DEVELOPMENT OF A PARTIAL CONTAINMENT SYSTEM (PCS) TO AID IN THE OPEN AIR EXCAVATION AND REMOVAL OF CHEMICAL WEAPONS MATERIAL

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1.0 INTRODUCTION

A portable system for the capture of chemical agent gases released accidentally during the recovery of "discovered" non-explosively configured chemical warfare material has been designed, fabricated and tested at Southwest Research Institute. The system is designed specifically to support traditional trenching operations where a backhoe is employed to excavate a 4 ft wide and 4 ft deep linear trench. The system consists of two open-air exhaust hoods that are connected via 42 in. diameter duct to a "Y" containing a large exhaust fan with a 48 in. outlet duct. One hood consists of a 2 ft high by 10 ft long vertical face that is placed adjacent to the trench side during excavation. The second hood is placed horizontally over the trench, opposite the backhoe, and has a neoprene flap designed to seal off the "cleared" trench behind. The system is run continually during excavation. In the event of a release, as detected by chemical alarms or other means, the backhoe is withdrawn, and a heavy duty polyester reinforced vinyl coated shroud or "awning" is deployed over the trenched area of the release.

Tests of the system indicate that, with approximately a 40,000 cfm exhaust flow rate, *capture efficiencies for releases in the trench under static conditions (no wind) with the shroud in the up or down position are practically 100%. With wind (in the tests varying from 5-10 mph in the worst case direction) the efficiency drops to 93%.* Capture efficiency considering releases outside the trench were also determined. *For a release at the edge of the trench closest to the backhoe and vertical hood face, efficiency drops to 62%. For a release on the soil berm (replicating a scenario where a breakage of a vial occurs upon bucket discharge), efficiency drops to 69%.*

2.0 PCS PROTOTYPE DESCRIPTION AND SPECIFICATIONS

Figures 1-4 show the fabricated PCS system. Fabrication was accomplished in accordance with the design and drawings submitted with our design report. Figures 1 and 2 show the vertical hood front with the shroud in the up and down position respectively. Figure 3 shows the horizontal hood, and figure 4 shows the "Y" and fan enclosure. All photos were taken inside the Sprung structure, where all prototype testing took place.

All metal parts of the system are 316 stainless. The ducts are 42 in. and 48 in. diameter steel wire reinforced polyvinyl hose, manufactured by Dura-Vent in Plymouth, Indiana. The shroud consists of schedule 40 316 stainless pipe covered with sewn TXN 14 vinyl coated polyester fabric (manufactured by Cooley Inc., Pawtuckett, Rhode Island). The fan is a 48 in., 41820 cfm (at 1/8 in. static pressure) BAT 48 fan/motor/drive unit manufactured by Penn Ventilator Co., Inc.

3.0 PCS PROTOTYPE SIMULANT AND CAPTURE EFFICIENCY TESTS

3.1 Selected Simulant

The non-explosively configured chemical warfare material (CWM) such as chemical agent identification sets (CAIS) contain numerous chemical warfare agents in various configurations. Set components include glass vials containing dilute concentrations of relatively non-toxic or volatile compounds to neat, highly toxic agents such as sulfur mustard. In order to provide conservative estimates of performance, the compound phosgene was selected as representative of the set components. Phosgene was selected as the primary hazard due to its high vapor pressure and relatively low vapor density. This means that the compound is readily converted to a gas which is easily dispersed. Given the application of the capture hood, the time of release and gas volume generated is of greater importance than simulating the toxicity or even concentration resulting from such a release. In order to select an appropriate simulant, criteria included simulation of the vapor pressure and vapor density of phosgene.

The criteria determined to be appropriate for the selection of a phosgene simulant was boiling point, vapor pressure and density. Duration of release was established within a 5 to 10 minute range. The release type was a continuous feed of pure simulant for the entire test interval.

Trifluoromethane was selected as a simulant primarily due to its low vapor density and ease of measurement. Chlorinated freons are actually the best simulant for this testing, however due to ozone depletion, chlorinated freons are not an option for simulants. Trifluoromethane has a significantly lower boiling point and higher vapor pressure than phosgene. This allowed a very conservative estimate of capture hood performance to be determined. The vapor density is a little higher than that of phosgene, however most gases with lower vapor density are either very difficult to measure, flammable, or highly toxic.

3.2 Instrument Calibration

Several standards were used to calibrate the Miran 1B2 infrared instrument for the tracer gas, Freon 23 (trifluoromethane). Freon 23 was injected into Tedlar bags to obtain the following concentrations: 0.5, 10, 50, 100, and 500 ppmv (parts per million volume). For each bag, the concentration was entered manually into the Miran 1B2, and the instrument sampled gas from the bag and correlated the resulting infrared absorbance with the nominal concentration. After all the bags were sampled, a regression was performed, and the curve was determined to be linear. This curve was used throughout the performance tests. Whenever the air was sampled in the hood system, the instrument determined the infrared absorbance of the system air and correlated that absorbance with the stored calibration curve to produce a concentration reading.

3.3 Baseline Concentration Determination

In order to determine the capture efficiency of the hood system, the maximum total efficiency of the system has to be determined. The maximum possible efficiency for the system can be found by releasing the tracer gas directly into one of the hoods and taking a concentration reading in the large duct at the end of the system. This concentration reading, or baseline concentration, represents 100% capture efficiency. When the gas is released in the trench, the resulting concentration in the large duct divided by the baseline concentration, will give the fraction of gas captured by the hood system.

The gas flowrate used does not matter, since relative, not absolute, concentrations are important. The flowrate was high enough to give significant concentration readings without difficulty. The same flowrate was used throughout any particular test, if not for all of the tests.

3.4 Test Setup and Protocol

Seven scenarios were tested. The first scenario was the "static" case where no simulated "wind" was directed at the hoods with the independent approximately 20000 cfm fan. Scenario 2 consisted of the "shroud" or trench cover in the lowered position. The final prototype of the cover includes 3 1 ft^2 openings on the front of the cover, and 1 1 ft^2 opening on each end. All were opened for this scenario. Additionally, the trench was configured identically to that used in the mock-up tests, where the end away from the horizontal duct was sloped to better replicate an "in-process" trench in the field. This sloped end resulted in an additional 4 ft^2 area for make-up air for the shroud down test. Scenario 3 included the independent fan directed towards (the flow parallel to) the trench from the end away from the horizontal hood (1133 fpm (13 mph) velocity at the face, a maximum of 340 fpm velocity (4 mph) at the trench (at the ground surface on the trench centerline)). Scenario 4 consisted of the fan located approximately 3 ft from the rear of the horizontal hood directed parallel to the trench (the velocity at the trench was a maximum of 190 fpm (2 mph)) , and Scenario 5 had the fan positioned on top of the "spoil berm" of the trench, directed towards and perpendicular to the trench (maximum velocity at the trench equal to 300 fpm (3.5 mph)).

Scenarios 6 and 7 were conducted in the static condition (no wind fan operating) to evaluate the capture efficiencies at points actually outside of the trench.

For each of these scenarios, F23 was released at a flowrate of 5 lpm at two locations. Location x_1 was at the center of the vertical hood face, 6-12 in. off of the opposite side of the trench, at a height about 2 ft from the trench bottom. Location x_2 was in the corner farthest from the horizontal hood, on the opposite side of the trench from the vertical hood, at a height about 1 ft off of the trench bottom. In scenario 6, the release point was located at the extreme edge of the sloped trench side nearest the vertical hood, about 2 ft from the vertical face edge on the trench edge. The release point for scenario 7 was located a the top of the earth "spoil" mound adjacent to the trench. Figures 5-8 illustrate the release point locations. Figure 5 shows the point x1 location, Figure 6 the x2 location, Figure 7 the scenario 6 location, and Figure 8 the scenario 7 location.

For all tests the door of the fabric arch structure was opened to a width of approximately 1.5 ft, to approximate the 36 ft^2 area required to match the face openings of the PCS hoods, thus allowing an equivalent makeup air path.

The test protocol included, for each of these scenarios, the following:

1. Before each test, allow the background levels to drop as much as possible.

2. Determine maximum velocity reading in the large duct, and take velocity readings in the hood faces.

3. Take background readings of Freon 23 in the large duct and outside the system (ambient).

4. Start the flow of gas. Release gas directly into the side draft hood and measure the maximum concentration in the large duct in order to determine the baseline concentration.

5. Move the gas release point into the trench at location X1.

6. Measure the maximum concentration of F23 in the large duct.

7. Move the gas release location to X2.

8. Take maximum reading in the large duct.

9. Determine baseline concentration again.

10. Stop the gas flow. Record the background levels again.

This protocol was slightly modified for scenarios 6 and 7, where only one release point was used for each of those scenarios.

3.5 Test Results

As Table 1 below illustrates, *capture efficiencies for releases in the trench under static conditions (no wind) with the shroud in the up or down position are practically 100%. With wind (in the tests varying from 5-10 mph in the worst case direction) the efficiency drops to 93%. Capture efficiency considering releases outside the trench were also determined. For a release at the edge of the trench closest to the backhoe and vertical hood face, efficiency drops to 62%. For a release on the soil berm (replicating a scenario where a breakage of a vial occurs upon bucket discharge), efficiency drops to 69%.*

Table 1. Summary Table for PCS Concentration Test Results

Test Setup	Side Draft Hood Flow (cfm) (Based on avg. vel.)	End Draft Hood Flow (cfm) (Based on avg. vel.)	Exit Duct Flow (cfm) (Based on max. vel.)	Gas Release Point	Gas Capture Efficiency (%)
Scenario #1	16500	16000	40200	X1 X2	100 100
Scenario #2	shroud down	shroud down	36400	X1 X2	102 108
Scenario #3	17200	15400	39000	X1 X2	100 100
Scenario #4	15900	15000	39000	X1 X2	90 97
Scenario #5	16100	14900	39000	X1 X2	100 100
Scenario #6	16500	16000	40200	X6 X6	59 65
Scenario #7	16500	16000	40200	X7 X7	63 74

Some comments on the flow measurements are appropriate here. The difference in the air flows (in and out) may be due to fluctuations in readings, especially the measurements for F1 through F5, because the makeup air rushing in through the door (open 1.5 feet) causes gusty wind to enter the hood faces. Additionally, the flow in the large duct appeared to be turbulent when the S-type pitot tube was used. The maximum velocity reading obtained with the Shortridge Multimeter

ADM-870 (standard pitot tube) was equal to the average velocity obtained with the S-type pitot tube. The maximum velocity measured by the ADM-870 was about 3200 fpm. Because the flow is turbulent, the pitot tube was rotated to find the maximum reading. Since the angle of rotation was not greater than 20 degrees from the horizontal, the flow in the duct is not too turbulent to take readings with the standard pitot tube. One side of the large duct gives low velocity readings, and the other side gives high readings, just as in the case with the S-type pitot tube. It was decided that the side with the high velocities would be examined during the tests to determine the maximum velocity in the duct. The maximum velocity would then correspond to the average that would have been found using the S-type pitot tube.

The results indicate that the PCS system, operating under the test parameters and conditions imposed, performs very well and at a relatively high capture efficiency. Some relative comparisons of performance under varying wind conditions and for the four different release points can also be derived from the results. The worst case capture with the simulated wind was observed for Scenario 4 with the release at location x1 and the highest efficiency was gained with the shroud lowered (Scenario 2). Scenarios 3 (wind into the trench from opposite the horizontal hood) and Scenario 5 (wind from across the trench) achieved 100% captures. The overall worst case capture was seen with the release point outside the trench in Scenario 6.

These results differed somewhat from the mock up tests, due primarily to the now even distribution of flows between the two ducts, and the overall higher flowrate.

4.0 PCS OPERATION RECOMMENDATIONS

Although the results considering wind effects on capture efficiency are deemed qualitative, as described below, it is recommended that windscreens of approximately 10 ft height be placed to the rear of the horizontal hood, and behind the soil spoil area, if possible. It is felt that the backhoe will provide a measure of wind protection for the third open face of the setup.

4.1 Recommended Additional Tests and Evaluation

While the tests of the prototype system have resulted in high efficiency numbers for agent capture, several comments should be made regarding the test setup and applicability of the results to field operations.

First, while "wind" velocity was increased in these final tests over that measured in the mock up tests, tests with simulated wind must be considered qualitative in terms of PCS system performance. The localized flows produced by any fan source will never simulate wind completely, unless the face of the "wind" fan is on the order of 2 times the PCS system width, or about 20 ft in diameter. This being impractical, it is suggested that the first exercise during field application of the PCS system be a repeat of the capture efficiency test series while the system is exposed to actual meteorological variations, including wind speed changes and direction changes. These conditions could be monitored with portable instruments and actual efficiency reduction quantified.

Secondly, the approximately 40,000 cfm flowrate required a substantial amount of make up air to be drawn through the open Sprung structure door. This flow was obviously highly directional across the trench end away from the horizontal hood, and could actually have enhanced the capture efficiencies measured. This is yet another justification for further "field" testing.

Finally, the PCS system will remain incomplete until a filter system is sized and tested in conjunction with the present setup. Limitations of filter size and number may restrict the PCS flowrate to lower values, and, again, capture efficiency tests will require repeating after the fan and drive pulleys are modified. For example, the present system, while highly efficient, will require 5 M-12 filter systems, assuming each system can handle approximately 8000 cfm.

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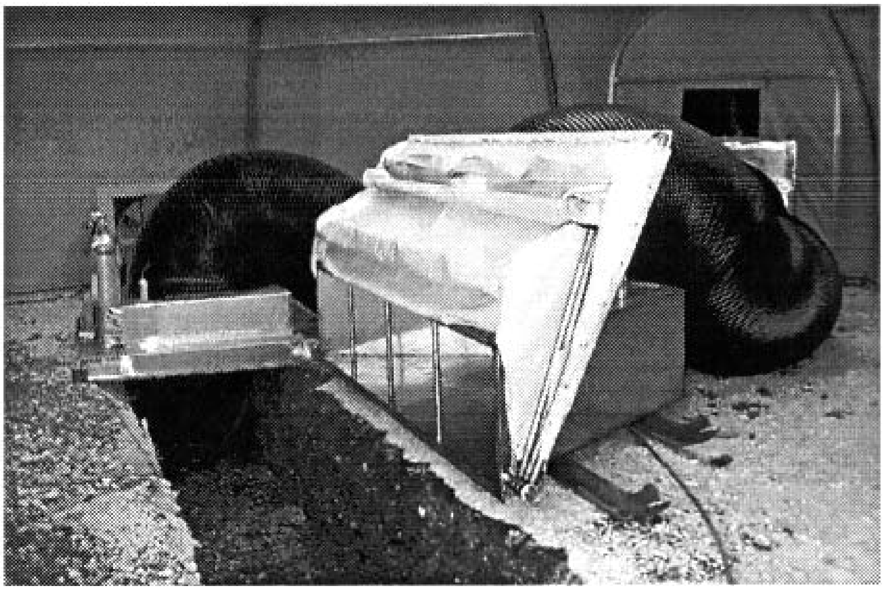

Figure 1. PCS Vertical Hood (Shroud Up Position)

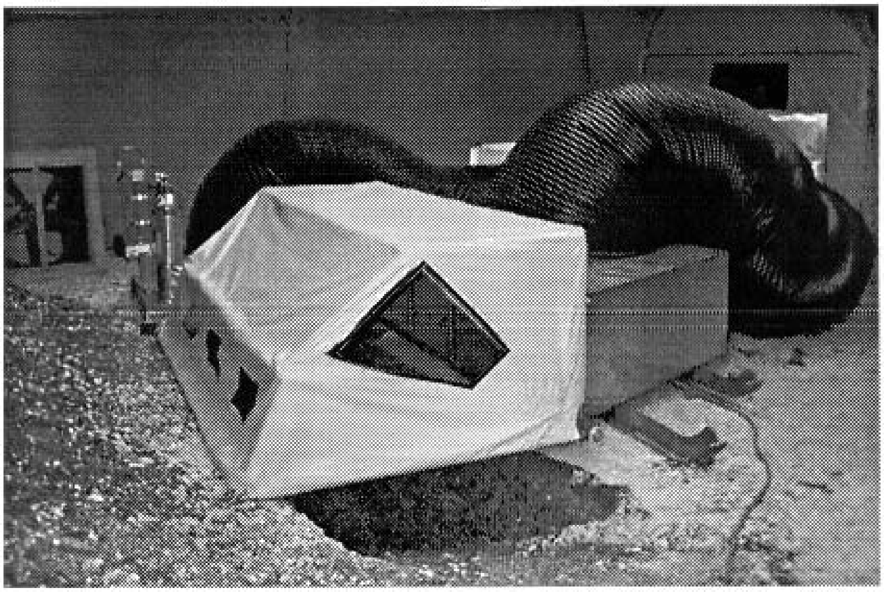

Figure 2. PCS Vertical Hood (Shroud Down Position)

Figure 3. PCS Horizontal Hood

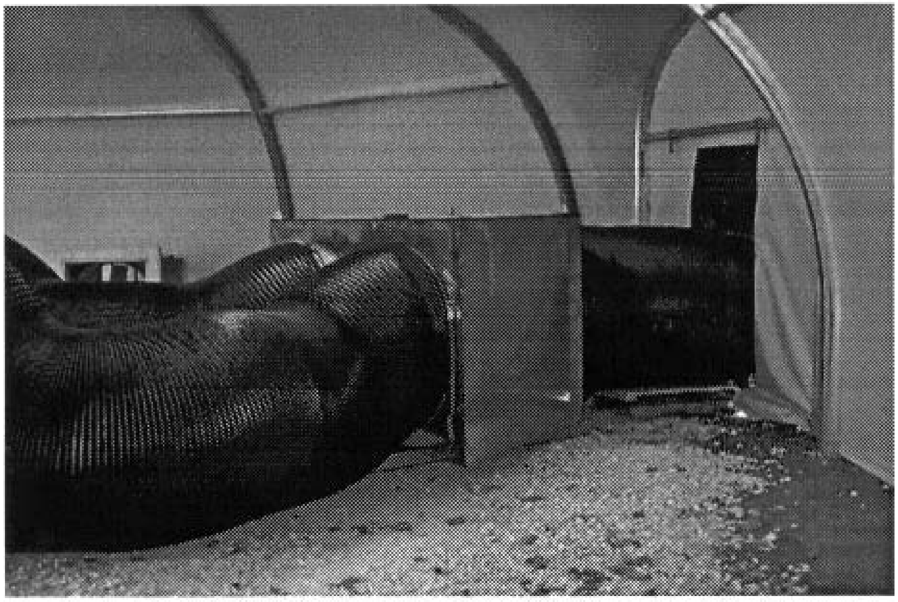

Figure 4. PCS "Y" and Fan Enclosure

Figure 5. X1 Release Point Location — Middle Trench, Spoil Side

Figure 6. X2 Release Point Location — Sloped End of Trench, Spoil Side

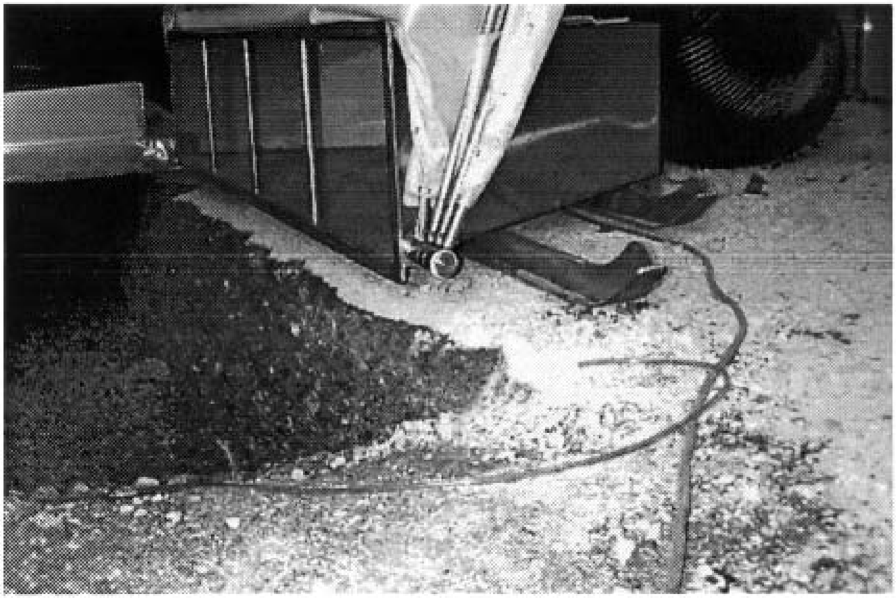

Figure 7. Release Position for Scenario 6

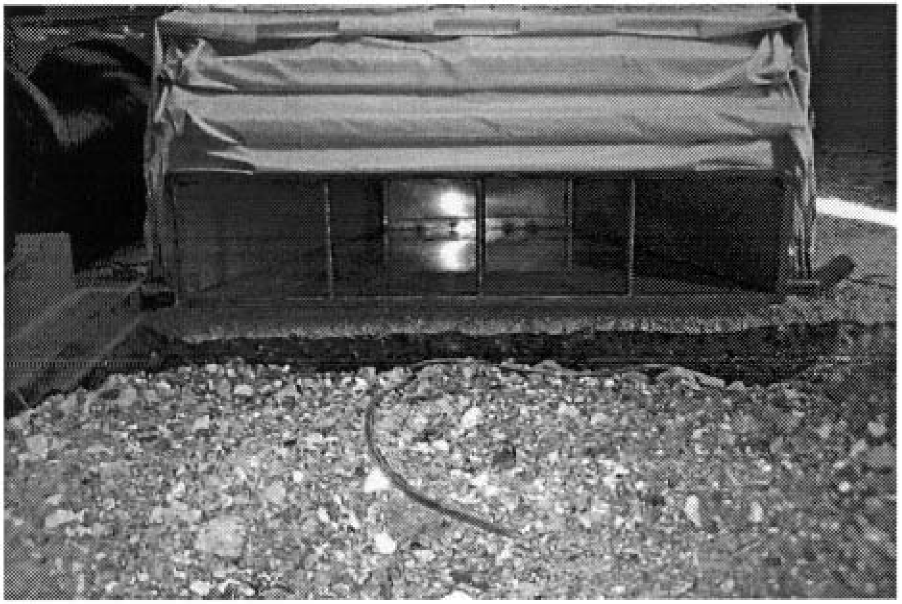

Figure 8. Release Position for Scenario 7