USAFSAM-TP-86-2

CHEMICAL DEFENSE COLLECTIVE PROTECTION TECHNOLOGY: VOLUME 1

Effects of Airlock Dimension, Clothing, and Exposure Concentration on Vapor Transport

James P. Conkle, Ph.D.
Roberto E. Miranda, B.S.
Joseph R. Fischer, Jr., M.S.
Roger W. Page, Jr., Lieutenant Colonel, USAF
David L. Bartlett, Master Sergeant, USAF

December 1986

Interim Technical Paper for Period 4 - 7 February 1985

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, TX 78235-5301

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAFSAM-TP-86-2	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine 6b. OFFICE SYMBOL (If applicable) USAFSAM/VNC	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks AFB, TX 78235-5301	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION USAF School of Aerospace Medicine 8b. OFFICE SYMBOL (If applicable) USAFSAM/VNC	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks AFB, TX 78235-5301	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 62202F PROJECT NO: 2729 TASK NO: 03 WORK UNIT ACCESSION NO: 06

11. TITLE (Include Security Classification)
CHEMICAL DEFENSE COLLECTIVE PROTECTION TECHNOLOGY: VOLUME 1
Effects of Airlock Dimension, Clothing, and Exposure Concentration on Vapor Transport

12. PERSONAL AUTHOR(S) Conkle, James P.; Miranda, Roberto E.; Fischer, Joseph R., Jr.; Page, Roger W., Jr.; Bartlett, David L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim Technical Paper	FROM 4 Feb 85 TO 7 Feb 85	1986 December	37

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
15	02, 03	
14	02	
06	17	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Chemical defense; collective protection technology; contamination control area; vapor transport; vapor permeation of clothing; vapor offgassing; chemical defense shelter processing; chemical agent simulant; (Cont'd. on p. ii)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Procedures for processing personnel through chemical defense collective shelters were employed to examine the contamination of Toxic Safe Areas (TSAs), in shelters, as a result of transport of chemical agent vapor on clothing underlayers. The quantity of vapor thus transported into the TSAs was examined as a function of: airlock design; type of outer clothing worn during exposure; and vapor exposure concentration. A simulated Survivable Collective Protection Shelter Contamination Control Area facility, at the USAF School of Aerospace Medicine (Brooks Air Force Base, Texas), was employed. Personnel--dressed either in fatigues over T-shirt and jockey shorts, or in Flyer's charcoal undercoverall (United Kingdom) over aircrew undershirt and drawers--were first exposed to chemical warfare agent simulant (methyl salicylate) vapor, and were then processed through the Liquid Hazard Area and Vapor Hazard Area. Processing included passage through either the original design airlock or a modified design airlock before entry into the TSA. Inside the TSA, individual subjects were isolated within sealed glass offgassing booths; and vapor offgassed
(Cont'd. on p. ii)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL James P. Conkle, Ph.D.	22b. TELEPHONE (Include Area Code) (512)536-3159 22c. OFFICE SYMBOL USAFSAM/VNC

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

18. SUBJECT TERMS (Cont'd.)

mustard simulant; methyl salicylate; and oil of wintergreen.

19. ABSTRACT (Cont'd.)

from each subject over a 2-h period was measured. Data indicate that the charcoal undercoverall (UK) reduced the quantity of vapor transported into the TSA, and hence increased the protection of the individual more than did the fatigues. However, no statistical evidence of airlock differences was found.

CONTENTS

(Cont'd. on next page)

FIGURES

(Cont'd. on facing page)

*Caption is paraphrased here, for the convenience of the reader.

TABLES

ACKNOWLEDGMENT

The authors wish to acknowledge the on-site assistance of Emily M. Gause, Technical Writer (Technology Incorporated, 300 Breesport, San Antonio, Texas 78216), in the preparation and writing of this Technical Paper.

CHEMICAL DEFENSE COLLECTIVE PROTECTION TECHNOLOGY: VOLUME 1

Effects of Airlock Dimension, Clothing, and Exposure Concentration on Vapor Transport

INTRODUCTION

U.S. Air Force chemical defense measures include the design and development of safe environment collective shelter facilities for the protection of air and ground crews. Collective shelters can provide safe environments only as long as no significant level of contamination is introduced by entering personnel. For this reason, processing of personnel through collective shelters must be carefully defined and closely monitored.

Using a simulated SCPS-2 CCA* facility (Appendix A), the Chemical Defense Branch of the USAF School of Aerospace Medicine (USAFSAM) conducts continuing studies on the potential contributions of various personnel-processing factors to the contamination of collective shelter areas. Relevant processing factors include the types of clothing worn by entering personnel, decontamination procedures, and modifications of shelter design and construction. These factors are all variables which will affect the degree of protection afforded by the SCPS-2 facility.

In event of chemical attack, the clothing factor could be critically important to collective shelter function. Contamination of Toxic Safe Areas (TSAs) of shelters by transport (carry-through) of chemical agent vapors on clothing of entering personnel has been shown to be a major problem (1, 2).

The quantity of vapor carried through on clothing is dependent upon a number of factors. Ongoing within the Chemical Defense Branch is an examination of the extent of vapor transport associated with processing such factors as: (1) clothing type or combination (clothing assembly); (2) certain aspects of shelter design (e.g., airlock specification); and (3) shelter operation conditions (e.g., dwell time in airlocks, use of sorbent powder [fuller's earth: FE], or method of application of sorbent). Results of the separate experiments are to be presented as a series of technical papers, or interim progress reports, each of which will describe one or more separate experiment(s) on the relationships of specific processing factors to the carry-through of chemical agent simulant vapor.

The present interim report is the first of several concerned with whether or not significant quantities of simulant vapor contaminant could be transported into the TSA on the underclothing of personnel who have been exposed to vapor while wearing regulation air- and/or ground-crew clothing assemblies.

---

*Survivable Collective Protection Shelter Contamination Control Area.
EDITOR'S NOTE: This Technical Paper, Volume 1, is soon to be followed by Volume 2 --USAFSAM-TP-86-5.

SPECIFIC OBJECTIVES

Specific objectives of the experiments described in this interim report were:

(1) To employ a chemical warfare (CW) agent simulant, methyl salicylate, to compare the extent of contamination of the TSA by agent simulant transported on the undergarments of personnel who have been exposed while wearing: (a) the standard military 2-piece fatigues; or (b) the Flyer's charcoal undercoverall (UK).

(2) To compare the contamination-reducing capacities of an airlock design modification resulting in a volume of 0.8785 m^3 (31.044 ft^3), as compared with the SCPS-2 specified airlock design which has a volume of 2.1848 m^3 (77.201 ft^3).

EQUIPMENT AND PROCEDURES

Equipment

Only that equipment modified for the present experiments is described in this report section. (The simulated SCPS-2 CCA facility, vapor exposure equipment, offgassing booths, and ancillary atmospheric sampling apparatus are described in detail in Appendix A: "Documentation of Equipment.")

Airlock Modification

One of the airlocks in these experiments was modified by reducing the length from 1.048 m (3.438 ft) to 0.416 m (1.365 ft). The volume of the modified airlock was calculated to be 0.879 m^3 (31.044 ft^3), compared to a volume of 2.185 m^3 (77.201 ft^3) for the original SCPS-2 airlock. The modified airlock (Fig. 1) may be compared to the SCPS-2 design specification airlock shown in Appendix A (Fig. A-2). For both airlocks, air entered through louvers at the top of the cell and exited through an adjustable vent near the bottom of the door, with an airflow rate of 350 cfm.

Clothing Assemblies

The two clothing assemblies compared are itemized in Table 1; differences between the two assemblies worn during exposure are shown above the dotted line.

NOTE: All tables are grouped at close of text.

Figure 1. Modified (short) airlock.
[Volume = 0.879 m^3 (31.044 ft^3)]

Procedures

Described in Appendix B, "Documentation of Procedures," are: the methyl salicylate vapor exposure conditions; procedures for vapor generation, sampling, and measurement; methyl salicylate assay method; and data collection procedures.

Experimental Design

Four different concentrations of methyl salicylate vapor were employed on four days (Monday through Thursday of the same week). All exposures were for 5 min; and exposure concentrations are expressed as "Ct," or the product of mean vapor concentration (mg m^{-3}) and time (minutes).

The experimental design was developed so that each participant was dressed in each clothing assembly (with or without the charcoal undercoverall) for two days. Every day the individual was in a different glass offgassing booth. Individuals in unlike clothing assemblies passed through the short or long airlock. In this manner, the influences of subject stature and booth structural variations could be maintained at a minimum. The experimental design is summarized in Table 2.

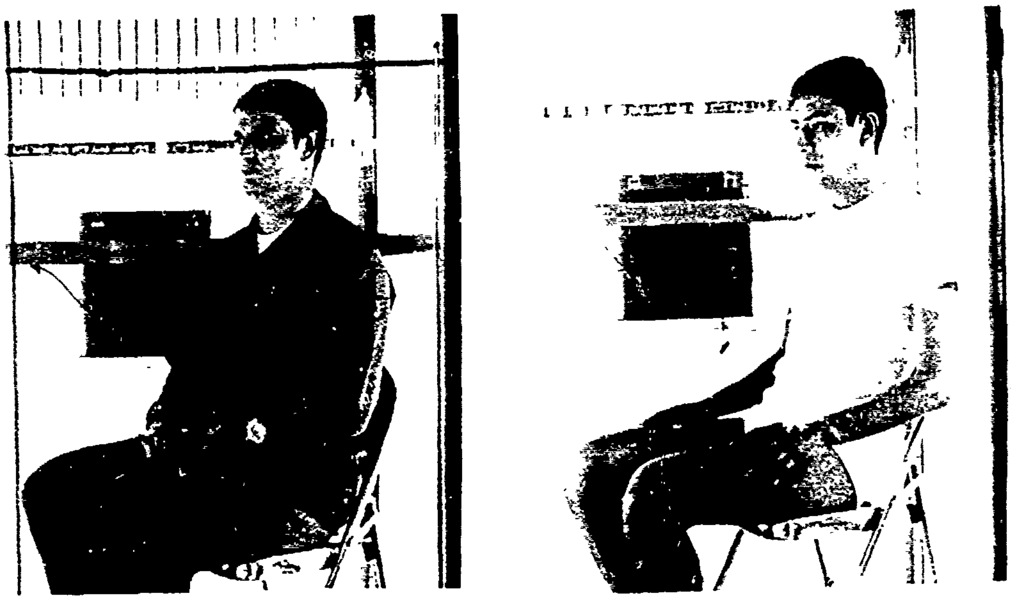
Experimental Protocol

Participants entered the vapor exposure booth simultaneously to ensure a uniform exposure of all participants to the same vapor level. After a 5-min exposure to the generated vapor levels, subjects exited the exposure booth, entered the Vapor Hazard Area (VHA), and removed their outer clothing. The removal of the fatigues left the participant in T-shirt and jockey shorts (Fig. 2), whereas the removal of the charcoal undercoverall (UK) left the participant in the white cotton Aircrew undershirt and white cotton Aircrew drawers (Fig. 3).

The participants passed through either the short or the long airlock, spending a total of 1.5 min therein (Table 2). The individuals then stood before the glass offgassing booth, and all entered at the same time. Ten minutes elapsed between departure from the vapor exposure booth and entry into the glass offgassing booths. Participants were required to spend 2 h in the glass offgassing booth, during which time the Sequential Impinger Sampler obtained samples of atmospheres every 15 min. Subsequent analyses of samples were carried out as described in Appendix B. Carbon dioxide levels were determined every half-hour of the offgassing period. The total air removed from the glass offgassing booth was 120.8 liters.

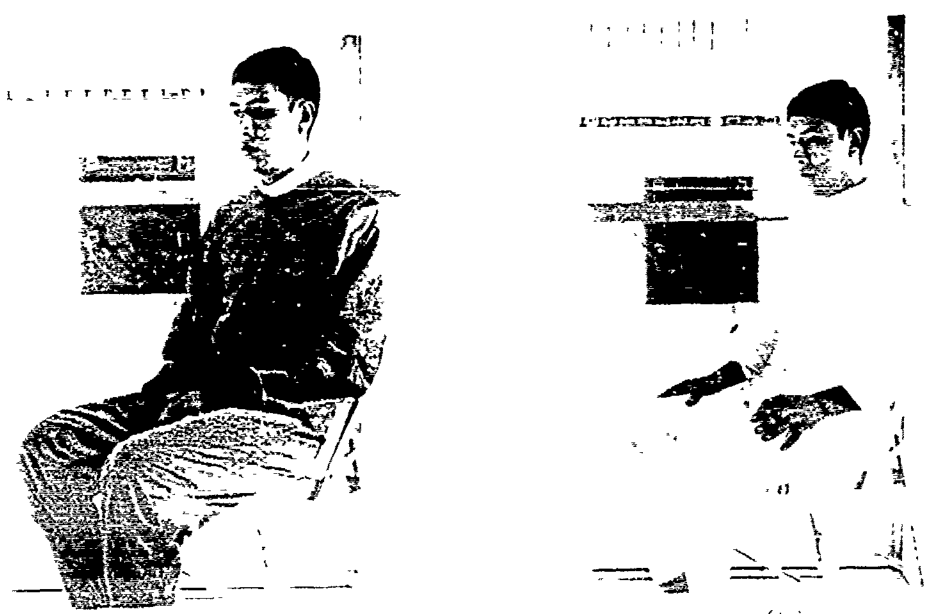
RESULTS

Methyl salicylate vapor levels in the exposure booth during exposure were measured, and these values are shown in Table 3. After individual subjects had removed the outer clothing worn during exposure and passed through an airlock into the TSA, they entered an offgassing booth where methyl salicylate vapor levels were measured every 15 min for the 2 h that the subject remained in the booth. In addition, vapor levels in each booth were measured for 1 h before the subject entered (background), and for 1 h after the subject exited. As a control measure, vapor levels within the TSA-- at a point immediately outside the four offgassing booths--were also obtained on the same schedule as measurements within the booths.



(a) (b)

Figure 2. Fatigues clothing assembly: (a) two-layer assembly worn during exposure; and (b) with outer fatigues layer removed for offgassing.



(a) (b)

Figure 3. Flyer's charcoal undercoveralls (UK) clothing assembly: (a) two-layer assembly worn during exposure; and (b) with outer charcoal layer removed for offgassing.

The physical characteristics of the participants appear in Table 4.

The atmospheric vapor levels measured for each experimental day are summarized in Tables 5 - 8. The values given in these Tables are raw data, uncorrected for background levels. Positions from which samples were obtained are indicated by a value of S-numerical which corresponds to positions indicated in the diagram of the SCPS-2 CCA facility (Appendix A: Fig. A-1). Positions S-8 through S-11 correspond to offgassing booths 1 through 4. Position S-12 is the sampling point within the TSA, immediately outside the offgassing booths.

For each subject offgassed, two separate quantities were analyzed statistically: vapor concentration at the end of the 2 h in the glass booth (i.e., last 15-min sample), and maximum vapor concentration (i.e., highest 15-min sample). An adjustment for background was made by subtracting the average of the four baseline values on each day in each booth; Table 9 shows the data that were subjected to statistical analysis.

For last and maximum values, respectively, a three-way analysis of variance was performed to evaluate day (Ct), airlock, and clothing differences; and interactions of these factors. Results of these analyses are shown in Table 10. To assist with interpretation, all appropriate means examined in the analysis are summarized in Table 11.

For both variables, the results were essentially the same. Statistical evidence indicated that, overall, the charcoal undercoveralls protected better than fatigues (p = .001 for last, p = .01 for max). More important, however, was the evidence that the magnitude of the charcoal undercoveralls versus fatigues difference was dependent on the amount of vapor exposure. There was a significant day (Ct)-by-clothing interaction: p = .003 for last, and p = .038 for maximum. As shown in Figure 4, the only large difference occurred on day 4 (the day of highest vapor exposure). A followup t-test, comparing the respective charcoal undercoverall and fatigues means on each day, generally supported this finding (Fig. 4).

The analysis of variance did not give any indication of airlock differences (Tables 10 and 11). On a day-by-day basis, data on the subjects utilizing the long and short airlocks yielded similar booth vapor concentrations (Fig. 5).

DISCUSSION AND CONCLUSIONS

The design and physical layout of the exposure and glass offgassing booths functioned extremely well to meet the goals of the study. Use of one of the undressing booths for exposure to vapor approximates where vapor exposure will begin in the SCPS-2 CCA facility. The remainder of the facility duplicates the path that individuals will take in entering the Toxic Safe Area (TSA) of a collective protection shelter. The glass offgassing booths, plus the sensitivity of the Sequential Impinger sampling procedure, affords an excellent medium through which to study the vapor carried into the TSA by an individual. The

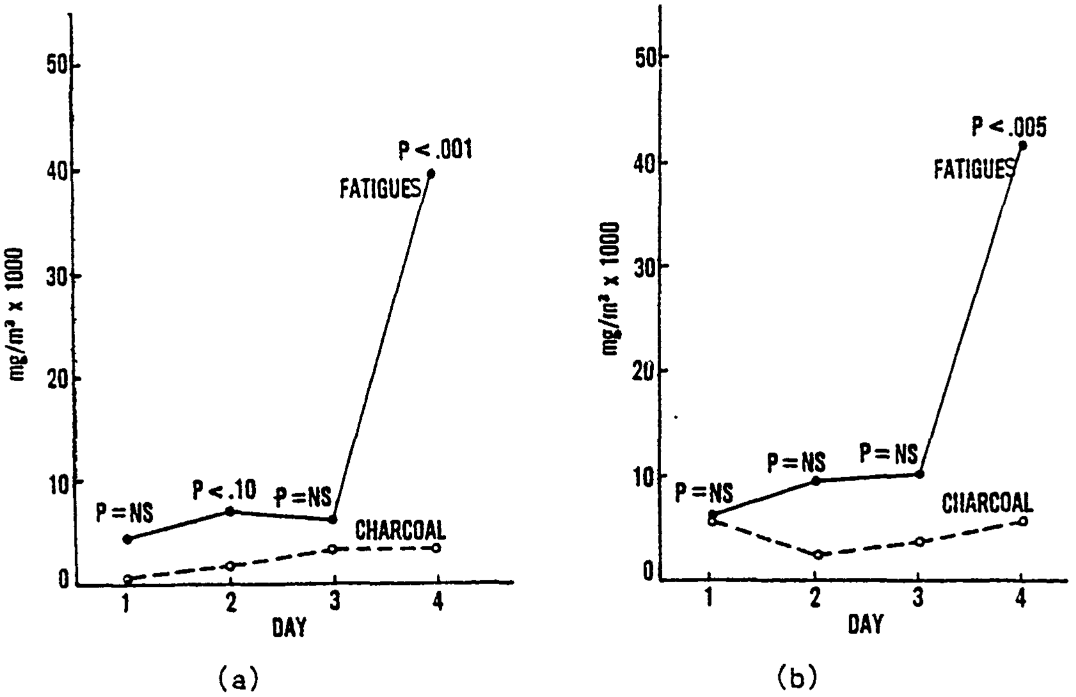


Figure 4. Mean last sample (a) and maximum sample (b) values vs. exposure concentration (Ct, indicated here as exposure day) for each clothing assembly; actual Ct values for each day are shown in Table 3. Statistical significance evaluated by t-test.

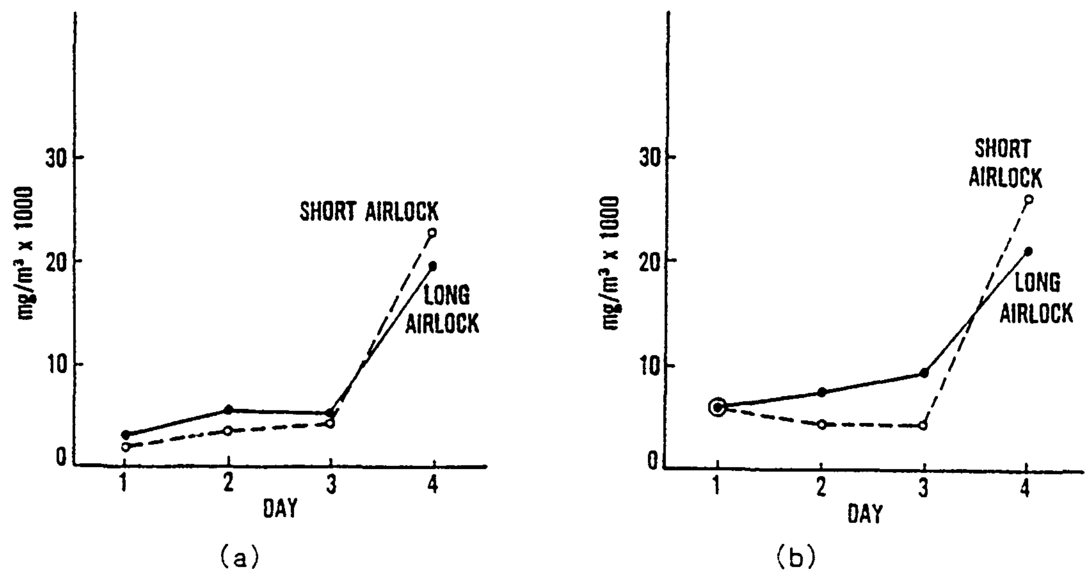


Figure 5. Mean last sample (a) and maximum sample (b) values vs. exposure concentration (Ct, indicated here as exposure day) for each airlock; actual Ct values for each day are shown in Table 3.

system of pairs employed for each of the factors by this experimental design provides a systematic study of both mechanical and clothing vapor transfer. The surfaces of the glass offgassing booths are easily cleaned after the experiment, and have a minimum sorption of methyl salicylate as compared with offgassing cells used in past studies.

On the basis of the data obtained, the charcoal undercoverall appeared to protect an individual over the entire range of vapor exposures studied. Fatigues, however, while not poor in protection at low exposures, failed to protect well on day four--the day of highest exposure.

No statistical evidence of airlock differences was found. Since the tests are based on small samples, however, the probability is low for detecting anything other than a very large airlock difference. Before recommending that the long airlocks be replaced by the short in order to conserve space, further studies should be conducted in which primary emphasis would be placed on comparison of the two airlocks.

The use of the charcoal-containing undercoverall will decrease transport of vapor into the TSA. The concept of two layers of garment has been shown to increase the safety of the individual, since the charcoal-containing layer will provide for more rapid processing of the individual through a collective protection contaminant control area. This concept could also possibly decrease the space required for the don/doff operation. The current facility can be used not only to evaluate various garments for the transport of chemical agent simulant through the system, but also to examine the effects of procedural changes. These procedural changes include the effects of airflow, residence time, and volume of airlocks as related to decrease in vapor transport through the system. In addition, the effect of varying exposure time length with the same resulting Ct can be studied. An effective analytical system has thus been developed for the study of the parameters of collective protection facilities and their associated contaminant control areas.

REFERENCES

1. Crook, J. W., F. W. Oberst, and F. R. McGrath. Desorption of GB vapor from various types of clothing. Report No. 2023. AD 095141, Army Chemical Warfare Laboratories, Army Chemical Center, Md., Apr 1956.

2. Gilchrist, H. L. A comparative study of world war casualties from gas and other weapons. AD-E750741. Chemical Warfare School, Edgewood Arsenal, Md. United States Government Printing Office. Washington, D.C., 1928.

TABLES

TABLE 1. CLOTHING ASSEMBLIES COMPARED

	Fatigues	Undercoverall
Exposure		
	Fatigues, std. mil., 2-pc.	Undercoverall, Flyers, UK
	T-shirt (underwear)	Undershirt, Aircrew (underwear)
	Jockey shorts (underwear)	Drawers, Aircrew (underwear)
	- - - - - - - - - - - -	- - - - - - - - - - - - - - -
	Hood, chem. biol. (M6A2)	Hood, chem. biol. (M6A2)
	Mask, CB protective (M17)	Mask, CB protective (M17)
	Gloves, CP (ground crew)	Gloves, CP (ground crew)
	Gloves, Insert, cotton knit	Gloves, Insert, cotton knit
	Socks, tube, men's white	Socks, tube, men's white
	Plastic bag over feet, socks	Plastic bag over feet, socks
Offgassing		
	T-shirt (underwear)	Aircrew undershirt (underwear)
	Jockey shorts (underwear)	Aircrew drawers (underwear)

CB = chem. biol.
CP = chemical protective

TABLE 2. EXPERIMENTAL DESIGN FOR COMPARING VAPOR TRANSPORT PROPERTIES OF CLOTHING

Day of exposure[a]	Conditions for Subject No. 1	2	3	4
1	Fatigues Airlock S Booth 1 (S-8)	Undercoverall Airlock S Booth 2 (S-9)	Fatigues Airlock L Booth 3 (S-10)	Undercoverall Airlock L Booth 4 (S-11)
2	Undercoverall Airlock L Booth 2 (S-9)	Fatigues Airlock L Booth 3 (S-10)	Undercoverall Airlock S Booth 4 (S-11)	Fatigues Airlock S Booth 1 (S-8)
3	Fatigues Airlock S Booth 3 (S-10)	Undercoverall Airlock S Booth 4 (S-11)	Fatigues Airlock L Booth 1 (S-8)	Undercoverall Airlock L Booth 2 (S-9)
4	Undercoverall Airlock L Booth 4 (S-11)	Fatigues Airlock L Booth 1 (S-8)	Undercoverall Airlock S Booth 2 (S-9)	Fatigues Airlock S Booth 3 (S-10)

[a] Exposure concentration (Ct) varied each experimental day.
Airlock designations: L = Long (original); and S = Short (modified).
S-8 to S-11: Positions from which samples were obtained. (Refer to Fig. A-1.)

TABLE 3. METHYL SALICYLATE VAPOR EXPOSURE LEVELS

Day	Ct ($mg\ min\ m^{-3}$)
1	31.71
2	54.81
3	61.30
4	87.05

Ct = Exposure concentration

TABLE 4. PHYSICAL CHARACTERISTICS OF SUBJECTS

Subject	Height		Weight	
	cm	(in.)	kg	(lb)
1	165.1	(65)	61.68	(136)
2	185.4	(73)	75.28	(166)
3	182.2	(71.75)	91.15	(201)
4	182.9	(72)	71.20	(157)

TABLE 5. METHYL SALICYLATE LEVELS FOR DAY 1 (Ct = 31.71) (mg m^{-3})

Time (15-min increment)	Position sampled* S-8	S-9	S-10	S-11	S-12
1	.004	.005	.008	.005	.003
2	.004	.005	.007	.005	.003
3	.004	.005	.005	.006	.005
4	.004	.005	.006	.005	.003
5	.006	.006	.005	.006	.003
6	.009	.007	.012	.007	.003
7	.009	.009	.010	.008	.003
8	.007	.012	.014	.007	.003
9	.009	.010	.012	.006	.004
10	.009	.008	.009	.010	.003
11	.006	.006	.010	.010	.003
12	.008	.005	.012	.006	.004
13	.006	.007	.006	.008	.004
14	.007	.006	.008	.009	.003
15	.005	.007	.011	.006	.004
16	.005	.007	.009	.009	.003

*S-8 to S-12: Refer to Figure A-1.

TABLE 6. METHYL SALICYLATE LEVELS FOR DAY 2 (Ct = 54.81) (mg m^{-3})

Time (15-min increment)	Position sampled* S-8	S-9	S-10	S-11	S-12
1	.002	.002	.003	.003	.002
2	.003	.003	.003	.005	.003
3	.003	.003	.003	.003	.003
4	.003	.003	.003	.003	.003
5	.005	.004	.006	.004	.003
6	.008	.004	.011	.006	.002
7	.008	.004	.013	.004	.002
8	.009	.004	.013	.005	.002
9	.009	.003	.014	.005	.002
10	.008	.005	.016	.006	.003
11	.009	.004	.015	.006	.002
12	.008	.005	.012	.005	.003
13	.007	.005	.012	.005	.002
14	.007	.004	.007	.005	.002
15	.007	.004	.011	.007	.003
16	.007	.004	.011	.010	.002

*S-8 to S-12: Refer to Figure A-1.

TABLE 7. METHYL SALICYLATE LEVELS FOR DAY 3 (Ct = 61.30)

(mg m^{-3})

Time (15-min increment)	Position sampled* S-8	S-9	S-10	S-11	S-12
1	.003	.003	.002	.002	.002
2	.003	.004	.003	.002	.002
3	.004	.006	.003	.002	.002
4	.003	.005	.002	.002	.002
5	.008	.004	.004	.004	.002
6	.014	.005	.005	.004	.002
7	.016	.005	.007	.006	.002
8	.019	.008	.006	.005	.002
9	.016	.006	.007	.005	.002
10	.015	.006	.007	.005	.002
11	.012	.007	.007	.005	.003
12	.011	.007	.007	.006	.007
13	.010	.006	.007	.007	.003
14	.011	.006	.006	.005	.002
15	.012	.007	.007	.006	.002
16	.008	.006	.006	.005	.002

*S-8 to S-12: Refer to Figure A-1.

TABLE 8. METHYL SALICYLATE LEVELS FOR DAY 4 (Ct = 87.05)

(mg m^{-3})

Time (15-min increment)	Position sampled* S-8	S-9	S-10	S-11	S-12
1	.003	.002	.003	.003	.001
2	.003	.002	.003	.002	.002
3	.003	.003	.004	.002	.002
4	.004	.002	.002	.002	.003
5	.010	.004	.018	.005	.003
6	.022	.008	.034	.008	.002
7	.025	.005	.042	.006	.002
8	.031	.005	.042	.005	.003
9	.034	.003	.048	.005	.001
10	.036	.005	.049	.007	.002
11	.032	.005	.050	.008	.002
12	.040	.006	.045	.005	.003
13	.029	.007	.038	.005	.002
14	.001	.007	.040	.005	.003
15	.026	.005	.037	.005	.002
16	.025	.005	.038	.004	.002

*S-8 to S-12: Refer to Figure A-1.

TABLE 9. OFFGASSED METHYL SALICYLATE VAPOR MEASUREMENTS SUBJECTED TO STATISTICAL ANALYSIS (Values in mg m^{-3}, corrected for background)

Day	Airlock size	Clothing	Last value	Maximum value
1	Short	Fatigues	.0040	.0050
1	Short	Charcoal	.0000	.0070
1	Long	Fatigues	.0055	.0075
1	Long	Charcoal	.0008	.0048
2	Short	Fatigues	.0052	.0062
2	Long	Charcoal	.0022	.0022
2	Long	Fatigues	.0090	.0130
2	Short	Charcoal	.0015	.0025
3	Long	Fatigues	.0078	.0158
3	Long	Charcoal	.0025	.0035
3	Short	Fatigues	.0045	.0045
3	Short	Charcoal	.0040	.0040
4	Long	Fatigues	.0368	.0368
4	Short	Charcoal	.0038	.0058
4	Short	Fatigues	.0420	.0470
4	Long	Charcoal	.0028	.0058

Charcoal = Flyer's charcoal undercoverall (UK).

TABLE 10. ANALYSES OF VARIANCE

Source	df	Last value MSQ ($\times 10^4$)	Last value F ratio	Last value p	Maximum value MSQ ($\times 10^4$)	Maximum value F ratio	Maximum value p
Day	3	3.0631	80.48	.002	3.0625	13.57	.030
Airlock	1	0.0032	0.08	.792	0.0329	0.15	.728
D x A	3	0.0551	1.45	.384	0.2082	0.92	.526
Clothing	1	5.9110	155.31	.001	6.2813	27.83	.013
D x C	3	2.5630	67.34	.003	2.5674	11.38	.038
A x C	1	0.0113	0.30	.624	0.1097	0.49	.536
Error	3	0.0381			0.2257		

MSQ = mean square

TABLE 11. MEAN VALUES COMPARED BY THREE-WAY ANALYSES OF VARIANCE

Factor(s)		N	Mean Last value	Mean Maximum value
Day				
1		4	.0026	.0061
2		4	.0045	.0060
3		4	.0047	.0069
4		4	.0213	.0238
Airlock				
Long		8	.0084	.0112
Short		8	.0081	.0102
Clothing				
Charcoal		8	.0022	.0044
Fatigues		8	.0143	.0170
Day x Airlock				
1	Long	2	.0031	.0061
1	Short	2	.0020	.0060
2	Long	2	.0056	.0076
2	Short	2	.0034	.0044
3	Long	2	.0051	.0096
3	Short	2	.0042	.0042
4	Long	2	.0198	.0212
4	Short	2	.0229	.0264
Day x Clothing				
1	Charcoal	2	.0004	.0059
1	Fatigues	2	.0048	.0062
2	Charcoal	2	.0019	.0024
2	Fatigues	2	.0071	.0096
3	Charcoal	2	.0032	.0038
3	Fatigues	2	.0061	.0101
4	Charcoal	2	.0032	.0058
4	Fatigues	2	.0394	.0419
Airlock x Clothing				
Long	Charcoal	4	.0021	.0041
Long	Fatigues	4	.0148	.0182
Short	Charcoal	4	.0023	.0048
Short	Fatigues	4	.0139	.0157

Charcoal = Flyer's charcoal undercoverall (UK).

APPENDIX A:

DOCUMENTATION OF EQUIPMENT

APPENDIX A: DOCUMENTATION OF EQUIPMENT

SCPS-2 CCA Simulation Structure

The simulated Survivable Collective Protection Shelter Contamination Control Area (SCPS-2 CCA) facility at the USAF School of Aerospace Medicine, Brooks AFB, Texas, is diagrammed in Figure A-1. This facility is constructed of plywood, with inside walls coated with white epoxy paint to simulate the concrete structure of the operational SCPS-2 CCA units*. Internal dimensions of the simulated SCPS-2 CCA are 2.438 m (8 ft) high by 3.658 m (12 ft) wide; and each area, or section, is 2.438 m (8 ft) long. Airflow through the structure meets the operational design requirements of 1200-1800 cfm*.

The SCPS-2 CCA design provides for three stages of contamination control, with airborne contaminants being removed through entrainment by a flow of filtered air through the structure. Personnel enter SCPS-2 against the air stream into the first zone where decontamination is initiated. Within this first zone, outer clothing is: treated with fuller's earth (FE) to adsorb liquid agent or simulant· removed; and stored. Since pools or droplets of liquid agent could possibly be present, this zone is designated a "Liquid Hazard Area" (LHA). Within the LHA are 3 changing booths, approximately 1.219 m (4 ft) wide x 1.829 m (6 ft) long. Auxiliary equipment within the LHA includes trays of FE, benches, mirrors, and special racks (Fig. A-1).

Decontamination and removal of clothing and protective gear continues through the second zone of the CCA, which is a Vapor Hazard Area (VHA). After having been processed through both of these initial zones of the SCPS-2 CCA, personnel enter 1 of 4 airlocks which separate the VHA from the third zone, the TSA. In the TSA, personnel are able to dispense with the use of masks, etc., and are free to rest.

So that experiments in this facility can be monitored, sealed Plexiglas viewports are located at several points around the structure. These viewports and various sampling ports can be accessed by a raised walkway, 0.914 m (3 ft) wide, surrounding the facility.

Airlocks

Four airlocks, approximately 1.048 m by 0.856 m (3.438 ft by 2.807 ft), are positioned between the VHA and the TSA (Fig. A-1). The volume of the design specification airlock is 2.186 m^3 (77.204 ft^3)*; a photograph of this airlock is shown in Figure A-2. Air enters through louvers at the top of the cell on one side and exits through an adjustable vent near the bottom of the door on the opposite side. Under standard operational conditions, airflow is 9.905 m^3 min^{-1} (350 cfm), with a residence time of 1.5 min per subject.

---

*Anderson, L., et al., Survivable collective protection shelter, SCPS-2 Design specification index drawings, X3320-16-0020 through X3320-16-71920, Systems Research Laboratories, Inc., Dayton, O., Oct 1984.

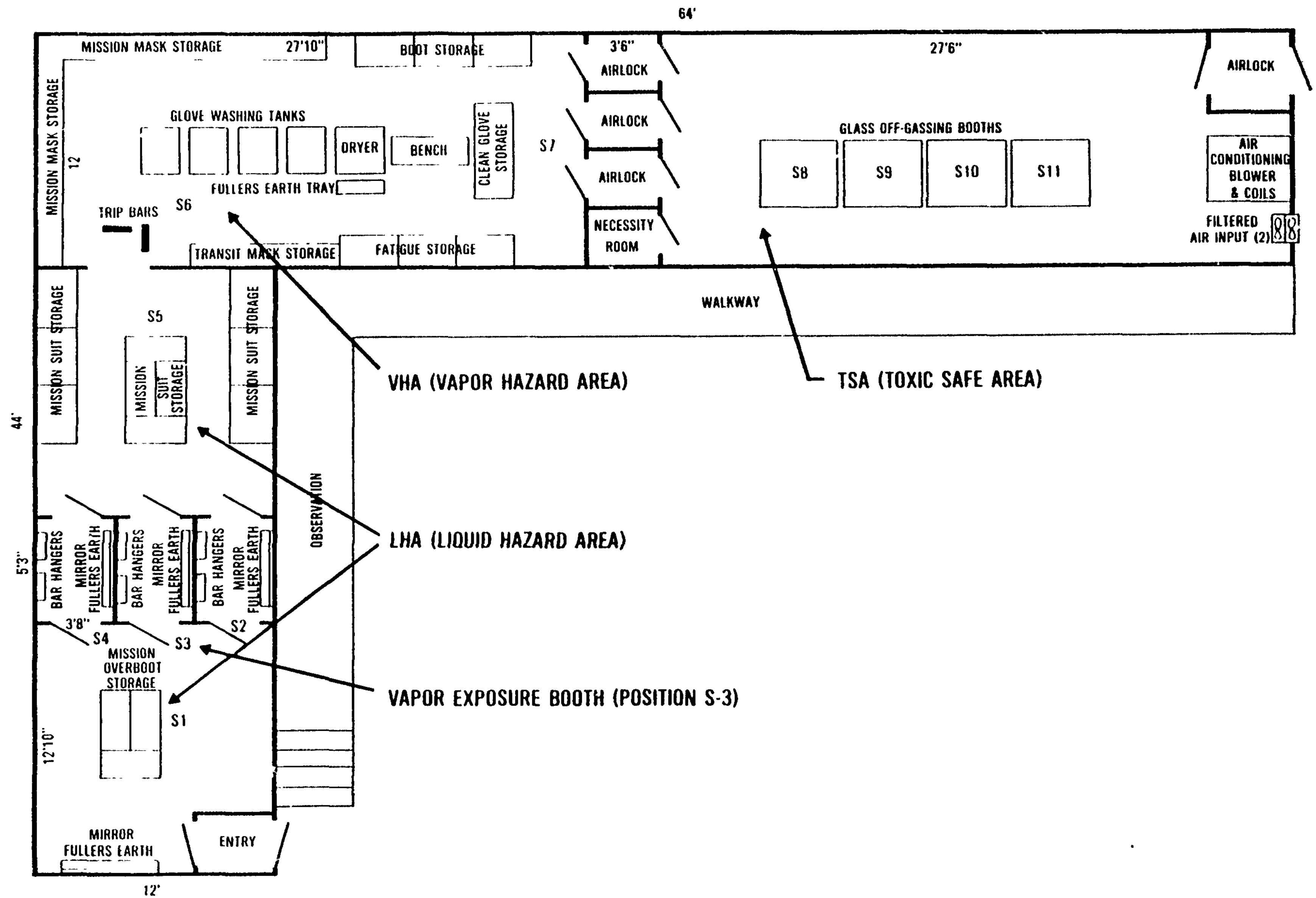


Figure A-1. Simulated survivable collective protection shelter, contamination control area (SCPS-2 CCA) facility (Brooks Air Force Base, Texas).

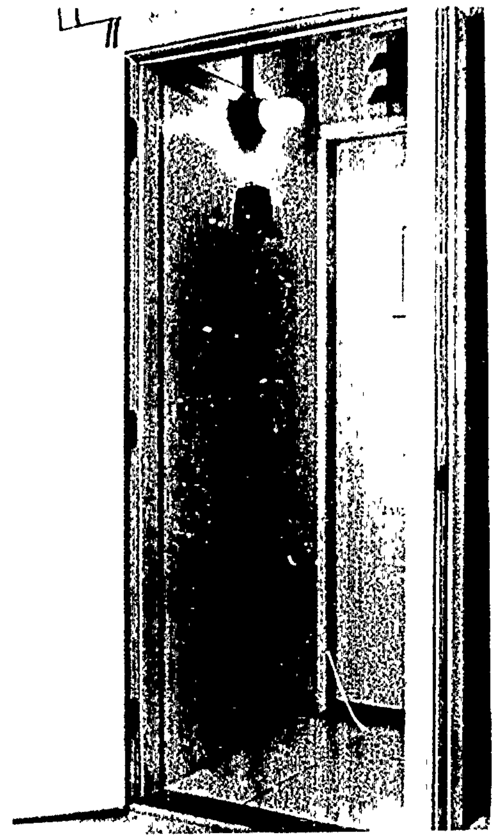


Figure A-2. SCPS-2 CCA Design Specification airlock [2.186 m^3 (77.204 ft^3) volume; 9.905 m^3 min^{-1} (350 cfm)]. Airflow is from louvers at top of one side to vent at bottom of opposite side.

--APPENDIX A--

Offgassing Booths

In order to collect and measure the quantity of chemical agent simulant vapor transported into the TSA by personnel under the conditions of a given experiment, four sealed booths for offgassing were designed and fabricated; several views of these booths are shown in Figures A-3 to A-5. The booths were constructed of glass, stainless steel, and chrome-plated steel, with Viton as gasket material. Dimensions of the booths were 1.194 m (3.917 ft) long by 1.054 m (3.458 ft) wide by 2.077 m (6.813 ft) high. Internal volume of the booths was calculated to be 2.613 m^3 (92.276 ft^3). Volume displacement--due to the presence of the impingers and connecting tubes, chair, or the individual who was being offgassed--was not taken into account in these calculations.

As illustrated in Figures A-3 through A-5, three sides of a booth are of glass; the other side is stainless steel, with a door 1.524 m (5 ft) high by 0.864 m (2.833 ft) wide which has a walk-in refrigerator door handle so that the door can be opened from the inside. The top of the cell has ports for 24 brass bulkhead fittings, through each of which 1/4-in. stainless steel tubing enters; each piece of this tubing is then connected to a glass impinger sampler by a 5.1-cm (2-in.) piece of Tygon tubing. Two additional sampling ports are located in the top, for an oxygen sensor and a temperature probe.

The four offgassing booths are within the TSA of the facility (Fig. A-1). Air within the TSA was sampled adjacent to the booths to detect any contamination of air outside the booths (Fig. A-1, position S-12).

Impinger Sampler

The Sequential Impinger Sampler (SIS) apparatus, developed by the USAF School of Aerospace Medicine (USAFSAM), consists of a bank of multiple impinger tubes arranged so that a timer and solenoid valve system opens a new impinger every 15 min for a sampling period of 15 min (Fig. A-5).

Impingers are obtained from Ace Glass, Inc. (25 ml, model BC779, 24/40 standard taper, with 24/40, P2479, stoppers). Orifices are re-sized to a uniform range of 7.62 - 10.16 mm (0.030 - 0.040 in.). The SIS apparatus consists of: an aluminum casing, 28 x 33 x 43 cm (11 x 13 x 17 in.); a Brailsford and Co. Model TD-1AS pump; and a Scannivalve 24-port scanning valve, Model 24C9121-433. The apparatus is powered either by a 24-V battery set, or by 100/120/220 or 230-240 VAC, from 47 to 63 Hz.

--APPENDIX A--

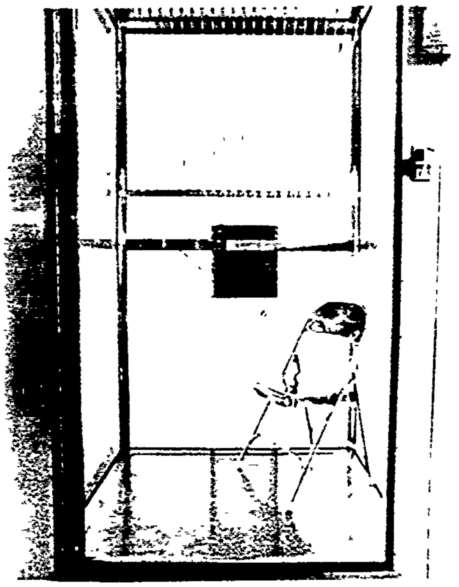


Figure A-3. Interior of glass offgassing booth.

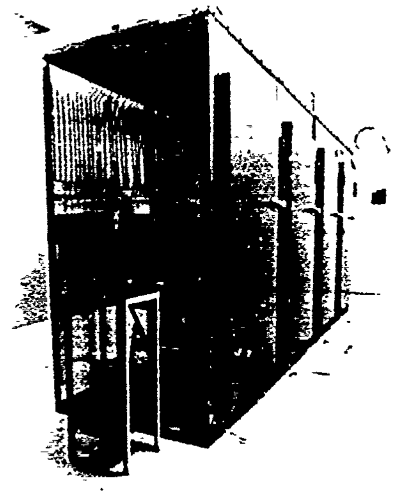


Figure A-4. Exterior of offgassing booths from entrance side.

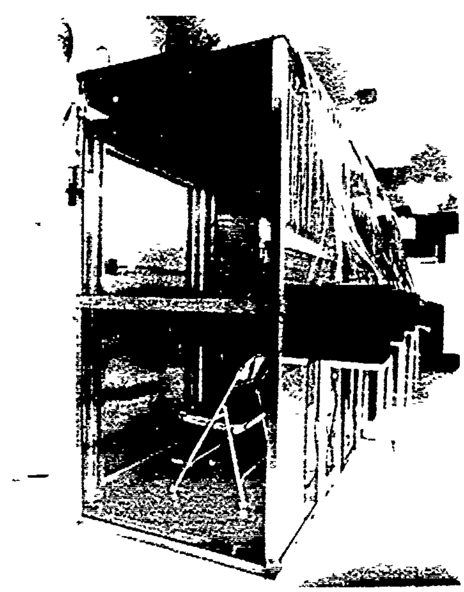


Figure A-5. Offgassing booth with sequential impinger sampling apparatus.

APPENDIX B:

DOCUMENTATION OF PROCEDURES

APPENDIX B: DOCUMENTATION OF PROCEDURES

Chemical Warfare Agent Simulant Selection

Non-toxic chemicals which possess physical properties similar to those of chemical warfare (CW) agents have been selected, and such CW agent simulants are employed in research and development concerned with SCPS-2 CCA procedures and potential modifications of design specifications. Methyl salicylate (oil of wintergreen) is used as a simulant for CW agents of intermediate volatility, particularly mustard (H)*. Relevant physical properties of methyl salicylate and several CW agents are shown in Table B-1. Methyl salicylate, which possesses an intermediate range of volatility, can be employed in either the vapor or liquid (aerosol) form. Methyl salicylate is employed as a CW agent simulant in shelter processing research conducted at the USAFSAM SCPS-2 CCA facility.

TABLE B-1. PHYSICOCHEMICAL PROPERTIES OF METHYL SALICYLATE AND SELECTED CHEMICAL WARFARE AGENTS

Property	Chemical compound					
	GB	GD	VX	HD	H	MeS[a]
Mol. Wt.	140.1	182.2	267.4	159.1	159.1	152.1
B.P. (°C)	158	198	298	217	228(dec)	220-224
Volatility (torr at 25°C)	21,000	3,500	15	1,400	630	930
Density ($g\ ml^{-1}$)	1.089	1.022	1.008	1.269	1.274	1.183
Density (vapor at 25°C)	4.83	6.28	9.22	5.4	5.5	5.24
Viscosity (Cp)	1.37	3.10	10.0	4.5	4.42	3.34

[a]methyl salicylate
GB = sarin; GD = soman; H = mustard; HD = distilled mustard;
VX = $C_2H_5P(O)(CH_3)SCH_2CH_2N[CH(CH_3)_2]2$

* Development of Candidate Chemical Simulant List: Evaluation of candidate chemical simulants which may be used in chemically hazardous operations. AFAMRL-TR-82-28. Air Force Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio 45433, May 1982.

--APPENDIX B--

Methyl salicylate, N.F. grade, is obtained from Moyco Industries (Philadelphia, Pa.).

Methyl Salicylate Vapor Exposure Conditions

For exposure to methyl salicylate vapor atmospheres under conditions of defined vapor concentration and time (Ct), a booth within the LHA is employed (Fig. A-1). All experimental subjects enter the exposure booth simultaneously to ensure uniform exposure conditions. Vapor generation is then initiated, with vapor entering the booth through a vapor-dispersal unit in the center of the ceiling. Subjects usually remain in the booth for 5 min, during which time the vapor concentration is continually increasing. Upon exiting the exposure booth, subjects enter the VHA and remove outer clothing.

Samples of exposure booth atmospheres are collected over the entire 5-min exposure period by an Impinger Sampler (Appendix A), and are subsequently assayed for methyl salicylate content (total milligrams of methyl salicylate vapor entering booth during the 5-min period); a mean quantity of methyl salicylate vapor per minute of exposure is calculated. This value is converted to milligrams of methyl salicylate per cubic meter of booth volume ($mg\ m^{-3}$), and multiplied by 5 min to arrive at an estimated value of Ct ($mg\ min\ m^{-3}$).

Methyl Salicylate Vapor Generation

Methyl salicylate vapor exposure atmospheres are generated by passing a stream of air over thin films of liquid methyl salicylate. The air stream containing methyl salicylate vapor is then directed through the exposure booth while subjects are present. Actual atmospheric concentrations produced within the booth over the entire exposure period are monitored.

The apparatus employed for vapor generation is shown in Figure B-1; this apparatus is immediately over the exposure booth. An airstream of 500 LPM flow rate is produced by means of a Rotron blower (Model SL 284 FG) and Fisher Porter flowmeter (Model 8204800876A6). This airstream enters a cylinder, into which one or more tubes of Vycor brand porous ("Thirsty") glass, with 40-Å pore diameter, extend through Cajon Ultra-torr S-4UT1-4 fittings, which have been modified.

These porous glass tubes contain varying quantities of methyl salicylate, depending upon the vapor concentration to be produced (Fig. B-1). The methyl salicylate migrates through the tubes, forming films of liquid on the outer surfaces. The liquid films are vaporized by the entering airstream, and the airstream containing the methyl salicylate vapor is conducted immediately into the exposure booth. The concentration of vapor in the airstream is manipulated by varying the quantity of liquid methyl salicylate within the glass tubes. Calibration curves have been determined for establishing relationships between quantity of liquid methyl salicylate in the tubes and concentration of vapor within the exposure booth.

--APPENDIX B--

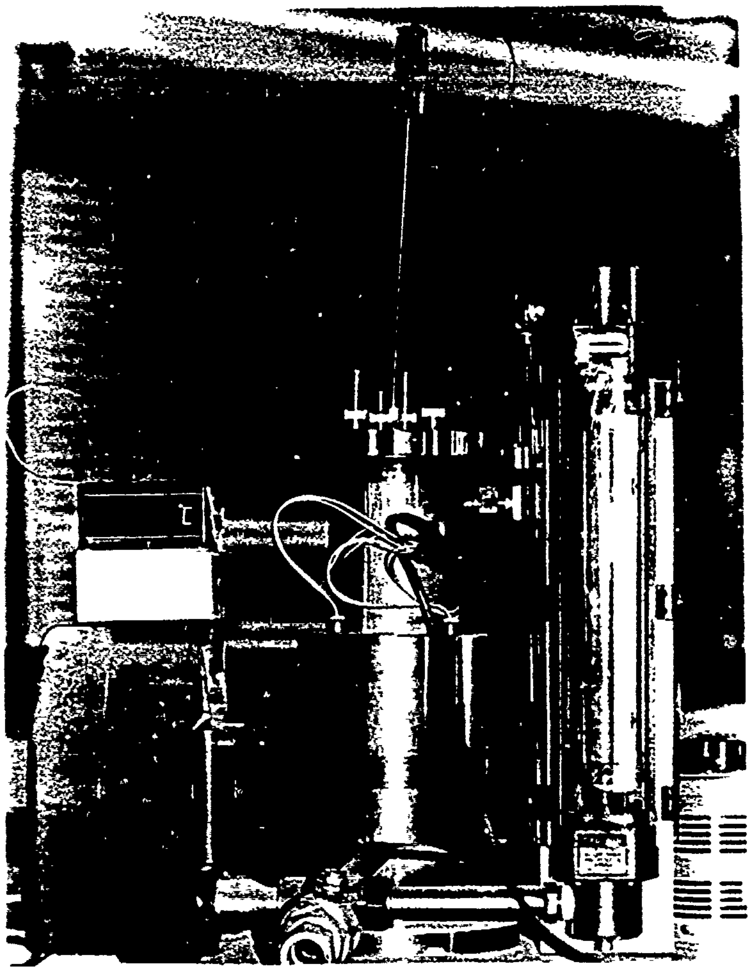


Figure B-1. Apparatus for generation of methyl salicylate vapor.

Methyl Salicylate Aerosol Exposure Conditions

Individual subjects are sprayed in open air with aerosolized methyl salicylate containing Tinopal SWN, a fluorescent laundry detergent whitener used as a marker of exposure. Tinopal SWN is obtained from Ciba-Geigy Corporation. Methyl salicylate may be employed either neat or thickened. Exposure levels are monitored by means of multiple glass microscope slides attached to subjects: the slides are subsequently removed and assayed for trapped methyl salicylate.

Methyl salicylate neat is aerosolized by a T100 sprayer with TEEJET nozzle (Model 8000067), supplied by B & G Company (Oklahoma City, Okla.). This system yields droplets of 0.3-mm mass mean diameter. Spray densities ranging from 0.5 to 10.0 g m^{-2} have been used for some methyl salicylate exposures; however, a spray density of 5.00 g m^{-2} is normally employed. The person operating the sprayer wears mask and goggles, or chemical defense mask, in order to protect his eyes from the aerosol.

--APPENDIX B--

Methyl salicylate is thickened by incorporation of Acryloid K125EA (Rohm and Haas). Thickened methyl salicylate is sprayed with a DeVilbiss JGA-502 spray gun with a P-KB-521 pressure cup and an air compressor. Reservoir pressure is 9 psi, and inlet head pressure, 90 psi. The nozzle employed is model AV-15-FF, which produces droplets of 3.0- to 6.0-mm mass mean diameter. For exposures to thickened simulant, mask voicemitters are covered to prevent staining by the Tinopal dissolved in the methyl salicylate.

Methyl Salicylate Vapor Sampling and Measurement

Samples of atmospheres present in the offgassing booths are collected by the Sequential Impinger Sampler for subsequent assay for methyl salicylate concentration. Impinger tubes contain 15 ml of a 1:1 solution of 0.1 N sodium hydroxide (NaOH) and methanol to trap methyl salicylate vapor. The tube contents are diluted to 25 ml, and are stored for 24 h to ensure completion of hydrolysis of methyl salicylate prior to fluorimetric assay of the hydrolysis products.

Methyl Salicylate Aerosol Sampling and Measurement

Aerosol exposure concentration is monitored by means of glass microscope slides attached, with tape, to the front and back of the subject (5 slides to each side). After exposure, slides are removed and placed in a slide caddy filled with NaOH-methanol solution; this solution is subsequently assayed for methyl salicylate content.

Data Collection

Results of assays of methyl salicylate content of individual SIS sample tubes are recorded for each subject by position within the SCPS-2 CCA Simulation facility (Appendix A: Fig. A-1), and by time. These data are entered into a DEC Microvax I computer for storage and subsequent analysis, employing software developed in-house for this application.

Decontamination

Decontamination procedures have been developed for use by personnel processing through the SCPS-2 CCA facility. These procedures involve: scavenging, by adsorption onto fuller's earth within the LHA, the CW agents associated with outer protective clothing and gear; cautious, programmed removal and storage of outer contaminated clothing; and passage of individual personnel through an airlock with a high, localized airflow before their entry into the TSA.

FE, a kaolin of widespread occurrence, efficiently adsorbs chemicals in liquid form. FE is composed primarily of aluminum silicates; most of the FE used at USAFSAM has been the Surrey Finest (approximately 200- to 400-mesh size), obtained from Great Britain.

--APPENDIX B--

Methyl Salicylate Assay

Samples of methyl salicylate trapped in 1:1 NaOH-methanol are allowed to stand for 24 h prior to assay in order to ensure complete hydrolysis of the methyl salicylate. Suitable dilutions of these solutions are prepared, and hydrolysis products are assayed fluorimetrically with excitation at 300 nm and emission at 405 nm. Standard solutions are prepared by dilution of known quantities of neat methyl salicylate, and these standards are assayed concomitantly with each batch of samples. A Perkin-Elmer Model LS-5 or Model 3000 Spectrofluorometer is employed. The sensitivity of this assay permits detection of 1.45 ng hydrolyzed methyl salicylate per milliliter solution, with a fluorescence yield of 0.6 units at a sensitivity setting of 2.