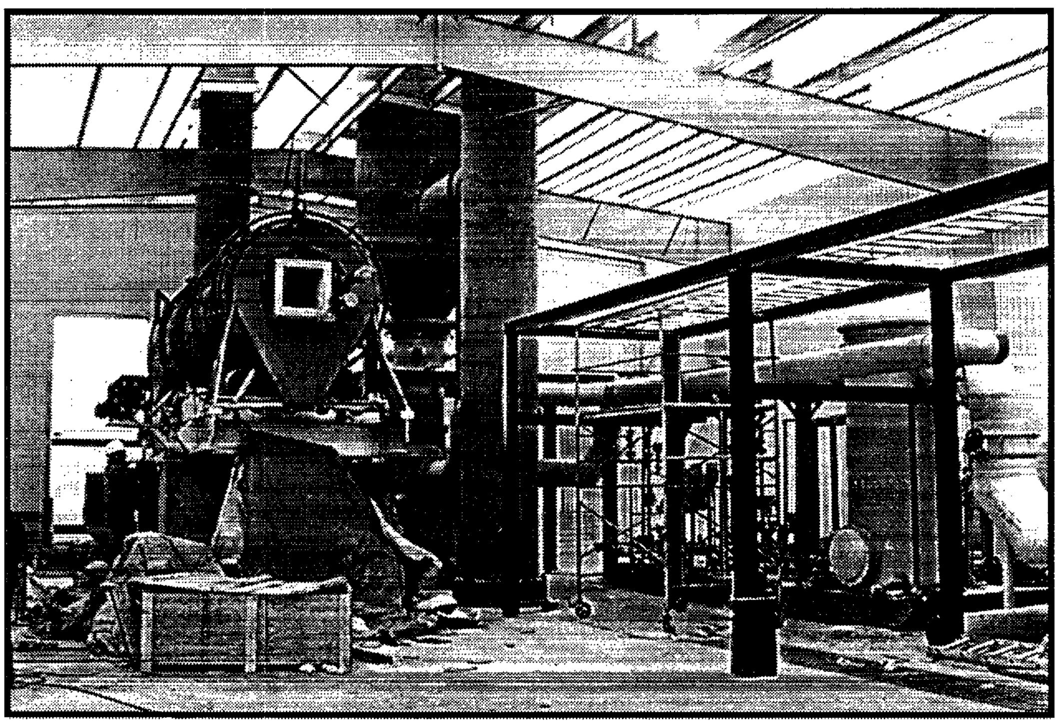


Installation of Rotary Kiln

Figure 6.4

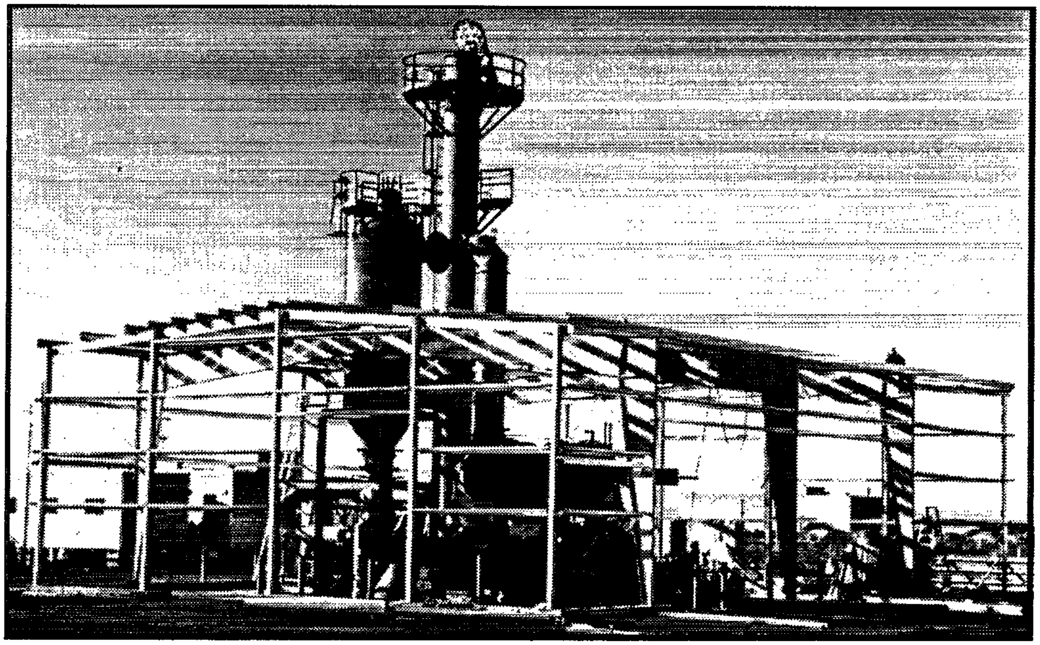
Secondary Combustion Chamber and Scrubber System Installation

Figure 6.5



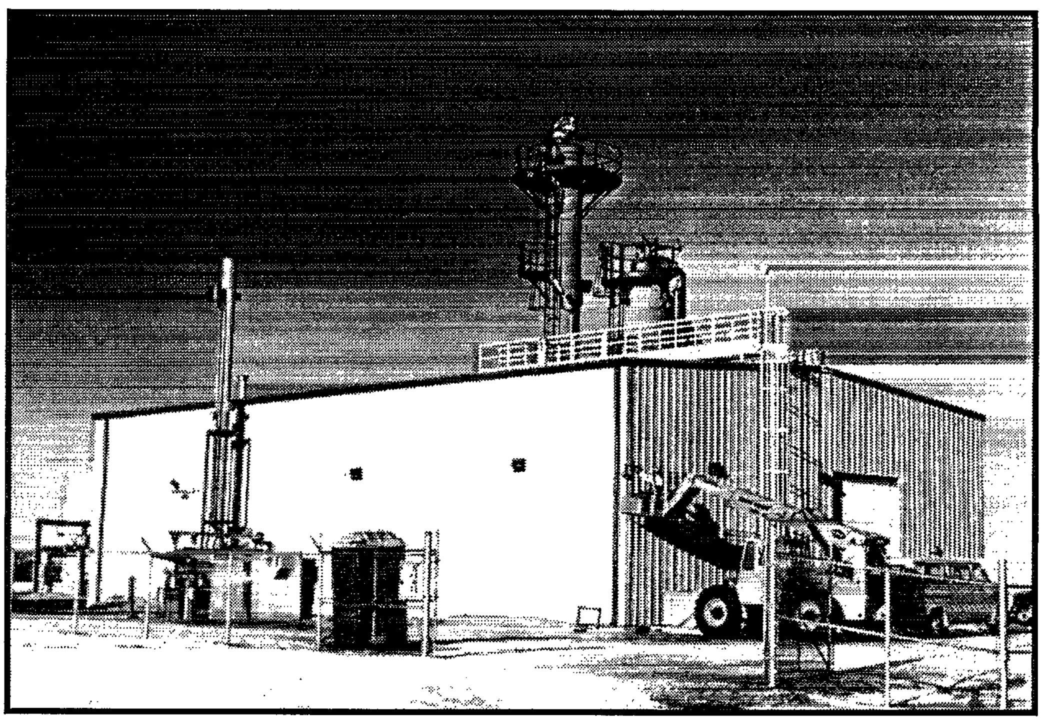
Incinerator Components Mounted Inside The Thermal Destruction Building

Figure 6.6



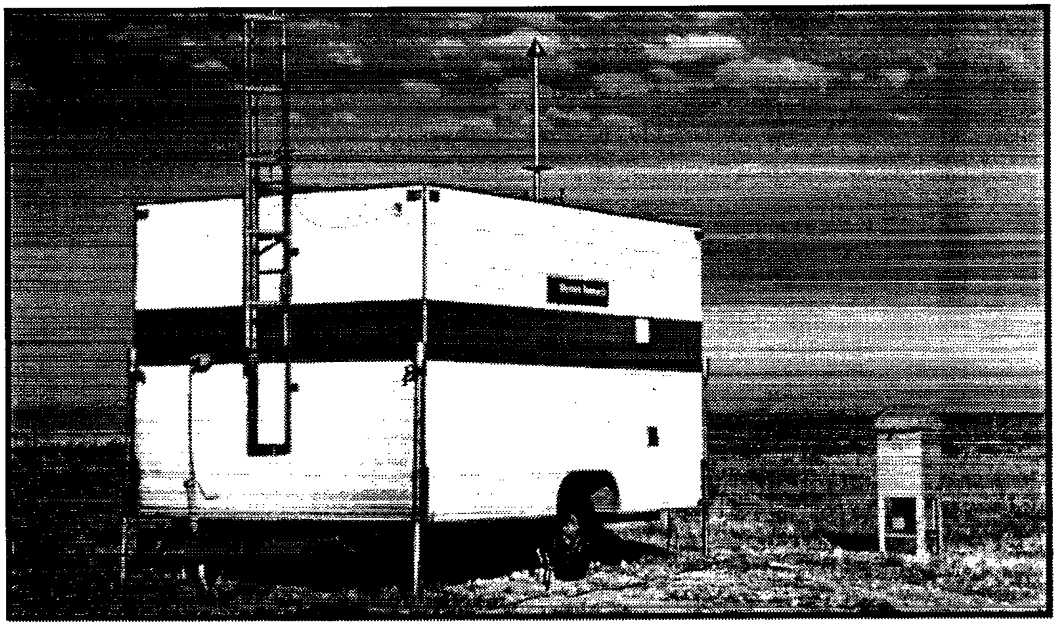
Thermal Destruction Building Construction

Figure 6.7



Cameron Centre Thermal Destruction Building

Figure 6.8



Western Research Air Quality Monitoring Trailer

As shown in Figure 6.1, the four trailers were joined through a common corridor section. The DRES CAM array computer system and display monitor (see Section 6.4) were placed in this area; the monitor was readily visible to all personnel in the trailer complex as they moved from one trailer to another.

A 6-inch water pipeline was constructed by CFB Suffield to supply utility water to the site for emergency fire-fighting purposes. This water supply was also used by CSL for the incinerator scrubber system as the site groundwater well, originally designated for this purpose, did not have sufficient capacity to sustain scrubber operation.

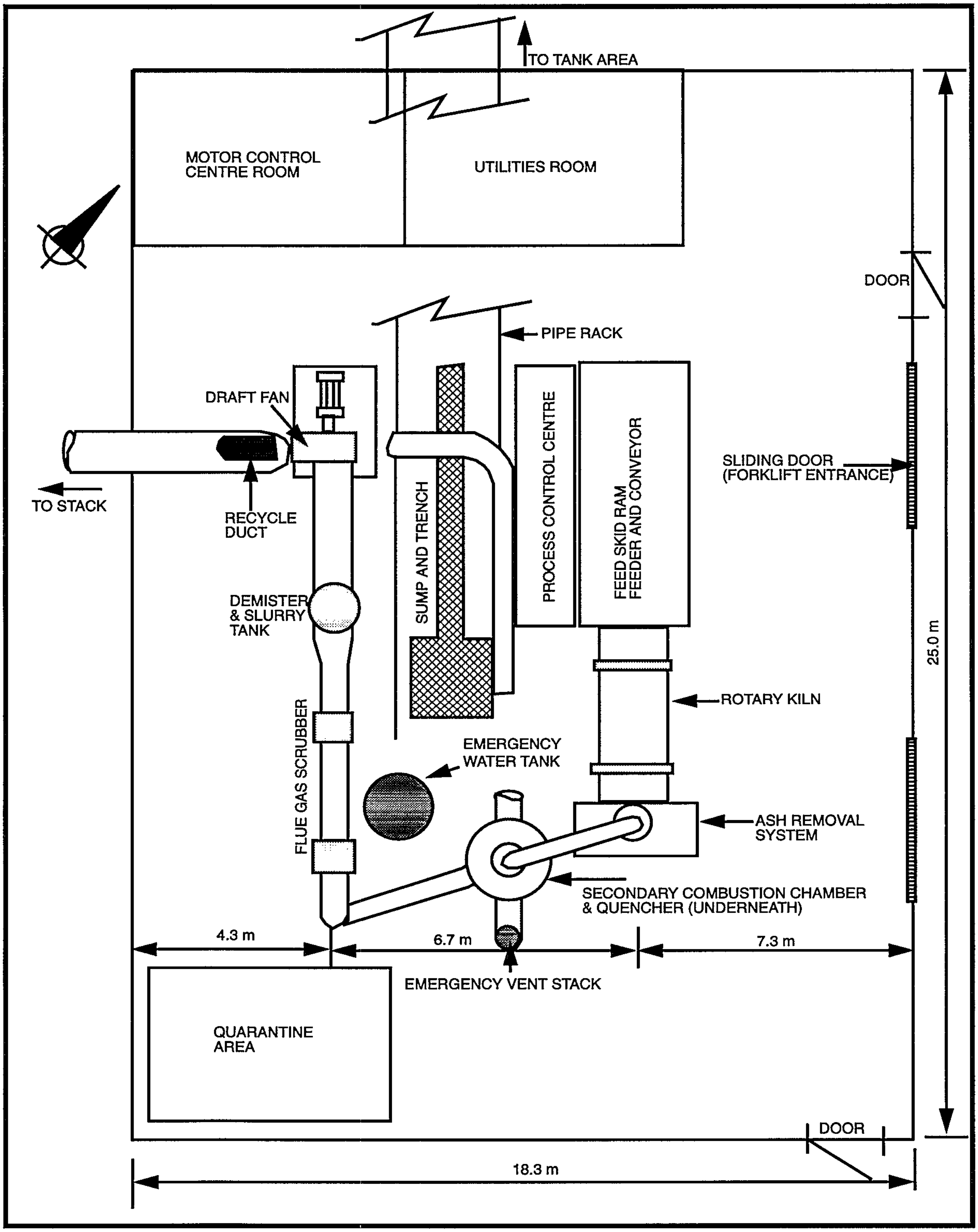
To fulfil a contractual requirement, CSL also installed a security fence around the Cameron Centre lagoon. The Cameron Centre incinerator facilities were completed in December 1990.

6.3 Incinerator Desrcription

Chem-Security Ltd. supplied a transportable, high temperature incinerator system based on a two-stage combustion design, viz: a rotary kiln primary combustion chamber and a down-fired secondary combustion chamber backed by a wet flue gas scrubbing system. Fuel for the incinerator was supplied from a natural gas source located nearby at the Cameron Centre. As shown schematically in Figures 6.9 and 6.10, the major components included the following:

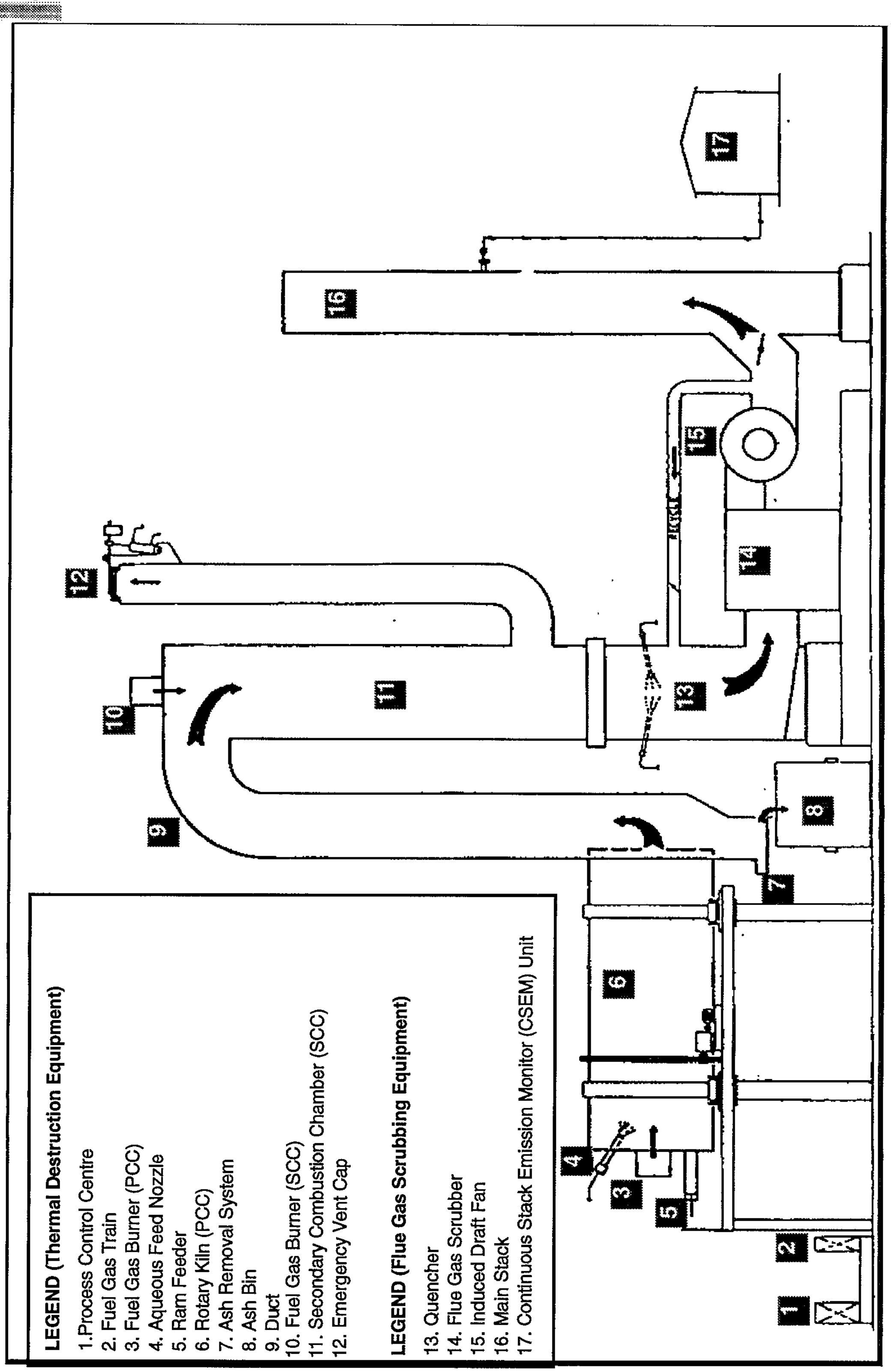
- a skid-mounted rotary kiln (Figure 6.11) with a solid waste processing capacity of 1.5 tonnes/hour, operating temperature range 800°C - 1200°C, and rated heat release capacity ranging up to approximately 1000 kW (3.5 MM BTU/hour). This Primary Combustion Chamber (PCC) was designed to ensure 99.9999% destruction and removal efficiency (DRE) for organic compounds [13]. The unit could be fired using a variety of different fuels such as propane, natural gas and diesel. Waste feedstock could be introduced into the kiln in three distinctly different modes; either as liquid waste only using a liquid burner injection head, as a combined feed of liquids and solid waste or as solid waste only. In this latter case, a special pneumatic ram feeder (Figure 6.12) designed specifically for Project Swiftsure wastes was used, either alone or in combination with the liquid burner head. Solids were contained in incinerable cardboard boxes (size: 18 inches x 18 inches x 72 inches) which could be loaded in single batches into the ram feeder. The kiln was equipped with special "puff proof" seals to prevent outward leakage of combustion products in the event of positive pressure transients during the introduction of waste. Kiln rotational speeds could be varied through hydraulic drive motors to vary solids residence time within the unit (normally 45 - 60 minutes per batch). The kiln was mounted on concrete piles on a downward 1° incline to promote transfer of incinerated solids to a special ash discharge system. This latter system (Figure 6.13) consisted of a discharge chute located in a water bath and a rotating scoop to remove the cooled solid waste into bins.
- A vertical down-fired secondary combustion chamber (SCC) with a rated 2.5 seconds gas residence time, operating temperature range of 1100°C - 1300°C and heat capacity of 1000 kW (3.5 MM BTU/hour).
- An emergency stack and pneumatic vent cap system. Normally, this system remains closed under the negative operating pressure (e.g. -0.5 inches Water Gauge) of the incinerator system.
- A water spray quench unit which rapidly cools hot combustion gases exiting the SCC to approximately 85°C.
- A skid-mounted Hydro-Sonic wet scrubber unit (Figure 6.14) which recirculates sodium hydroxide (caustic) solution through tandem venturi nozzles to remove acid gases and particulate matter prior to discharge of the flue gas to the main stack. Under normal operating conditions, this system consumes source water at 50 L/

Figure 6.9



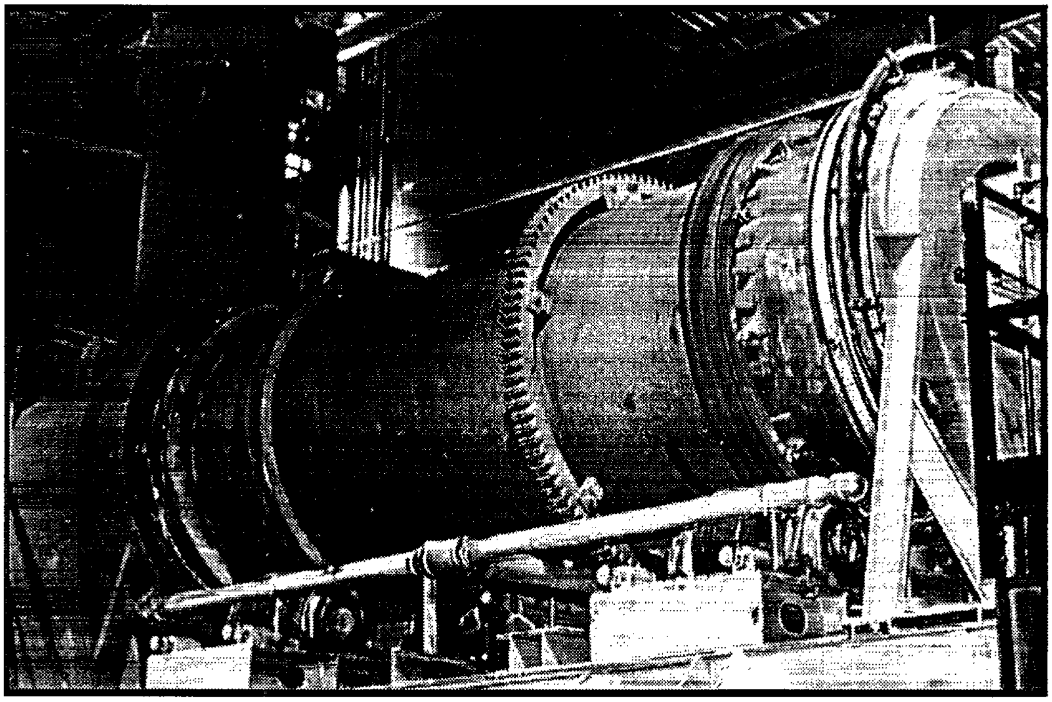
Thermal Destruction Building Equipment Layout

Figure 6.10



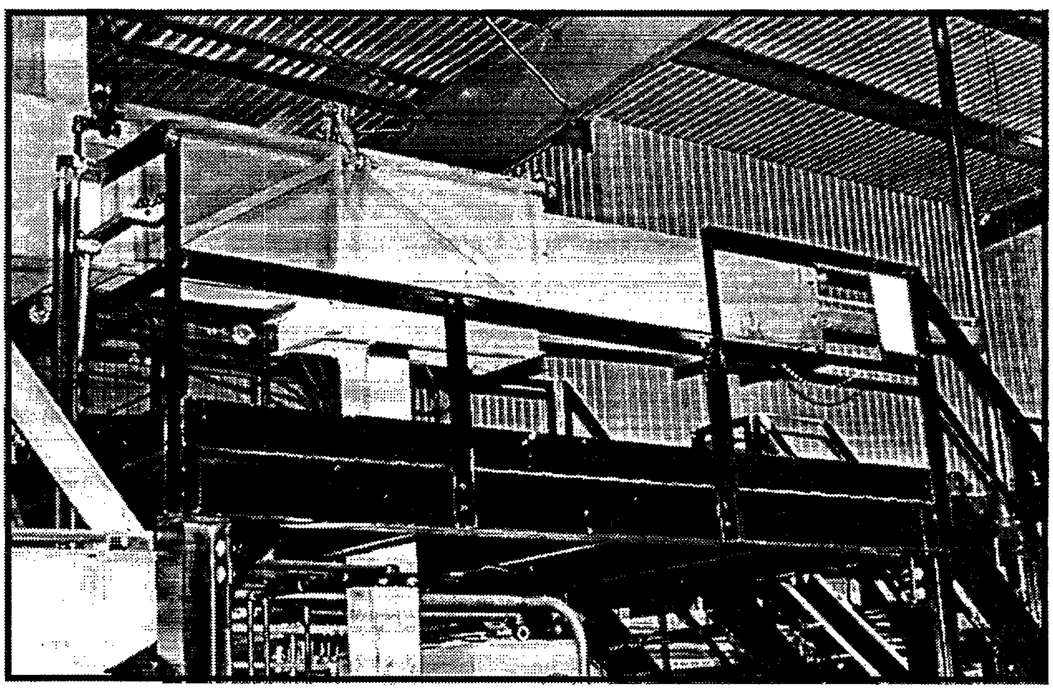
Schematic (Side View) of Incinerator System Components

Figure 6.11



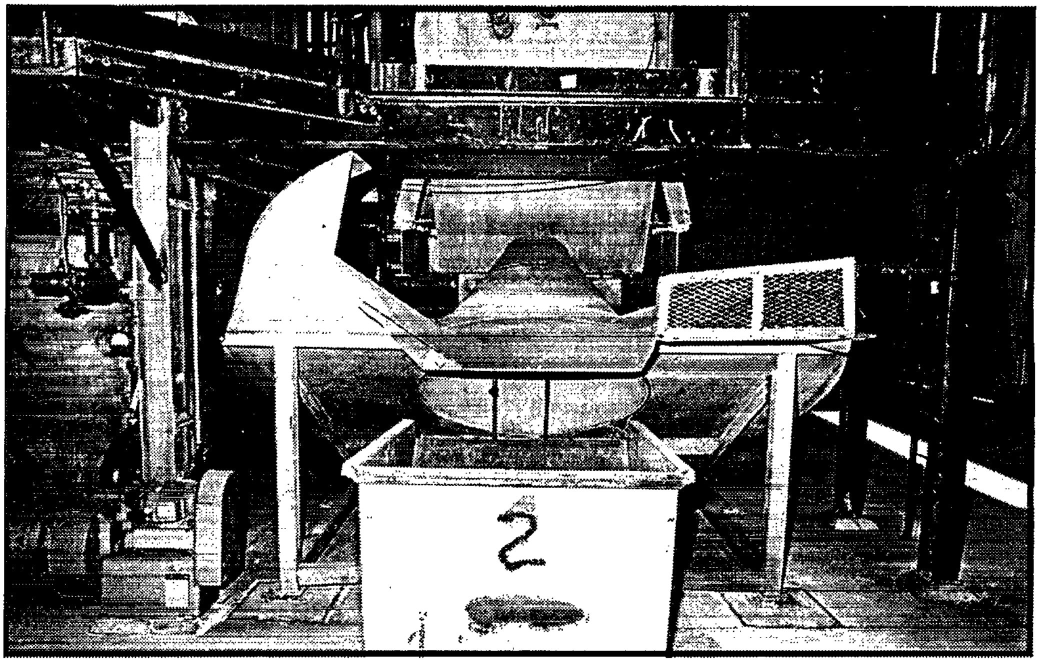
Skid-Mounted Rotary Kiln

Figure 6.12



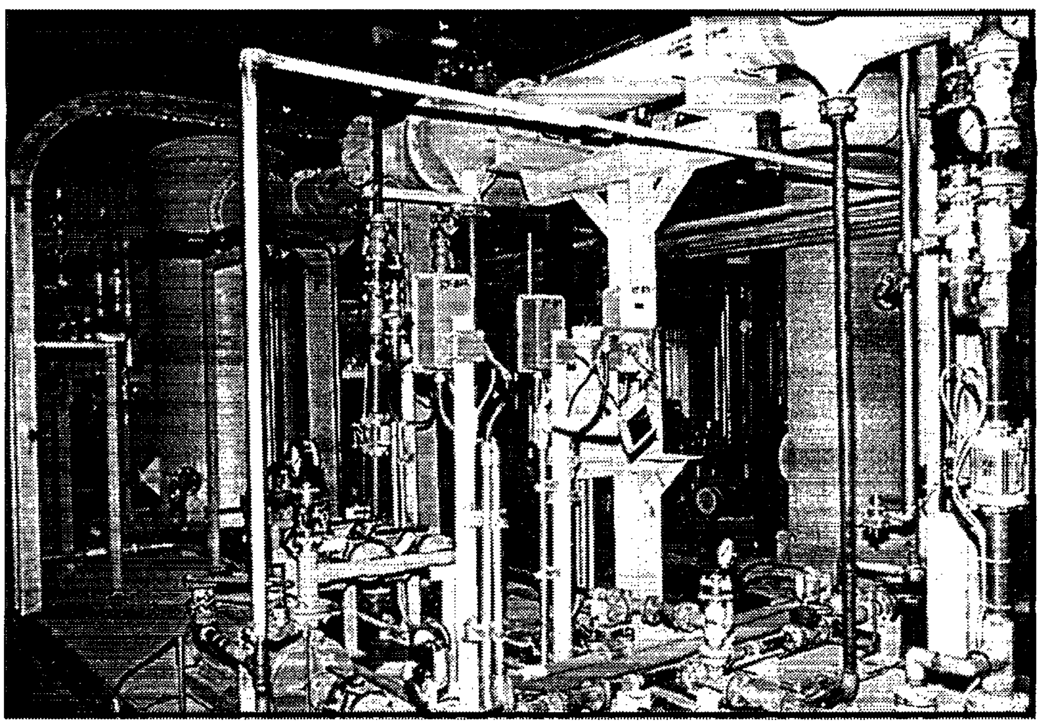
Solid Waste Ram Feeder

Figure 6.13



Incinerator Ash Discharge System

Figure 6.14



Skid-Mounted Wet Scrubbing System

min and discharges recirculated water containing salts (scrubber blowdown) at 35 L/min into holding tanks located in the tank farm adjacent to the incinerator building. After analysis of the holding tank contents, the blowdown is then batch discharged to the Cameron Centre lagoon to allow evaporation of water to the atmosphere.

- An induced draft fan which draws combustion air through the system under negative pressure.
- A main stack equipped with a Continuous Stack Emissions Monitoring (CSEM) unit (see Incinerator Emissions Monitoring Systems, below).
- Process control and utility support equipment including a diesel-fired emergency electric generator, alarm systems, process logic controllers, and data acquisition systems.

A more detailed description of the physical characteristics, and components of the incinerator system are given elsewhere [13,48].

In general, the operation of the incinerator system was highly automated; under normal waste processing conditions, the entire system was run by three contractor personnel, including a supervisor and two system operators, on any given shift. Other personnel were used to load waste feedstock or undertake maintenance work.

6.4 Incinerator Emissions Monitoring Sysrems

The Continuous Stack Emissions Monitoring (CSEM) system provided the primary means to monitor incinerator performance on a real-time basis. The following parameters were monitored continuously:

- mustard chemical agent (HD)
- total hydrocarbons (THC as methane)
- hydrogen chloride (HCl)
- sulphur dioxide (SO_2)
- oxides of nitrogen (NOx)
- carbon monoxide (CO)
- oxygen content (O_2)
- stack gas temperature and velocity.

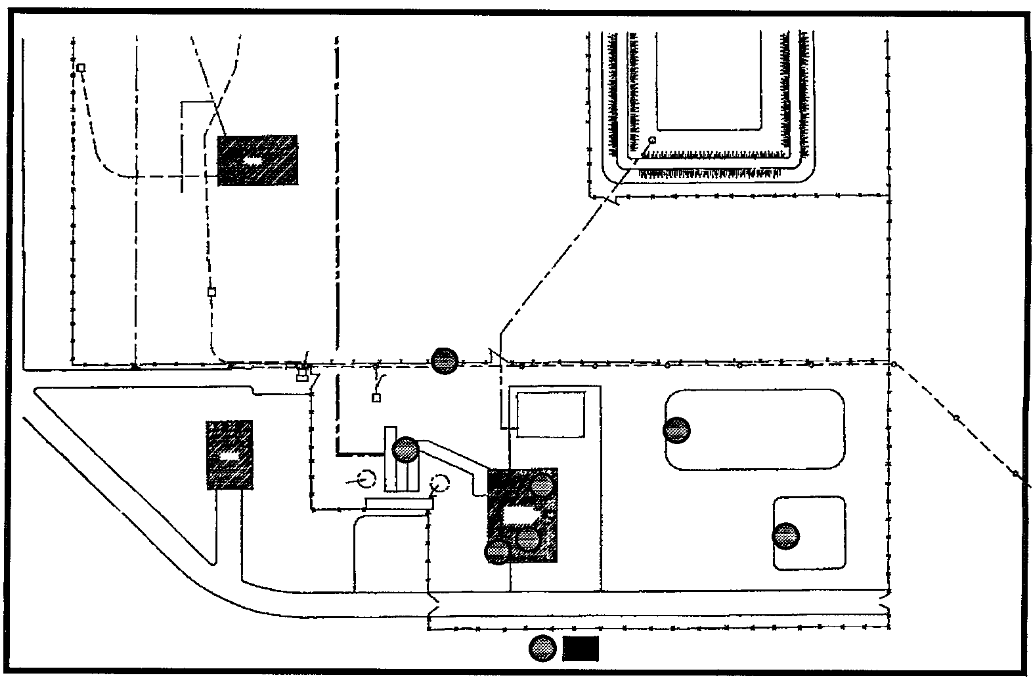
The concentrations of all parameters except for temperature and velocity were measured by individual commercial gas analyzers after withdrawing flue gas through a heated probe and dryer to remove water content. A portable gas chromatograph designed and programmed to detect chemical warfare agents (MINICAMS) was adapted for use as a stack analyzer for mustard. All monitoring data from the analyzers was transmitted to a computer-controlled data acquisition system which also served to trigger warnings and alarms when concentrations approached the permissible limits .

To supplement the CSEM data, Western Research conducted manual stack sampling and analysis during the trial burn program to determine the metal content of collected particulate matter and the levels of chlorinated dioxins/furans produced.

The Western Research Air Quality Monitoring trailer was used to monitor meteorological conditions as well as acquire hourly averaged concentration data for SO_2, nitrogen oxide (NO) and nitrogen dioxide (NO_2). High-volume air sampling for particulates was carried out over a 24-hour period every sixth day.

DRES installed a prototype chemical agent monitoring array at the incinerator facility to assist CSL in monitoring for fugitive mustard agent emissions during storage and processing of mustard waste at the site. This array consisted of 8 Chemical Agent Monitors (CAMs) mounted at fixed positions in and adjacent to the incinerator building and linked by cable to a computer-based display system located in the site Administration Trailer. Figure 6.15 shows schematically the locations of the CAM array sensors. The display system showed the current status of the monitors and was capable of initiating an alarm if mustard was detected at any one of the positions. The CAMs were capable of instantaneously detecting mustard vapour concentrations at levels considered safe for unprotected personnel over periods of hours (detection limit < 0.01 mg/m^3). A second display was installed in a nearby building (Building 60) which was monitored by DRES staff who were available to provide decontamination and emergency response capabilities in support Project Swiftsure operations. During incineration of chemical agent waste, the CAM array was tested and calibrated regularly using methyl salicylate, a mustard agent simulant.

Figure 6.15



Swiftsure CAM Array Schematic (Cameron Centre)

6 .5 Predicted Operating Performance

Various project-specific requirements with respect to incineration operations were developed by DRES in consultation with Environment Canada and Alberta Environment. Following contract award and during development of the Project Swiftsure EPP, Chem-Security Ltd. incorporated certain design features into the incinerator equipment to meet these requirements. For example:

- ❖ The incinerator and flue gas scrubbing system were designed and operated to meet the maximum stack emission concentration limits specified in Table 2.3.
- ❖ Stack emissions were not to exceed the maximum ground-level concentration values specified in Table 2.4.
- ❖ Wastewater discharged from the scrubber system to the on-site lagoon was not to contain metal concentrations in excess of those specified in Table 2.5.
- ❖ Wastewater, metals and ashes resulting from the incineration process were not to contain any detectable mustard or related organic byproducts.

The incinerator stack was designed to maintain acceptable air quality even under adverse meteorological conditions. For example, a stack height of 12.2 m and diameter of 0.46 m produced a flue gas exit speed of 13.4 m/second under normal operating conditions. This ensured that the 95th percentile wind speed of 10 m/second at this height was less than the exit speed. Moreover, air quality impacts from incinerator emissions based on this design were predicted using the US Environmental Protection Agency's Industrial Source Complex plume dispersion model. The prediction data [13], summarized in Table 6.1, showed that maximum ground level concentrations from emissions were well below allowable limits and occurred close to the incinerator site. This is also shown in Figures 6.16 and 6.17 which illustrate predicted maximum 72-hour average ground-level mustard and one-hour average sulphur dioxide concentrations, respectively. The maximum one-hour average ground-level concentrations in district communities were also calculated. As shown in Table 6.2, predicted maximum concentrations in various locations were very small compared to permissible levels.

6 .6 Incinerator Safeguards

A number of safeguards were built into the incinerator equipment to ensure proper operation and means to safely shut down the system in the event of an emergency. Automatic control of the system was provided through the Process Control System (PCS) which operated the incinerator and wet scrubber systems by means of a programmable logic controller that received signals from various sensors, analyzers and monitors. Manual override of the PCS was possible based on visual observation of signals and data from a control panel which displayed equipment status. The PCS controlled the rotary kiln and secondary combustion chamber operating temperatures, various safety alarms

Table 6.1

PREDICTED MAXIMUM GROUND-LEVEL CONCENTRATIONS FOR MAXIMUM STACK EMISSIONS COMPARED TO PROJECT AIR QUALITY LIMITS

Downwind Distance = 100m

MATERIAL	AVERAGING TIME (h)	DIRECTION	PREDICTED MAX. CONCENTRATION (ppb)[1]	AIR QUALITY LIMIT (ppb)
Sulphur Dioxide	1	E	54	170
	24	W	12	60
Nitrogen Dioxide	1	E	91	210
	24	W	20	110
Hydrogen Chloride	1	E	29	66
Carbon Monoxide	1	E	28	13000
	8	E	10	5200
Particulates	24	W	2.4 $\mu g/m^3$	100$\mu g/m^3$
Mustard	8	E	0.00097	0.45
	72	W	0.00044	0.015
Arsenic	24	W	0.12	-
Copper	24	W	0.61	-
Lead	24	W	0.61	-

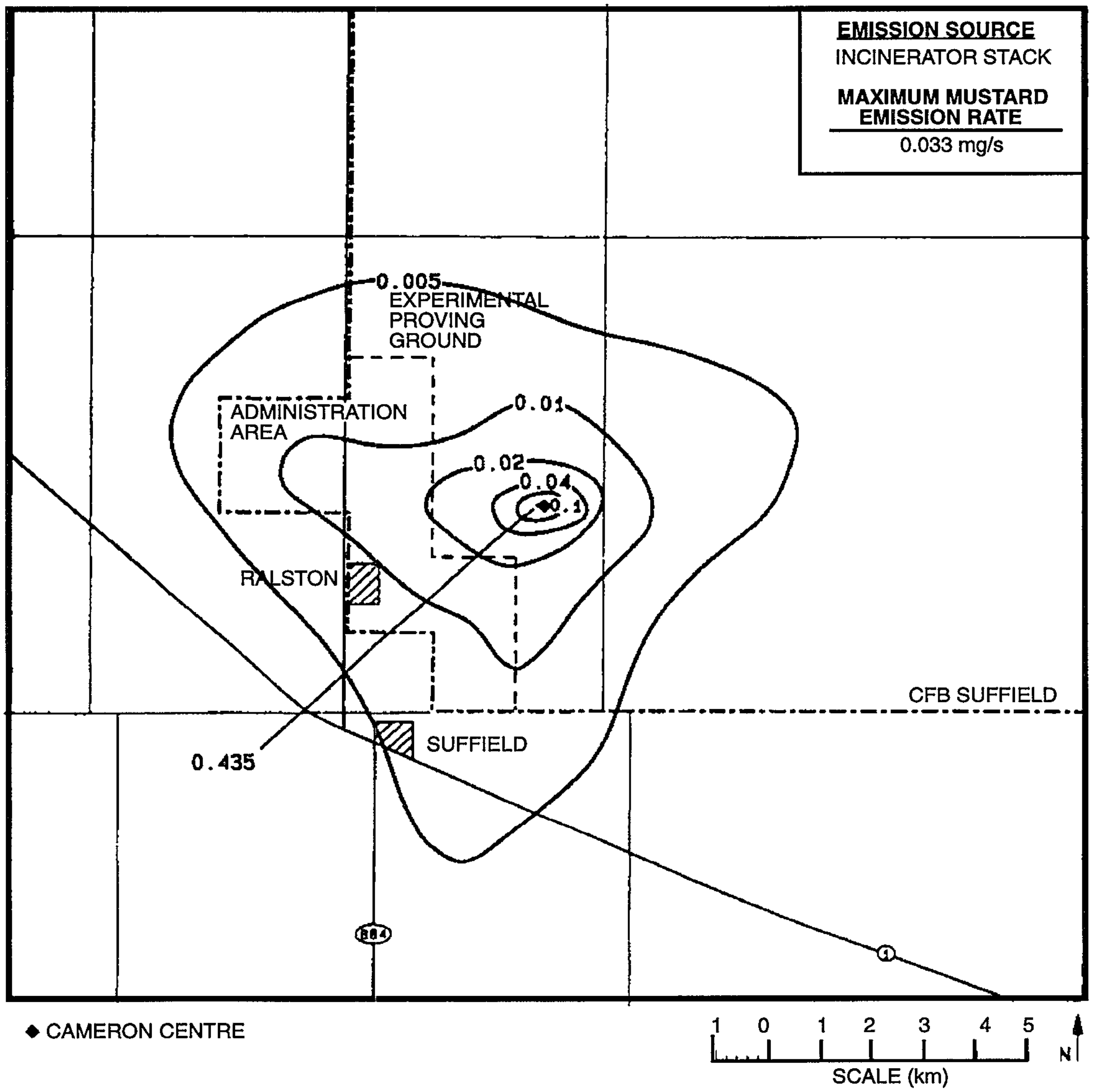
1. ppb= parts per billion

and shut-down controls, fuel gas and combustion air supplies, and various analyzers and instruments associated with the CSEM system. Some of the safety and emergency control actions which could be undertaken automatically and/or manually were as follows:

6.6.1 Primary Safety Actions

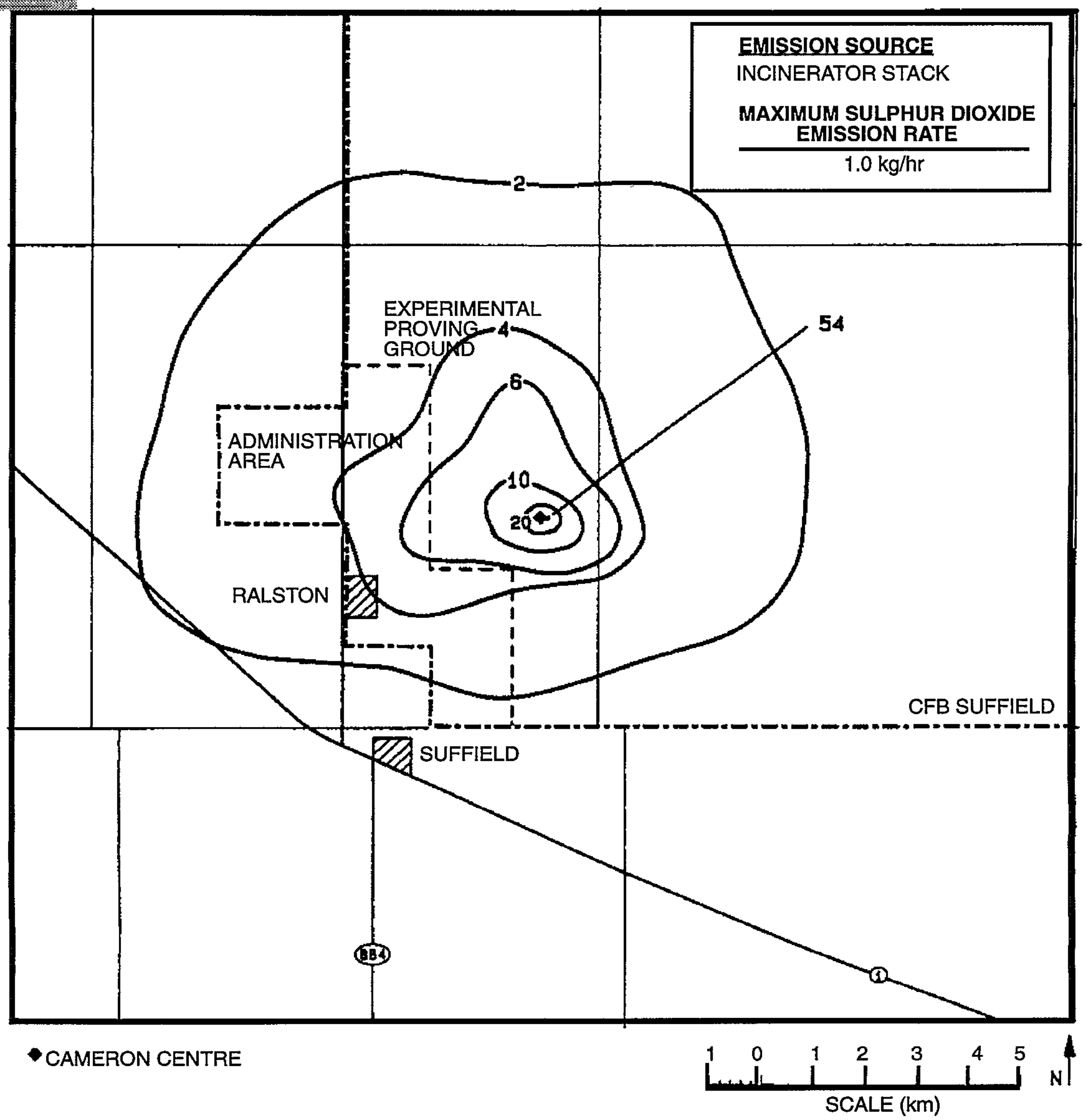
- shut-down of the rotary kiln and ram feeder results if low combustion air pressure, flame failure, excess temperature and/or positive pressure in the rotary kiln is detected;
- simultaneous shut-down of the rotary kiln and SCC occurs if the SCC experiences low combustion air pressure, flame failure, excess temperature, low temperature or if excess temperature exists at the exit to the quench system;
- warnings are provided if certain equipment begins to exhibit "out-of-limit" process conditions. With the rotary kiln, for example, warning is given for low or high fuel gas pressure, low rotation speed or temperature excursions which

Figure 6.16



Predicted Maximum 72-Hour Average Ground Level Mustard Concentrations (ppt) For Maximum-Allowable Incinerator Emissions

Figure 6.17



Predicted Maximum One-Hour Average Ground-Level Sulphur Dioxide Concentrations (ppm) For Maximum-Allowable Incinerator Emissions approach pre-set limits. Low temperatures in the rotary kiln and/or SCC will prevent the waste feed system from operating.

Table 6.2

PREDICTED MAXIMUM ONE-HOUR AVERAGE GROUND-LEVEL CONTAMINANT CONCENTRATIONS IN SELECTED COMMUNITIES FOR MAXIMUM ALLOWABLE STACK EMISSIONS

Locale	Mustard (ppt)[1]	CO (ppb)[2]	NO_2 (ppb)	SO_2 (ppb)	HCl (ppb)	Particulates (μg/m^3)
Ralston	0.19	2.0	6.3	3.8	2.0	0.75
Suffield	0.030	0.32	1.0	0.61	0.32	0.12
Brooks	0.007	0.074	0.24	0.14	0.075	0.028
Buffalo	0.006	0.060	0.19	0.12	0.061	0.023
Jenner	0.004	0.040	0.13	0.078	0.041	0.015
Medicine Hat	0.003	0.034	0.11	0.065	0.034	0.013
Empress	0.002	0.024	0.077	0.046	0.024	0.013
Air Quality Limit	15[3]	13000	210	170	66	100[4]
Ralston/Limit Comparison Ratio (%)[5]	1.3	0.015	3.0	2.2	3.0	0.75

1 ppt = parts per trillion

2 ppb = parts per billion

3 Specified 72-hour average concentration limit for protection of the general population.

4 24-hour average

5 Ratio of maximum predicted concentration at Ralston to maximum allowable level (air quality limit) expressed as a percentage value.

6.6.2 Emergency Actions

An automated or manual emergency shut down of the incinerator system takes place for the emergency conditions listed below. In general, where the operators could possibly prevent a complete shut down, pre-alarms were provided to give sufficient time to take corrective action.

- combustion temperatures too high. A shut-down occurs when the combustion temperature reaches a high temperature limit after operating conditions have been established.
- sudden loss of refractory lining integrity.
- failure of the ash discharge system.
- high carbon monoxide readings from the CSEM system.
- loss of water to the quench system.
- power failure.
- loss of instrument air or induction fan failure.

6 .7 Contractor Site Management

The CSL organization chart for project operations at DRES is shown in Figure 6.18. In general, the CSL Site Superintendent was responsible for the day-to-day activities conducted at the Cameron Centre site and at the field storage sites. This individual was the primary contact between CSL and the DRES project team during the operational phase of Project Swiftsure. The CSL/Western Research Project Manager, who resided in Calgary, assumed overall responsibility for the project from the company's perspective and provided direction to the Site Superintendent with respect to resource allocation, contractual matters and scheduling. A Project Process Engineer was also available to provide advice on technical matters and undertake troubleshooting activities on site as the need arose.

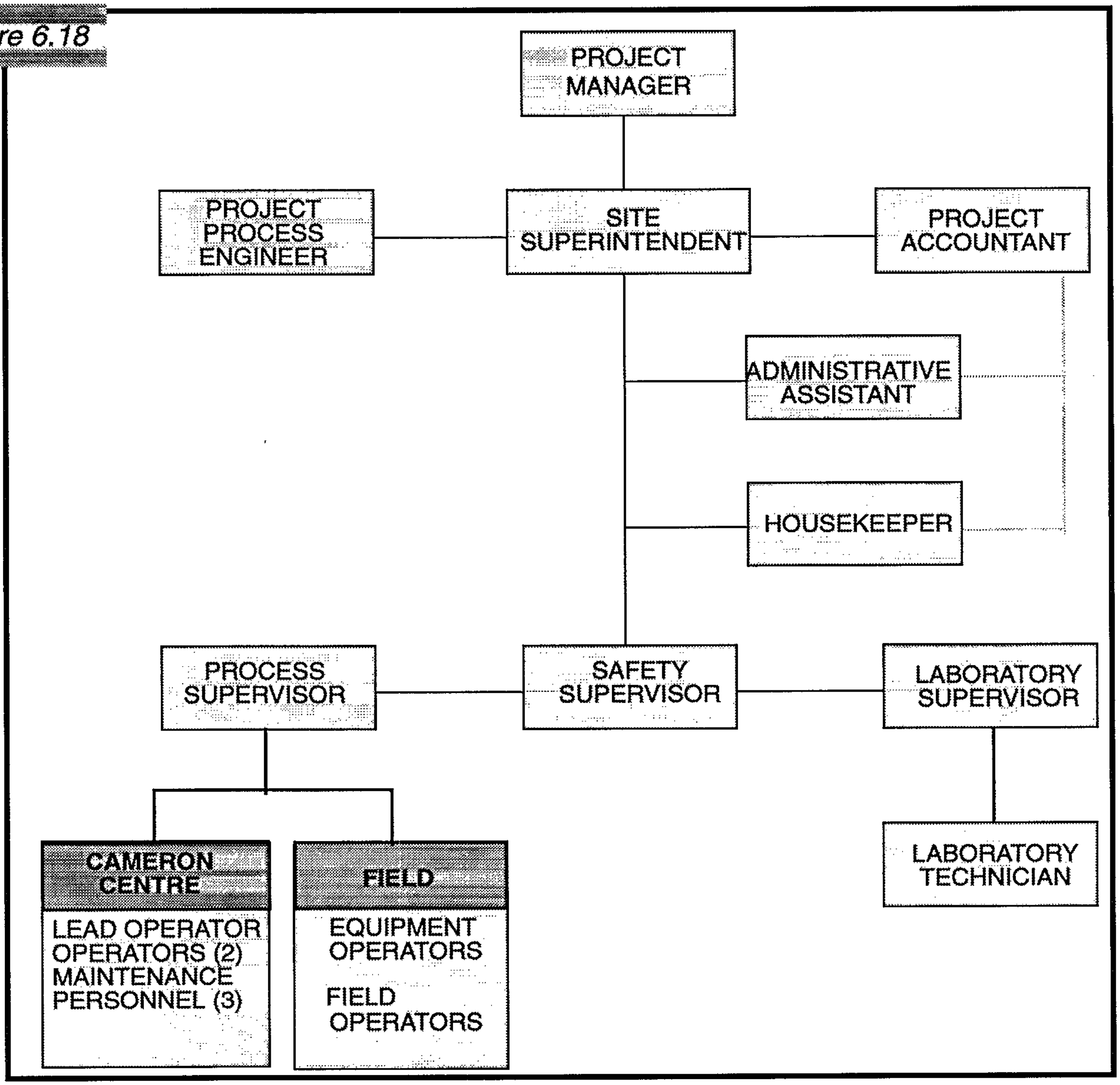
6 .8 Incinerator Commissioning

Starting in December 1990, various incinerator equipment subsystems were subjected to performance checks prior to lighting the pilot burners in the rotary kiln and secondary combustion chamber. These subsystems included the instrument/utility air supply, emergency shower/eyewash station, emergency generator, uninterruptible power supply, scrubber caustic feed and utility water and fuel gas supply units. Other pre-commissioning checks were carried out on the rotary kiln and the solid waste feed, ash discharge and scrubber systems. The main burners were then run on natural gas for extended periods in order to remove moisture from interior components and to cure the refractory lining of the rotary kiln and secondary combustion chamber to 1200^{o}C. During this stage, which took place during January and February 1991, both the solids waste feeder and liquid burner heads were tested for mechanical and electrical operability. Non-hazardous solid scrap waste was incinerated to check the complete operating performance of the incinerator system. Following this, 27.4 tonnes of miscellaneous shredded scrap inventory from the 490 Site was processed during the month of February.

The on-site laboratory became operational and the scrubber water (blowdown) analysis program using a commercial laboratory commenced during these waste processing operations. At the same time, the procedures were refined for transferring packaged waste from the field storage sites to the Cameron Centre and from the Contaminated Materials Laydown Area into the incinerator solids feed system.

The sulphur hexafluoride (SF_6) injector system which was employed during the incinerator Trial Burn program (see Section 6.9) was subjected to a number of commissioning tests during February. With the liquid burner head installed and using diesel fuel as a simulant for liquid waste, SF_6 was metered in with the diesel fuel and burned while the operation of the Continuous Stack Emissions Monitoring (CSEM) system was monitored.

Figure 6.18



Chem-Security Ltd. Organization Chart For On-Site Operations

6.9 Incinerator Trial Burns

Trial burns were conducted on the Project Swiftsure incinerator prior to the start of routine burning of agent-related waste inventory. These tests were designed to demonstrate that the incinerator could achieve its design objectives and meet project-specific emission standards during normal operation. Prior to starting the tests, a protocol document [42] was prepared by Western Research in November 1990 and submitted for review by Environment Canada, Alberta Environment and National Defence. The reviewing agencies accepted [43] this document on 20 February 1991.

During March 1991, two separate Trial Burns were conducted. The first (Trial Burn 1) demonstrated that the incinerator could achieve target values for destruction and removal efficiencies and for acid gas (SO_2) removal by processing a difficult-to-burn surrogate chemical, sulphur hexafluoride (SF_6). This Trial Burn was also used to optimize operating conditions for the incinerator for use during Trial Burn 2 and during subsequent operations. Trial Burn 2 demonstrated that all project-specific emission criteria could be met while burning mustard chemical agent at design capacity.

The proposed operating conditions for Trial Burn 1 and for Trial Burn 2 are given in Table 6.3.

6.9.1 Trial Burn 1

This Trial Burn, which was conducted over the period 5-6 March 1991, involved three separate tests, each repeated several times. The incinerator was operated under different conditions while injecting diesel fuel, a substitute for liquid waste, through the liquid burner head into the rotary kiln. Simultaneously, SF_6 and SO_2 were metered into the diesel supply from pressurized bottles. The SF_6 injection rate was based on a target DRE of 99.9999% and the ability to analyze for SF_6 in the stack gas at ten times greater than the detection limit of the monitoring equipment. In the case of SO_2, the injection rate was predetermined on a target removal efficiency of 95% and detecting residual SO_2 concentrations in the stack gas at about half the permissible concentration limit using the CSEM system. A full description of the test set-up is given elsewhere [42].

Sulphur hexafluoride stack concentrations and stack gas flow rates were recorded approximately every 10 minutes with a total of 7-8 instantaneous SF_6 emission rates calculated for each test period. The average of the measured concentrations was then used to calculate the average emission rate and the DRE for each test. Standard source testing methods [42, and references therein] were used to determine the average stack gas SO_2 concentration and average stack gas volume flow rate over a period of one hour.

Sulphur hexafluoride had previously been used as a suitable surrogate to prove the capabilities of the hazardous waste incinerator facility at the Alberta Special Waste Treatment Centre, Swan Hills [44]. This compound is also a suitable surrogate for mustard in that it is thermally more stable than the chemical agent. As shown in Table 6.4, the temperature range required to provide 99% destruction of SF_6 during two seconds ($T_{99}^{(2)}$) ranks higher than the temperature range for mustard [42,45]. This implies that achieving a high DRE value for SF_6 at temperatures well above that required for mustard thermal destruction will result in an even higher DRE for mustard itself.

Table 6.3

SUMMARY OF PROPOSED INCINERATOR OPERATING CONDITIONS DURING TRIAL BURNS

PARAMETER	VALUE	UNITS
SF_6 injection rate	0.25	kg/hour
SO_2 injection rate	9	kg/hour
Diesel feed rate	80	L/hour
Mustard feed rate	49.5	kg/hour
Rotary Kiln (PCC) temperature	750 - 900	^{o}C
SCC temperature	1200	^{o}C
SCC flue gas residence time	2.5	seconds
Flue gas O_2 content (SCC exit)	5.4	dry vol%
Scrubber effluent pH	9	-
Caustic[1] addition rate (scrubber)	11 to 48	kg/hour
Flue gas exhaust rate (stack)[2]	2487	dry m^3/hour

1 Caustic as 50% (wt/wt) sodium hydroxide (NaOH).
2 Corrected to 25°C and 101.325 kPa.

Table 6.4

THEORETICAL THERMAL STABILITY CLASSES

COMPOUND	THERMAL STABILITY CLASS[1]	$T_{99}^{(2)}$[2] RANGE (^{o}C)
Sulphur Hexafluoride	1	900 - 1590
Mustard	4	604 - 695

1 Class 1 is thermally very stable while Class 9 is the least stable with a $T_{99}^{(2)}$ of 100°C to 320°C[45].

2 $T_{99}^{(2)}$ is the temperature required for 99% destruction of the compound at a gas phase residence time of two seconds.

6.9.2 Trial Burn 2

The second Trial Burn was conducted during 21-25 March 1991 and consisted of four separate tests in which bulk mustard chemical agent was burned under the optimized conditions established during Trial Burn 1. The mustard was obtained from each of four one-ton containers, which were relocated to the 14A Site from the Hickey Storage Site, and from mustard-contaminated shell casings located at the 14A Site. The mustard was packaged in polyethylene-lined cardboard boxes (see Section 7.2.4) and introduced into the incinerator in batches via the solids waste feed system.

A 4" x 8" metal test coupon contaminated with mustard was inserted into 10 mustard-containing boxes to determine the performance of the incinerator with respect to thermal decontamination of metal scrap. The test coupons were obtained from Flying Cow projectiles at the 14A Site. Ten duplicate coupons were analyzed in the CSL on-site laboratory to determine the level of mustard contamination present. The incinerated coupons were also analyzed for mustard residue to determine the effectiveness of the thermal decontamination process.

A typical test employed the following procedure:

- ❖ A mustard batch (16.5 kg), equivalent to one-third of the hourly design rate (49.5 kg mustard/hour), was burned for approximately 20 minutes in the rotary kiln under optimized conditions to verify that the thermal destruction of mustard was adequate for this residence time;
- ❖ CSEM system readings were taken during this period to verify that stack mustard concentrations did not exceed the permissible limit of 0.03 mg/m^3. In addition, no readings above the detection limit of the CSEM mustard analyzer signalled that complete destruction of the mustard batch had occurred by the end of the 20-minute period;
- ❖ The rotary kiln was then fed with three batches (up to a total of 49.5 kg mustard) at hourly intervals to test the incinerator system at design capacity for mustard. In this case, stack monitoring (CSEM) and stack sampling surveys (see below) commenced immediately upon introduction of the batches and continued over a four hour period. The stack sampling program was temporarily halted for approximately 15 minutes during each subsequent batch feed operation to accomodate the temporary reduction in fuel and air flow rates during ram feeder operation.

The maximum mustard feed rate of 49.5 kg/hour was dictated by the SO_2 emission limit when assuming a target SO_2 removal efficiency of 95% and to ensure compliance with the stack emission concentration limits set for mustard, HCl and SO_2.

In accordance with standard stack survey test methods [42], the following stack gas parameters were measured during tests run at the maximum feed rate:

- ❖ air volume flow rate and temperature;
- ❖ average particulate and trace metal concentrations;

- average residual mustard concentration;
- average HCl concentration;
- average SO_2 concentration;
- average NOx concentration, and
- average concentrations of chlorinated dioxins and furans, total expressed as 2,3,7,8-tetrachloro-p-dibenzodioxin (T4CDD) equivalent.

Triplicate manual stack sampling surveys were conducted during Trial Burn 2. In addition, the CSEM system was used to measure and record stack concentrations for HCl, SO_2, NOx (as NO_2), CO, total hydrocarbons (as methane), oxygen and mustard, as well as stack air flow rate and temperature. Dry emission concentrations of each compound at standard reference conditions (25 ^oC, 101.325 kPa and 11 vol% O_2) were calculated for each test.

In addition to the stack monitoring program, several other processes were sampled and analyzed during the tests including the waste feed to the incinerator, the scrubber make-up water and effluent (blowdown), ash, and fuel supply. The waste feed was tested for heating value, chloride, sulphide and metal content. The diesel fuel used during Trial Burn 1 was analyzed for heating value and composition. The volumes of water used for scrubber make-up and produced as blowdown were measured and the metal contributions to the blowdown from the make-up water were determined. Ash produced during the incineration process was analyzed for a variety of different metals in accordance with standard methods [42] and subjected to a metals leachate test [46].

6 .10 Trial Burn Results

The trial burn results, as well as results from supplementary tests conducted after the formal trial burn program, were documented in several reports [47-52] which were submitted to National Defence, Environment Canada and Alberta Environment for review and acceptance. The documents were also reviewed by the citizens' advisory committee and their technical consultant.

6.10.1 Trial Burn 1

On 5 March 1991, SF_6 and SO_2 tests were initiated with two tests involving sulphur dioxide completed on this date. The sulphur hexafluoride tests were halted due to a leak from the SF_6 injection system which caused contamination of the air inside the incinerator building. Three complete sets of tests involving injection of SF_6 and SO_2 were completed on 6 March. During the Trial Burn, CSL made several changes to the proposed operating conditions as described in the Trial Burn Protocol (see Table 6.4) in order to facilitate accurate data collection. Some important variations from the approved protocol were as follows [47]:

- During preliminary testing, it was found that the proposed 0.25 kg/hour mass flow rate for SF_6 did not produce any detectable amounts of SF_6 in the stack exhaust gas. Residual sulphur hexafluoride became detectable only when the mass flow rate was increased to 0.78 kg/hour, i.e. 300% of the design rating. This latter result confirmed the exceptional performance of the incinerator system with respect to the thermal destruction of SF_6.

- The diesel feed rate of 80 L/hour was reduced by approximately 50% to relieve problems associated with flame pattern and flame propagation at the higher feed rate. The diesel fuel feed rates for the three Trial Burn 1 tests 1,2 and 3 were 32.7 L/hour, 37.7 L/hour and 34.9 L/hour, respectively. The feed rate for SO_2 which was injected into the diesel fuel was also reduced but in a variable fashion; test 1 provided 72% (6.5 kg/hour) of the proposed rate while tests 2 and 3 rates were 55% (4.95 kg/hour) and 91% (8.2 kg/hour), respectively.
- The rotary kiln was operated in the temperature range 980-990°C, a slightly higher range than specified in the protocol document. Previous SF_6 destruction and removal tests had indicated that operating the kiln between 900 - 990°C would enable SF_6 DRE to exceed 99.9999+% provided the temperature of the secondary combustion chamber was maintained above 1200°C.
- A 20% (wt/wt) aqueous NaOH solution was chosen as the caustic buffer for the scrubber system water rather than a 50% (wt/wt) solution. Injecting the more concentrated caustic solution into the scrubbing system yielded false control information due to the instantaneous increase in the scrubber water pH.

Table 6.5 summarizes the results from the three separate tests involving SF_6 thermal destruction. The results of the SO_2 acid gas removal tests are summarized in Table 6.6. Aside from the initial problems encountered with SF_6 leaks from the injection system, Trial Burn 1 was completed successfully and yielded an average DRE of 99.9999972% while injecting SF_6 directly into the liquid fuel stream and thereby subjecting the surrogate to the primary flame zone in the incinerator. Preliminary testing carried out in February 1991 [48] demonstrated an average DRE of 99.9999888% while injecting SF_6 into the waste combustion air stream (thus bypassing the primary flame zone) while processing non-hazardous solid waste. These tests demonstrated that, under the given operating conditions, the incinerator was capable of achieving DREs in excess of "six nines" while processing either liquid waste in a continuous mode or solid waste in a batch mode [47].

The correct functioning of the scrubber system was also demonstrated with acid gas (SO_2) removal efficiencies exceeding 97% during each test.

The Trial Burn One report [47] was submitted to DND and forwarded to Environment Canada for review on 20 March 1991.

6.10.2 Trial Burn 2

Chem-Security Ltd. completed four separate tests involving the incineration of mustard during the period 20 - 25 March 1991. Some variances from the trial burn protocol which occurred during these tests were as follows:

- The mustard feed rate was reduced from 49.5 kg/hour to 33 kg/hour to ensure carbon monoxide emission levels did not exceed the project limit of 57 mg/m^3. All other emissions remained well below project limits even at the design feed rate of 49.5 kg/hour.

Table 6.5

TRIAL BURN 1 RESULTS SUMMARY
SF_6 DESTRUCTION AND REMOVAL EFFICIENCIES

	TEST 1	TEST 2	TEST 3
DATE:	5 Mar 91	6 Mar 91	6 Mar 91
Repeat Injections	8	7	8
Stack SF_6 Concentration Range (ppt)[1]	0	0 - 6.0	0 - 1.7
Average Stack Air Flow (wet) (m^3/hour)	4535.8±290.3	4430.1± 201.6	4544.3±54.3
Average Stack Gas Water Content (%)	57.04	57.14	61.31
Calculated Average Stack Air Flow (dry) (m^3/hour)	1949±124	1899±86	1758±23
DRE[2,3] Range per test (%)	99.9999965 - 99.9999971	99.9999903 - 99.9999984	99.9999975 - 99.9999986
Average DRE per test (%)	99.9999967	99.9999966	99.9999983

AVERAGE DRE (%) 99.9999972

1 parts per trillion

2 $$\text{DRE \%} = \left(1 - \frac{Q \times [SF_6]_m \times 10^{-12}}{[SF_6]i}\right) \times 100$$

where Q = stack air flow rate (dry m^3/hour)
$[SF_6]_m$ = measured SF_6 stack gas concentration (ppt)
$[SF_6]_i$ = SF_6 injection rate (kg/hour)

3 A SF_6 concentration of 1 ppt (i.e. detection limit of SF_6 analyzer) is assumed in the calculation of DRE if the measured concentration in the exhaust gas is less than 1 ppt.

Table 6.6

TRIAL BURN 1 RESULTS SUMMARY
ACID GAS (SO_2) REMOVAL EFFICIENCY

DATE	TEST	TEMPERATURE (°C) PCC	SCC	RESIDENCE TIME (Seconds)	ACID GAS REMOVAL (%)
5 Mar 91	1[1]	-	-	-	98.8
5 Mar 91	2[1]	-	-	-	98.8
6 Mar 91	3	976.1	1211.1	3.6	97.5
6 Mar 91	4	990.0	1211.0	3.5	99.5
6 Mar 91	5	988.0	1210.6	3.5	98.0
					AVERAGE: 98.5

1 PCC and SCC temperature readings were unavailable due to CSEM computer failure. Tests were repeated on 6 March.

- Manual stack sampling was maintained throughout each mustard incineration cycle as opposed to only during batch feed operations. This approach was taken to ensure the stack sampling program would encompass all emissions which might occur during a normal solid waste feed operation; i.e emissions which might result from normal process oscillations which occur during waste feed preparation as well as those associated with process stabilization after waste is introduced into the incinerator.
- An unexpected plant shutdown during the first test (TB2-T1) led to shorter-than-normal sampling times for SO_2, HCl and dioxin/furans, as well as eliminating the NOx sampling altogether. To compensate, CSL performed duplicate sampling for SO_2, HCl and NOx during the second test run (TB2-T2), as well as collecting one additional full set of stack gas samples during the fourth test (TB2-T4).
- CSL elected to collect and analyze scrubber blowdown samples for dioxin/furan content to supplement the stack sampling data for these compounds.

Trial Burn 2 emission monitoring results for the four tests based on the CSEM system measurements and manual stack sampling analyses are summarized in Table 6.7. Particulates, metals and dioxins/furans were determined by manual stack sampling only. For comparison, the average stack gas component concentrations as percentages of the project emission limits are given in Table 6.8. The data in this latter Table has been averaged over the entire period of Trial Burn 2 and includes both CSEM system and manual stack sampling results. A summary of the incinerator operating conditions as well as calculated mustard destruction and acid gas removal efficiencies are given in Table 6.9. The mustard average DRE and acid gas removal efficiency over the four tests were 99.999972% and 99.7%, respectively.

Table 6.7

SUMMARY OF TRIAL BURN 2 EMISSION MONITORING RESULTS[1,2]

COMPONENT	COMPONENT CONCENTRATION[3] (mg/m^3) TB2-T1	TB2-T2	TB2-T3	TB2-T4	AVERAGE	LIMIT
	20 Mar 91	21 Mar 91	22 Mar 91	25 Mar 91		
Particulates	63	72	39	76	62.5	20
SO_2						
CSEM:	42.5	11.6	16.6	72.2	35.7	250
Manual:	91.2	22.3	8.4	1.3	30.8	
HCl						
CSEM:	35.9	11.6	8.4	1.6	14.4	75
Manual:	6.6	8.4	4.6	5.5	6.3	
NO_x						
CSEM:	90.9	69.6	82.2	134.9	94.4	300
Manual:	-	114.5	104.0	113.0	110.5	
CO						
CSEM:	31.9	62.4	78.1	25.8	49.6	57
Manual:	-	-	-	-	-	
THC						
CSEM:	12.0	2.7	0.7	14.3	7.4	45
Manual:	-	-	-	-	-	
Mustard						
CSEM:	<0.0034	<0.0017	<0.0013	<0.0015	<0.0020	0.03
Manual:	0	0	0	0	0	
Arsenic	0.01	0.02	0.01	0.01	0.01	1
Copper	1.45	2.80	0.39	1.70	1.58	5
Lead	0.68	0.88	0.32	0.96	0.71	5
Dioxins/Furans[4]	$<0.1x10^{-6}$	$<0.1x10^{-6}$	$<0.1x10^{-6}$	$<0.1x10^{-6}$	$<0.1x10^{-6}$	$12x10^{-6}$

1 CSEM results for each test are averaged over the entire period of the test.

2 Stack sampling results for each test are averaged over the sampling period only. For test TB2-T2 (21 Mar 91), SO_2, HCl and NOx values are averaged for duplicate tests.

3 Concentrations are corrected to reference conditions of 11% O_2, 101.325 kPa and 25°C on a dry basis.

4 Reported as 2,3,7,8-tetrachloro-p-dibenzodioxin (T4CDD) toxic equivalent.

Table 6.8

COMPARISON OF TRIAL BURN 2 EMISSIONS WITH PROJECT LIMITS

COMPONENT	AVERAGE CONCENTRATION (mg/m^3)	% OF EMISSION LIMIT
Particulates	62.5	312.5
SO_2	33.3	13.3
HCl	10.4	13.8
NO_x	102	34.0
CO	49.6	87.0
Hydrocarbons	7.4	16.4
Mustard[1]	<0.002	<6.7
Arsenic	0.01	1.0
Copper	1.58	31.6
Lead	0.71	14.2
Dioxins/Furans[2]	$<0.1 \times 10^{-6}$	<0.8

1 No mustard detected in stack survey samples. Results are based on minimum detection limit of stack mustard analyzer.

2 No dioxins (T4CDD equivalent) detected in stack samples. Furans (T4CDF equivalent) range: 0.010 - 1.1 ng/m^3.

As shown by the data, combustion gases that may not be completely removed by scrubber system, i.e. acid gases and oxides of nitrogen, as well as products of incomplete combustion (PIC's), were all well below the limits set for the project. Dioxin/furan concentrations (T4CDD equivalent) in the stack effluent were found to be well below the limit of 12×10^{-6} mg/m^3. No dioxins were actually detected in the stack samples whereas furans were in the range 0.01 - 1.1 ng/m^3 [49].

The average particulate emission concentration of 62.5 mg/m^3 which occurred during the Trial Burn exceeded the project-specific limit of 20 mg/m^3. This was less than the 70 mg/m^3 regulatory limit imposed by Alberta Environment for operation of the rocking kiln incinerators at the Alberta Special Waste Treatment Centre, Swan Hills, but greater than the historical average particulate emission rate of 12.4 mg/m^3 demonstrated by this facility [53]. To rectify this problem, CSL undertook a series of modifications to the scrubber system and conducted additional compliance tests (see Supplementary Performance Tests, below) while the trial burn results were under review.

Table 6.9

MUSTARD DESTRUCTION AND ACID GAS REMOVAL EFFICIENCIES

PARAMETER[1]	TB2-T1	TB2-T2	TB2-T3	TB2-T4
Stack Gas Flow Rate (wet) (mg/m^3)	5359.4	5351.1	5691.6	5219.1
Stack Gas Water Content[2] (%)	55.9	54.7	46.7	55.5
Stack Gas Flow Rate[3] (dry) (mg/m^3)	1776.2	1626.4	1704.6	2077.1
PCC Temperature[4] (°C)	982.0	979.5	981.3	959.6
PCC Excess O_2 Content (wet) (%)	5.3	6.9	6.7	6.1
SCC Temperature[4] (°C)	1197.6	1204.0	1212.7	1218.6
SCC Residence Time[4] (seconds)	3.0	3.1	2.8	3.1
Stack Excess O_2 Content[4] (dry) (%)	7.7	5.6	3.3	9.3
Mustard Feed Rate (kg/hour)	33.0	33.0	26.4	16.5
Mustard Stack Concentration[5] (mg/m^3)	0.00340	0.00167	0.00126	0.00150
Mustard DRE[6] (%)	99.999981	99.999991	99.999992	99.999983
Acid Gas Removal Efficiency[7] (%)	99.3	99.8	99.9	99.9

1 Values quoted are the average for each test.

2 Determined from manual stack sampling survey.

3 Values are dry and corrected to reference conditions of 11% O_2, 101.325 kPa and 25°C.

4 Based on data recorded and computed by the CSEM system.

5 Based on the minimum detection limit of the CSEM stack gas analyzer as no mustard was found in manual stack survey samples.

6 Destruction and Removal Efficiency (DRE) is calculated as follows:

$$DRE\ \% = \left[1 - \frac{[HD] \times Q_{dry}}{HD_f}\right] \times 100$$

where: [HD] = stack gas mustard concentration (mg/Rm^3, dry)
Q_{dry} = stack gas flow rate, dry (Rm^3/hour)
HD_f = mustard feed rate (mg/hour)

7 Average removal efficiency of equivalent sulphur and chlorine components in the stack gas compared to equivalent sulphur and chlorine components in the mustard feedstock.

The trial burn results demonstrated that the incinerator was capable of destroying mustard at a DRE which approached 99.99999% ("seven nines"), i.e. well above the design criteria set for the project. The DRE calculated for mustard was based on the minimum detection limit for the MINICAMS stack gas analyzer, as no mustard was found in stack samples acquired during the manual sampling program. The calculated acid gas removal efficiency of the scrubber system also exceeded the 95% removal efficiency requirement; the overall removal efficiency average based on the CSEM data was 99.44%, whereas the manual stack sampling data showed an average of 99.9%.

Analysis results for the solid combustion products recovered from the ash discharge system and for the scrubber blowdown are shown in Tables 6.10 and 6.11, respectively. In general, no residual mustard was found in these process byproducts. The scrubber fluid showed only trace amounts of lead and arsenic which were well below the project limits. The scrubber blowdown concentrations for copper, lead and arsenic were corrected for contributions from the fresh make-up water. On average, the flow rate of make-up water to the scrubber was 30 L/minute, whereas blowdown water was produced at a rate of 12.7 L/minute during the tests (ratio: approx. 2.5). The scrubber blowdown was also analyzed for dioxins and furans on a quantitiative basis. As shown by the data in Table 6.11, the average T4CDD equivalent concentration of the blowdown was 0.0472 ng/L, well below the Canadian Environmental Protection Act limit of 0.6 ng/L for mobile PCB incinerators [7].

The metal coupons recovered from the trial burns were free of residual mustard, thus confirming the incinerator's capability to thermally decontaminate the Project Swiftsure scrap metal inventory.

The Trial Burn 2 Report [49] was submitted to DRES and forwarded to Environment Canada and Alberta Environment for review on 9 May 1991. During the Trial Burn 2 period, all of the mustard (2087 kg total weight) stored in the four one-ton containers was incinerated.

6.11 Supplementary Performance Tests

6.11.1 Thickened Mustard Incineration

At the request of DRES, CSL carried out a special test on 26 March 1991, in which thickened mustard (mustard containing polymeric additives) was incinerated. This test was undertaken to examine incinerator performance while processing a different variety of mustard feedstock and to demonstrate the ability of the incineration system to minimize the formation of dioxins and furans.

The thickened mustard was obtained from Flying Cows, spray tanks and a heavy-walled cylinder which were part of the 14A Site inventory. The agent was of a semi-solid consistency which permitted rough partitioning of the material into cardboard boxes, as used previously by CSL for the mustard trial burns. Absorbent material (see Section 7.2.4) was placed in the boxes to eliminate any free liquid present. No metal coupons were included. The total weight of thickened mustard packaged (28 boxes) for the special test was 870 kg.

Table 6.10

ASH ANALYSES RESULTS FOR TRIAL BURN 2

Component	CONCENTRATION (mg/L) TB2-T1	TB2-T2	TB2-T3	TB2-T4	Average	Limit	% of Limit
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	5.0	<0.02
Barium	0.17	0.03	0.02	0.05	0.07	110.0	0.06
Boron	0.12	0.05	0.04	0.07	0.07	500.0	0.01
Cadmium	0.48	0.03	0.01	0.05	0.14	0.5	28.5
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	5.0	<0.2
Copper	-	-	-	-	-	5.0	-
Cyanide	<2.0	<2.0	<2.0	<2.0	<2.0	20.0	<10.0
Fluoride	0.12	<0.1	<0.1	<0.1	0.11	150.0	0.07
Lead	<0.04	<0.04	<0.04	<0.04	<0.04	5.0	<0.8
Mercury	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.1	<0.5
Selenium	0.002	<0.002	<0.002	<0.002	<0.002	1.0	<0.2
Silver	<0.005	<0.005	<0.005	<0.005	<0.005	5.0	<0.1
Mustard[1]	<0.001	<0.001	<0.001	<0.001	<0.001	1.0	<1.0

1 The lower detection limit (0.001 mg/L) of the mustard analyzer was used to calculate concentrations as no mustard was found in the ash samples.

Table 6.11

TRIAL BURN 2 SCRUBBER FLUID ANALYSIS RESULTS

Component	CONCENTRATION (mg/L) TB2-T1	TB2-T2	TB2-T3	TB2-T4	Average	Limit	% of Limit
Arsenic	<0.001	0.002	<0.001	0.012	0.004	0.1	4.0
Copper	0.015	0.020	0.010	0.007	0.013	0.1	13.0
Lead	<0.040	<0.040	<0.040	0.060	0.045	0.1	45.0
Mustard[1]	<0.001	<0.001	<0.001	<0.001	<0.001	1.0	<0.1
Dioxins/ Furans[2]	0.0433 ng/L	0.0182 ng/L	0.0535 ng/L	0.0738 ng/L	0.0472 ng/L	0.6[3] ng/L	7.9

1 No mustard was detected in scrubber fluid samples. The lower detection limit of the analytical instrumentation is 0.001 mg/L.
2 Dioxins and Furans reported as 2,3,7,8-tetrachloro-p-dibenzodioxin (T4CDD) toxic equivalent.
3 Limit specified in the Canadian Environmental Protection Act for mobile incinerator scrubber fluid discharge.

The test was run in accordance with the Trial Burn Protocol with the following variations:

- Thickened mustard was processed over a period of 2 hours to stabilize the system before starting the performance tests as well as after the test period to complete the destruction of the entire stock pile under optimized operating conditions;
- The thickened mustard feed rate was increased beyond 49.5 kg/hour as the CSEM data indicated that the combustion and scrubbing performance of the incinerator were excellent. For example [50], during the performance testing and during different hourly periods, three separate mustard batches, each batch consisting of three box es,were processed at rates of 84.5 kg/hour, 95.5 kg/hour and 95.5 kg/hour. A fourth batch consisting of two boxes was processed at a rate of 57.5 kg/hour.
- As during Trial Burn 2, stack sampling occurred throughout the mustard incineration cycle as opposed to only during batch feed operations;
- Manual stack sampling for particulates, mustard, HCl, SO_2 and NO_x was not performed as the focus of the test was to quantify dioxin/furan emissions from the stack and in the scrubber blowdown. Instead, the CSEM system was used to provide average concentration data for these materials.
- As during Trial Burn 2, CSL also analyzed the scrubber fluid for dioxin/furan content.

While processing thickened mustard, stack emissions were found [50] to contain less than 0.0187 ng/m^3 T4CDD toxic equivalent which was far below the project-specified limit of 12 ng/m^3. Furthermore, the scrubber effluent was found to contain 0.187 ng/L T4CDD toxic equivalent which was well below the Canadian Environmental Protection Act guideline of 0.6 ng/L for mobile PCB incinerators [7].

A comparison between the Trial Burn 2 data and the average data obtained during the performance test on 26 March 1991 is given in Table 6.12. The performance of the incineration system on 26 March was superior to that shown during Trial Burn 2, despite a three-fold increase in the mustard processing rate. This may be related to a decreased rate of mustard vaporization in the rotary kiln for the thickened material as compared to the mustard used during Trial Burn 2. A decreased vaporization rate would facilitate a more thorough burnout of material in the kiln and yield a lower flow rate of unburned gases entering the secondary combustion chamber. Ultimately, this would lead to a more constant rate of acid gas introduction to the scrubber system, resulting in improved scrubbing efficiency by lowering the instantaneous acid gas loading of the system.

The scrubber blowdown was analyzed for mustard and total organic content to conform to the normal procedures which CSL employed during operational waste incineration. Mustard and dioxins were not found above the detection limit of the laboratory gas chromatographic instrumentation.

Two separate samples of the scrubber blowdown were also analyzed for metal content, although this was not the prime focus of the performance test. The first sample was found to contain copper and lead concentrations of 3.3 and 0.27 mg/L, respectively, which exceeded project guidelines of 0.1 mg/L for these metals. Copper and lead concentrations in the second (later) sample were found to be 0.25 mg/L and less than 0.04 mg/L, respectively. This was unexpected in view of the fact that the mustard feedstock for this test contained no metal components. Two possible explanations were as follows:

- The high metal content may have resulted from vaporization of a metal slag deposited on the rotary kiln refractory during previous incineration of metal items at lower temperatures (the rotary kiln temperature during the performance test was 950°C);
- The thickened mustard may have contained significant levels of copper and lead due to leaching of metals from the agent containers during prolonged storage (e.g. from copper-lined spray tanks or Flying Cow lead nose cones).

In general, the performance test demonstrated that thickened mustard incineration did not produce significant amounts of dioxins/furans, although this feedstock contained polymeric precursors which could enhance the formation of such combustion products. In addition, the incinerator maintained stack gas concentrations well within project limits while yielding thermal destruction and acid gas removal efficiencies within design expectations. The report describing the thickened mustard performance test [50] was submitted to DRES and forwarded to Environment Canada and Alberta Environment for review on 28 May 1991.

Based on the favourable trial burn results obtained for tests involving bulk and thickened mustard, DND authorized CSL to proceed in the interim with the incineration of mustard-contaminated scrap material, as this involved operating the system well below the mustard feed rate design capacity. This feedstock was also used during supplementary tests to demonstrate that the incinerator could meet particulate emission limits (see below).

6.11.2 Particulate Performance Attainment Tests

In order to achieve compliance with the particulate emission limit set for the project, CSL performed two separate upgrades to the incinerator scrubber system and, in each case, carried out tests to determine particulate emission rates for the incinerator. An inventory of mustard-contaminated scrap metal (shredded drums and ordnance items) was selected as feedstock for these tests, as all of the bulk and thickened mustard had been destroyed during the Trial Burn program. Although the mustard in this case was "aged", the combustion products were expected to be identical to those produced by burning bulk mustard. However, incineration of "aged" mustard contained in metal items was expected to produce higher amounts of particulate matter.

Table 6.12

COMPARISON OF PERFORMANCE TEST[1] AND TRIAL BURN 2 DATA[2,3]

COMPONENT	PROJECT EMISSION LIMIT (mg/m^3)	TRIAL BURN 2 DATA (mg/m^3)	PERFORMANCE TEST DATA (mg/m^3)
SO_2	250	35.7	55.2
HCl	75	14.4	1.1
NO_x	300	94.4	81.2
CO	57	49.6	23.0
THC	45	7.4	5.6
Mustard	0.03	<0.002	<0.0013
Dioxins/Furans	12×10^{-6}	$<0.1 \times 10^{-6}$	0.0187×10^{-6}
PARAMETER			
Mustard Feed Rate		27.2 kg/hour	83.25 kg/hour
Mustard DRE		99.999987%	>99.99999%
SO_2 Removal		99.06%	99.75%
HCl Removal		99.81%	>99.99%

1 Averaged data for performance test carried out 26 March 1991.

2 Averaged data for four mustard incineration tests carried out during Trial Burn 2.

3 Data obtained from the CSEM system, except for dioxins and furans. Concentrations are on a dry basis, corrected to 11% O_2, 101.325 kPa and 25°C.

Particulate Test 1 was performed on 1 May 1991 and involved a manual stack sampling program to determine particulate concentrations while processing mustard-contaminated, heavy-walled ordnance items at different feed rates. During the test, filter elements of various size ranges were installed in the scrubber system downstream of the caustic injection point in the first stage scrubber water line. In addition, the scrubber fluid recirculation loop was upgraded to provide a higher liquid-to-gas ratio. Table 6.13 provides a summary of the system operating conditions and the results of the stack sampling to determine particulate concentrations. The collected particulate matter was subjected to a detailed analysis for various metals and other components; the analytical results are summarized in Table 6.14.

Under the given conditions, the scrubber system modifications resulted in a substantial reduction in stack particulate emissions from previous levels;

however, the particulate emissions still exceeded the project limit of 20 mg/m^3. By normalizing the feed rate data to 179 kg/hour, it was calculated [51] that the project limit could be met while filtering the scrubber water with 1-micron filter elements. This assumption was examined during further testing (see below). The Particulate Test 1 report [51] was submitted to DRES and forwarded to Environment Canada for review on 4 June 1991. This report and the Trial Burn Program reports submitted previously were accepted by Environment Canada in July 1991 [54]. In the interim, Chem-Security Ltd. restricted contaminated metal feed rates to approximately 180 kg/hour and maintained 1-micron filter elements in the scrubber system.

Addtional tests (Particulate Test 2) were carried out 17-21 June 1991 in which the incinerator waste feedrate was varied while the scrubber system had no filters, 1-micron- or 5-micron filter elements installed. Table 6.15 provides a summary of the selected conditions for five separate groups of tests, with each group consisting of three identical runs (total of 15 runs during Particulate Test 2). The incinerator was operated under optimized conditions during these tests while stack emission levels were determined through manual sampling and analysis and from data supplied by the CSEM system, as per the previous Trial Burn program.

The stack particulate emission concentrations found for each test are shown in Table 6.16 along with the calculated average concentration for each test group. The results indicated that the Project Swiftsure particulate emission limit of 20 mg/m^3 was met during one of the processing conditions (test group 3) while the maximum emission limit was exceeded by less than 20% for two of the remaining four processing conditions. By normalizing the feed rates for the tests, it was found [52] that three of the five selected processing conditions would produce acceptable particulate emission concentrations.

Table 6.17 summarizes the scrubbing system capability for particulate removal at various normalized feed rates and other processing conditions. The last row in this Table represents a feed rate adjustment under the given conditions which would be required to achieve the project particulate emission limit. For example, a minus value for a given feedrate indicates a reduction in feed rate required to achieve the project limit, whereas a positive value indicates the amount the feed rate can be increased and still maintain acceptable particulate emissions.

Normalizing Particulate Test 1 feed rate data to 179 kg/hour for the processing condition which utilized a 1-micron filter (Run 2) yields a predicted stack particulate emission concentration of 19.5 mg/m^3 [51]. This compares favourably to the results for Particulate Test 2/Test Group 3 which also utilizes 1-micron filtering. In this latter case, a normalized feed rate of 175 kg/hour (versus 179 kg/hour for the Particulate Test 1 data) is predicted to yield the same particulate emission concentration of 19.5 mg/m^3. This direct comparison of the separate tests confirms the validity of using normalized feed rates to predict particulate emission levels under a given set of processing conditions. The results of the comparison show that the feed rate normalization method is accurate to within 2% in predicting particulate emission levels.

Table 6.13

PARTICULATE TEST 1 OPERATING CONDITIONS AND RESULTS

PARAMETER	TEST RUN No. 1	2	3	4
Feed Rate (kg/hour)	273.5	422.5	178.5	179.0
Scrubber Water Flow Rate (L/min)	138.1	138.8	131.7	137.7
Scrubber Fluid pH	9.4	9.1	9.4	9.5
Scrubber Filter Element Size	none[1]	1µ	3µ	5µ
Stack Gas Flow Rate (dry) (m^3/hour)	2683.8	2270.2	2007.7	2181.0
Stack Particulate Concentration[2] (mg/m^3)	119	46	62	51

1 In this case, the scrubber water was not filtered.
2 Concentrations are on a dry basis and corrected to reference conditions of 11% O_2, 101.325 kPa and 25 °C.

Table 6.14

PARTICULATE TEST 1 SAMPLE COMPOSITION

PARAMETER ANALYZED	PARTICULATE COMPOSITION (wt %) TEST 1	TEST 2	TEST 3	TEST 4	AVERAGE COMPOSITION (wt %)
Arsenic	0.8	0.6	0.8	0.6	0.7
Copper	1.8	0.4	1.7	2.8	1.7
Lead[1]	6.3	7.4	7.4	6.4	6.9
Carbon	14.6	3.8	20.6	9.4	12.1
Iron	4.5	0.9	2.6	0.6	2.2
Sulphate	22.0	18.3	20.8	13.1	18.6

1 During the first test (no filtering), the lead concentration in the particulate matter was 7.49 mg/m^3, i.e. exceeded the stack emission limit of 5 mg/m^3. With filtering, the lead stack emissions were reduced to 3.42 mg/m^3, 4.59 mg/m^3 and 3.24 mg/m^3 for Tests 2,3 and 4, respectively.

Following completion of the particulate tests, CSL imposed the following processing conditions for the remaining Project Swiftsure inventory to ensure the particulate emission limit was met:

- ❖ The normalized waste feed rate to the rotary kiln was limited to 130 kg/hour with no filters installed in the scrubber system (i.e 91% of the 143 kg/hour feed rate for this processing condition);
- ❖ An hourly scrubbing system liquid-to-gas ratio of 20.3 or 18.8 was maintained while operating without filters or with 1-micron filters, respectively;
- ❖ The pH of the scrubber fluid was maintained above 8.3 on an hourly average.

Other emissions monitoring data obtained during Particulate Test 2 are summarized in Table 6.18 and the average values compared to the project limits. As was the case during the Trial Burn program, emissions produced by the incinerator system were well within limits while processing mustard-contaminated scrap. However, as occurred during the ealier thickened mustard trial burn, the lead emissions approached the project-specified limit, especially when processing contaminated scrap metal feedstock at higher rates.

The Particulate Test 2 report [52] was submitted to DRES and forwarded to Environment Canada on 15 August 1991.

Table 6.15

CONDITIONS SELECTED FOR PARTICULATE TEST 2

TEST GROUP	TESTS	OPERATING PARAMETERS FEED RATE (kg/h)	 FILTER
1	PT2-T1 PT2-T2 PT2-T3	220	1-micron
2	PT2-T4 PT2-T5 PT2-T9	300	1-micron
3	PT2-T6 PT2-T7 PT2-T8	140	1-micron
4	PT2-T10 PT2-T11 PT2-T12	180	5-micron
5	PT2-T13 PT2-T14 PT2-T15	160	none

Table 6.16

PARTICULATE TEST 2 EMISSION RESULTS

TEST GROUP	TEST	FEED RATE (kg/hour)	PARTICULATE CONCENTRATION (mg/m3)	RATIO TO EMISSION LIMIT
1	PT2-T1	244.3	29.25	1.46
	PT2-T2	187.1	21.30	1.07
	PT2-T3	235.9	32.17	1.61
	AVERAGE:	**222.4**	**27.57**	**1.38**
2	PT2-T4	325.5	30.69	1.53
	PT2-T5	308.6	19.02	0.95
	PT2-T9	245.3	22.53	1.13
	AVERAGE:	**293.1**	**24.08**	**1.20**
3	PT2-T6	131.8	11.73	0.59
	PT2-T7	144.0	13.35	0.67
	PT2-T8	152.6	22.66	1.13
	AVERAGE:	**142.8**	**15.91**	**0.80**
4	PT2-T10	188.0	16.47	0.82
	PT2-T11	186.7	32.56	1.63
	PT2-T12	207.5	50.75	2.54
	AVERAGE:	**194.1**	**33.26**	**1.66**
5	PT2-T13	167.0	23.15	1.16
	PT2-T14	148.0	23.27	1.16
	PT2-T15	174.7	22.05	1.10
	AVERAGE:	**163.2**	**22.82**	**1.14**

Table 6.17

PARTICULATE TEST 2 NORMALIZED PROCESSING CONDITIONS AND RELATED PARTICULATE EMISSION VALUES

PARAMETER	TEST GROUP[1] 1	2	3	4	5
Average Scrubber Liquid-To-Gas Ratio	18.5	18.6	18.8	19.2	20.3
Average Scrubber pH	8.7	8.9	8.3	8.1	8.3
Average Particulate Concentration[2] (mg/m^3)	27.57	24.08	15.91	33.26	22.82
Average Feed Rate (kg/hour)	222.4	293.1	142.8	194.1	163.2
Normalized Feed Rate[3] For Attainment Of Particulate Limit (kg/hour)	161.3	243.4	179.5	116.7	143.0
Average Feed Rate vs Normalized Feed Rate[4] (kg/hour)	-61.1	-49.7	+36.7	-77.4	-20.2

1 The test group number is the grouping of performance tests run under controlled conditions using the same processing parameters.

2 Concentrations are on a dry basis and corrected to reference conditions of 11% O_2, 101.325 kPa and 25°C.

3 $$\text{Normalized Feed Rate} = \frac{\text{Average Feed Rate} \times 20\ mg/m^3}{\text{Average Particulate Concentration}}$$

4 The data represents the change in feed rate, either a reduction (-) or an increase (+), which would be required to achieve the project particulate emission limit of 20 mg/m^3.

Table 6.18

STACK EMISSION RESULTS DURING PARTICULATE TEST 2

COMPONENT	TEST GROUP COMPONENT CONCENTRATION[1] (mg/m^3) 1	2	3	4	5	AVERAGE	% OF LIMIT
Particulate[2]	27.57	24.08	15.91	33.26	22.82	24.72	124
SO_2[3]	6.0	4.9	3.3	39.0	35.8	17.8	7.1
HCl[3]	12.9	8.8	12.6	9.4	8.7	10.5	14.0
NO_x[3]	108.0	115.2	127.5	98.7	120.0	113.9	38.0
CO[3]	18.0	12.2	18.1	19.3	18.9	17.3	30.4
THC[3]	2.3	0.5	1.0	0.7	0.5	1.0	2.2
Mustard[3]	0.000	0.000	0.000	0.000	0.000	<0.0013[4]	<4.3
Arsenic[2]	0.06	0.03	0.02	0.02	0.03	0.03	3.2
Copper[2]	0.64	0.38	0.16	0.42	0.41	0.40	8.0
Lead[2]	4.75	4.59	2.34	5.43	3.81	4.2	83.6

1 Concentrations are on a dry basis and corrected to reference conditions of 11% O_2, 101.325 kPa and 25°C.

2 Based on analytical results from manual stack sampling program.

3 Based on CSEM system data.

4 The detection limit of the CSEM system mustard analyzer is used to calculate the stack gas mustard concentration as no mustard was found in samples collected during the manual stack sampling program.

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CHAPTER VII

AGENT WASTE DESTRUCTION OPERATIONS

7.0 AGENT WASTE DESTRUCTION OPERATIONS

7.1 Initial Preparations

Chem-Security Ltd. commenced final waste inventory surveys and packaging operations at the 490 and 14A Sites starting in October 1990, following DND approval of the EPP. DRES specialists from the Field Operations Section (FOS) and Decontamination Group supported the field packaging operations. CSL hired workers from the local area to supplement their own staff; these workers were supervised by experienced CSL personnel seconded from the incineration operation and by DRES FOS Field Trials Officers. At any given time, from 18 to 26 persons were involved in waste preparation activities at the field sites.

Prior to starting field work, each CSL worker underwent a comprehensive training program which provided information on DRES EPG operations policy, CSL operating policy and procedures, and the project Health and Safety Plans. This included hands-on training in personal protective equipment, decontamination and various waste management techniques. Workers also underwent a full medical examination which included an assessment of their suitability for physical labour and their ability to work for prolonged periods in protective equipment. After completing their assignments or upon terminating employment, all CSL site staff were offered a follow-up free medical examination to confirm the absence of any effects from chemical agent exposure. Approximately 80% of all CSL staff hired for Project Swiftsure opted to take this offered program upon completion of their duties.

Field work was scheduled for DRES normal working hours, *viz:* 0800-1630 during weekdays with operations ceasing after 1500 on Friday. On several occasions, operations continued on weekends or for extended hours during the week in order to complete critical tasks in a timely fashion; for example, shredding drums or draining large projectiles. The DRES Field Operations Section controlled and coordinated access to the EPG work sites at all times. Every Monday morning, CSL site supervisors and safety specialists met with DRES project management and Field Operations Section staff to discuss planned activities, schedules, technical and safety problems and measures taken to maintain an efficient, safe work environment. The FOS Field Trials Officer (FTO) assumed overall responsibility for general site safety at all EPG sites. The FTO had local authority to immediately suspend operations or close a particular site in the event of an emergency or any activity deemed to compromise personnel safety.

Engineering designs (equipment), safety procedures and personnel protective equipment appropriate to a particular task were employed to minimize worker exposure to mustard, lewisite and other hazardous chemicals. Prevention of injury from physical hazards was also emphasized. Chemical Agent Monitors were used during all operations to monitor for the presence of potentially hazardous levels of agent vapour. CSL and DRES staff working at EPG sites used portable and vehicle-mounted radio sets to maintain constant communication with the DRES Field Operations Section base radio set (Alpha).

7.2 Field Packaging Operations

7.2.1 Preliminary Preparations by DRES

During the summer of 1989, DRES FOS staff and Canadian Forces ammunition technicians examined and sorted the variety of waste at the 490 Site to remove any potentially explosive items. All personnel wore the CF NBC chemical protective ensemble while carrying out this work to avoid potential exposure to agent-contaminated items. Small scrap material deemed free-from-explosives was packaged in large, heavy-walled cardboard containers ("Tri-walls"). Empty one-ton containers, large bomb fragments, scrap metal and other materials, large ordnance casings and some empty drums were stacked into three separate piles to await final inspection and disposal under contract. The four pits containing mustard-contaminated drums were left undisturbed except for the removal of small items near the pit rims. Approximately 50 explosive, non-chemical ordnance items were located, removed to a separate location at the 490 site and destroyed by detonation.

During 1989 and 1990, FOS staff surveyed, sorted and catalogued the ordnance inventory stored at the 14A Site. Over 1500 items, involving a variety of ordnance suspected of containing either chemical agent fills, explosives, or both, were carefully X-rayed using the portable X-ray system. Individual non-explosive items containing unknown fills were perforated using remotely-activated shaped explosive charges and samples of fills taken for analysis. The perforated items were plugged using silicone caulking material and sealed with "gun tape". Most of these items were found to have fills based on mustard formulations. Two perforated 25-pounder shells were suspected of containing nerve agent fills, as evidenced by CAM responses. These shells were immediately immersed in a solution of methanol/potassium hydroxide *in-situ* to destroy the agent. The used neutralizing solution was added to the bulk waste neutralizing solution at the Willis Centre while the shell casings were heat-treated as described previously (Section 4.1.1).

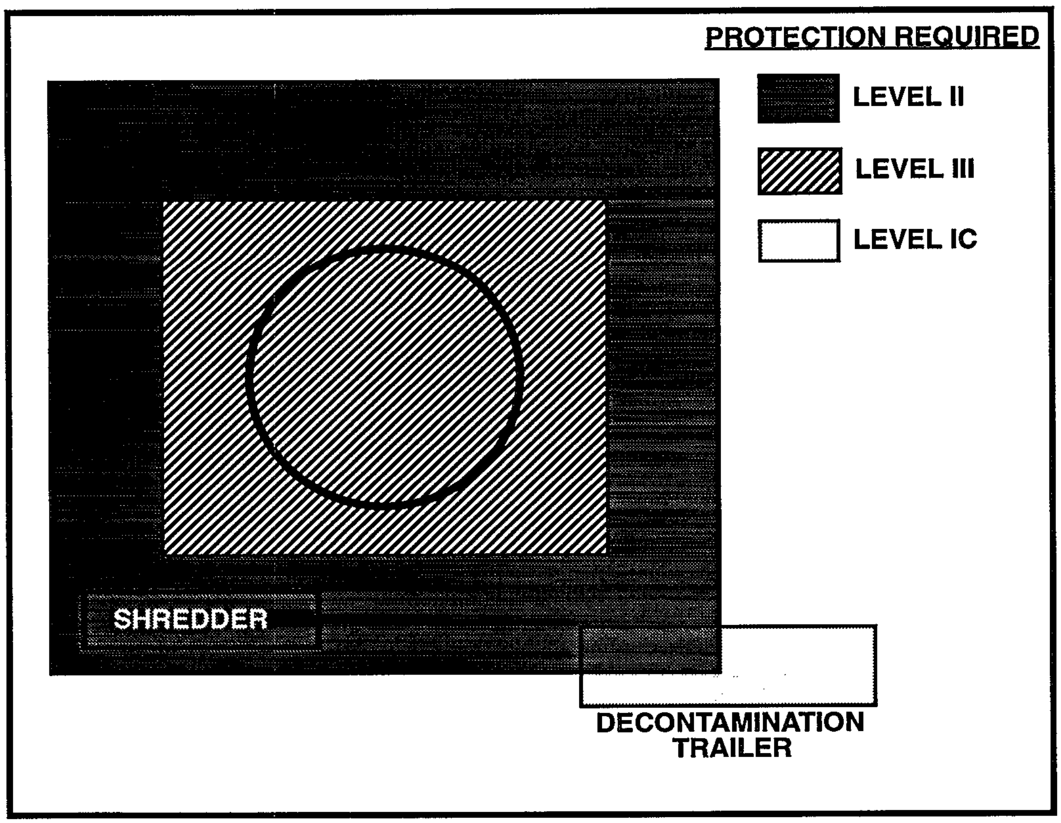
As noted previously (Section 4.3), ordnance items containing fills such as white phosphorus, tear gas or high explosives were destroyed by explosive demolition. Overall, 145 items stored at the 14A site were destroyed individually or in small groups in this manner as it was deemed too hazardous to remove and dispose of these items by other means. This demolition method involved placing approximately 100 pounds of explosive around each item and remotely activating the explosive charge under ideal meteorological conditions. Items destroyed in this manner included 4.2-inch mortars, Livens mortars, aircraft bombs, German ordnance and heavy-walled cylinders suspected or known to contain chemical fills and/or explosives.

On March 15, 1991, the Project Swiftsure mobile monitoring laboratory (see Section 9) was brought to the 14A site to conduct air quality measurements during a demolition event (mustard-filled/explosive Livens mortar). No mustard was detected on one-hour air samples which were collected approximately 1 km downwind; a rapid, transient rise in particulate concentrations, which remained within project-specified limits, occurred shortly after the explosion.

7.2.2 Site Preparations

Chem-Security Ltd. established a system of area control at the 490 Site utilizing procedures similar to those employed by DRES for hazardous field operations. This system involved deploying mobile decontamination and rest facilities, conducting air monitoring surveys, and using different levels of protective clothing to minimize the risk of personnel exposure to chemical agents and physical hazards [13]. The control area used at the 490 Site is shown schematically in Figure 7.1. The primary support facility was a decontamination trailer where staff donned and doffed protective clothing at the start and finish of each work shift. CSL also installed a lunchroom/rest trailer adjacent to the decontamination trailer to accommodate staff who were working full daily shifts at the 490 Site. A portion of the fence surrounding the 490 Site inner compound was removed and the CSL decontamination trailer positioned in this opening to act as the transition point between "clean" and "dirty" areas. A dedicated vehicle stationed on the "dirty" side was used to transport staff to and from the work areas in the inner 490 Site compound.

Figure 7.1



Schematic of 490 Site Field Operations Area Control

DRES deployed a mobile decontamination trailer at the 490 Site as well as at other field sites to support DRES field staff. By mutual agreement, CSL and DRES used each other's facilities when this was expedient or when tasking permitted. The DRES decontamination trailer was used extensively by CSL staff when work was in progress at the 14A site. DRES transferred the four one-ton mustard containers and the two one-ton containers of lewisite from the Hickey Storage Site to the 14A and 490 Sites, respectively; therefore, CSL was not required to provide facilities for the Hickey Storage Site. No special facilities were required at the Willis Centre Site when CSL transferred the bulk neutralized nerve agent solution to a tanker truck for transport to the Cameron Centre.

During field operations, the presence of agent (primarily mustard) was monitored using hand-held CAMs supplied to CSL by DRES. The primary uses of the CAMs were as follows:

- to detect the presence of mustard in items being handled and packaged;
- to monitor for fugitive emissions at the perimeters of various control zones;
- to monitor for potential contamination on protective clothing during operations and during decontamination drills;
- to monitor the air in the lunchroom/rest facility to confirm the absence of agent vapour.

As indicated in Figure 7.1, three levels of protective clothing were specified for use in field operations [13]:

- Level IC: light protective clothing consisting of cotton coverall, respirator at ready, rubber/leather outer gloves, latex inner gloves, steel-toed chemically-resistant boots, hard hat and safety glasses. This clothing was worn, for example, during maintenance and administrative work in non-contaminated areas of the site;
- Level II: medium protective clothing consisting of thermal underwear, the CF NBC Individual Protective Ensemble with C3 NBC respirator, and gloves, boots, and hard hat as per Level IC clothing. This was the normal level of protection used for most field operations as well as for incinerator operators during the processing of mustard items at the Cameron Centre. This clothing was worn, for example, by equipment operators during shredding, packaging of "dry" scrap waste, cutting scrap items with oxy-acetylene torches, and by standby emergency crews and work- site supervisors.
- Level III: heavy protective clothing which consisted of Level II clothing covered with Tyvek impermeable coveralls. This clothing was worn during lewisite neutralization operations, excavating drum pits where liquid was present, decontaminating equipment such as the drum shredder and support vehicles, and packaging "wet" waste such as thickened mustard obtained from opened "Flying Cow" projectiles.

Self-contained breathing apparatus was also available on-site for situations where the Site Supervisor deemed supplied air was necessary, such as entering excavated pits where oxygen deficiency was possible. All personnel entering the work area at each site were required to pass through the decontamination trailer to don the appropriate level of protective clothing and undergo a respirator leak test using amyl acetate ("banana oil test"). Upon leaving the work area, personnel returned to the trailer where decontamination, clothing removal and showering activities were completed before leaving the trailer on the "clean" side. All portable equipment used was also subject to decontamination; if this was not possible, items (e.g. used charcoal filters and contaminated, worn protective clothing) were packaged as waste inventory and destroyed by incineration.

7.2.3 Waste Profile Numbers

CSL established a numbering system which permitted the waste inventory to be tracked from field packaging operations through to destruction by incineration or chemical neutralization. This system used a series of Waste Profile Numbers (WPNs) which were assigned according to specific types of waste. The WPNs for contract-specified waste which was incinerated are given in Table 7.1. WPNs were also assigned to laboratory and incinerator plant-generated waste, to waste generated during field operations, and to extra waste which was found, but not accounted for, in the original contract specification (see Section 7.2.5, below).

7.2.4 Waste Preparation

Several different approaches were employed with respect to packaging and processing the waste inventory. For example:

- *Mustard and Mustard-Filled Items:*
  During the winter of 1991 and under cold conditions (< 5°C), mustard was drained in batches from pre-heated (20°C) one-ton containers into a calibrated container with a marked volume equivalent to 16.5 kg mustard. This operation was carried out in a heated enclosure placed around the ton containers. For each batch, the contents of the calibration container were then transferred into a heavy-duty plastic bag which was securely tied, taken outdoors and placed in a one cubic foot card-board box lined with polyethylene sheet where the mustard was allowed to freeze. Absorbent material (vermiculite) was then added to the box to fill the void volume. Each box was then bound and overpacked in an 18" x 18" x 72" wax-lined cardboard box which contained 5 cubic feet of absorbent, an amount sufficient to absorb all of the mustard should a leak occur. Larger boxes were bound, weighed on a scale, then immediately transported in sealed metal cargo containers to the Cameron Centre where the boxes were unloaded and processed via the rotary kiln solids waste ram feed system. This pneumatically-operated ram feeder was designed to introduce one box at a time into the kiln under closed conditions.

Table 7.1

INCINERATOR FEEDSTOCK
ORIGINAL INVENTORY WASTE PROFILE NUMBERS

WASTE PROFILE No.	DESCRIPTION
05	Shredded vehicle tires
07	Pre-packaged scrap (Tri-wall Boxes)
10	Drums shredded by DRES
20	Drums shredded by CSL
30	Empty Livens mortars
31	Contaminated Livens mortars (mustard)
37	Emptied mustard ton container
38	Emptied lewisite ton container
39	Neutralized nerve agent solution
40	4000 L plastic storage tank
41	Mustard hydrolysis vat fragments
42	Ordnance fragments and casings
45	Contaminated artillery shells
46	Empty artillery shells
47	Aircraft bombs
50	Contaminated 4.2-inch mortars (mustard)
51	Mustard-filled Flying Cows/Casings
55	Flying Cow contents (mustard)
56	Aerial spray tank casings
58	Mustard from spray tanks
60	Mustard from pressure cylinder
66	Mustard-filled 115-lb bombs
90	Mustard from ton containers
91	Mustard from ton containers/metal coupon

During cold weather, DRES staff punctured ordnance items with small explosive perforating charges. CSL then sealed these items individually or in groups in the same kind of polyethylene-lined cardboard boxes as used for the bulk mustard. The boxes were filled with absorbent material (vermiculite), transported to the Cameron Centre and incinerated. The thermally-decontaminated ordnance was recovered from the incinerator ash discharge system and stored outdoors to await final disposal.

The “Flying Cows” located at the 14A Site contained thickened mustard fills. Individual projectiles were placed in an open metal tank and cut into sections using a powered rotary saw. The thickened mustard was scooped into plastic bags using locally-designed hand tools. The plastic bags were sealed and placed into heavy-walled cardboard boxes in the same fashion as the bulk mustard. The cardboard boxes were filled with absorbent, sealed, transported to the Cameron Centre and incinerated. This thicked mustard formed part of the mustard inventory destroyed during the special incinerator trial burn carried out on 26 March, 1991 (see Section 6.11.1). The Flying Cow sections were packaged in other cardboard boxes and thermally treated in the same manner as the other mustard-contaminated scrap metal (see below).

❖ *Contaminated Scrap:*
Empty drums were first shredded using the transportable metal shredder (Figure 4.13). Shredding was carried out primarily in cooler weather to minimize fugitive emissions from the shredding process. The shreds were packaged in cardboard boxes (approx. 100 kg of shreds per box) and fed into the incinerator via the ram feeder. The clean metal was then recovered from the incinerator ash discharge system and stored outdoors to await final disposal. Usually, several dozen boxes containing the drum shreds were stored temporarily at the Cameron Centre Contaminated Materials Laydown Area to await processing, as shown in Figure 7.2. This was usually sufficient to maintain one or two days worth of continuous processing.

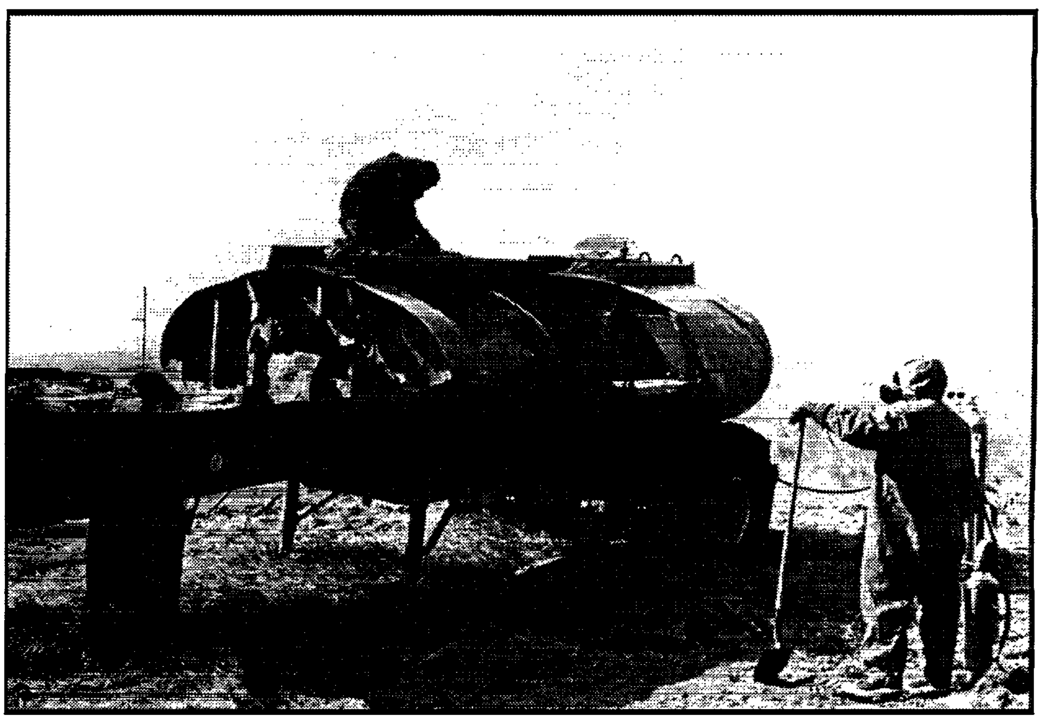
❖ Vehicles:
Scrap vehicles and metal parts which could not be shredded were subjected to a heat treatment *in-situ* to remove any potential surface contamination. Eleven vehicles in total required heat treatment. Two of the tanker trucks contained a sludge-like material which was removed after the vehicles were first cut open using oxy-acetylene torches (Figure 7.3). The sludge in one case was found to be high in mustard content; this material was packaged and incinerated. The second sludge, which contained thiodiglycol, was removed and placed in 210 L plastic barrels to await final disposal.

Before the vehicles were heat treated, the tires were removed and shredded and the immediate area was cleared of any surface grass and vegetation. Methanol was then poured from drums over the vehicles and ignited, producing an intense heat. After combustion ceased and the vehicles had cooled, various parts were subjected to batch swab analysis to confirm the absence of chemical agent contamination before commencing final disposal.

Figure 7.2

Packaged Waste Inventory Awaiting Incineration

Figure 7.3



490 Site Vehicle Dismantling Operations

7.2.5 Contract Amendments

As described in Chapter V, a number of changes to the Environmental Protection Plan and associated disposal contract were required as a result of public meetings and reviews held on Project Swiftsure. During the course of operations, several other changes to the project contract were required. Some of the important contract amendments with respect to field operations were as follows:

- ❖ Additional Scrap Inventory:- as packaging operations proceeded at the 490 Site, CSL noted that the original project estimate of contaminated scrap metal (i.e. 250 tonnes) was much less than the available material which could be recovered and packaged. This problem arose from the way in which the waste was stored originally. For example, during initial inventory surveys, drums and other items piled in the four pits could not be counted accurately without physically separating each item. This was also the case with the large surface scrap piles which were produced during the sorting and removal of explosive items. The weight of scrap which had been previously sorted by DRES and packaged in Tri-wall containers was found to be reasonably accurate. Thus, an additional 150 tonnes of scrap material was estimated for contractual purposes, with the final cost of the disposal contract amended to reflect this change. This additional inventory was assigned special Waste Profile Numbers as shown in Table 7.2.
- ❖ Inventory Modifications:- the original project inventory was modified to replace 4 tonnes of industrial solvents with approximately 4 tonnes of laboratory/field waste. This reflected the view that the industrial solvents retained commercial value and could eventually be sold or recycled on the open market.
- ❖ Waste Byproduct Disposal:- the original contract specified that treatment byproducts such as incinerator ash, neutralization waste, etc. could be diposed off-site at approved commercial facilities, provided the materials met appropriate environmental standards for waste disposal. The contract was amended to require all treatment waste to be disposed of on-site in an environmentally acceptable manner. This amendment reflected the Alberta Environment policy which required Project Swiftsure to be constrained within DND property at CFB Suffield.

Table 7.2

ADDITIONAL WASTE PROFILE NUMBERS

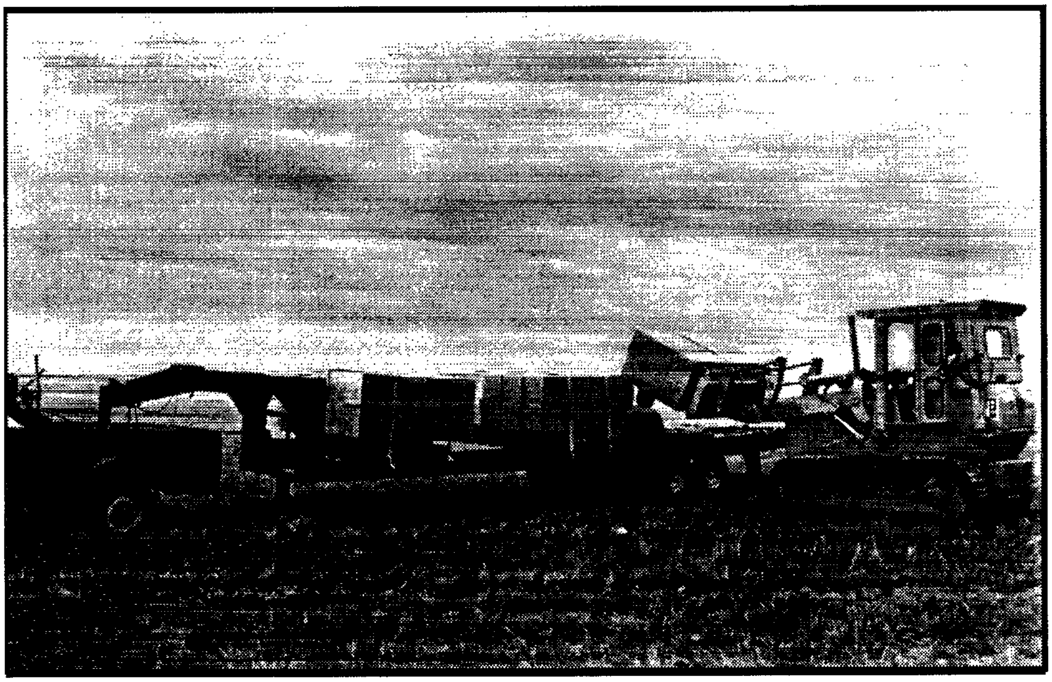
WASTE PROFILE No.	DESCRIPTION
Process, Laboratory and Plant-Generated Waste	
1001	DRES laboratory waste (14A Site)
2009	Field-generated waste (14A Site)
2012	CSL laboratory waste
2016	Field-generated waste (490 Site)
2025	DRES Field-generated waste (Hickey Site)
2027	Incinerator building solid waste
2028	Incinerator building liquid waste
Contract Additions to Original Inventory	
3007	Additional heavy-walled scrap (WPN 07)
3012	Spray Tank and contents (mustard)
3020	Additional drum shreds (WPN 20)
4001	Miscellaneous 490 Site scrap
4005	Used protective clothing

7.3 Waste Transportation

As shown in Figure 7.4, cardboard boxes containing contaminated scrap metal items were bound together in groups of approximately 20 and loaded on a flat-deck fifth-wheel trailer dedicated to transporting agent- related waste. A sealed cargo container (sea-van) was used for those boxes filled with frozen bulk mustard, thickened mustard or mustard-filled ordnance. Prior to leaving a field site, CSL informed DRES Field Operations Section by radio that a waste shipment was ready for transport to the Cameron Centre. DRES checked that the pre-selected transportation route was clear of all other vehicles before granting permission to proceed. The truck towing the loaded trailer was followed by a pilot vehicle which contained all the necessary emergency response equipment and trained personnel to deal with any potential accidents or waste spills. This pilot vehicle used flashing red lights for warning purposes and was in constant radio communication with DRES FOS, CFB Suffield Range Control and the waste truck. All vehicle drivers and support personnel wore Level II protective clothing and CF NBC respirators during the actual transportation of the packaged waste. The truck and the pilot vehicle were restricted to a maximum speed of 50 km/hour while enroute.

Upon arrival at the Cameron Centre, the cardboard boxes or sea-van containers were off-loaded and placed in the Contaminated Materials Laydown Area to await further processing. Under wet weather conditions, the boxes were covered with a tarpaulin to keep them dry.

Figure 7.4



Loading Packaged Waste Inventory For Transport

7.4 Incineration Operations

7.4.1 Emergency Response Exercise

An emergency response exercise was held at the Cameron Centre to confirm the preparedness of CSL staff and DRES/CFB Suffield support units in dealing with potential agent-related emergencies. This unannounced exercise was held 8 March, 1991, just prior to trial burns and operations involving the on-site waste feed and incineration of mustard agent. The details of the exercise plan were known only to the Head of the DRES Field Operations Section, his senior field trials officers, the CSL Site Superintendent and one of his lead operators. CFB Suffield emergency responder units (medical, firefighting) were informed of the possibility of an exercise but were not given any further details or timings.

The exercise involved a simulated mustard liquid spill from a damaged waste box while introducing the box into the waste feed system inside the incinerator building. The scenario included an injured CSL employee who was exposed to agent vapours through a breach in his protective suit. Water coloured with a yellow dye was used as the mustard simulant.

At 1000 hours on March 8, the CSL Site Superintendent entered the incinerator building unobserved, poured 1 L of simulant from a bottle under the solids waste feeder and activated the building alarm. Simultaneously, the CSL lead operator wearing a respirator and dressed in protective clothing partially opened his ensemble and lay on the building floor near the spill.

The response to this incident followed the emergency response procedure described in the Swiftsure Environmental Protection Plan with all appropriate responders, project management and information coordinators receiving notification within minutes. Simulated communications with DRES and CSL senior management, Environment Canada, National Defence Headquarters and the media were initiated. On-site decontamination with liquid adsorbent material and first-aid medical were performed by CSL shift staff and DRES Decontamination staff who were called in from a nearby building. The simulated casualty was removed from the spill site, decontaminated and removed from protective clothing in accordance with established procedures and transferred to the CFB Suffield emergency medical unit which arrived on-site from the Base within 15 minutes. Clean-up and decontamination of the spill was completed within 30 minutes and the exercise was terminated at 1030.

A post-exercise briefing with all principal units represented was held the same day to discuss results and any problem areas. In general, the exercise demonstrated that staff training, response organizations and communications links were capable of dealing with such potential worst-case emergencies.

7.4.2 Waste Processing Procedure

A fork-lift equipped with a special cage to contain single boxes was used to bring waste from the Contaminated Materials Laydown area into the incinerator building for loading into the solids waste ram feed. Each box was weighed on a platform scale prior to incinerating. A typical processing procedure was as follows:

- A single box was placed in the ram feeder using the fork-lift.
- The box was forced into the rotary kiln through the ram feeder air lock and allowed to burn for approximately 20 - 35 minutes while the kiln was slowly rotated at a speed of approximately 2-5 rpm.
- Any ash or metal scrap recovered from the ash discharge chute was transferred mechanically into a large metal hopper. When the hopper was nearly full, it was moved into a "quarantine" area where the contents of the hopper were allowed to cool to ambient temperature.
- Representative surface swab samples were taken of each metal batch and submitted to the on-site laboratory for analysis of mustard or organo-sulphur contamination (see Section 7.7.1 Analysis and Certification). Samples were deemed to be "contamination-free" and safe for further handling when analyses showed < 1 ppm mustard or organo- sulphur residuals.
- Contamination-free, processed metal scrap was removed outside to the Decontaminated Materials Laydown Area to await final disposal.
- Any ash recovered during the process was also analyzed in the on-site laboratory for metal content and for the presence of any mustard or organo-sulphur contamination.

The incinerator was operated continuously on a 24-hour basis using three 8-hour shifts. Heavily-contaminated scrap or ordnance items containing mustard fills were incinerated only during normal DRES working hours. In the evenings or overnight, lightly contaminated scrap, laboratory and field waste or non-hazardous scrap was processed. The incinerator was also shut down for periodic maintenance (e.g. a few days each month) or to troubleshoot problems in the CSEM system or other sub-systems as the need arose.

Table 7.3

INCINERATOR MONTHLY OPERATING STATISTICS

1991 DATES	OPERATING TIME (Hours)	ACTIVITY	WPN PROCESSED
January			
8 - 11	12	Commissioning	-
12 - 31	396	Refractory Cure	-
February			
3 - 5	57	Test Main Burners	-
9 - 21	265	Test Main Burners	-
22 - 28	156	Test Liquid Head	-
March			
1 - 3	68	Test Liquid Head	-
4 - 6	68	Trial Burn 1 (SF_6)	-
8 - 13	108	Solids Feed Tests	07
17 - 31	295	Trial Burn 2 (HD)	07/10/55/58/60/90/91
April			
4 - 8	81	Processing Waste	30
11 - 20	207	Processing Waste	10/20/46/2009/2027
27 - 30	80	Processing Waste	10/20/2009/3007
May			
1 - 4	68.5	Particulate Tests	20/2009/3007
13 - 16	59.5	Processing Waste	20/37/42/47/3007
28 - 31	73	Processing Waste	37/41
June			
1 - 2	48	Processing Waste	41
11 - 13	20	Particulate Tests	20
14 - 28	217.5	Processing Waste	05/20/2012
July			
2 - 13	245	Processing Waste	07/20/51/2027/3007
16 - 21	89	Processing Waste	20/39/51
23 - 31	108	Processing Waste	20/39/40/2009 51/2027
August			
1 - 20	357	Processing Waste	05/07/20/31/45 50/51/56/66/1001 2027/3020
24 - 31	131.5	Processing Waste	07/51/1001/3020
September			
1 - 10	198.5	Processing Waste	45/2016/3007 3012/3020
15 - 23	127.5	Processing Waste	2012/2027/3007
29 - 30	47	Processing Waste	3007
October			
1 - 6	127.5	Processing Waste	3007
November			
5 - 27	479.5	Processing Waste	38/2012/2016/2025 2027/2028/3007 3020/4001/4005
28 - 29	24	Final Burn-out	-

7.4.3 Incinerator Operating Statistics

The operating statistics for the incinerator over the period January to November 1991 are summarized in Table 7.3. During the eight month waste processing period following the trial burns, the incinerator availability averaged approximately 55%, well below the industry average of 70-75%. This was due to the frequent repairs to the rotary kiln refractory lining as a result of abrasion and impacts from the scrap metal feedstock. Regular maintenance was performed on the system during each refractory replacement operation. A prolonged shut down of the system occurred in mid-May 1991 to remove a lead-containing slag which formed in the rotary kiln (see Section 7.9).

The incinerator was also shut down for 3 weeks in October 1991 to enable CSL to dedicate their experienced staff to the lewisite destruction operation which was carried out at the 490 site. Waste incineration was completed by the end of November 1991.

7.4.4 Waste Processing Totals

The total amount of waste inventory, according to waste profile number, which was incinerated during Project Swiftsure is summarized in Table 7.4. The inventory amounts listed exclude the weight of the cardboard boxes which were used for packaging. The amount of metal (376 tonnes) and miscellaneous scrap (48 tonnes) processed, based on CSL weighings, greatly exceeded the original project estimate of 290 tonnes. However, less mustard (9.3 tonnes) was packaged and burned than the original estimate of 12 tonnes. The mustard total was derived from the wieght of agent destroyed during the the trial burns plus known fill weights of processed mustard-filled ordnance.

The protective clothing used by both DRES and CSL personnel during the course of Project Swiftsure was incinerated following the completion of field operations. This ensured that any worn or contaminated clothing would not be inadvertently re-used at a later time in situations where a high level of chemical protection was required.

Table 7.4

PROJECT SWIFTSURE INCINERATOR PROCESSING SUMMARY

DESCRIPTION	WPN[1]	AMOUNT PROCESSED[2] (tonnes)
1. Original inventory		
Shredded Tires	05	2.55
Tri-Wall Scrap	07	74.53
Shredded Drums	10/20	151.71
Empty Livens Mortars	30	23.76
Contaminated Livens Mortars (HD)	31	0.61
Empty Ton-Containers	37/38	9.51
Neutralized Nerve Agent Solution	39	3.5
Plastic Storage Tank	40	0.02
Steel Hydrolysis Vat	41	4.31
Ordnance Fragments	42	1.42
Contaminated Artillery Shells	45	4.95
Empty Shells and Bombs	46/47	5.89
Mustard-Filled Flying Cows/Casings	51	10.75
Thickened Mustard from Flying Cows/Tanks/Cylinders	55/58/60	0.87
Spray Tank Casings	56	0.33
Mustard-Filled 115-lb Bombs	66	0.24
Mustard Trial Burn Material	90/91	2.09
2. Process Waste and Additional Inventory		
DRES Laboratory Waste (14A)	1001	3.56
Field-Generated Waste (14A)	2009	4.13
CSL Laboratory Waste	2012	0.28
Field-Generated Waste (490)	2016	1.11
DRES Solid Waste (Hickey Site)	2025	0.35
Incinerator Building Solid Waste	2027	4.82
Incinerator Building Liquid Waste	2028	4.85
Additional Heavy-Walled Scrap	3007	86.07
Mustard-Filled Spray Tank	3012	0.01
Additional Drum Shreds	3020	10.89
Miscellaneous Scrap (490)	4001	47.80
Used Protective Clothing	4005	0.58

1 Waste Profile Number.
2 Inventory weights listed exclude the weights of the cardboard boxes used for packaging.

7.5 Lewisite Neutraliztion

The incineration of lewisite or its neutralization products potentially could produce arsenic-containing stack emissions or contaminate internal incinerator components with arsenic residues. These concerns were shared by the public; therefore, a program was developed to destroy the lewisite by a chemical process. The project EPP was modified to reflect this change in the proposed destruction method.

7.5.1 Pilot Scale Tests

Under a separate contract with Chem-Security Ltd., Professor Michael Benn, Chemistry Department, University of Calgary, carried out several experiments to determine the optimum method for destroying lewisite by chemical neutralization. Small samples of munitions-grade lewisite were supplied by DRES to support these studies. The lewisite destruction procedure eventually chosen was based on early research [55] which described the hydrogen peroxide oxidation of lewisite isomers and subsequent alkali-induced decomposition of the arsonic acids to arsenate salts with the production of acetylene. A full description of the laboratory tests is given elsewhere [56].

Based on these preliminary tests, a pilot-scale neutralization unit was constructed of glass and teflon parts and delivered to the Cameron Centre site in March 1991. A schematic of the unit is shown in Figure 7.5. The capacity of the main reaction vessel (glass) was approximately 8 litres. The unit used a circulating pump manufactured with a teflon-substitute material (kynar), as a teflon pump was not available. A heated enclosure erected adjacent to the incinerator building was used to house the unit; this avoided the possibility of contaminating the inside of the incinerator building with arsenic residues in the event of an accident.

Four separate tests were conducted during 5 - 11 April 1991 to optimize reaction conditions and processing parameters, as well as to determine materials compatibility with lewisite samples taken from the one-ton containers stored at the Hickey Site. As illustrated in Figure 7.5, the neutralization process embodied three steps:

- Step 1: conversion of lewisite to lewisite oxide (2- chlorovinylarsine oxide) by addition of the agent to a heated (60°C) 15% (w/v) solution of hydrogen peroxide in water at pH 1-2;
- Step 2: catalytic decomposition of excess peroxide to water and oxygen by adding sodium hydroxide to raise the pH to 4-6 and circulating the reaction solution through a bed containing manganese dioxide;
- Step 3: conversion of lewisite oxide to sodium arsenate and sodium chloride in solution by adding sodium hydroxide to adjust the pH to 11, with the release of acetylene gas.

Table 7.5 lists the concentration limits which were set for certain reactants during various steps to verify completion of the neutralization reaction.

Table 7.5

PROCESS CONTROL LIMITS FOR LEWISITE NEUTRALIZATION

PROCESS STEP	PARAMETER	ANALYSIS METHOD	CONCENTRATION LIMIT
1	Lewisite	GC/FID[1]	1 mg/L
2	H_2O_2	Titration	0.1% (w/v)
3	Lewisite Lewisite Oxide	GC/FID GC/FID	1 mg/L 5 mg/L

1 Gas chromatography with flame ionization detection. Lewisite is first derivatized with 3,4-dimercaptotoluene in hexane solution prior to analysis.

During steps 2 and 3, the unit was operated under a nitrogen atmosphere to exclude air (oxygen) from the process.

A total of 706 grams of lewisite was neutralized during the pilot-scale tests, using 6.5 or 7.5 litre batches containing from 43 to 464 grams agent. Following Step 1, the average concentration of residual lewisite was 0.4 mg/L, yielding an average conversion (destruction) efficiency of >99.997% for this step.

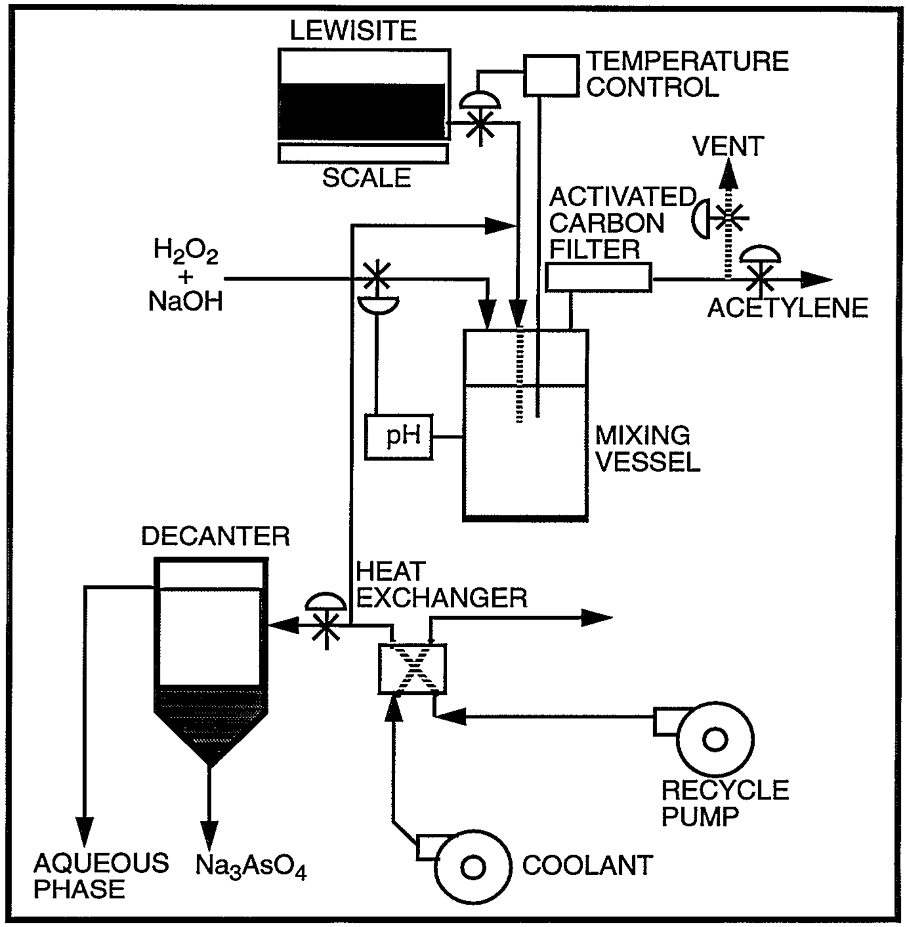
Experiments were also carried out to investigate suitable concrete mixtures for permanently containing the arsenic salts solution produced by the neutralization process. A successful formulation was developed which incorporated the arsenic-containing solution from Step 3, sodium silicate, sodium sulphate and Portland cement in the following proportions:

Arsenate/chloride salt solution	40%
Sodium silicate (liquid)	5%
Sodium sulphate	5%
Type 10 Normal Portland cement	50%.

Typically, this mixture was cast into 2-cubic inch blocks and cured at ambient temperatures for 5 days. Standard leachate tests using water were then carried out on the cubes to determine whether metals could be extracted from the concrete matrix. The results of leachate tests carried out on two stabilization cubes made with the successful formulation are shown in Table 7.6.

Based on the pilot-scale tests, CSL developed design parameters and processing conditions for a larger, transportable unit which was subsequently used for the destruction of all remaining lewisite inventory.

Figure 7.5



REACTIONS

Step 1:

$(Cl\text{-}CH{=}CH\text{-}AsCl_2) + H_2O_2 + H_2O \longrightarrow (Cl\text{-}CH{=}CH\text{-}AsO_3H_2) + HCl$

Step 2:

Excess peroxide removed by catalytic decomposition with manganese dioxide.

Step 3:

$(Cl\text{-}CH{=}CH\text{-}AsO_3H_2) + 2HCl + 6NaOH \longrightarrow Na_3AsO_4 + C_2H_2 + 3NaCl + 5H_2O$

OVERALL REACTION:

$(Cl\text{-}CH{=}CH\text{-}AsCl_2) + H_2O_2 + 6NaOH \longrightarrow Na_3AsO_4 + C_2H_2 + 3NaCl + 4H_2O$

Schematic Of Pilot-Scale Lewisite Neutralization Apparatus

Table 7.6

LEACHATE ANALYSIS RESULTS FOR STABILIZED ARSENATE SOLUTION

PARAMETER	CONCENTRATION (mg/L) LIMIT[1]	SAMPLE 1	SAMPLE 2
Arsenic	5.0	0.26	0.23
Barium	100.0	0.38	0.49
Boron	500.0	0.01	<0.01
Cadmium	0.5	0.005	0.006
Chromium	5.0	0.46	0.42
Copper	-	0.019	0.019
Cyanide	20.0	0.003	0.002
Fluoride	150.0	0.10	0.009
Lead	5.0	<0.01	0.01
Mercury	0.1	0.030	0.014
Nitrites	-	0.042	0.056
Nitrates	-	0.012	0.012
Selenium	1.0	<0.0002	<0.0002
Silver	5.0	<0.01	<0.01
Uranium	-	0.1	0.2
Zinc	-	<0.001	<0.001

1 Canadian General Standards Board (CGSB), Leachate Extraction Procedure 164-GP-1 MP. Ottawa, Ontario. February 1987 [46].

7.5.2 Full-scale Neutralization Operations

DRES transferred the two one-ton lewisite containers from the Hickey Storage Site to the 490 Site in preparation for the destruction of this agent by chemical neutralization. CSL carried out the lewisite destruction using a transportable unit (Figure 7.6) which was fabricated in Calgary during the summer of 1991. Special components such as teflon-lined pipe and reaction vessels were incorporated to resist corrosion from the agent, neutralized products and reactants used in the destruction process.

The unit was specially designed to accept bulk liquid metered in from one-ton containers. Compressed air-driven diaphram pumps were used for fluid circulation rather than electrical pumps as the neutralization process produced acetylene, a combustible gas. The unit was delivered to the 490 Site in two large sections in late August 1991 and was assembled by CSL in early September. The unit was located just inside the west fence of the 490 Site inner compound in an area known to be free of contamination. Over the next several weeks, utility support equipment including a water tank, air compressors, a generator and refrigeration system were connected and tested. Commissioning tests on the complete neutralization unit were carried out, first with water, then peroxide and caustic solution. Trial runs of the neutralization process itself were conducted between 26 September and 6 October with full-scale, routine neutralization of lewisite commencing on 7 October 1991. The neutralization process used the three basic steps which were refined during the earlier pilot-scale tests (see above). The entire stockpile was completely destroyed by 2 November, 1991. During this period, incineration and associated waste processing activities were suspended to enable CSL to dedicate all experienced personnel to the neutralization operation. During processing, personnel wore the CF NBC protective ensemble covered with Tyvek coveralls and augmented with plastic aprons and sleeves for liquid splash protection (Level III protection).

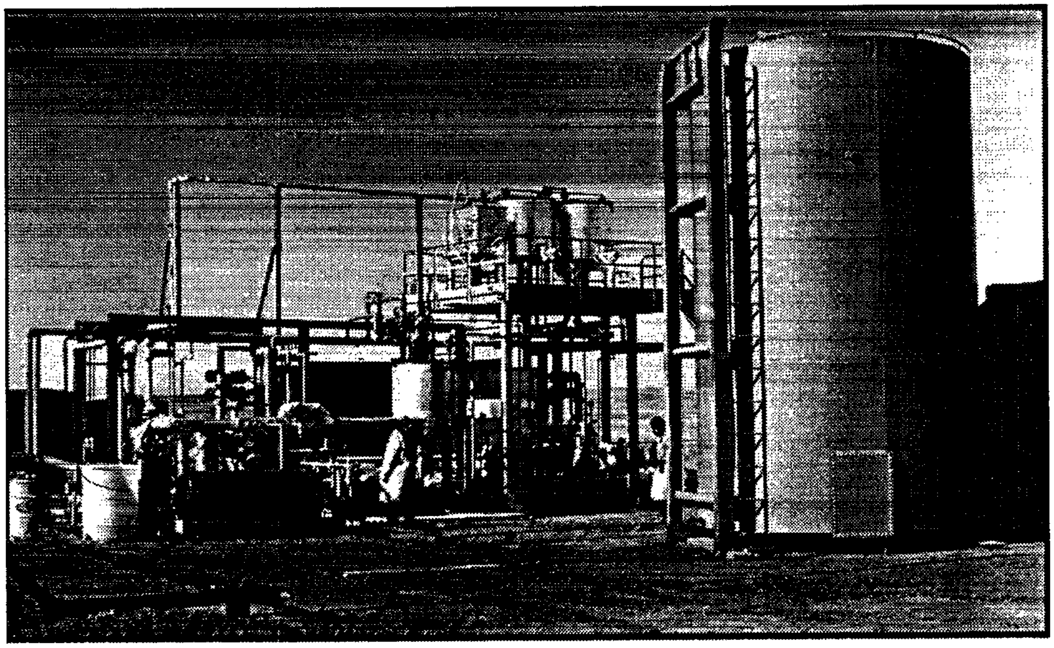
The arsenic salt-containing solution resulting from each batch process (see below) was collected and stored, first in plastic drums then in a steel tank, analyzed for lewisite content and subsequently stabilized in the previously-developed concrete formulation for final disposal (see Section 7.6.2 below).

Step 1 of the process was deemed to be the most hazardous part of the operation as this involved processing lewisite directly. Therefore, this operation was restricted to normal working hours during the week. Chem-Security Ltd. was allowed to proceed with the other steps on an unrestricted basis.

Processing all of the lewisite in the two one-ton containers required 20 separate batch runs. Initially, small batches of 20 litres each were processed on a trial basis; batch size was increased to 90-100 litres (approx. 165-185 kg lewisite) by mid-October 1991. A batch of this latter size was processed every 24 hours. The total volume of lewisite destroyed using the neutralization unit was 1622 litres (2.97 tonnes). This was approximately 14% more than the original estimate of 2.56 tonnes lewisite of approximate 65% purity.

Residual lewisite concentration at the completion of Steps 1 and 3 averaged 0.5 mg/L and 0.09 mg/L, respectively. As was the case during the pilot-scale tests, the low concentrations of lewisite found at the end of step 1 demonstrated that agent destruction was actually occurring as opposed to simple dilution from the addition of reagents. Confirmation of low lewisite concentrations at the end of step 3 was a contractual requirement to certify the completeness of the agent destruction. The overall destruction efficiency for the full-scale lewisite neutralization process was >99.9998%. Decommissioning and decontamination of the neutralization unit commenced on 3 November 1991 by flushing internal components with a 30% peroxide solution. During the decontamination operation and while circulating caustic solution through the unit, an explosion occurred within the main reaction vessel which blew the reactor lid off (see Section 7.9). Fortunately, this incident did not harm nearby personnel nor did it produce any measurable environmental impact. Exterior surfaces of the reaction vessels and piping were washed with a bleach solution. Analysis of swab surface samples demonstrated that the exterior surfaces were free of contamination. The unit was then removed from the 490 Site on 13 December 1991.

Figure 7.6



Full-Scale Lewisite Neutralization Unit

7.6 Secondary Waste Treatment Methods

7.6.1 Waste Water Treatment

Scrubber blowdown water from the incinerator was discharged to a lined lagoon during operations. Concentrations of dissolved metals in this water were subject to strict environmental limits, particularly for the metals lead, copper and arsenic. For example, a discharge quality normally associated with drinking water standards (0.1 mg/L metal content) was specified for the blowdown, even though the discharge was to a lagoon which had no outlet to a drinking water system. Scrubber blowdown batches generated during each 48 hours of incinerator operation were retained in large holding tanks and analyzed for metal content prior to discharge.

During the course of processing scrap metal and ordnance containers, metal concentration levels in the blowdown occasionally exceeded limits, particularly for lead. The problem was traced to the melting of lead and copper alloys in the ordnance and scrap under the high temperatures employed during incineration. Chem-Security Ltd. applied various treatment methods in an attempt to decrease the dissolved metals content in the blowdown. In some cases, DRES permitted out-of-specification discharges to the lagoon during operations in order that the problem could be examined and resolved in a timely manner.

Initially, CSL treated the scrubber water with sodium hydroxide to precipitate dissolved lead as lead hydroxide and to allow the precipitate to settle to the bottom of the blowdown holding tank. The water in the top 90% of the tank was then pumped to the lagoon and periodic tank cleanings were performed to remove and store the tank bottom sludge for further treatment. This procedure permitted approximately half (2850 m^3) of the incinerator scrubber blowdown to meet project-specified limits for metals content.

During scrap metal incineration, CSL carried out a detailed sampling program to determine the extent of the lead contamination problem in the lagoon. Water samples were acquired from four different quadrants of the lagoon at depths of 0 m, 0.75 m, 1.50 m and 2.25 m and analyzed for lead, copper and arsenic content. As shown in Table 7.7, the sampling results indicated that the lagoon water required remediation in order to comply with project-specified limits for dissolved metal content.

Chem-Security Ltd. commenced a remediation project by pumping the lagoon water to above-ground storage tanks and adding powdered lime to precipitate lead hydroxide. Lime was found to be an effective and cheap alternative to caustic for this purpose. Lead hydroxide and excess lime were allowed to settle out and the water (pH = 12) was transferred to a separate tank and neutralized by addition of hydrochloric acid. Treated water which has dissolved metal content as shown in Table 7.7 was then discharged directly into a nearby natural slough. The increase in copper content to the allowable limit was believed to have arisen from the use of lime and hydrochloric acid which contained dissolved copper. Approximately 6500 m^3 of lagoon water was treated in this fashion, yielding 60 m^3 of tank bottom sludge for further treatment and disposal.

After completing the removal and treatment of the lagoon water, CSL recovered approximately 250 m^3 of lagoon bottom sludge using a vacuum truck. This sludge, which was fairly fluid (slurry-like) and high in dissolved metal content as shown in Table 7.7, was stored in above-ground tanks for further treatment. A laboratory study was undertaken with samples of the lagoon sludge to find a method for reducing the metals content in order to render the sludge suitable for disposal as non-hazardous waste. As listed in Table 7.8, remediation methods examined included precipitation, flocculation, solvent extraction, and ultrafiltration. Ultimately, CSL developed a full-scale method which involved precipitation of arsenic as iron arsenide, followed by removal of lead/copper hydroxides and carbonates by filtration. This treatment proved effective for removing lead and arsenic; copper removal was only partially successful as the metal was bound into the sludge as a complex chelate. Thus, all bottom sludge was remediated using this method and discharged back to the lagoon. As shown in Table 7.7, a composite sample of the treated sludge met project-specified limits with the exception of copper. Discharge of the out-of-specification material to the lagoon was allowed as all practical methods to meet the limit had been examined and the sludge was contained in an environmentally-acceptable manner. The precipitated material from the lagoon sludge remediation program was subjected to a leachate test [57,58] and shown to be non-hazardous. Nonetheless, this material was stabilized with flyash (see below, Stabilization) and placed into polyethylene-lined bags for final disposal.

Table 7.7

RESULTS OF LAGOON WATER AND SLUDGE REMEDIATION PROGRAM

METAL	CONCENTRATION (mg/L) BEFORE REMEDIATION	PROJECT LIMIT	AFTER REMEDIATION
Lagoon Water			
Lead	0.2	0.1	0.05
Copper	0.01	0.1	0.1
Arsenic	0.08	0.1	0.05
Bottom Sludge			
Lead	34 - 140	0.1	<0.042
Copper	0.03 - 1.3	0.1	0.21
Arsenic	0.35 - 0.42	0.1	<0.05

7.6.2 Stabilization

Arsenic salts from the neutralization of lewisite as well as the sludges which resulted from the waste water treatment procedures were stabilized in a concrete matrix prior to final disposal. Incinerator ash was found to pass leachate criteria for metals [57] and thus required no further treatment. For the lewisite neutralization byproduct (arsenate slurry), initial laboratory studies indicated that a mixture of lime and incinerator flyash had potential for stabilizing the arsenic in a manner which would prevent leaching into the environment (e.g. by rain water). This mixture proved unsuccessful in pilot-scale tests. Ultimately, a reagent mixture of Portland cement/arsenate slurry, sodium sulphate and sodium silicate (90:5:5) proved satisfactory in stabilizing the arsenic into a non-leachable form suitable for landfilling. First, a small rotary mixer, then a transportable, continuous cement processor were used to mix the ingredients with arsenate slurry, which was then poured into 210 L polyethylene barrels to cure and harden. Typically, the final product contained approximately 30% by weight arsenic slurry, with an arsenic concentration of 3.5% (35,000 ppm). The volume of concrete-stabilized waste produced in this manner was 100 m^3.

A second waste requiring stabilization was the tank bottom sludges containing settled suspended solids and dissolved metals precipitated from the scrubber blowdown water and lagoon bottom sludge. The sludge was capable of passing leachate tests which indicated the material was non-hazardous and required no further treatment. Tests for polychlorinated dibenzodioxins and dibenzofurans (dioxins/furans) conducted on scrubber blowdown and the tank bottom sludges indicated the presence of trace amounts of these highly toxic compounds. For example, a representative sample of tank bottom sludge was found to contain dioxins/furans at a total concentration of 1 ng/L T4CDD equivalent in 63 g/L suspended solids, or approximately 15 parts per trillion T4CDD equivalent. This level is approximately 350 times below the limit proposed by Alberta Environment [58] for inclusion in new provincial environmental protection legislation. Nonetheless, this sludge and other tank bottom

Table 7.8

LAGOON SLUDGE TREATMENT METHODS INVESTIGATED

METHOD	DEGREE OF SUCCESS		
	HIGH	PARTIAL	LOW
Precipitation			
1. metal sulphates precipitated with sodium sulphate			X
2. metal sulphides precipitated with sulphides	X H_2S		
3. addition of sodium carbonate		X	
4. addition of ferric chloride	X arsenic		X metals
5. addition of magnesium oxide			X
Flocculation			
6. addition of alum			X
7. sodium silofluoride addition			X
8. addition of sodium silicate			X
9. addition of polyacrylamide			X
10. addition of bentonite		X	
11. potassium amyl xanthate addition	X		
Solvent Extraction			
12. addition of quaternary amine			X
Ultrafiltration			
13. ozone/ultraviolet oxidation and ultrafiltration		X	
Combined Treatment			
14a. add ferric chloride with pH adjustment (arsenic precipitation)	X arsenic		
14b. add sodium carbonate and bentonite with pH adjustment (lead/copper precipitation)	X lead	X copper	

bottom sludges resulting from wastewater treatment activities were stabilized, first with the same reagent mixture used with the arsenic slurry, then with Portland cement and flyash. During the course of Project Swiftsure, 26 m^3 of tank bottom sludges were treated in this manner. In general, the tank bottom sludges did not actually require the use of the arsenic stabilization formulation; it was used primarily to consume the extra Portland cement which had been purchased for the project. The use of flyash was chosen as it was a well-known stabilization material with a broad range of effectiveness. The stabilized products were placed in 1 m^3 polyethylene-lined fibre bags or in 210 L polyethylene barrels and allowed to cure for 24 to 48 hours prior to conducting certification tests.

7.7 Final Waste Product Disposal

The products generated during the agent destruction program which required final disposal are listed in Table 7.9. In keeping with the policy developed for Project Swiftsure, these products were disposed of on-site in a manner which presented no safety or environmental hazards. The incinerated, clean metal had commercial value; therefore, this material was sold to a scrap metal dealer and melted in a foundry to produce recycled metal feedstock.

Table 7.9

SUMMARY OF FINAL WASTE PRODUCTS FOR DISPOSAL

PROCESS	FINAL PRODUCT	AMOUNT
Incineration	Clean Scrap Metal	377 Tonnes
Incineration	Ash/Slag/Refractory	5 Bags
Heat Treatment	Clean Scrap Vehicles	25 Tonnes
Neutralization[1]	Concrete-Stabilized Arsenic Salts	$100\ m^3$ 414 Barrels
Stabilization	Concrete-Stabilized Tank Sludge	$86\ m^3$ 43 Barrels
	Lagoon Sludge	209 Bags

1 Arsenic salts produced from neutralization of lewisite. Nerve agent neutralization produced secondary waste which was destroyed by incineration.

7.7.1 Analysis And Certification

Prior to disposal, batches of each type of waste were analyzed to confirm that no residual chemical agent contamination remained and that other hazardous substances such as heavy metals (e.g. arsenic, copper, lead) were within specified concentration limits. The CSL on-site laboratory, as well as a commercial laboratory (AGAT Laboratories, Calgary), were used to conduct routine analyses of various process streams and waste products. The analytical methods and sampling protocols used in the on-site laboratory are described in Annex C. A summary of the test methods employed for each class of final waste product is given in Table 7.10.

Table 7.10

SUMMARY OF CERTIFICATION METHODS

PROCESSED MATERIAL	SPECIFIED PROJECT LIMIT	METHOD	LABORATORY ANALYSIS
Scrap Metal	< 1 ppm Mustard	Batch Swab	GC/FPD[1]
Scrap Vehicles	< 1 ppm Mustard Organosulphate	Surface Swab	GC/FPD
Sludges	Metals[2] Dioxins/Furans[3]	Leachate Test Sample	AAS[4] GC/MS[5]
Stabilized Arsenic Salts	Metals	Leachate Test	AAS
Stabilized Sludges	Metals	Leachate Test	AAS

1 Gas chromatography with flame photometric detection (sulphur mode).
2 Leachate limits for metals as specified in Reference 58.
3 Limits for dioxins/furans in sludge as specified in Reference 58.
4 Atomic absorption spectroscopy
5 Gas chromatography with mass spectrometric detection.

For example [59], every fiftieth container of stabilized sludge and every tenth container of arsenic-stabilized waste were subjected to leachate tests in triplicate to certify that the batch materials were non-hazardous and suitable for landfilling. Typical leachate analysis results for a stabilized tank bottom sludge are shown in Table 7.11. With respect to the incinerated scrap metal, hexane-soaked cotton pads were used to take surface swab samples from batches of processed metal. The swabs were analyzed for mustard content using gas chromatography. Scrap metal mustard contamination was not found above the specified project limit (< 1 ppm), although one batch required re-processing due to evidence of other organo-sulphur compounds. Swab samples were also taken from various locations on the heat-treated vehicle parts and analyzed both for mustard and total organo-sulphur content. The results for the vehicle swab tests are given in Table 7.12. Prior to final disposal, the contractor certified the non-hazardous nature of the waste products.

Table 7.11

TYPICAL BLOWDOWN SLUDGE LEACHATE ANALYSIS

PARAMETER	CONCENTRATION (mg/L) MEASURED	ALLOWABLE LIMIT
Fluoride	0.05	150
Cyanide	0.002	20
Arsenic	0.065	5.0
Barium	0.26	100
Boron	0.29	500
Cadmium	<0.001	0.5
Chromium	0.025	5.0
Lead	<0.01	5.0
Mercury	<0.0001	0.1
Selenium	<0.002	1.0
Copper	<0.01	-
Silver	<0.01	5.0

7.7.2 Landfilling

A special landfill cell with the dimensions shown schematically in Figure 7.7 was constructed near the existing CFB Suffield landfill. This Figure also shows the arrangement for placing the plastic barrels and fibre bags containing concrete-stabilized waste. The cell was located just north of the access gate on Coyote Road, as shown on the map [60] in Figure 7.8.

Although all wastes scheduled for landfilling in the cell were non-hazardous, its construction followed the guidelines for landfilling hazardous waste [61]. The cell was of a conventional entombment design (see Figure 3, p. 15 of Reference 61) and did not incorporate an engineered liner for containment purposes. This use of a natural containment concept was possible because:

- favourable soil and groundwater characteristics existed at and near the landfill site. For example [13], the soil in the area is generally clay-like in texture with hydraulic conductivity in the range 10^{-6} to 10^{-7} cm/second. The water table is located at depths exceeding 20 m. Therefore, any fluid or water-soluble contaminants released would theoretically take more than 60 years to migrate to the water table. Many hundreds of years would be required for effluent concentrations to exceed current drinking water standards. It was noted that the groundwater itself was already of poor quality from natural mineralization;

Table 7.12

SCRAP VEHICLE SWAB TEST RESULTS

SWAB No.	SAMPLE LOCATION	CONCENTRATION ($\mu g/100\ cm^2$) MUSTARD	ORGANOSULPHUR
1	Vehicle Roof Exterior	<1	<1
2	Vehicle Fender Exterior	<1	<1
3	Vehicle Cab Interior	<1	<1
4	Melted Fuel Bowser Tank	<1	14.0
5	Vehicle Front Bumper	<1	<1
6	Vehicle Hood Exterior	<1	<1
7	Fuel Bowser Front Wheel Well	<1	<1
8	Fuel Bowser Frame	<1	<1
9	Cargo Truck Bed Interior	<1	<1
10	Truck Cab Back Exterior	<1	2.41
11	Tanker Truck Frame	<1	<1
12	Fuel Bowser Front Bumper	<1	<1

- the solid waste was highly resistant to leaching and each bag or barrel was the equivalent of a self-contained cell with a “liner” for the waste material;
- the amount of precipitation in the area is extremely low with the average evaporation rate of 90 cm/year greatly exceeding the average precipitation rate of 34 cm/year [13];
- natural water run-off in the area is away from the landfill site;
- The site is in an area already designated for landfill use.

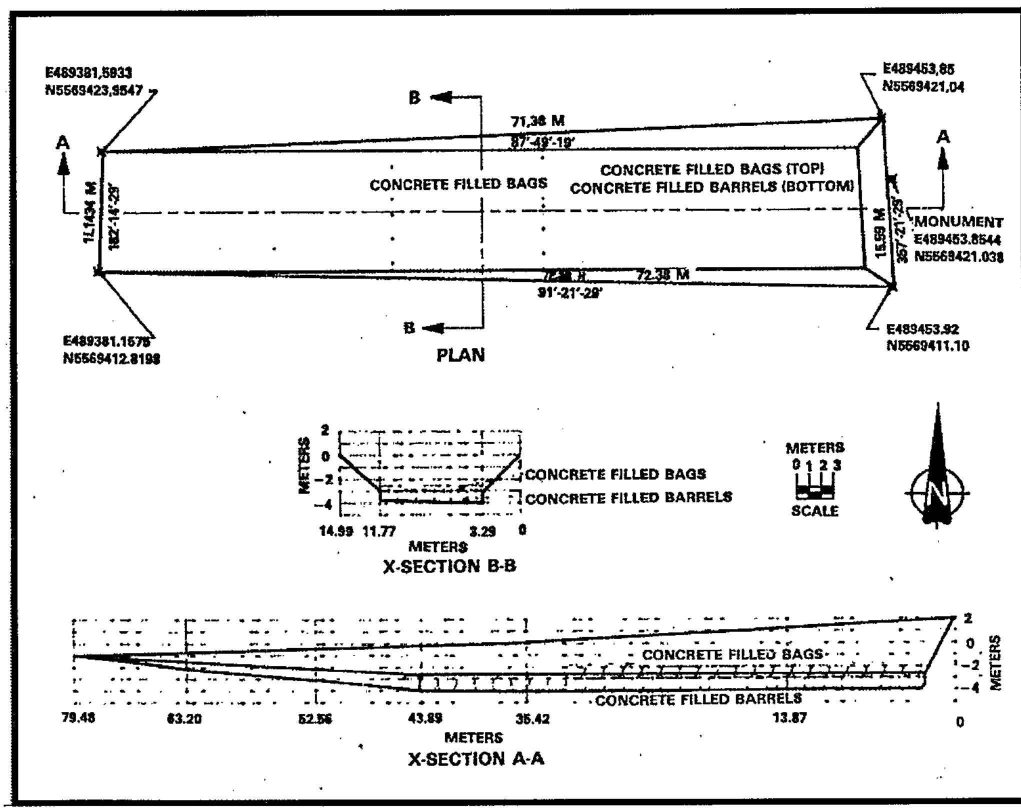
Plastic barrels containing concrete-stabilized arsenic salts were mounted on wooden pallets, 4 barrels to the pallet, and placed in the landfill cell starting at the deepest end (Figure 7.9). The barrels were then covered with fibre bags containing the concrete-stabilized tank bottom and lagoon sludges (Figure 7.10). Finally, bags containing incinerator ash and used refractory material were placed in front of the plastic barrel pallets at the shallow end of the cell. In total, the final waste products associated with Project Swiftsure consisted of 457 barrels and 214 bags placed into the cell in the manner described. The cell was then filled with compacted earth with the centre of the soil cover forming a shallow crown approximately 1 m above ground level.

The cell was marked with a plaque to designate its purpose and contents.

The barrels containing mustard hydrolysate residues recovered from the scrap vehicle treatment program (see Section 7.2.4 Waste Preparation), were placed in the 490 site pits from which the contaminated drums had been removed. Lime was added to the surface soil in the pits which were then filled in with additional soil and graded level. The cell was marked with a plaque to designate its purpose and contents.

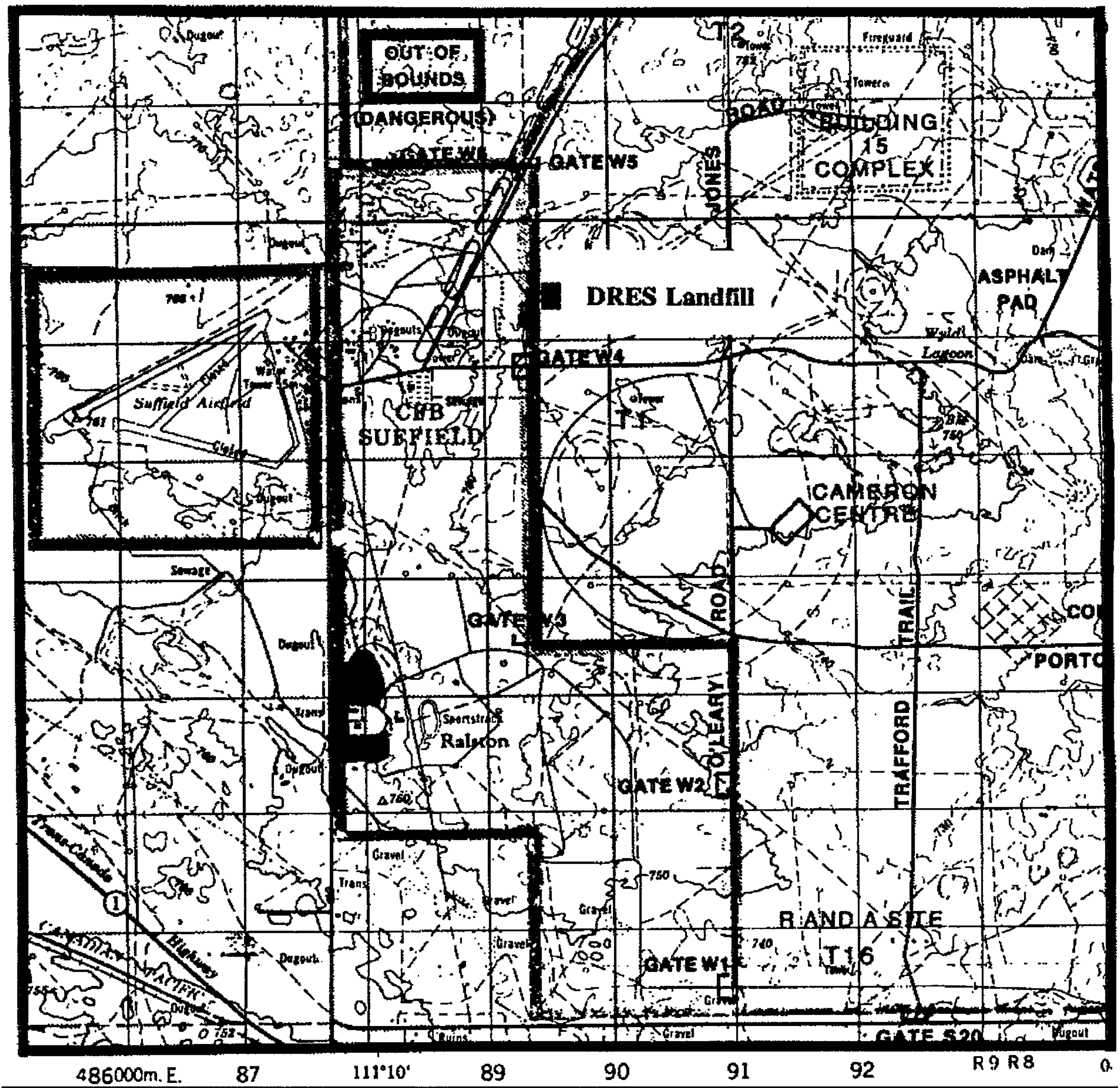
The barrels containing mustard hydrolysate residues recovered from the scrap vehicle treatment program (see Section 7.2.4 Waste Preparation), were placed in the storage pits from which the contaminated drums had been removed. Lime was added to the surface soil in the pits which were then filled in with additional soil and graded level.

Figure 7.7



Schematic Of DRES Landfill Cell For Disposal Of Project Swiftsure Final Waste Products

Figure 7.8



Location of Project Swiftsure Landfill Cell

7.7.3 Metal Recycling

The incinerated scrap metal (Figure 7.11), which consisted of drum shreds, ordnance bodies and metal pieces cut from larger items, was recycled rather than landfilled. Under contract, Canadian Consolidated Salvage, Edmonton, purchased the scrap and removed it to a regional foundry in Calgary for melting into metal feedstock. A total of 378 tonnes of metal was removed at a purchased value of approximately $29 per tonne (total purchase price of $11,000). The amount of metal recovered was very close to the processing weight estimated by CSL (377 tonnes).

Although certified as meeting project-specified limits for residual mustard agent contamination, the vehicle parts were not included in the metal consigned for recycling as this scrap had not been incinerated in the same manner as the other metal. Instead, the parts were removed to a secure area adjacent to the DRES landfill cell for outdoor storage. These and other scrap metal parts will be retained until sufficient material has accumulated to implement a metal recycling program in the future.

Figure 7.9

Concrete-Stabilized Arsenic Waste Barrels In DRES Landfill

Figure 7.10

Landfilled Project Swiftsure Concrete-Stabilized Waste

7.8 Progress Reporting

Constant communication between DRES project management and Chem-Security Ltd. officials took place to ensure maximum safety during waste disposal operations and effective utilization of available resources. For example:

- Formal meetings were held between DRES and CSL supervisory staff every Monday morning at the DRES Field Operations Section to discuss weekly schedules, contractual matters, progress in waste inventory destruction and operational problems. These meetings were supplemented by on-site meetings between DRES field supervisors and CSL supervisors at critical stages in waste destruction operations.
- Under the terms of their contract, CSL provided DRES with daily, weekly and monthly reports which summarized the activities undertaken in the given time period. The monthly reports gave updates on the waste inventory packaged and processed, described technical problems encountered and overcome, listed contractual issues resolved, and provided a schedule of activities planned for the following month.
- On behalf of DRES, the Project Swiftsure Manager produced status reports, first on a bi-weekly basis and then monthly, which were forwarded for information purposes to the Project Swiftsure Director and Associate CRAD in Ottawa.
- Prime contractors (e.g. CSL, RWDI) involved in Project Swiftsure produced technical reports which were provided to DRES and forwarded to Environment Canada for review purposes.
- Following completion of all operations, CSL provided DRES with a project summary report [62] which described the work carried out under contract, technology and procedures employed, modifications

to the scope of work, and which included a number of conclusions and recommendations made from a retrospective view of the entire project.

In addition to the formal reports described above, DRES issued news releases which described important events during the course of the project (see Section 9.6, Media Presentations).

7.9 Incidents

During the disposal of chemical agent waste, several incidents occurred which had potential to affect the health and safety of personnel or produce environmental impacts. These incidents resulted from procedural problems or equipment malfunctions. In each case, corrective action was taken immediately and a thorough investigation was undertaken with the aim of preventing similar incidents from occurring as the project proceeded. In many cases, the events were reported by the media either through issued news releases or independent reporting (see Table 9.6, Section 9.6 Media Presentations, for examples). The Swiftsure Project Manager immediately informed the Citizens' Environmental Protection Committee of any incident which was then discussed at the next meeting of the Committee.

Figure 7.11

Processed Scrap Metal For Recycling

7.9.1 Unknown Gas Exposure

Chem-Security Ltd. employed a back-hoe equipped with a special grapple to remove contaminated drums from the 490 Site storage pits. On 17 October 1990 during a drum removal operation from a pit which was partially filled with water, two fully-protected DRES employees working approximately 50 m downwind felt momentarily nauseous as an unknown gas penetrated their respirator canisters. Work was immediately suspended and the personnel involved were removed immediately to the Base Medical Clinic for a thorough examination. The two individuals recovered rapidly from their exposure. Air samples were collected from around the site and from air trapped in the drums, as the portable Chemical Agent Monitors at the site had not responded during the event. The analyzed samples showed no chemical agents or other organic compounds but did indicate elevated carbon monoxide and carbon dioxide levels. Although not conclusive, the results suggested that the long-stagnant water in the pit, when disturbed by the drum removal process, had released quantities of "swamp gas" (methane, carbon monoxide and other gases). Charcoal-based respirator canisters will not protect against such gases. To prevent a similar occurrence, staff were directed to always work upwind of the drum removal equipment.

7.9.2 Mustard Agent Exposures

In three separate incidents during waste preparation activities at the 490 Site, two CSL field workers appeared to have been exposed to low levels of mustard agent vapour. In the first incident (April 15), a field worker's respirator canister worked loose and fell off while he was packaging contaminated drum shreds. No immediate effects were observed; however, the following day the individual complained of eye irritation and a small blister developed on his nose. The individual was sent to Medicine Hat Regional Hospital for observation and then released for return to work. Eight days later (April 23), a second worker developed small blisters on his forearms after having carried out repair and maintenance work on the Transportable Shredder. Here, the problem was traced to the individual's protective suit which had been worn and over-laundered to the point where protective capability was lost. The worker was treated with the DRES-developed reactive skin decontaminant to accelerate the burn healing process.

Immediately after the second incident, DRES issued a stop order for all activities at the 490 Site and instructed CSL to review their safety procedures. Site operations resumed on 6 May after CSL instituted several changes to the protocols for wearing, laundering and re-using their protective suits. All respirator canisters were taped securely to their mounts to prevent loosening during field work. CSL also enlarged their 490 Site decontamination facility by placing a second trailer beside the first and connecting the trailers with a covered walkway. This arrangement improved the level of control for contaminated clothing surveys and separated the clothing donning and doffing areas from the rest areas.

The third incident (June 1991) occurred when a CSL employee tripped and fell on his knees while working at the 490 Site drum pits. The result was a small mustard blister which developed on one knee several days later. The cause was attributed to local mustard contamination on the ground being driven by the force of the fall through the worker's protective suit. CSL field staff were re-instructed on the importance of immediately changing contaminated protective clothing.

7.9.3 Explosive Munitions

Prior to starting packaging operations at the 490 Site, DRES and DND explosive ordnance specialists examined scrap materials, removed explosive items and packaged sorted scrap in "Tri-wall" boxes. However, despite this effort, CSL field staff encountered a number of explosive fuses which still remained with this scrap. This discovery alerted CSL staff to the possibility of finding other explosive items at this site. As packaging operations progressed, other fuses, live fuse ends, intact ordnance and blocks of TNT were found. The contract with CSL stated that DRES would remove all explosive items from the 490 Site prior to CSL commencing operations. However, DRES noted that at least year would have been required to certify the entire 490 Site as free-from-explosives, an unacceptable time frame given the project schedule and contractual obligations. Therefore, CSL and DRES developed an effective working arrangement whereby DRES explosives experts pre-inspected all materials scheduled to be handled by CSL, certifying each lot as explosives-free prior to CSL shipping the waste consignment to the Cameron Centre for processing.

7.9.4 Incinerator Stack Emission Excursions

During incinerator operations a number of temporary stack exhaust gas excursions occurred which caused Project Swiftsure emission limits for specific parameters to be exceeded. These excursions (3 x CO, 2 x SO_2, 1 x NO_x, 2 x HCl and 1 x Total Hydrocarbons) were duly reported by CSL to DRES and the information forwarded to Environment Canada. The excursions were of short duration (usually minutes) and resulted from such factors as equipment component failure, utility power outages, flame failure, or waste stratification causing scrubber system overload. One stack exhaust gas mustard concentration excursion was experienced upon restarting the incinerator system on emergency power after a utility power failure at the Cameron Centre.

The carbon monoxide excursions occurred during one night shift (16-17 April 1991) when the operators attempted to process boxes of shredded scrap at a rate which exceeded specified limits (4 boxes per hour). The SO_2 excursions (17 April 1991) were traced to a faulty pH controller on the scrubber system. The unit was repaired and a weekly preventative maintenance schedule instituted for this critical controller.

Ambient particulate concentration results obtained by the Western Research Air Quality Monitoring trailer at the Cameron Centre showed several instances where particulate levels exceeded project limits (see Section 8.5.2 and Table 8.21). However, events not associated with incinerator operations such as windy conditions or local activities creating excessive dust were believed to have caused the high particulate readings.

Ambient air quality surveys conducted in May 1991 around the Cameron Centre using the mobile laboratory twice showed trace quantities of mustard vapour (see Section 8.4.2). These emissions were attributable to incinerator processing delays which had allowed several boxes of contaminated shreds located in the Contaminated Materials Laydown Area to deteriorate. These boxes were removed to the 490 Site and re-packaged. A longer term solution to this problem was provided by using a waterproof tarpaulin to cover the boxes during storage at the Cameron Centre.

7.9.5 Incinerator Lead Slag

During commissioning tests and trial burns, CSL experienced no difficulties in achieving project limits for dissolved metals in the incinerator scrubber blowdown water. However, starting in May 1991, the sudden appearance of high levels of lead in the blowdown led to a change in the operating conditions for the rotary kiln. It was believed that the lead was the result of a slag build-up in the kiln from processing items such as Flying Cows which contained lead nose cones. Appearance of lead in the scrubber blowdown resulted from operating the kiln at temperatures above the melting point of lead (>1000 ^{o}C) causing vaporization and carry through of the metal. On several occasions, CSL shut down the incinerator system and attempted to physically remove the slag from the refractory lining of the kiln. CSL also instituted a change in operating conditions such as decreasing the kiln temperature to approximately 800 ^{o}C (while leaving the secondary combustion chamber at 1200 ^{o}C) to take advantage of the vapour pressure curve for lead and treating the incinerator wastewater to remove lead prior to discharge to the lagoon (see Section 7.6.1, above). Ultimately, the lagoon water itself was subjected to an extensive remediation program to remove excess lead content.

7.9.6 Lewisite Reactor Explosion

This incident occurred on 3 November 1991 during decommissioning of the lewisite neutralization unit. To decontaminate interior components, the unit was flushed with a 30% hydrogen peroxide solution which was found to be acidic after circulating thoroughly through the system. CSL attempted to neutralize this solution within the unit by adding the alkaline fluid remaining from the last batch of lewisite neutralization (step 3 solution). An overpressure developed in the reactor vessel which caused the lid to blow off. Personnel working nearby were not injured by the reactor lid; subsequent analysis of the remaining fluid and the surrounding soil demonstrated that no adverse environmental impact had occurred from the incident and that decontamination of internal system components was complete. It was determined that water had frozen within the unit under the cold ambient conditions and had disabled the pressure-relief valves. The exterior of the neutralization unit was washed down with a bleach solution to complete the decontamination program.

7.9.7 Arsenic Waste Storage Building Fire

The arsenic waste recovered from the lewisite neutralization process was stabilized in concrete, using plastic barrels as forms while the concrete cured and hardened. Under warm ambient conditions, barrels were usually placed outdoors and the concrete allowed to cure over a 48-hour period. During this process, small quantities of a combustible gas (acetylene) are released to the atmosphere.

On 29 November 1991, CSL utilized a Cameron Centre utility building to store 104 barrels of stabilized arsenic waste, as cold outdoor temperatures prevented proper curing of the concrete mixture. After placing the barrels in the building, the doors were closed and the natural gas-fired building heaters were turned up to maximum to accelerate the curing process. During the early morning hours, an explosion occurred which blew out the main door of the building and caused some of the plastic barrels to ignite and burn. No one was injured in this incident and the night shift emergency response team were able to quickly extinguish the barrel fires. Damage to the building was confined to the door and some burned insulation near the ceiling-mounted heaters; CSL undertook all repairs to restore the building to its original condition.

The likely cause of the explosion within the building was the release and build-up of acetylene gas which was then ignited by the building heaters.

Following this incident, all remaining barrels of arsenic waste were cured and hardened outdoors by covering the barrels with a tarpaulin and directing hot air under the cover from a diesel-fired portable generator.

7.9.8 Miscellaneous Incidents

Despite the hazardous nature of the waste feedstock, CSL did not incur any Lost Time Accidents directly attributable to explosives or chemical warfare agents. Two lost time accidents did occur; in one case a CSL employee overexerted himself and developed a ruptured inguinal hernia while lifting a trailer hitch while another employee suffered a bruised knee while handling a large piece of scrap steel. In other incidents, damage to government-owned equipment occurred. For example:

- Overpressure developed in the rotary kiln when a large, congealed piece of incinerator slag/ash was discharged into the water-submerged ash wheel. The kiln was shut down for several hours to repair minor damage to the ash wheel retaining skirt;
- A vehicle was backed into the incinerator building wall, causing some superficial damage. The wall was repaired shortly after the incident;
- A number of CSL project vehicles suffered minor damages due to traffic accidents off-site.

In all cases, CSL undertook steps to prevent further such occurrences as the project proceeded, including staff briefings and issuance of safety instructions.

7.10 Decommissioning Activities

Following completion of waste processing in late November 1991, the incinerator was subjected to a high temperature (>1000 ^{o}C) "burn-out" where the system was operated solely on natural gas fuel for two days. After cooling, exterior surfaces of the incinerator, ram feeder and program control console were decontaminated using a combination of steam and bleach solution. Exterior surface swab samples were taken of the ram feeder and ash discharge chute and analyzed to confirm the absence of any contamination. Portable CAMs were also used to survey various equipment items to confirm that no residual mustard vapour hazards existed. The natural gas, water and electrical supplies were then disconnected from the incinerator to render the unit non-operational.

During incinerator decommissioning, all equipment at the waste storage sites such as the Transportable Shredder, service vehicles and trailers were decontaminated by CSL using steam and bleach solution. The washings and waste water from this process were collected, analyzed for any possible mustard contamination and discharged to the Cameron Centre lagoon.

Each Project Swiftsure site was inspected by CSL and DRES staff to determine that contractual obligations had been fulfilled. Following agreement and resolution of any outstanding issues, CSL issued certificates of completion for each of the sites. On 6 January 1992, a general Certificate of Completion was issued by DRES to CSL which stated that all contractual obligations with respect to Project Swiftsure had been satisfied and that all specified deliverables and equipment on loan had been transferred to the custody of DRES.

7.11 Incinerator Removal

Destruction of the chemical agent waste inventory was completed successfully by the end of 1991, in accordance with the Minister of National Defence directive. However, the removal of the incinerator, as promised during public meetings on Project Swiftsure, remained an issue until a final decision on its disposition was made in March 1992.

In August 1991, the United Nations (UN) approached Canada with the possibility of using the Project Swiftsure incinerator to destroy Iraq's chemical weapons inventory. At the time, the UN was examining the use of such incinerator technology to meet the requirements of Security Council Resolution 687, which required Iraq to declare and yield for disposal all of its weapons of mass destruction. Canada agreed to offer the Swiftsure incinerator to the UN pending the completion of waste destruction operations at DRES. Ultimately, the UN decided that Iraq would conduct chemical agent destruction operations under UN supervision, using available Iraqi equipment and personnel. A letter was forwarded to Canada in February 1992 which stated that the offer to use the Swiftsure incinerator would not be pursued further.

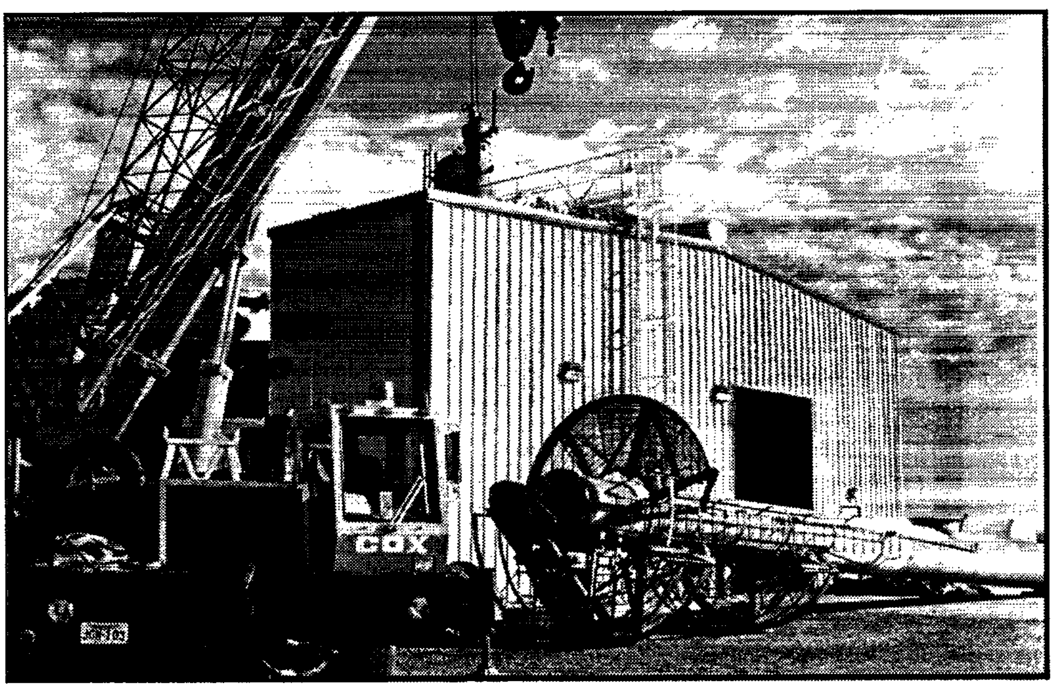
In the interim and following the UN decision, DRES made arrangements to sell the incinerator to private industry through Supply and Services Canada, Crown Assets Distribution Centre, Edmonton. The incinerator was advertised for sale in several trade magazines during February - March 1992 and the incineration system was formally declared surplus to Crown Assets on 2 April 1992. A bid package was prepared and issued on 14 April 1992 with a closing date of 14 May 1992. Equipment viewings were held at DRES on 1 - 8 May 1992 to allow potential buyers to prepare bid submissions.

Considerable interest was expressed in the incinerator and six companies sent representatives to view the equipment. When tenders closed on 14 May 1992, two bids were received, both of which were deemed unacceptable for technical reasons. Therefore, Crown Assets re-offered the incinerator for sale with a closing date of 11 June 1992.

Three bids were received in response to the second offer. The incinerator and auxiliary equipment were sold to C.B.H. Canada Resources Inc., Red Deer, Alberta for $255,100.00, the highest acceptable bid received.

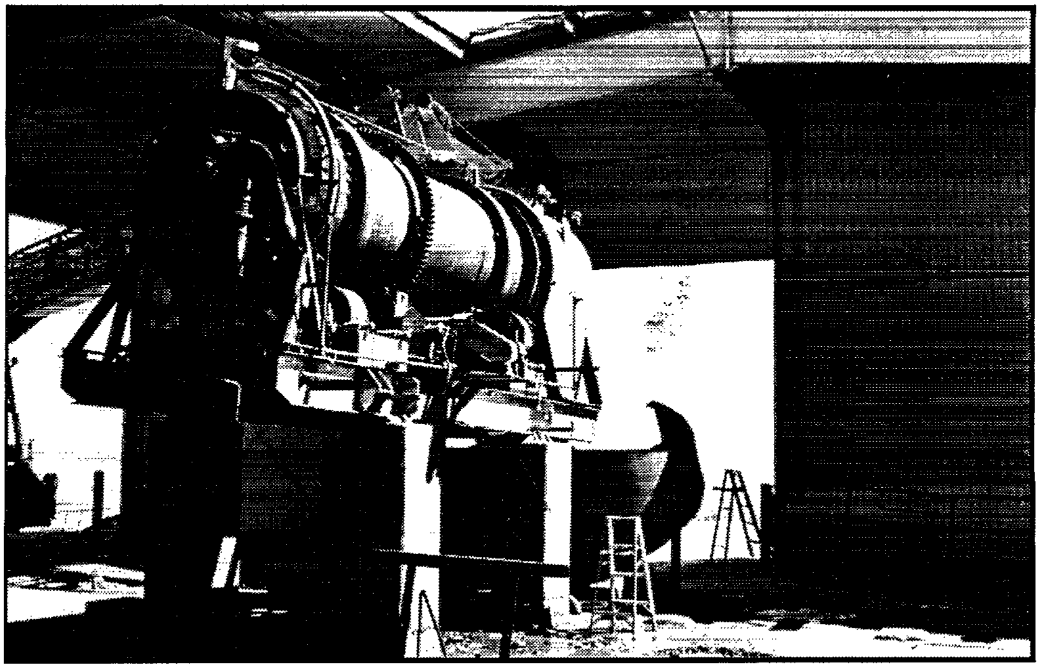
During the equipment removal process, C.B.H. Canada Resources set up a temporary office at the Cameron Centre to provide on-site management. The initial stage of the process involved disconnecting electrical, fuel and water supplies and removing smaller pieces of equipment. A side wall of the thermal destruction building as well as a portion of the roof were then temporarily removed to allow the major incinerator items to be moved outside and placed on transport trucks. As shown in Figures 7.12 and 7.13, large cranes were used to lift and remove the equipment through these openings. The concrete support piles for the rotary kiln were removed (Figure 7.14) and, following the complete removal of all equipment items, the building wall panel and roof portions were replaced. Other holes in the building structure, including openings for the main stack ductwork, exhaust holes for the emergency generator and utility piping holes, were sealed off. The incinerator removal and site clean-up operations were completed by 7 August 1992.

Figure 7.12



Secondary Combustion Chamber And Emergency Vent Stack Removal

Figure 7.13



Rotary Kiln Readied For Removal

Figure 7.14

Rotary Kiln Support Piles Removed

Project Swiftsure Final Report

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CHAPTER VIII
ENVIRONMENTAL MONITORING PROGRAM

8.0 ENVIRONMENTAL MONITORING PROGRAM

8.1 Background

Modern incinerators such as the Swiftsure incinerator are highly efficient and representative of the best available technology. However, such equipment is not 100% efficient and, therefore, some discharge of contaminants to the environment was expected during processing of chemical agent waste. A monitoring program was implemented to ensure these discharges were not hazardous to human health nor detrimental to the natural environment. The aims of this program were to:

- monitor incinerator stack emissions produced during the processing of chemical agent waste;
- determine the impact of such emissions on air quality near the incinerator facility and in district communities, and
- verify that contaminant concentrations were within the limits set for the project by Environment Canada and Alberta Environment (see Table 2.4).

The monitoring program involved retrospective air sampling and analysis as well as the use of fixed and mobile monitoring equipment which could instantaneously detect airborne emissions. Special activities were included to satisfy the interests of the Citizens' Environmental Protection Committee: for example, the monitoring of dioxins/furans in the incinerator scrubber blowdown and in the ambient environment near the incinerator facility. Other related activities included the analysis of incinerator particulate emissions and scrubber blowdown for metal content.

8.2 Program Scope

The agencies involved in the environmental monitoring program included DRES, and Chem-Security/Western Research, who conducted monitoring activities in the vicinity of the Cameron Centre, as well as an independent contractor hired to carry out more extensive surveys on the DRES EPG and in district communities. Reports which presented the results of the various monitoring programs were supplied to the federal and provincial environmental agencies and to the citizens' committee for review as soon as the reports became available. The environmental agencies opted to forgo their own monitoring in view of the project monitoring program in place.

Environmental monitoring included the following activities:

- Portable Chemical Agent Monitors (CAMs, see Figure 3.5) were used by DRES and Chem-Security Ltd. personnel to conduct surveys of storage sites, neutralization facilities, field packaging operations and the incinerator site. These devices were operated whenever the possibility of fugitive agent vapour emissions existed (e.g. during packaging operations) and to confirm that personnel decontamination was being carried out properly.

- DRES developed, installed and operated a fixed array of eight CAMs at the incinerator site to continuously monitor for fugitive agent emissions (See Section 6.4 Incinerator Emissions Monitoring Systems). No actual chemical agent alarms were recorded by this array over the course of the project. On a few occasions during warmer weather, CAMs located near the vicinity of the Cameron Centre Contaminated Materials Laydown Area produced short-lived, intermittent responses at the minimum ("one bar") level (see below, Field Monitoring Program Results). An advanced development model of the prototype Swiftsure CAM array, the Chemical Agent Detection System Mark II (CADS II), was successfully deployed to support the Canadian Forces during the 1991 Gulf Crisis.
- As previously described (Section 6.4), a Continuous Stack Emissions Monitoring (CSEM) system was supplied with the incinerator. This system continuously measured stack concentrations of mustard, particulates, mustard combustion products (SO_2 and HCl), carbon monoxide, total hydrocarbons, oxides of nitrogen as well as flue gas oxygen content and temperature. Chem-Security Ltd. routinely updated and reported information from the CSEM system using a computer-based Data Acquisition System located within the incinerator building. Using the CSEM system, the operational performance of the incinerator was readily determined during the processing of chemical agent waste.
- During incinerator trial burns, an extensive stack sampling program was carried out by Western Research to supplement the data acquired with the CSEM system and to verify that the incinerator was capable of achieving the emission standards set for the project. This program involved acquiring in-stack samples and subjecting these to detailed retrospective analysis according to protocols recognized and approved by the environmental agencies. Samples were analyzed for the same combustion gases monitored by the CSEM system as well as for mustard, dioxins/furans and metals. The composition of collected particulate matter was also determined. The results of the trial burn stack sampling program were described previously (See Section 6.10, Trial Burn Results).
- Chem-Security Ltd. collected batches of scrubber blowdown and forwarded these to a commercial laboratory (AGAT Laboratories, Calgary) for analysis of organics and metals (arsenic, copper and lead) prior to discharge of the fluid to the Cameron Centre lagoon. The samples were taken either from the temporary storage tanks containing blowdown batches or directly from the scrubber system re-circulating loop. A sampling and analysis plan was devised by DRES to assist Chem-Security screen and analyze scrubber blowdown samples for the possible presence of dioxins and furans should the blowdown contain organic compounds. During the course of Project Swiftsure, only one sample was forwarded to

DRES for such screening; this sample was found to be free of dioxins and furans or any agent-related compounds.

- The citizens' committee technical consultant occasionally visited the incinerator facility and selected samples of scrubber fluid at random for dioxin/furan analysis at an independent laboratory (Zenon Labs, Vancouver, B.C.).
- Western Research installed an instrumented Air Quality Monitoring (AQM) trailer (see Figure 6.8) downwind of the incinerator at approximately 100 m in the prevailing wind direction (see Sections 6.2 and 8.5 for further details). The AQM trailer provided a daily record of meteorological conditions as well as air quality data with respect to SO_2 and oxides of nitrogen. Samples of particulate matter were collected on filter media to determine ambient particulate concentrations at this site.
- A mobile laboratory (Figure 8.1) was operated by an independent contractor (i.e. not associated with Western Research Partnership) to monitor air quality near the incinerator facility and in district communities surrounding the DRES EPG. The mobile laboratory is fully described elsewhere [63]. This unit, which was operated by Canadian Environmental Monitoring under sub-contract to Rowan Williams Davies Irwin, Inc. (RWDI), contained identical instrumentation to that used in the incinerator CSEM system. For example, the mobile laboratory could monitor continuously for the following parameters: mustard, SO_2, HCl, oxides of nitrogen, carbon monoxide, and particulates.

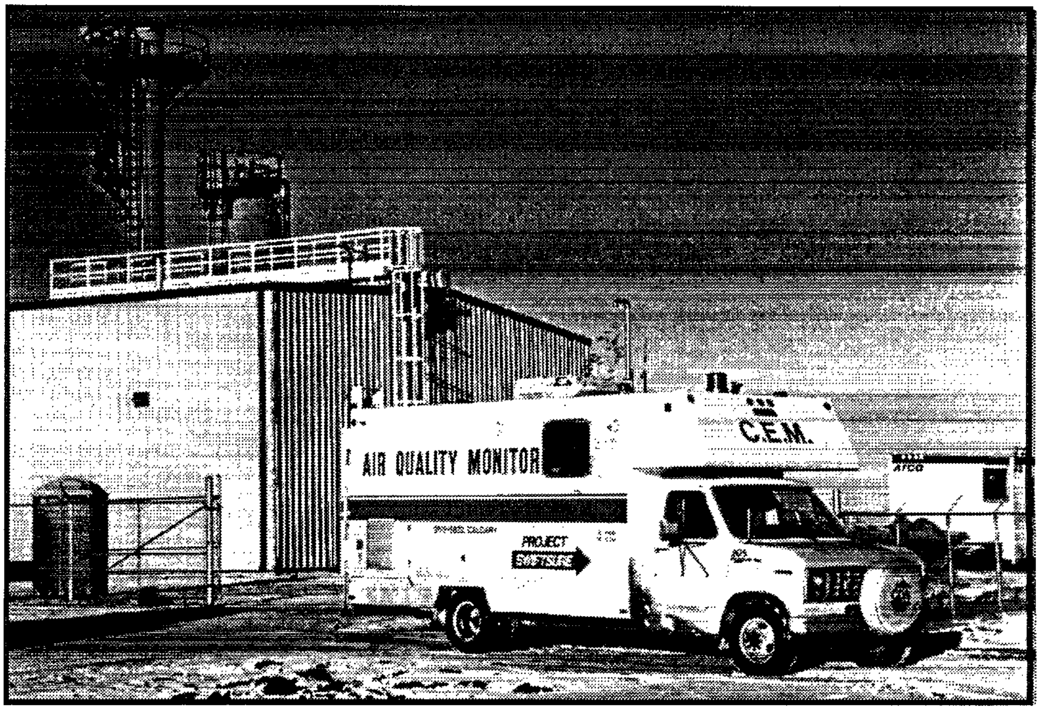
The mobile laboratory was also capable of collecting air samples through an adsorbent cartridge for retrospective analysis of organic compounds. The laboratory also included on-board power supplies, meteorological sensors, calibration systems, computing systems and communication links.

In support of the environmental monitoring program, RWDI developed a computer-based dispersion model (EVENT) which was used to optimize the location of the mobile laboratory downwind of the incinerator [63]. This model also enhanced the project emergency response capability; for example, in the event of an emergency, maximum agent concentrations could be pinpointed and concentration profiles displayed under continuously updated meteorological conditions.

- RWDI installed a fixed array of three high-volume air samplers at the incinerator site to collect air samples for retrospective analysis of airborne particulate matter (metal content) and dioxins/furans. This system enabled the environmental impact of incinerator operations to be further quantified with respect to particulate emissions.
- RWDI installed meteorological equipment on a 100 m tower located east southeast of the Cameron Centre on the DRES EPG. This equipment provided continuous meteorological information in support of the various monitoring programs. Sensors mounted on the tower measured the following parameters: wind speed, wind

direction, air temperature at three elevations, soil temperature at two depths and ambient relative humidity. Dew point estimates were calculated from the temperature and relative humidity readings. A data logger controlled all data acquisition; this system performed data collation, scaling and computing tasks and could be readily accessed through a modem and cellular telephone link for remote transmission of meteorological information.

Figure 8.1



Mobile Air Monitoring Laboratory

8.3 Independant Field Monitoring Program

8.3.1 Overview

RWDI carried out the field monitoring program under SSC Contract W8464-0-KA11/01-XSG, "Air Quality Monitoring During Operation Of The DRES Hazardous Waste Incinerator", using the mobile air monitoring laboratory and the high-volume air samplers supported by meteorological data acquired at the EPG tower. Under this contract, RWDI designed a program which verified that incineration operations were not producing emissions which exceeded the air quality limits set for Project Swiftsure. The program commenced in December 1990 and continued through to August 1991, during which time incinerator trial burns were completed and the bulk of the agent waste was incinerated under operational conditions. RWDI also responded to air quality-related issues raised by the public and by the Citizens' Environmental Protection Committee and confirmed through acquired monitoring data that unsafe conditions or non-compliance with respect to the air quality limits were not occurring during chemical agent waste destruction. The program was also used to monitor the safety of field waste packaging operations, the handling and storage of agent-related feedstock and the explosive destruction of unsafe ordnance at the 14 Alpha site.

8.3.2 Work Packages

The work program was designed to monitor air quality downwind of the incinerator at specified distances and locations on the DRES EPG and in district communities. Individual Work Packages were drawn up by DRES in consultation with RWDI that described specific air quality monitoring surveys. As listed in Table 8.1, a total of seven Work Packages were implemented in which the mobile monitoring laboratory was deployed; two of these involved community-based monitoring while the other five involved monitoring on the DRES EPG. Typical Work Packages for Community monitoring and DRES EPG monitoring surveys are described in Annexes C and D, respectively. Data on normal air quality in communities and on the DRES EPG were acquired during Work Packages 1C and 1D, respectively. During agent waste processing, measurements were made before and during incinerator operation to compare with previously-acquired data and to determine the impact of emissions on normal air quality.

Air quality surveys were not undertaken continuously throughout Project Swiftsure for practical and economic reasons. For example, the incinerator was shut down periodically to perform scheduled maintenance, repairs and conduct systems tests which did not involve waste processing (see Table 7.3). These operations were not expected to produce an impact on air quality. Therefore, once baseline information on normal air quality had been acquired (i.e no incineration activity), intense monitoring and data collection Work Packages were scheduled to coincide with critical incinerator operations such as trial burns and processing contaminated scrap metal. All surveys consisted of a number of continuous days of mobile monitoring (e.g. 10 to 25 days).

Air quality measurements were made continuously whenever possible during each Work Package. Normally, the mobile laboratory was manned from 0830 hours to 1600 hours during each work day. After working hours, the unit was usually parked at the Cameron Centre near the incinerator building and placed in a mode which allowed monitoring and sampling to continue automatically. Additional monitoring data, either baseline or emissions-related, was thereby provided depending on the prevailing wind direction and the operational status of the incinerator. The laboratory was removed occasionally to Calgary for vehicle repairs and maintenance, upgrades to the monitoring equipment or during extended periods of incinerator inactivity.

The mobile laboratory measured air quality with respect to the following parameters of interest: sulphur dioxide (SO_2), hydrochloric acid (HCl), oxides of nitrogen (NO, NO_2 and NOx), carbon monoxide (CO), total suspended particulate matter (TSP) and mustard (HD). A description [63] of

Table 8.1

INDEPENDENT AIR MONITORING PROGRAM WORK PACKAGE SUMMARY

WORK PACKAGE	TYPE[1]	INCLUSIVE DATES	NUMBER OF DAYS	INCINERATOR ACTIVITIES
1D	EPG	3-14 Dec 1990	10	Under Construction
1C	Community	7-18 Jan 1991	10	Under Construction
2D	EPG	14 Jan - 15 Feb 1991	20	Commissioning Tests
3D	EPG	25 Feb - 29 Mar 1991	25	Commissioning Tests Trial Burns Scrap Metal Processing[2]
2C	Community	8 - 19 April 1991	10	Maintenance Scrap Metal Processing
4D	EPG	29 Apr - 7 June 1991	19	Maintenance Scrap Metal Processing
5D	EPG	8 - 19 Aug 1991	10	Scrap Metal Processing

1 Work Packages involved monitoring air quality either in the vicinity of the incinerator facility (EPG Package) or in district communities surrounding the DRES EPG (Community Package).

2 Included mustard-contaminated inventory items and mustard-contaminated scrap metal.

the monitoring equipment used is given in Table 8.2. At any given location, the concentration of each parameter was measured continuously over a minimum period of one hour. The one-hour average concentration for each parameter was then compared to the air quality limits specified for Project Swiftsure, as listed in Table 2.4.

Interim reports containing monitoring data, data summaries and analyses were provided by RWDI simultaneously to DRES and to the Citizens' Environmental Protection Committee (CEPC) following completion of each mobile monitoring survey [64-70]. The RWDI project manager also attended several CEPC meetings to report on Work Packages and to receive input or address concerns raised by the group with respect to the field monitoring program. For example, two additional surveys were implemented which involved use of the high-volume air sampling array to collect samples for the analysis of airborne metals and dioxins/furans. Both interim and final reports [71,72] were issued with the results of these additional surveys.

Table 8.2

AIR QUALITY MONITORS USED IN THE PROJECT SWIFTSURE MOBILE MONITORING LABORATORY

PARAMETER	INSTRUMENT	OPERATING PRINCIPLE	MINIMUM DETECTION LIMIT	PRECISION
Sulphur Dioxide	Dasibi 4108	Pulsed Fluorescence	1 ppb	1 ppb
Hydrogen Chloride	Interscan 1360	Electrochemical Sensor	0.02 ppm	±1%
Oxides of Nitrogen	Monitor Labs 8840	Chemiluminescence	0.002 ppm	±1%
Carbon Monoxide	Monitor Labs 8830	Infrared Correlation	0.1 ppm	0.1 ppm
Particulates	TEOM 1400	Microweighing	5 $\mu g/m^3$	5 $\mu g/m^3$
Mustard	CMS FM1001A	GC/FPD[1]	<0.1 $\mu g/m^3$	n/a

1 Gas chromatography with flame photometric detection (sulphur mode).

8.3.3 Community Liaison

RWDI retained Acres International Ltd., Calgary, to provide a community liaison service during visits of the mobile monitoring laboratory to district communities (Work Packages 1C, 2C). This service complemented the larger Project Swiftsure public consultation program which was ongoing at the same time.

Working together with DRES and Venture Communications Ltd., Acres finalized a list of community contacts in December 1990. This list [63] included mayors, community officials, town council members and the CEPC chairman. Before starting community air quality monitoring, Acres advised the contacts by letter and follow-up telephone call of the aims of the Project Swiftsure environmental monitoring program and the reasons for conducting air sampling in their community. The schedule for the mobile monitoring laboratory was also provided. Invitations to visit the unit whenever it was operating in a particular community were extended to the general public. As part of the Swiftsure public consultation program, advertisements were placed in local newspapers in order to inform the public of the program and the monitoring schedule. An example of a community monitoring advertisement is shown in Figure 8.2. A brochure was also prepared by Venture Communications (see Section 9.7) which described the air monitoring program. This brochure was made available in district communities as a hand-out to assist in answering specific questions on the Project Swiftsure air quality monitoring program.

Figure 8.2

Independent air monitoring for Project Swiftsure gives additional level of confidence

An independent, mobile air monitoring lab will sample ambient air during all phases of Project Swiftsure. The lab has begun the job of gathering information on air quality on the CFB Suffield range and in communities around the range. The mobile air monitoring lab will be a frequent visitor to CFB Suffield and area communities over most of 1991.

Defence Research Establishment Suffield introduced the independent air monitoring program to provide an additional level of public confidence in the monitoring of Project Swiftsure-a chemical agent waste disposal program planned to be completed before the end of 1991.

The mobile lab is operated by Canadian Environmental Monitoring and provides independent, real-time data on local ambient air quality. The monitoring program will measure air quality before, during and after the job. The entire project is proceeding under an Environmental Protection Plan approved by Environment Canada, Alberta Environment, Health and Welfare Canada and Department of National Defence.

The appearance of the mobile monitoring lab in or around your community does not indicate something is wrong. Instead, it's there to monitor the air so the public can be assured that incinerator emissions are within acceptable limits and pose no safety or health hazard.

If you want more information about Project Swiftsure, or the independent air monitoring program, call the Project Swiftsure Information Line toll-free at 1-800-661-6510.

Published in the public interest
by Defence Research Establishment Suffield

Community Air Monitoring Program Advertisement

Acres placed over 100 telephone calls in support of the community liaison service. The company also sent out over 35 correspondence letters which addressed specific scheduling and information requests outside of the scope of the material provided in the hand-outs.

Detailed discussions of the monitoring programs took place during CEPC meetings; thus, the local news media in attendance reported the results of each community air quality survey on a regular basis. The capabilities of the mobile monitoring laboratory were demonstrated for Brooks town council and CEPC members during a CEPC meeting held in Brooks on 3 October 1991.

Public reaction to the community monitoring and overall environmental monitoring program for Project Swiftsure was generally positive, especially once the program was fully explained and advertised. This high-visibility approach was successful in providing public assurance that the chemical agent waste incineration was being carried out safely without health or environmental risks.

8.3.4 Baseline Air Quality Surveys

The DRES EPG is an area free of industrial activity and can be considered a typical rural setting. The air quality monitoring program covered both this area as well as several nearby district communities. The larger communities such as Medicine Hat and Brooks are typically urban. Therefore, it was important to acquire baseline air quality data from the EPG and from the communities before commencing incinerator operations in order to determine the true impact of the incinerator emissions. It was also important to determine whether the district communities were affecting EPG air quality.

Several of the incinerator emissions monitored by the mobile laboratory, for example SO_2, CO, and particulates, are known to be present in the atmosphere as naturally-occurring trace constituents. Typical atmospheric concentrations in areas far removed from human activity and industry (e.g. wilderness parks) have been reported as follows:

- sulphur dioxide — 0.1 to 10 ppb [73]
- total suspended particulates — 10 to 100 $\mu g/m^3$ [73]
- carbon monoxide — 0.1 to 0.2 ppm [74]
- nitrogen oxides (e.g. NO_2) — 0.1 to 0.5 ppb [75]
- hydrogen chloride — < 2ppb [76].

Mustard chemical agent is not found in the natural environment; therefore, detectable levels of mustard were not expected during background air quality surveys.

Background levels of SO_2 and NO_2 typical of rural Alberta have been reported for an Acid Deposition Research Program site at Fortress Mountain, west of Calgary [77]. The mean concentrations at this site over a two-year period were 0.33 ppb and 1.2 ppb for sulphur dioxide and nitrogen dioxide, respectively.

For comparison to the Project Swiftsure air quality measurements, data from nearby urban centres in Alberta and Saskatchewan are presented in Table 8.3. The information is taken from the 1988 monitoring report for the Canadian National Air Pollution Surveillance Network in the cities of Calgary, Edmonton and Saskatoon [78]. The maximum hourly, daily and annual mean concentrations for SO_2, CO, NO_2 and total suspended particulate matter are reported in this Table where data is available. The monitoring sites chosen for these cities were located in either residential or commercial areas.

Table 8.3

PEAK URBAN AIR QUALITY LEVELS - 1988

PARAMETER	AVERAGING TIME	LOCATION[1]				
		A	B	C	D	E
Sulphur Dioxide (ppm)	1 Hour	0.02	n/a	n/a	n/a	n/a
	24 Hours	0.00	n/a	n/a	n/a	n/a
	Annual	0.00	n/a	n/a	n/a	n/a
Carbon Monoxide (ppm)	1 Hour	6	26	26	13	34
	24 Hours	2	9	6	4	11
	Annual	0.4	1.3	1.5	0.7	1.7
Nitrogen Dioxide (ppm)	1 Hour	0.11	0.10	0.13	013	0.19
	24 Hours	0.04	0.05	0.06	0.05	0.07
	Annual	0.017	0.020	0.028	0.019	0.035
Total Suspended Particulates ($\mu g/m^3$)	24 Hours	226	117	209	163	95
	Annual Mean	41	39	60	72	38

1 Locations are as follows:
A. Idylwyld Drive and 33rd Street, Saskatoon, Saskatchewan.
B. 127th Street and 133rd Avenue, Edmonton, Alberta.
C. 10255 - 104th Street, Edmonton, Alberta.
D. 39th Street and 29th Avenue SW, Calgary, Alberta.
E. 611 - 4th Street SW, Calgary, Alberta.

8.4 Field Monitoring Program Results

8.4.1 Community Monitoring Surveys

Air quality measurements were conducted in district communities during two separate Work Packages. Figure 8.3 shows the locations of those communities surrounding the DRES EPG where the mobile laboratory was used to monitor air quality. Work Package 1C, which was carried out over the period 7 - 18 January 1991, provided 10 days of community background air quality data prior to the start-up of the Swiftsure incinerator. Work Package 2C covered the period 8 - 19 April 1991 and provided 10 days of air quality data during incinerator operations for comparison to the previously-collected background data. Monitoring was performed in selected communities downwind of the incinerator according to the prevailing wind direction.

The following parameters were monitored continuously during Work Package 1C:

- ❖ sulphur dioxide;
- ❖ carbon monoxide;
- ❖ nitric oxide;
- ❖ nitrogen dioxide, and oxides of nitrogen.

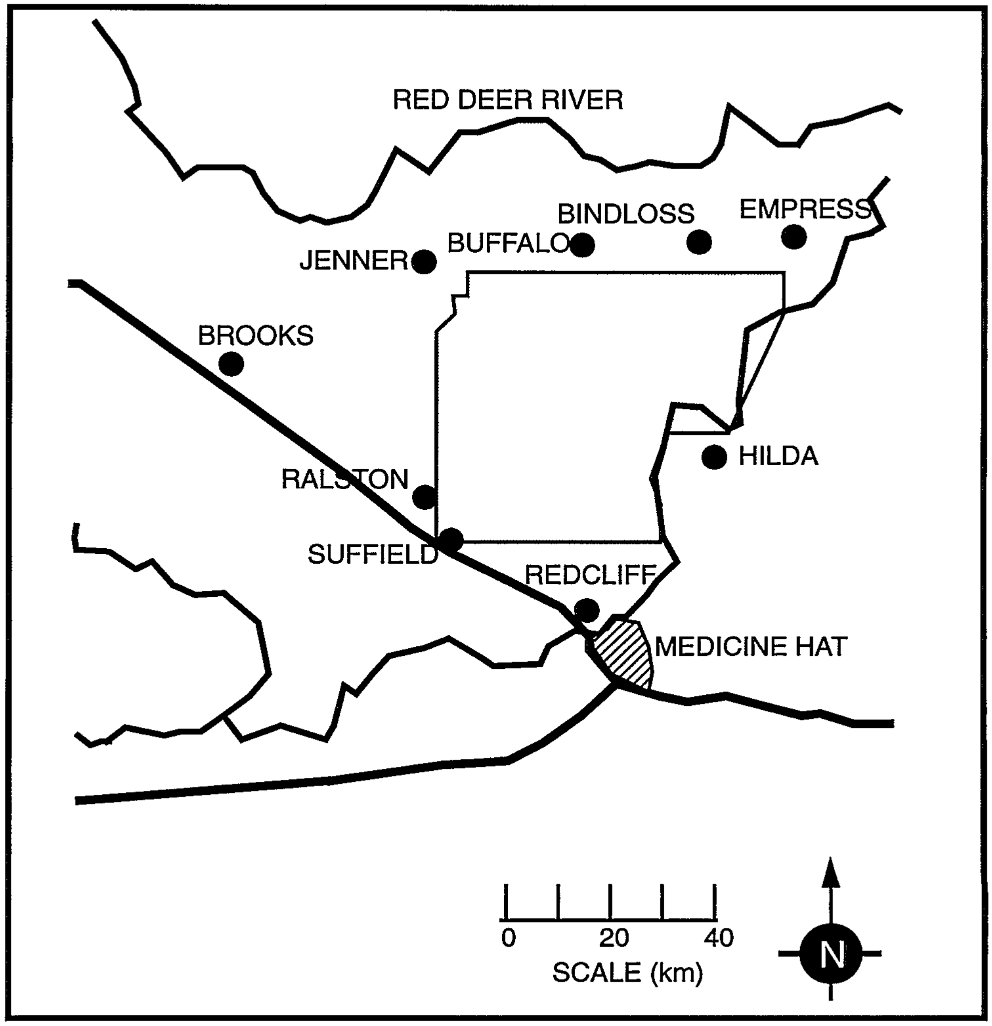
Monitoring for particulates, hydrogen chloride and mustard was not carried out as the appropriate equipment was unavailable at the start of this Work Package. Instead, volatile organic samples were taken at different times using adsorbent tubes. In each case, the tubes were analyzed for the presence of mustard. A total of six tubes were each exposed to the ambient air for a period of approximately 8 hours at a flow rate of 100 mL/minute.

For Work Package 2C, all of the above parameters as well as hydrogen chloride and total suspended particulate matter were monitored. One volatile organic sample tube was exposed to the ambient air for approximately 8 hours at 100 mL/minute and subsequently analyzed for mustard.

During these Work Packages, considerable travel time was accrued as the mobile laboratory moved from community to community. As a result, fewer hours of actual data collection were recorded in community monitoring programs in comparison to the monitoring programs carried out on the EPG. For example, of the 133 hours spent during Work Package 1C, 30 hours were actually related to acquiring data within communities. For Work Package 2C, 66 hours of a total of 83 hours were spent in acquiring community air quality data.

The communities which were visited on a daily basis depended upon the prevailing wind direction. During Work Package 1C, the most frequent wind direction was west southwest (34%) with west through west-southwesterly winds accounting for approximately two-thirds of all wind directions. The next most frequent wind direction was east-northeast (10.9%). Therefore, much of the mobile air quality monitoring was conducted in communities to the east and northeast of the incinerator site during this Work Package. By contrast, northerly through easterly winds accounted for nearly 55% of all wind directions during Work Package 2C; as a result, the mobile laboratory visited communities mainly to the south and west of the incinerator site. Table 8.4 provides a summary for both Work Packages, indicating the percentage of monitoring time spent in each communities where data was collected [63].

Figure 8.3



Community Air Quality Monitoring Locations

Figures 8.4 and 8.5 display the 1-hour maximum, minimum and average concentrations of the compounds of interest for each community visited during Work Packages 1C and 2C, respectively. There was no detectable mustard found in the seven samples acquired during the two Work Packages. The one mustard sample for Work Package 2C was taken on 15 April 1991 while the incinerator was processing contaminated scrap metal. The analytical equipment used (gas chromatograph with flame photometric detector) had a minimum detection limit of 5 nanograms (5×10^{-9} g) for this agent in the collected sample; this is equivalent to a mustard detection limit of 0.02 ppb when the sample air volume is taken into account.

For all compounds of interest, the measured concentrations were well within the air quality limits set for Project Swiftsure. The data from Work Package 1C, acquired during ambient temperatures ranging from -34°C to +3°C, suggested that the communities surrounding the DRES EPG possessed typical rural air quality that was possibly influenced by distant industrial and oilfield sources and local vehicular traffic. Small concentrations of carbon monoxide and oxides of nitrogen were noted in the mobile laboratory's daily logs as being related to power plant emissions from the laboratory vehicle and from parked cars idling nearby. All concentrations of sulphur dioxide were below the reporting threshold of 0.01 ppm. All 1-hour carbon monoxide readings were much less than the air quality limit of 13 ppm while concentrations of nitrogen dioxide were below 0.03 ppm, which was much less than the hourly limit of 0.21 ppm. No noticeable increase in any of the monitored parameters occurred while the mobile laboratory was parked at the Cameron Centre and on those occasions when the incinerator was undergoing refractory curing.

Table 8.4

COMMUNITY MONITORING WORK PACKAGE COMPARISON

	READINGS[1]		MONITORING TIME (%)	
COMMUNITY	WP1C	WP2C	WP1C	WP2C
Brooks	2	9	6.1	13.6
Buffalo	3	4	12.1	6.1
Bindloss	2	-	6.1	-
Empress	2	-	6.1	-
Hilda	2	-	6.1	-
Jenner	6	14	18.2	21.2
Medicine Hat[2]	7	-	21.3	-
Ralston	2	13	9.1	19.7
Redcliff	2	-	9.1	-
Suffield	2	26	6.1	39.4
Total:	**30**	**66**	**100**	**100**

1 Number of hourly readings taken at each location.

2 Two separate locations were monitored in Medicine Hat:
Brier Park (23rd Street NE): 6.1% of WP1C total
Riverside Water Slide: 15.2% of WP1C total

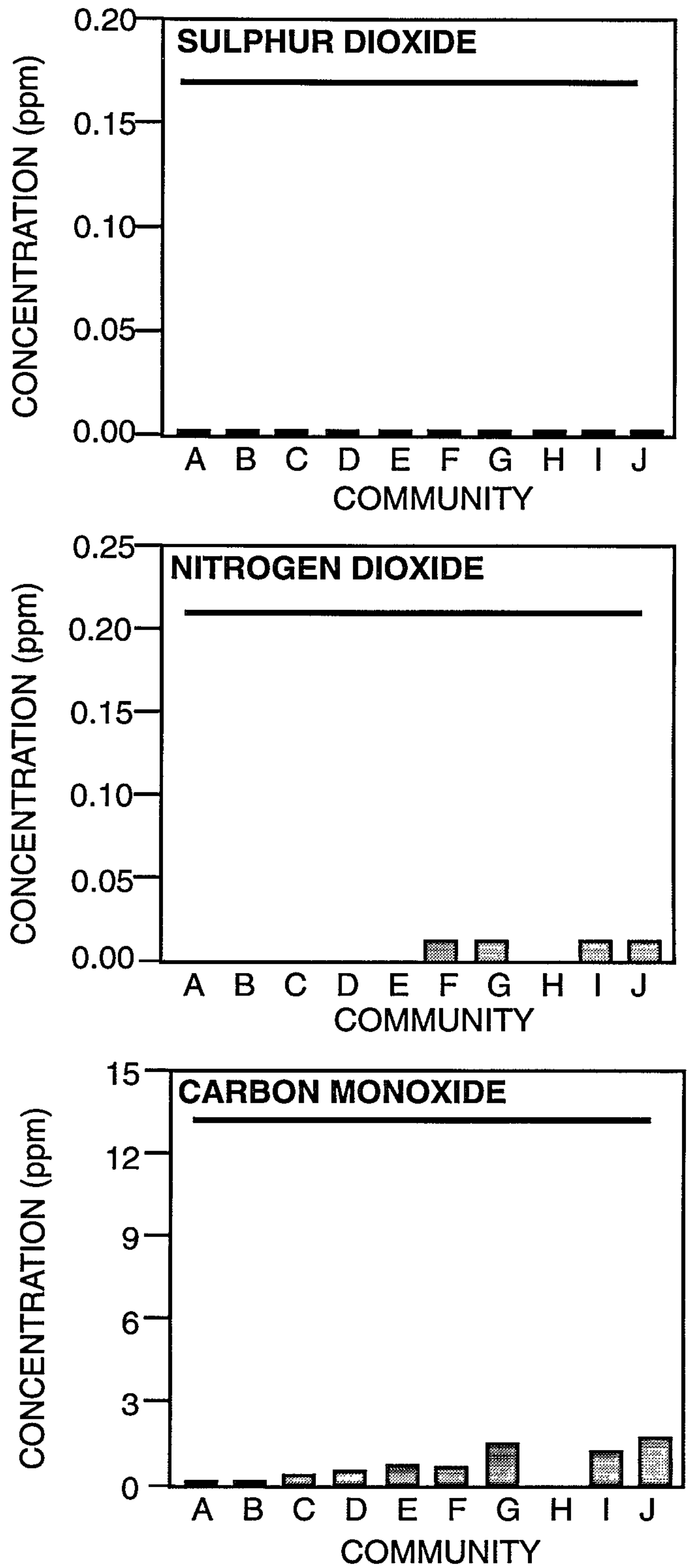
Figure 8.4

KEY:

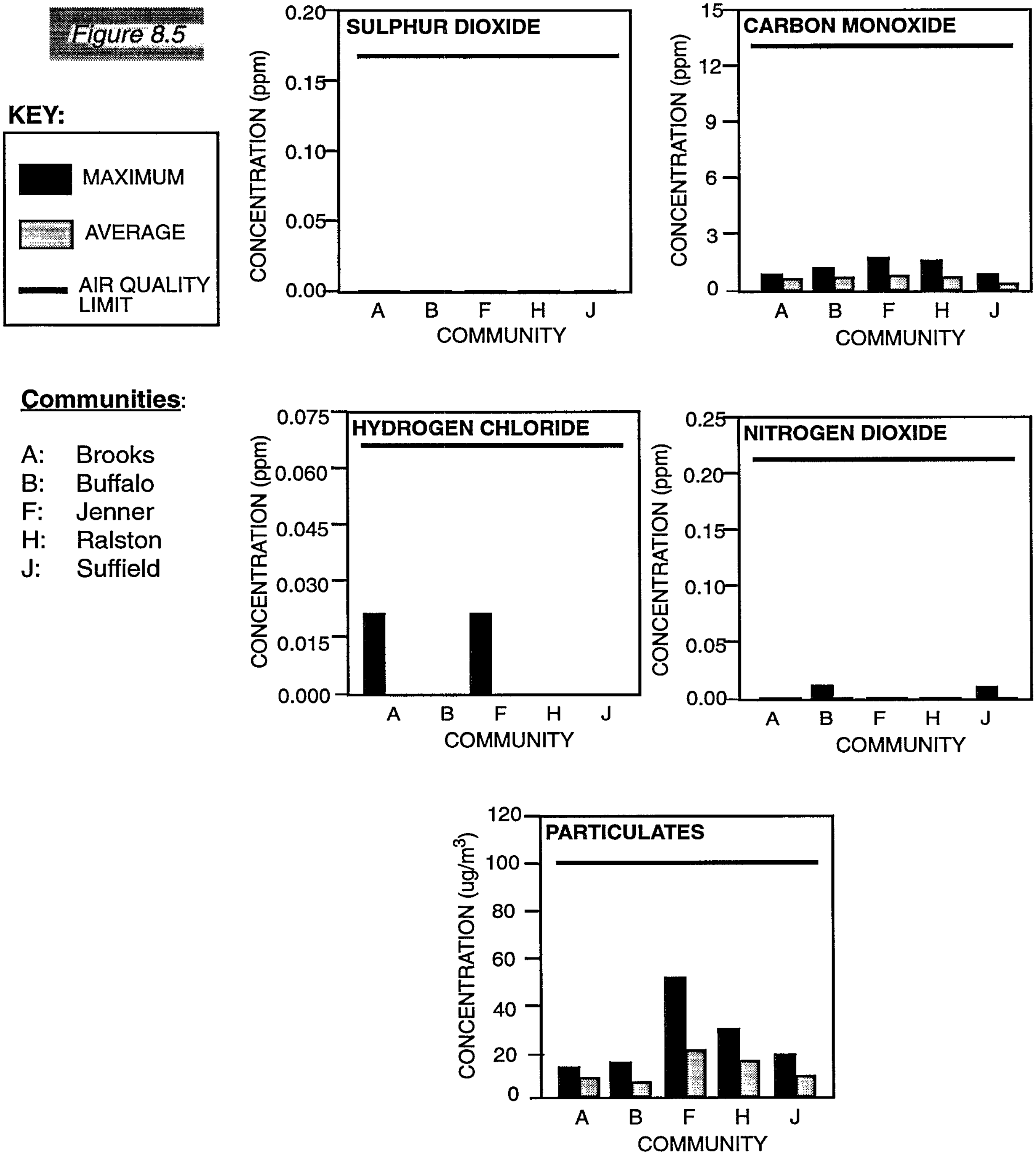
- MAX. 1-HOUR AVERAGE
- AIR QUALITY LIMIT

Communities:

A: Brooks
B: Buffalo
C: Bindloss
D; Empress
E: Hilda
F: Jenner
G: Medicine Hat
H: Ralston
I: Redcliff
J: Suffield



Work Package 1C Community Air Quality Monitoring Results



Work Package 2C Community Air Quality Monitoring Results

The data for Work Package 2C was acquired in April 1991 when the ambient temperatures ranged between +3°C and +9°C and while the incinerator was in operation (for part of the time) processing contaminated scrap metal. All carbon monoxide concentrations measured were well below the air quality limit of 13 ppm for one hour and 5.2 ppm for eight hours. A maximum 1-hour CO concentration of 1.3 ppm was recorded when the mobile laboratory was parked at the Cameron Centre on the evening of 9 April. At this time, the incinerator was undergoing maintenance prior to start-up on 10 April 1991. Small concentrations (approx. 1 ppm) of CO measured on 16 April and again on 19 April at Jenner and Ralston, respectively, were noted in the daily logs as being attributed to emissions from the mobile laboratory power plant. For other non-zero concentrations of carbon monoxide, local traffic or other combustion sources were likely causes. The resulting impact on community air quality would be insignificant in any case where the Swiftsure incinerator is considered the sole source of the measured CO concentrations.

All hydrogen chloride concentrations measured were well below the air quality limit of 0.066 ppm for one hour. The maximum HCl concentration measured in the surrounding communities was 0.02 ppm in Jenner and Brooks. HCl concentrations measurements during the community survey were below the minimum detection limit of the laboratory monitoring instrument when the incinerator was in operation. One-hour maximum HCl concentrations of 0.040 ppm were recorded on 9-10 April while the mobile laboratory was parked at the Cameron Centre overnight.

The 1-hour maximum concentration of NOx was 0.02 ppm, recorded during the afternoon of 16 April. This was attributed to mobile laboratory power plant emissions entering the air sampling intake. The 1-hour maximum NO_2 concentrations of 0.01 ppm measured in the communities of Suffield and Buffalo were much lower than the hourly air quality limit of 0.21 ppm. Most of the data acquired for oxides of nitrogen was below the minimum reporting limit of 0.01 ppm.

Concentrations of sulphur dioxide at the reporting threshold of 0.01 ppm were recorded only on one occasion for one hour (18 April) when the mobile laboratory was parked at the Cameron Centre. No measurements of SO_2 exceeded 0.01 ppm in any community.

Total suspended particulate concentrations measured during Work Package 2C ranged from 1 $\mu g/m^3$ to 50 $\mu g/m^3$. The 1-hour maximum TSP value of 50 $\mu g/m^3$, recorded in Jenner, was attributed to the grading of a parking lot adjacent to the location of the mobile laboratory. The calculated maximum 24-hour average TSP concentration for all locations was 17 $\mu g/m^3$, well below the project (and provincial) air quality limit of 100 $\mu g/m^3$. Typical background concentrations of TSP in a rural area range from 10 $\mu g/m^3$ to 100 $\mu g/m^3$. Thus, as with the carbon monoxide data, it could not be inferred that the Swiftsure incinerator was producing an impact on community air quality with respect to particulate emissions.

In general, the SO_2, HCl, CO, NO_2 and TSP concentrations recorded during the Project Swiftsure community air quality surveys were lower than readings typically found in urban commercial and industrial environments (see Table 8.3, for example). The data for the two community Work Packages were relatively similar with slight increases in carbon monoxide levels found in Work Package 2C readily attributable to such factors as increased industrial and vehicular activity in the spring compared to the winter months. In both cases, the communities downwind of the EPG exhibited typical rural, non-industrial setting air quality, which remained unchanged during incineration operations. This conclusion was readily supported by data acquired from monitoring activities carried out on the DRES EPG which showed that there was no significant change in air quality in close proximity to the incinerator site during agent waste processing operations (see EPG Monitoring Surveys, below).

8.4.2 EPG Monitoring Surveys

An extensive assessment of air quality in the vicinity of the incinerator was conducted during five separate Work Packages. Work Package 1D was designed to provide 10 days of background air quality monitoring on the DRES EPG before the incinerator became operational at the Cameron Centre. The remaining Work Packages 2D - 5D provided data during periods when the incinerator was undergoing trial burns or when agent waste material was being processed and incinerated. The operating status of the incinerator during the five Work Packages is summarized in Table 8.1.

Monitoring was performed downwind of the incinerator at pre-selected distances of 100 m, 200 m, 500 m, 1 km, 2 km and 5 km, with data collected over at least a one-hour period at each distance during a working day. At the completion of each day, the mobile laboratory was parked at the Cameron Centre where the instrumentation was allowed to run and collect data overnight. For a given prevailing wind direction, monitoring was performed in one of four zones:

- Zone 1:- an area northeast of the incinerator which was monitored on days with south to southwest winds;
- Zone 2: - an area east of the incinerator which was monitored on days with southwest to west winds;
- Zone 3: - an area west of the incinerator which was monitored on days with northeast to southeast winds. This zone includes the CFB Suffield administration area where DRES is located;
- Zone 4: - an area southeast of the incinerator which was monitored on days with northwest to north winds.

The location of the mobile laboratory could be readily adjusted from one zone to another on days when large shifts in the prevailing wind direction occurred. For comparison purposes and correlation with meteorological information, the monitoring results were referred to the appropriate zone where the data was collected. In general, the laboratory was positioned on the closest accessible roadway or fireguard trail for each of the selected downwind distances. Where no roadway existed at a particular distance (e.g. 500 m south of the Cameron Centre), the nearest accessible location was selected and used each time monitoring was required at this distance.

The DRES EPG monitoring survey measured concentrations of the following compounds: SO_2, NO_2, NO_x, CO, TSP and mustard. During the first three Work Packages (1D - 3D), 26 air samples were collected on adsorbent cartridges and analyzed for mustard content. Each adsorbent cartridge was exposed to the ambient air for a period of approximately 8 hours at a flow rate of 100 mL/minute. For the last two Work Packages (4D, 5D), the CMS FM1001A MINICAMS agent analyzer was installed in the mobile laboratory and used for monitoring mustard vapour on a continuous basis. Hydrogen chloride monitoring was not carried out due to problems with the HCl analyzer which required it to be returned to the manufacturer for repairs after the second community monitoring survey.

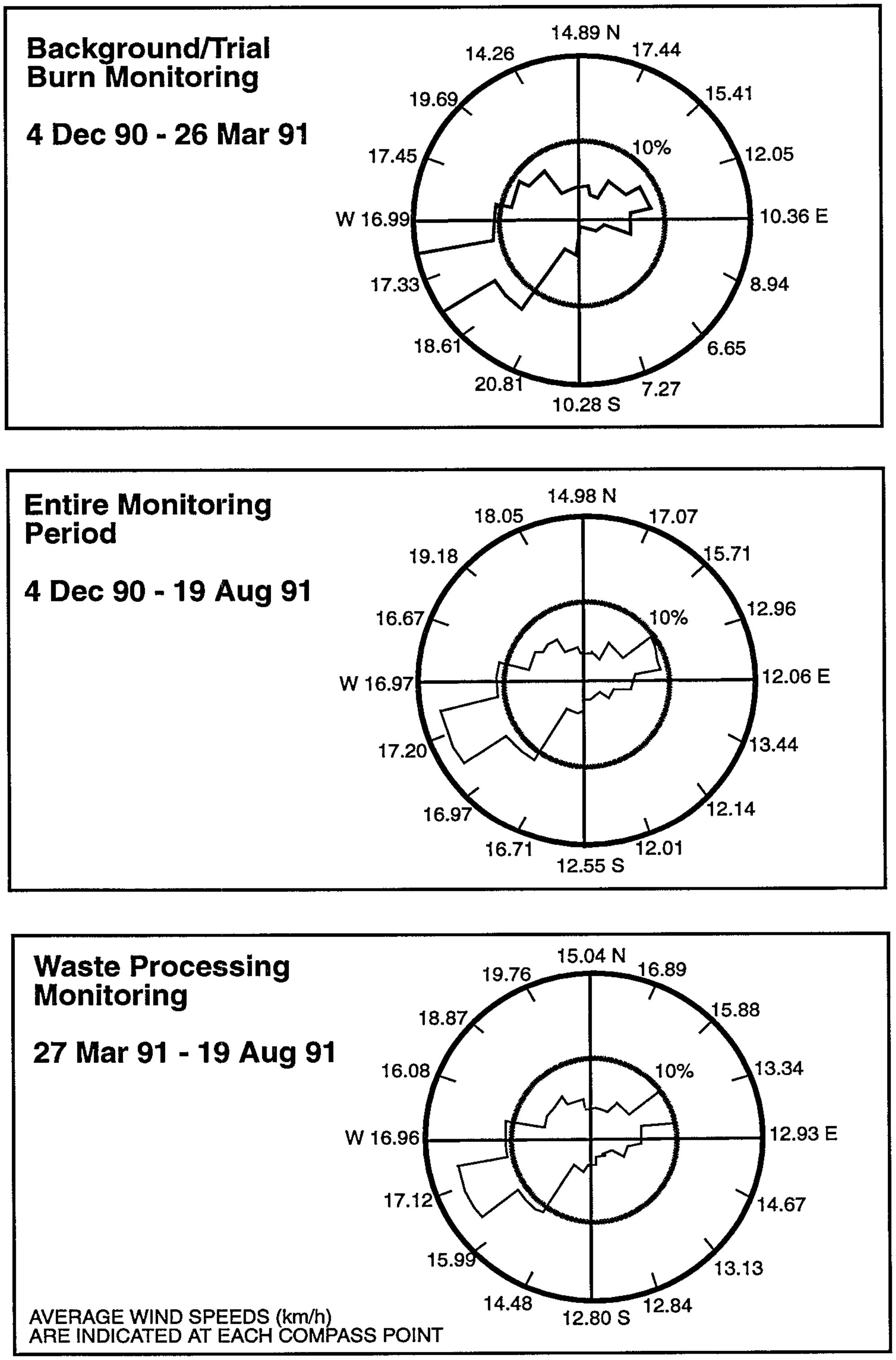
As shown in Figure 8.6, wind distribution patterns (wind roses) were determined for the entire monitoring survey, for the period before incinerator operations, and during incinerator operations. In all cases, the dominant wind direction was west southwest, with southwest and west winds also occurring over 10% of the time. South southeast and south were the least frequent wind directions. During incinerator operations, east winds were slightly more frequent than would be expected from the climatic norm [63] while northwesterly wind directions were slightly lower than normal. These slight shifts in normal wind patterns were indicative of the altered weather pattern over Alberta during the spring and summer of 1991 which featured cooler and wetter weather than normal.

The measured one-hour maximum, minimum and average concentrations for each compound at different distances from the incinerator for each of the four monitoring zones results are summarized in Tables 8.5 - 8.9. The Tables also list the number of one-hour measurements made at each location during the air quality survey. The concentrations of each compound plotted as a function of downwind distance from the incinerator are shown in Figures 8.7 to 8.11; in each case, the 1-hour maximum and daily average values are averaged over the four different monitoring zones.

To determine the effect of incinerator operations on the normal air quality associated with the DRES EPG, the results were analyzed for all work packages and compared using two separate data sets; one set for periods when the incinerator was not operating (background data) and a second set for periods when waste material was being incinerated (operational data). The data set comparison is shown in Figure 8.12 where average concentrations for CO, particulates, and mustard are plotted against the six downwind monitoring distances.

Sulphur dioxide concentrations did not exceed the reporting minimum level of 0.01 ppm when the incinerator was operating, as was the case during the entire EPG monitoring survey. Most of the NO_2 concentrations were also below the minimum reporting level. Therefore, the average concentrations for these two compounds were listed as zero for all data sets. No systematic variations in the maximum NO_2 concentrations were observed at the various distances downwind of the incinerator.

Figure 8.6



Wind Distribution Patterns During EPG Air Quality Surveys

Table 8.5

SUMMARY OF SO_2 CONCENTRATIONS (ppm) AT DIFFERENT DISTANCES DOWNWIND OF THE SWIFTSURE INCINERATOR

WORK PACKAGES 1D - 5D

ZONE[1]	DATA	DOWNWIND DISTANCE						ZONE
		100 m	200 m	500 m	1 km	2 km	5 km	SUMMARY
1	Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	22	17	22	16	23	24	124
2	Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	15	13	15	12	12	19	86
3	Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	22	13	27	12	9	8	90
4	Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	25	11	11	10	11	10	78
Totals	Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	84	54	75	50	55	61	639

1 Zone 1 (northeast) monitored on days with southwesterly winds.
Zone 2 (east) monitored on days with westerly winds.
Zone 3 (west) monitored on days with easterly winds.
Zone 4 (southeast) monitored on days with northwesterly winds.

2 Number refers to the total mumber of valid one-hour samples acquired at each location (distance) in each Zone.

Table 8.6

SUMMARY OF NO_2 CONCENTRATIONS (ppm) AT DIFFERENT DISTANCES DOWNWIND OF THE SWIFTSURE INCINERATOR

WORK PACKAGES 1D - 5D

ZONE[1]	DATA	DOWNWIND DISTANCE						ZONE SUMMARY
		100 m	200 m	500 m	1 km	2 km	5 km	
1	Maximum	0.01	0.00	0.00	0.00	0.01	0.01	0.01
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	22	17	22	16	23	24	124
2	Maximum	0.01	0.01	0.01	0.00	0.00	0.01	0.01
	Minimum	0.00	0.00	0.00	.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	15	13	15	12	12	19	86
3	Maximum	0.01	0.01	0.03	0.01	0.00	0.02	0.03
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	22	13	27	12	9	8	90
4	Maximum	0.01	0.01	0.00	0.01	0.00	0.01	0.01
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	25	11	11	10	11	10	78
Totals	Maximum	0.01	0.01	0.03	0.01	0.01	0.02	0.03
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Number[2]	84	54	75	50	55	61	379

1 Zone 1 (northeast) monitored on days with southwesterly winds.
Zone 2 (east) monitored on days with westerly winds.
Zone 3 (west) monitored on days with easterly winds.
Zone 4 (southeast) monitored on days with northwesterly winds.

2 Number refers to the total mumber of valid one-hour samples acquired at each location (distance) in each Zone.

Table 8.7

SUMMARY OF CO CONCENTRATIONS (ppm) AT DIFFERENT DISTANCES DOWNWIND OF THE SWIFTSURE INCINERATOR

WORK PACKAGES 1D-5D

ZONE[1]	DATA	DOWNWIND DISTANCE 100 m	200 m	500 m	1 km	2 km	5 km	ZONE SUMMARY
1	Maximum	1.8	1.5	0.7	1.2	0.7	0.9	1.8
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.6	0.3	0.4	0.3	0.3	0.4	0.4
	Number[2]	22	17	22	16	23	24	124
2	Maximum	8.5	0.9	1.9	0.8	0.7	0.9	8.5
	Minimum	0.2	0.1	0.2	0.0	0.0	0.0	0.0
	Average	1.1	0.5	0.5	0.4	0.4	0.4	0.6
	Number[2]	15	13	15	12	12	19	86
3	Maximum	0.9	4.8	3.8	0.7	0.6	2.0	4.8
	Minimum	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.5	0.7	0.7	0.3	0.2	0.7	0.5
	Number[2]	22	13	27	12	9	8	90
4	Maximum	1.1	0.5	0.5	0.5	0.5	3.6	3.6
	Minimum	0.0	0.0	0.0	0.0	0.0	0.1	0.0
	Average	0.3	0.2	0.3	0.2	0.3	0.9	0.4
	Number[2]	25	11	11	10	11	10	78
Totals	Maximum	8.5	4.8	0.5	1.2	0.7	3.6	8.5
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.6	0.4	0.5	0.3	0.3	0.5	0.3
	Number[2]	84	54	75	50	55	61	379

1 Zone 1 (northeast) monitored on days with southwesterly winds.
Zone 2 (east) monitored on days with westerly winds.
Zone 3 (west) monitored on days with easterly winds.
Zone 4 (southeast) monitored on days with northwesterly winds.

2 Number refers to the total mumber of valid one-hour samples acquired at each location (distance) in each Zone.

Table 8.8

SUMMARY OF PARTICULATE CONCENTRATIONS (μg/m^3) AT DIFFERENT DISTANCES DOWNWIND OF THE SWIFTSURE INCINERATOR

WORK PACKAGES 1D - 5D

		DOWNWIND DISTANCE						ZONE
ZONE[1]	DATA	100 m	200 m	500 m	1 km	2 km	5 km	SUMMARY
1	Maximum	22.0	25.0	49.0	17.0	23.0	15.0	49.0
	Minimum	4.0	3.8	0.0	1.0	0.0	2.0	0.0
	Average	8.8	10.0	10.1	7.4	10.1	6.0	8.8
	Number[2]	12	13	16	9	10	12	72
2	Maximum	31.0	56.1	79.0	9.0	36.2	10.7	79.0
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average	9.6	13.1	19.5	4.2	18.5	4.6	12.2
	Number[2]	9	6	8	5	5	4	37
3	Maximum	56.0	22.0	51.9	19.0	10.0	24.0	56.0
	Minimum	5.0	0.0	1.0	6.0	0.0	0.0	0.0
	Average	19.5	11.3	11.0	12.9	6.0	15.0	13.6
	Number[2]	15	7	18	6	3	2	51
4	Maximum	29.0	2.0	26.5	8.5	22.1	15.8	29.0
	Minimum	0.0	0.0	0.0	0.0	0.0	0.01	0.0
	Average	11.0	1.0	16.0	5.3	10.4	8.6	10.3
	Number[2]	14	2	4	2	3	3	28
Totals	Maximum	56.0	56.1	79.0	19.0	36.2	24.0	79.0
	Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average	12.8	10.3	12.6	8.0	11.6	7.0	11.0
	Number[2]	50	28	46	22	21	21	188

1 Zone 1 (northeast) monitored on days with southwesterly winds.
Zone 2 (east) monitored on days with westerly winds.
Zone 3 (west) monitored on days with easterly winds.
Zone 4 (southeast) monitored on days with northwesterly winds.

2 Number refers to the total mumber of valid one-hour samples acquired at each location (distance) in each Zone.

Table 8. 9

SUMMARY OF MUSTARD CONCENTRATIONS (ppb) AT DIFFERENT DISTANCES DOWNWIND OF THE SWIFTSURE INCINERATOR

WORK PACKAGES 1D - 5D

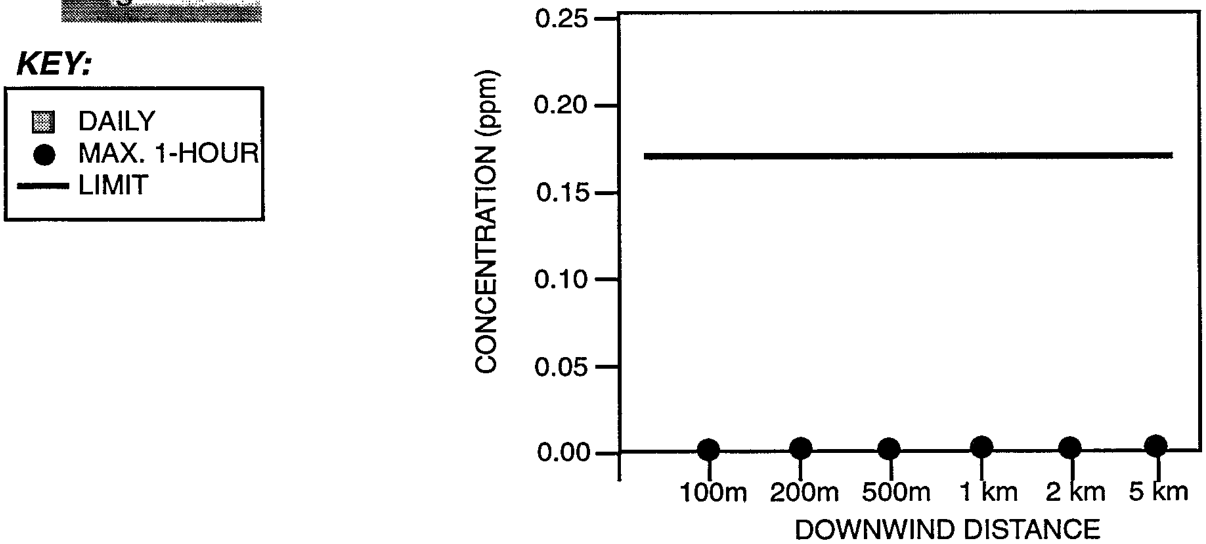
		DOWNWIND DISTANCE						ZONE
ZONE[1]	DATA[2]	100 m	200 m	500 m	1 km	2 km	5 km	SUMMARY
1	Maximum	0.023	0.023	0.014	0.046	0.037	0.028	0.046
	Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Average	0.002	0.003	0.001	0.002	0.003	0.004	0.002
	Number[3]	22	22	76	12	35	43	210
2	Maximum	0.055	0.023	0.018	0.041	0.037	0.041	0.055
	Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Average	0.004	0.001	0.001	0.005	0.001	0.001	0.002
	Number[3]	93	77	64	12	48	48	330
3	Maximum	0.028	0.018	0.023	0.028	0.028	0.000	0.028
	Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Average	0.007	0.003	0.002	0.001	0.008	0.000	0.003
	Number[3]	18	39	87	45	11	0	200
4	Maximum	0.032	0.018	0.000	0.000	0.000	0.000	0.032
	Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Average	0.001	0.002	0.000	0.000	0.000	0.000	0.001
	Number[3]	142	27	10	23	23	23	248
Totals	Maximum	0.055	0.023	0.023	0.046	0.037	0.041	0.055
	Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Average	0.002	0.002	0.001	0.001	0.003	0.002	0.002
	Number[3]	275	165	237	92	105	114	988

1 Zone 1 (northeast) monitored on days with southwesterly winds.
Zone 2 (east) monitored on days with westerly winds.
Zone 3 (west) monitored on days with easterly winds.
Zone 4 (southeast) monitored on days with northwesterly winds.

2 The data is based on a compilation of 5 minute readings from the MINICAMS mustard analyzer.

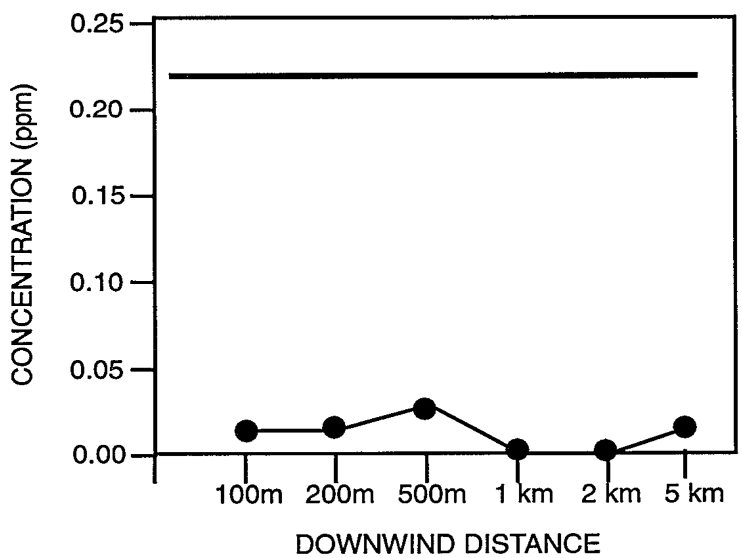
3 Number refers to the total mumber of valid one-hour samples acquired at each location (distance) in each Zone.

Figure 8.7



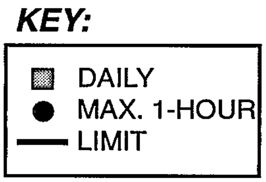
SO_2 Concentrations Versus Distance From The Incinerator

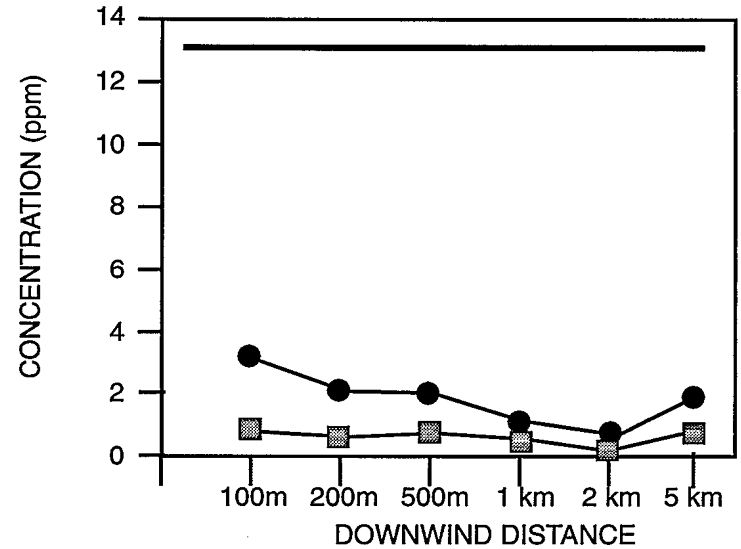
Figure 8.8



NO_2 Concentrations Versus Distance From The Incinerator

Figure 8.9





CO Concentrations Versus Distance From The Incinerator

Figure 8.10

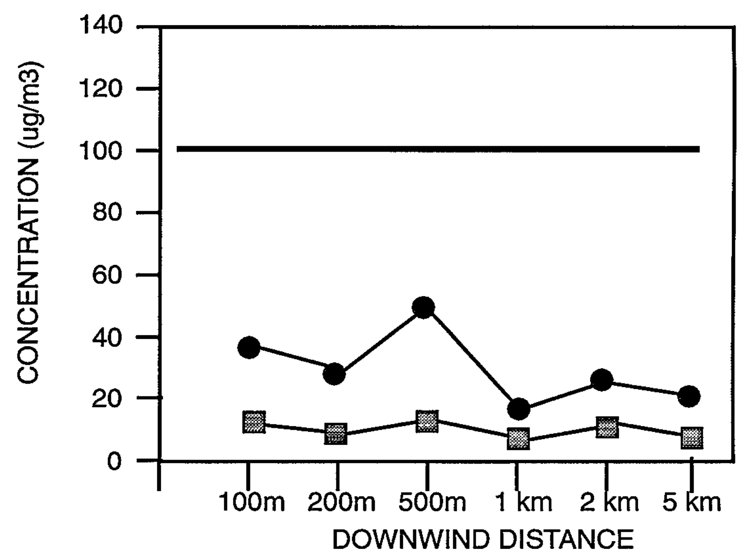
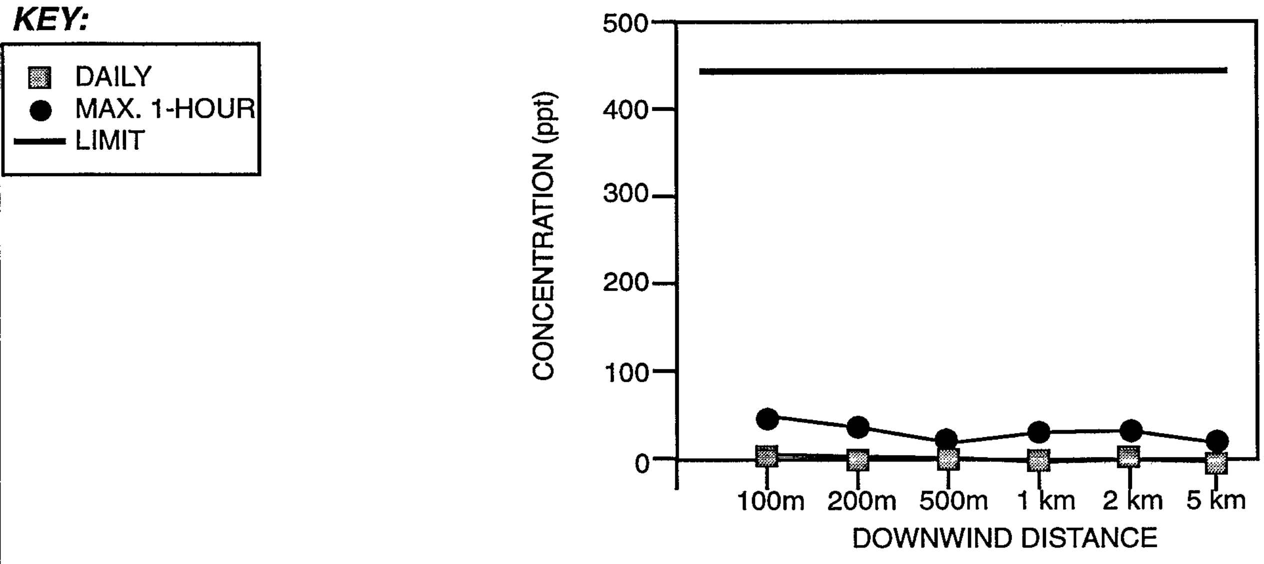


Figure 8.10

Particulate Concentrations Versus Distance From The Incinerator

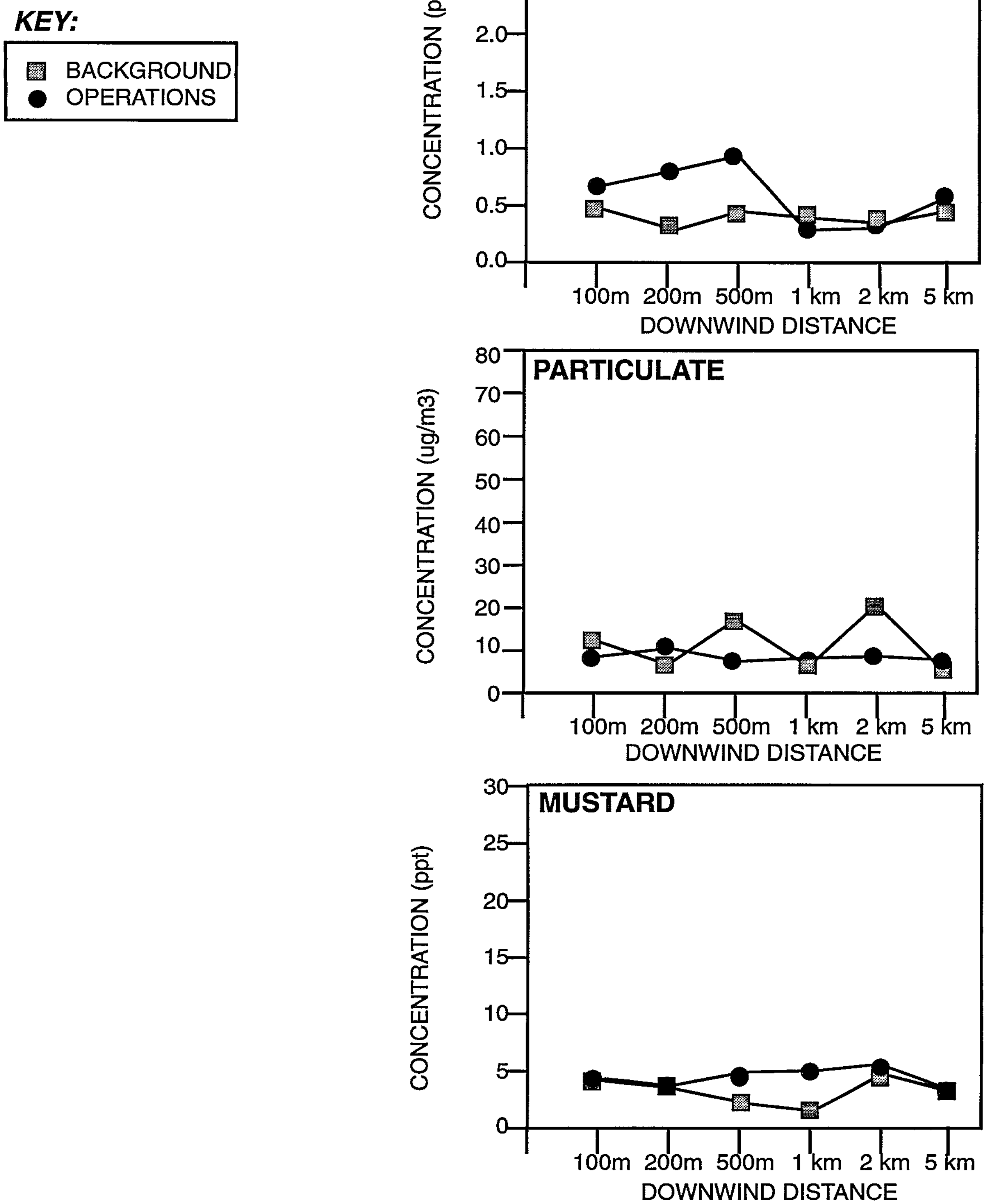
Figure 8.11



Mustard Concentrations Versus Distance From The Incinerator

Average hourly CO concentrations varied little with downwind distance during periods when the incinerator was not operating (see Figure 8.12); this data can be considered representative of the normal levels of CO associated with the DRES EPG. In general, the data compares favourably with levels of carbon monoxide found during the two community air quality surveys. As shown in Figure 8.9, 1-hour maximum CO concentrations were slightly higher for distances up to 500 m downwind of the incinerator during operations but were very similar to background concentrations at greater distances. All CO concentrations (including maximum readings) were well below the hourly and daily CO air quality limits of 13 ppm and 5.2 ppm, respectively.

Figure 8.12



Examples of Comparative Air Quality Data
Background vs Incinerator Operations

One-hour total suspended particulate concentrations (see Table 8.8 and Figures 8.10, 8.12) did not show any systematic variation which would suggest the incinerator was the source of the particulate matter or was causing a change in the normal levels of particulate matter found in the EPG environment. This occurred despite the fact that the incinerator exceeded the 20 mg/m^3 stack particulate emission limit during trial burns and while compliance tests were conducted to rectify this problem. Interestingly, the highest average downwind TSP concentrations occurred when the incinerator was not operating (Figure 8.12). In general, average TSP concentrations measured on the DRES EPG compared favourably to average TSP concentrations found during the second community monitoring survey. It should be noted that 1-hour maximum TSP readings were higher at locations less than 1 km from the incinerator (see Figure 8.10) but, given the data variability, it was not possible to determine whether the source was the incinerator or other sources such as vehicle traffic, road dust or blowing soil.

During the EPG background air quality survey (Work Package 1D) and other Work Packages (2D, 3D), no mustard was detected on the 26 occasions that 8-hour air samples were collected on adsorbent tubes. A one-hour sample was drawn on 15 March during a special explosive disposal operation involving old mustard-filled ordnance at the 14A Site. In addition, two other one-hour samples were collected near the Cameron Centre on 21 March and 25 March during incinerator trial burns involving bulk mustard. No mustard was detected in any of these one-hour samples.

Very low (less than 0.008 ppb) 1-hour average concentrations of mustard were detected when surveys were conducted using the MINICAMS analyzer (see Table 8.9 and Figure 8.11). Average concentrations at the 500 m and 1 km downwind distances were slightly higher when the incinerator was processing agent waste compared to periods when it was not operating (see Figure 8.12). This unexpected result differed from previous predictions [13] which indicated that any mustard emissions would produce maximum ground level concentrations at approximately 100 m from the incinerator stack (see Figure 6.15 for example). However, mustard concentration measurements did not show any systematic increases during the incineration of mustard or mustard-contaminated inventory compared to periods when the incinerator was not operating. Therefore, potential sources of mustard emissions other than the incinerator stack had to be considered; these other sources included the Cameron Centre Contaminated Materials Laydown Area (see Figure 6.1) where waste was stored temporarily awaiting incineration, waste handling operations at the Cameron Centre and the drum shredding operations at the 490 Site.

One-hour maximum mustard concentrations of 0.060 ppb and 0.078 ppb were measured on 9 May when the mobile laboratory was parked at the Cameron Centre to monitor potential emissions from the nearby Contaminated Materials Laydown Area. The incinerator was not operating on this date nor on the previous day (8 May) when mustard concentrations were also measured close to the Laydown Area. The presence of mustard was also recorded on 10 May when the mobile laboratory was located downwind of the 490 Site drum shredding operations. Low, but detectable, mustard concentrations were found frequently in May and early June when the incinerator was shut down for maintenance, especially during those times when the mobile laboratory was parked at the Cameron Centre. These readings suggested that mustard emissions were occurring from sources other than the incinerator, with the most likely source being the Contaminated Materials Laydown Area. Using CAMs, a manual survey of this area confirmed that some badly-weathered boxes containing contaminated scrap metal were emitting mustard vapour; the leaking boxes were removed to the 490 Site and repackaged.

The mustard destruction and removal efficiency of >99.9999%, as confirmed during incinerator trial burns, combined with the relatively low waste feedrate employed provided confidence that stack emissions would not contain mustard at concentrations at which could be distinguished from other potential low level mustard releases. In any case, maximum one-hour mustard concentrations measured were well below the 8-hour air quality limit of 0.45 ppb set for Project Swiftsure; average one-hour concentrations were less than the 72-hour limit of 0.015 ppb. That is, for unprotected monitoring personnel and site workers who may have been potentially exposed to mustard vapour, the exposure would have been far less than the limits set to prevent physiological effects in unprotected personnel [19], even if one assumes continuous daily exposure (8 hours) at the maximum recorded concentrations.

8.4.3 Dioxins/Furans Surveys

The high-volume air sampler array installed near the Cameron Centre incinerator building was employed to collect 24-hour air samples for dioxin/furan analyses during four separate periods in 1991, as follows:

- 15 - 16 May (1430 to 1430 hours). The incinerator was operating for 24 hours on 15 May and 2 hours on 16 May during which time a total of 7,214 kg of mustard-contaminated scrap was processed;
- 22 - 23 May (1400 to 1400 hours). On May 22, the incinerator was shut down for inspection and maintenance and resumed operation on 23 May for performance checks. No hazardous waste was processed during this sampling period;
- 9 - 10 August (0900 to 0900 hours). Incineration continued for over 30 hours during this sampling period and involved the burning of 4,220 kg of agent waste inventory, including Livens mortars (full), mustard-filled ordnance, open ordnance casings, mustard-filled Flying Cows, and spray tanks, as well as the re-burn of some drum shreds and shredded vehicle tires;
- 16 - 17 August (0930 to 0930 hours). A total of 2,221 kg of mustard-filled ordnance and non-hazardous scrap material was incinerated over a 16.5 hour period commencing 16 August.

A numerical dispersion model (Industrial Source Complex (ISC) model) was used to predict the optimum location for the air samplers. Using long-term meteorological conditions, this model predicted that maximum ground level concentrations of dioxins/furans would occur at about 150 m to the east northeast of the incinerator. To accomodate normal cross-wind spread, two samplers were placed about 20 m apart at this distance and direction downwind, i.e. placed 10 m on either side of the predicted centre-line of the incinerator plume. The third sampler was located "upwind" on the roof of Building 60 to avoid excessive exposure to road traffic dust. In general, any or all of the samplers could be considered as being upwind or downwind of the incinerator depending on the prevailing wind direction.

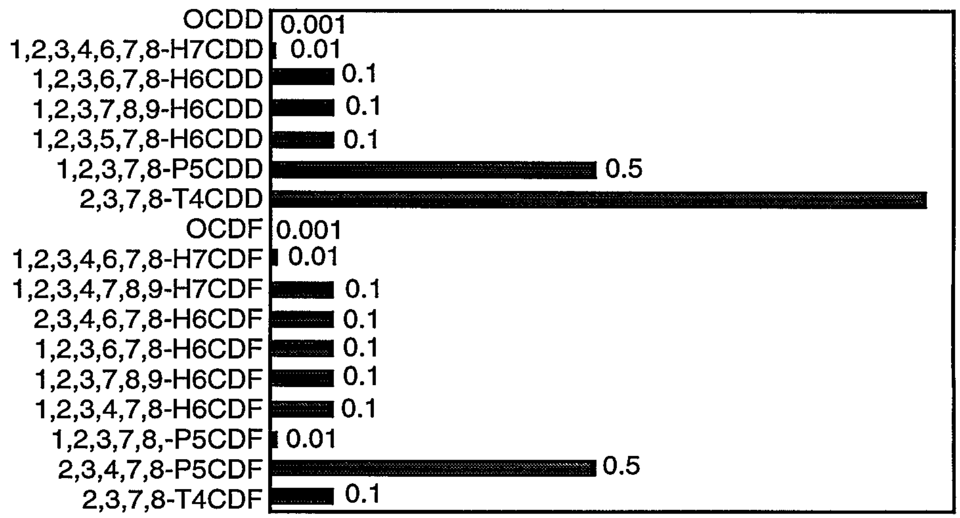
Each sampler was fitted with a quartz-fibre filter followed by a cartridge of polyurethane foam (PUF). The quartz-fibre filter was designed to collect the particulate portion of the air sample while the PUF collected airborne vapour. A summary of the installation and operating procedures for the high-volume samplers is given elsewhere [71]. The total volume of air sampled over each period was approximately 360 m^3 at a continuous flow rate of approximately 15 m^3/hour.

For dioxin/furan analysis, each PUF filter was spiked in the field with 50 L of 2,3,7,8-tetrachloro-p-dibenzodioxin (T4CDD) and in the laboratory with six surrogate dioxin standards to evaluate the sampling protocol, handling, storage and precision of the analytical procedure. A field blank was provided for each sampling period. Collected air samples were analyzed for the known dioxin and furan congeners by Wellington Environmental Consultants, Guelph, Ontario, using gas chromatography/mass spectrometry instrumentation [72].

Tables 8.10 to 8.13 provide summaries of the dioxins/furans concentrations found in collected air samples for each of the four sampling periods described previously. In each Table, the Toxic Equivalency (TEQ) concentration relative to T4CDD is calculated for each of the dioxin or furan congeners present. Figure 8.13 illustrates the toxic equivalency factors assigned [79] to various chlorinated dioxin and furan congeners. The results of the dioxin/furan sampling survey may be compared to guidelines developed by the Ontario government and by the Federal-Ontario Ad Hoc Group on Multimedia Standards. These guidelines define the maximum tolerable daily intake (TDI) using the T4CDD toxic equivalency concentration and are based on a lifetime exposure under average conditions [80]. A TDI of 10,000 fg/kg (femtograms/kg $=10^{-15}$ grams per kilogram) of body weight is the "highest value expected not to cause any adverse health effects" [80]. Environment Canada has set a guideline concentration of 5,000 TEQ fg/m^3 total dioxins and furans for the ambient environment.

These compounds are ubiquitous in the atmosphere and ambient environment, are extremely stable [81], and are produced by a variety of combustion processes such as forest fires, fuel combustion, smelters and municipal waste incineration. Fuel combustion is estimated to contribute to approximately 15% of US dioxin releases [82]. The daily intake from the atmosphere for an average adult is estimated to be 70 fg/kg of body weight, accounting for 3 to 10% of the total exposure. Food intake accounts for 87 to 96% with the remainder from water, soil and consumer products. The Environment Canada guideline concentration of 5,000 TEQ fg/m^3 allocates 10% of the TDI to air, assuming that a 70 kg adult breathes 20 m^3 of air per day.

Figure 8.13



Dioxin and Furan Congeners Toxicity Equivalency Factors

Table 8.10

AMBIENT DIOXIN AND FURAN CONCENTRATIONS (fg/m^3)
Sampling Period: 15 - 16 May 1991

COMPOUND[1]	CONCENTRATION[2]			T4CDD TOXIC EQUIVALENT[3]		
	Sampler[4] 1	Sampler 2	Sampler 3	Sampler 1	Sampler 2	Sampler 3
PCDDs						
1234678-H7	-	33.6	-	-	3.4	-
Total H7CDD	-	56.0	-	-	3.4	-
OCDD	-	193.3	207.4	-	0.2	0.2
Total PCDDs	-	249.3	207.4	-	3.6	0.2
PCDFs	-	-	-	-	-	-
PCDDs + PCDFs	-	249.3	207.4	-	3.6	0.2

1 Chlorinated dioxins /furans not listed were not detected in the collected air samples.

2 All concentration values are corrected for cartridge blanks.

3 The TEQ concentrations are based on the toxicity of the various congeners relative to 2,3,7,8-T4CDD.

4 Sampler #1 is located northwest of the incinerator while samplers #2 and #3 are located east north east of the incinerator.

Table 8.11

AMBIENT DIOXIN AND FURAN CONCENTRATIONS (fg/m^3)

Sampling Period: 22 - 23 May 1991

COMPOUND[1]	CONCENTRATION[2]			T4CDD TOXIC EQUIVALENT[3]		
	Sampler[4] 1	Sampler 2	Sampler 3	Sampler 1	Sampler 2	Sampler 3
PCDDs						
OCDD	82.2	107.3	86.8	0.1	0.1	0.1
Total PCDDs	82.2	107.3	86.8	0.1	0.1	0.1
PCDFs						
Total T4CDF	73.7	-	-	7.4	-	-
Total PCDFs	73.7	-	-	7.4	-	-
PCDDs + PCDFs	155.9	107.3	86.8	7.5	0.1	0.1

1 Chlorinated dioxins/furans not listed were not detected in the collected air samples.

2 All concentration values are corrected for cartridge blanks.

3 The TEQ concentrations are based on the toxicity of the various congeners relative to 2,3,7,8-T4CDD.

4 Sampler #1 is located northwest of the incinerator while samplers #2 and #3 are located east north east of the incinerator.

Table 8.12

AMBIENT DIOXIN AND FURAN CONCENTRATIONS (fg/m^3)

Sampling Period: 9 - 10 August 1991

COMPOUND[1]	CONCENTRATION[2]			T4CDD TOXIC EQUIVALENT[3]		
	Sampler[4] 1	Sampler 2	Sampler 3	Sampler 1	Sampler 2	Sampler 3
PCDDs						
Total	P5CDD	5.0	-	-	2.5	- -
Total H6CDD	5.0	-	-	0.5	-	-
1234678-H7	-	23.9	31.3	-	2.4	3.1
Total H7CDD	17.5	23.9	56.3	0.2	0.2	3.4
OCDD	154.6	170.6	131.3	0.2	0.2	0.1
Total PCDDs	182.1	194.5	187.5	3.4	2.6	3.5
PCDFs						
Total T4CDF	5.0	-	-	0.5	-	-
Total P5CDF	17.5	-	-	0.2	-	-
Total H6CDF	12.5	-	-	1.2	-	-
1234678-H7	5.0	13.6	9.4	0.5	1.4	0.9
Total H7CDF	15.0	13.6	9.4	0.6	1.4	0.9
Total PCDFs	49.9	13.6	9.4	2.5	1.4	0.9
PCDDs + PCDFs	231.9	208.1	196.9	5.9	4.0	4.4

1 Chlorinated dioxins/furans not listed were not detected in the collected air samples .

2 All concentration values are corrected for cartridge blanks.

3 The TEQ concentrations are based on the toxicity of the various congeners relative to 2,3,7,8-T4CDD.

4 Sampler #1 is located northwest of the incinerator while samplers #2 and #3 are located east north east of the incinerator.

Table 8.13

AMBIENT DIOXIN AND FURAN CONCENTRATIONS (fg/m^3)

Sampling Period: 16 - 17 August 1991

COMPOUND[1]	CONCENTRATION[2]			T4CDD TOXIC EQUIVALENT[3]		
	Sampler[4] 1	Sampler 2	Sampler 3	Sampler 1	Sampler 2	Sampler 3
PCDDs						
Total T4CDD	10.6	11.8	8.8	10.6	11.8	8.8
12378-P5	-	5.9	-	-	0.1	-
Total P5CDD	-	5.9	-	-	0.1	-
1234678-H7	-	23.6	-	-	2.4	-
Total H7CDD	13.3	38.3	20.3	1.3	3.8	2.0
OCDD	141.0	153.4	182.	4 0.1	0.2	0.2
Total PCDDs	164.9	209.4	211.6	12.1	15.9	11.0
PCDFs						
Total P5CDF	10.6	11.8	-	0.1	0.1	-
Total PCDFs	10.6	11.8	-	0.1	0.1	-
PCDDs + PCDFs	175.5	221.2	211.6	12.2	16.0	11.0

1 Chlorinated dioxins/furans not listed were not detected in the collected air samples .

2 All concentration values are corrected for cartridge blanks.

3 The TEQ concentrations are based on the toxicity of the various congeners relative to 2,3,7,8-T4CDD.

4 Sampler #1 is located northwest of the incinerator while samplers #2 and #3 are located east north east of the incinerator.

Concentrations of dioxins and furans tend to be higher in urban areas compared to rural areas. For example [82], dioxin and furan levels of 1000 to 4000 fg/m^3 have been measured in the atmosphere of some US cities. Air quality measurements for dioxins/furans carried out by Environment Canada in Ontario showed [83] mean concentrations of 370 TEQ fg/m^3 for 18 samples in Windsor (urban) and 220 TEQ fg/m^3 for 15 samples taken at Walpole Island (rural). Another series of measurements taken in rural Ontario locations showed the following results [84]:

- Dorset: 21 - 760 TEQ fg/m^3 (10 samples);
- Marathon: 74 and 1806 TEQ fg/m^3 for 2 samples, and
- Smooth Rock Falls: 11 - 96 TEQ fg/m^3 for 2 samples.

The latter two sites were located close to pulp and paper mills which are suspected sources of dioxins and furans.

The concentrations of dioxins and furans found in the air quality survey at the Cameron Centre incinerator site were extremely low, as were the corresponding toxic equivalencies. For example:

- No furans were found in the air samples collected during the 15- 16 May sampling period, while only dioxins were detected in samples collected at Samplers #2 and #3. These samplers were upwind of the incinerator during this period (prevailing winds were east-north east through east-southeast) while Sampler #1 was downwind for a number of hours. A total of 3.8 TEQ fg/m^3 dioxins was found in the collected samples;
- The incinerator was not operating during the 22-23 May sampling period. However, 7.4 TEQ fg/m^3 of furans and 0.1 TEQ fg/m^3 of dioxins were found in Sampler #1 samples while 0.1 TEQ fg/m^3 of dioxins and no furans were found for Samplers #2 and #3. The wind directions varied between north northeast and south southeast during this sampling period; therefore, all samplers could be considered "upwind" or "background" samplers;
- Dioxins and furans were detected for all three samplers during the 9-10 August sampling period and while mustard-contaminated inventory was incinerated. The total TEQ amounts were 2.8, 3.9 and 4.4 fg/m^3 for Samplers #1, #2 and #3, respectively. Samplers #2 and #3 were downwind of the incinerator for a portion of the day while Sampler #1 was always upwind;
- Dioxins and furans were also found for all three samplers during the 16-17 August survey during which mustard-contaminated inventory was incinerated for part of the time. The total TEQ amounts were 2.2, 16.0 and 11.0 fg/m^3 for Samplers #1, #2 and #3, respectively. Winds were frequently from a direction which placed Samplers #2 and #3 downwind and Sampler #1 upwind. Dioxins contributed most to the total TEQ amount.

Because the wind direction did not place any sampler continuously downwind during the two monitoring periods in May, the low dioxin/furan concentrations found cannot be directly attributable to the incinerator and may be considered "background". In any case, the incinerator was not operating during the second sampling survey. Likely sources for the dioxins/furans included other on-site combustion sources (automobile and truck emissions), the emissions from an asphalt plant operating approximately 4 km to the south-east, contaminated wind-blown soil or long-range transport via air masses contaminated in some distance area.

During the final two sampling periods in August, a portion of the dioxin/furan concentrations detected (e.g. 1 to 4 TEQ fg/m^3) might be attributable to the incinerator. However, this is by no means conclusive given the extremely small levels measured around the incinerator site, the small number of samples collected and the high variability between the samples. If the incinerator was the sole source of the measured dioxins and furans, its contribution was a very minor one; i.e. 2-3 orders of magnitude less than the Environment Canada guideline of 5,000 TEQ fg/m^3.

8.4.4 Metals Surveys

The high-volume samplers were also used to collect particulate samples during Project Swiftsure incineration operations. Three separate 24-hour periods were scheduled where airborne particulates were collected for the analysis of metal content, as follows:

- 13 - 14 June (1030 to 1030 hours). The incinerator was undergoing particulate and lead emissions tests while burning fuel gas only;
- 16 - 17 July (1300 to 1330 hours). The incinerator was operational and processing mustard-contaminated scrap. On 16 July, 894 kg of Flying Cow casings were incinerated over a 10 hour period. Incineration continued through most of 17 July (23 hours) and involved the processing of or re-burning of 1020 kg and 1371 kg of Flying Cow casings, respectively;
- 17 - 18 July (1330 to 1400 hours). Incineration of Flying Cow casings (1460 kg) and their re-burns (198 kg) continued for 18 hours on 18 July.

Incineration of the above materials was expected to generate particulate matter which potentially could contain traces of metals such as copper, lead, iron and zinc.

For metal analysis, the quartz-fibre sample filters were removed following a given 24-hour sampling period exposure and forwarded to Northwest Laboratories, Edmonton, Alberta. A blank (unexposed) filter was also forwarded with each of the exposed sample sets to determine the metal content of the filter medium. The metal content of the collected particulate matter was determined by induced ion-coupled plasma (ICP) analysis [72]. The total weight of metal collected on the filter was divided by the total airflow drawn through the sampler to give the 24-hour average concentration.

Metals in particulate form raise many potential health concerns associated with their presence in the ambient environment. Air quality standards, guidelines or criteria have been set for a number of metals and metallic compounds in several jurisdictions. For Project Swiftsure, Environment Canada set specific stack emission limits for arsenic (1 mg/m^3), lead (5 mg/m^3) and copper (5 mg/m^3) (see Table 2.3). Air quality criteria set by Ontario for various metals are given in Table 8.14. Provincial air quality standards for lead range between 3 and 6 $\mu g/m^3$ [73].

During the particulate survey conducted at the Cameron Centre incinerator site, the sampling filters were analyzed and concentrations reported for the following metals:

- Aluminum
- Barium
- Beryllium
- Cadmium
- Cobalt
- Chromium
- Copper
- Iron
- Lead
- Molybdenum
- Nickel
- Phosphorus
- Potassium
- Sodium
- Vanadium
- Zinc

Many of these metals are common components of soils and clays and thus make up a large proportion of the metals usually found in suspended particulate matter, especially in rural areas. The concentration of metals found in collected particulate matter for the three sampling periods are given in Tables 8.15 - 8.17.

Table 8.14

ONTARIO AIR QUALITY CRITERIA FOR METALS

	CONCENTRATION ($\mu g/m^3$)	
METAL	24-HOUR LIMIT	POINT-OF-IMPINGEMENT[1]
Barium	10	30
Beryllium	0.01	0.03
Cadmium	2	5
Chromium	1.5	5
Colbalt	0.1	0.3
Copper	50	100
Iron	4	10
Lead	5	10
Magnesium	120	100
Manganese	10	30
Molybdenum	120	100
Nickel	2	5
Vanadium	2	5
Zinc	120	100

1 The point-of-impingement concentration is based on a one-half hour averaging time.

Table 8.15

METAL CONCENTRATIONS IN COLLECTED PARTICULATE MATTER

Sampling Period: 13-14 June 1991

METAL[1]	24- HOUR CONCENTRATION ($\mu g/m^3$) SAMPLER[2] 1	SAMPLER 2	SAMPLER 3
Aluminum	0.17	0.22	0.22
Calcium	0.69	0.63	0.53
Copper	0.07	0.06	0.06
Iron	0.64	0.53	0.53
Magnesium	0.17	0.16	0.16
Manganese	0.02	0.02	0.02
Phosphorus	0.04	0.03	0.06
Zinc	0.002	0.02	0.01
Total Metals	**1.80**	**1.67**	**1.59**

1 Metals which are not listed in the table were not found above the detection limit of the analytical equipment. All concentrations are corrected for the filter blank.

2 Sampler #1 is located northwest of the incinerator. Samplers #2 and #3 are located east northeast of the incinerator.

Table 8.16

METAL CONCENTRATIONS IN COLLECTED PARTICULATE MATTER

Sampling Period: 16-17 July 1991

METAL[1]	24- HOUR CONCENTRATION ($\mu g/m^3$) SAMPLER[2] 1	SAMPLER 2	SAMPLER 3
Aluminum	1.41	1.11	1.08
Barium	0.01	0.07	0.02
Calcium	3.55	2.65	3.72
Copper	0.26	0.74	0.70
Iron	2.76	1.41	1.73
Lead	nd[3]	0.05	0.63
Magnesium	0.90	0.79	0.70
Manganese	0.08	0.04	0.05
Nickel	nd	0.007	0.006
Phosphorus	0.08	0.10	0.12
Potassium	0.10	0.28	0.39
Sodium	nd	nd	1.26
Zinc	0.002	0.02	0.01
Total Metals	**9.15**	**7.27**	**10.42**

1 Metals which are not listed in the table were not found above the detection limit of the analytical equipment. All concentrations are corrected for the filter blank

2 Sampler #1 is located northwest of the incinerator. Samplers #2 and #3 are located east northeast of the incinerator.

3 not detected.

Table 8.17

METAL CONCENTRATIONS IN COLLECTED PARTICULATE MATTER

Sampling Period: 17-18 July 1991

METAL[1]	24- HOUR CONCENTRATION ($\mu g/m^3$) SAMPLER[2] 1	SAMPLER 2	SAMPLER 3
Aluminum	0.07	0.05	0.05
Barium	0.003	0.002	0.002
Calcium	0.29	0.08	0.18
Chromium	nd[3]	0.0002	0.0002
Copper	0.01	0.01	0.003
Iron	0.15	0.08	0.08
Lead	nd	nd	0.004
Magnesium	0.07	0.04	0.05
Manganese	0.005	0.003	0.003
Phosphorus	0.005	0.008	0.009
Potassium	0.10	0.28	0.39
Sodium	0.50	0.51	0.68
Vanadium	0.0001	nd	nd
Zinc	0.002	0.02	0.01
Total Metals	1.21	1.08	1.46

1 Metals which are not listed in the table were not found above the detection limit of the analytical equipment. All concentrations are corrected for the filter blank.

2 Sampler #1 is located northwest of the incinerator. Samplers #2 and #3 are located east northeast of the incinerator.

3 not detected.

For the period 13-14 June, the prevailing winds were from the west southwest and southwest, which placed Sampler #1 upwind and Samplers #2 and #3 downwind of the incinerator. Metals commonly found in the natural environment, including aluminum, calcium, iron and sodium made up over 80% of the total metal concentration present. Several metals were not found in the collected particulate samples, including beryllium, cadmium, cobalt, lead, molybdenum, nickel and vanadium. For most of the metals, concentration differences were small between the three sampling positions, with several metals exhibiting higher concentrations for the sample collected from the upwind sampler. Since the incinerator was not burning hazardous waste during this period, the results may be indicative of the metal content usually found in airborne particulate matter on the DRES EPG. All metal concentrations were relatively low and much less than the air quality criteria shown in Table 8.14.

During 16-17 July 1991, prevailing winds were predominantly west southeasterly and westerly, with an east to southeasterly direction occurring about 20% of the time. Thus, all three samplers were downwind of the incinerator for some time during the sampling period. Aluminum, calcium, iron and sodium made up over 70% of the metals found in collected samples; these are common to the natural environment and may also be found in stack particulate matter. The samples did not contain beryllium, cadmium, cobalt, chromium, molybdenum or vanadium.

All metal concentrations were below the air quality criteria with minor concentrations of copper being detected (0.74$\mu g/m^3$ and 0.70 $\mu g/m^3$ for Samplers #2 and #3, respectively) which were well below the Ontario criteria of 50 $\mu g/m^3$. Copper was known to be present in the waste stream undergoing incineration at the time, as it is one of the metals present in shell casings (e.g. firing bands). Another possible source of copper may be in particulate matter discharged by the brushes in the electric motor of the high volume sampler. Since Samplers #2 and #3 showed similar copper concentrations, and both samplers were downwind of the incinerator for longer periods compared to Sampler #1, it is possible that the incinerator was the source of the copper found in the particulate matter collected during 16-17 July 1991.

Aluminum, calcium, iron and sodium made up over 87% of the metals found during the 17-18 July sampling period. The prevailing wind directions (west southwest (52%) and west (36%)) were such that Sampler #1 was always upwind and Samplers #2 and #3 were always downwind of the incinerator throughout the sampling period. Interestingly, except for chromium, potassium, sodium, phosphorus and lead, the concentrations of metals were higher in the sample obtained from the upwind sampler. While the presence of these metals may be indicative of incinerator emissions, certain metals (e.g., iron, copper, zinc) which might be expected to occur in high concentrations during incineration of Flying Cow casings were found in lower amounts downwind. None of the metal concentrations exceeded air quality guidelines or criteria. No beryllium, cadmium, cobalt, molybdenum and nickel were found in any of the samples collected during this period.

The results of the three separate surveys indicated that the metal content in particulates collected in the vicinity of the incinerator was quite low, often several orders of magnitude less than established guidelines. As with the results of the dioxin/furan survey, the incinerator could not be conclusively eliminated as the sole source of the metals found in the ambient environment. Nonetheless, even if incinerator particulate emissions were assumed to be the only contributing source of any or all of the metals, the impact on the environment due to metal contamination was insignificant.

8.4.5 Comparison of Monitoring Results With Predictions

Prior to construction and operation of the incinerator, a commercial plume dispersion model was used to predict the maximum ground level concentrations which might result from emissions from the incinerator stack at the maximum allowable limits [13]. Based on hourly meteorological data collected over one year, the maximum ground level concentrations of various emissions were predicted to occur approximately 100 m east northeast of the stack (i.e. near the two downwind high-volume air samplers and the Western Research Air Quality Monitoring trailer). Using the predicted hourly concentration data, maximum concentrations were calculated for other periods such as 8 hours, 24 hours or 72 hours as applicable. The modelling predictions referred strictly to emissions from the incinerator stack and did not account for background air quality or for other sources in the vicinity of the Cameron Centre such as vehicle traffic.

The predicted maximum ground level concentrations for various incinerator emissions is compared in Table 8.18 with the actual measurements obtained during the field monitoring program. The following points should be noted in this comparison:

- the predicted concentrations do not account for background levels present under normal (i.e. non-incineration) conditions;
- average background levels of e.g. total suspended particulate matter may be much higher than the predicted concentration from stack emissions;
- for mustard, background concentrations are expected to be zero. During the field monitoring program, small background levels of mustard were found occasionally, the sources of which were not incinerator emissions.

The predicted maximum 24-hour ground-level particulate concentration from incinerator emissions was 2.4 $\mu g/m^3$, a value quite small compared to natural background levels. For example, measured 1-hour particulate concentrations at 100 m downwind of the incinerator ranged from 0 to 56 $\mu g/\mu m^3$ but did not show any correlation with incinerator operations. As the particulate monitor was not operated over a full 24-hour period at the 100 m downwind distance, a direct 24-hour comparison between the monitored and predicted values was not possible.

The maximum measured concentration of copper in the particulate matter was 0.74 $\mu g/m^3$ at the fixed sampler distance of 150 m downwind of the incinerator. Assuming a small background level of copper, this agrees quite well with the predicted 24-hour maximum ground level concentration of 0.61 μg/m^3 for copper at 100 m downwind. The comparison for lead is equally as good; for example, the predicted maximum 24-hour ground-level concentration of particulate lead (0.61 μg/m^3) is nearly identical to that obtained with the downwind samplers at 150 m over a 24-hour period (0.63 μg/m^3).

Table 8.18

PREDICTED VS MEASURED MAXIMUM GROUND-LEVEL CONCENTRATIONS FROM INCINERATOR EMISSIONS

PARAMETER	AVERAGING TIME (HOURS)	MAXIMUM CONCENTRATION[1] PREDICTED[2]	MEASURED[3]
Total Suspended Particulates	1	-	56 μg/m^3
	24	2.4μg/m^3	-
Particulate Copper	24	0.61 μg/m^3	0.74 μg/m^3
Particulate Lead	24	0.61 μg/m^3	0.63 μg/m^3
Sulphur Dioxide	1	0.054 ppm	<0.005 ppm
	24	0.012 ppm	-
Hydrogen Chloride	1	0.029 ppm	0.040 ppm
Nitrogen Oxides	1	0.091 ppm	0.010ppm
	24	0.020 ppm	-
Carbon Monoxide	1	0.028 ppm	8.5 ppm
	8	0.010 ppm	-
Mustard	1	-	0.055 ppb
	8	0.00097 ppb	-
	72	0.00044 ppb	-

1 Maximum predicted concentrations as well as measured values (mobile laboratory) refer to a distance 100 m downwind of the incinerator, except metal particulates. Measured metal particulate values refer to a 150 m downwind distance (high-volume air samplers).

2 Predicted data taken from Reference 13, Table 4-6.

3 Measured data reported in Reference 63.

For sulphur dioxide, no measurement exceeded 0.005 ppm at the 100 m downwind distance during incinerator operations. This is less than the predicted maximum ground-level concentration of 0.05 ppm for a one-hour period. The maximum measured concentration of NO_2 at 100 m downwind of the incinerator was 0.01 ppm. Based on the reasonable assumption that NO_2 makes up approximately 10% of measured oxides of nitrogen, then the measured value is close to the predicted one-hour maximum value for NO_2 (i.e., 0.009 ppm). The maximum measured NO_2 concentration during the monitoring survey was 0.03 ppm at a distance 500 m downwind of the incinerator.

For carbon monoxide, the maximum measured one-hour concentration at 100 m downwind distance was 8.5 ppm, a value much higher than the predicted maximum ground-level concentration of 0.028 ppm. The high measured CO concentration appears to be an anomaly attributable to sources such as the mobile laboratory power plant. Analysis of all data at the 100 m distance shows no similar high readings which can be attributed to the incinerator. The average CO concentration at this distance was 0.6 ppm.

Measurement of HCl was limited during the field monitoring program. The maximum measured one-hour concentration was 0.04 ppm when the mobile monitoring laboratory was parked overnight at the Cameron Centre. The maximum predicted ground-level concentration of HCl at 100 m distance from the incinerator was 0.029 ppm.

In the case of mustard, no agent was found on 8-hour air samples collected at various locations on the DRES EPG. Low concentrations of mustard were detected by the mobile laboratory mustard monitor over one-hour periods from sources other than incinerator stack emissions. Therefore, no direct comparison between predicted and measured data is possible in this case. The stack emissions were found to be free of mustard during the trial burn program [49,50].

In general, where monitoring results could be compared directly with the predicted ground-level concentrations as reported in the Project Swiftsure EPP [13], the agreement is relatively good between the two data sets.

Overall, the field monitoring programs carried out on the DRES EPG and in district communities supported the original EPP contention that, if properly operated, the incinerator could safely destroy the agent waste materials in an environmentally-acceptable manner. Measured levels of various possible airborne emissions resulting from the incineration process were nearly indistinguishable from background levels found in the natural environment of the region.

8.5 Other Environmental Monitoring Programs

8.5.1 Overview

Chem-Security Ltd. relied heavily on the incinerator Continuous Stack Emissions Monitoring system to provide information on the performance of the incinerator, both during trial burns (see Chapter VI) and during the destruction of chemical agent waste under operational conditions (see Chapter VII). Supplementary environmental monitoring activities carried out during Project Swiftsure included the following:

- Western Research operated an Air Quality Monitoring (AQM) trailer at a fixed location 100 m to the east of the incinerator. This trailer (see Figure 6.8) incorporated instrumentation which provided continuous data on wind speed and direction, temperature and temperature gradient, and SO_2, NO and NO_2 concentration readings. Associated with the trailer was a high-volume air sampler for collection of particulate samples and a solid sorbent tube sampling system for collection of airborne organic samples (e.g. mustard) over a 24-hour period. Western Research provided a monthly data summary to DRES which was forwarded to Environment Canada for review. The AQM trailer operated for a period of one year starting in September 1990 and provided data on background air quality data as well as data during incinerator operations for comparison purposes.
- Chem-Security Ltd. took samples of scrubber water from the two batch holding tanks located outside the incinerator building during each 24 hours of operation and before discharging the fluid to the site lagoon.
- In response to a suggestion proposed by the citizens' committee Technical Consultant, scrubber water samples were also acquired directly from the scrubber system recirculating loop, particularly when heavily- contaminated scrap metal was being processed. All samples were screened in the on-site laboratory for organics and forwarded to a commercial laboratory (AGAT Laboratories, Calgary) for analysis of arsenic, lead and copper content. To supplement this program, the Technical Consultant occasionally chose random scrubber fluid samples which were forwarded to a commercial laboratory (Zenon Laboratories, Burnaby, B.C.) for analysis of dioxin/furan content.
- Chem-Security Ltd. monitored the water quality of the site lagoon with respect to metal content (arsenic, lead and copper) and undertook a detailed sampling program and remediation effort when it was found the water exceeded specifications for lead content (see Section 7.6).

Table 8.19

MONITORING EFFICIENCY OF SELECTED AQM TRAILER LOCATION

MONTH	INCINERATOR STATUS	% TOTAL TIME[1] DOWNWIND	% TOTAL TIME[1] WITH EMISSIONS
1990			
September	Background	11.1	0.0
October	Background	8.5	0.0
November	Background	7.6	0.0
December	Background	3.6	0.0
1991			
January	Commissioning	14.0	11.7
February	Commissioning	5.6	5.5
March 1-31	Operational	5.1	2.7
March 20-25	Trial Burns	4.2	4.2
April	Operational	5.0	3.1
May	Operational	3.5	2.0
June 1-13[2]	Operational	4.3	0
June 14-30	Operational	15.9	14.4
July	Operational	nd[3]	approx. 13
August	Operational	11.5	11.3

1 DOWNWIND data refers to percentage of time when the prevailing wind direction placed the AQM trailer downwind of the incinerator stack. EMISSIONS data refers to the percentage of the time the trailer was downwind while the incinerator was operating.

2 The AQM Trailer was moved on 13 June to a more favourable 100 m downwind location (east northeast of the incinerator stack).

3 No data available due to malfunction of the wind direction monitor. Data obtained from the DRES Meteorology Group showed the trailer was in the proper downwind monitoring direction approximately 17% of the time.

8.5.2 Air Quality Monitoring Trailer Results

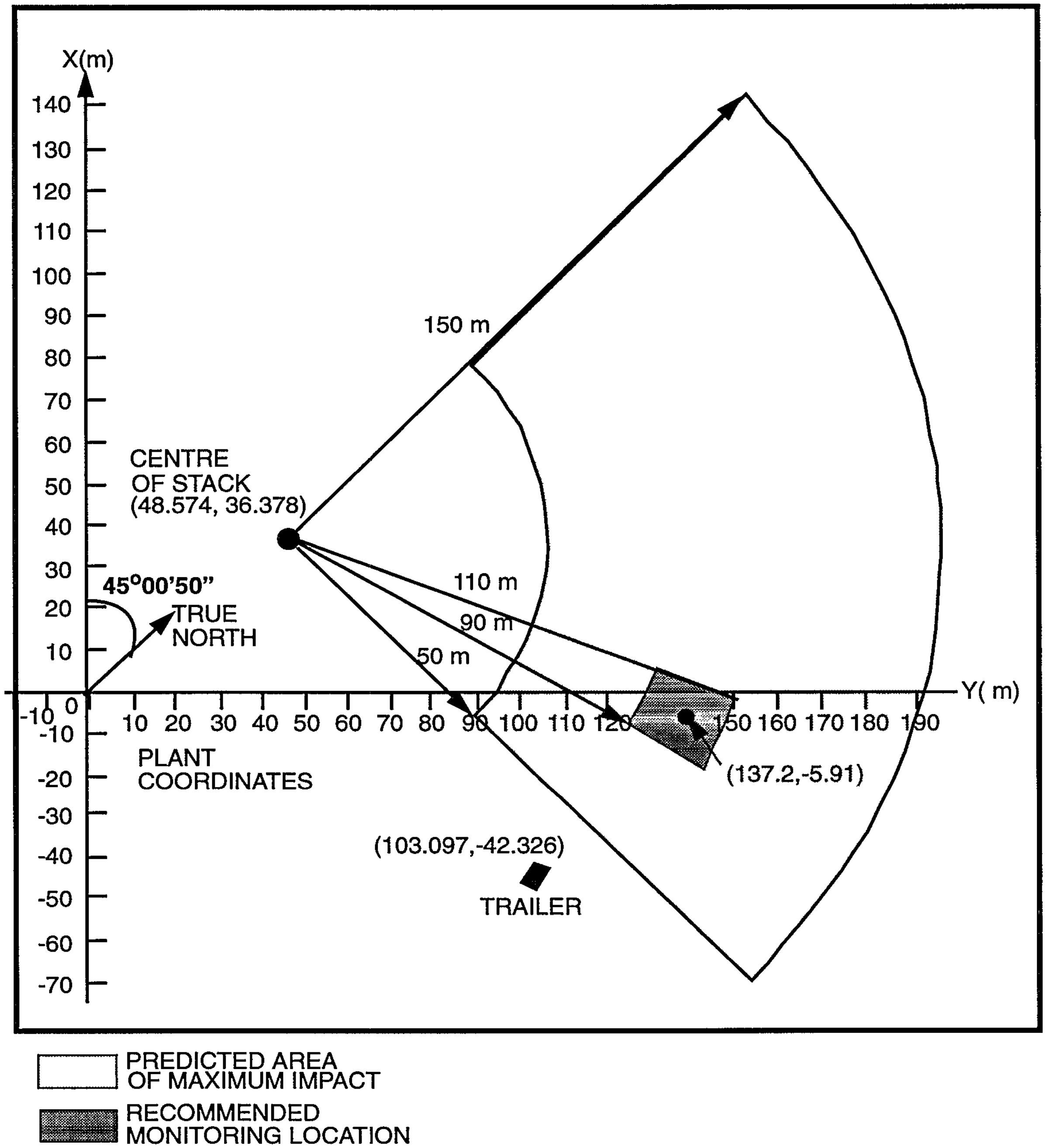
Several months after the AQM trailer began acquiring data, a study was undertaken based on meteorological records to determine the percentage of time the trailer was directly downwind of the incinerator, i.e. in a position to provide valid data related to stack emissions. The results of this study are summarized in Table 8.19. This Table also indicates when the AQM trailer was directly downwind while the incinerator was operating. In general, the percentage of time the trailer was downwind of the incinerator was relatively low during the fall of 1990 and spring of 1991. This, combined with dispersion modelling undertaken by the independent contractor, indicated that the trailer was not positioned at the location where maximum ground-level concentrations were predicted [13] to occur. Using historical meteorological data, the dispersion model predicted that incinerator emissions would impact an area from 60 m to 150 m to the east through northeast of the stack, with maximum ground-level concentrations occurring from 95 m to 150 m downwind, as shown in Figure 8.14. Data gathered by the trailer over the period September 1990 to May 1991 showed that winds were most predominantly from the west southwest (Figure 8.15), in agreement with historical data. Therefore, the AQM trailer was relocated in mid-June to a location east northeast of the incinerator at 100 m distance to maximize the exposure of the monitoring equipment to incinerator emissions.

During Project Swiftsure, the AQM equipment proved to be highly reliable. For example, operating time for the various instruments ranged between 95 and 100% for each month throughout the monitoring program.

One-hour maximum, daily maximum and monthly average concentrations of sulphur dioxide and nitrogen dioxide, as measured by the AQM trailer, are shown in Figures 8.16 and 8.17, respectively. In general, all concentrations were well below the air quality limits set for Project Swiftsure; there was little difference between background readings and those readings acquired when the AQM trailer was directly downwind while the incinerator was operating. The results for sulphur dioxide and nitrogen dioxide agreed well with corresponding data obtained by the mobile laboratory when it was located downwind of the incinerator at the 100 m distance.

Total suspended particulate concentrations, as determined from samples acquired by the AQM trailer high-volume sampler, are summarized in Table 8.20. In each case, particulate concentration is reported as the average over a 24-hour sample collection period. Samples were usually collected at intervals of approximately 5-6 days for those months where multiple sampling occurred. The operational status of the incinerator during each sampling period is also indicated in this Table. With the exception of two samples collected during April 1991 (6 April and 24 April) and one sample collected on 29 July 1991, 24-hour total suspended particulate concentrations were well below the air quality limit of 100 $\mu g/m^3$ and did not show any obvious correlation with operation of the incinerator. The three samples which exceeded air quality limits occurred on days with moderate (e.g approx. 25-30 km/h) winds from the southwest, during which time the incinerator was in operation processing con-

Figure 8.14

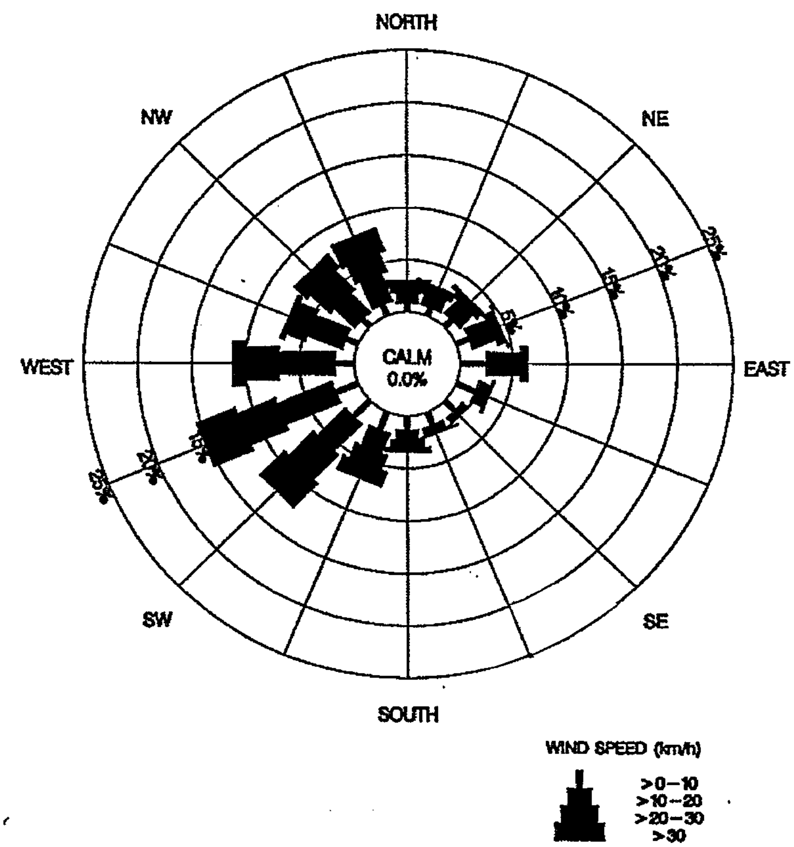


Actual And Recommended Locations For The AQM
Trailer Relative To The Incinerator Stack

taminated scrap metal. In these cases, a comparison of results between the AQM trailer and the mobile laboratory at 100 m downwind of the incinerator could not be made as the mobile laboratory was not engaged in EPG monitoring activities on the specified dates.

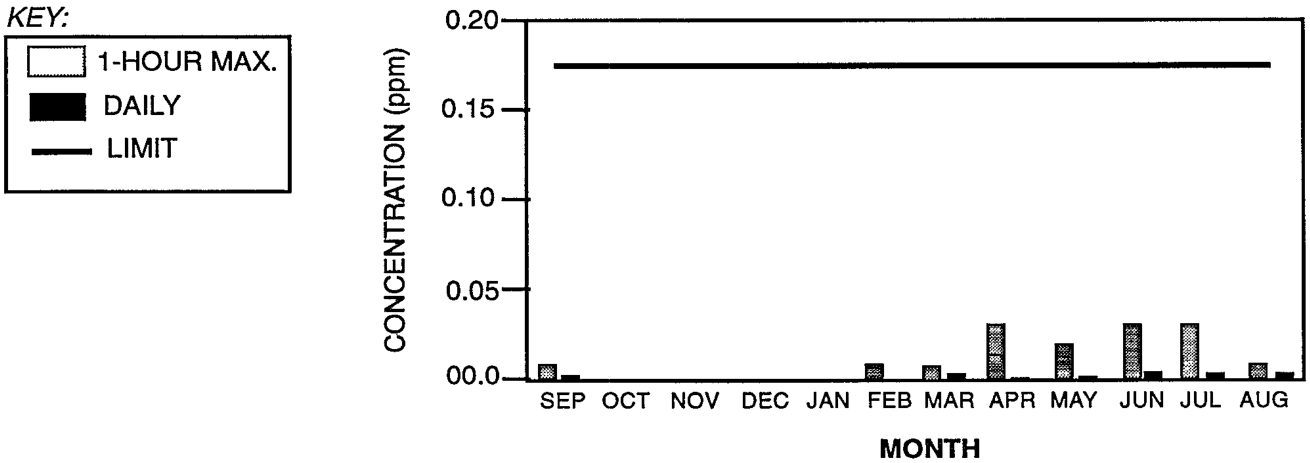
The particulate matter collected by the AQM trailer high-volume sampler was subjected to detailed metal analysis as well as analysis for dioxin/furan content on several occasions during incinerator operations. The data for the metal analyses is summarized in Table 8.21. In general, the results agree favourably with those obtained from the high-volume sampler array deployed around the incinerator site by the independent contractor; *viz:* the constituents normally found in the natural environment made up the bulk of the particulate matter composition and metals which could be associated with incineration operations (e.g. arsenic, copper, lead) were well within allowable limits. With respect to dioxins/furans, the collected particulate matter did not contain these compounds above the levels found in blank or background samples collected under similar conditions.

Figure 8.15



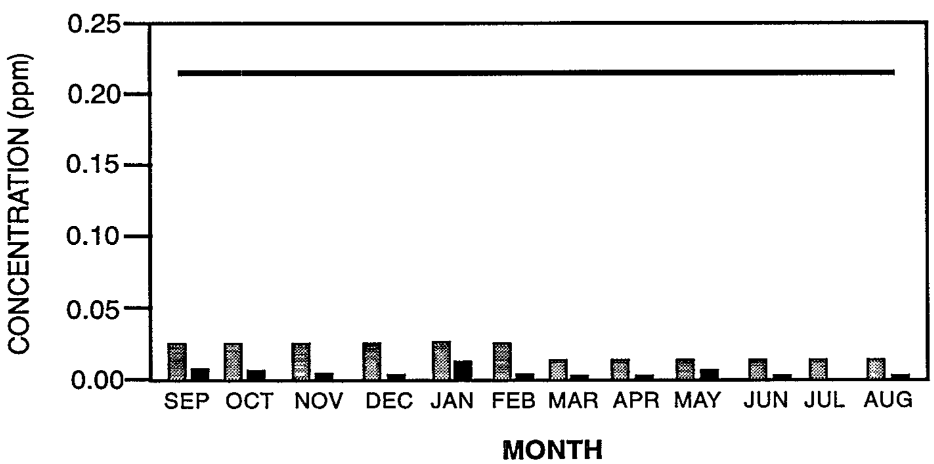
AQM Trailer Wind Speed and Direction Data
Sept 90 - May 91 Monitoring Period

Figure 8.16



Sulphur Dioxide AQM Trailer Data Summary

Figure 8.17



Nitrogen Dioxide AQM Trailer Data Summary

Table 8.20

TOTAL SUSPENDED PARTICULATE CONCENTRATIONS MEASURED BY AIR QUALITY MONITORING TRAILER

MONTH	No. OF SAMPLES	INCINERATOR OPERATION	CONCENTRATION ($\mu g/m^3$)
1990			
September	1	no	73.1
October	0	no	-
November	0	no	-
December	4	no	4.3, 7.6, 9.3,
		no	84.4
1991			
January	5	no	11.8
		test	3.6, 3.8, 3.8
		test	20.7
February	4	test	4.7, 5.9
		test	10.2, 26.7
March	6	no	15.5
		yes	1.4, 2.0, 5.9
		yes	7.3, 8.5
April	5	yes	4.3, 17.4
		yes	31.2, 120.1
		no	163.8
May	4	no	2.1, 12.1
		no	17.3, 28.9
June 1-13	2	no	20.0
		yes	27.5
June 14-30	3	yes	5.4, 5.8, 19.2
July	5	yes	11.9, 12.2
		yes	34.3, 35.8
		yes	112.1
August	6	yes	5.3, 12.9, 31.1
		yes	38.0, 68.2
		no	19.9

Table 8.21

AQM TRAILER HIGH-VOLUME AIR SAMPLER METAL ANALYSES OF COLLECTED PARTICULATES

COMPONENT	CONCENTRATION (μg/m³) DATE:[1] 17/06	23/06	05/07	23/07	12/08	16/08
Arsenic	0.0003	0.0006	<0.001	0.0001	0.0002	0.0002
Aluminum	0.1	<0.09	0.1	0.33	<0.004	0.01
Barium	0.014	0.012	0.012	0.014	0.003	0.007
Boron	<0.05	<0.05	0.06	0.06	0.36	0.21
Cadmium	<0.0002	<0.0002	<0.0001	<0.0002	0.0006	<0.0002
Calcium	<0.35	<0.35	0.17	0.35	1.05	1.04
Chromium	0.001	0.002	0.001	0.002	0.005	0.002
Copper	0.11	0.07	0.09	0.13	0.12	0.06
Iron	0.25	0.04	0.09	0.36	0.08	0.49
Lead	0.004	0.020	0.018	<0.003	0.006	0.020
Magnesium	2.52	<0.81	0.46	0.12	0.39	0.34
Manganese	0.005	0.001	0.003	0.010	0.002	0.010
Molybdenum	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005
Nickel	<0.001	<0.001	<0.001	<0.001	<0.001	0.004
Phosphorus	0.28	0.28	0.19	0.16	0.32	0.17
Potassium	<0.12	<0.12	0.023	0.20	0.28	0.25
Silicon	0.064	0.012	<0.0006	0.040	0.140	0.064
Silver	<0.0004	<0.0004	0.006	0.0006	<0.0004	<0.0004
Sodium	<1.15	<1.15	2.31	<3.50	12.10	6.39
Tin	<0.001	<0.002	<0.001	<0.002	<0.001	<0.0005
Vanadium	<0.0005	<0.0005	0.0002	0.0010	<0.0005	<0.0005
Zinc	0.019	0.008	0.007	0.005	0.010	0.016

1 1991 Date format given as dd/mm. For example, 17/06 = 17 June 1991.

8.5.3 Random Scrubber Fluid Samples

During public meetings held to review Project Swiftsure (see Chapter IX), concerns were raised that incineration of mustard or mustard- contaminated items might possibly produce dioxins/furans. Data obtained from the manual stack sampling program during incinerator trial burns showed that dioxin/furan emissions were well within limits; this was also confirmed during subsequent waste processing operations by the independent air quality monitoring program (see Section 8.4.3, above) and by samples obtained by the AQM trailer. Nonetheless, members of the Project Swiftsure citizens' group felt that stack sampling for dioxins/furans should continue throughout the project. To address this concern, DRES developed an efficient, cost-effective alternative to the expensive, time-consuming stack sampling method. This alternative method involved the routine screening of incinerator scrubber fluid batch samples for organic compounds, and specifically for dioxins and furans, during incineration of mustard-containing waste inventory. The scrubber fluid sampling and analysis plan is described in Annex F. To further address the citizens' committee concerns on this issue, their Technical Consultant acquired random samples of scrubber fluid for dioxin/furan analysis at a commercial laboratory. The consultant selected these samples from amongst those which had been collected previously by Chem-Security Ltd. and submitted for analysis to verify that the scrubber fluid met project requirements for discharge to the Cameron Centre lagoon.

The objectives of the random scrubber fluid sampling survey were two-fold:

- ❖ to estimate corresponding stack concentrations of dioxins/furans,
- ❖ and to assess the scrubber fluid sampling and analysis plan.

The results of the sampling survey are summarized in Table 8.22. The sample obtained in March 1991 during the incinerator trial burn program showed a a trace of one furan congener (2,3,7,8-tetrachloro-dibenzofuran) and no dioxins. This result was considered atypical as a variety of furans and dioxins normally are produced during the combustion of chlorinated waste material. While no dioxins/furans were detected in other scrubber water samples acquired from the holding tanks, a sample of sludge obtained from the bottom of one holding tank was found to contain 1.0 ng/L of dioxins/furans (T4CDD toxicity equivalent) at a suspended solids concentration of 63 g/L, or approximately 15 parts-per-trillion T4CDD equivalent. This level is approximately 350 times below the 5 parts-per-billion limit proposed by Alberta Environment [58] for discharge of wastewater containing dioxins/furans. Assuming that dioxin loading on particulate matter captured by the scrubber system is representative of the dioxin loading of stack particulate emissions, the sludge dioxin/furan content corresponds to a stack concentration of 0.3 picograms/m^3 T4CDD equivalent, well below the project limit of 12 ng/m^3 T4CDD equivalent.

Table 8.22

**SUMMARY OF RESULTS
SCRUBBER FLUID RANDOM SAMPLING PROGRAM
FOR DIOXINS/FURANS**

DATE 1991	No. OF SAMPLES	SAMPLING LOCATION[1]	TEQ CONCENTRATION[2] (ng/L)
19 Mar	1	SV 620	0.47
1 Apr	1	SV 621	nd[3]
8 May	1	SV 620	nd
9 July	1	SV 621 Top	nd
9 July	1	SV 621 Bottom Sludge	1.0

1 Sampling locations included the two water effluent holding tanks associated with the incinerator scrubber system. These holding tanks are designated SV 620 and SV 621.

2 Total concentration of dioxins and furans expressed as a toxicity equivalent concentration relative to 2,3,7,8- tetrachloro-p-dibenzodioxin (T4CDD).

3 Not detected

8 .6 Discussion

The aim of the environmental monitoring program, which was carried out before and during the incineration of chemical agent waste, was to assure DND, environmental regulatory agencies and the public that Project Swiftsure was being conducted in a safe, environmentally-responsible manner. Surveys of the DRES EPG and surrounding communities indicated that the district possessed relatively good air quality characteristic of a non-industrialized, rural setting. The monitoring program showed that incinerator operations and waste processing activities had no discernible impact on this air quality.

The mobile monitoring laboratory, which was equipped with the same sensitive instrumentation as used in the incinerator stack emissions monitoring system, provided a versatile and effective means for providing continuous air quality data, as well as serving as an independent means to monitor incinerator performance. This highly-visible unit verified that project-specific emission standards were being met at all times, thereby providing the public with the necessary assurance that incineration of agent waste was not causing any health risks or environmental impacts.

DRES and the project contractors expended considerable effort to show that mustard agent incineration did not produce dioxins/furans in significant quantities. The dioxin/furan survey results confirmed that, provided the incinerator was operated within specifications, its design was capable of preventing the formation of these combustion byproducts when processing chlorinated feedstock (i.e. mustard).

The strict particulate emission standard set for Project Swiftsure proved to be difficult, but not insurmountable, to meet. Most likely, the cardboard boxes used to package waste inventory were the major source of particulates during incineration. Chem-Security Ltd. successfully met the particulate emission limit by installing filters in the scrubber system and processing waste at a lower rate. With larger solid waste incinerators, low particulate emission levels are attained by incorporating a particulate filter array ("baghouse") downstream of the wet scrubber system. A baghouse was not incorporated into the Swiftsure incinerator design in view of the added cost versus the options which were available to meet the project-specific emission requirement.

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CHAPTER IX
PUBLIC CONSULTATION

9.0 PUBLIC CONSULTATION

9.1 Consultation Objectives

During the early stages of Project Swiftsure, DRES identified the need for a strong, pro-active public consultation program to provide for information exchange and communications between the project proponents and the public in the district communities. A list of communities in the vicinity of the EPG is given in Table 9.1 Despite the inherent controversial nature of the project, the possibility existed that public support could be gained through this program, given the demonstrated openness of DND with respect to the results of the Barton Report [3]. In addition, many area residents regard DRES as a vital part of the community, especially in Medicine Hat where most DRES staff live.

The general approach taken was to determine the important project-related issues, address these to the satisfaction of the public before proceeding, and develop participatory relationships to strengthen public confidence in project plans and operations. This approach embodied public consultation objectives recommended by the Federal Environmental Assessment Review Office, namely [16]:

- informing interested parties in the project area;
- initiating a dialogue and exchange of information throughout all phases of the project, but particularly during planning and destruction activities;
- soliciting views and input into project plans, particularly the Environmental Protection Plan, to avoid unforseen developments or adverse reactions.

9.2 Public Consultation Program Development

Initially, the National Defence Headquarters agency, Director General Information (DG Info), lead the public consultation program with support from DRES and Chem-Security Ltd. Subsequently, Maureen Payne Associates, a public relations firm, was hired under DND contract to assist in development of the program. After the contract with Maureen Payne Associates had expired, the responsibility for managing the day-to-day public consultation activities was transferred to DRES. Venture Communications Ltd. was hired through the competitive bidding process to assist DRES in the area of public consultation.

The planned public consultation program continued to evolve in response to and through interaction with the public as the project progressed. Several different methods were utilized with varying degrees of success (see Section 9.3, Consultation Methods). The program covered five distinct phases which coincided with different activities associated with Project Swiftsure planning and implementation. These phases included:

- Phase I (late 1989 to mid-March 1990): planning and public information meetings to introduce the district communities and local staff to Project Swiftsure. This phase was implemented through National Defence Headquarters; DRES became the lead agency for the subsequent phases.

Table 9.1

DISTRICT COMMUNITIES IN THE VICINITY OF THE DRES EXPERIMENTAL PROVING GROUND

COMMUNITY	POPULATION[1]	DISTANCE[2] (km) FROM INCINERATOR
Ralston	422	3.5
Suffield	169	5
Redcliff	3834	32
Medicine Hat	42290	40
Jenner	<50	55
Brooks	9464	64
Buffalo	<50	69
Bindloss	<50	80
Hilda	65	81
Empress	229	92

1 Population based on 1989 Province of Alberta census.

2 Straight-line distance from the Cameron Centre incinerator site to the centre of the community.

- Phase II (mid-March to October 1990): formation of a volunteer citizens' committee and public workshops held to review the project Environmental Protection Plan.
- Phase III: (November 1990 - April 1991): installation and successful commissioning of the agent destruction technology as well as implementation of environmental monitoring programs.
- Phase IV: (May - December 1991): Implementation and completion of agent waste destruction and environmental monitoring programs;
- Phase V: (January - September 1992): removal of incinerator technology and completion of the consultation program and citizens' committee involvement.

During initial planning for the public consultation program, several target audiences were identified:

- **Local Communities:**- Project Swiftsure was recognized primarily as a local issue. Gaining acceptance in the district communities was therefore crucial to successfully undertaking and completing the agent destruction activities. Of importance was the need to inform local citizens, political leaders, and the media of the project objectives and the positive benefits of destroying the chemical agent waste compared to other options such as permanent storage.

- **Federal and Provincial Politicians:**- At the Provincial level, the local Member of the Legislative Assembly (MLA) from Medicine Hat and Deputy Premier of Alberta (Hon. Jim Horsman) as well as the Alberta Minister of Environment (Hon. Ralph Klein) and MLA from the Bow Valley riding (Hon. Tom Musgrove) were to be kept aware of Project Swiftsure, its progress, and associated issues so that informed and knowledgeable responses could be provided as required to all interested parties. Federally, the Minister of National Defence and the local Member of Parliament (MP) from Medicine Hat (Mr. Bob Porter) were also to be kept fully informed in the event the project became a national issue or if timely, local support was required.

- **Media:**- The media was considered to be an important vehicle for informing the local communities and was considered the key element regarding dissemination of information at the provincial and national levels. The approach was to keep the local media fully informed on a pro-active basis.

- **DRES and CFB Suffield Staff:**- The most credible spokespersons for any given National Defence project are the Department's own employees. Thus, it was vital to inform fully the staff at DRES and CFB Suffield regarding Project Swiftsure so that they could carry timely, appropriate messages to the surrounding communities.

- **Special Interest Groups:**- A negative initial reaction to the project was expected from local environmental and peace groups. It was important, therefore, to inform these groups of positive aspects associated with the project; for example, improving the EPG environment, performing chemical agent "demilitarization", and instituting safeguards which would provide health protection.

9.3 Consultation Methods

In general, the public was given opportunities to "buy into" the project by participating directly in the planning process and with the project proponents in monitoring its progress and eventual outcome. The philosophy adopted was to consider the public as "part of the solution, not part of the problem". The consultation program was relatively low-key and aimed at keeping issues focused at the local or regional level without raising the project to national status.

The program incorporated the following methods:

- Open public meetings and workshops;
- Small group meetings, presentations and site visits;
- Media presentations;

- Information brochures;
- A Community Information Newsletter;
- A toll-free telephone information service, and
- A citizens' advisory committee.

While each method contributed in some degree to the overall program, the most significant methods which shaped the project and defined its success were the open public meetings and the participation of a volunteer citizens' group known as the "Citizens' Environmental Protection Committee - Project Swiftsure" (CEPC).

9.4 Public Meetings

9.4.1 Information Meetings

Project Swiftsure was formally introduced to district residents through a series of open meetings held during February 1990 in several communities surrounding the CFB Suffield range. A special briefing, open to all DRES and CFB Suffield staff, was given on February 12-13, 1990 in the Ralston Community Theatre. Public meetings were held in the communities of Buffalo, Medicine Hat, Ralston, Suffield, and Empress. Residents from other nearby communities such as Brooks, Redcliff, Jenner, Patricia, Idlesleigh, Bindloss, Hilda, and Schuler also attended one or more of these meetings. In each case, the venue was the local Community Hall, except in Medicine Hat where the meeting was held in the Travelodge Motel banquet/conference room. Mayor Ted Grimm of Medicine Hat was present at the Medicine Hat and Suffield meetings; Mayor Jean Franklin of Brooks attended the Suffield meeting.

Advance notice of the meetings was given primarily through newspaper advertising (Figure 9.1) and, in the case of Empress, through direct mail notice to all community residents. For example, advertisements were placed in the following local newspapers beginning two weeks prior to the scheduled meeting dates:

- Medicine Hat News
- Bow Island County Commentator
- Brooks Bulletin

A news release was prepared and issued February 1, 1990 to radio stations CHAT (Medicine Hat), CJCY (Medicine Hat), Q13 (Brooks) and to the newspapers listed above. Empress was added to the schedule following a request from residents who attended the meeting in Buffalo.

A team consisting of a moderator from DG Info (Major Laszlo Tollas), the Project Swiftsure director and manager, and representatives from Chem-Security Ltd., Western Research, and Maureen Payne Associates were present at each meeting. Typically, the format included introductions by the moderator, a project overview presented by DRES (Dr John McAndless), a brief description of the incinerator technology by the CSL representatives (John Clay and Tom Kinderwater), and a discussion of the proposed contents of the project

Figure 9.1

Swiftsure Public Meetings

During the past few years, Defence Research Establishment Suffield (DRES) has been carrying out the destruction of old chemical stocks and the clean-up of its physical site. During the next 18 months the remaining chemicals and contaminated materials will be destroyed by neutralization and incineration. The project is known as Operation Swiftsure.

The development of an Environmental Protection Plan (EPP) is the first phase in the process to clean up Suffield.

An information meeting will be held in:

Buffalo:
Monday, February 12, 1990 at the Buffalo Community Hall
Time:
7:00 p.m.

Medicine Hat:
Tuesday, February 20, 1990 at the Medicine Hat Travelodge
Suffield:
Wednesday, February 21, 1990 at the Suffield Community Hall

This meeting is to explain the project and the steps being taken to ensure a safe and environmentally responsible clean-up program.

Coffee and light refreshments will be served.

CANADIAN
ARMED
FORCES

Advertisement For Public Information Meetings

Environmental Protection Plan from the Western Research representative (Dr Gordon Brown). The public was invited to ask questions following the presentations. Fact sheets describing Project Swiftsure were distributed to all present. Maureen Payne Associates personnel documented all questions and answers using written notes as well as electronic recording equipment. Attendance at each of the meetings is summarized in Table 9.2.

During the meetings, the public raised a number of concerns regarding uses for the incinerator following completion of the agent destruction operations. Of prime concern was the notion that CFB Suffield might become a permanent hazardous waste disposal site for Southern Alberta or a site for disposing of Canadian military wastes. To mitigate this concern, a written policy statement was provided by the National Defence Associate Deputy Minister of Materiel which stated that the incinerator would be dismantled and removed following completion of Project Swiftsure [21]. Only agent-related waste and contaminated materials as listed in the EPP were to be destroyed during the course of the project.

Related DND policy statements which prohibited importing of wastes into the project as well as the plan to conduct a complete on-site destruction operation addressed other concerns regarding the off-site transportation of Swiftsure-related wastes.

The Project Ploughshares organization made a group presentation at the Medicine Hat meeting. While this peace group was in favour of the proper destruction of the chemical warfare agents, they requested that Project Swiftsure be subjected to a full public (panel) review in accordance with the federal Environmental Assessment Review Process (Stage III, EARP). This view was supported by a Greenpeace representative and by members of the Grasslands Naturalists, a Medicine Hat environmental group. In response, DND distributed the registered initial environmental screening document [18] and invited the groups to participate in the development of the project Environmental Protection Plan.

In general, the concerns raised at the February 1990 public meetings fell into the following six categories:

❖ **Policy**

The public was concerned about the fate and usage of the incinerator following Project Swiftsure, whether stated DND policy would change, and whether a full panel review according to the EARP guidelines was needed.

❖ **DRES Historical Activities**

The public raised concerns regarding potential health and environmental impacts from previous mustard and nerve agent destruction operations and waste disposal activities such as the land farming of mustard hydrolysate sludge. There was some concern that military activities and DRES research and development programs might be responsible for certain illnesses or diseases in the district communities.

Table 9.2

ATTENDANCE AT PROJECT SWIFTSURE PUBLIC MEETINGS

LOCALE	DATE 1990	ATTENDANCE
A. PUBLIC INFORMATION MEETINGS		
Buffalo	12 February	23
Ralston[1]	12,13 February	162
Ralston[2]	13 February	9
Medicine Hat	20 February	65
Suffield	21 February	29
Empress	22 February	21
B. EPP REVIEW MEETINGS		
Suffield	31 July	28
Empress	1 August	13
Medicine Hat	2 August	34

1 Two separate Project Swiftsure briefings for DRES and CFB Suffield Staff.
2 Open meeting for Ralston community residents.

❖ **Public Consultation**

The public was interested in how they could participate in the development of the EPP and the project plans. As well, they wanted information on the roles assumed by other government agencies such as Environment Canada and Alberta Environment.

❖ **Environment**

The public raised concerns regarding possible contamination of soil and surface water at the storage sites and what impact incinerator emissions would have on the environment. The public requested that environmental monitoring be carried out by an independent agency and that an independent consultant be hired to review the EPP.

❖ **Health and Safety**

The public requested further information on the short- and long-term potential health effects related to incinerator emissions and what emergency response plans were in place to protect workers and the general public in case of accidents.

❖ **Technical Issues**

Questions were raised on how process residues would be disposed of, how the incinerator was configured and operated, how emissions would be monitored, and what could be expected during emergency situations arising during incineration of chemical agents. The public also wanted assurance that wastes, other than those specified in the project plan, would not be incinerated.

The issues raised as described above were addressed during the subsequent development of the EPP, with specific questions and responses provided in the document submitted for public review in July-August 1990.

The public reaction to Project Swiftsure at the information meetings varied widely and tended to be locale-dependent. For example, in communities close to DRES such as Ralston and Suffield, overall support for the project aims and approaches was evident. This likely reflected the fact that many of the residents were knowledgeable of DRES programs and, in some cases, were retired DRES or CFB Suffield employees. In Medicine Hat, the larger audience provided a forum for special interest groups to express their philosophies which included mistrust of government, military and environmental regulatory agencies. In the more distant communities such as Empress, the residents were less informed regarding DRES and CFB Suffield. They were particularly concerned about possible health effects resulting from past and present activities carried out by these "secretive" organizations and were highly mistrustful of a government-sponsored project such as Swiftsure.

9.4.2 EPP Review Meetings

Following the public information meetings, the Project Swiftsure Environmental Protection Plan was developed and copies of the plan placed in district libraries in June 1990. Public meetings were held 31 July - 2 August, 1990, in Suffield, Empress and Medicine Hat to review the EPP. Again, advance notice was given to the public through a series of newspaper advertisements (Figure 9.2) and news releases to the local media.

The EPP review meetings differed significantly from the earlier public information meetings in that a "workshop" format was used where issues could be raised and discussed in a small group setting as opposed to a general panel discussion. As shown in Table 9.3, a number of resource personnel were present at the meetings to facilitate the EPP review process. Information handouts and source reference materials were made available to meeting attendees, as follows:

- ❖ Information Summary/Project Swiftsure Environmental Protection Plan;
- ❖ Copy of an open letter from the Minister of National Defence (Hon. Bill McKnight) stating that the incinerator would be removed upon project completion [36];
- ❖ A brochure describing the role of the Project Swiftsure Citizens' Environmental Protection Committee;

Figure 9.2

Project Swiftsure

Environmental Protection Plan

An Open Invitation

Interested area residents are invited to attend and discuss environmental and public protection measures to be incorporated into Project Swiftsure.

Project Swiftsure has been proposed by Defence Research Establishment Suffield (DRES) as a safe method of destroying chemical agents and waste materials stored at DRES.

The Environmental Protection Plan (EPP) prepared for the project was made available publicly in late June and copies are now available to area residents at the following libraries:

- Medicine Hat Public Library
- Redcliff Public Library
- Brooks Public Library
- Ralston/Suffield Library in the Canex Centre
- Bow Island Public Library
- Irvine Town Hall Office
- Medicine Hat College Library
- Brooks Campus of the Medicine Hat College Library

Summaries of the EPP have also been prepared and are available through the libraries listed above.

At the meetings which will be held July 31 and August 1 and 2, representatives of DRES, Western Research, Chem-Security Ltd. and CanTox Inc. will present information about the Environmental Protection Plan and be available to answer questions.

Suffield Community Hall
July 31 7:00 p.m.
Empress Community Hall
August 1 7:00 p.m.
Medicine Hat Travelodge
Kodiak Room
August 2 7:00 p.m.

Project Swiftsure Citizens' Environmental Protection Committee

Citizens' Environmental Protection Committee members will be present. The committee is currently conducting a review of the EPP with the assistance of an outside, independent consultant and solicits your concerns.

For further information on Project Swiftsure, please call the toll-free line

1-800-661-6510

or write to

Defence Research Establishment Suffield
Box 4000
Medicine Hat, Alberta T1A 8K6

Advertisement for EPP Review Meetings

Table 9.3

RESOURCE PERSONNEL FOR EPP REVIEW MEETINGS

NATIONAL DEFENCE HEADQUARTERS
Eugene Belovich, Project Director Swiftsure
Major Laszlo Tollas, Public Information Officer

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD
Dr John McAndless, Project Manager Swiftsure

WESTERN RESEARCH
Dr Gordon Brown, EPP Project Manager
Kurt Hansen, Senior Environmental Engineer
Mike Schroeder, Senior Meteorologist
Don Colley[1], General Manager Environmental Engineering

CANTOX INC.
Dr Bob Willes, Senior Toxicologist

CHEM-SECURITY LTD.
Tom Kinderwater, Site Superintendent
Al Matheson, Safety Supervisor
Al Wakelin[1], Project Manager

VENTURE COMMUNICATIONS LTD.
Brian McCutcheon, Community Relations Consultant

[1] Medicine Hat meeting only

- Copies of Environment Canada and Alberta Environment letters requesting information from the project proponents to assist in the official review of the EPP, and
- List of resource personnel available for consultation at the EPP workshops.

Each EPP review meeting took the following form:

- The first third of the meeting included presentations by DRES, Western Research, and Cantox Inc. representatives to provide an overview of Project Swiftsure, the Environmental Protection Plan, and the health risk studies which had been conducted, respectively;
- The presentations were followed by small group discussions in a workshop setting. Here, the audience was free to move about to discuss issues and consult with resource personnel stationed at three separate locations within the meeting room. Each location featured a key field covered in the EPP such as incineration technology,

health risk assessments, or safety and environmental monitoring programs. Incinerator display models and schematic diagrams were available to assist the discussions. Questions raised by the public and answers provided by resource personnel during the small group discussions were recorded (on flip charts).

- During the final third of the meeting, the results of the small group discussions were reported to the entire audience. This included briefings on what issues had been resolved, what outstanding issues remained, and how the EPP would be further developed with the input received. The meeting was then opened for general discussion to ensure all points-of-view had been covered.

The EPP meetings were facilitated by Mr. Brian McCutcheon (Venture Communications Ltd.) who introduced resource personnel and moderated the general discussions.

Table 9.2 lists the attendance at each of the three EPP review meetings. Attendees included the general public, municipal officials, members of the Citizens' Environmental Protection Committee, and news media representatives from the region. At Empress, the second and third portions of the proceedings were combined as there were not enough people present to make the separate small group discussions practical.

The workshop format proved effective for focusing and covering the important issues related to the project EPP and for creating awareness of true public participation in the development of project plans. Special interest groups did not actively dominate the proceedings, as the format did not provide an opportunity to address a large, uninformed audience.

The issues covered during the meetings were considered in the development of the EPP Supplementary Information document (EPP Volume III) which was subsequently approved by National Defence in September 1990 [40]. As before, this volume of the document was distributed to district libraries to complete the EPP.

Both the information meetings and EPP review meetings received extensive media coverage in local newspaper, radio, and television. CBC Radio (Calgary) also covered the Medicine Hat and Suffield information meetings.

9.5 Small Group Presentations and Site Visits

Starting in February 1990 and continuing throughout the project, on-site tours and briefings were held at DRES for provincial, regional, and municipal officials, local community groups, and other interested parties, as summarized in Table 9.4. The local media were usually invited and, in many cases, attended and reported on these visits.

In July 1990, DRES arranged a special visit to the Alberta Special Waste Treatment Centre, Swan Hills, for members of the Citizens' Environmental Protection Committee to give them an appreciation of waste destruction technology comparable to that proposed for Project Swiftsure. In addition, the Project Swiftsure manager gave presentations at the request of community groups in Medicine Hat, as listed in Table 9.5.

Formal reports [85-90] on Project Swiftsure were also presented by the project manager to several scientific/engineering conferences or to special international meetings, including the following:

- USSR Visiting Delegation, DRES (July 1989);
- HAZTECH Canada (West) Conference, Calgary (November 1990);
- United Nations Special Commission, Advisory Committee On Chemical Agent Destruction, New York (May 1991);
- United Nations Meeting, Specialist On Chemical Agent Destruction Methods, Geneva (October 1991);
- Alberta Environmental Services Association, Spring Convention, Banff (March 1992);
- US Academy of Sciences, Committee on Alternative Chemical Demilitarization Technologies, Washington D.C. (June 1992), and
- Air & Waste Management Association, 85th Annual Convention, Kansas City (June 1992).

Table 9.4

SUMMARY OF PROJECT SWIFTSURE SITE VISITS

DATE	VISITORS	SITES VISITED
18 July 89	USSR Delegation	Willis Centre[1] EPG Sites
12 Feb 90	Local Politicians, Community Leaders	DRES Cameron Centre[1]
13 Feb 90	Media	DRES Cameron Centre
14 May 90	Environment Canada Officials	EPG Sites Cameron Centre
7 June 90	CEPC, Media	EPG Sites Cameron Centre
5 July 90	CEPC	ASWTC Swan Hills
4 Dec 90	Media	Cameron Centre
13 Dec 90	CEPC	Cameron Centre
29,30,31 Jan 91	Community Disaster Services Officials, Politicians, Media	DRES Cameron Centre
5 June 91	DRES Employees	Cameron Centre

Table 9.4 (cont'd)

SUMMARY OF PROJECT SWIFTSURE SITE VISITS (CONT'D)

DATE	VISITORS	SITES VISITED
20 June 91	Alberta Health Inspectors (meeting)	DRES Cameron Centre
21 Aug 91	Media	Cameron Centre
6,7 Sept 91	General Public	DRES Open House Cameron Centre
8 May 92	Commercial Firms	Cameron Centre
2 July 92	Commercial Firms	Cameron Centre
23 July 92	CEPC	DRES Cameron Centre
4 Sept 92	Environment Minister MLA Bow Valley	Cameron Centre

1 Nerve agent neutralization was conducted at the Willis Centre. The incinerator facility was located at the Cameron Centre.

Table 9.5

PRESENTATIONS TO COMMUNITY SERVICE ORGANIZATIONS

DATE	ORGANIZATION
28 March 90	Medicine Hat Optimist Club
2 April 90	Medicine Hat Rotary Club
25 April 90	APEGGA[1]
22 May 90	Beta Sigma Phi International Sorority
24 May 90	Saamis Rotary Club
17 September 90	Alberta Energy Company Ltd.
24 September 90	Wives of Medicine Hat Rotarians
12 February 91	Redcliff Town Council
22 April 91	Beta Sigma Phi International Sorority
1 October 91	Brooks Town Council
27 January 92	Beta Sigma Phi International Sorority
27 April 92	Beta Sigma Phi International Sorority

1 Association of Professional Engineers, Geologists and Geophysicists of Alberta

9.6 Media Presentations

Project Swiftsure was first announced on 25 January 1989 during a nationally-televised briefing by the Minister of National Defence (the Hon. Perrin Beatty) to outline the results of the Barton Report. Additional details on project plans were provided in news releases starting in July 1989 and continuing throughout, especially when key activities such as installing and testing the incinerator were imminent. Project news releases to September 1990 were collated and included for reference in the Environmental Protection Plan. A summary of the project- related news releases issued by DND is given in Table 9.6.

Table 9.6

SUMMARY OF PROJECT SWIFTSURE FORMAL NEWS RELEASES

No.	DATE ISSUED	SUBJECT
1	25 Jan 89	National Defence project announcement
2	01 Jul 89	USSR Delegation visits DRES
3	01 Feb 90	Public information meetings
4	17 Jul 90	EPP public review meetings
5	03 Oct 90	Acceptance of revised EPP
6	22 Oct 90	EPP available in public libraries
7	02 Nov 90	Independent air monitoring contractor
8	16 Jan 91	Community air monitoring program
9	04 Apr 91	DRES EPG air monitoring program
10	09 Apr 91	Revised waste inventory estimate
11	02 May 91	Contractor field operation safety review
12	08 May 91	Resumption of field operations
13	06 Jun 91	Trial Burn results announced
14	12 Jun 91	Lead problem in incinerator scrubber
15	13 Jun 91	Citizens' Committee satisfied with progress
16	01 Aug 91	Project Swiftsure progress report
17	02 Aug 91	Environment Canada Trial Burn approval
18	18 Sep 91	Mustard incineration completed
19	05 Nov 91	Agent destruction operations completed
20	27 Nov 91	Project Swiftsure operations completed
21	20 Mar 92	Sale and removal of incinerator announced
22	06 Jul 92	Incinerator sale completed

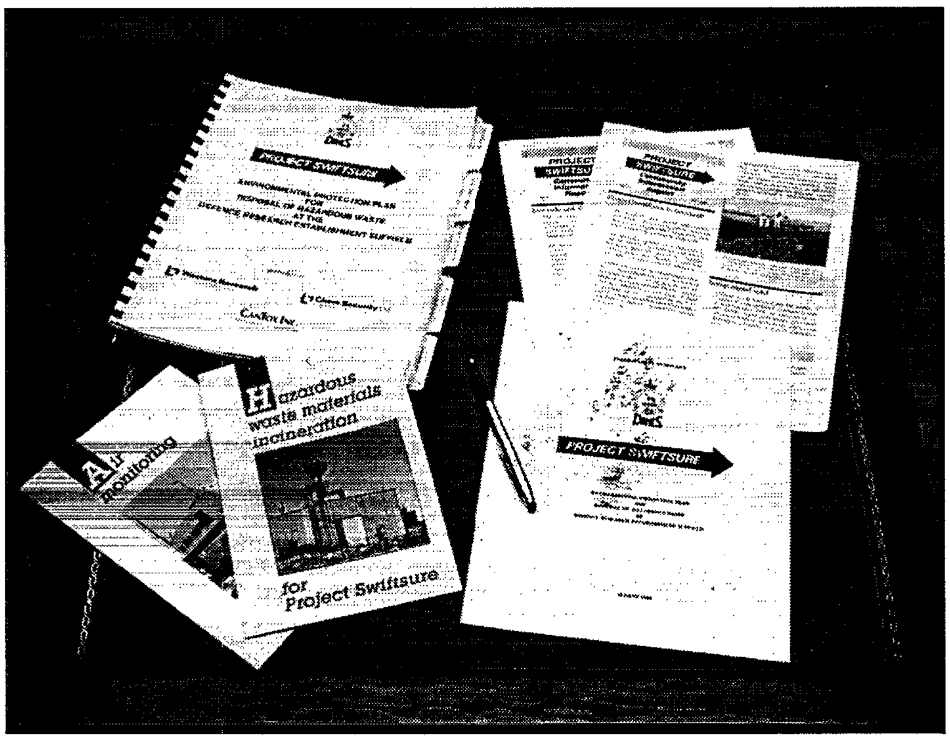
On 13 February 1990, a special briefing and site tour was held at DRES for news media. This tour attracted local newspaper, radio and television representatives as well as media representatives from Calgary (CBC Radio) and Lethbridge (CFCN Television).

Throughout Project Swiftsure, the local media regularly reported on project-related issues by attending Citizens' Environmental Protection Committee meetings (see below). Local newspaper reports were effective in disseminating timely information to the general public. On more controversial issues, interviews with the project manager and with CEPC members were conducted by the local radio and television stations in Medicine Hat or by CBC Radio in Calgary.

9.7 Information Brochures, Surveys and Newsletters

Figure 9.3 illustrates some of the important documents prepared for public information purposes, including the Project Swiftsure EPP and examples of brochures and the Community Information Newsletter.

Figure 9.3



Project Swiftsure Documents And Information Hand-Outs

A hand-out prepared by DRES which outlined the project policy, aims, technical approaches, and schedule, including a questionnaire, was distributed at the February 1990 public information meetings. Only two completed questionnaires were returned. This poor response was believed to reflect general agreement-in-principle for the need to carry out destruction of the chemical agent waste. This conclusion was supported by the results of the 1990 "Annual Spring Questionnaire" distributed to all (approximately 10,000) households in

Medicine Hat by the Honourable Jim Horsman, MLA. This questionnaire, which was designed to elicit response on a number of topical Medicine Hat issues contained eight questions, including the following:

"Do you approve of the plan to neutralize and destroy chemicals and contaminated materials at Canadian Forces Base Suffield?".

Approximately 1000 questionnaires were returned to the MLA constituency office. The following responses were recorded for the Swiftsure-related question:

Yes	73%
No	18%
Don't Know	9%

The constituency office issued a letter to DRES which stated that this response "indicates solid support for your project".

Following the February public meetings, DRES prepared a second hand-out which further outlined the project and described the proposed contents of the Environmental Protection Plan. This hand-out was distributed at the EPP review meetings held in July-August 1990. As well, Venture Communications Ltd. prepared two separate six-page brochures which were available as hand-outs at public meetings, site tours, open houses, and special presentations. These explained the technology to be employed during the project. The first, entitled "Hazardous Waste Incineration For Project Swiftsure", described the incinerator equipment, its operating capability, and safeguards to ensure emission standards set for the project would be met. The independent monitoring program established to verify environmental compliance was described in the second brochure entitled "Air Monitoring For Project Swiftsure".

Starting in November 1990, Venture Communications, with the assistance of DRES, produced a monthly Community Information Newsletter which was distributed widely by mail to community leaders, libraries, special interest groups, media, government officials at all levels, and to DRES, CFB Suffield, and National Defence headquarters staff. The Newsletter covered timely issues such as installation, testing and operation of the incinerator, monitoring programs, project support activities, special events, and issues covered by the citizens' committee. Included were interviews with key project personnel as well as photographs of project-related equipment and activities. By December 1991, fourteen separate issues of the Newsletter had been produced and distributed. A final Newsletter was issued in September 1992 to complete the public consultation program. This last Newsletter reported on the removal of the incinerator technology and the disbanding of the citizens' committee.

The Community Information Newsletter proved effective in providing reference information, progress reports, introducing project personnel, and demonstrating DND's commitment to addressing various public issues to a wide audience.

9.8 Toll-Free telephone Line

In February 1990, a toll-free "information hot-line", which included a message recorder, was installed at DRES to facilitate direct public contact on project-related issues. The date, time, caller identification, and topic raised for discussion were logged for all incoming calls. The project manager, assisted by the DRES Canadian Forces Liaison Officer, fielded all enquiries. The telephone system was removed in December 1991 following completion of waste destruction operations.

A total of 68 calls were received on this hot-line, 6 of which were considered directly relevant to project-specific issues. For example, these latter callers expressed concern that unreported accidents were triggering the (perceived) unexpected appearance of the Project Swiftsure Mobile Air Monitoring Laboratory in district communities or else registered complaints about medical conditions which were thought to be related to agent destruction operations. The remaining calls were of an administrative or general information nature and included a few "crank" calls from unidentified sources.

The telephone line symbolized the accessibility of the project to the general public. It was also potentially useful as a communications tool in emergency situations. In practical terms, however, the toll-free telephone proved less effective than the other approaches employed during the public consultation program.

9.9 Citizens' Environmental Protection Committee

9.9.1 Formation

DND recognized from the outset that periodically holding large, open public meetings, aside from the logistics problems, was an inefficient way to generate public trust and support for the aims of Project Swiftsure. Experience gained during the DND Goose Bay PCB destruction project [1], showed that an approach which involved consultation with a citizens' advisory group tended to focus issues, allowed for effective public participation in the decision-making process, and potentially could engender some trust amongst the various parties involved. Therefore, this public consultation approach was also adopted for Project Swiftsure.

Following the February information meetings, DRES initiated contact with approximately 40 public officials, citizens, and special interest groups, inviting volunteers to form a liaison committee for Project Swiftsure. Those contacted primarily were individuals who had raised rational concerns at the public meetings or who had spoken on behalf of their community interest. The committee was invited to examine all aspects of the proposed project, to initiate an independent review of the plans and technological approaches, and to plan for on-going public participation and consultation in the development and implementation of the Project Swiftsure Environmental Protection Plan.

Of those contacted, 11 people initially agreed to volunteer their time to participate in a citizens' committee for the project. The initial organizational meeting was held at DRES on 7 March 1990. The name Citizens' Environmental Protection Committee - Project Swiftsure (CEPC) was unanimously selected by its members to reflect the primary focus of the committee's efforts and activities. The committee also selected a chairman at this time and began development of its own terms of reference. Although the participants were somewhat polarized in their views, a strong consensus existed with regard to the project objective, viz: the safe destruction of the chemical agent waste stored at DRES. With the mutual consent of the members and to assist the Committee undertake its work, DRES agreed to cover project-related out- of-pocket expenses; for example, travel costs to attend meetings and long-distance telephone charges.

The CEPC membership represented a broad cross-section of backgrounds and interests. The members included ranchers, a chemical engineer, a chemistry professor, a registered nurse, a housewife, a physician, and members of special interest groups. Over the course of Project Swiftsure, the composition of the Committee changed occasionally; however, a core group remained which maintained the original diversity. All members who served on the CEPC are listed in Table 9.7.

9.9.2 Meetings

Between 7 March 1990 and the final meeting on 23 July 1992, the CEPC held over 40 public meetings. Most of these were held in the evenings at the Medicine Hat College (see Figure 9.4), while others were held at DRES or in district communities. Initially, meetings were held on a bi-weekly basis then on a three-week or monthly basis as the project progressed and issues were dealt with.

Figure 9.4

Citizens' Environmental Protection Committee Meeting

Table 9.7

CITIZENS' ENVIRONMENTAL PROTECTION COMMITTEE MEMBERSHIP

NAME	ALBERTA RESIDENCE
Core Members	
Mr Harold Fieldberg (Chairman)	Bindloss
Mr Norm Bauer, B.Sc.	Hilda
Mrs Hazel Carlson	Brooks
Dr Ted Cowtan, M.D.	Medicine Hat
Ms Dawn Dickinson, M.Sc.	Medicine Hat
Dr Brian Lloyd, Ph.D.	Medicine Hat
Mr Brian McNally, P.Eng.	Medicine Hat
Ms Veronica Swan	Medicine Hat
Ms Evelyn Tate, R.N.	Medicine Hat
Ms Nancy Tripp	Medicine Hat
Short-Term Members	
Ms Yvonne Haase	Suffield
Dr Tom Jones, M.D.	Medicine Hat
Mr Jim Ridley	Medicine Hat
Mr Brent Skidmore	Medicine Hat
Ms Debra Solberg	Brooks
Technical Consultant	
Mr Brian Stuckert, P.Eng	Calgary

The Committee adopted a philosophy of holding open meetings and invited the local media to attend. At least one media representative attended every meeting. DRES representatives were also present at all meetings with various project contractors, special guests or government officials invited to attend as required. At the request of CEPC, the Project Swiftsure manager prepared meeting minutes which were distributed to Committee members, invited attendees as well as to the local media and contacts at Environment Canada and National Defence.

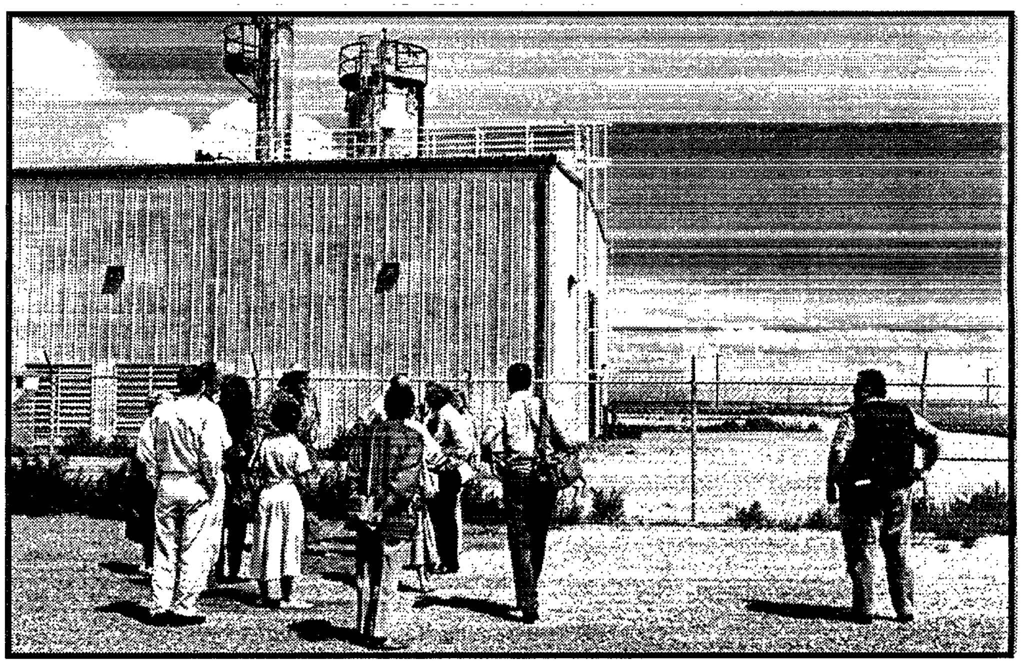
From time-to-time, special CEPC meetings were held in conjunction with other events such as site visits to DRES (see Figure 9.5), the tour of the Alberta Special Waste Treatment Centre, or demonstration of the Swiftsure Mobile Air Monitoring Laboratory to the Brooks town council.

9.9.3 Terms Of Reference

On 1 June 1990, the CEPC developed and issued the following terms of reference which became the basis for on- going work:

- Ensure that safety to people and complete protection for the environment remain paramount during the development and implementation of Project Swiftsure;
- Ensure that the incinerator and components are dismantled and removed from CFB Suffield within 3 months of project completion or by 31 December 1991, whichever comes first;
- Seek written affirmation from the Minister of National Defence that the incinerator removal shall take place;
- Determine total quantities, identify and analyze all starting materials and reactants being disposed of (i.e. inventory), including all emissions and residues after incinerator trial burns and throughout the duration of the project;
- Produce recommendations for the disposal of final waste products;
- Conduct random monitoring by an appointed representative of the Citizens' Committee of emissions and of products being disposed of;
- Ensure safe shut down of operations if emission standards are exceeded;
- Produce on-going reports to the communities and immediate reporting to the media of project-related activities, and
- Provide a short written report to be made public following the final stages of Project Swiftsure.

Figure 9.5



Citizens' Committee and Media Visit the Swiftsure Incinerator Site

9.9.4 CEPC Technical Consultant

The Project Swiftsure EPP described many different, sophisticated technologies which were proposed for mitigating or eliminating potential health risks and environmental impacts. Initially, the Committee was concerned that members would need to devote much time and effort simply to acquire sufficient knowledge to deal competently with the complex technical issues. Therefore, the Committee requested that the services of an independent technical consultant be provided. In agreeing with this proposal, DRES requested that the CEPC be responsible for selecting their consultant while the necessary financial support and contracts to provide such services would be arranged through DND. In June 1990, after review of several candidates, the Committee chose Mr Brian Stuckert of Calto Industries Inc., Calgary, to serve as the CEPC Technical Consultant. Although funded by DND, the consultant reported to the Committee and worked in their best interest. This approach fostered trust amongst the parties involved and demonstrated DND's commitment to the public consultation process. The consultant continued to advise the CEPC until their final meeting in July 1992.

The mandate of the Technical Consultant initially involved an independent detailed review of the EPP. This was later expanded to include monitoring the chemical warfare agent destruction operations to ensure compliance with the approved EPP. This active role included the acquisition of random process samples for analysis. Furthermore, the Technical Consultant addressed and discussed CEPC and public concerns, assessed responses provided by DRES and by CSL, and debated issues as they arose. The overall role was to facilitate communications while ensuring that all concerns were appropriately covered. The Technical Consultant generally reported first to the CEPC on any project-related issues under review.

The Technical Consultant's review of the EPP, as well as project operations, involved addressing the rationale for technology and process selection, as well as specific concerns regarding potential impacts on the project workers, the public, and the environment. Some of the key factors examined and addressed were as follows:

- The rationale for selecting incineration as the process of choice for all waste streams was questioned. For lewisite, it was subsequently determined that destruction by neutralization/solidification was a more appropriate approach than neutralization followed by incineration;
- Although the incinerator equipment and operating conditions were designed to prevent the formation of chlorinated dioxins/furans, concerns were raised regarding the potential production of these compounds during the incineration of mustard. Consequently, dioxins/furans were included in the overall monitoring program as a supplement to the stack sampling program that was undertaken durng trial burns. DRES proposed and developed a novel method to routinely screen the incinerator scrubber fluid for dioxins. This screening method was used in turn to signal the requirement for

implementing a detailed stack sampling program should a specified "trigger" level of dioxins be detected.

- The original program to monitor incinerator emissions and any impacts on ambient air quality was essentially "self- policing" (i.e. carried out only by DRES and CSL). To address this, DRES implemented a separate air monitoring program which was carried out by a contractor using a mobile laboratory (See Chapter VIII: Environmental Monitoring). In addition to providing supplementary data, this program component was viewed as a valuable addition to the emergency response capability for the project by providing timely impact and plume mitigation data in the event of an accident. A member of CEPC participated in the process to review proposals and select the contractor to carry out the separate air monitoring program.
- As a result of concerns regarding the limited number of incinerator trial burns, additional stack sampling, fixed- station air sampling and scrubber fluid particulate analysis were added to the overall monitoring program [63]. These additional components were used to monitor potential emissions from any waste materials which had not been processed during trial burns (e.g. neutralized nerve agent solution and standard waste resulting from laboratory operations).

The Technical Consultant proved invaluable in assisting the Committee to understand the complex issues involved which, in turn, enabled members to make informed recommendations for project improvements. The Consultant also acted as a credible focal point through which DRES, contractors and members of the Committee could establish common ground when dealing with controversial technical matters.

9.9.5 Specific Highlights Of CEPC Activities

The following highlights, in chronological order, describe some of the important CEPC activities undertaken during Project Swiftsure:

- June 1990: The terms of reference of the Committee are issued;
- June 1990: CEPC members tour the DRES EPG waste storage sites with local news media;
- July 1990: CEPC members visit the Alberta Special Waste Treatment Centre, Swan Hills, to view comparable incinerator technology and waste disposal practices, as well as to confer with members of the Swan Hills citizens' advisory committee;
- July 1990: In reply to a letter received from the CEPC Chairman, the Hon. Bill McKnight, Minister of National Defence, provides written assurance to CEPC and the district public that the incinerator equipment will be removed upon completion of the project;
- August 1990: Committee members participate in the public workshops to review the project EPP and, through their technical consultant, prepare a report on the EPP for consideration by government reviewing agencies.

- November 1990: At CEPC request, an independent air monitoring program is established to monitor air quality on the EPG and in district communities during the course of Project Swiftsure. A CEPC member participates in the contractor selection process;
- December 1990: CEPC members tour the incinerator building and equipment installed at the DRES Cameron Centre site;
- February 1991: CEPC reviews and concurs with the DRES proposal to monitor dioxins/furans formation by incinerator scrubber fluid sampling and analysis as opposed to implementing an expensive, time-consuming stack sampling program for these materials;
- April 1991: CEPC reviews the incinerator trial burn data prior to approval of the trial burn results by Environment Canada;
- May 1991: CEPC recommends a change in the scrubber fluid sampling protocol to further improve the method with respect to acquiring representative samples for analysis;
- Summer 1991: CEPC reviews all process control, air monitoring and stack emissions data during course of agent destruction operations;
- November 1991: CEPC reviews and concurs with the DRES plan to sell the incinerated scrap metal for recycling purposes.
- January 1992: CEPC examines proposed options for the sale and removal of the incinerator equipment;
- Spring 1992: CEPC, with DRES and Venture Communications Ltd. assistance, prepares a report on the Committee's activities and achievements for distribution to the public;
- July 1992: CEPC holds their final meeting at DRES, inspects the incinerator removal progress and issues their final report [91].

9.9.6 Committee Recommendations

For reference, the Committee published a series of guidelines and recommendations in their final report [91] to assist other citizens' groups and project proponents in dealing with issues involving potential impacts on public safety and/or the environment. Many of these recommendations were based on the lessons learned and approaches adopted by the CEPC, DRES, and contractors during Project Swiftsure. The recommendations are summarized as follows:

- Public involvement in project planning should occur at the earliest possible stage. The Committee noted that, with Project Swiftsure, planning and contractual arrangements were well advanced before involving the public. During public consultation, the plans required substantial changes which might have been more readily accommodated at an earlier stage in the project (e.g., the requirement to remove the incinerator technology).
- A citizens' committee is an effective means of establishing an early dialogue with project proponents, for determining the important

issues, and for providing the forum for resolving problems;

- Citizens' committee meetings should be open to the public with the media and project proponents invited to attend. This approach, which was used for CEPC meetings, proved effective for widely disseminating information about project progress and the resolution of issues of interest to the general public;
- Well-defined terms of reference and goals should be established early and maintained by citizens' committees during their involvement in a project;
- Members of citizens' committees should have a broad range of backgrounds and views of the project and be willing to dedicate the time necessary to fully represent their community interests. In the case of Project Swiftsure, committee members were volunteers rather than appointed by project proponents or special interest groups.
- For complex projects, the committee should engage the services of an independent technical consultant. In the case of Project Swiftsure, a consultant was selected by the committee and reported first to the committee on all technical matters. To show good faith in this process and by mutual consent, DND funded but did not control the activities of the technical consultant.
- Minutes of citizens' committee meetings should be recorded and distributed to all interested parties;
- Whenever possible, citizens' committees should be invited to view the proposed technology and operations sites during different stages of a project. During Project Swiftsure, DRES provided photographs during CEPC meetings which proved effective for progress reporting in the interim between scheduled on-site visits.
- Project proponents should offer to and cover legitimate out-of-pocket expenses for committee members when the committee is amenable to such an offer;
- Committee members should endeavour to gain as much knowledge as possible about a project so that informed decisions can be made. As well, project proponents should adopt an open approach and provide to the fullest extent possible any information requested by the committee;
- Committee decisions on project-related issues should be reached by a consensus approach rather than by voting;
- Citizens' committees should document their activities, achievements, and recommendations in the form of public reports at various stages of their involvement in a project and especially at project conclusion.

In addition to the above general recommendations, the CEPC recommended that the strict emission levels achieved during Project Swiftsure be adopted as standards by government regulatory agencies and applied to other incineration projects. The CEPC also recommended that, for expensive projects like Swiftsure, information on operating costs should be made available on a regular basis. A project expense summary, as shown in Table 9.8, was provided to CEPC for inclusion in their final report.

9.9.7 CEPC Achievements

The Committee enhanced the credibility of the public consultation program through its commitment to achieving the common goal of destroying the chemical agent waste in a safe and environmentally-responsible manner and by their direct participation in the development of project plans, the EPP and operational activities. Through this process and media reporting of Committee activities, the CEPC quickly became the recognized focal point and interface for representing community interests in the project.

Important documents such as the EPP and Trial Burn Reports were examined by the Committee in parallel with reviews conducted by government agencies. CEPC consensus reached on issues and acceptance of the documents tended to expedite the overall approval process. In several cases, the Committee provided input which resulted in significant modifications to project plans, leading to approaches which achieved a higher degree of environmental protection.

As the project progressed, members gained a good working knowledge of the project technologies and processes which enabled informed decisions to be made on various technical issues. As the CEPC became more informed, the concerns raised became smaller in number and focused on the more complex, difficult-to-resolve issues. Through continued interest and input, the stringent limits set for incinerator emissions and waste water discharge were achieved during destruction operations.

The Committee also provided the impetus which led DRES to develop a novel and efficient scrubber fluid sampling and analysis method for the detection of dioxin/furans during the mustard incineration process. This method may prove to be a viable alternative to stack sampling methods for detecting specific combustion products during commercial waste incineration. The Committee established a network of contacts with government authorities at all levels which assisted in gaining acceptance for certain project initiatives such as recycling the processed scrap metal. As the project progressed, a cooperative working relationship was established with DRES and the contractors involved which led to the development of a certain degree of trust. Ultimately, this cooperative approach and direct involvement amongst project proponents, contractors, and the CEPC led to successful communication and the achievement of the aims of all parties.

In general, the Project Swiftsure Citizens' Environmental Protection Committee demonstrated that citizens' groups can be an effective means by which government organizations and the public can communicate and maintain dialogue on controversial projects. The interaction between citizens' groups and the Department of National Defence during the Goose Bay PCB destruction project achieved similar results [1].

Table 9.8

PROJECT SWIFTSURE EXPENSE SUMMARY 1989-1992

PROJECT SWIFTSURE

ITEM	COST ($K[1])
Project Operations Management[2]	1040.5
Temporary Duty Travel	73.2
Contracts:	
Hazardous Waste Disposal System (CSL/WR)	14374.0
Shredder Development/Construction (Shred-Tech)	755.0
EPG Soil Survey (RMC)	741.4
Independent Air Monitoring (RWDI)	535.0
Public Consultation (MPA/Venture)	222.8
Citizens' Committee -- Total	82.9
Archived Literature Survey	55.0
	Total: 17879.8

CITIZENS' ENVIRONMENTAL PROTECTION COMMITTEE

ITEM	COST ($K)
Technical Consultant	68.0
Out-Of-Pocket Expenses	4.0
ASWTC Trip	2.1
CEPC Hand-Out Brochure	0.8
CEPC Final Report	8.0
	Total: 82.9

CEPC Total as a percentage of total project cost: 0.46%

1 $K = $1000. For example, $73.2K = $73,200

2 Project operations management included direct equipment purchases, maintenance and staff over time costs associated with DRES support of Project Swiftsure.

9.10 Discussion

As a result of the consultation program employed, public acceptance for the project goals was gained, effective dialogue was maintained, and timely information was disseminated to show that operations were conducted in a safe, environmentally-responsible manner. This program embodied approaches which allowed direct public participation during project planning and implementation. Examples of this include public review of the Environmental Protection Plan and interaction with a volunteer citizens' advisory group during destruction operations. An "open" philosophy was adopted for the program which proved effective in disseminating information and creating trust. For example, the citizens' group meetings were open to the public and attended by the media.

In general, public consultation proved to be a key element in the overall success of Project Swiftsure. The program ultimately produced a positive image for DRES in the district communities.

Project Swiftsure Final Report

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CHAPTER X

CONCLUSIONS AND RECOMMENDATIONS

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 General

- Project Swiftsure chemical agent destruction operations were completed before 1992, in accordance with the directive issued by the Minister of National Defence. In general, Departmental support in the form of political will, priority and financing enabled this directive to be successfully met in a timely fashion.
- Project Swiftsure embodied the philosophy of using best available technology to meet the stringent safety and environmental protection limits which were applied to the project. In some cases (e.g. particulate emissions), the limits were more strict than standards applied to Canadian commercial hazardous waste disposal operations.
- The project environmental monitoring program provided the necessary data to verify that the chemical agent waste was destroyed in a safe, environmentally-responsible manner.
- DRES expertise was essential in carrying out the agent destruction programs, especially in the case of the nerve agent stockpile, as no Canadian contractor previously had the requisite experience in this area.
- The selection and use of known, proven destruction methods (chemical neutralization, incineration) enabled the project proponents to more readily gain public acceptance for Project Swiftsure.
- A strong public consultation program during the planning and operational phases played an essential role in gaining acceptance for the project goals and alleviating concerns regarding health, safety and environmental issues. Meaningful consultation with the public was achieved through a variety of methods including information newsletters, public information meetings, workshops, site visits and dialogue with a citizens' group which represented the public view on matters related to Project Swiftsure.
- Contract Statements of Work and supporting documents for all major contracts, including contracts for destruction operations, environmental monitoring and public consultation, provided sufficient information to permit potential contractors to competitively bid on the proposed work. In each case, the evaluation process utilized by Supply and Services Canada enabled the most qualified, technically responsive and lowest-priced bidder to be selected for contract award.

10.2 Project Organization

- The scope of Project Swiftsure tended to be complex, involving the interaction of government officials from several departments, scientific and technical experts, contractors, politicians, citizens' groups and the media. Strong project management was essential to ensure project goals were maintained and operations were carried out effectively.
- A lean, effective Departmental organisation which embodied project matrix principles proved successful in terms of managing Project Swiftsure activities. Clear roles were assigned to the key participants. The number of positions which possessed direct decision-making authority was kept small; this combined with well-established lines of communication amongst the key participants enabled the project to proceed in a timely fashion.
- A safety-related incident which occurred shortly after initiating field work under contract was related, in part, to contractor inexperience with respect to established procedures used by DRES for EPG field activities. Further incidents of this nature were prevented by strict adherence to the contract statement of work which designated DRES as having ultimate authority and responsibility for safety at EPG sites.

10.3 Project Concept

- The Project Swiftsure concept plan embodied a system which employed both chemical neutralization and incineration to destroy the variety of stored chemical agent waste. Critical alternative methods (e.g. explosive demolition) were also employed to destroy small numbers of items which were not amenable to the prime destruction methods or were considered too dangerous to handle. The concept plan provided the necessary reference information to gain approval for project implementation and funding.
- The original concept plan was modified as the project proceeded, yet the plan continued to comply with the requirement to dispose of the waste in a safe, environmentally acceptable, expeditious and cost-effective manner. Modifications to the concept plan occurred as a result of:
  a) the public consultation process,
  b) better identification of the waste inventory as the project progressed, and
  c) contractor process modifications due to weather, process variations and scheduling of various project activities.

  Some examples of plan modifications are as follows:

  - lewisite was destroyed by chemical neutralization followed by stabilization of arsenic-containing process byproducts for landfilling, rather than incinerating the process byproducts. A transportable neutralization unit was employed to treat the lewisite *in-situ* rather than transporting the agent to a centralized neutralization facility.

- one general-purpose incinerator, as opposed to two separate incinerators for specific waste streams, served the required purpose for incinerating the chemical agent waste inventory.
- industrial solvents, originally scheduled for incineration, were removed from the project inventory and replaced with laboratory waste.
- the need to neutralize bulk mustard was eliminated as the entire stockpile of mustard stored in one- ton containers was destroyed during incinerator trial burns. Mustard which was thickened or had degraded through aging was not amenable to neutralization; these forms of agent were also destroyed by incineration.
- in response to public concerns, dioxins/furans were monitored in various wastestreams during incineration of mustard.
- as a result of the public consultation process, DRES implemented an independent air quality monitoring program using a mobile laboratory.
- the incinerator was removed from CFB Suffield following completion of Project Swiftsure, rather than keeping the unit to destroy general waste generated by CFB Suffield and DRES programs.

❖ The amount of scrap waste to be processed was greatly underestimated in the original plan due to the co-mingled nature of the waste and the manner in which it was stored; for example in pits or in large piles. This problem was resolved by re-estimating the waste inventory and implementing appropriate contract amendments as the project proceeded.

10.4 Policy

❖ Project Swiftsure was conducted in accordance with DND policy on safety and environmental protection management, the Canadian Environmental Protection Act and other appropriate regulations such as the Transportation of Dangerous Goods Act. In general, the most stringent of either provincial (Alberta) or federal regulations were followed, where applicable.

❖ A complete on-site operation was conducted on the DRES EPG with no waste imported for disposal nor any waste removed for disposal at commercial facilities, in accordance with DND and Alberta Environment policy. Incineration of contaminated metal items produced clean scrap metal which was recycled off- site. This material was not considered waste because of its commercial value.

❖ The incinerator was removed upon project completion in accordance with DND policy developed in response to the public consultation program.

10.5 Technology Application

- A commercially-available 7 MM BTU/hour transportable incinerator utilizing an industrial standard two-stage combustion design proved suitable for mustard agent destruction. The incinerator was an excellent match of equipment capacity to waste volume and heat release characteristics. It is recommended that this equipment be used by industry either as a liquid waste incinerator, or for solid waste which is relatively low in water content and heating value.
- Optimizing incinerator operating conditions using sulphur hexafluoride (SF_6) proved effective in producing a destruction and removal efficiency exceeding 99.9999% for mustard chemical agent. The incinerator did not produce detectable mustard emissions during the processing of bulk mustard or mustard-contaminated scrap inventory. It is recommended that industry continue to use non-toxic surrogate compounds to determine incinerator destruction and removal efficiencies prior to demonstrating performance on actual waste feedstock.
- The Cameron Centre proved to be an ideal site for conducting incineration operations. This well-developed site presented minimal sensitive environmental features and its close proximity to DRES provided assurance to the public that the project proponents had confidence in the safety of the incineration process.
- Lewisite was successfully destroyed using a process based on caustic peroxide oxidation. This process was used in a full-scale, transportable apparatus designed to process the agent directly from one-ton containers.
- During Project Swiftsure, lewisite destruction involved successful scale-up from 3.7 gram laboratory batches, through 50 gram pilot-scale batches to 180 kilogram full-scale processing batches. A further 10-fold scale-up appears feasible and is recommended to support Canadian capabilities in international chemical demilitarization projects which require lewisite destruction.
- The self-contained transportable shredder, which was developed for Project Swiftsure to volume reduce large items such as mustard-contaminated drums, functioned well and safely minimized contamination spread during the shredding of such items.
  This shredder offered more flexibility for waste processing and overcame perceived deficiencies associated with a shredding/compaction unit integrated directly with the incinerator.
- Shaped explosive charges were used successfully to perforate or cut ordnance items which were otherwise too dangerous to handle. Opening items by this means provided field crews with a high degree of safety, especially when operations were carried out under cooler conditions. Perforated items containing frozen mustard fills could be incinerated directly without having to remove the chemical agent fill.

- The Canadian Forces Individual Protective Equipment provided adequate personal protection during agent waste processing, provided the users understood the limitations of the equipment. Contractor personnel found the C3 respirator to be a comfortable, effective method of respiratory protection. The respirator canister had to be secured with tape to prevent loosening during heavy work. The use of splash protection (Tyvek coveralls) over the IPE resulted in frequent suit changes on hot days (>25°C), as the suits became wet from perspiration (i.e. which potentially compromised their protective capability).
- The prototype CAM array, developed for Project Swiftsure, provided the basic design for the CADS II chemical agent detection system which was successfully deployed to support Canadian operations during the Gulf Crisis. The CAM array provided the necessary capability to continuously and automatically monitor for fugitive agent emissions in and around the Swiftsure incinerator facility.

10.6 Schedule

- The original schedule proposed by the contractor (project completion by July 91) was not met, although the contractor was successful in meeting the ministerial directive to complete destruction operations before 1992. The main delays were associated with the public review process required for the Environmental Protection Plan and the requirement to process additional inventory as the project proceeded.
- Scheduling field operations such as waste packaging, shredding, and ordnance perforation for the cooler months provided a higher degree of safety and environmental protection with respect to fugitive agent emissions and accidental releases.

10.7 Environmental Protection Plan

- The Environmental Protection Plan, which was prepared in advance of conducting destruction operations, effectively described the safety and environmental protection measures which were employed and was the key document which guided the course of Project Swiftsure. The EPP continues to be a valuable reference document.
- Distribution of the EPP to public libraries was a cost-effective means to make the document available to the general public, special interest groups and interested individuals.
- Public consultation during development of the EPP provided input which ultimately improved the overall agent destruction process in terms of safety and environmental protection. The EPP review provided a means by which the public could actively participate in the project planning process, thus lending credibility to the Project Swiftsure public consultation program.

- Public participation in the development and review of the Environmental Protection Plan satisfied concerns that the project was meeting requirements of the federal environmental assessment review process.

10.8 Waste Processing

- The waste profile numbering system utilized by Chem- Security Ltd. provided a well-defined means to establish waste throughput rates, track inventory and define waste destruction progress during packaging, transport, storage and destruction operations.
- By processing mustard chemical agent in a frozen form and in a batch-wise fashion, the storage, handling and processing risks normally associated with liquid chemical agents were greatly reduced.
- Processing ordnance items containing lead components produced lead contamination inside the incinerator system which created delays in the project schedule. This problem was partially rectified by physically removing the lead contamination (slag) and operating the incinerator at a temperature below the vaporization point of lead.
- The incinerator operated with an availability of 55% over an eight-month waste processing period. This was well below industry standards normally found for solid waste incinerators (e.g. 70-75% availability). The prime cause for incinerator down-time was the frequent need to replace rotary kiln refractory lining damaged by impact and abrasion during the incineration of heavy scrap and ordnance items.
- The incinerator system, which incorporated both solid waste and liquid waste input systems, provided the necessary versatility to process all of the Project Swiftsure incinerable waste inventory. For example, the neutralized nerve agent solution and contaminated scrap metal were processed simultaneously rather than as separate waste streams.
- Chem-Security Ltd. did not anticipate the problems which arose with respect to the dissolved metals content in the incinerator scrubber blowdown, in spite of the overly strict limits which were set by Environment Canada. The contractor's response to rectifying the problem of excessive levels of metals, while admirable, was relatively slow and cumbersome. Future installations which require compliance with such onerous wastewater discharge limits should include appropriate means to flocculate, precipitate, filter and separate the precipitated matter (i.e. a small on-site water treatment plant is required).

10.9 Cost

- The overall cost of Project Swiftsure (approx. $18 million) greatly exceeded the original estimate of $10 million. The destruction contract award, additional public consultation, environmental monitoring and contract amendments which reflected input from the public consultation process were the main reasons for the extra costs.
- The benefits of the citizens' advisory committee with respect to the successful outcome of Project Swiftsure far outweighed the costs related to this committee. The costs directly associated with the citizens' committee were less than 0.5% of the total project cost.

10.10 Contract Amendments

- Amendments to the waste destruction contract were required as a result of the public consultation process and the requirement to process additional scrap material which was not accounted for during the original project inventory surveys.
- The scrap inventory was difficult to estimate with a high degree of accuracy due to the manner in which the scrap was co-mingled and stored in open pits. This was particularly true for the empty contaminated drums and ordnance items stored at the 490 Site.
- Other contract amendments were made to reflect changes to the Environmental Protection Plan as a result of the public consultation process. Examples of major amendments include those related to the lewisite destruction method and removal of the incinerator at project completion. A separate contract was raised to provide an independent environmental monitoring program to supplement the incinerator monitoring data supplied by Chem-Security Ltd.
- Future contracts of a similar nature need to be more explicit with respect to possible contingencies. The contract should define methods for addressing delays and recovering associated costs; for example, to account for possibilities such as the further discovery of explosive ordnance, despite certification of sites as being free-from- explosives.

10.11 Environmental Monitoring

- The mobile monitoring laboratory proved to be a versatile and effective means of carrying out air quality surveys. The use of continuous monitoring equipment was essential for providing the public, regulatory agencies and DND with necessary and timely assurance regarding the safety of project operations. The data provided by the mobile laboratory also served as an independent check on incinerator performance and Chem-Security Ltd. operating procedures. In turn, the incinerator Continuous Stack Emissions Monitoring system enabled incinerator performance to be continuously monitored to ensure project-specific stack emission limits were not exceeded. Such equipment proved to be far more versatile and effective in determining performance compared to an intermittent stack sampling program.

- The environmental monitoring program proved conclusively that the incinerator had no discernible impact on air quality during the destruction of chemical agent waste. Data provided during the program validated predictions on incinerator performance and emission levels as described in the Environmental Protection Plan.
- The performance of the incinerator system was excellent in terms of meeting stack emission limits set for the project. Several modifications to the scrubber system and processing conditions were required to meet the strict particulate emission limit of 20 mg/m^3. It should be noted that, during Project Swiftsure, the particulate emissions limit set for other federal and provincial hazardous waste incineration facilities was 50 mg/m^3.
- In general, project-specific emission limits were quite strict (e.g. particulates). The limits set for wastewater discharge to the lined lagoon at the Cameron Centre were overly strict and contributed to the overall project expense.
- The DRES-developed scrubber blowdown screening method for organics and dioxins/furans enabled the project to proceed without the requirement to institute an expensive, time- consuming stack sampling program for dioxins/furans. The concept of using scrubber water quality to infer stack gas quality needs to be evaluated further. For example, scrubber water quality is specific to the waste stream being processed and to system operating parameters, and may only serve as a rough guide as to the concentrations of stack gas components.
- Maintenance of adequate air quality with respect to chemical agent emissions was adhered to throughout field waste processing operations, due in part to carrying out hazardous operations during cooler weather. Future field operations of this nature, such as shredding contaminated items, should be more closely monitored as fugitive emissions from this type of equipment (in its current configuration) will remain an issue.

10.12 Public Consultation

- Negative public reaction to project-specific factors (i.e. use of incineration, disposal of chemical warfare agents and government sponsorship) was overcome through the public consultation program. Meaningful consultation and open information exchange ultimately engendered a sense of trust amongst the parties involved.
- The value of public consultation was demonstrated throughout the project and led to improvements in environmental protection with respect to the procedures proposed in the original concept plan and Environmental Protection Plan. For example, the plan to incinerate neutralized lewisite was replaced in favour of a neutralization/stabilization process in response to public input.

- The involvement of a citizens' committee to act as a focal point for public input into project planning and implementation was a key element in gaining public acceptance for the project and maintaining dialogue with the public as the project proceeded. It is recommended that a citizens' liaison committee be established from the onset for future projects of this nature.
- A volunteer citizens' committee representing a wide cross-section of experience and interests proved successful for Project Swiftsure, as opposed to a committee with members appointed by the project proponents or special interest groups. The committee remained free to develop its own terms of reference and operating method. The committee philosophy of holding open meetings attended by the media and project proponents was highly successful in disseminating timely information to the general public and for focusing the project-specific issues. The committee settled issues by a consensus approach rather than by voting: this approach tended to depolarize the committee members.
- The use of an independent technical consultant is recommended to assist citizens' committees in resolving complex technical issues. DND demonstrated commitment to a meaningful consultation process by providing funds to support a committee-selected consultant and by addressing all issues raised by the consultant on behalf of the committee.
- With respect to Project Swiftsure, certain issues may have been resolved more quickly had the public been consulted at an earlier stage during project planning. For example, post-project uses for the incinerator and contractual arrangements, which were already well advanced, required significant modification following the initial public meetings.

10.13 Decommissioning

- All equipment and facilities used for the destruction of chemical warfare agents were successfully decontaminated according to the criteria specified in the Western Research partnership contract.

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Project Swiftsure Final Report

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ANNEXES

ANNEX A

DUTIES AND RESPONSIBILITIES OF THE PROJECT SWIFTSURE DIRECTOR AND PROJECT MANAGER

Project Director

The Project Director (Mr. Eugene Belovich) was responsible for implementing policy and planning on a day-to-day basis with the Project Manager, as determined by CRAD/Associate CRAD. Other duties of the Project Director were as follows:

- ♦ develop an inter/intra-departmental project management organization and liaise with other Departmental agencies and matrix organizations such as Director Conservation and Environment (DCE) and Director General Information (DG Info) on project-related matters;
- ♦ prepare documentation required for Departmental approval and allocation of funds and personnel resources to support project requirements;
- ♦ in conjunction with the Project Manager and other Departmental experts, assess various technical, financial, scheduling and monitoring options to ensure the project met Departmental policy and approved operational requirements;
- ♦ in conjunction with the Project Manager and Departmental communication specialists, develop public communication initiatives during project planning;
- ♦ plan and develop project schedules, studies and tasking in support of project objectives within National Defence Headquarters;
- ♦ prepare project outlines, status reports and ministerial briefing notes as required during planning and implementation phases.

Project Manager

The Project Manager (Dr. John McAndless) was responsible, on behalf of the Project Director, to implement and oversee the agent destruction program and provide advice on policy, scientific and contractual issues. He was also responsible for all on-site (DRES) operational activities on a day-to-day basis. Other duties of the Project Manager included the following:

- ♦ develop and implement an approved operational plan;
- ♦ develop contract work statements and participate in contract bid evaluation, selection and negotiation processes;
- ♦ represent the Department and act as project spokesman at public meetings and during media enquiries;
- ♦ in conjunction with the Project Director and Departmental specialists, develop and implement a public communications program;
- ♦ assist in preparing news releases, project newsletters and documentation of citizen advisory group activities;
- ♦ interact and liaise with federal and provincial environmental agencies regarding regulatory standards, approval protocols and monitoring requirements for project operations;
- ♦ allocate and schedule DRES personnel and resources to meet project objectives;
- ♦ monitor contractors activities and assist with technical problem troubleshooting where appropriate;
- ♦ develop specialized disposal methods and equipment;
- ♦ prepare project status reports, briefings and technical documentation as required.

DRES personnel and resources were drawn on a priority basis to support the project from the two technical Divisions within the Establishment (Defence Sciences (DSD) and Defence Technologies (DTD)), as well as from the Program Support Division (PSD). A critical element from this latter division was the Field Operations Section (FOS), which provided personnel with expertise in explosives demolition, hazardous materiel handling, field safety, meteorology, personal protective systems, communications and operations management. The DSD Decontamination Group were informally incorporated as part of the Field Operations Section during all operations on the DRES EPG.

ANNEX B

PHYSICAL AND PHYSIOLOGICAL PROPERTIES OF CHEMICAL WARFARE AGENTS SLATED FOR DESTRUCTION

Physical Properties

AGENT	FORMULA	QUANTITY (Tonnes)	ITEMS	PROPERTIES
Mustard (HD)	(bis) 2-chloroethyl sulphide	12	Ton Containers 210-L drums 155-mm Shells 105-mm Shells Flying Cows Misc.Ordnance	M.W. 159.1 g/mole Fuel Value: 8400 BTU/lb Volatility: 610 mg/m^3 (20°C) m.p. 14°C b.p. 217°C[1] Density: 1.27 g/cc Flash point: 107°C (closed cup) Viscosity:[2] 4.5 centipoise h/v:[3] 94 cal/g
Lewisite (L)	2-chlorovinyl-dichloro arsine	2.5	Ton Containers	M.W. 207.4 g/mole Volatility: 4480 mg/m^3 (20°C) m.p. -18°C b.p. 190°C Density: 1.89 g/cc Flash point: none h/v: 58 cal/g
Tabun (GA)	N,N-dimethyl phosphoramido cyanidate	0.15	Ton Container 155-mm Shell	M.W. 162.3 Volatility: 610 mg/m^3 (25°C) m.p. -50°C b.p. 120°C Density: 1.073 g/cc Flash point: 78°C h/v: 79.6 cal/g
Sarin (GB)	isopropyl methylphosphono fluoridate	0.12	105-mm Shell	M.W. 141.0 Volatility: 22000 mg/m^3 (25°C) m.p. -50°C b.p. 158°C Density: 1.09 g/cc Flash point: none h/v: 80 cal/g

AGENT	FORMULA	QUANTITY (Tonnes)	ITEMS	PROPERTIES
VX	ethyl diisopropyl aminoethylmethyl phosphorothiolate	0.03	Misc. Containers	M.W. 267.4 Volatility: 10.5 mg/m³ (25°C) m.p. -51°C b.p. 298°C (decomposes) Density: 1.01 g/cc Flash point: 159°C h/v: 78.2 cal/g

[1] Mustard thermal decomposition occurs in the temperature range 149-177°C.

[2] Mustard may be thickened with e.g 5% poly(methyl methacrylate) or other polymers to yield a viscosity of approx. 6 poise.

[3] h/v = heat of vaporization (calories/gram)

Physiological Properties

Mustard

1. Median Lethal Dosage (LCt_{50})

- Inhalation: 1500 mg.min/m^3
- Skin absorption: 10000 mg.min/m^3

2. Median Incapacitation Dosage (ICt_{50})

- Eye injury: 200 mg.min/m^3
- Skin absorption: 2000 mg.min/m^3

Wet skin absorbs more mustard than dry skin. For this reason, HD exerts a casualty effect at lower concentrations in hot, humid weather, since the body is then moist with perspiration. Skin absorption dosages given above apply to temperatures of approximately 21-27°C where the body is not perspiring excessively. Above 27°C, perspiration causes increased skin adsorption. The incapacitation dosage drops rapidly as perspiration increases: for example, at 32°C a dosage of 1000 mg.min/m^3 could be incapacitating.

3. Rate Of Detoxification. Very low. Very small, repeated exposures are cumulative in their effects or more than cumulative due to sensitization. This has been shown in the post-war case histories of workers in mustard-filling plants. Exposure to vapours from spilled mustard causes minor symptoms such as "red eye" (conjunctivitis). Repeated exposure to such vapours produces 100 percent disability by irritating the lungs and causing a chronic cough and chest pain.

4. Skin and Eye Toxicity. Eyes are very susceptible to low concentrations. Higher concentrations are required to produce incapacitating effects by skin absorption.

5. Rate Of Action. Delayed - usually 4 to 5 hours after exposure until first symptoms appear. Latent periods have been observed up to 24 hours and, in rare cases, up to 12 days.

6. Physiological Action. Mustard acts first as a cell irritant and finally as a cell poison on all tissue surfaces contacted. The first symptoms of HD poisoning usually appear in 4 to 6 hours; the higher the exposure concentration the shorter the time interval to appearance of first symptoms. The physiological action of mustard may be described as local and systemic. The local action results in conjunctivitis or inflammation of the eyes; erythema (skin redness) which may be followed by blistering or ulceration; and inflammation of the nose, throat, trachea, bronchi and lung tissue. Susceptibility also varies with individuals. Injuries produced by HD heal much more slowly and are more liable to infection than physical burns of similar intensity or burns produced by most other chemicals. Systemic effects of mustard may include malaise, vomiting and fever, with the time of onset about the same as that for skin erythema. With amounts approaching the lethal dose, injury to bone marrow, lymph nodes, and spleen may result. Such damage is reflected in the peripheral blood by a drop in white blood cells. As these cells are essential for preventing infections, a significant drop in white blood cells will cause mustard casualties to be far more susceptible than normal to local and overwhelming infections.

7. Protection Required. Protective mask and permeable protective clothing for vapour and small droplets; impermeable protective ensemble for large droplets, splashes and smears.

8. Decontaminants. Supertropical bleach (STB), fire or DS2. Liquid agent on the skin may be decontaminated by the use of the Canadian Forces Reactive Skin Decontaminant (RSD) lotion or the US Army M13 Individual Decontamination and Re-impregnating Kit or the M258 Skin Decontamination Kit.

9. Persistency. Depends upon the weather. Heavily splashed liquid persists 1-2 days in concentrations sufficient to produce significant numbers of casualties under average weather conditions. The agent will persist for several weeks or months under very cold conditions.

Lewisite

1. Median Lethal Dosage (LCt_{50})

- Inhalation: 1200-1500 mg.min/m^3
- Skin absorption: 100000 mg.min/m^3

When the humidity is high, L hydrolyzes so rapidly that a concentration sufficient to cause skin blistering is difficult to maintain. This is further compounded by the high vapour pressure and short duration of effectiveness of L.

2. Median Incapacitation Dosage (ICt_{50})

- Eye injury (from vapour): <300 mg.min/m^3
- Skin absorption: >1500 mg.min/m^3

Lewisite irritates the eyes and gives immediate warning of its presence.

3. Rate of Detoxification. The body does not detoxify lewisite.

4. Skin and Eye Toxicity. An exposure to 1500 mg.min/m^3 of lewisite produces sever and probably permanent corneal damage to the eyes. L has approximately the same blistering action on the skin as HD, even though the lethal dosage for L is much higher.

5. Rate of Action. Rapid.

6. Physiological Action. L produces effects similar to those produced by HD but, in addition, acts as a systemic poison, causing pulmonary edema, diarrhoea, restlessness, weakness, subnormal body temperature, and low blood pressure. In order of severity and appearance of symptoms, lewisite is: a blister agent; a toxic lung irritant; and, when absorbed in the tissues, a systemic poison. Liquid lewisite causes an immediate searing sensation in the eye and permanent loss of sight if not decontaminated within 1 minute with large amounts of water. L produces an immediate and strong stinging sensation to the skin; reddening of the skin starts within 30 minutes. Blistering does not appear until after about 13 hours. Like mustard, lewisite is a cell poison. Skin burns are much deeper than those caused by mustard. When inhaled in high concentrations, L may be fatal in as short a time as ten minutes.

7. Protection Required. Protective mask and permeable protective clothing for vapour and small droplets; impermeable protective ensemble for protection against large droplets, splashes, and smears.

8. Decontaminants. Supertropical bleach (STB), DS2 or caustic soda. Liquid agent on the skin may be decontaminated by the use of the skin decontamination pad in the M258 Skin Decontamination Kit.

9 Persistency. Somewhat shorter compared to mustard. Very short duration under humid conditions.

Nerve Agents

1. Median Lethal Dosage (LCt_{50})

- Inhalation: 400 mg.min/m^3 (GA)
  70 mg.min/m^3 (GB)

100 $mg.min/m^3$ (VX)

- Skin absorption: 0.01 mg/kg (GA, GB)
  1 mg ingested (VX)

2. Median Incapacitation Dosage (ICt_{50})

- Inhalation: 300 $mg.min/m^3$ (GA)
  35 $mg.min/m^3$ (GB)
  50 $mg.min/m^3$ (VX)

- Skin Absorption: 8000 $mg.min/m^3$ (vapour) (GB)

3. Rate of Detoxification. Typically very slow. Effects are essentially cumulative and lethal dosages can build up rapidly from repeated exposures.

4. Skin and Eye Toxicity. Eye membranes form an efficient entry pathway for the nerve agents. At low, sub-lethal dosages, dimness of vision and pinpointing of the iris occurs (miosis). GA liquid will always penetrate the skin and is extremely toxic in this form. Both GB and VX are not toxic to skin tissue but will immediately penetrate the skin and enter the bloodstream.

5. Rate of Action. Immediate. Lethal skin dosages and vapour inhalation will cause death within minutes.

6. Physiological Action. The nerve agents interfere with the formation of cholinesterase in the neural synapses, producing over-stimulation of the peripheral and central nervous system which, in turn, causes over-reactivity in the muscles and malfunctioning of various body organs. Typically, massive congestion of various body enzymes and fluids occurs in all the major organs, throughout the nervous system, and within the brain.

7. Protection Required. Protective mask and fully protective permeable clothing ensemble must be worn at all times. In the presence of liquid nerve agent, an impermeable protective ensemble is required.

8. Decontaminants. Strong alkaline/oxidizing solutions. Examples include potassium hydroxide/methanol, aqueous caustic (sodium hydroxide), bleach, and ammonia with steam. In the case of GA, chlorine-based decontaminants produce hydrogen cyanide as a by-product; therefore, extensive flushing is mandated with their use.

9. Persistency. GA:- splashed liquid may remain for several days at temperatures around 25°C. The agent may remain for indeterminate periods in cold weather although hydrolysis with snow will occur.
GB:- essentially non-persistent as the agent evaporates at about the same rate as water.
VX:- highly persistent, especially in acidic soils. The agent may last several weeks under temperate conditions.

ANNEX C

PROJECT SWIFTSURE ON-SITE LABORATORY ROUTINE SAMPLING AND ANALYSIS METHODS EMPLOYED

The on-site laboratory performed several routine analyses to ensure that processed metal, scrubber blowdown water and other process residues met the criteria laid out in the Environmental Protection Plan for disposal in an environmentally-acceptable manner. During lewisite destruction, the laboratory also analyzed reaction solutions to measure the completeness of the destruction process. The following sampling protocols and analytical methods were employed for the listed types of material:

Incinerator Slag

Samples of incinerator slag recovered from the ash discharge collection bins were taken in 40 mL screw cap glass vials. A small amount of ash and metal scraps were collected from at least three different locations in the slag bin with enough material collected in each case to nearly fill the sample vials.

Approximately 10 grams of sample were weighed to an accuracy of 0.1 g into a tared 100 mL beaker. The sample was shaken to thoroughly mix the ash and metal scraps. Approximately 50 mL of hexane was added to the beaker and the sample extracted using ultrasonification for ten minutes. The hexane extract was then filtered through Whatman #1 filter paper to a rotary evaporator flask. If necessary, the extract was dried by filtering through a layer of sodium sulphate placed on the filter paper. Iso-octane (1 mL) was added to the flask and the sample extract was reduced to 1 mL in volume by rotary evaporation under vacuum. The sample was then analyzed for mustard content using a Hewlett-Packard Model 5890 gas chromatograph equipped with a cold on-column injector and flame photometric detector. Mustard and organo-sulphur results were reported in parts per million based on original sample weight.

Metals

Processed (incinerated or heat-treated) and unprocessed metal was checked for mustard contamination by taking swab samples. A 10 cm x 10 cm cotton gauze pad was soaked in hexane and placed in a 40 mL screw cap glass vial. A 100 cm^2 template was placed on the metal sample and the area inside the template wiped thoroughly with the hexane-soaked swab. The swab was re-sealed in the vial, labelled and sent to the laboratory. At the laboratory, the swab was transferred to a beaker, the vial rinsed with hexane and the washings added to the beaker. Sufficient hexane was added to the beaker to cover the swab and the sample was extracted by ultrasonification for ten minutes. The hexane extract was then filtered through Whatman #1 filter paper into a rotary evaporator flask. The same sample volume reduction and analysis procedure as described above for the slag analysis was then followed. The results were reported as mustard and organo-sulphur weight per unit area (micrograms/100 cm^2).

Scrubber Blowdown Water

Scrubber blowdown water samples were taken from each storage tank when the tanks were nearly full and prior to discharge of the water to the lagoon. The sample line on the tank was flushed by filling a two-gallon bucket three times. Three one-litre samples of water were then taken from the bucket from the third filling. One sample was forwarded to the on-site laboratory for mustard and organic compound screening, the second to a commercial laboratory for metals analysis (after completion of the screening tests), and the third sample was retained for a period of three weeks in the event further analyses were required.

A one litre water sample was extracted in a separatory funnel three times with 50 mL of hexane. The hexane extracts were separated and filtered through Whatman #1 filter paper into a rotary evaporator flask. If necessary, the extracts were filtered through a layer of sodium sulphate to remove traces of water. Three mL of iso-octane was added and the sample volume was reduced to 3 mL by rotary evaporation under vacuum. The sample was then split into 3 one-millilitre portions: one for analysis, one for repeat analysis and one for archive purposes.

The sample was analyzed for mustard content on a Hewlett-Packard Model 5890 gas chromatograph equipped with a cold on-column injector and flame photometric detector. Results for mustard and organo-sulphur compounds were reported in parts per million (mg/L sample). The same sample is re-analyzed on a second gas chromatograph equipped with a flame ionization detector which is sensitive to organic compounds.

Detected organic compounds were not quantified or identified. Instead, the sample was compared to a blank sample extracted with hexane and prepared in the same manner. If any organic compounds found in the scrubber water extract were significantly different from the blank, the sample was forwarded to DRES for quantitative analysis using gas chromatography/mass spectrometry[1].

On-stream Scrubber Blowdown Water

Three times a week (Monday, Wednesday and Friday), samples of water were taken directly from the scrubber cyclone separator while the incinerator was in operation. Three one-litre samples were taken: one for analysis, one for repeat analysis as necessary and one for archiving.

The sample was extracted in the same manner as the scrubber blowdown tank samples with the exception that the extract was reduced to 1 mL in volume rather than 3 mL. The sample was subjected only to a screen for organic compounds by gas chromatography/flame ionization detection and was not analyzed for mustard or metals.

Wastewater Analysis

Wastewater from the incinerator facility was collected in a sump and transferred to a holding tank prior to discharge to the site lagoon. Prior to emptying the holding tank to the lagoon, a sample was taken for mustard and organic compound screening. The method employed was the same as that employed for the scrubber blowdown water with the exception that the extract volume was reduced to 1 mL in volume rather than 3 mL.

Lewisite Neutralization Solutions

Lewisite is neutralized in a three step-process in which:
1) the agent is reacted with hydrogen peroxide to form lewisite oxide (2-chlorovinyl arsine oxide), 2) residual peroxide is removed by a catalyst and 3) lewisite oxide is

[1] Only one such sample was forwarded to DRES during the course of Project Swiftsure. Analysis for chlorinated dioxins/furans was carried out but these compounds were not found in the sample provided.

converted to arsenate salts and acetylene by reaction with sodium hydroxide. A separate step consists of stabilizing the arsenic-containing salt solution in concrete (see stabilized arsenic salts). Samples of neutralization solutions were forwarded to the laboratory at the end of step 1 and step 3 for each batch of lewisite reacted.

Solution samples were taken from the sample valve on the lewisite neutralization apparatus. Approximately 2 L of solution were flushed from the valve and retained in a waste barrel for reprocessing or stabilization. A 0.25 L sample was then taken using a new 1 L plastic bottle. The sample bottle was placed inside a plastic bag which in turn was sealed in a bucket containing charcoal or vermiculite absorbent. The sealed sample was then transported to the laboratory for analysis.

Step 1 solutions were measured for pH and analyzed for residual hydrogen peroxide and lewisite content. Hydrogen peroxide was determined by sodium thiosulphate titration. Lewisite was extracted from the solution using a dilute solution of 3,4-dimercaptotoluene in hexane. During the extraction process, lewisite was converted to a hydrolytically-stable derivative which could be analyzed by gas chromatography without decomposition.

The hexane extract was filtered through Whatman #1 paper containing sodium sulphate to remove water and into a rotary evaporator flask. One mL of iso-octane was added to the flask and the extract was reduced in volume to 1 mL. The sample was analyzed on a gas chromatograph equipped with a split-splitless injector and an electron capture detector. The detection limit of this method was 0.02 ppm. Lewisite was reported in parts per million (mg/L).

Step 3 solutions were prepared and analyzed in the same way with the exception of analysis for lewisite oxide. To analyze for lewisite oxide, the sample solutions were acidified with hydrochloric acid to convert the oxide to lewisite. The sample was then extracted and analyzed in the same manner as the step 1 samples. Lewisite oxide content was determined as the difference in lewisite content between the acidified and non-acidified samples.

Stabilized Arsenic Salts

In the final step of the lewisite neutralization, the solution from step 3 of the process is stabilized in concrete. The concrete formulation is stored in plastic barrels.

While the concrete is setting, a sample is taken from each barrel and placed in a 2" x 2" x 2" plastic form using a trowel. Three samples are taken from every tenth barrel for detailed leachate tests.

The concrete cubes were cured in the on-site laboratory using an environmental chamber. Cured cubes designated for leachate analysis were then forwarded to a commercial laboratory while the remaining cubes were archived for reference purposes.

ANNEX D

COMMUNITY AIR QUALITY MONITORING WORK PACKAGE EXAMPLE

TYPE: Background Air Quality Monitoring - Communities

NUMBER: 1C

PERIOD: 27 December 90 - 18 January 91

NOTES:

1. Work Packages shall be carried out in accordance with the Statement of Work, Supply and Services Canada Standing Offer W8464-0-KA11/01-XSG. The methodology employed shall conform to RWDI Proposal #90-438P, dated 16 August 1990, as amended by correspondence filed with the Administrative Authority, Supply and Services Canada (Edmonton).

2. Work Packages shall follow the same generic schedule (see Note 4) for background air quality monitoring, trial burns or incineration of chemical agent waste under operational conditions.

3. Unless otherwise specified, the airborne compounds or materials to be monitored are as follows:

Compound	Concentration Limit (ppb)	Averaging Time (hours)
SO_2	170	1
	60	24
NOx (as NO_2)	210	1
	110	24
HCl	66	1
CO	13,000	1
	5,200	8
Particulates	100 ($\mu g/m^3$)	24
Mustard	0.45	8
	0.015	72

4. The Work Package Generic Schedule is as follows:

- Day 1 -Work Package Call-out.
- Day 7 -Monitoring personnel and equipment to specified field locations;
  -Instruments, meteorology equipment calibrated;
  -Program co-ordinated with DRES, incinerator contractor, public communication re monitoring locations, activities.
- Day 8 - Day T -Air quality monitoring at specified locations;
  -Data archived daily;
  -Daily debrief or verbal report on results;
  -Any collected samples forwarded to laboratory for analysis.
- Day (T+1) -Park and secure mobile unit at DRES or designated location;
  -Monitoring personnel return to home base.
- Day (T+5) -Analysis of lab samples completed, where applicable;
  -Air quality and met data interpreted and report prepared.
- Day (T+8) -Work Package report forwarded to DRES (3 copies), to CEPC Chairman (2 copies) and to CEPC Technical Consultant (1 copy).

5. Day 1 (call-up) is the first date listed above under PERIOD. Day T, the second date listed under PERIOD, is the final day of monitoring operations.

WORK PACKAGE 1C SCOPE

1. Acquire background air quality data with respect to listed compounds in Communities which are downwind of the DRES Cameron Centre Site. The Communities are selected on each monitoring day according to the prevailing wind direction, as follows:

Prevailing Wind	Monitored Communities
S	**Jenner**
SW	**Buffalo, Bindloss, Empress**
W	**Hilda, Medicine Hat**
NW	**Medicine Hat, Redcliff**
N	**Ralston, Suffield**
NE	**Ralston, Suffield**
E	**Ralston, Suffield, Brooks**
SE	**Ralston, Jenner, Brooks**

2. The mobile unit will operate in, or near, these communities at the following specified locations which may vary during repeat monitoring on separate occasions:

Community	Monitoring Location
Medicine Hat/Redcliff	**Waterslide, Powerhouse Road** **Brier Park (Western Co-Op)** **Redcliff Rectangle Parking Lot**
Brooks	**Lakeside Feedlot** **City Hall Parking Lot** **Horticultural Centre**
Empress	**Hospital Parking Lot**
Bindloss	**J. Harold Fieldberg Farm**
Buffalo	**Community Hall Parking Lot**
Hilda	**N. Bauer Farm**
Jenner	**T. Musgrove Farm**
Ralston	**Community Arena Parking Lot**
Suffield	**Community Hall Parking Lot**

3. Advance warning shall be given by the contractor to all Communities/locations expected to be monitored during this Work Package.

WORK PACKAGE 1C TYPICAL DAILY SCHEDULE

Notes:

1. 0815 - 0830 daily:- briefing with DRES staff and/or acquire general weather forecast from DRES Met Centre (544-4699) and any met information from contractor-installed equipment.

2. Air quality data shall be acquired for a minimum 1-hour period at each monitoring location.

3. Depending upon final daily monitoring location, the mobile unit may be parked at DRES in a specified, secure location. AC power to maintain instrument operation can be provided.

4. 1600 daily:- provide verbal or phone-in report to DRES Project Manager (544-4635), acquire general next-day weather forecast from DRES Met Centre (544-4699).

5. Where possible, the daily schedule shall be flexible to accommodate significant changes in prevailing wind direction.

6. Air quality monitoring is not required during weekends during this Work Package.

7. Pending the availability of the MINICAMS mustard monitoring equipment, a VOC (volatile organic compound) sampler shall be utilized to collect air samples for subsequent laboratory analysis for mustard. One sample shall be collected daily in the closest community downwind of the Cameron Centre Site. The estimated number of VOC samples to be collected during this Work Package is 5-10. Sampling shall be of sufficient duration to ensure the specified 8-hour TWA concentration value for mustard can be detected during subsequent analysis.

Monitoring Day 1: Prevailing Wind:- **WEST (example)** 07 Jan 91

Morning a.m. -Move unit from DRES to Medicine Hat, Power House Road site;
-Acquire Medicine Hat met and air quality data;
-Move unit to Hilda, N. Bauer Farm.

Afternoon p.m. -Acquire Hilda met and air quality data;
-Return unit to Medicine Hat accommodation or to DRES as appropriate.

Monitoring Day 2: Prevailing Wind:- **NORTH-EAST (example)** 08 Jan 91

Morning a.m. -Move unit from DRES or Medicine Hat to Suffield, Community Hall parking lot;
-Acquire Suffield met and air quality data;
-wind shift to EAST/SOUTH-EAST (example) noted.
Daily plan modified to accommodate monitoring downwind communities.
-Move unit to Ralston Arena parking lot.

Afternoon p.m. -Acquire met and air quality data for Ralston;
-Move unit to Jenner, T.Musgrove Farm
-Acquire met and air quality data for Jenner;
-Return unit to DRES for overnight parking.

Monitoring Day 3: Prevailing Wind:- **SOUTH-WEST (example)** 09 Jan 91

Morning a.m. -Move unit from DRES to Buffalo Community Hall parking lot;
-Acquire Buffalo met and air quality data;
-Move unit to Bindloss, H. Fieldberg farm;
-Acquire Bindloss met and air quality data;

Afternoon p.m. -Move unit to Empress Hospital parking lot;
-Acquire Empress met and air quality data;
-Move unit to DRES or Medicine Hat depending upon time and next day

weather forecast.

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Monitoring Day T: Prevailing Wind:- **WEST (example)** 18 Jan 91

Morning a.m. -Same as Day 1, change Medicine Hat monitoring location to Brier Park.

Afternoon p.m. -Same as for Day 1 (Hilda). If sufficient Hilda data previously acquired, a new location e.g. Schuler may be selected for monitoring after prior consultation.

ANNEX E

DRES EXPERIMENTAL PROVING GROUND
AIR QUALITY MONITORING WORK PACKAGE EXAMPLE

TYPE: Operational Air Quality Monitoring - DRES EPG

NUMBER: 5D

PERIOD: 29 July 91 -19 August 1991

NOTES:

1. Work Packages shall be carried out in accordance with the Statement of Work, Supply and Services Canada Standing Offer W8464-0-KA11/01-XSG. The methodology employed shall conform to RWDI Proposal #90-438P, dated 16 August 1990, as amended by correspondence filed with the Administrative Authority, Supply and Services Canada (Edmonton).

2. Work Packages shall follow the same generic schedule (see Note 4) for background air quality monitoring, trial burns or incineration of chemical agent waste under operational conditions.

3. Unless otherwise specified, the airborne compounds or materials to be monitored are as follows:

Compound	Concentration Limit (ppb)	Averaging Time (hours)
SO_2	170	1
	60	24
NOx (as NO_2)	210	1
	110	24
HCl	66	1
CO	13,000	1
	5,200	8
Particulates	100 ($\mu g/m^3$)	24
Mustard	0.45	8
	0.015	72

4. The Work Package Generic Schedule is as follows:

- Day 1 -Work Package Call-out.
- Day 7 -Monitoring personnel and equipment to specified field locations;
  -Instruments, meteorology equipment calibrated;
  -Program co-ordinated with DRES, incinerator contractor, public communication re monitoring locations, activities.
- Day 8 - Day T -Air quality monitoring at specified locations;
  -Data archived daily;
  -Daily debrief or verbal report on results;
  -Any collected samples forwarded to laboratory for analysis.
- Day (T+1) -Park and secure mobile unit at DRES or designated location;
  -Monitoring personnel return to home base.
- Day (T+5) -Analysis of lab samples completed, where applicable;
  -Air quality and met data interpreted and report prepared.
- Day (T+8) -Work Package report forwarded to DRES (3 copies), to CEPC Chairman (2 copies) and to CEPC Technical Consultant (1 copy).

5. Day 1 (call-up) is the first date listed above under PERIOD. Day T, the second date listed under PERIOD, is the final day of monitoring operations.

<u>WORK PACKAGE 5D SCOPE</u>

1. Acquire air quality data on the DRES Experimental Proving Ground with respect to the listed compounds, using a "line-of-sight" method at specified downwind distances from the Cameron Centre Site. This site shall be designated as a "point source" for monitoring purposes. Downwind monitoring locations shall be selected at the following distances from the point source: 100m, 200m, 500m, 1 km, 2km and 5km.

2. For given prevailing wind directions, a location as close as possible to each distance shall be selected and monitored for a minimum of 1 hour. All six distances shall be monitored on a daily basis. Figure 1E illustrates the four most common wind directions with the most common being SW (Priority 1).

3. Figure 2E shows a map of the DRES EPG near the Cameron Centre with the specified monitoring distances superimposed. In general, the nearest accessible roadway or fireguard trail at any given distance in the prevailing wind direction shall be used to

locate the monitoring vehicle. Where no roadway exists at a particular distance, (e.g 500m south of the Cameron Centre), then the distance at the nearest accessible location shall be estimated from maps and this distance used to correlate with the collected data.

4. Figure 3E shows the Cameron Centre with the specified 100m monitoring distance superimposed.

5. Data shall be tabulated and reported in the form of concentration for each specified compound at the six given (or selected alternate) distances downwind of the point source for the following general wind directions: N (0°), NE (45°), E (90°), SE (135°), S (180), SW (225°), W (270°) and NW (315°).

6. Data for each specified compound shall be plotted in terms of concentration versus downwind distance for the general wind directions noted above. The data may be averaged if more than one data point has been acquired for any given distance in any one of the general wind directions, provided the project-specific air quality limit for the specified compound has not been exceeded.

7. Daily data shall be collected whether the incinerator is operational or not. On days when the incinerator is operational, data collected shall be so noted as being "Operational" data. Otherwise, the data shall be known as "Background" data.

8. Occasionally, and as directed by the Project Manager Swiftsure following consultation, the mobile unit may conduct air monitoring for the compounds listed above at other locations on the Experimental Proving Ground. Such locations may include, for example, the 490 Site, Hickey Storage Site or 14A Site. Such data shall be included in the Work Package report under separate headings such as "Chemical Neutralization Tests", "Packaging And Transportation Operations", etc. as appropriate.

<u>WORK PACKAGE 5D TYPICAL DAILY SCHEDULE</u>

<u>Notes</u>:

1. 0815 - 0830 daily:- briefing with DRES staff and/or acquire general weather

forecast from DRES Met Centre (544-4700) and any met information from contractor-installed equipment.

2. Air quality data shall be acquired for a minimum 1-hour period for each monitoring location.

3. The mobile unit may be parked at DRES Building 60 (Cameron Centre) following daily monitoring activities.

4. 1600 daily:- provide verbal or phone-in report to DRES Project Manager (544-4635), acquire general next-day weather forecast from DRES Met Centre (544-4700).

5. Where possible, the daily schedule shall be flexible to accomodate significant changes in prevailing wind direction.

6. Air quality monitoring shall not be required during weekends or on statutory holidays (e.g August 5, 1991). There shall be close consultation between RWDI/CEM, DRES and the incinerator contractor to co-ordinate and schedule incinerator operations and the air quality monitoring program.

7. The contractor shall maintain radio contact with FOS/Range Control during monitoring operations on the DRES EPG.

8. The MINICAMS equipment shall be used to monitor for the presence of mustard. A VOC (volatile organic compound) sampler shall be available to collect air samples for subsequent laboratory analysis for mustard should this be required to verify positive MINICAMS readings.

9. Through scheduling and consultation, the mobile unit may be required on occasion to be available at the Cameron Centre for inspection and public visits. Data collection is not required during such occasions; the dates/times of any inspection tours shall be so noted in the Work Package report.

Monitoring Day 1: Prevailing Wind:- **WEST (example)** 6 Aug 91

Note: In all examples given, the reverse monitoring sequence may also be employed; i.e. start at location F in the a.m. and complete the daily monitoring at location A in the p.m.

Morning a.m. -Mobilize unit to the following locations and distances from the Cameron Centre and acquire meteorological and air quality data;

A. Cameron Centre inside perimeter fence, east side (100m),
B. Cameron Centre outside perimeter fence, east side (200m),
C. Nearest accessible trail, east of Cameron Centre, approximately 500m or other selected distance.

Afternoon p.m. -Mobilize unit to the following locations and acquire meteorological and air quality data;
D. Trafford Trail, 1 km east of Cameron Centre,
E. Concrete pad area north of Porton Trail (2 km),
F. Nearest accessible trail at approx. 5 km between Porton Trail and Coyote Road, or Pronghorn Road east of Cameron Centre (6 km),
-Return unit to designated parking area at Cameron Centre.

Monitoring Day 2: Prevailing Wind:- **NORTH-EAST (example)** 7 Aug 91

Morning a.m. -Mobilize unit to the following locations and acquire meteorological and air quality data;
F. Jenner Road transformer station, near junction of Jenner Road and South Boundary Road (5 km),
-Wind shift to EAST/SOUTH-EAST (example) noted. Daily plan modified to accomodate monitoring downwind locations;
-Move unit to the following locations to continue monitoring program;
E. Porton Trail West, between Gate W4 and W3 (2 km),
D. O'Leary Road, northwest of Cameron Centre (1 km).

Afternoon p.m. -Mobilize unit to the following locations and acquire meteorological and air quality data;
C. Near junction of O'Leary and Cameron Centre Entrance Roads (500m),
B. Outside of Cameron Centre perimeter fence, north-west side (200m),
A. Inside Cameron Centre perimeter, north-west side (100m).
-Return unit to Cameron Centre parking area.

Monitoring Day 3: Prevailing Wind:- **SOUTH-WEST (example)** 8 Aug 91

Morning a.m. -Mobilize unit to the following locations and acquire meteorological and air quality data;
A. Inside Cameron Centre perimeter, north-east side (100m),
B. Outside Cameron Centre fence, north-east side (200m),
C. Nearest fireguard trail, north of Cameron Centre and east of O'Leary Road (500m),

Afternoon p.m. -Continue air monitoring program at the following locations;
D. Trafford Trail, north-east of Cameron Centre (1 km),
E. Coyote Road, east of Trafford Trail junction (2 km),
F. Watson Trail, east of Building 15 Complex (5 km).
-Return unit to Cameron Centre parking area.

. . . . .
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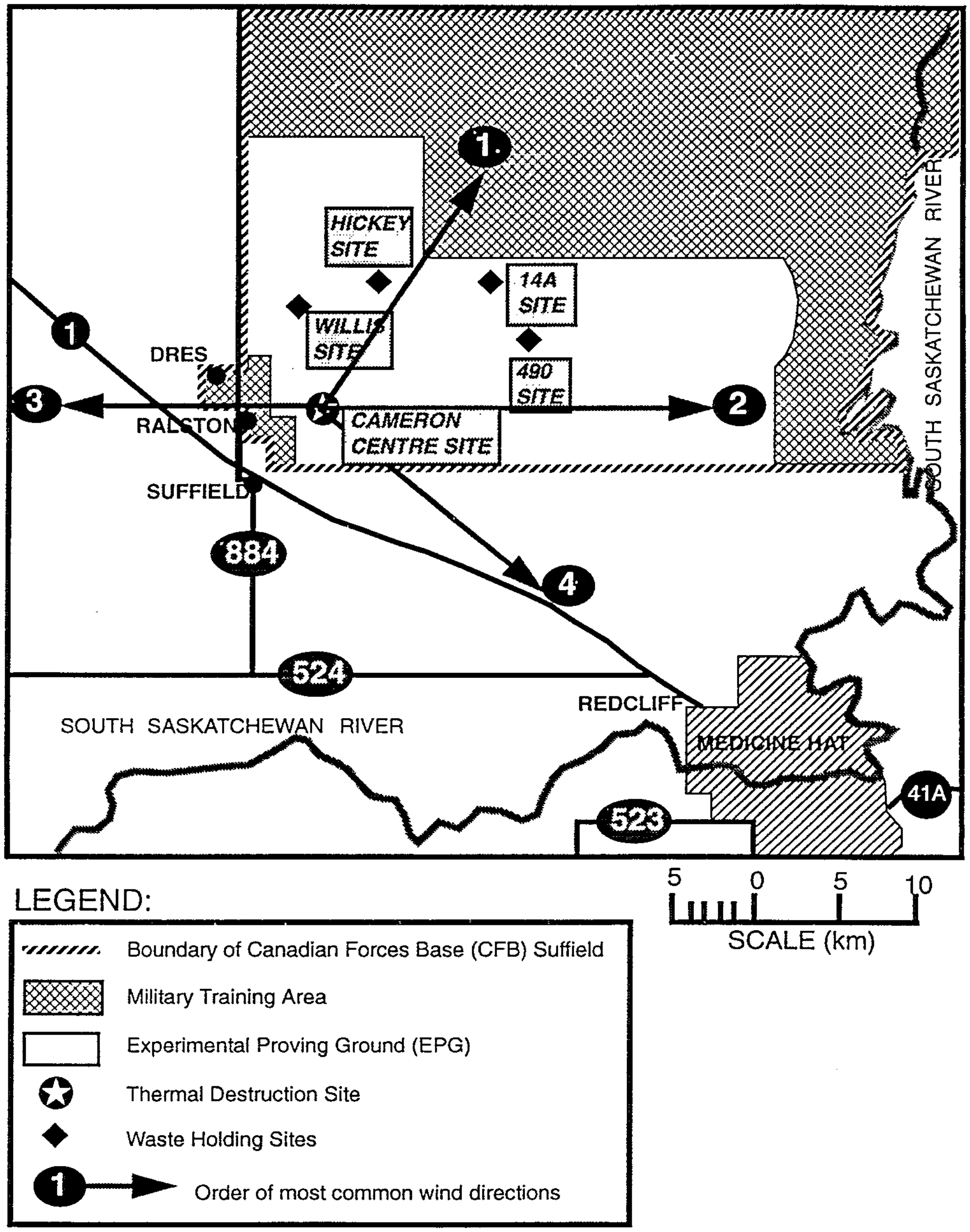
Monitoring Day T: Prevailing Wind:- **WEST (example)** 19 Aug 91

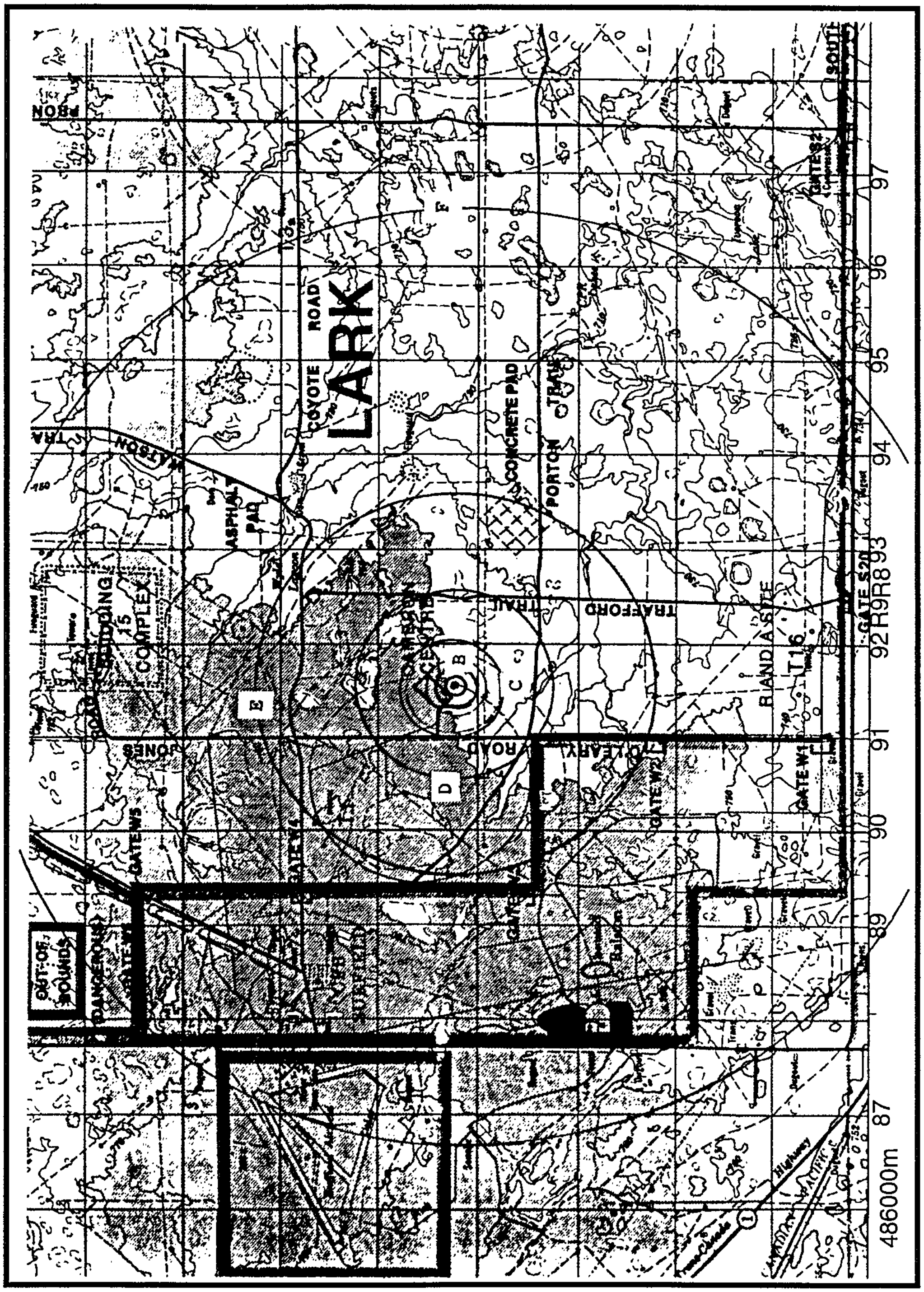
Morning a.m. -Same as Day 1.
Afternoon p.m. -Same as for Day 1.

Figure 1E



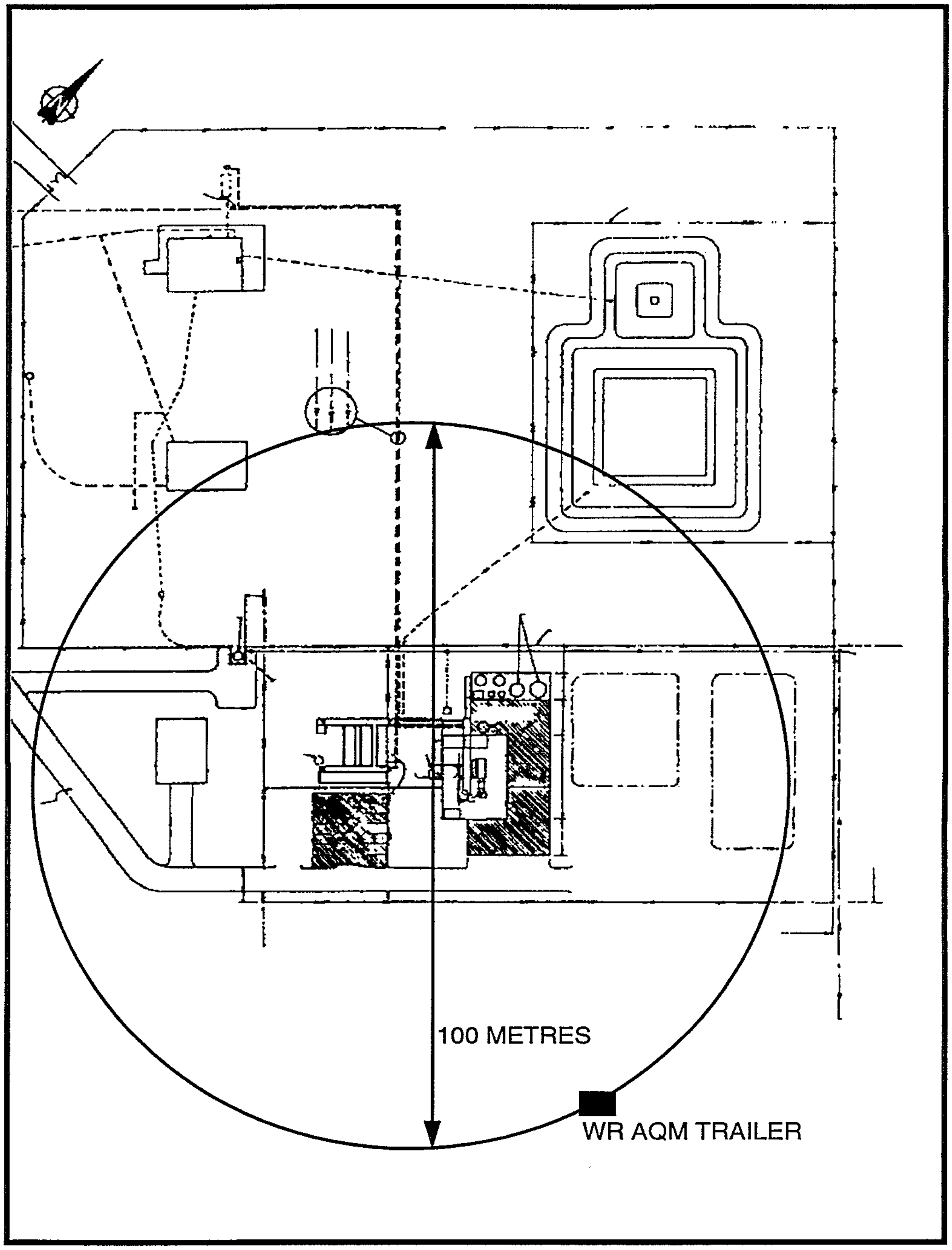
Common Wind Directions for Project Swiftsure Locations

Figure 2E



EPG Air Quality Monitoring Survey Distances

Figure 3E



Cameron Centre Air Quality Monitoring Locations (100m)

ANNEX F

SAMPLING PLAN

ANALYSIS OF INCINERATOR SCRUBBER FLUID FOR DIOXINS AND OTHER ORGANIC CHEMICALS

Background

Best-available incineration technology will be used to destroy all hazardous and non-hazardous waste listed under the Project Swiftsure inventory, with the exception of arsenic-containing waste related to lewisite chemical agent. In this latter case, lewisite will be destroyed by chemical neutralization with the arsenic-containing secondary waste stabilized in concrete for landfilling.

There are six different waste streams to be separately incinerated during the project:

a. mustard chemical agent ("bulk" mustard)
b. aged, decomposed mustard
c. mustard thickened with additives (e.g. plexiglas)
d. scrap metal contaminated with traces of mustard
e. neutralized nerve agent solution
f. dunnage (non-contaminated metal, wood, plastic scrap)

Only waste streams a.- d. contain chlorinated material essential for the potential formation of chlorinated dibenzodioxins and dibenzofurans (hereafter called "dioxins" and "furans", respectively).

The incinerator combines a high temperature two-stage combustion system with a wet flue gas scrubbing system. In addition, a Continuous Stack Emission Monitoring (CSEM) system is employed to verify that any emissions following the scrubbing stage meet standards set for the project by Environment Canada. Throughout the project, the CSEM system will monitor continuously for the expected combustion products of mustard (sulphur dioxide, hydrogen chloride), as well as mustard itself and other parameters such as flue gas temperature, velocity, oxygen content, carbon monoxide, oxides of nitrogen and particulates.

During all phases of incineration, the scrubber system fluid (water at pH 7-9) will be analyzed for traces of heavy metals as well as organic chemicals (particularly mustard) to ensure the water meets requirements for discharge to an on-site evaporating lagoon. During trial burns designed to set optimum incinerator operating conditions, in-stack samples for dioxins/furans will also be taken to verify that these organics are not produced from the combustion of mustard. Mustard is not a known precursor for dioxin formation. In addition, the high temperature operating conditions and rapid flue gas temperature quenching within the incinerator should fully mitigate dioxin production from any of the waste streams listed above.

To provide further assurance that dioxins are not being formed during incinerator trial burns and subsequent operations, it is proposed that the incinerator scrubber fluid analysis program be expanded to include dioxin screening during all phases of the project. The expanded sampling and analysis program provides a flexible, cost-effective and timely alternative to a continuous in-stack sampling program for dioxins.

Rationale

Data acquired from operation of the Alberta Special Waste Treatment Centre, Swan Hills, indicates the following:

♦ Under purposely-derived abnormal operating conditions during the incineration of PCBs (polychlorinated biphenyls), dioxins concurrently were found in scrubber fluid samples and in-stack samples;

♦ Under the above conditions, dioxins were concentrated 400-fold in the scrubber fluid on an equal volume basis compared to in-stack samples;

♦ No dioxins were found in either scrubber fluid or in-stack samples when incinerator conditions were adjusted to ensure the efficient destruction of PCBs.

This data indicates that scrubber fluid screening and analysis is a viable method for identifying dioxin formation during combustion of chlorinated precursors. The Project Swiftsure incinerator and scrubbing system are very similar in design and operation to the systems at Swan Hills; thus, the method has application to the DRES waste disposal project.

Purpose

The purpose of the expanded scrubber fluid analysis program for Project Swiftsure is:

- To determine whether dioxins are produced subsequent to the incinerator combustion stages for all waste streams and during all phases of the project;
- To signal the requirement for any follow-up action including adjusting incinerator operating conditions in order to eliminate dioxin formation;
- To determine that the scrubber fluid meets requirements with respect to metals and organics content (particularly mustard and dioxins) for discharge to an on-site lagoon;
- To supplement data acquired from the continuous stack monitoring and independent air monitoring programs.

Sampling Plan

1. Sampling Frequency

Scrubber fluid sampling for screening and analysis purposes will occur for each of the seven designated waste streams to be incinerated as follows:

Trial Burns

- SF_6 tests: scrubber fluid samples taken as control samples for comparison purposes. One batch sample.
- Mustard tests: one batch sample per run, including each repeat test. One batch sample for scrubber fluid awaiting certification for discharge to the on-site lagoon.

Normal Operations

One batch sample per each 24 hours of operation for each waste stream being processed. One batch sample for each scrubber fluid volume awaiting certification for discharge to the on-site lagoon.

Upset Conditions

Upset conditions are described in Appendix 1. One or more samples taken immediately during or shortly after the upset condition has occurred.

2. Sampling Locations

Under normal operating conditions, including trial burns, scrubber fluid samples will be taken from the blowdown storage tank. During upset conditions, samples will be acquired directly from the scrubber system recirculating loop, as shown in Figure 1F.

3. Sample Volumes

3 x scrubber fluid samples will be individually acquired in 1-litre laboratory-certified sampling bottles. Total volume per sample: 3 L. One (1) litre of sample will be set aside as a reserve should additional analysis be required in an off-site laboratory.

4. Sample Processing

The sample processing schematic is shown in Figure 2F. All acquired samples are first screened for organics using gas chromatography/flame ionization detection (GC/FID) in the CSL on-site laboratory. Aliquots of these samples are sent to an off-site laboratory for verification of trace metal content. Samples containing suspected organics are forwarded to the DRES Analytical Laboratory for mustard and dioxin identification/verification by gas chromatography/mass spectrometry (GC/MS). Samples suspected of containing dioxins are forwarded to an off-site laboratory for confirmation identification and quantitation. Any batch of scrubber fluid containing organics resulting from the incineration process will be incinerated as a waste feedstock to eliminate the organics.

5. Analytical Methodology

a. Screening (CSL on-site laboratory)

Scrubber fluid, 1 L, is extracted with 50 mL hexane and the hexane extract dried, then concentrated to approximately 1 mL by rotary evaporation and nitrogen blowdown. 1 μL samples are syringe-injected into a HP 5890 gas chromatograph equipped with a flame ionization detector. The sample is screened for the presence of organics (FID response). The presence of mustard and 2,3,7,8-T4CDD (dioxin) is determined by comparison of GC retention times with known standards under the same chromatographic conditions. Hexane extracts of make-up water for use as scrubber fluid are run under the same conditions to provide reference (control) samples. Hexane solutions spiked with known amounts of mustard and 2,3,7,8-T4CDD are run as standards to determine GC retention times.

Detection Limit: (conservative) 1 nanogram

b. Identification (DRES Analytical Laboratory)

Concentrated hexane extracts of scrubber fluid containing organics are forwarded to DRES, along with reference standards. 1 μL samples are syringe-injected into a HP 5890 gas chromatograph equipped with a VG TRIO mass spectrometric detector. Those sample components exhibiting mustard and/or dioxin retention times are identified by comparison of associated mass spectral fragmentation spectra with computer-based reference spectra and with known standards. Samples identified as containing dioxins are forwarded to an independent laboratory (through the air monitoring contractor) for quantitative analysis of dioxins.

Detection Limit: (conservative) 100 picograms

Reporting

As required under Contract W8464-9-KA02/01-XSG, results of laboratory screening will be included in daily logs and weekly reports associated with Project Swiftsure documentation. Reports (verbal and/or written) on scrubber fluid analyses will be provided to the Citizen's Environmental Protection Committee at regularly scheduled meetings. Written reports will be forwarded immediately to DRES, the Chairman CEPC and the CEPC Technical Consultant should any mustard or dioxin components be identified in scrubber fluid samples. Such reports will contain information on the incinerator processing conditions and waste feedstock which corresponds to the contaminated scrubber fluid batch samples. Follow-up action to eliminate mustard and/or dioxin components in the scrubber fluid will be outlined.

APPENDIX 1

LIST OF UPSET CONDITIONS

During incineration of Project Swiftsure waste streams, the following upset and/or emergency conditions, should they occur, will require that the scrubber fluid be sampled and analyzed for the presence of organics, particularly mustard and dioxins. Samples shall be withdrawn from the scrubber recirculating system rather than the blowdown storage tanks (normal operations).

1. Uncontrolled opening of the incinerator emergency vent cap:
   - rotary kiln and/or secondary combustion chamber temperature exceeds set upper limit;
   - loss of water to the quench system at critical lower limit;
   - loss of instrument air or induction fan failure;
   - power failure;
   - sudden loss of incinerator refractory lining integrity.

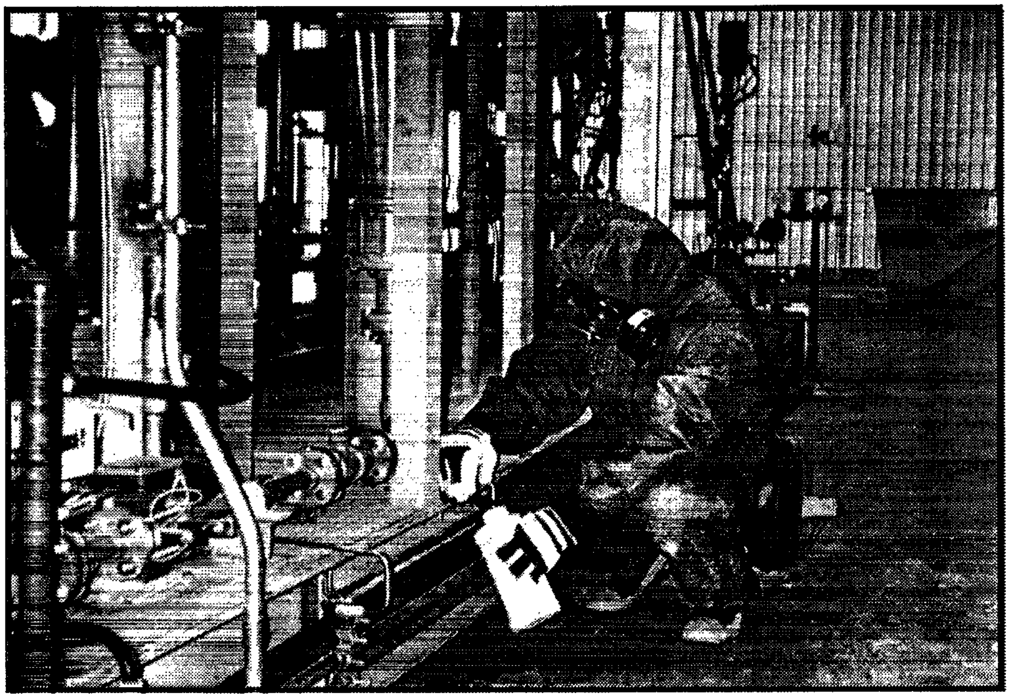
2. Combustion temperature below set lower limit: Shut-down sequence initiated by the Process Control System during incineration of waste feedstock.

3. Incomplete combustion during waste incineration: High reading of Carbon Monoxide monitor, coupled with low oxygen readings, high total hydrocarbon readings and/or low secondary combustion chamber temperatures.

4. Automated or manual shut down of the rotary kiln for any reason during waste incineration.

5. Emission limits exceeded: readings from the Continuous Stack Emissions Monitoring system indicate that one or more of the monitored emissions have exceeded the stack concentration limits set for Project Swiftsure.

Figure 1F



Scrubber Fluid Sampling Location (Upset Conditions)

Figure 2F

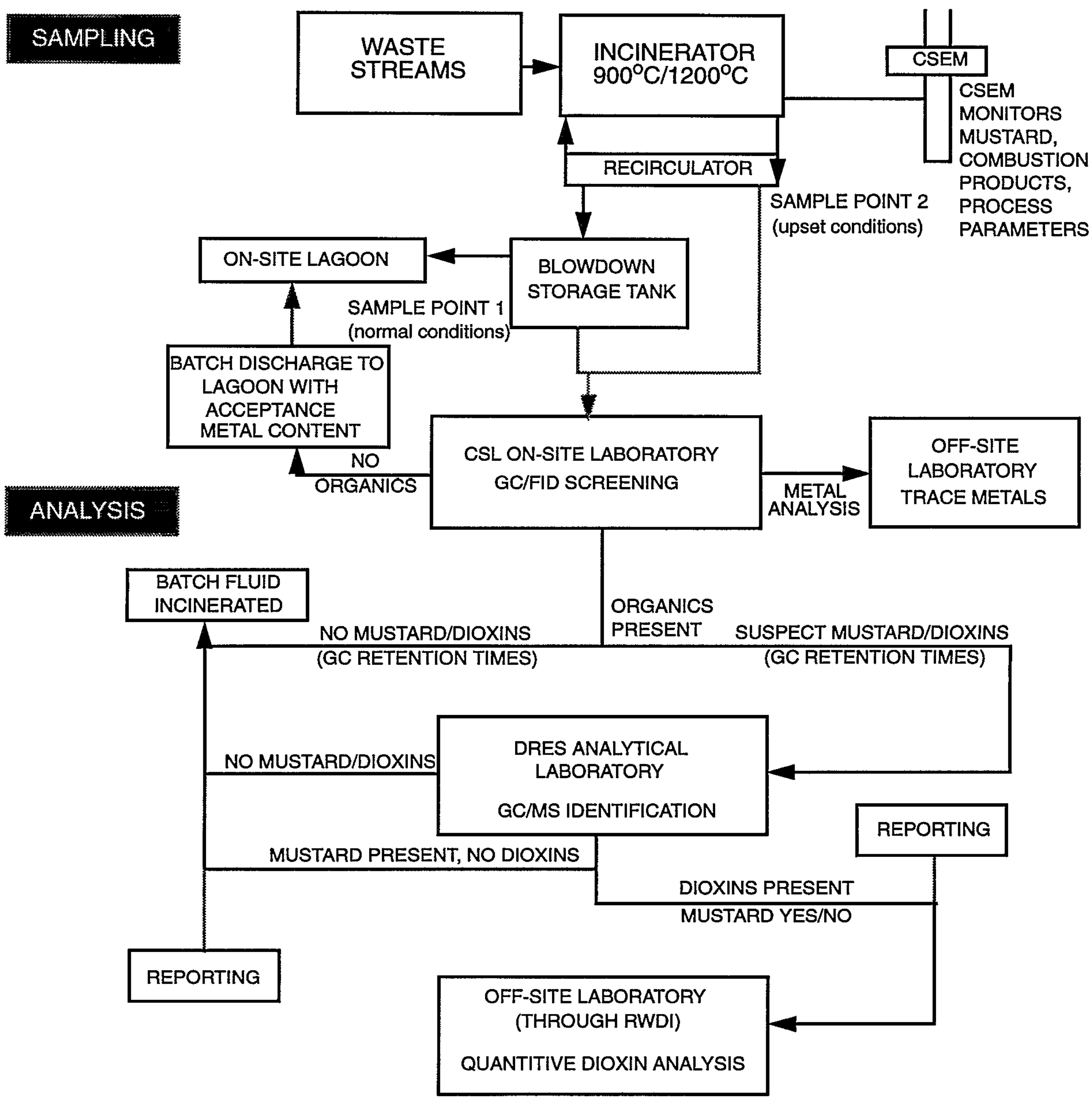


Figure 2F

Scrubber Fluid Sampling and Analysis Schematic

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Project Swiftsure describes a three-year project at the Defence Research Establishment Suffield to safely destroy stockpiles of mustard lewisite, nerve agents and decontaminate scrap material which was stored on the DRES Experimental Proving Ground. Using both in-house and contracted resources, the agent waste was destroyed by chemical neutralization or incineration. With the exception of the arsenic byproducts from the lewisite neutralization process, all secondary waste generated by chemical neutralization was incinerated. Mustard in different forms was thermally destroyed using a transportable incinerator of commercial design.

Extensive environmental monitoring and public consultation programs were conducted during the project. Results of the monitoring programs verified that the chemical warfare agents were destroyed in a safe, environmentally-responsible manner.

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