

**COST AND PERFORMANCE REPORT**

**FOR**

**PHOTOLYTIC DESTRUCTION TECHNOLOGY  
DEMONSTRATION**

**NAS NORTH ISLAND, SITE 9**

NAVAL FACILITIES ENGINEERING SERVICE CENTER  
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## **Section 1.0 Introduction**

### **1.1 Demonstration Program Background**

In July 1996, the Navy Environmental Leadership Program (NELP) issued a Broad Agency Announcement (BAA), Solicitation N47408-96-R-6342, for demonstrating a remediation technology for environmental cleanup. The Navy's goal in issuing this BAA was to demonstrate innovative technologies that are at the advanced development stage and are ready for field implementation. Process Technologies' Incorporated (PTI) responded to the BAA, which resulted in the selection of their Photolytic Destruction Technology for demonstration at Naval Air Station (NAS) North Island Installation Restoration (IR) Site 9. The goal of the demonstration was to obtain the necessary cost and performance data on the PTI system demonstration at NAS North Island, Site 9, and make a comparison with other commercially-available treatment technologies. This data will be compiled by the Naval Facilities Engineering Service Center (NFESC) and provided in a summary report to be distributed within all of the Department of Defense (DoD). The two potential benefits to PTI are potential immediate full-scale implementation at NAS North Island and potential future use within the federal government at other sites with similar volatile organic compound (VOC) air streams requiring treatment.

### **1.2 Site Description**

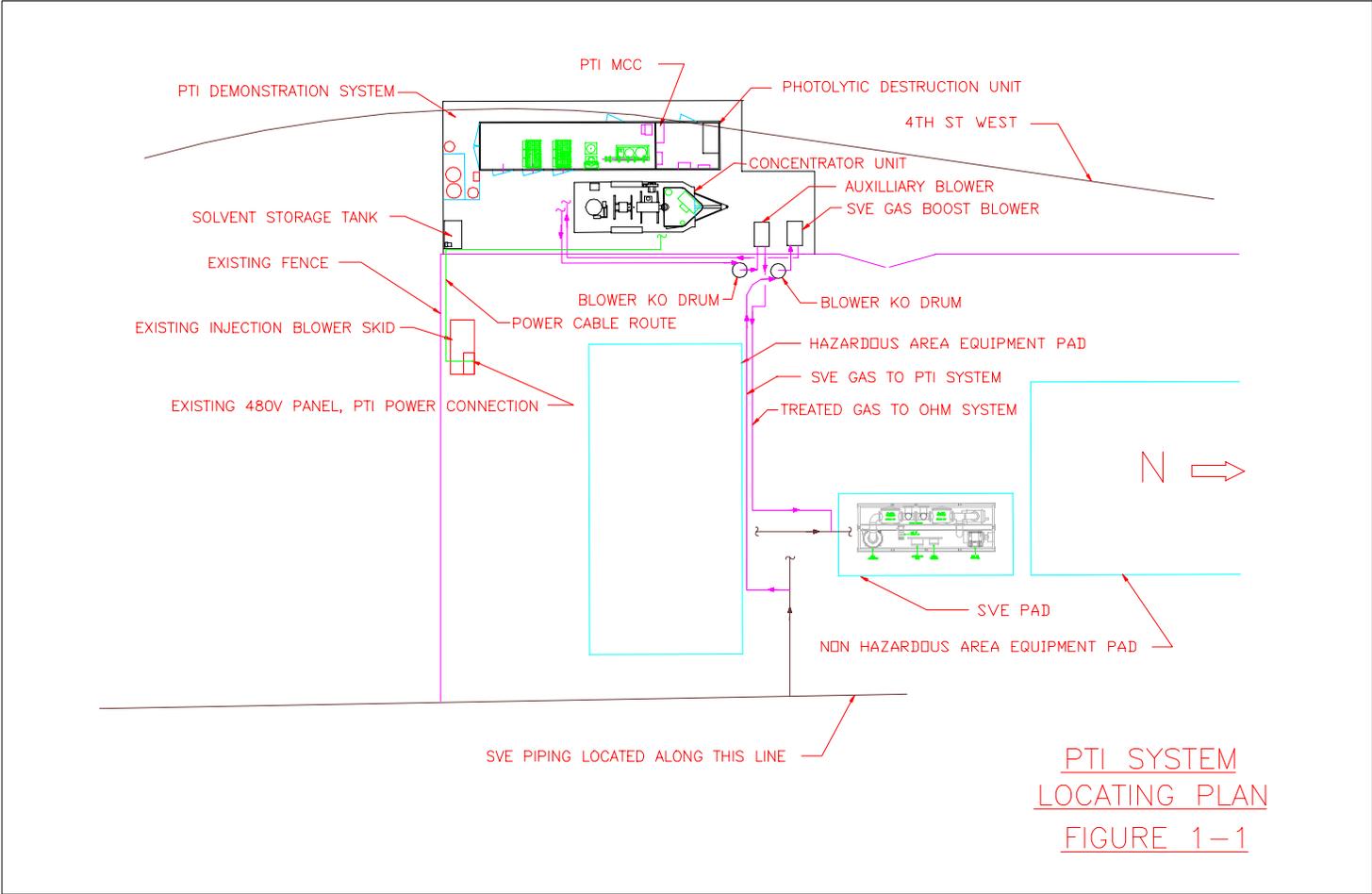
#### **Location**

NAS North Island is located in southern San Diego County, across San Diego Bay from the downtown area, on the northern end of Coronado. Twelve sites on NAS North Island were identified as IR sites owing to their historical use as hazardous materials generating and/or disposal sites. Site 9 is one of these IR sites.

For this demonstration, the PTI System was installed to interface with an existing Soil Vapor Extraction and Treatment System (SVE&T). The SVE&T was installed at Site 9 in 1997, to remove and treat the contaminated soil vapor from Site 9's Area 1 and 3 SVE wells. PTI treated soil vapor from the Area 3 wells only. Figure 1-1 presents the PTI System Locating Plan indicating the location of the PTI System as it relates to SVE&T the facility.

#### **Geology**

The uppermost layer at Site 9 consists of approximately 100 feet of poorly graded fine sand and silty sand with shell beds. Several layers of clay, clayey sand and silt exist from approximately 35 feet below grade surface (bgs) to 150 feet bgs. The character of the vadose zone, which is 8 to 10 feet thick, is suitable for soil vapor extraction (SVE). The shallow nature of the vadose zone at Site 9 required installation of horizontal SVE wells to effectively capture VOCs in the vadose zone (OHM Remediation Services Corp. (OHM)1996).



### Chemicals of Concern

Five VOCs were found in vadose zone soil at Site 9 in concentrations that exceed the United States Environmental Protection Agency (EPA) Region IX Industrial Preliminary Remediation Goals (PRGs). These are cis-1,2-dichloroethylene (DCE), 1,1-DCE, tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride (OHM 1996). For the demonstration, compounds known to exist at concentrations >2ppmv were also added to this list.

**Table 1-1: Chemicals of Concern**

Chemical Name	Concentration in SVE Vapor <sup>1</sup>
Octane <sup>2</sup>	96.44
Tetrachloroethene	31.40
Trichloroethene	27.60
cis-1,2-Dichloroethene	22.20
Toluene	14.20
1,1-Dichloroethene	N.D.
Vinyl Chloride	N.D.

Notes:

1. Average SVE vapor concentration, as measured during Steady-State Operations, by EPA Method TO-14.
2. The concentration of Octane was calculated using the equation:  
$$\text{Concentration}_{\text{Octane}} = [(\text{Total Vapor Concentration by FID}) - (\text{Total Vapor Concentration by TO-14}) - (\text{Methane Concentration})] \div 8.$$

### Site History

Site 9, the Chemical Waste Disposal Area, includes a low-lying depressed area in the northeastern corner that was used for liquid chemical waste disposal beginning in the 1940s (OHM 1996). Disposal in this area was halted when it became apparent that mixing of wastes was generating chemical reactions that caused fires. Part of the depression was excavated and back-filled with clean, compacted fill for construction of the aircraft run-up pad and taxi-way in 1974. The remainder was filled in with soil and concrete rubble in 1978 (OHM 1996).

Beginning in 1968, wastes were segregated into four parallel trenches near the eastern edge of Site 9. The trenches received solvents, caustics, acids, and Sermetel W (a semi-synthetic high-temperature coating of ceramic and metallic compounds consisting of metallic carbides). Disposal of wastes in the trenches ended in the mid-1970s when installation of an Industrial Waste Treatment Plant (IWTP) was completed. The southeast corner of Site 9, extending to the fence line which houses the Naval Weapons Center (NWC), was used intermittently for liquid waste disposal from the 1950s to 1978 (OHM 1996).

In general, VOCs, semi-volatile organic compounds (SVOCs), petroleum hydrocarbons, metals, and polychlorinated biphenyls (PCBs) have been detected in soils at the Site 9 disposal areas (OHM 1996).

### **Non-Time-Critical Removal Action (NTCRA)**

Presently, a Non-Time-Critical Removal Action is in place at Site 9 to remove VOCs from vadose zone soil. The NTCRA work at Site 9 consists of the following, and is described in more detail in Section 2.3:

- Extraction of VOCs from soil by SVE. A series of horizontal SVE wells and air injection wells have been installed in Areas 1 and 3.
- Treatment of extracted soil vapor by vapor phase activated carbon adsorption.

### **1.3 Demonstration Objectives**

This demonstration was performed to obtain the relevant data needed for Navy project managers, and other decision makers, to evaluate the PTI system's applicability for a project while reducing cost on the project. The PTI technology will be compared with all other emerging and commercially available technologies so remedial project managers (RPMs) can make the optimum business decisions for the Navy and other DoD.

The objectives of this demonstration were as follows:

1. Determine the total average DRE achieved by the PTI system for all VOCs measured in the SVE off-gas, as well as individual DREs for critical VOCs.
2. Develop treatment cost data for a 3,000 standard cubic feet per minute (scfm) PTI system, designed to achieve the DREs measured above, for VOC-contaminated soil vapor similar to those at Site 9.
3. Characterize and quantify secondary waste streams generated by the PTI system at Site 9 and determine the appropriate disposal option(s) for each. Estimate the costs of disposal of all secondary waste streams generated.
4. Characterize and quantify all residuals, including hydrochloric acid, chlorine, phosgene, carbon monoxide and dioxins, exiting the PTI system.
5. Document observed operating problems and their solutions.
6. Disseminate the results of the demonstration throughout the DoD, DOE, private industry, state regulatory agencies and the NAS North Island RAB.

## Section 2.0 Technology Description

PTI's VOC treatment system consists of a fluidized bed concentration unit and a photolytic destruction unit (PDU). The concentration unit produces a low flow, high concentration VOC vapor that is then processed through the PDU. For most treatment or recovery technologies, it is desirable for the unit to receive a low cubic feet per minute (cfm) flow with high levels of VOCs, rather than the high flow and dilute VOCs typically found. The concentration unit can pre-concentrate organics up to 1,000 times while correspondingly decreasing the cfm flow.

The concentration unit includes a chilled-water condenser to preferentially remove non-chlorinated hydrocarbons from the vent gas prior to treatment in the photolytic destruction unit. The PDU is most cost-effective when treating high concentration vapors containing chlorinated hydrocarbons. PTI has combined the two technologies to provide a system that can treat a variety of contaminated VOC vapor streams. Figure 2-1 is a simplified schematic diagram of the PTI System. A detailed description of the technology as it was demonstrated at Site 9 is presented below.

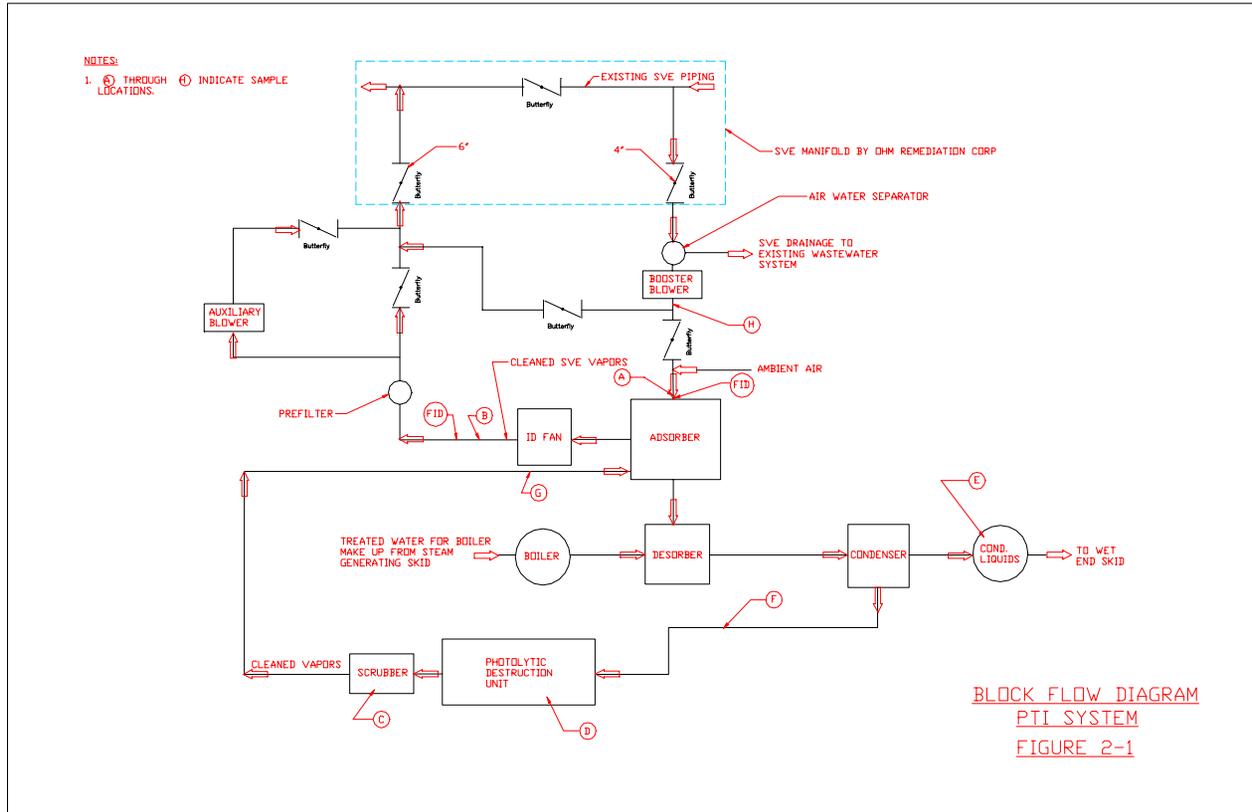
### 2.1 Concentration Unit

The Concentration Unit consists of three major components: an adsorber, desorber and condenser. The following is a description of each component and its basic unit operations:

#### Adsorber

The adsorber develops a fluidized bed of adsorbent beads to extract organic vapors from the SVE vapor. The adsorbent beads are specifically designed to extract VOCs from high humidity gas streams. The adsorber has multiple stages of adsorption trays to control the flow of adsorbent beads. As the beads flow from one tray to the next, they adsorb the VOCs from the gas stream, in a process referred to as "loading". Fluidization of the adsorbent media bed enhances the kinetics and improves the capture rate. On a static bed, a small break between carbon pieces will allow the gas flow to select the path of least resistance and much of the flow will pass without adsorption. The constant movement of the media allows for all portions of the adsorbent to be utilized.

The adsorber is operated under a slight negative pressure so that SVE vapors can be drawn into the adsorber. A manually operated flow control system is used to bring 250 scfm of SVE vapors into the unit. As noted earlier, the SVE flow rate is adjusted based on the actual VOC concentrations that are experienced during operation. Additional ambient air (trim air) is mixed with the SVE vapor before entering the adsorber. A manually operated flow control system is used to draw a minimum of 400 scfm of combined gas flow into the unit.



The combined gas flow moves upward through multiple stages of trays to contact the adsorbent media used to adsorb VOCs from the gas stream. The adsorbent beads flow downward through the unit (tray-to-tray) while the gas flows upward at sufficient velocity to fluidize each stage of adsorbent media. This allows intimate and thorough contact of the gas with the adsorbent. The treated gas passes through an internal screen prior to its return to the existing SVE piping at a point down-stream from the tie-in. The internal screen ensures that the adsorbent beads are retained within the adsorber.

### **Desorber**

The Desorber evaporates the VOCs from the loaded adsorbent beads. High-pressure steam (60 psig) provides energy through a heat exchanger to desorb the organics from the adsorbent beads. A low pressure steam (atmospheric pressure) is used as the carrier vapor to sweep the desorbed organic vapors from the desorber. The desorbed “lean” adsorbent beads are then immediately recycled to the adsorber, to begin another cycle.

The “loaded” adsorbent beads are pneumatically transferred from the bottom of the adsorber to the top of the desorber. The adsorbent beads flow downward in a plug-flow manner. The desorber contains a steam-heated heat exchanger that warms the adsorbent to 300° F. This heat vaporizes the adsorbed VOCs. Low pressure, superheated steam is used to sweep the desorbed VOCs out of the desorber and into the condenser. The “lean” adsorbent is pneumatically recycled to the top of the adsorber for reuse. This provides for the continuous, closed-loop operation of the adsorbent beads through the concentrator system.

A small electrically-heated boiler was used to generate steam for the desorber and provide the low pressure sweep steam. Make-up water for the steam generator was provided from the existing SVE&T Steam Generating Skid, and boiler blowdown was drained to an existing wastewater sump located adjacent to the SVE&T Steam Generating Skid.

### **Condenser**

The condenser is cooled with chilled water to preferentially remove the water vapor and non-halogenated organics in the concentrated sweep vapor. A portion of the halogenated chemicals is also removed in the condenser. The condenser temperature can be controlled with a thermostat to achieve the desired condensing conditions. During the first few weeks of operation, evaluations were made to determine the preferred operating temperature for the condenser. A chilled water system is used for the condenser. Heat is rejected from the refrigeration unit using an air-cooled heat exchanger. Condensate was collected in a “day” tank and then transferred to the existing gravity separator located on the SVE&T wet-end skid. The day tank was sampled prior to transfer of the SVE&T gravity separator.

## **2.2 Photolytic Destruction Unit (PDU)**

The PDU, located between the condenser and the recycle line to the adsorber, processes the non-condensable vapors from the condenser. The PDU consists of two major components: the photolytic reactors and a wet scrubber. A description of each component and its basic unit operations is discussed below:

## **Photolytic Reactors**

Two photolytic reactors, each capable of treating up to 5 scfm of concentrated, contaminated vapor were included with the system. Non-condensable vapors from the condenser flow into the PDU. The non-condensable vapors are mixed with ambient air prior to entering the PDU to control the vapors to less than 20% of the lower explosive limit (LEL) for the gas mixture. This adjustment is made manually, based on analytical test results.

The mixture of VOC-laden vapor and ambient air passes through the photolytic reactors, where the vapors are exposed to high levels of photons produced by ultraviolet (UV) lamps. The VOCs break into free radicals which react with the alkaline compounds contained in the reagent panels. This reaction works to prevent the formation of undesirable by-products in the process exhaust stream. The reagent panels are located adjacent to the UV lamps.

When the reagent panels are exhausted (fully utilized), acid gases from the reactors will be predominantly reacted in the Wet Scrubber system. The pH of the scrubber solution is reduced as high loadings of acid gas are processed. A rapid drop in the scrubber solution pH is an indicator that the reagent panels need to be replaced. During the demonstration, two sets of reagent panels were used. At the completion of the technology demonstration, the reagent panels were tested using the EPA Toxicity Characteristic Leaching Procedure (TCLP) to verify that the panels could be disposed as sanitary rather than hazardous waste.

To control the temperature inside the reactors, a closed-loop cooling water system provides cooling water to plate-type heat exchangers that are located between the reagent panels. Heat energy from the lamps, and heat of reaction from the neutralization reactions, are removed via the internal heat exchangers. The closed-loop cooling system circulates the water from the heat exchangers through a radiator system where air rejects the heat to atmosphere. The cooling system has two pumps, one operating and one backup.

## **Wet Scrubber**

The VOC-free gas from the photolytic reactors flows through a caustic scrubber system to remove any trace amounts of hydrogen chloride, or other acidic by-products that are not reacted with the reagent panels. The scrubbing system operates with a 5% caustic soda solution as the reagent. Two pumps are provided with the system, one operating and one backup.

The clean, scrubbed gas flows back to the inlet of the Concentration Unit. An emergency by-pass system is included so the cleaned and scrubbed gas can be processed through a canister of activated carbon prior to recycle to the adsorber outlet in the event that the Concentration Unit trips off-line.

Prior to disposal, the spent scrubber solution is pumped out of the scrubber recycle tank, through an activated carbon canister, and into a 55 gallon drum. Samples of the solution in the drum were analyzed for comparison with the site discharge permit requirements. This analysis proved the water could be drained into the site sanitary sewer system.

The PTI System is capable of being operated in three different process configurations. They are:

Configuration-1: Concentration-Condensation-Photolytic Destruction

Configuration-2: Concentration- Condensation

Configuration-3: Concentration- Photolytic Destruction

Each of these process flow configurations was evaluated during this technology demonstration. Refer to “*Process Technologies Incorporated Technology Demonstration Final Work Plan*” (Work Plan) for additional information regarding the process flow configurations that were evaluated.

### **2.3 PTI and SVE System Interface**

For this demonstration, the PTI System was installed to interface with an existing SVE&T. The SVE&T was installed at Site 9 in 1997, to remove and treat the contaminated soil vapor. Figure 1-1 presents the PTI System Locating Plan indicating the location of the PTI System as it relates to the SVE&T facility.

The SVE vapor is drawn from the wells by SVE blowers located at the treatment facility. The SVE&T System is rated at 3,000 scfm of vapor flow. VOCs are removed from the SVE vapor using a regenerative vapor phase activated carbon (VPAC) system. The SVE&T System consists of six equipment skids: the SVE System Skid, VPAC System Skid, Wet-End Skid, Steam Generating Skid, Injection Blower Skid, and Cooling Water Skid. The PTI System pulled SVE vapors from, and re-injected treated gas to, the SVE System Skid.

The PTI System used for this demonstration was designed to treat 500 scfm of SVE vapor, and to remove a minimum of 3.6 pounds per hour (lbs/hr) of VOCs. During the operation of the system it was determined that the maximum flow rate that could be treated was actually 440 scfm. The average composition of the SVE vapor from the Area 3 wells was calculated to be 191.84 ppmv of VOCs. This is equivalent to approximately 1.22 lbs/hr of VOCs at the 500 scfm design rate, which is approximately one-third the projected VOC removal capability of the PTI System used for this demonstration.

The SVE vapor was drawn from the Area 3 SVE piping from a nozzle located on the SVE well manifold piping. OHM installed the manifold system, complete with a diversion valve and isolation block valves. Figure 2-1 identifies the approximate tie-in point, and schematically shows the major process operations associated with the PTI System. PTI installed a booster blower to draw the SVE vapors into the PTI System. The booster blower was equipped with an air/water separator to remove any free moisture from the SVE vapor. Water collected in the separator was drained to the existing OHM Wet End system.

After treatment through the PTI System, the treated gas was returned to the manifold piping for subsequent processing through the existing VPAC System. In addition to the booster blower, PTI also provided an auxiliary blower for the treated gas leaving the PTI system. This blower was used when the SVE&T blower systems were inoperative to allow the PTI technology to continue to operate.

## **2.4 Technology Applicability**

Photolytic destruction has been demonstrated to destroy VOCs in SVE and chemical storage tank vents off-gas. Off-gas streams from air strippers, air spargers and process vent streams are other likely applications for the technology. Pilot and commercial-scale work has shown that photolytic destruction is best suited for destroying low-flow, high concentration gas streams containing halogenated VOCs. For the treatment of high flow, dilute gas streams, a concentrator is used as a pretreatment method, prior to destruction by photolytic destruction. The Concentration Unit has been installed and in use in Europe for the control of VOC emissions from paint spray booth and fiberglass reinforced plastics operations. This demonstration was the first commercial demonstration of the PDU and Concentration Unit in the United States.

## **2.5 Commercialization and Intellectual Property**

The photolytic destruction technology is manufactured and sold as PDUs by PTI. The PDUs are protected by 5 U.S. and 2 international patents. The concentrator technology is manufactured and sold by PTI under license to MIAB, an air pollution control equipment manufacturer located in MÖlnbacka, Sweden.

## **2.6 Competing Technologies**

The PTI system competes with conventional VOC treatment technologies such as activated carbon and flameless thermal oxidation.

## **2.7 Technology Maturity**

Photolytic destruction is an innovative air treatment technology, although variations have been applied for the treatment of contaminated water. The technology, together with the concentrator, is being implemented on a commercial scale for the treatment of air stripper off-gas and other SVE sites. The Concentration Unit has been in use in Europe since 1990.

## Section 3.0 Experience And Findings Of The Demonstration

Below is a summary table listing the order and dates of major events completed during the demonstration.

**Table 3-1. Schedule of Project Activities**

Activity	Date(s)
Contract Award	July 31, 1997
Kick-Off Meeting	August 15, 1997
Work Plan Development	August 16 - October 3, 1997
Mobilization	October 7-11, 1997
Installation	October 11, 1997
Startup	October 12 - October 18, 1997
Parametric Tests	October 24, 1997 - January 8, 1998
Steady-State Tests	January 17 - February 6, 1998
Demobilization	February 7 - February 12, 1998

### 3.1 PTI System Mobilization and Installation

Prior to initiating the on-site work, the PTI system was pre-assembled and tested to verify mechanical, electrical and instrumentation integrity. This testing was performed at PTI's facility in Boise, Idaho. The U.S. Navy's Project Manager and Contracting Officer's Technical Representative (COTR) were on hand to witness a portion of the pre-mobilization testing.

Prior to mobilizing the PTI system to Site 9, PTI personnel together with assistance from OHM site personnel, performed various on-site mobilization activities. These activities were performed several days in advance of shipping the PTI System. They included:

- Preparation of an area of approximately 20' wide by 50' long to receive the PTI System, the Booster Blower and Auxiliary Blower Modules.
- Installation of tie-in connections for the field-run piping for the boiler feed water, SVE vapor inlet piping, treated vapor outlet piping, potable water, and condensate transfer piping. Since this was a temporary facility, piping runs were all above ground and were anchored onto cribbing supports. Walk-over stiles were placed where appropriate to prevent tripping hazards.
- Installation of conduit and wiring from an existing 480 volt, 200 amp electrical service, adjacent to the Injection Blower Skid, to the PTI System (see Figure 1-1).

The PTI equipment was delivered to the site, on October 11, 1997, in the form of modules that were interconnected with field-run piping, and electrical and instrumentation wiring. The equipment modules consisted of:

- Concentrator Unit Trailer Module (adsorber, desorber, fan, pneumatic transfer system, condenser, refrigeration unit, boiler unit, and all associated electrical equipment and controls - see Figure 3-1).
- Solvent Storage Tank Module (skid-mounted condensate storage tank and pump).
- The PDU Container Module (all of the PDU process equipment pre-piped, pre-wired and pre-instrumented. This module also contained the motor control center and the programmable logic control (PLC) system common to all of the modules. A small work office was also included in the PDU Module - see Figure 3-2).
- SVE Booster Blower Module (booster blower, water knockout, motor starter, and instrumentation/controls).
- Auxiliary Blower Module (auxiliary blower, pre-filter, motor starter, and instrumentation/controls).

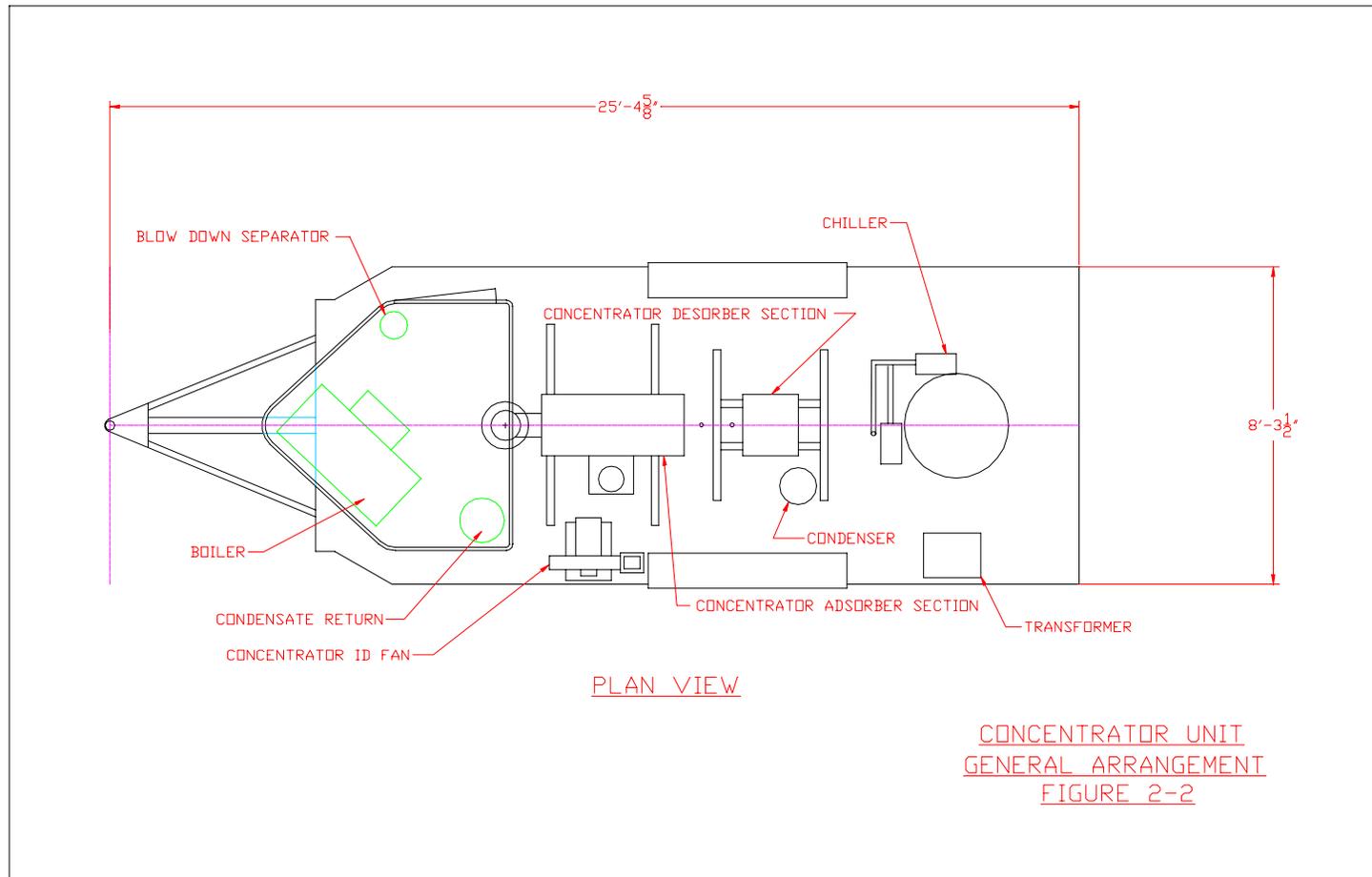
The PTI System was installed adjacent to the southwest section of the security fencing surrounding the SVE&T system. Figure 1-1 identifies the location of the PTI System installation at the SVE&T facility. A crane was used for positioning of the equipment at the proper location. All of the PTI System modules were placed on cribbing as the primary support for the units. Grounding rods were placed at appropriate locations and grounding wires were provided to ensure the safe operation of the System. Installation of the equipment was completed in one day.

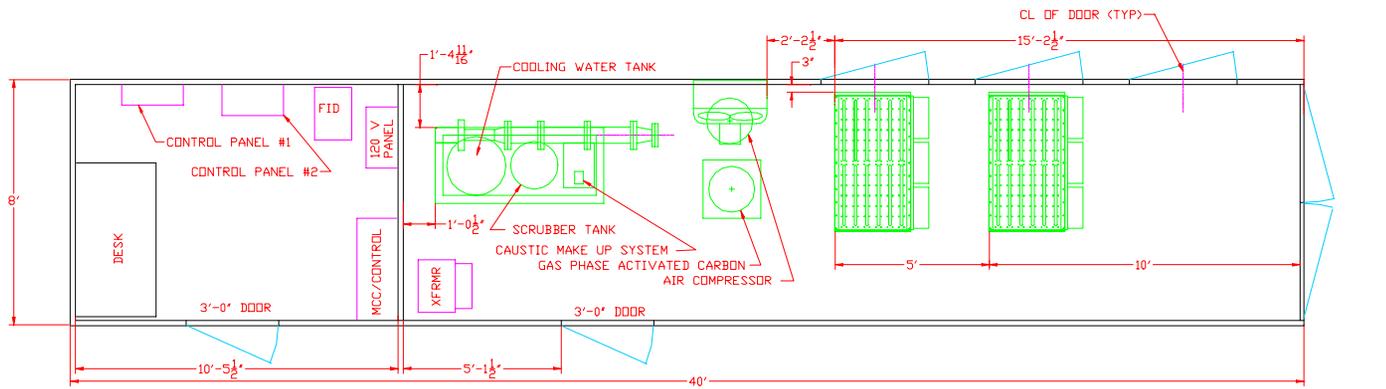
### **3.2 PTI System Start-Up**

A mechanical check-out of the PTI system commenced on October 12<sup>th</sup>, after completion of installation activities. During this phase of the demonstration, the following start-up activities were completed:

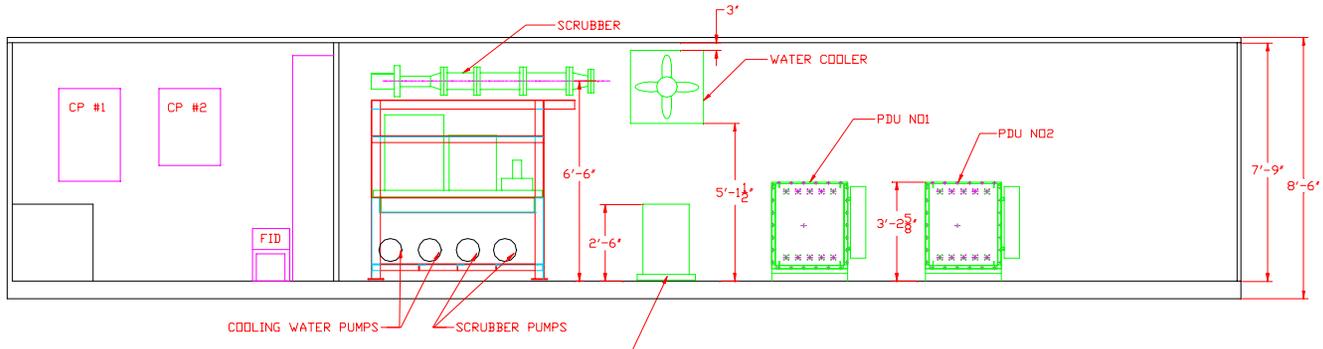
- Field-run piping and electrical inter-ties to connect the existing SVE&T modules and SVE manifold piping to the PTI System modules.
- Performed system integrity checks (mechanical, piping, electrical, and instrumentation).
- Verified operation of SVE booster and auxiliary blowers.
- Loaded adsorbent beads into adsorber and desorber.
- Loaded reagent panels in PDU reactors.
- Performed mechanical start-up of the Concentrator Unit.
- Modified PDU inlet gas piping to accept dilution air.

PTI began processing SVE vapors from the Area 3 well piping beginning October 18<sup>th</sup>.





PLAN VIEW



ELEVATION VIEW

PHOTOLYTIC DESTRUCTION UNIT  
 GENERAL ARRANGEMENT  
 FIGURE 2-3

### 3.3 PTI System Operation

The PTI technology demonstration was performed in two phases. Phase 1 involved Parametric Testing to establish the optimal process configuration for Site 9 conditions. Once established, this configuration was implemented for Phase 2 of the demonstration, Steady-State Testing.

#### Parametric Tests (October 24, 1997 through January 8, 1998)

Phase 1 consisted of Parametric Testing, which involved varying the feed gas flow from the SVE system and the condenser temperature. Three process configurations, discussed in detail below, were evaluated during the Parametric Testing. During this period the PTI System processed SVE off-gas for a total of 378 hours. Between tests, the system was shutdown to make the necessary process changes to perform the next series of tests. Because of this intermittent operation of the system, an on-line availability rating was not calculated for the Parametric Tests. The results of the Parametric Tests are discussed below:

#### Configuration 1: Concentration-Condensation-Photolytic Destruction

Process Configuration-1 involved the use of all of the PTI System components. In this mode of operation, low boiling, non-condensable organics that do not condense in the condenser unit, are processed through the PDU.

Table 3-2 presents the operational parameters and performance results achieved during Configuration-1 tests. The VOC concentration data was collected and recorded using an on-line FID. The use of an on-line, continuous monitoring system allowed PTI to readily observe the effect of making system changes on performance. Note that Test 1-1, involving an SVE flow rate of 100 cfm, was not performed per the Work Plan, as it was not possible to operate the SVE Booster Blower at a flow-rate less than 150 cfm.

**Table 3-2. Configuration 1 Parametric Test Results**

Process Parameters	Test 1-2	Test 1-3	Test 1-4	Test 1-5	Test 1-6
SVE Flow (scfm)	151	209	245	290	259
Make-up Air (scfm)	306	290	223	160	111
Condenser Temperature (°F)	69	67	59	52	60
Inlet Concentration (ppmc) <sup>1</sup>	279	309	366	1,367	1,453
Outlet Concentration (ppmc)	188	86	127	513	463
Average DRE (%)	32.62	72.17	65.30	62.47	68.13

Note: 1. VOC concentration as measured by an on-line FID.

The system was shutdown after completion of Test 1-6 to make the following modifications to the concentrator with the intention of improving system removal efficiencies:

- Replaced the flapper/check valve that controls the flow of adsorbent beads into the top of the desorber. Because the original valve was not sealing well, it was believed that concentrated VOCs could be discharged to the top adsorber tray, and vented to the VPAC System.
- Installed taller weir plates in the adsorber to allow for a thicker layer of beads to form on each adsorption tray.
- Replaced the desorber downcomer tubes with smaller diameter tubes to increase the Adsorbent beads residence time in the desorber.
- Increased desorption temperature by 20 °F, to approximately 285 °F, to increase the removal of solvent from the adsorbent beads.
- Increased vacuum pressure in desorber from -0.3 mm to -0.5mm to increase the solvent desorption rate, and ensure that no solvent vapors could be allowed to vent back to the adsorber.
- Added additional adsorbent beads to the Concentrator Unit.

After making the above modifications, the system was restarted and tests 1-4 through 1-6 were repeated. The results of these tests are presented in Table 3-3.

**Table 3-3. Configuration 1A Parametric Test Results**

<b>Process Parameters</b>	<b>Test 1-4a</b>	<b>Test 1-5a</b>	<b>Test 1-6a</b>
<b>SVE Flow (scfm)</b>	265	267	266
<b>Make-up Air (scfm)</b>	149	130	133
<b>Condenser Temperature (°F)</b>	62	52	69
<b>Inlet Concentration (ppmc)<sup>1</sup></b>	928	1,009	1,022
<b>Outlet Concentration (ppmc)</b>	55	112	265
<b>Average DRE (%)</b>	94.07	88.90	74.07

Note: 1. VOC concentration as measured by an on-line FID.

It was evident, based on the higher DREs achieved during Configuration 1A Tests, that the System mechanical and operational changes were very effective. The lower “Average DRE %” achieved during Test 1-6A is related to the condenser temperature. At high condenser temperatures, less VOCs are condensed, thereby causing a greater recycle load of VOCs to return to the adsorber. A high recycle load of VOCs can “overload” the adsorber, thereby reducing process removal efficiencies.

**Configuration 2 Test: Concentration-Condensation (No PDU)**

Process Configuration-2 eliminates the use of the PDU to destroy the low boiling organic compounds. Rather, the VOCs are condensed into a liquid for off-site disposal. Any non-condensable vapors are recycled to the inlet of the adsorber. The results achieved during this series of tests, illustrated in Table 3-4, as evidenced by the lower “Average DRE %”, show an increase in the recycle load of VOCs into the adsorber, leading to break-through of the chemicals into the adsorber outlet. PTI believes that higher “Average DRE %s” might have been achieved if tests were run at lower condenser temperatures. Operating the condenser at lower temperatures would have decreased the re-circulation load of low boiling point compounds to the adsorber.

**Table 3-4. Configuration 2 Parametric Test Results**

Process Parameters	Test 2-2	Test 2-3	Test 2-4	Test 2-5	Test 2-6
SVE Flow (scfm)	148	211	258	262	215
Make-up Air (scfm)	169	210	68	141	124
Condenser Temperature (°F)	80	66	78	50	67
Inlet Concentration (ppmc) <sup>1</sup>	966	337	1,427	1,860	1,110
Outlet Concentration (ppmc)	582	115	414	551	433
Average DRE (%)	39.75	65.88	70.99	70.38	60.99

Note: 1. VOC concentration as measured by an on-line FID.

**Configuration 3 Test: Concentration- PDU (No Condensation)**

Process Configuration-3 eliminates the use of the condenser and instead, all of the concentrated organic vapors are processed through the PDU. In this mode of operation, air rather than steam was used to sweep the concentrated vapors from the desorber. In order to operate the unit safely, the concentration of organic vapors was limited to levels that do not exceed 20% of the LEL.

Table 3-5 presents the operational parameters and performance results achieved during Configuration-3 tests. The lower than expected level of VOCs in the SVE off-gas enabled PTI to run Test 3-1 at a much higher SVE flow rate than originally designed. No further Configuration-3 tests were conducted because it was felt that no improvement over Configuration-1 test results would be achieved in this operational mode. Therefore, the System was shut-down to prepare for Steady-State Operation.

**Table 3-5. Configuration 3 Parametric Test Results**

<b>Process Parameters</b>	<b>Test 3-1</b>
<b>SVE Flow (scfm)</b>	215
<b>Make-up Air (scfm)</b>	200
<b>Condenser Temperature (°F)</b>	NA
<b>Inlet Concentration (ppmc)<sup>1</sup></b>	1,443
<b>Outlet Concentration (ppmc)</b>	480
<b>Average DRE (%)</b>	66.74

Note: 1. VOC concentration as measured by an on-line FID.

Upon review of the Parametric Test data, it was determined that the optimal operation parameters for long-term operation at Site 9 would be those which mimicked Test 1-4a. During this test, the System achieved the highest DRE (91.79%), using a higher condenser temperature (62° F), than other tests run at or near an average SVE flow rate of 265 scfm.

**Steady-State Operation (January 17, 1998, through February 6, 1998)**

After completion of the Parametric Tests, the System was shutdown to prepare for Steady-State operation. During this shutdown the following work was performed:

- Installed software in the PLC to record the inlet and outlet FID measurements 24-hours per day.
- Installed a kilowatt meter to monitor system power consumption.
- Installed a water meter to monitor water consumption by the steam boiler (the PDU cooling water and condenser chiller water systems are self-contained and require little make-up water).
- Added adsorbent media to the Concentration Unit to replace any adsorbent beads lost to attrition during the Parametric Tests.
- Replaced the reagent panels with new panels. A sample was taken and sent to an independent laboratory for analysis.
- Repaired a number of small leaks observed in the condenser.
- Installed an eductor system to transport the adsorbent beads from the adsorber to the desorber. A positive pressure transport system, rather than the original negative pressure system, was used to prevent the plugging of adsorbent beads at the desorber inlet flapper valve.

Steady-State Operation began on January 17, 1998, and was completed on February 6, 1998. During this phase of testing, the System was operated 24-hours per day, 7-days per week, except during process shutdowns and holidays. The unit operated unattended during normal off-hours, weekends, and during weapons loading activities. The PTI System operated for a total of 440 hours during this period, and achieved an 89% on-line availability.

During the second week of Steady-State Operation, the decision was made to switch from using hot-air desorption to steam desorption. It was determined from the analytical test results that using steam desorption resulted in a higher removal efficiency. PTI chose to continue the use of steam as a desorption gas for the remainder of the demonstration. A summary of system performance during this period is provided in Tables 3-6 and 3-7.

**Table 3-6. Steady-State Test Results - Hot Air Desorption**

<b>Process Parameters</b>	<b>Low</b>	<b>High</b>	<b>Average</b>
<b>SVE Flow (scfm)</b>	239	267	245
<b>Make-up Air (scfm)</b>	57	157	100
<b>Condenser Temperature (°F)</b>	80	90	83
<b>Inlet Concentration (ppmc)<sup>1</sup></b>	890	1,175	995
<b>Outlet Concentration (ppmc)</b>	83	170	125
<b>DRE</b>	80.90	92.94	87.37

Note: 1. VOC concentration as measured by an on-line FID.

**Table 3-7. Steady-State Test Results - Steam Desorption**

<b>Process Parameters</b>	<b>Low</b>	<b>High</b>	<b>Average</b>
<b>SVE Flow (scfm)</b>	243	307	267
<b>Make-up Air (scfm)</b>	51	102	76
<b>Condenser Temperature (°F)</b>	88	110	96
<b>Inlet Concentration (ppmc)<sup>1</sup></b>	1,010	1,141	1,056
<b>Outlet Concentration (ppmc)</b>	14	93	44
<b>DRE</b>	91.85	96.76	95.93

Note: 1. VOC concentration as measured by an on-line FID.

### 3.4 Demobilization

After completion of the Phase 2 Steady-State Tests, the System was decontaminated and decommissioned. The decontamination work was performed in two steps. First, the Concentrator Unit was operated, using ambient air only, in a recycle mode to remove organics retained in the adsorbent beads. The organics were treated with the PDUs.

After the adsorbent was regenerated, the system was taken off-line and disassembled. Mechanical equipment that had been exposed to contamination was cleaned in conformance with the procedures defined in the Health and Safety Plan (Work Plan). Decontamination materials were also disposed in conformance with the Health and Safety Plan.

The reagent panels were composite sampled during removal from each of the PDUs. The sample was subjected to TCLP testing. The results of the tests, proved the panels to be safe for landfill disposal. Originally, PTI had planned to dispose of the panels in the Miramar Landfill, however this landfill's disposal application requirements were such that demobilization would have been delayed. As PTI had committed the use of the equipment for another project, it chose to have the panels shipped to its facility in Boise, Idaho, where the panels were disposed.

The liquid condensate collected during the demonstration was pumped into 55-gallon liquid storage containers and stored on the OHM Hazardous Waste Pad. Each of the containers were labeled as follows: "*Solvent Condensate, Analysis Pending, Generated on February 12<sup>th</sup>, 1998*". The condensate was sampled by PTI and analyzed for VOCs as per the Quality Assurance Project Plan (QAPP). The results of the analysis showed the composition of the condensate to be similar to that collected by the OHM treatment system. The condensate was then combined with the OHM solvent for disposal.

The scrubber liquid was treated with liquid-phase granular activated carbon and analyzed as per the QAPP. The results of the testing showed the liquid to be safe for disposal in the OHM sump, for discharge to the base sanitary sewer system.

Similarly, the chiller water, cooling water and boiler blowdown were all discharged to the OHM sump, for discharge to the base sanitary sewer system.

### **3.5 System Performance**

This section discusses the test results with respect to the objectives of the demonstration.

#### **Objective 1. Determine the total average DRE achieved by the PTI System for all VOCs measured in the SVE off-gas, as well as individual DREs for critical VOCs.**

The determination of the total VOC removal efficiency for the PTI System was to be calculated by inputting the process inlet and outlet VOC concentrations, as measured with EPA Method TO-12, into the following equation:  $(TO-12_{inlet} - TO-12_{outlet}) / TO-12_{inlet}$ . However, a review of the analytical results show that the TO-12 analysis does not account for all VOCs in the SVE gas stream. This is manifested by comparing the VOC concentration as measured by the on-line FID, with that measured by EPA Method TO-12. The FID method has the advantage of pulling the gas sample through a heated line directly to the internal GC. The use of a heated line prevents the condensation, or "drop out", of any compounds with high boiling points. EPA Method TO-12, on the other hand, requires the capture of the sample gas in a summa canister. When the summa canister has been received by the analytical lab, it is pressurized to 10 psig to remove the volatile constituents. Unfortunately, the heavier weight compounds remain in the canister. For this reason, PTI chose to use the on-line FID reading to measure total VOC removal efficiency. The results of the total VOC removal calculations, presented in Table 3-8, shows an average System DRE of 95.44%, during Steady-State Operations, and using steam as the desorption gas in the Concentration Unit.

**Table 3-8. PTI System Average Total VOC Removal Efficiency**

Date	Desorption Method	Inlet Conc. <sup>1</sup> (ppmc)	Outlet Conc. <sup>1</sup> (ppmc)	DRE (%)
1/19/98	hot air	890	170	80.90
1/22/98	hot air	920	124	86.52
1/26/98	steam	1,175	83	92.94
1/30/98	steam	1,141	93	91.85
2/4/98	steam	1,090	49	95.50
2/5/98	steam	1,020	33	96.76
2/5/98	steam	1,020	14	98.63
2/6/98	steam	1,010	31	96.93
<b>Average</b>		1,033	75	92.50 <sup>2</sup>

Notes:

- VOC concentration as measured by an on-line FID.
- Average system DRE using steam desorption was 95.93%.

Individual DREs for the critical VOCs were determined by TO-14 analysis. The critical VOCs were selected from a composite list of chemicals from recent sampling events at Site 9, Area 3. Critical VOCs are defined as those which were present in the composite data at levels  $\geq 2$  ppmv. Table 3-9 presents the individual DREs for each of the critical VOCs.

**Table 3-9. Individual VOC Removal Efficiencies for Critical Compounds**

Compound Name	Inlet		Outlet		Average DRE (%)
	Conc. <sup>1</sup> (ppmv)	Mass Rate (lbs/hr)	Conc. (ppmv)	Mass Rate (lbs/hr)	
As Octane <sup>2</sup>	96.44	0.5831	0.06	0.0004	99.92
Tetrachloroethene	31.40	0.2703	2.44	0.0278	89.72
Trichloroethene	27.60	0.1895	4.02	0.0363	80.83
cis-1,2-Dichloroethene	22.20	0.1129	4.40	0.0294	73.98
Toluene	14.20	0.0679	0.74	0.0047	93.13
1,1-Dichloroethene	ND <sup>3</sup>	0.0000	ND	0.0000	NA <sup>4</sup>
Vinyl Chloride	ND	0.0000	ND	0.0000	NA
<b>Totals</b>	191.84	1.2238	11.65	0.0986	91.94

Notes:

- Compound concentrations as measured by EPA Method TO-14.
- The concentration of Octane was calculated as: [(Total VOC concentration by FID) - (Total VOC concentration by TO-14) - (Methane concentration)]  $\div$  8.
- “ND” denotes the concentration was below the detection limit of the analytical equipment.
- “NA” denotes not applicable as the compound was not detected in the SVE vapor.

The destruction and removal efficiency of the PDUs was calculated separately by measuring the VOC concentrations at the inlet and outlet to the PDU System. The results of these calculations, presented in Table 3-10, show an average PDU DRE of 97.29%.

**Table 3-10. PDU Average Total and Individual VOC Removal Efficiencies**

Compound Name <sup>1</sup>	Inlet		Outlet		Average DRE (%)
	Conc. (ppmv)	Mass Rate (lbs/hr)	Conc. (ppmv)	Mass Rate (lbs/hr)	
cis-1,2-Dichloroethene	742.86	0.0623	8.11	0.0007	98.85
1,1,1-Trichloroethane	12.00	0.0013	0.08	0.0000	99.27
Trichloroethene	688.57	0.0799	17.70	0.0022	97.29
Toluene	205.86	0.0172	11.62	0.0010	94.18
Tetrachloroethene	334.29	0.0501	11.79	0.0018	96.36
Ethylbenzene	2.80	0.0003	0.10	0.0000	96.21
Xylenes (total)	11.60	0.0012	0.44	0.0000	95.89
1,2,4-Trimethylbenzene	4.50	0.0005	ND	0.0000	>92.22
<b>Totals</b>	<b>2,002.47</b>	<b>0.2128</b>	<b>49.82</b>	<b>0.0058</b>	<b>&gt;97.27</b>

Note: 1. Only those compounds measured at the PDU inlet are included. Several additional compounds were measured at the PDU outlet, but because of the large difference in reporting limits were not measured at the PDU inlet.

**Objective 3. Characterize and quantify secondary waste streams generated by the PTI system at Site 9 and determine the appropriate disposal option(s) for each. Estimate the costs of disposal of all secondary waste streams generated.**

The secondary waste streams produced from the PTI system included: spent reagent panels from the PDUs, scrubber blowdown, and liquid condensate from the condenser. Each of these waste sources was monitored throughout the demonstration. A brief discussion of the evaluation methods used for secondary waste streams from each sub-system is given below:

**Reagent Panels**

The reagent panels are used to capture and transform acidic radicals, formed by photo-dissociation of halogenated compounds, into stable, inert organic salts. One set each of fresh panels were installed in the PDU reactors for Phase 1 and Phase 2 tests. At the completion of the demonstration, samples taken from the spent reagent panels were analyzed according to the TCLP test method. The results of these analyses demonstrate that the panels were non-hazardous waste. The total weight of reagent used in the demonstration was approximately 960 lbs, over a period of 1,229 hours. The approximate cost of the panels consumed during the demonstration was \$700.00. Due to strict time limitations, PTI chose to landfill the waste in Boise, Idaho, rather than in the Miramar landfill.

**Scrubber Blowdown**

The PTI system includes a small (25 scfm) acid gas scrubber which operates in a batch mode. The aqueous scrubber discharge was tested to determine whether the waste meets

the NAS North Island sanitary sewer acceptance criteria. The scrubber blowdown was analyzed for VOCs by EPA Method 8260A. Total dissolved solids (TDS) and total suspended solids (TSS) were determined by methods 160.1 and 160.2, respectively; and pH was determined with the pH probe in the scrubber unit. The results of these analyses show that the liquid met the discharge requirements. The total volume of liquid discharged at the completion of the demonstration was 18.5 gallons. The approximate cost of the caustic chemicals used in the scrubber during the demonstration was \$62.00.

### **Liquid Condensate**

The PTI system utilizes a water-cooled condenser to preferentially remove non-chlorinated hydrocarbons from the concentrated gas stream, prior to treatment in the PDUs. This condensate was sampled and analyzed for disposal purposes using EPA Method 8260A. As the sample analysis confirmed, the composition of the condensate was found to be typical of the current SVE&T operation. Therefore, the condensate was pumped to the SVE&T wet-end skid. Approximately 255 gallons of condensate were collected during the demonstration. The estimated cost to dispose of the liquid condensate, at \$0.17/lb., was \$347.00.

### **Objective 4. Characterize and quantify all residuals, including hydrochloric acid (HCl), ozone, chlorine, phosgene, carbon monoxide and dioxins, exiting the PTI system.**

The concentrations of HCl, chlorine, phosgene and carbon monoxide were measured at the PDU outlet and the PTI system outlet. Ozone analysis was not performed due to an oversight by PTI. Dioxin analysis was not performed as no PCB-indicating compounds were measured in the SVE off-gas.

### **HCl and Chlorine**

Sampling and analysis for HCl and chlorine was performed using EPA Method 26A. Gas samples were taken at the outlet of the PDU scrubber and at the outlet of the adsorber, the total system outlet. HCl was measured at a concentration of 22.1 ppbv (PDU scrubber outlet) and 0.18 ppbv (System outlet), while chlorine was measured at a concentration of 7.4 ppbv and 0.04 ppbv, respectively.

### **Phosgene**

Phosgene was determined by EPA Method TO-6. Gas samples were taken at the outlet of the PDU scrubber and at the outlet of the adsorber. At these sample locations, phosgene was measured at concentrations of 1,472.7 ppbv and 23.8 ppbv, respectively.

### **CO**

Carbon monoxide was determined by ASTM D-1946. CO was measured in the SVE off-gas and at the PTI System outlet, to determine the amount of CO produced in the System. The concentration of CO was below the detection limit of 0.0025% (v/v) in the SVE off-gas, and an average of 0.0056% (v/v) at the system outlet. Therefore, the amount of CO produced in the PTI System was between 0.0031 and 0.0056%.

## Dioxins

Dioxin testing was to be performed, using EPA Method 23.0, only if PCB-indicating compounds were found to be in the SVE off-gas stream. Past demonstrations of the PTI system have shown no dioxin formation when PCBs are not present. Because the potential for PCBs exists in the contaminated soil at Site 9, Area 3, PCBs, pesticides and SVOCs were sampled for during week 1 using California Air Resources Board (CARB) Method 429. This analysis showed no presence of PCB-indicating compounds present in the SVE off-gas, therefore no dioxin tests were performed.

A tabular comparison of the System residuals to allowable levels within the San Diego Air pollution Control District is presented in Table 3-11. This comparison shows that the residual levels were in fact below known maximum allowable levels for CO and HCl. In a conversation with a San Diego Air Pollution Control District manager, PTI learned that emission standards for chlorine and phosgene are not established but reviewed and determined on a case-by-case basis. For the purposes of this report a formal emissions review application was not submitted.

**Table 3-11. Residuals Data**

<b>Contaminant</b>	<b>Measured Concentration</b>	<b>Maximum Allowable Emission<sup>1</sup></b>	<b>Analytical Method</b>
Carbon Monoxide	5.9 ppmv	none	ASTM-D1946
Chlorine	0.04 ppbv	NA <sup>2</sup>	EPA Method 26A
Hydrochloric Acid	0.18 ppbv	<10 ppmv	EPA Method 26A
Phosgene	23.8 ppbv	NA <sup>2</sup>	EPA Method TO-6

Notes:

1. "Maximum Allowable Emissions" as determined by the San Diego Air Pollution Control District.
2. "NA" denotes no standard available. According to the San Diego County Air Pollution District, the maximum allowable emission for this compound is determined on a case-by-case basis. A formal review of the process residues by the governing regulatory agencies was not part of the scope of this project.

## 3.6 Parameters Affecting Treatment Cost or Performance

This section discusses the observations and lessons learned with respect to the objectives of the demonstration. Table 3-12 shows the Parameters Affecting Treatment Cost or Performance.

**Table 3-12. Parameters Affecting Treatment Cost or Performance**

<b>System Parameters</b>	<b>Value</b>	<b>Measurement Procedure</b>
SVE Flow Rate	239 to 307 cfm	Flow meter, pitot tube.
Operating Vacuum	0 to -35" w.c.	Pressure gauge.
Residence Time	9 seconds - Concentrator 3 minutes - PDU	Calculated.
System Throughput	0.83 to 1.45 lbs/hr	On-line FID reading at system inlet and outlet.
Gas Inlet Temperature	89 to 113° F	Thermocouple.

**Objective 5. Document observed operating problems and their solutions.**

This demonstration of an integrated Concentrator Unit and PDU was the first of its kind for the treatment and destruction of gas-phase VOCs. In fact, this project was the first field implementation of a concentrator system by PTI. This demonstration provided an invaluable learning experience for PTI, and will hopefully provide valuable cost and performance data for the U.S. Navy and other DoD agencies.

Process operating parameters were monitored by PTI personnel throughout the test period on a regular basis. A discussion of problems encountered with each of the PTI System modules follows. PTI is confident that all of the operational problems encountered were resolved satisfactorily, and further plans to incorporate design modifications into the system to prevent these problems on future installations. A discussion of these problems and their solutions for each component of the system is given below.

**Concentrator Unit**

- The most significant operational problems were encountered during the Parametric Tests as a direct result of very heavy rains. All of these problems were due to rain water or condensate getting sucked into the adsorber or desorber (both units operate under vacuum), and subsequently plugging the flow of adsorbent beads. This plugged flow would result in a system shutdown due to a high pressure alarm. Several measures were taken to prevent this plugging from occurring: insulating the desorber and adsorbent transfer lines to prevent condensate from forming in these areas; extending the PDU return line into the adsorber approximately 12 inches (") to prevent condensate from collecting in the adsorber downcomer sections; sealing all seams in the adsorber and adsorbent transfer containers with silicon; piping the adsorber pressure vents to a manifold header to prevent the transfer of rain water into the adsorber; and placing c-clamps to tighten the seals between adsorber stages.
- A fine mesh screen, installed at the outlet of the adsorber to prevent adsorbent beads from exiting the system, became plugged with a very fine black powder. PTI believes this powder was created from the conditioning of the adsorbent beads. If not monitored, PTI found that this plugging would eventually shutdown the system on a high pressure alarm. To solve this problem, the screen was replaced with a perforated plate having 60% free area and 0.05" diameter holes.

- A high-temperature excursion (650 °F) was noted in the desorber, forcing the shutdown of the system. PTI determined that the temperature excursion was caused by the plugging of adsorbent beads at the bottom of the desorber. Once plugged, the beads were subjected to high temperatures (285 °F) for a prolonged period of time, in excess of 12 hours. PTI believes these high temperature conditions, coupled with high concentrations of solvent, led to an exothermic reaction. The system was allowed to cool and later inspected. No visible signs of damage were present, and samples of the adsorbent beads were taken for analysis. This problem was not experienced again.
- A couple of leaks were noted at a weld point in the condenser. These were repaired on-line with J-B Weld®.
- Higher than expected attrition of the adsorbent beads was experienced throughout the demonstration. PTI is not sure if this is a characteristic of the adsorbent material itself or, a result of high shear forces breaking the adsorbent beads down. PTI will be making equipment modifications to reduce gas flow velocities in the adsorber and the transfer tubes to reduce high shear forces.
- Initially, PTI was unable to operate the desorber using strip steam unattended due to a PLC programming error. This was corrected by making a minor modification in the control program.

## **PDU**

- During continuous operation, the outlet manifold of each PDU reactor would become choked with a very dry, friable, material believed to be caused by the condensation of heavy-chained hydrocarbons leaving the relatively hot reactor internal area and entering the cooler transfer line to the scrubber. A similar material was noted during operations at McClellan Air Force Base (AFB). During the McClellan AFB demonstration this material was tested using EPA Method 8015-M and shown to contain “unidentified extractable hydrocarbons in the C9 to C22 range” (CH<sub>2</sub>M Hill). To overcome this problem, PTI would routinely “rod-out” this material, thereby clearing the outlet manifold and capturing the material in the scrubber. PTI plans to incorporate an automatic purge system to keep the outlet manifold clear in future designs.
- PTI discovered that a transformer ballast used to power the UV lamps in the PDU reactors had been damaged during shipping. The damaged ballast was replaced.

## **3.7 System Costs**

This section discusses the costs with respect to the objectives of the demonstration.

**Objective 2. Develop treatment cost data for a 3,000 standard cubic feet per minute (scfm) PTI system, designed to achieve the DREs measured above, for VOC-contaminated soil vapor similar to those at Site 9. PTI will operate their system in several configurations and parameters to fully demonstrate the performance of the system under differing conditions while obtaining the supporting cost data. Cost data will be reduced to a \$/lb. of VOC treated at various removal efficiencies. These costs will be compared to the costs to achieve an overall removal efficiency of 99% of VOCs at NAS North Island Site 9 using regenerative carbon adsorption and thermal oxidation.**

The cost estimate shown in Table 3-13 was developed using data collected from the demonstration. Standard engineering principles were used to scale-up costs for a 3,000 scfm system. This is the size system presently required to treat 100% of the soil vapor gas being extracted at Site 9. The \$/LB. of VOC treated is estimated to be \$3.77. The assumptions made to derive the 3,000 scfm treatment system cost are in Table 3-14. Table 3-15 displays costs by the standardized work-breakdown (WBS) structure.

**Table 3-13. 3,000 scfm PTI System Cost Summary**

<b><u>Capital Costs</u></b> <sup>1,2</sup>		
<b>Concentrator Unit</b>	Size (cfm)	3,000
	Cost	\$310,000
<b>PDU</b>	Size (cfm)	6
	Cost	\$87,343
<b>Mobilization &amp; Installation</b> <sup>3</sup>		\$17,146
	<b>Total Capital Costs</b>	<b>\$414,489</b>
<b><u>Annual Operations and Maintenance Costs</u></b>		
<b>Power</b>	On-Line Availability <sup>4</sup>	89%
	Removal Efficiency <sup>5</sup>	95%
	Power Costs/kwh <sup>6</sup>	\$0.07
	Total Load <sup>7</sup> (kw)	218
	<b>Total Electricity Cost</b>	<b>\$118,973 per year</b>
<b>Consumables</b>	Reagent Panels <sup>8</sup>	\$4,061
	UV Lamps <sup>9</sup>	\$3,817
	Caustic Solution <sup>10</sup>	\$783
	Boiler Chemicals <sup>11</sup>	\$6,184
	<b>Total Consumables Cost</b>	<b>\$14,844 per year</b>
<b>Solvent Condensate</b>	Condensate Disposal <sup>12</sup>	<b>\$18,339 per year</b>
<b>Labor</b>	Maintenance Labor <sup>13</sup>	\$5,436
	Operating Labor <sup>14</sup>	\$67,364
	<b>Total Labor Cost</b>	<b>\$72,800 per year</b>
	<b>Total Operating Cost</b>	<b>\$224,957 per year</b>
<b><u>Cost per Pound of VOC Treated</u></b> <sup>15</sup>		
<b>VOCs Treated (pounds)</b>		95,479 per year
	Over Cleanup	<b>286,437 in 3 years</b>
<b>Equipment &amp; Operating Costs</b>	Over Cleanup	\$1,081,254 in 3 years
	<b>Cost per Pound</b>	<b>\$3.77</b>

**Table 3-14. Assumptions and Basis for Costs**

<p>1. Costs are based on those incurred during the demonstration.</p> <p>2. Equipment Capital Costs are vendor-supplied prices.</p> <p>3. Mobilization and Installation costs are based on actual costs incurred for the demonstration, plus 20% to account for the additional weight of a 3,000 scfm Concentration Unit.</p> <p>4. On-line availability is 89%, or 7,796 operational hours per year.</p> <p>5. Average VOC loading at 3,000 scfm is 196 ppmv, or 12.24 lbs/hr.</p> <p>6. The process controls VOC emissions to &lt;25 ppmv.</p> <p>7. Total Power Load of 218 kwh, calculated as follows: Concentrator power load = <math>(3,000 \text{ cfm} \div 300\text{cfm}) \times 31 = 310\text{kw}</math> PDU power load (2 reactors) = 15.1 kw Other utilities power load = 5.2 kw Total design power load = <math>310 + 15.1 + 5.2 = 330.30 \text{ kw}</math> <u>Design power load for 440 cfm system = 57 kw</u> Actual measured power load = 38.5 kw = 66% Actual normal power load = <math>330.30 \text{ kw} \times 66\% = \underline{218 \text{ kw}}</math></p> <p>8. Reagent panel cost = 24 panels, replaced every 4 weeks x \$14.63/panel</p> <p>9. UV lamps replacement cost = 144 lamps with a 10,000 hour lifetime x \$34.00/lamp.</p> <p>10. Scrubber caustic solution = 231.55 gallons/year x \$186.00 per 55-gallon barrel.</p> <p>11. Boiler water chemicals = <math>(584.73 \text{ gallons of chemical} \times \\$10.00/\text{gallon}) + (\\$12.00/\text{month water softener rental}) + (1.07 \text{ filter changes/month} * \\$15.00/\text{filter})</math></p> <p>12. Condensate disposal assumes 70% of VOCs condensed, yielding <math>(76,192 \text{ lbs/year} \times \\$0.17/\text{lb.}) + (4 \text{ pickups/year} \times (\\$1,275.00 \text{ transportation} + \\$65.00 \text{ labor})) + (\text{solvent profile at } \\$550.00)</math></p> <p>13. Maintenance labor for the PDU = labor cost of \$35.00/hr x 74 hours per year ( to replace reagent panels, UV lamps and caustic solution); maintenance labor for the concentrator = \$35.00/hr x 81 hours per year (for boiler water treatment).</p> <p>14. Operating labor = (1) technical service person, making \$35.00/hr (including overhead factor of 1.4) x (2,080 hours per year - maintenance hours listed above in 13.)</p> <p>15. Cost per lb. of VOC Treated = <math>(\text{Equipment \&amp; Operating Costs for a 3-year cleanup}) \div (\text{VOCs treated in a 3-year period})</math></p>
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**Table 3-15. Standardized Cost Breakdown**

	<b>WBS No.</b>	<b>Cost Element</b>	<b>Unit Cost</b>	<b>No. of Units</b>	<b>Cost</b>
Before Treatment Cost Elements	331.01.03	<b>Demonstration Work Plan</b>	\$7,628.80	fixed price	\$7,628.80
	331.01	<b>Mobilization and Preparatory Work:</b> mobilization of equipment and personnel	\$3,124.00	fixed price	\$3,124.00
	331.03	<b>Site Work:</b> installation of electrical utilities, field run gas piping equipment installation	\$12,011.00	fixed price	\$12,011.00
	331.09	<b>Liquids Collection and Containment:</b> establish liquids containment area field run piping to discharge waste water to site sewer	\$2,000.00	fixed price	\$2,000.00
Treatment Cost Elements	331.12	<b>Chemical Treatment:</b> Photolytic Oxidation of VOCs equipment rental equipment O&M	\$1.51/lb of VOC treated	1,151	\$1,738.01
	331.13	<b>Physical Treatment:</b> VOC Concentration equipment rental equipment O&M	\$1.74/lb of VOC treated	1,151	\$2,002.74
	331.02	<b>Monitoring, Sampling, Testing, and Analysis:</b> of SVE gas stream, process outlet, process residues	\$57,762.50	fixed price	\$57,762.50
After Treatment Cost Elements	331.21	<b>Demobilization:</b> of equipment and personnel	\$3,124.00	fixed price	\$3,124.00
	331.19	<b>Disposal:</b> of liquid condensate, PDU reagent panels, PDU cooling water, condenser chiller water scrubber solution	included in price above	fixed price	included in price above
	331.21.06	<b>Prepare and submit Final Report</b>	\$4,334.64	fixed price	\$4,334.64
		<b>Total Demonstration Costs:</b>			\$93,725.69

## Section 4.0 Conclusions and Recommendations

The following conclusions were developed by PTI from the technology demonstration:

- The PTI System is relatively quick to install and ready for operation as demonstrated by the experience at Site 9, where it was installed and commissioned within one week. The equipment operated continuously, 24-hours per day, seven days per week, achieving an on-line availability of 89%.
- For treatment of the SVE off-gas at Site 9, Configuration-1: “Concentration-Condensation-Photolytic Destruction” was the most efficient setup.
- The PTI system was successful in removing VOCs in the SVE off-gas to below the maximum allowable emissions at Site 9 of 25 ppmv. The average total DRE for VOCs was 95%. The PDU alone achieved an overall DRE of 97%. These results were computed from FID data.
- The estimated unit cost of implementing a 3,000 scfm PTI System at Site 9 is \$3.77 per lb. of VOC treated. The commercialization of the technology over the next few years will lower the treatment costs further.

Based upon this demonstration, PTI recommends implementing the following design modifications to enhance system performance and/or reduce treatment costs:

- Redesign the weather seals in the Concentration Unit to prevent ambient rainwater and humidity from entering the adsorber.
- Evaluate the performance of different adsorbent materials to determine which adsorbent would offer the highest removal efficiencies, cost effectively.

### **Objective 6. Disseminate the results of the demonstration throughout the DoD, DOE, private industry, state regulatory agencies and the NAS RAB.**

The results of this technology demonstration will be presented to other Naval Remedial Project Managers, compiled into a database for distribution to interested public and private sector parties, and shown on the NFESC web page. The RAB is a partnership between NAS North Island, local regulatory agencies and the local community. The purpose of the RAB is to review and comment on remedial action methods prior to implementation. Therefore, any innovative technology that is considered for implementation at NAS North Island will be reviewed by the RAB. This Final Report will be submitted to the RAB for their information and review.

## Section 5. References

*“Process Technologies Incorporated, Technology Demonstration Final Work Plan”*, NAS North Island, Site 9, Contract No. N47408-97-C0125, October 1997.

*“Photolytic Destruction Technology Memorandum”*, McClellan Air Force Base, Site S, Operable Unit D, CH<sub>2</sub>M Hill, June 1996.

*“Final Project Plan for Non-Time Critical Removal Action for Sites 9 and 11, Naval Air Station North Island, San Diego County, CA”*, OHM Remediation Services Corporation, April 1996.