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CHEMICAL AGENT MONITOR (CAM) FOLLOW-ON OPERATIONAL TEST AND EVALUATION SIMULANT TEST STRATEGY

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This report was intended to provide technical guidance to the U.S. Army Armor and Engineering (A&E) Board in the area of simulant use for the Chemical Agent Monitor (CAM) Follow-On Operational Test and Evaluation (FOT&E). The Operational Science Branch (Op Sci Br) was requested to support the A&E Board in their effort to design an FOT&E for the CAM using methyl salicylate (MS) as the H mode (mustard agent) simulant. Personnel from Op Sci Br were asked to design contamination technology and monitoring methods to test the machine/man interface and use doctrine, and analyze how well data is collected and evaluated.

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SUMMARY

This report is intended to provide technical guidance to the Armor and Engineering Board, in the area of simulant use, for the Chemical Agent Monitor (CAM) Follow-On Operational Test and Evaluation (FOT&E).

The report is structured into two major parts. The first part presents operational test concepts in order to indicate how the simulant technology should be employed, and the second part contains the simulant technology and guidance. Operational test concepts presented were not intended to indicate the actual test procedure to be used, but rather how the simulant technology can be applied to an operational test of the type planned for the CAM.

In addition to meeting technical goals set by the Armor & Engineering Board, safety, environmental impact, ease of decontamination, and ease of use were integrated into the technical decision making process for this test. In some cases, due to power, material, time, cost and personnel limitations, simpler and less accurate choices were required. The need to maintain realistic field conditions also limited options in controlling experimental variables.

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PREFACE

The work described in this report was authorized under Project No. 665712, Chemical Agent Monitor. This work was started in May 1988 and completed in April 1989.

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This report has been approved for release to the public.

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CHEMICAL AGENT MONITOR (CAM) FOLLOW-ON OPERATIONAL TEST AND EVALUATION SIMULANT TEST STRATEGY

1. INTRODUCTION

1.1 Purpose.

The purpose of this report is to provide methyl salicylate (MS) and dipropylene glycol monomethyl ether (DPGME) simulant use technology to support the follow-on operational test and evaluation (FOT&E) for the Chemical Agent Monitor (CAM).

1.2 Background.

The Army Armor and Engineering (A&E) Board has requested Operational Sciences Branch (Op Sci Br) assistance in designing their FOT&E for the CAM using MS as a simulant. The types of problems to be tested are large equipment, small equipment and personnel sorts; shelter contamination monitoring; field survey for key terrain and field survey for limits of contamination.

Our role is to design contamination technology and monitoring methods to accomplish the goals of the FOT&E. These test goal are as follows:

a. CAM operational verification
b. Test the man/machine interface.
c. Test the CAM use doctrine

The test conditions for the CAM are dictated in its draft employment field circular, FC 3-3-5[3]. The CAM will be expected to function under a wide range of weather conditions.
Mission weather conditions may require soldiers to use the CAM in the rain, in high wind environments and air temperatures ranging from as low as 32 °F to as high as 120 °F. It was also required that a simulant vapor hazard be produced to sufficiently challenge the test CAMs under these variable weather conditions.

Investigation of the CAM's response to various methyl salicylate (MS) vapor concentrations revealed that it was possible to produce predictable bar (hazard) response levels to the simulant for an individual CAM, but not for all CAMs. Also, real time monitoring of MS concentrations using the miniature infrared analyzer (MIRAN) 1A to support the CAM's bar readings would not be possible for all tests conducted, because the lower limit of the MIRAN's ability to detect MS vapor approaches the saturation point of the CAM. This is due to the CAM being approximately three orders of magnitude more sensitive to MS than the MIRAN (parts per billion compared to parts per million). In light of this limitation, it was decided to use referee CAM's to back-up the soldier's CAM response in the field. Another field test limitation to be taken into consideration is the control of concentration in space and time, it will be likely that two CAMs sampling at slightly different times or locations will see very different concentrations.

2. TEST APPROACH

Testing will be conducted in three phases: the equipment operational verification phase; the man/machine interface phase; and the doctrine test phase.

2.1 Equipment Operational Verification.

The equipment operational verification test will be conducted to ensure that prior to, and after each use, each CAM (test and referee) is functioning as designed and that no significant degradation in sensitivity has occurred. Valid test data must be obtained from working CAMs. Suspect failures can be checked in the field with the confidence checkers and back-up referee CAMs. The verification tests will be accomplished using a concentration controlled MS vapor generator and measuring the bar response for each CAM. The performance or response history of each CAM will be monitored throughout the FOT&E.

2.2 Man/Machine Interface Test.

The man/machine interface test will confirm that in a realistic environment, the user can locate contamination according to the equipment design. The course will be instrumented to ensure that the user is in a contaminated environment at designated locations and times as specified in the test matrix. This test will be specified by the A&E Board and will not employ doctrine. These tests are to validate that the user can successfully operate the equipment in a realistic environment. If a failure occurs and the equipment is found to be functioning properly, a user error will be scored. The user will be retrained until he/she passes the test. Passing the test indicates that the man/machine interface is acceptable and that these users are qualified to conduct the doctrine tests. The quality of training will also be scored for future use.

2.3 Doctrine Test.

The doctrine tests are to validate the CAM use procedures developed by the US Army Chemical School (Chem School) for the soldier. The A&E Board will layout realistic field problems involving contamination located at random locations and positioned within a potential hazard zone of key terrain and assets. The goal of these tests is to determine if the hazard zones can be identified, as they impact on key terrain and assets, using the CAM according to use doctrine in doctrine roles. Even if contamination is not over the key terrain or assets at the time of inspection, the user must be able to locate a contamination source which is able to produce a hazard under the given test conditions. The zones will be based on experimental data of downwind detectable distances controlled by contamination size, and moderate temperature and wind speeds. Tests will be conducted using working CAMs and certified users who have demonstrated their ability to use the CAM successfully in realistic situations. Failure to detect hazard zones will be scored and the doctrine's probability of success for each application determined according to scoring results. After completion of the FOT&E it is suggested that lessons learned be prepared and modified procedures be tested to enhance current use doctrine.

3. TEST STRATEGY

3.1 Equipment Operational Verification.

A standard vapor generator of the type used in production quality control inspection will be used to check each CAM's performance before and after each day of testing. The methyl salicylate vapor source or permeation tube, which is calibrated to release a standard concentration of vapor as a function of temperature, will be set to 0.05 mg/m^3 for a three bar CAM response. Each CAM's sensitivity will be monitored over the FOT&E test period and any degradation noted. CAMs not responding within the specified limits will either be repaired if identified by the user for repair or the test data *not scored against* the doctrine. The time of this condition will be noted. In addition to the vapor generator check, each CAM will be tested with the confidence checker. Care will be taken during these tests to minimize the exposure time of the CAM to the simulant, so the filter cap will be placed on the CAM after each bar reading taken.

3.2 Man/Machine Interface Test.

Two user tests are to be performed: the key terrain vapor hazard course and point source limits of a vapor hazard survey. Both tests will be conducted on the same course. The user will first follow a path marking where he first encounters a vapor hazard and when he/she passes out of the cloud. A person using a referee CAM will follow the user using a test CAM and confirm these results. Upon reaching his/her objective, the user will return to the marked zones and determine how far downwind he/she must go to stay out of the vapor hazard zone and mark a safe course to avoid the hazard. Scoring will proceed as follows:

a. User CAM responds and referee CAM responds - good test

b. User CAM responds and referee CAM does not - check referee CAM with the confidence checker:

  (1) If referee CAM checks out - an interface failure scored against user CAM

  (2) If referee CAM is at fault - rerun test with new referee CAM

c. User CAM does not respond and referee CAM does - check user CAM with the confidence checker:

  (1) If user CAM checks out - an interface failure scored against user CAM

  (2) If user CAM is at fault - rerun test with new user CAM

d. User CAM and referee CAM do not respond - check both CAMs with the confidence checkers:

  (1) If either CAM is bad - rerun test with good equipment

  (2) If both CAMs check out - check wind direction

If the wind direction should change during the course of conducting a test, MS vapor sources will be correspondingly relocated and the test rerun. The MIRAN 1A infrared gas analyzer will be used to detect if a significant MS vapor flux is being generated from the source should the need arise. (See Figure 1 for an example of a test course layout)

Test Set-up/Procedures.

a. Measure wind speed, direction and shift angle.

b. Layout course perpendicular to wind direction.

c. Position simulant vapor source pans as needed using distances and areas recommended by simulant use protocol.

d. Fill pans with simulant, allowing five to ten minutes for the vapor cloud to develop. (According to test matrix)

e. Check for cloud on course with a CAM and adjust the vapor source distance and/or course layout as required.

f. From off-site, randomly select a masked user with his/her test CAM according to the test matrix.

g. Provide two stakes to the user and record the time when he/she starts the test.

h. User marks where contamination is first encountered with a stake.

i. Referee follows ten feet behind user and confirms result.

j. User marks when contamination is no longer indicated with the second stake.

k. Referee confirms user CAM response.

l. Upon reaching objective user receives two more stakes.

m. User returns to original stakes and marks path around vapor hazard.

n. Referee follows user and confirms results.

o. Isolate user from other users who have not completed the course yet. Repeat tests are to be done with a different user and CAM.

p. Remove stakes and confirm vapor cloud over test path with a CAM before calling next user.

MAN/MACHINE TEST COURSE - CONCEPT

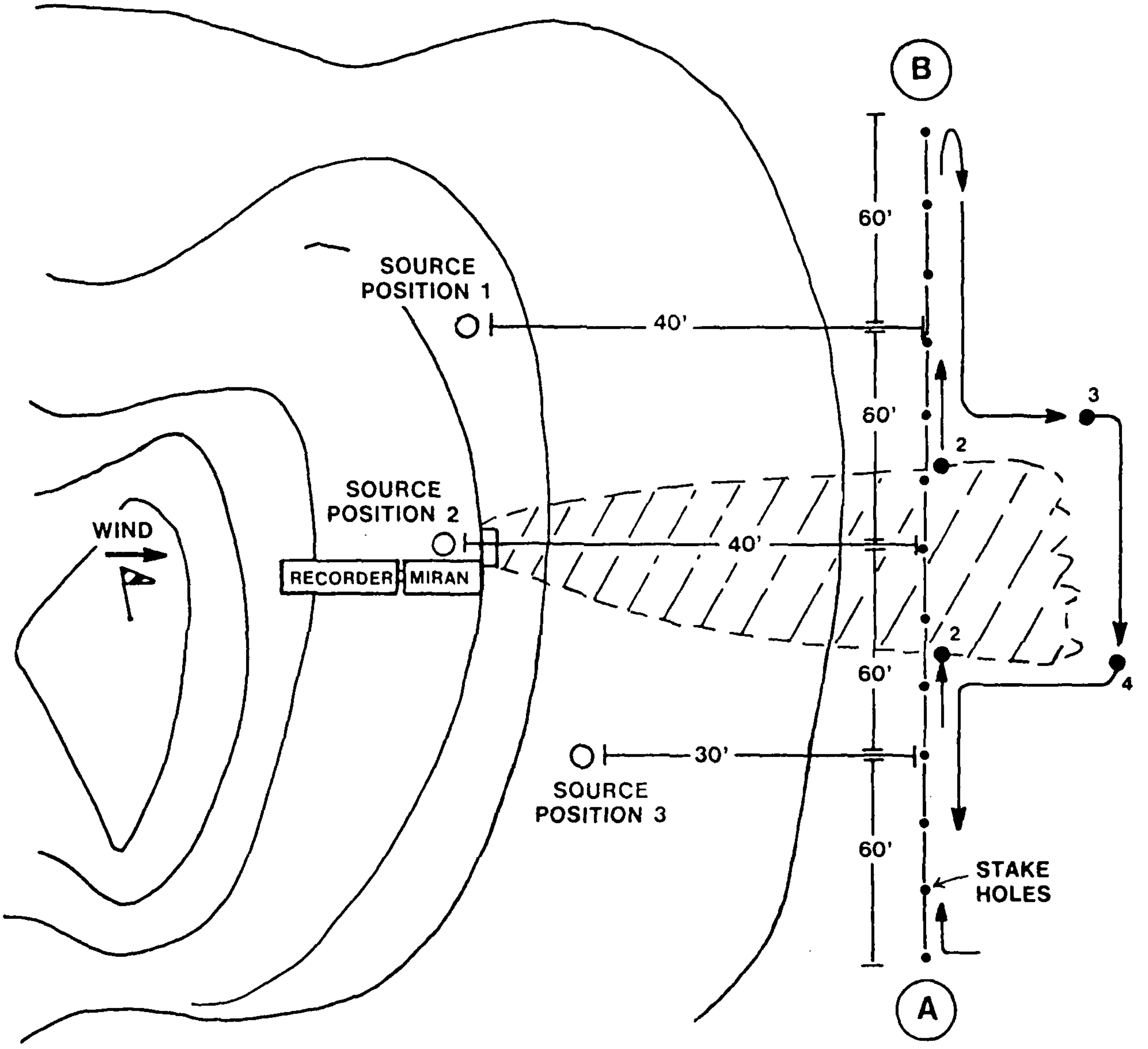


Figure 1. Man/Machine Test Course Concept

3.3 Doctrine Test.

3.3.1 Key Terrain Survey/Monitoring.

The user will travel a mapped course and locate five to ten zones of contamination crossing this terrain. The procedures used to accomplish this objective will be described by the user doctrine to be provided by the Chem School. Scoring will be based on the percent of zones identified by the users. An area of influence from the contamination source over the key terrain is a recon role for the CAM. Other mission activities on this course will be to survey two key locations for contamination and to establish a monitoring operation around an encampment. The sequence of events will be that a survey team clears a path from point A to point B (See Figure 2) and checks locations 1 and 2. A safe route will be mapped and troops will travel to point B, where a monitoring operation will be set up.

Test Set-up/Procedure.

The objective of this test is to reconstruct the hazard zones using CAM survey data which identify the potential limits of contamination to key terrain from source points. Monitoring will be conducted about a designated zone and as before, all user CAM responses will be confirmed by a referee CAM.

a. Select and layout on a map an objective course.

b. Record wind direction, speed and temperature.

c. Position five to ten vapor source points (contamination) within a three bar response to the objective course. Source points should be located on both sides, up and downwind from the course.

d. Call-up a certified masked user at random.

e. User marks hazard zones on map following doctrine procedures to accomplish tasks.

f. Data is relayed to senior NCO and evaluated. Data reported to the senior NCO maybe changed to test how evaluation changes under varying report conditions.

g. User conducts a monitoring operation at point B.

h. Isolate user from other users who have not completed the test yet.

i. Confirm MS vapor is still over course for next user with a referee CAM.

SAMPLE SURVEY COURSE

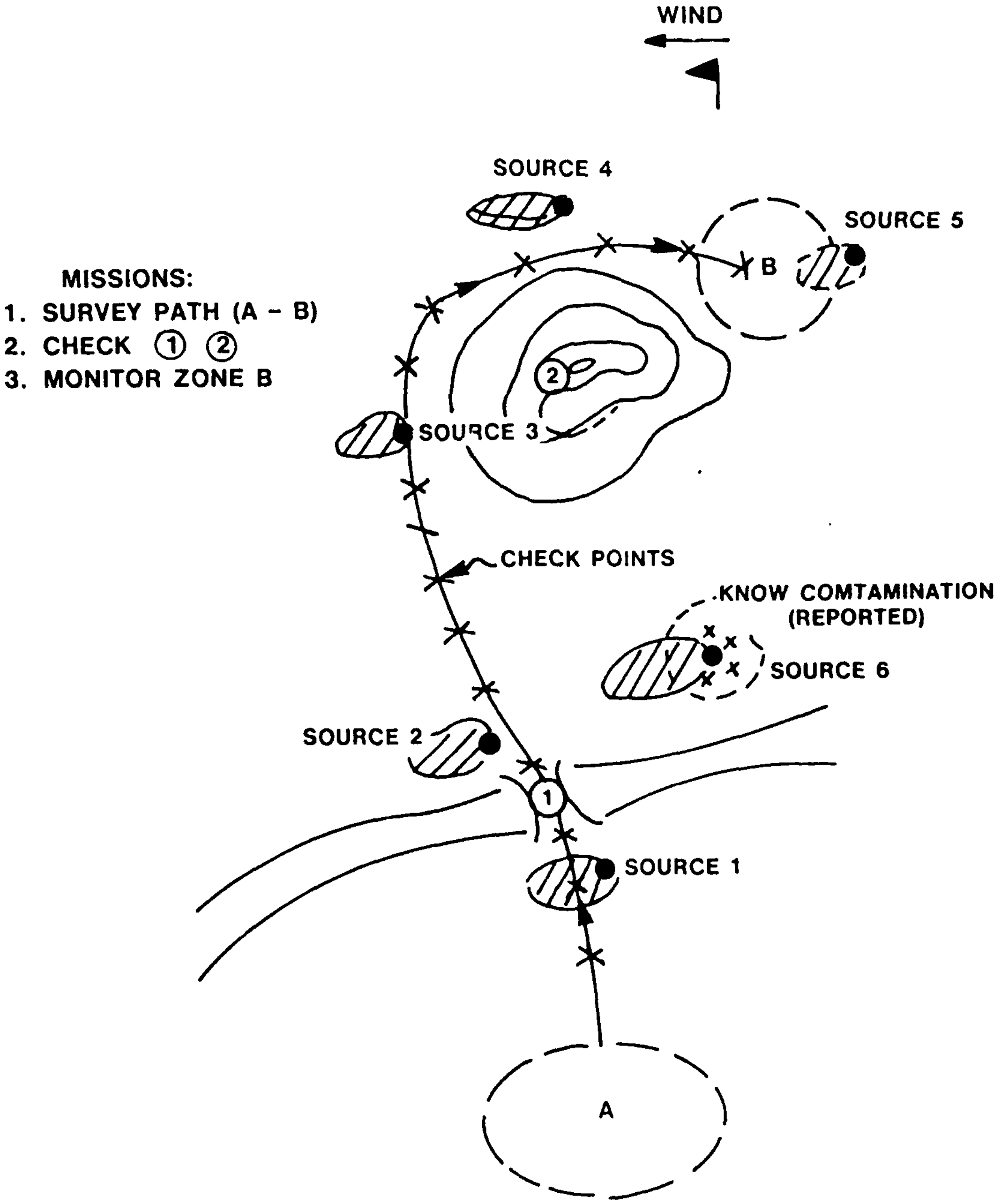


Figure 2. Sample Survey Course

3.3.2 Large Equipment Sort.

Three armored test vehicles with thirty contamination source points on each will be sorted. Some source points will contain active simulant while others will contain inert substances. One, two or all of the vehicles may be contaminated and sorting procedures will be carried out according to Chem School doctrine. Vehicles will be contaminated to a level to give at least a three bar response at not less than 10 ft downwind from the vehicle. (See Figure 3)

Test Set-up/Procedure.

The objective of this test is to have a soldier sort out the contaminated test vehicles from the clean vehicles using the CAM.

a. Record wind speed, direction and temperature.

b. According to test matrix, select vehicle to be contaminated with MS.

c. Fill positioned simulant and inert pans attached to the test vehicles accordingly.

d. Call-up a certified user in appropriate protective gear and with his/her assigned CAM.

e. User conducts sort test according to use doctrine and referee CAM confirms user CAM responses.

f. Isolate user from other users who have yet to perform the test after the current test is completed.

g. User reports test data to NCO for analysis.

h. Confirm MS vapor source points are still active by verifying with a referee CAM.

i. Call-up next user with another test CAM.

Decontamination of the contaminated test vehicles used will be accomplished by removing the simulant source pans from the vehicle(s) and washing the area where they were attached with a solvent (ethanol). A CAM will be used to confirm that no vapor source remains.

LARGE SORT

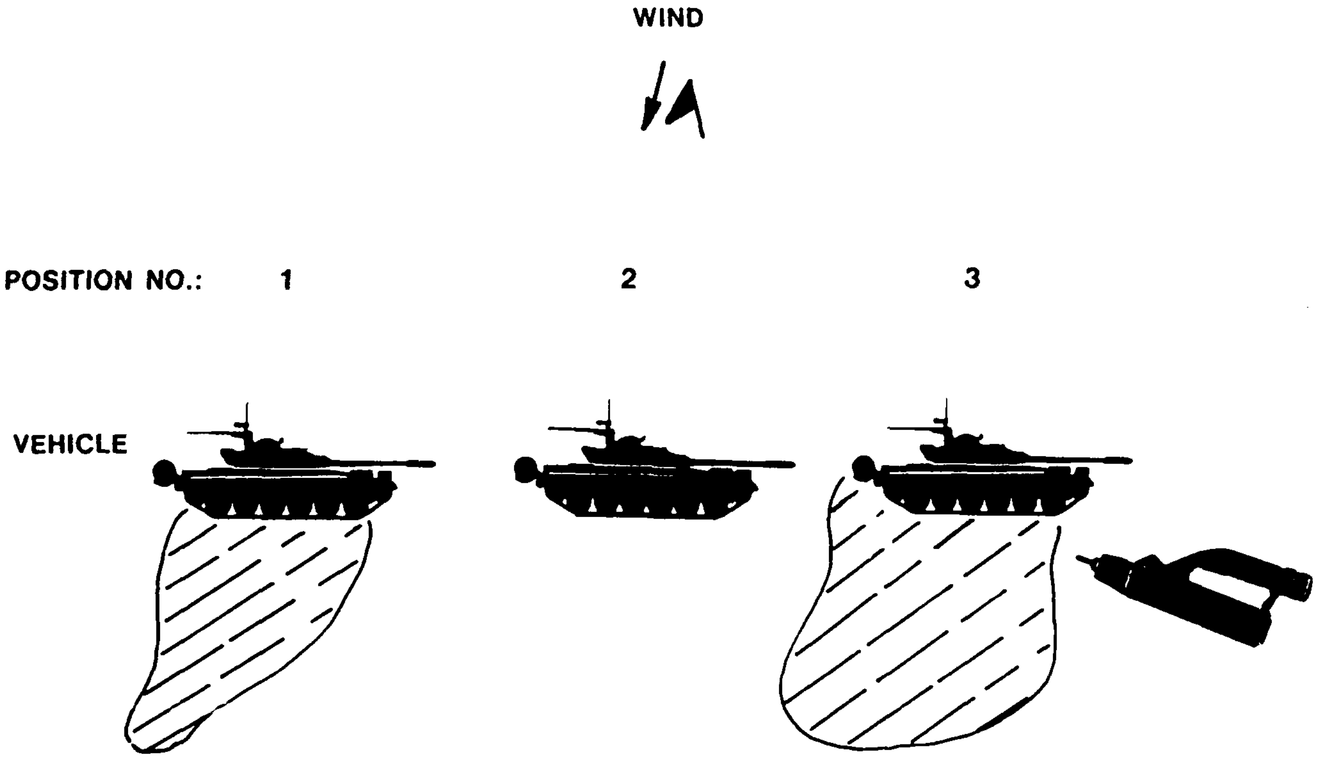


Figure 3. Large Equipment Sort

3.3.3 Small Equipment Sort.

Two, one or zero ammunition (ammo) cans/boxes will be contaminated with MS and placed together with clean cans to form a set of five cans. (See Figure 4)

Test Set-up/Procedures.

The objective of this test is to have a soldier sort the clean ammo cans or boxes from the contaminated ones using CAM doctrine.

a. Record wind speed, direction and temperature.

b. Contaminate the corresponding cans of ammunition according to the test matrix, using a calibrated syringe to ensure that all cans are contaminated equally.

c. Confirm a MS vapor is being evolved from the contaminated can by using a referee CAM. A three bar response 1 ft downwind should be obtained.

d. Select a certified user with a test CAM according to test matrix.

e. User performs sorting operation as stated in use doctrine and a referee CAM confirms the user CAM data.

f. Isolate user from other users who have yet to complete the test.

g. Recheck contaminated ammo boxes for sufficient vapor contamination using a referee CAM before calling next user. Recontaminate boxes if required.

SMALL SORT

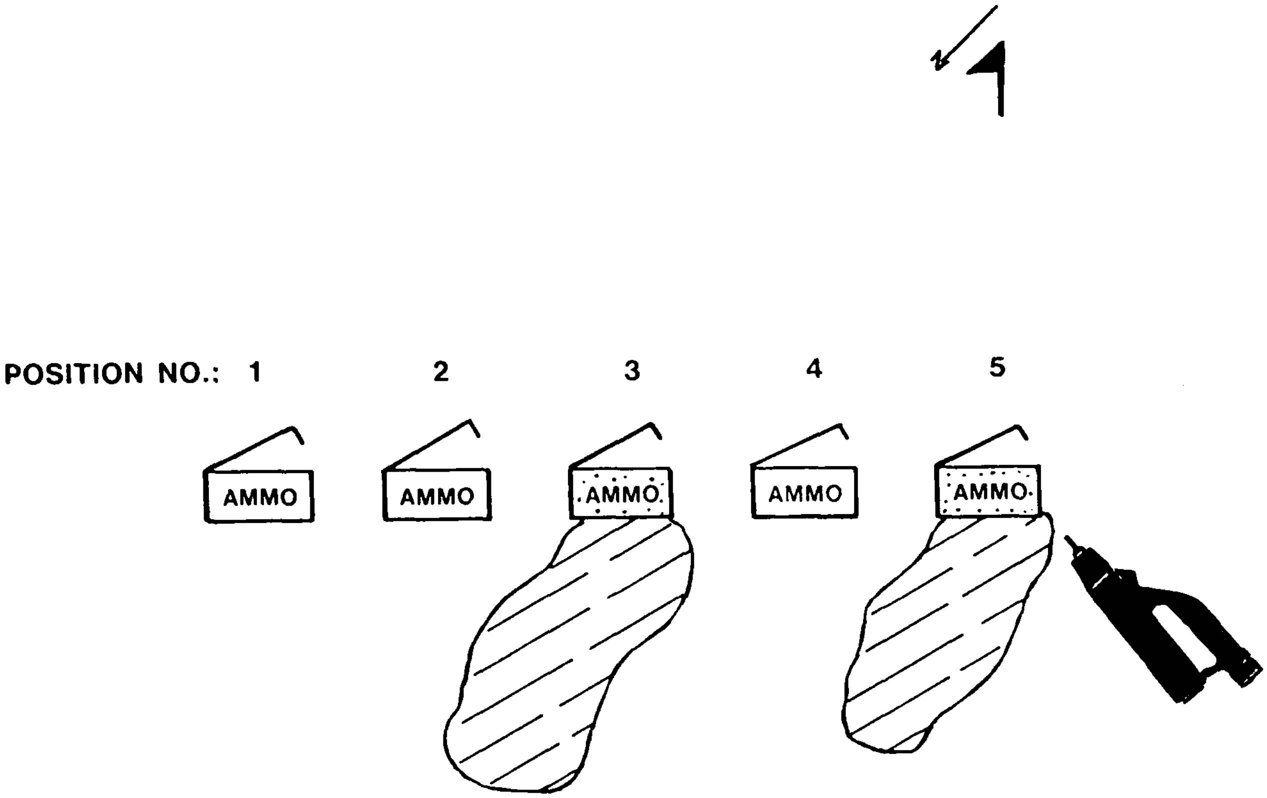


Figure 4. Small Equipment Sort

3.3.4 Personnel Sort.

Prior to entry into shelters or re-issue of equipment, personnel will be sorted to reduce the decontamination burden. Assuming hasty decontamination (decon) with redress into clean clothes, the mask hoods and boots worn by personnel will be the only sources of contamination. Therefore, these two items will be the only areas on personnel contaminated for this test. A soldier will be required to sort contaminated personnel from clean, using a CAM according to Chem School doctrine. (See Figure 5)

Test Set-up/Procedures.

The objective of this test is to challenge the CAM personnel sort doctrine. Some personnel will be contaminated on both their mask hood and boots, others will have contamination on one or the other. As before, contaminated personnel will be mixed with clean personnel, so a soldier will use a CAM to determine who is contaminated and who is not.

a. Record wind speed, direction and temperature.

b. Randomly select five test personnel to be sorted and determine who will be contaminated and where according to the test matrix.

c. Contaminate personnel by applying droplets of MS or inert simulant to their boots and/or mask hoods.

d. Confirm MS vapor from contaminated test personnel using a referee CAM.

e. Line-up test personnel and have a certified user in appropriate protective attire sort clean personnel from contaminated personnel using his/her test CAM according to use doctrine. Confirm the user CAM data with a referee CAM.

f. Isolate user from those users who have yet to complete the test.

g. Recheck MS vapor points on contaminated test personnel using a referee CAM and reapply more simulant if required.

h. Call-up next user for testing.

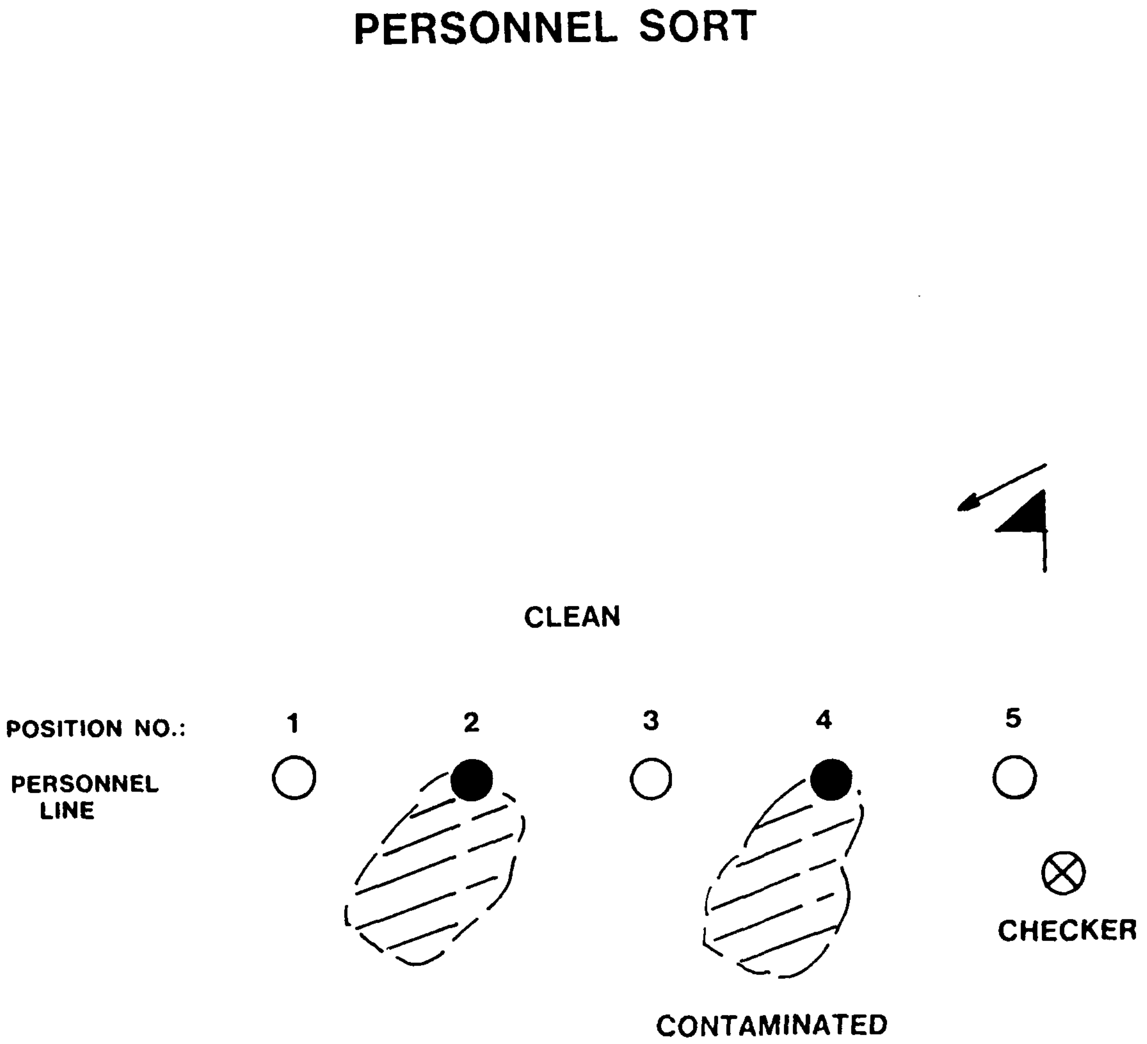


Figure 5. Personnel Sort

3.3.5 Shelter Monitoring.

During exit/entry procedures from a collectively protected shelter, it is expected that some personnel may still be slightly contaminated in spite of decontamination efforts. There is a vapor hazard threat posed by these slightly contaminated personnel. One proposed CAM application is to monitor the shelter contamination concentration to identify a breach in collective protection, by this or any other method. Liquid contamination point sources will be used to simulate the vapor threat to personnel in the shelter when a breach in protection has occurred. A user will attempt to detect the vapor threat using the CAM according to doctrine. (See Figure 6)

Test Set-up/Procedures.

a. Record shelter volume, blower air flow rate and air temperature.

b. Place three covered/contained MS vapor sources on a tray in the shelter.

c. Select a certified user with a test CAM and have user enter shelter according to doctrine.

d. According to the test matrix, send in additional test personnel at designated times.

e. Remove the covers from the MS vapor sources according to the test matrix.

f. User monitors the shelter according to CAM use doctrine and records the time when collective protection is breached in the shelter. Referee CAM is used to confirm the user CAM information.

g. Recover MS vapor sources after testing is completed and remove sources from shelter.

h. Check shelter for any residual MS contamination using a referee CAM. Monitor around the source point area and the shelter air exhaust for readings. If a simulant spill is discovered, clean the contaminated area with ethanol and vent shelter until no MS is indicated by the CAM.

SHELTER TEST

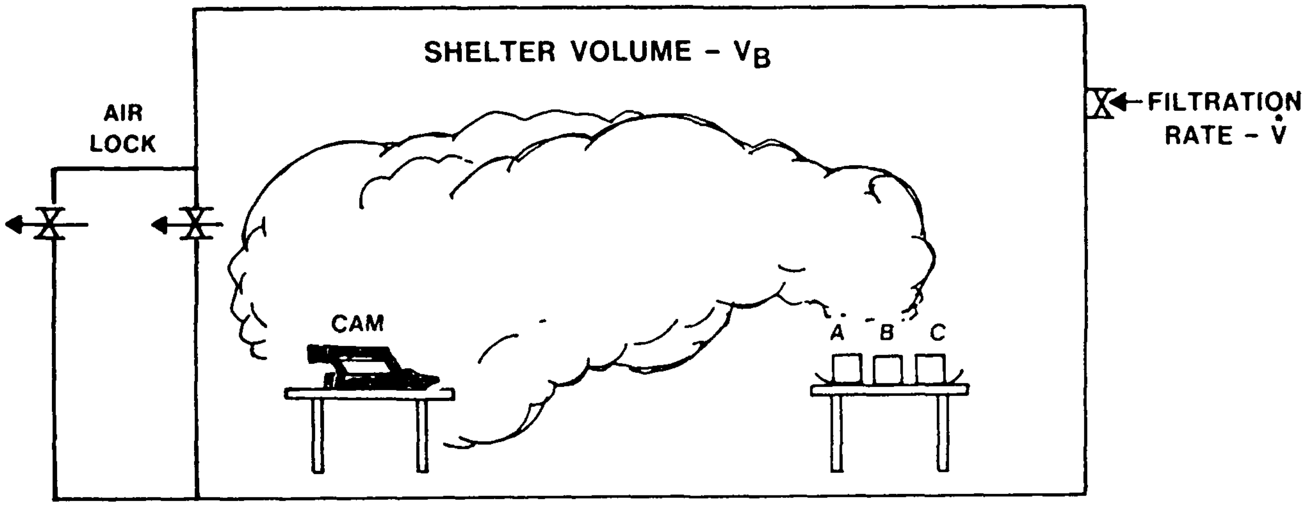


Figure 6. Shelter Test Concept

4. SIMULANT TECHNOLOGY

4.1 Vapor Contamination.

4.1.1 Field Applications.

Six 9 in. by 12 in. glass baking dishes containing the desired simulant and a foam filler material are to be placed 36 ft (approximately 12 m) from the detection point. (See Table 1 for guidance) The foam filler material should be trimmed to fit the area of the pan tightly. This precaution will not only minimize spillage, but will also enhance the evaporation rate of liquid simulant into the air. Evaporative test results indicated that the mass flux of MS vapor was greater for a vapor source with a saturated liquid foam/air interface surface than for a liquid/air interface surface.(See Appendix A) A downwind check with a referee CAM should always be used to confirm a response when a known vapor challenge is required. Based on wind speed, wind direction, air temperature and CAM readings, adjust the number of simulant vapor source pans and fine tune the distance between the vapor source and the target test area. It is important to keep the foam filler material saturated with simulant and the simulant level in the pans to within an inch of the top, because if the foam material dries out, it will inhibit evaporation. The effective downwind distance from a vapor source can be increased or decreased by raising or lowering the elevation of the pans relative to the ground. The following provides some additional guidance for using MS in the field:

a. Limit testing during wind speeds of 11 miles per hour (mph) which is approximately 5 meters per second (m/s) or less, for slightly unstable or stable conditions.

b. Limit offset (downwind) distance from the vapor source to the test path or target area to 12 m or less.

c. Run testing at temperatures of 80 °F (27 °C) or less. Test personnel are limited to wear MOPP IV gear for only fifteen minutes every hour at temperatures above 80 °F due to safety regulations.

d. As wind speed increases, (high wind velocities of 5 m/s or more) increasing the number of source pans becomes less useful due to increased eddying and dispersion of the vapor cloud. Decreasing the offset distance would work better.

e. Place vapor source pans in a line formation perpendicular to the wind direction. Increasing the number of pans tends to increase the cloud coverage over the terrain; however, downwind distance is influenced greater by wind stability and air temperature. (See Appendices A, B and C)

f. Example Problem:

1. TEST CONDITIONS: Stable, wind speed = 4 m/s, and temperature = 90 °F.

2. PROBLEM: Select offset distance between vapor source and test path, and the number of simulant pans required to produce at least a three bar response on a CAM.

3. SOLUTION: Based on the Table, a conservative solution would be test conditions stated at 80 °F with a 5 m/s wind speed, so five source pans could be placed 9 meters upwind from the test path or six pans could be placed 12 m upwind. Since the temperature is fairly high and the wind velocity is relatively low, it is recommended that six pans at 12 meters upwind be used.

Table. Field Application Guidance for an MS Vapor Source Concentration of 71.05 mg/m^3

Air Temperature (°F)/(°C)	Wind Speed (m/s)	Required Vapor Source Surface Area (m^2/number of source pans)	
80/26.7	1	0.054/1*	0.162/3**
100/37.8	1	0.054/1*	0.108/2**
80/26.7	5	0.270/5*	0.324/6**
100/37.8	5	0.216/4*	0.270/5**
80/26.7	8	0.486/9*	0.540/10**
100/37.8	8	0.378/7*	0.432/8**

* 9 m downwind distance from vapor source for a 3 bar CAM response.

** 12 m downwind distance from vapor source for a 3 bar CAM response.

4.1.2 Shelter Applications.

The following equation obtained from Appendix A, relates a 3 bar CAM response concentration after a 5-min resolution period for a source dish having a given surface area (A).

$$A = (0.05xQ)/(Fx(1-e^{-(5x(Q/V))})) \tag{1}$$

where: A = Surface area of one dish (cm^2)
F = Pad simulant vapor flux ($mg/min\text{-}cm^2$)
V = Volume of shelter (m^3)
Q = Shelter filtration rate (m^3/s)

Use the area of one source dish, since only one dish will be uncovered to release simulant vapor into the interior of the shelter at a time. This would be whenever a contaminated person would enter the shelter.(See Appendix A) Based on the experiments conducted investigating the flux of MS vapors from various pad or foam materials, it is suggested that 2-in. diameter glass (pytre) dishes with green scrub pad or Scotch Brite material be used as the vapor sources for the shelter.

4.2 Surface Contamination.

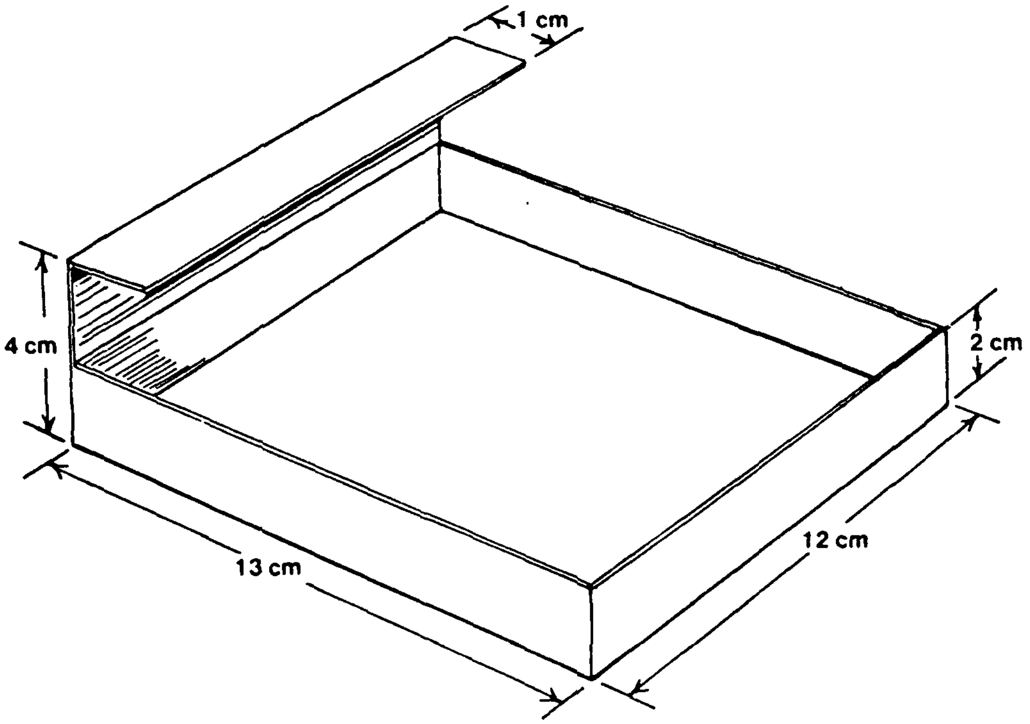
4.2.1 Small Equipment/Personnel Contamination.

It is recommended that a Hamilton Dispenser, model PB 500-1, with a 50-µL syringe, model 705 or 1705, be used to contaminate ammunition and personnel clothing. The dispenser is of a push button type which is calibrated to produce a 5-µL drop of liquid from the syringe each time the button is depressed. Five drops of MS should be applied to what ever item is to be contaminated and a referee CAM should be used to check if more drops are required or not.

4.2.2 Large Equipment/Vehicle Contamination.

The tanks and armored personnel carriers to be used for testing will have 6 in. by 3 in. metal source pans attached to them and hidden or camouflaged from test personnel sight. The pans will be attached to the vehicles by magnet or by another means which will not damage the surface of the vehicle. (See Figure 7) The pans will be filled to within an inch of the top with MS and a foam filler material will be inserted into the pan as stated in section 4.4.1.

HOLDER DESIGN



INSERT SPONGE PAD - FOAM RUBBER (OR SIMILAR MATERIAL)
- 3.8 cm X 11.8 cm X 12.8 cm

HOLDER - MAGNETIC METAL
ATTACHMENT - 2, 2 LB MAGNETS

Figure 7. Proposed Holder Design for a Simulant Source

4.3 Monitoring.

4.3.1 MIRAN-1A Operation.

Preliminary field tests using the MIRAN to monitor MS vapor concentration downwind from a vapor source were conducted (See Appendix D) and it became apparent that MIRAN use during the CAM trials to verify the test CAM readings would not be possible. The sensitivity of the MIRAN is much lower than the CAM's to MS vapor, so in order to obtain a vapor indication, the MIRAN would have to be placed to within 2 ft downwind of the vapor source instead of 40 or 50 ft downwind as with the CAM. The use of referee CAMs to confirm the test CAM responses was a result of this problem with the MIRAN. This lack in sensitivity did not mean the MIRAN was no longer required for the trials. The MIRAN-1A is a relatively durable piece of analytical equipment and it is portable. (See Appendix E for MIRAN use procedures) The instrument can still be used to verify that MS vapor is present inside the shelter for the CAM shelter test. This will be done by monitoring the ventilation exhaust of the shelter. The MIRAN also will undergo a QA/QC check at the beginning and end of each day's use and will be recalibrated if required.

4.3.2 Referee/User CAM Operation.

The use of the referee CAMs differs from the user or test CAMs in that they will be used for test preparation requirements involving vapor source confirmation, while user CAMs will be used strictly for the tests to be conducted at the trials. It is suggested that a three bar response or a 0.05 mg/m^3 concentration of MS be the target test CAM reading when preparing for a test. Both referee and user CAMs will undergo the same QA/QC checks with the vapor generators at the beginning and end of each day of testing, and a record of each CAM's response will be maintained and any degradation in performance noted.

5. CONCLUSION/RECOMMENDATIONS

This report provides the technical guidance and information on MS and DPGME simulant usage for test contamination requirements and CAM performance monitoring for the upcoming CAM FOT&E. The field test and computer generated MS vapor cloud data indicate that one could feasibly generated a MS simulant vapor cloud in a qualitative matter at a desired distance downwind and concentration, given the surrounding wind velocity, air temperature, and size of the MS liquid evaporative surface area. The contamination methods and procedures contained in this report can only be recommended, it is acceptable and highly likely that modifications to the guidance presented in this report be made, given the actual test conditions.

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APPENDIX A

EVAPORATIVE FLUX STUDIES

Tests were conducted to measure the rates of evaporation of liquid MS and MS from various pad materials. A 9 in. by 12 in. glass baking dish was placed in a test chamber. The volumetric flow of nitrogen to the chamber was carefully controlled as was its temperature and humidity. The baking pan was initially filled with MS and the first tests were performed with no pad material over the liquid surface. The next set of tests was conducted with using a green scrub pad and foam rubber material to cover the liquid surface of the pan. The air flow over the pan was also controlled and the amount of MS evaporated under the set test conditions was monitored with a MIRAN 1A infrared gas analyzer. The results indicated that the liquid MS/pad material/air interface system produced a greater evaporation rate than the liquid MS/air system. The greater evaporation rate was due to the pad material providing more surface area for air to liquid MS contact to take place. Test data also revealed that the green scrub pad material, being less dense and more fibrous when compared to the foam rubber material, provided less wetted surface area than the foam material, but allowed better air flow across this wetted surface. As a result, the green pads gave slightly greater flux values than the foam rubber pad.

A first order differential equation relating the surface area of the pan(w/pad material) containing liquid MS to the volumetric flowrate of the test chamber and MS vapor concentration generated inside the chamber was determined using the data obtained from the tests above. This equation is as follows:

$$A = (0.05xQ)/(Fx(1-e^{-(5x(Q/V))})$$

where: A = Surface area of pan (cm^2)
F = MS vapor flux from pan ($mg/min\text{-}cm^2$)
V = Volume of chamber (m^3)
Q = Chamber ventilation rate (m^3/s)

TABLE A-1. Evaporative Flux Data for MS Using a Control Chamber and a Mass Flow Controller for a Constant Evaporative Surface Area of 25.07 cm^2.

Surface Type	Max Temp (°F)	Miran Reading (mV)	Volumetric Flow (l/min)	Max Conc (mg/m^3)	Mass Flow (g/hr)	Mass* Flux ($g/hrcm^2$)
MS	84	240	10.	116.00	.0696	.002776
MS	80	155	10.	70.8	.0425	.001694
Foam	80	165	10.	76.11	.0456	.001819
Green Pad	80	200	10.	94.73	.0568	.002267

* Max readings in 10-15 min.
MIRAN used to measure concentration.
Box MS concentration kept low to prevent reduction in flux.
Weight loss was also checked and matched MIRAN results.

APPENDIX B

FIELD TEST RESULTS

The first CAM detection study was conducted to establish detection procedures and maximum downwind distances. Test conditions were judged to be slightly unstable, with local ground wind speeds of 0 to 2 mph. The temperature was high and the source was a foam rubber pad of .054 m^2 saturated with MS in a glass tray.

Due to rapid wind direction shifts the MS cloud moved much like a shaken water jet. The maximum vapor cloud downwind distance detected from this single source was about 40 ft at a height of 3 to 5 ft, having a width of about 6 ft during a short sample period.

In order to locate the cloud, it was necessary to monitor wind direction and use a CAM continuously until positive readings were obtained. This procedure will probably work best, for site contamination conformation checks, conducted prior to testing.

It should be noted that rapid wind shifts can result in MS puffs, rather than continuous coverage. Reduced distance will help under these conditions, but stable wind direction should be sought when ever possible.

The CAM study investigated the feasibility of using 2 in. x 2 in. rubber sample strips contaminated with 5 microliters (μL) of MS for personnel and small equipment sorts. 3+ Bar levels were noted beyond 2 ft. Even after extensive cleaning, solvent wipes, and dry wipes, it was possible to get high detector readings 2 ft away from the rubber. This suggests the total decon of clothing and equipment will be difficult to accomplish. Clothing will probably have to be replaced if contamination strips cannot be worn. Contamination rubber strips if used, should have a nonpermeable under layer followed by absorbent backing. Loading should be adjusted to match strip size, to prevent run off. Rubber strips should be at least 3 in. wide to prevent 5 μL drops from running off. The strips should be attached securely to test personnel clothing using a safety pin.

TABLE B-1. Downwind Vapor Plume Data for MS From a Single oint Source Using a CAM.

Distance (ft)	Height (ft)	Bar Reading (bars)
35	4	4
38	3	5
42	4	3
35	4	3
40	5	2
35	3	3
30	3	2
10	1,3,5	---
35	3	3
38	3	3

Field Test Conditions:

Source Area = .054 m^2
Temperature = 100 °F
Wind Speed = 0-2 mph, 1 ft above the surface
= 14 mph free stream reported by weather report
Wind Direction = Variable, 180°/20 min at 1 ft height
RH = 60%
Start time = 1400 hrs
Air stability = est. slight unstable
Typical width/length of cloud CWD section - 2 ft by 6 ft at 40 ft

TABLE B-2. Downwind MS Vapor Detection Data From a Contaminated Small Object.

Drop Size (μL)	Loading (drops)	Contaminated Surface Material
1	5	Rubber(Butyl)

2 foot response data - 3-6 bars before cleaning
- 2-5 bars after wipe, wash, ethanol, wipe, wash, dry wipe

TEST CONDITIONS:

TEMPERATURE = 96 °F
Local Wind Speed = 1 mph
TIME = 1100 hrs
RH = 60%
Air stability = Est. Neutral

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APPENDIX C

COMPUTER GENERATED DOWNWIND SIMULANT PROFILES

1. Discussion of Simulants.

The computer generated information provided in this appendix was obtained by using the D2PC vapor cloud model. It should be noted that some of the assumptions in the D2PC, primarily those pertaining to the vapor source release height and simulant vapor concentration dilution at lower air velocities (Reynolds Numbers) were boundary layer effects are more dominate, do not hold under the real test conditions. However, the MS and DPGME vapor data generated is a good approximation and provides a ballpark figure for test personnel to set-up the vapor contamination field, given the test air temperature, wind velocity, and desired simulant vapor concentration.

1.1 MS(HD Simulant).

a. Downwind distance for .01 and .05 mg/m^3 center-line concentration at slightly unstable conditions, variable wind speeds, temperatures, and evaporative areas are provided in Table C-2 and Figures C-1, C-2, C-3 and C-4.

b. Downwind area enveloped by .05 mg/m^3 profiles at slightly unstable conditions,variable wind speeds and temperatures are shown in Figures C-5, C-6 and C-7 using data from Table C-2.

c. Half-width concentration profiles vs stand off distance data under the following test conditions: wind speed = 1 m/s; Area = .324 m^2; Temp = 100 °F and Air stability = slightly unstable is provided in Table C-3 and Figures C-8, C-9 and C-10.

d. Vehicle above ground simulant vapor release profiles at various downwind distances and coverage areas are presented for several stabilities (slight instability & stable), temperatures, wind speeds, for .01 and .08 mg/m^3 concentrations of MS in Tables C-4 and C-5, and Figures C-11 thru C-14.

1.2 DPGME (G Simulant).

Half-width profiles at several stabilities are presented for 01, .05, .1 mg/m^3 at 100 °F; a wind speed = 1 m/s, and an evaporative area = .324 m^2 in Table C-6 and Figures C-15, C-16 and C-17.

2. Discussion of Computer Generated Data.

The data generated in this appendix came from the D2PC downwind hazard model, which was adapted to allow for spill release approximations. A major assumption in this model is that the free stream wind velocity is the same as the velocity above the surface. We have attempted to compensate for this by adjusting the evaporation length parameter (LEN). Even so, our experimental evaporation rates are two to three times higher than predicted by the model. In terms of downwind distance, this equates to 1 to 3 m less distance predicted by the model (app. 15%). In short the computer values are conservative. The assumed conditions for these runs were summer time at Lexington Blue Grass Kentucky (the closest location to Ft Knox that we have). The generated data were used to estimate the center-line downwind distance, enveloped area of cloud coverage, and half width cloud profiles for the simulant vapor cloud as defined in section 2.1.

2.1 Explanation of Terms.

Center-line Downwind Distance. This is the distance from the simulant source to the point, beyond which only lower concentrations than the designated concentrations are found. This is the maximum downwind distance possible under the specified conditions for the designated concentration.

a. Area of Cloud Coverage. This is the area enveloped by the designated concentration. Concentrations within this envelope are in general greater than or equal to the designated concentration.

b. Half-Width Profile. This profile refers to the cross-sectional area of a vapor cloud which is bisected by a centerline running from the point source to a designated concentration at a desired downwind distance from the point source. The cloud is assumed symmetric about the center line so the cloud width is twice the half-width. For vehicles with uniform contamination, add the length of vehicle normal to the wind, to the cloud width, to get the total width. The downwind distance sets an upper limit for stand off distance while the half-width data provides information on how much key terrain will be covered at or above the designated concentration.

c. Evaporative Area. This is the wetted area exposed to the environment for evaporation. Our unit of area was .054 m^2, a single glass tray.

d. Temperature. This is the ambient temperature.

e. Stability. This relates to the mixing characteristics of the air. Stability "C", is slightly unstable. Stability "D" is neutral and Stability "F" is stable. In the morning, the ground is cool and air is heating, this is a stable condition as mixing does not occur. Unstable conditions tend to occur latter in the day when the lower air is warm and the upper air is cool. Neutral is the transition condition.

f. Wind speed. Due to model approximations, use the wind speed at about 5 ft above the ground.

g. Release Height. This is the height at which the contamination is located above the ground.

h. Sample Height. This is the height at which the CAM samples the air for MS vapors and response data is obtained. To relate MS vapor cloud concentrations to CAM bar readings, Table C-1 below is provided.

TABLE C-1. CAM Bar Response To Relative Simulant Challenge Concentrations. (mg/m^3)

Bar Response	Simulant Type	
	H(MS)	G(DPM)
3	0.05	0.02
4	----	0.33
5	----	2.7
7	0.31	----

3. Discussion of Downwind Distance Profiles.

Increasing area and reducing wind speed increases downwind performance most when temperature is high. For low temperatures, you are locked into short stand off distances. The transition temperature appears to be in the 80 °F to 90 °F range. For 60 °F use 3 m or less distance with stable conditions low wind speed and areas of .3 m^2. For 80 °F use 9 m or less, with stable or neutral conditions, wind speeds below 3 m/s and areas above .3 m^2. For 100 °F use 12 m or less distance with slightly unstable or better conditions, wind speeds below 5 m/s and areas of .2 m^2 or more. In general try to run tests in the late morning with wind speeds below 5 m/s and temperatures above 90 °F. The stand off distance for .01 mg/m^3 at 60 °F appears to be about the same as the .05 mg/m^3 concentration at 100 °F. Exact CAM sensitivity will greatly effect downwind detection distance.

The symbol identifiers are as follows:

Symbol	°F	mg/m^3
□	60	.01
+	60	.05
◇	80	.01
△	80	.05
x	100	.01
▽	100	.05

3.1 Cloud Coverage Area.

Area of coverage appears to be approximately proportional to evaporation area.(See Table C-2) Wind sensitivity is greatest at the higher temperatures, but overall wind speed dependency is fairly low. Higher wind speed gives more cloud coverage.(See Figures C-1 thru C-7) Temperature on the other hand, greatly increases the area of coverage, because the evaporation rate of liquid MS is highly dependent on temperature. This suggests that sorting of small items on hot days may be difficult.

3.2 Half-Width Profiles.

Air stability is a major factor in achieving large areas of coverage over key terrain at desired concentrations.(See Table C-3) Under ideal conditions, up to 6 m of key terrain can be covered from a point source 40 m away (.324 m^2 source). 4 m of coverage should be considered about average.(See Figures C-8, C-9 and C-10) The exact sensitivity of the CAM could be expected to change he coverage by up to 4 m.

3.3 Vehicle Simulation Profiles.

For these tests, it is assumed that contamination is released 1.5 m above the ground.(See Tables C-4 and C-5) A source area of .66 m^2 gives approximately a 9 g/m^2 vapor flux from a 1000 ft^2 vehicle. Downwind data was computed at ground level, 1, 1.5, and 2 m above the ground.(See Figures C-11 thru C-14)

As expected reduced wind speed and greater release area give the best performance, however, air stability seems to be the most significant down wind distance factor. Reducing area of release has the greater effect on cloud half width and area of coverage. The .66 m^2 release can cover up to 25 m of key terrain while .33 m^2 gives 10 to 14 m.

3.4 Half-Width Profiles for DPGME.

The profiles were generated using the reported chemical/physical properties of the simulant.(See Table C-6) Since we do not have the time (or simulant) to conduct experiments to validate these predictions, it is suggested that field validation be conducted with working CAMS prior to testing.

Due to the response characteristics of the CAM, downwind detection will be better with DPGME than with MS. (ie. a 50 m stand-off with 18 m coverage at 100 °F, 1 m/s wind speed and .324 m^2 source area is generated for DPGME, but under the same test conditions, a 12 m stand-off with 4 m coverage is generated for MS. It should also be noted that for DPGME, because CAM sensitivity drops off so quickly that any reduction in CAM sensitivity will greatly reduce detection distance.(See Figures C-15, C-16 and C-17)

As expected, CAM sensitivity and air stability are the major factors controlling DPM's downwind distance and terrain coverage. A last point is one of DPM's evaporation rate. The projected evaporation rates are about three times faster than for MS, as a result, a 30 min to 1 hr refill rate can be expected.

TABLE C-2. MS Downwind Distance and Cloud Area Coverage Computer Generated Data Using the D2PC Simulation Model.

Vapor Source Area (m^2)	Temp (°F)	Wind Speed (m/s)	Downwind Distance (m)		Cloud Area (m^2)
0.054	60	1	6.0*	2.0**	6.7
0.162	60	1	11.0*	3.0**	16.0
0.324	60	1	15.0*	4.0**	29.2
0.540	60	1	19.0*	5.0**	46.7
0.054	60	3	5.0*	1.0**	5.2
0.162	60	3	8.0*	2.0**	13.6
0.324	60	3	12.0*	3.0**	25.3
0.540	60	3	15.0*	3.0**	40.7
0.054	60	5	4.0*	1.0**	4.7
0.162	60	5	8.0*	2.0**	12.9
0.324	60	5	11.0*	3.0**	24.1
0.540	60	5	14.0*	3.0**	38.9
0.054	60	9	4.0*	1.0**	4.1
0.162	60	9	7.0*	2.0**	12.0
0.324	60	9	10.0*	2.0**	22.7
0.540	60	9	13.0*	3.0**	36.7
0.054	80	1	10.0*	3.0**	9.2
0.162	80	1	18.0*	6.0**	20.2
0.324	80	1	25.0*	9.0**	36.3
0.540	80	1	32.0*	11.0**	84.5
0.054	80	3	8.0*	3.0**	8.1
0.162	80	3	14.0*	4.0**	18.3
0.324	80	3	20.0*	6.0**	33.0

Table C-2 continued:

Vapor Source Area (m^2)	Temp (°F)	Wind Speed (m/s)	Downwind Distance (m)		Cloud Area (m^2)
0.540	80	3	25.0*	8.0**	52.6
0.054	80	5	7.0*	2.0**	7.8
0.162	80	5	13.0*	4.0**	17.7
0.324	80	5	19.0*	6.0**	32.1
0.540	80	5	24.0*	7.0**	51.2
0.054	80	9	7.0*	2.0**	7.4
0.162	80	9	13.0*	4.0**	17.1
0.324	80	9	17.0*	5.0**	31.1
0.540	80	9	22.0*	6.0**	49.6
0.054	100	1	16.0*	6.0**	11.0
0.162	100	1	28.0*	11.0**	40.3
0.324	100	1	39.0*	15.0**	86.1
0.540	100	1	51.0*	19.0**	132.8
0.054	100	3	12.0*	4.0**	10.1
0.162	100	3	22.0*	8.0**	21.8
0.324	100	3	31.0*	11.0**	64.6
0.540	100	3	40.0*	14.0**	111.0
0.054	100	5	12.0*	4.0**	9.8
0.162	100	5	21.0*	7.0**	21.3
0.324	100	5	29.0*	11.0**	56.6
0.540	100	5	37.0*	13.0**	104.6
0.054	100	9	11.0*	4.0**	9.5
0.162	100	9	19.0*	7.0**	20.8
0.324	100	9	27.0*	10.0**	37.3
0.540	100	9	35.0*	12.0**	96.2

* 0.01 mg/m^3 MS vapor concentration data
** 0.05 mg/m^3 MS vapor concentration data

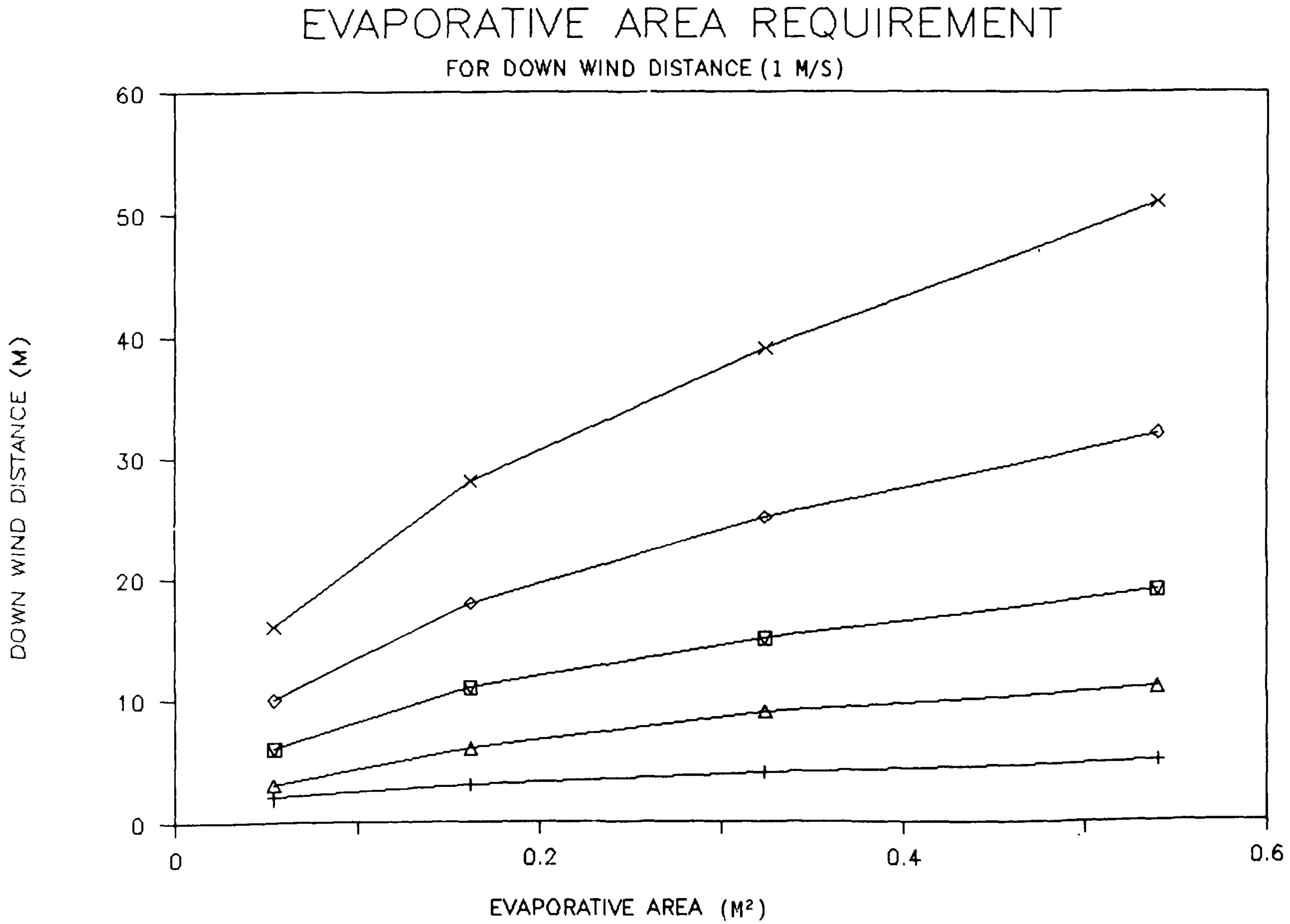

Figure C-1 - MS Downwind Distance vs. Vapor Source Surface Area Plots for a 1m/s Windspeed.

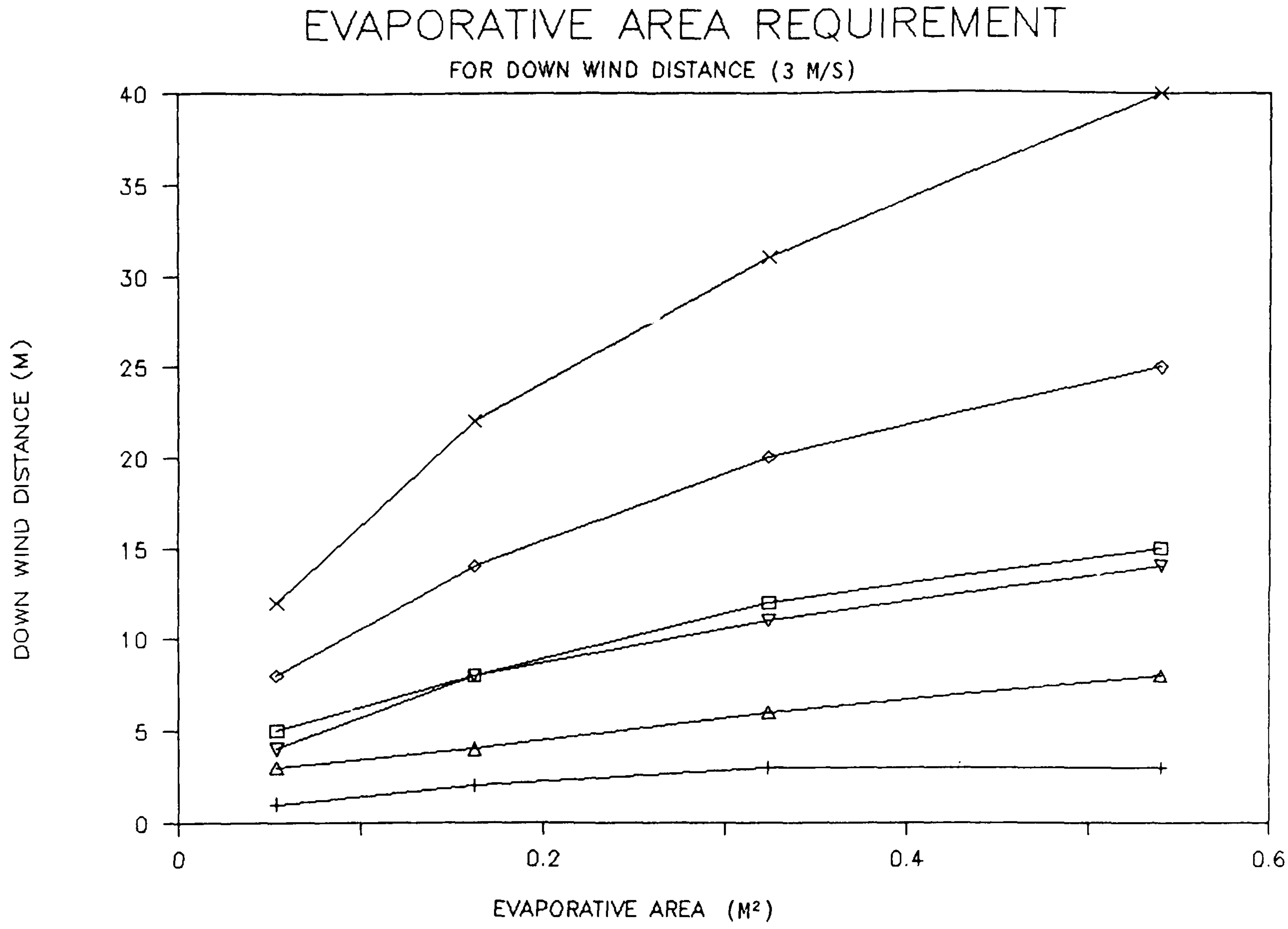

Figure C-2 - MS Downwind Distance vs. Vapor Source Surface Area Plots for a 3m/s Windspeed.

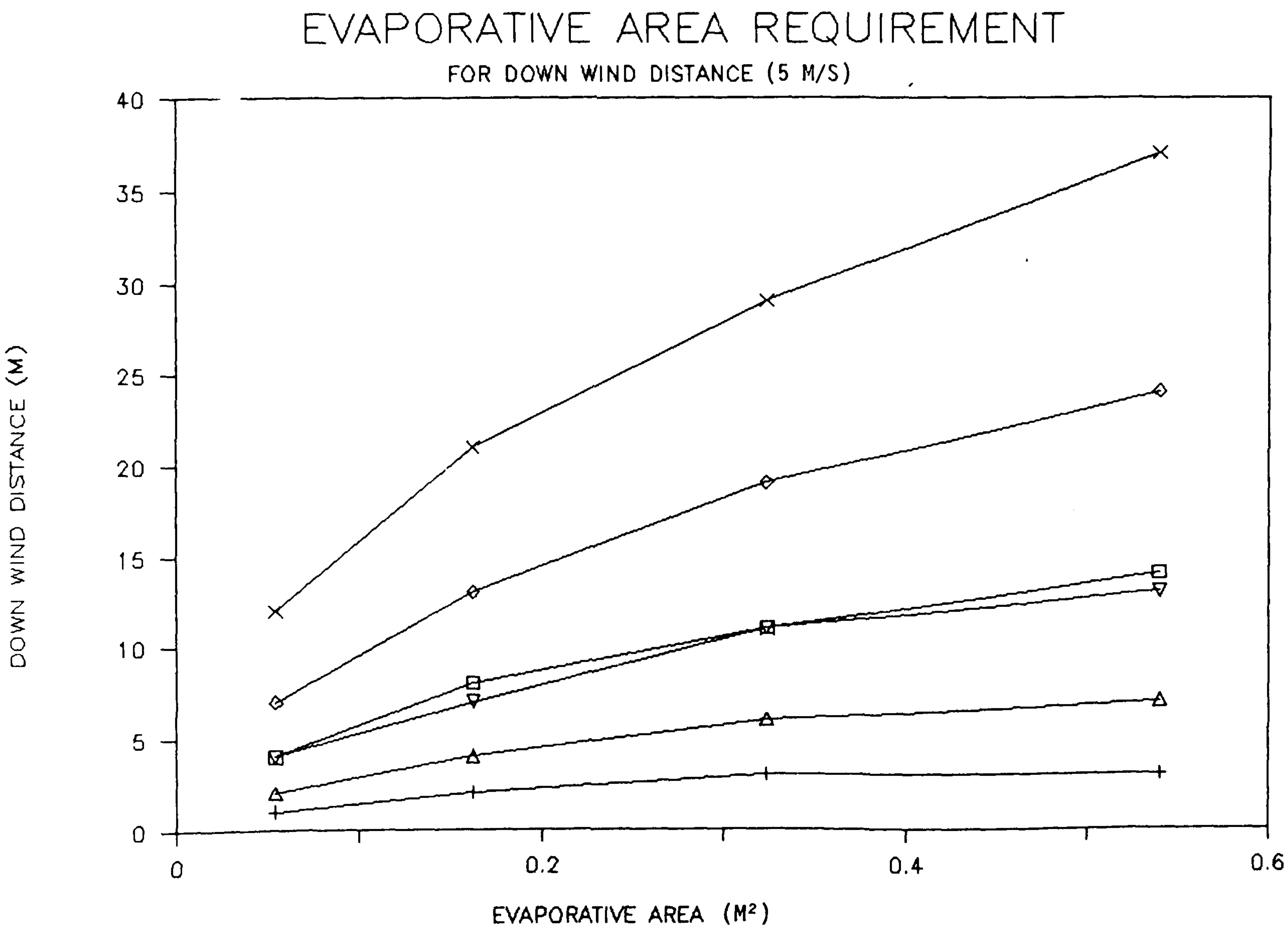

Figure C-3 - MS Downwind Distance vs. Vapor Source Surface Area Plots for a 5m/s Windspeed.

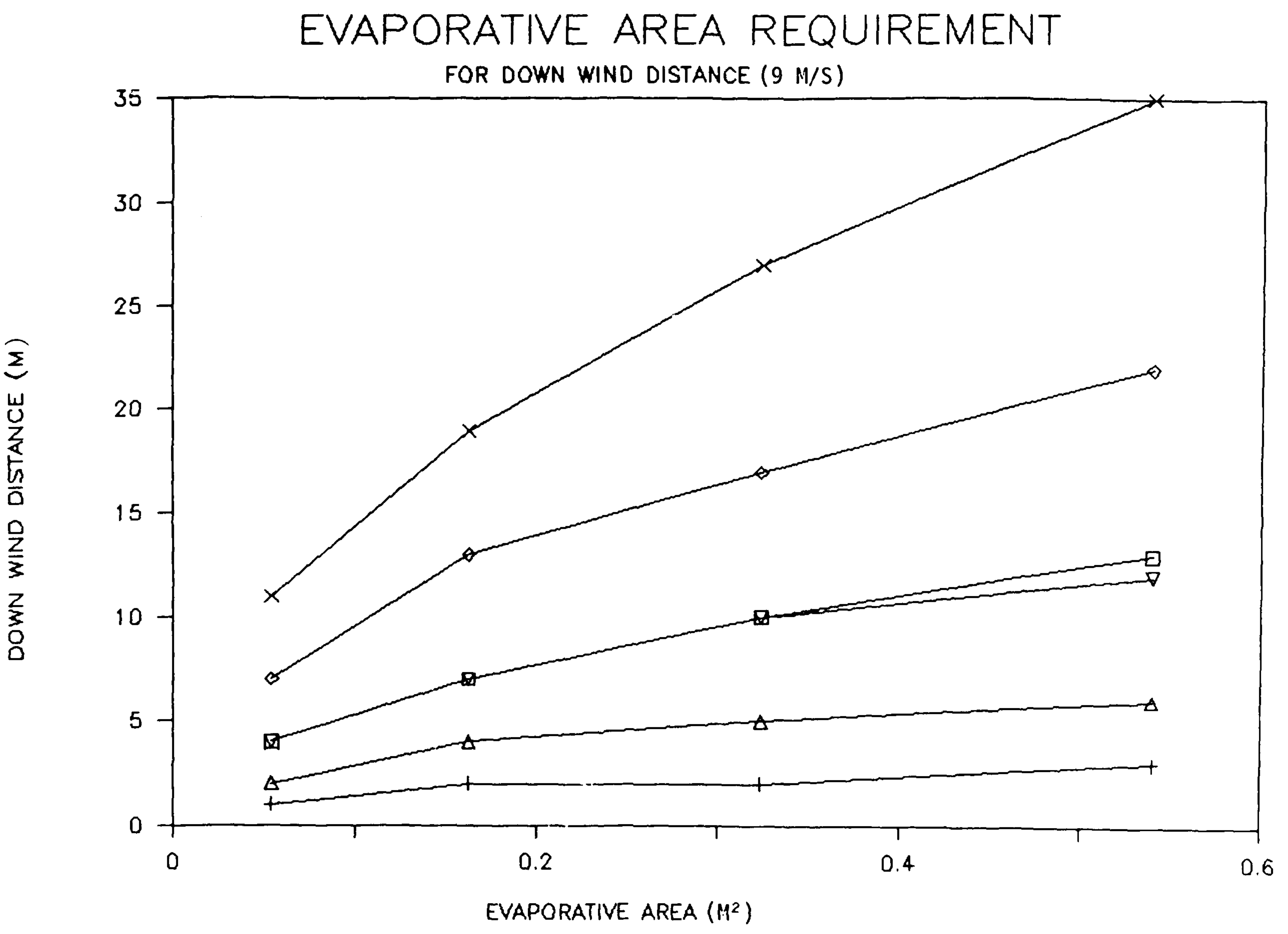

Figure C-4 - MS Downwind Distance vs. Vapor Source Surface Area Plots for a 9m/s Windspeed.

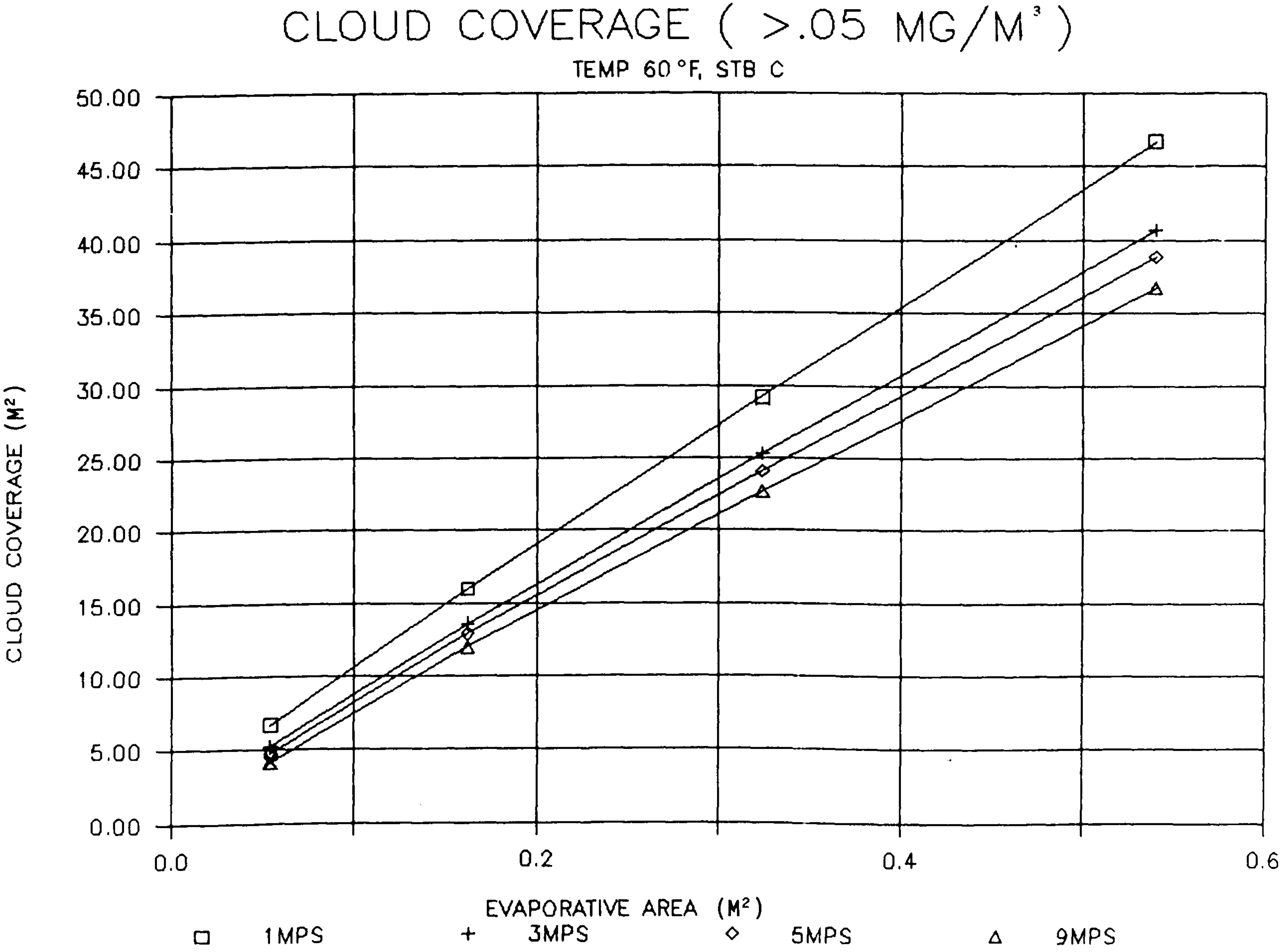

Figure C-5 - MS Cloud Coverage Area vs. Vapor Source Surface Area Plots at 60 degrees °F.

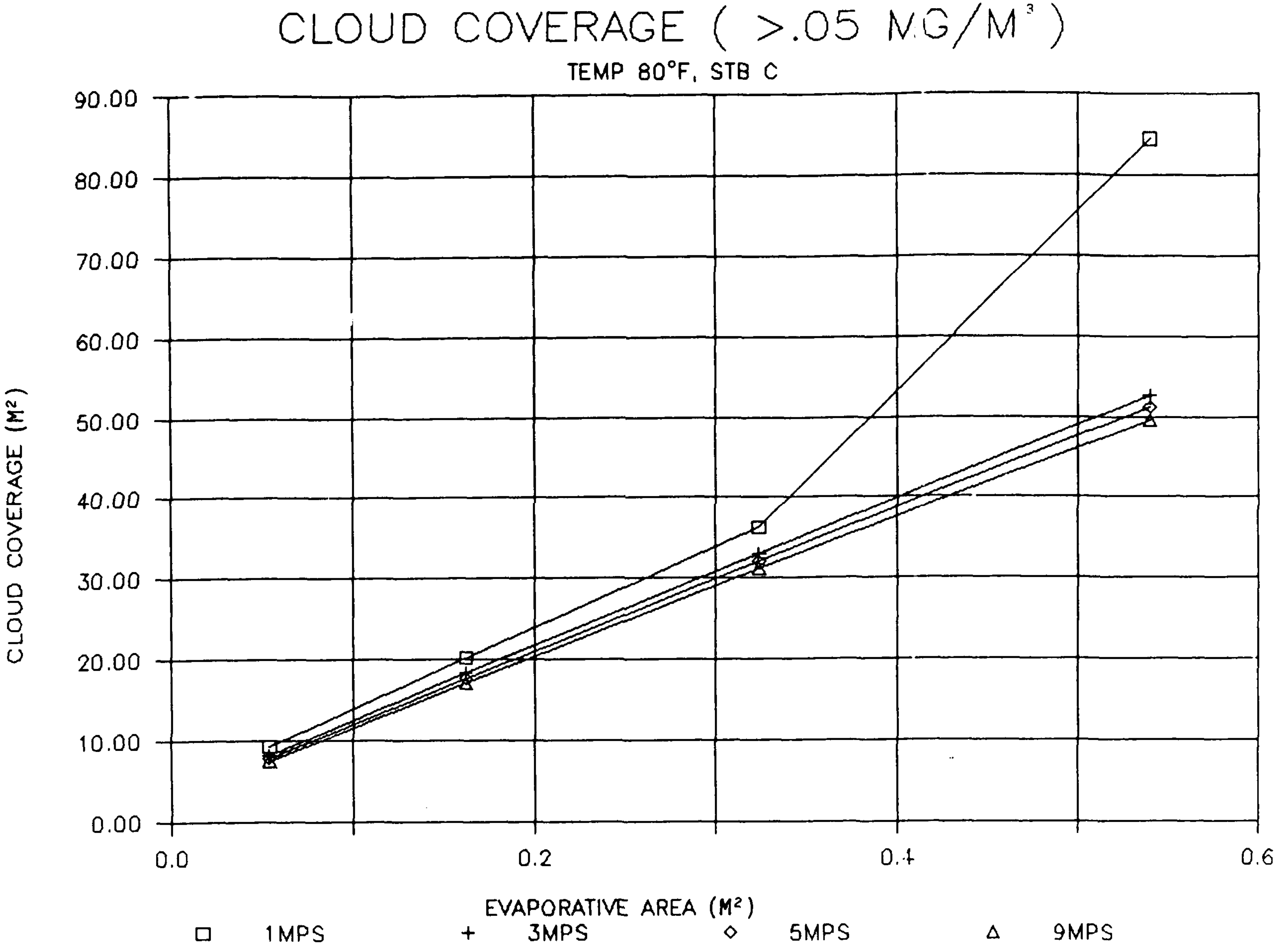

Figure C-6 - MS Cloud Coverage Area vs. Vapor Source Surface Area Plots at 80 °F.

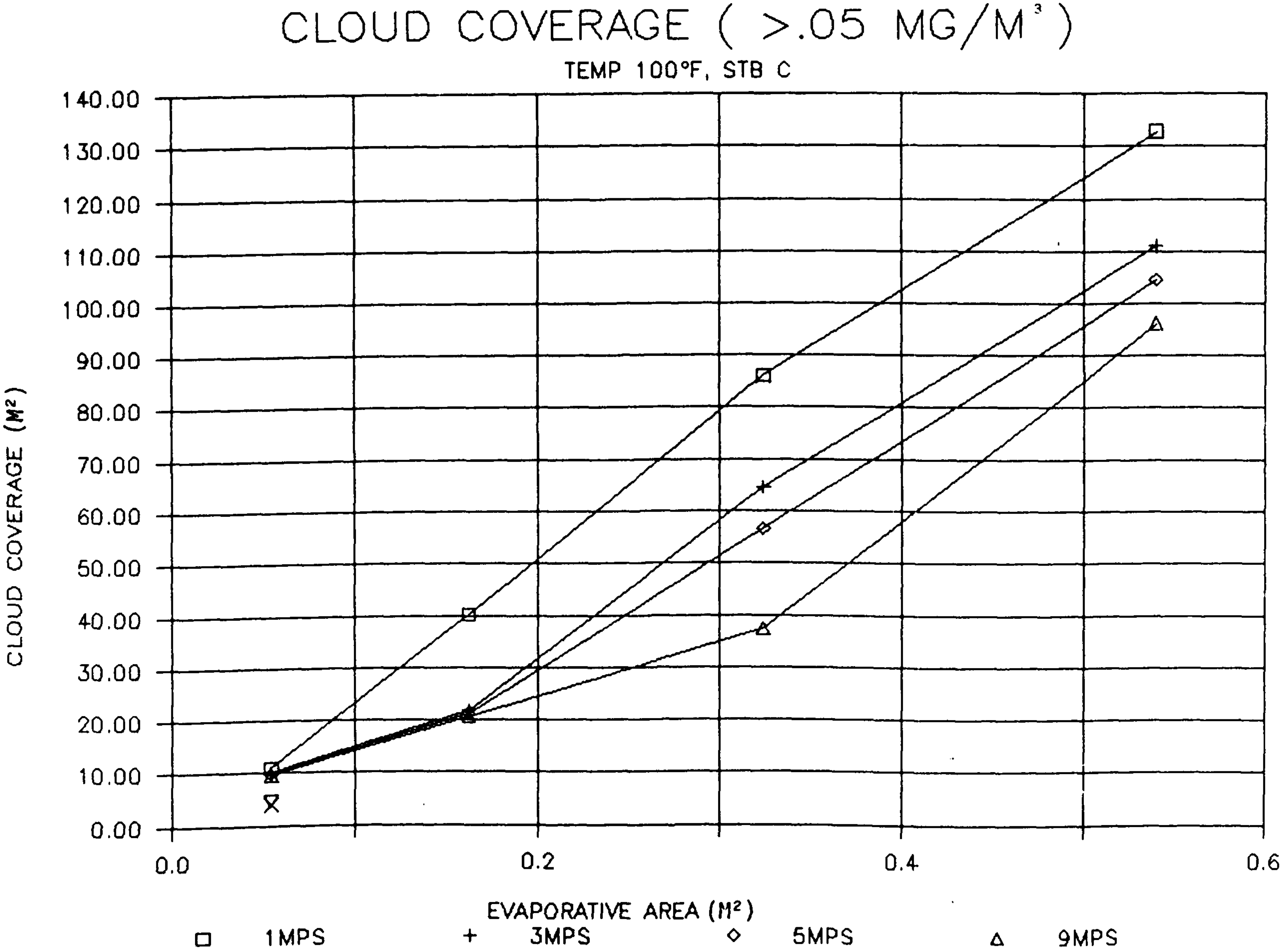

Figure C-7 - MS Cloud Coverage Area vs. Vapor Source Surface Area Plots at 100 °F.

TABLE C-3. Half-Width MS Vapor Cloud Profiles for Varying Air Stabilities and Downwind MS Concentrations for a 0.324 m^2 Vapor Source in a 1 m/s Wind at 100 F. (m)

Air Stability (STB)	Downwind Distance (m)	MS Concentration (mg/m^3)				
		0.01	0.02	0.03	0.04	0.05
F	1	2	2	2	2	2
	10	3	3	3	2	2
	20	4	3	3	3	2
	30	4	3	3	2	2
	40	4	3	3	2	1
	50	5	3	2	1	0
	60	5	3	1	0	0
	70	5	3	0	0	0
	80	5	2	0	0	0
	90	4	0	0	0	0
	100	4	0	0	0	0
D	1	3	2	2	2	2
	10	4	3	3	3	2
	20	5	4	3	2	1
	30	5	3	1	0	0
	40	5	1	0	0	0
	50	4	0	0	0	0
	60	2	0	0	0	0
	70	0	0	0	0	0
	80	0	0	0	0	0
	90	0	0	0	0	0
	100	0	0	0	0	0
C	1	3	2	2	2	2
	10	4	3	3	2	2
	20	5	3	0	0	0
	30	4	0	0	0	0
	40	0	0	0	0	0
	50	0	0	0	0	0
	60	0	0	0	0	0
	70	0	0	0	0	0
	80	0	0	0	0	0
	90	0	0	0	0	0
	100	0	0	0	0	0

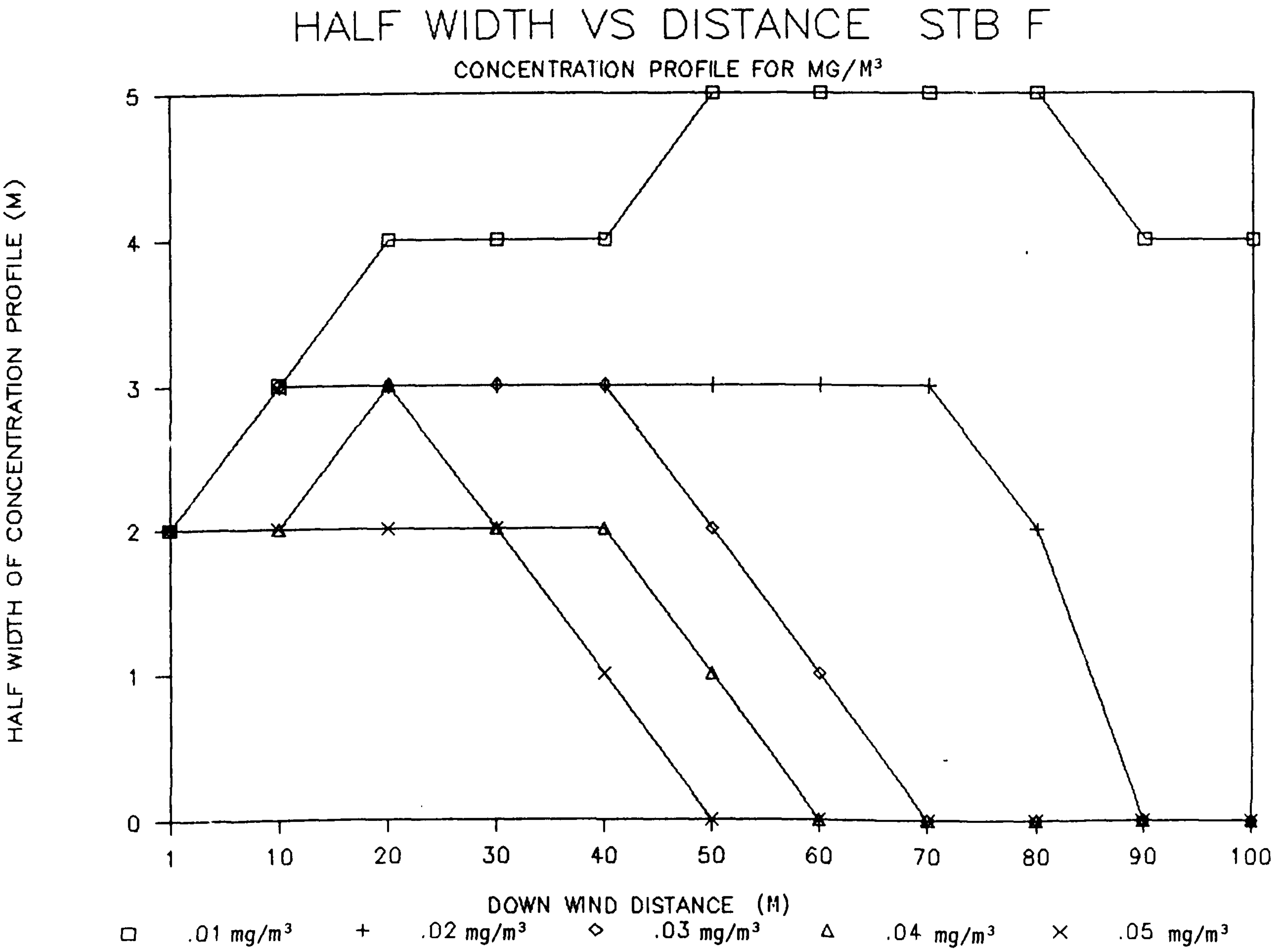

Figure C-8 - MS Vapor Concentration Half-Width Profiles vs Downwind Distance at Air Stability "F".

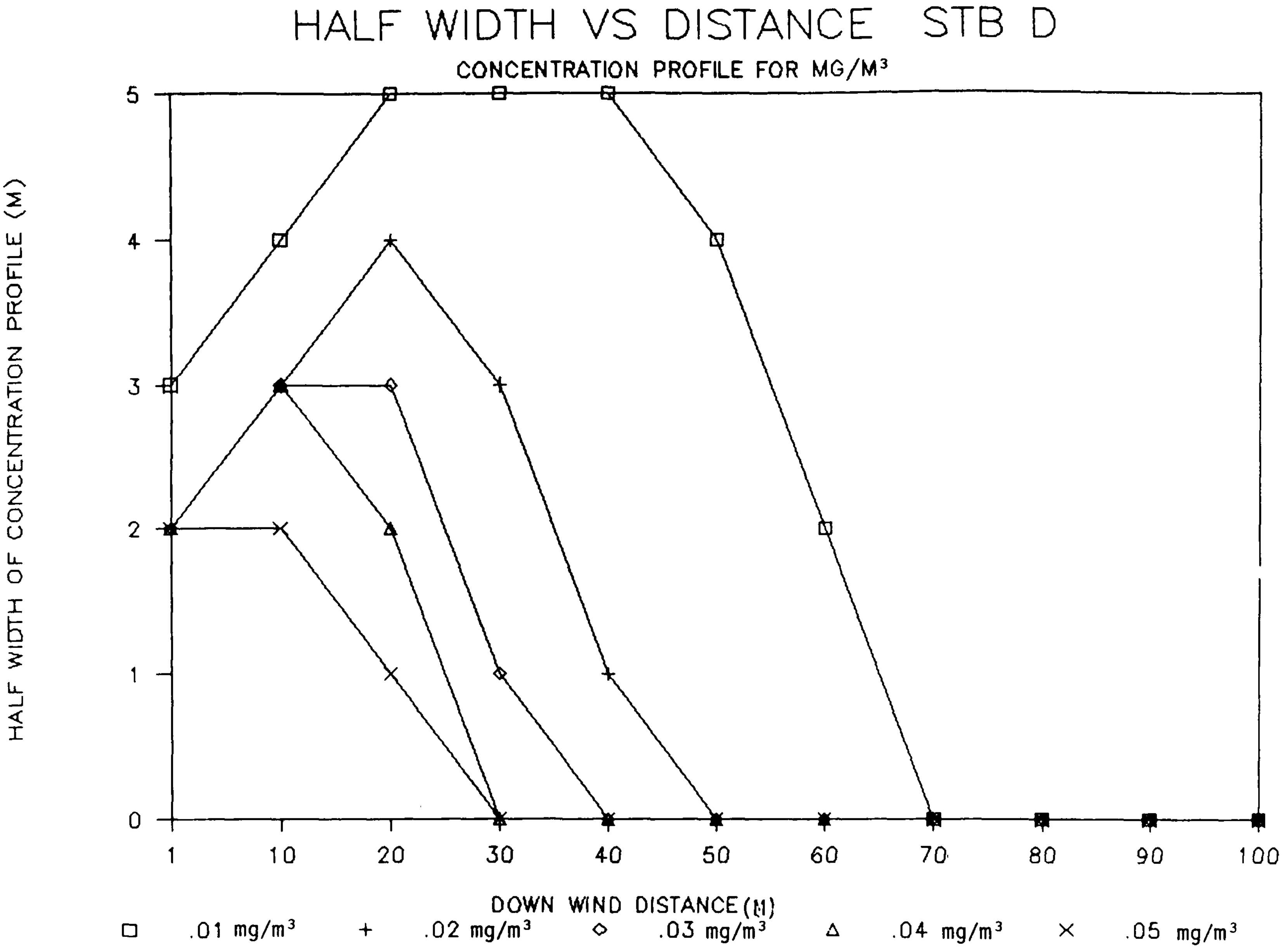

Figure C-9 - MS Vapor Concentration Half-Width Profiles vs. Downwind Distance at Air Stability "D".

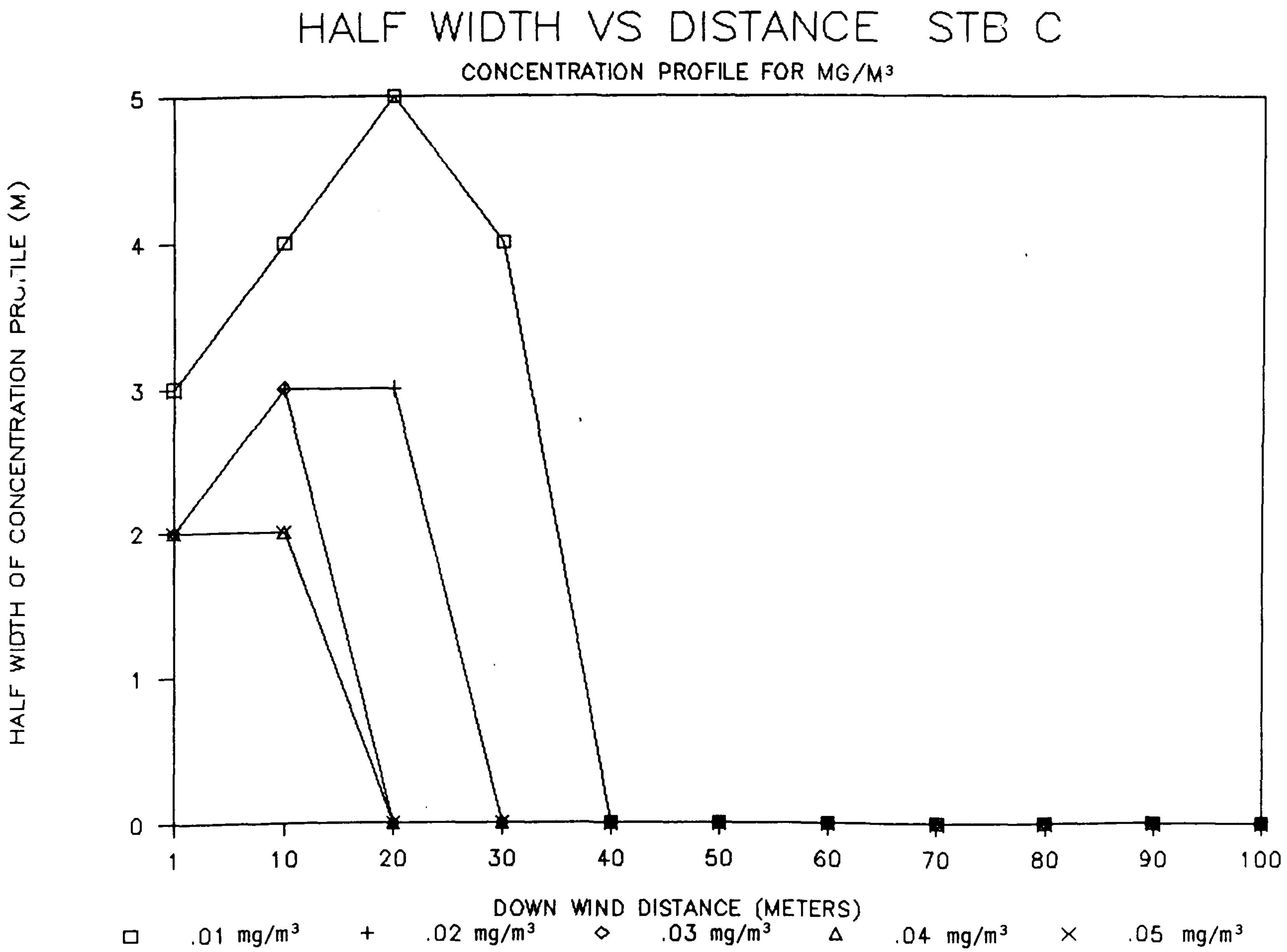

Figure **C-10** - MS Vapor Concentration Half-Width Profiles vs. Downwind Distance at Air Stability "C".

TABLE C-4. MS Vapor Cloud Data from a Contaminated Vehicle from a 0.66 m^2 Vapor Source At Various Elevations Above the Ground.

Air Stability (STB)	Release Height (m)	Temp (°F)	Wind Speed (m/s)	Downwind Dist (m)	Profile Area (m^2)
C	0	100	1	66*/21**	1563*/396**
	1	100	1	65*/17**	1228*/94**
	1.5	100	1	64*/0**	--------
	2	100	1	63*/0**	--------
	0	100	3	46*/13**	97*/27**
	1	100	3	44*/0**	65*/0**
	1.5	100	3	43*/0**	--------
	2	100	3	40*/0**	--------
F	0	100	1	315*/77**	--------
	1	100	1	312*/67**	--------
	1.5	100	1	307*/0**	--------
	2	100	1	301*/0**	--------
	0	100	3	202*/44**	3226*/585**
	1	100	3	197*/0**	2417*/0**
	1.5	100	3	189*/0**	--------
	2	100	3	177*/0**	--------
C	0	80	1	39*/10**	--------
	1	80	1	37*/0**	--------
	1.5	80	1	35*/0**	--------
	2	80	1	32*/0**	--------
	0	80	3	26*/5**	--------
	1	80	3	23*/0**	--------
	1.5	80	3	15*/0**	--------
	2	80	3	0*/0**	--------
F	0	80	1	164*/34**	--------
	1	80	1	158*/0**	--------
	1.5	80	1	149*/0**	--------
	2	80	1	134*/0**	--------
	0	80	3	101*/17**	--------
	1	80	3	93*/0**	--------
	1.5	80	3	80*/0**	--------
	2	80	3	0*/0**	--------

* 0.01 mg/m^3 MS concentration data
** 0.03 mg/m^3 MS concentration data

TABLE C-5. Half-Width Downwind Distance Profiles for MS Vapor Clouds from a Contaminated Vehicle at a Vapor Release Height of 1.5 m at 100 °F. (m)

Air Stability (STB)	Downwind Distance (m)	Wind Speed (m/s)	MS Vapor Conc(mg/m^3)		
			0.01	0.05	0.1
C*	1	1	13	10	9
	10	1	12	7	3
	20	1	13	2	0
	30	1	12	0	0
	40	1	11	0	0
	50	1	10	0	0
	60	1	6	0	0
	70	1	0	0	0
	1	3	12	9	8
	10	3	11	4	0
	20	3	10	0	0
	30	3	9	0	0
	40	3	6	0	0
	50	3	0	0	0
F*	1	3	13	10	8
	10	3	11	7	5
	20	3	11	6	0
	30	3	10	4	0
	40	3	10	2	0
	50	3	10	0	0
	60	3	10	0	0
	70	3	9	0	0
	80	3	9	0	0
	90	3	9	0	0
	100	3	9	0	0
	200	3	1	0	0
F**	1	1	7	5	5
	10	1	7	5	4
	20	1	7	4	3
	30	1	7	4	0
	40	1	7	3	0
	50	1	7	2	0
	60	1	7	0	0
	70	1	7	0	0
	80	1	7	0	0
	90	1	7	0	0
	100	1	7	0	0
	200	1	2	0	0

* Data from a vapor source surface area of 0.66 m^2
** Data from a vapor source surface area of 0.33 m^2

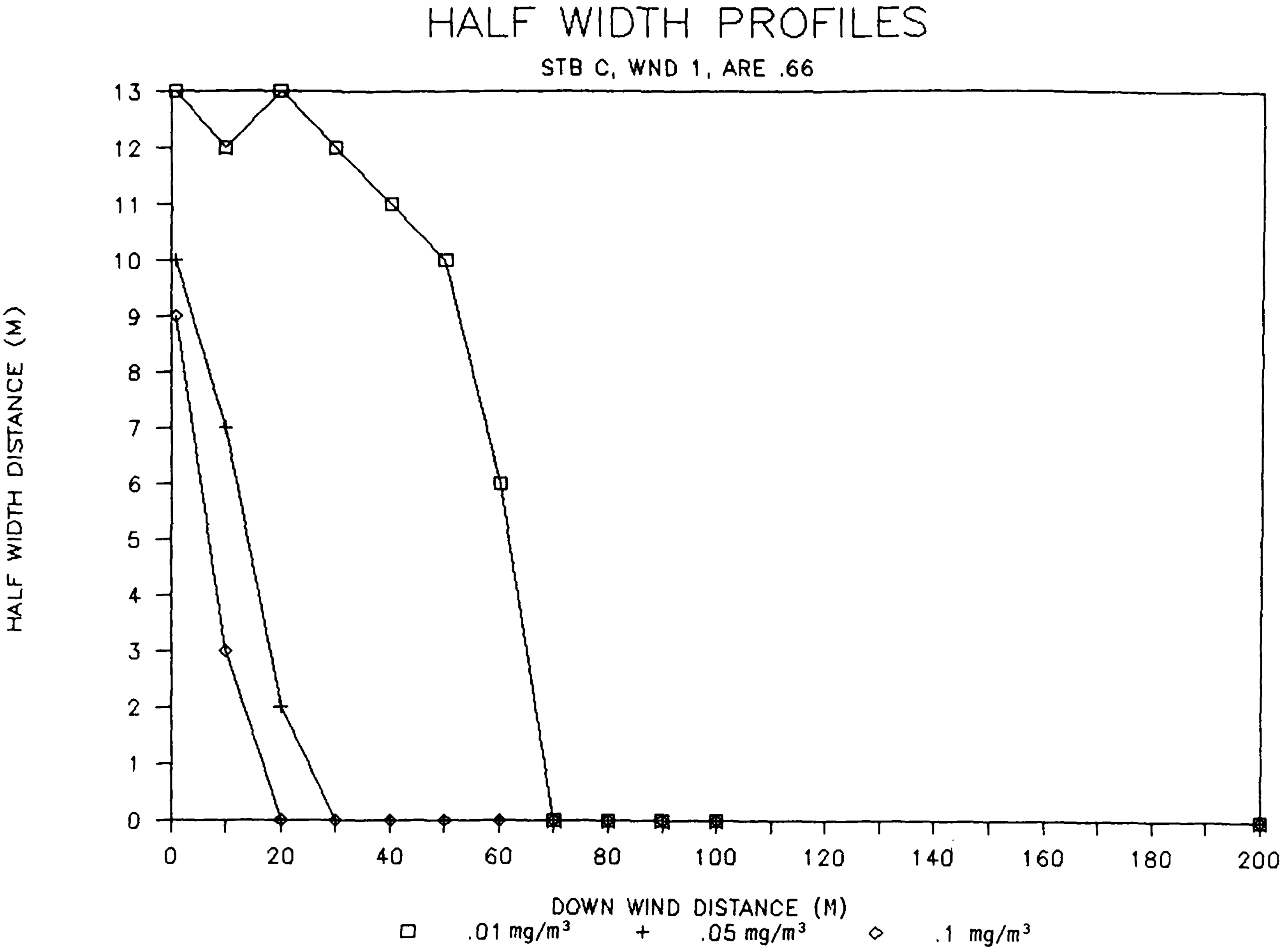

Figure C-11 - MS Vapor Half-Width Profiles vs Downwind Distance Plots from a Contaminated M1A1 Tank at a Winspeed of 1m/s, Air STB = "C" and a Source Evaporative Area = 0.66m².

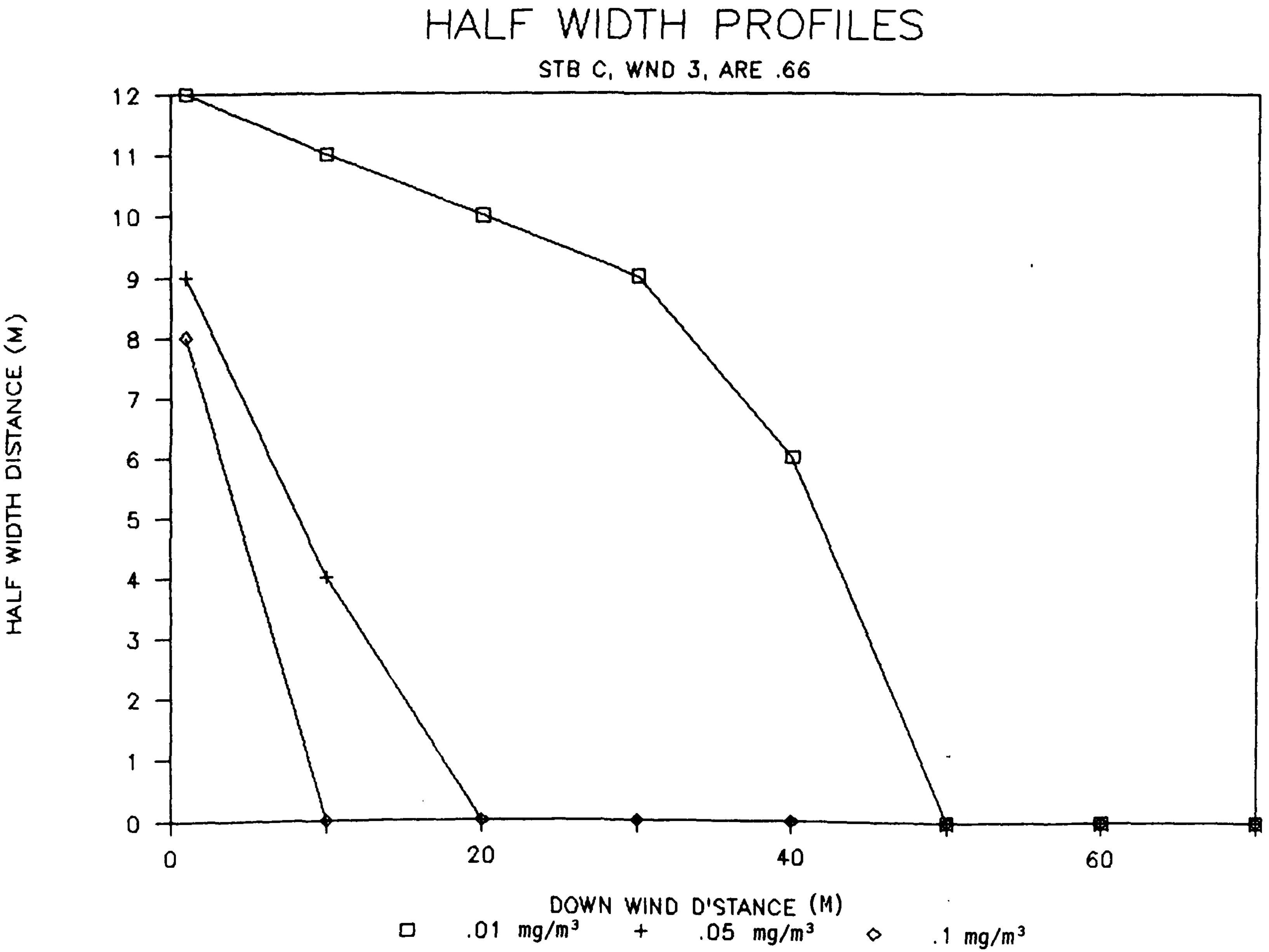

Figure **C-12** - MS Vapor Half-Width Profiles vs. Downwind Distance Plots from a Contaminated M1A1 Tank at a Windspeed of 3m/s, an Air STB = "C" and a Source Evaporative Area = 0.66m².

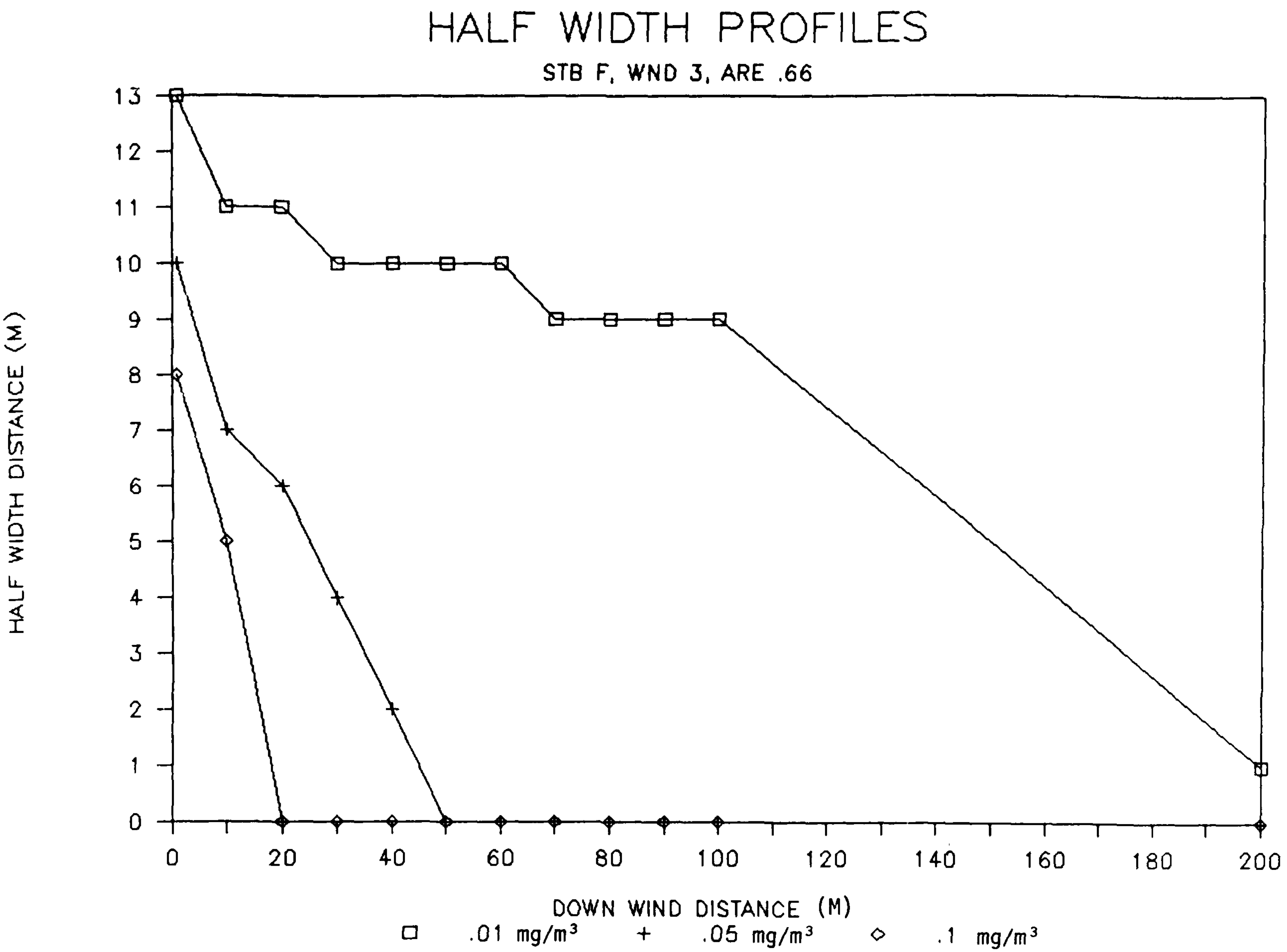

Figure C-13 - MS Vapor Half-Width Profiles vs. Downwind Distance Plots from a Contaminated M1A1 Tank at a Windspeed of 3m/s, an Air STB = "F" and a Source Evaporative Area = $0.66 m^2$.

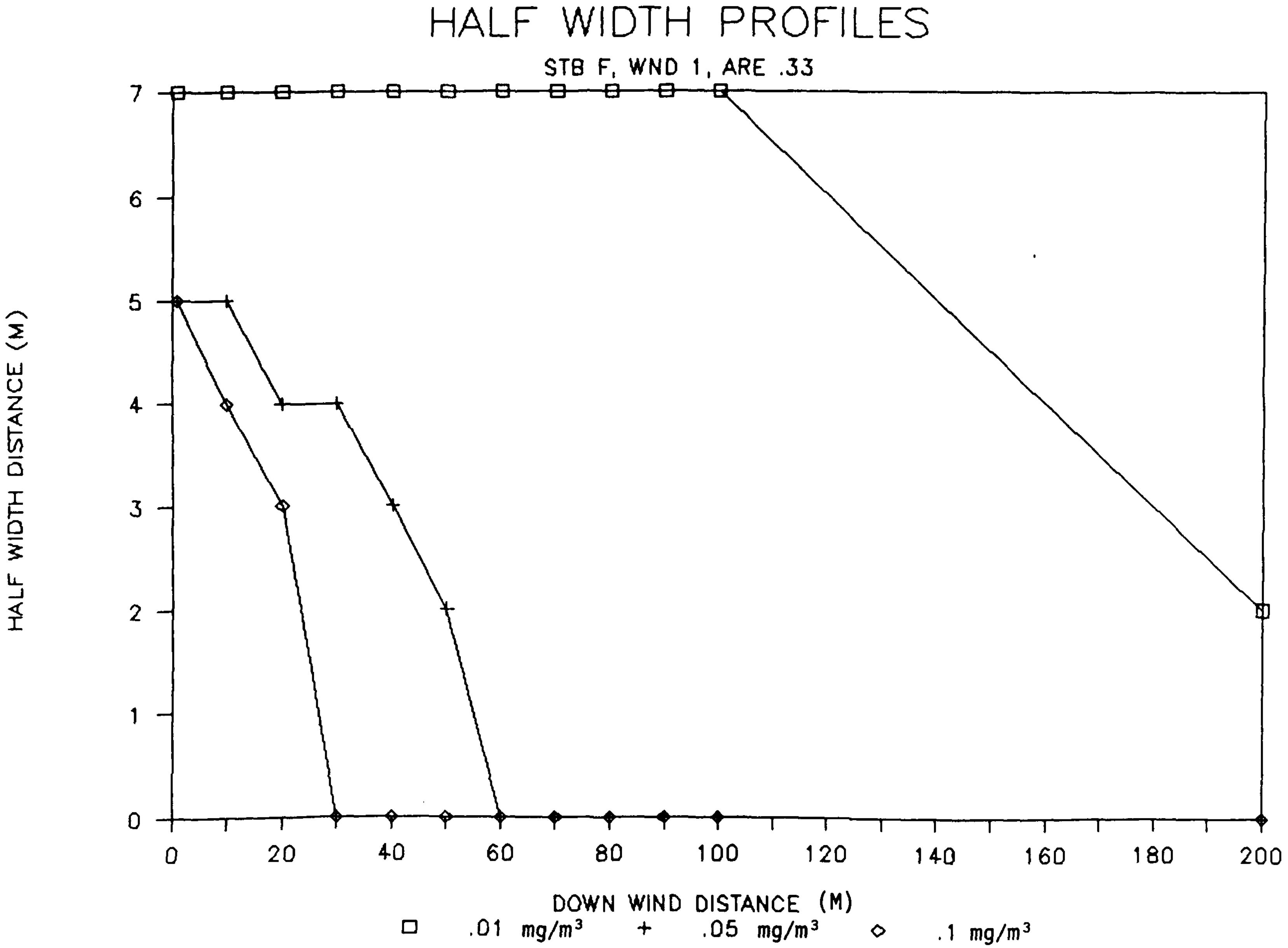

Figure C-14 - MS Vapor Half-Width Profiles vs. Downwind Distance Plots from a Contaminated M1A1 Tank at a Windspeed of 1m/s, an Air STB = "F" and a Source Evaporative Area = $0.33m^2$.

TABLE C-6. Downwind Half-Width Cloud Profiles for DPGME from a 0.324m^2 Vapor Source Surface Area in a 1m/s Wind at 100 °F. (m)

Air Stability (STB)	Downwind Distance (m)	Downwind Vapor Conc (mg/m^3)		
		0.01	0.05	0.1
C	1	3	2	2
	10	5	4	3
	20	7	4	2
	30	8	2	0
	40	9	0	0
	50	9	0	0
	60	8	0	0
	70	7	0	0
	80	0	0	0
D	1	3	2	2
	10	5	4	3
	20	6	4	3
	30	7	4	2
	40	8	4	0
	50	9	2	0
	60	9	0	0
	70	10	0	0
	80	10	0	0
	90	9	0	0
	100	9	0	0
	200	0	0	0
F	1	3	2	2
	10	4	3	3
	20	5	4	3
	30	5	4	3
	40	6	4	3
	50	6	4	3
	60	7	4	2
	70	7	4	0
	80	8	4	0
	90	8	3	0
	100	8	3	0
	200	9	0	0

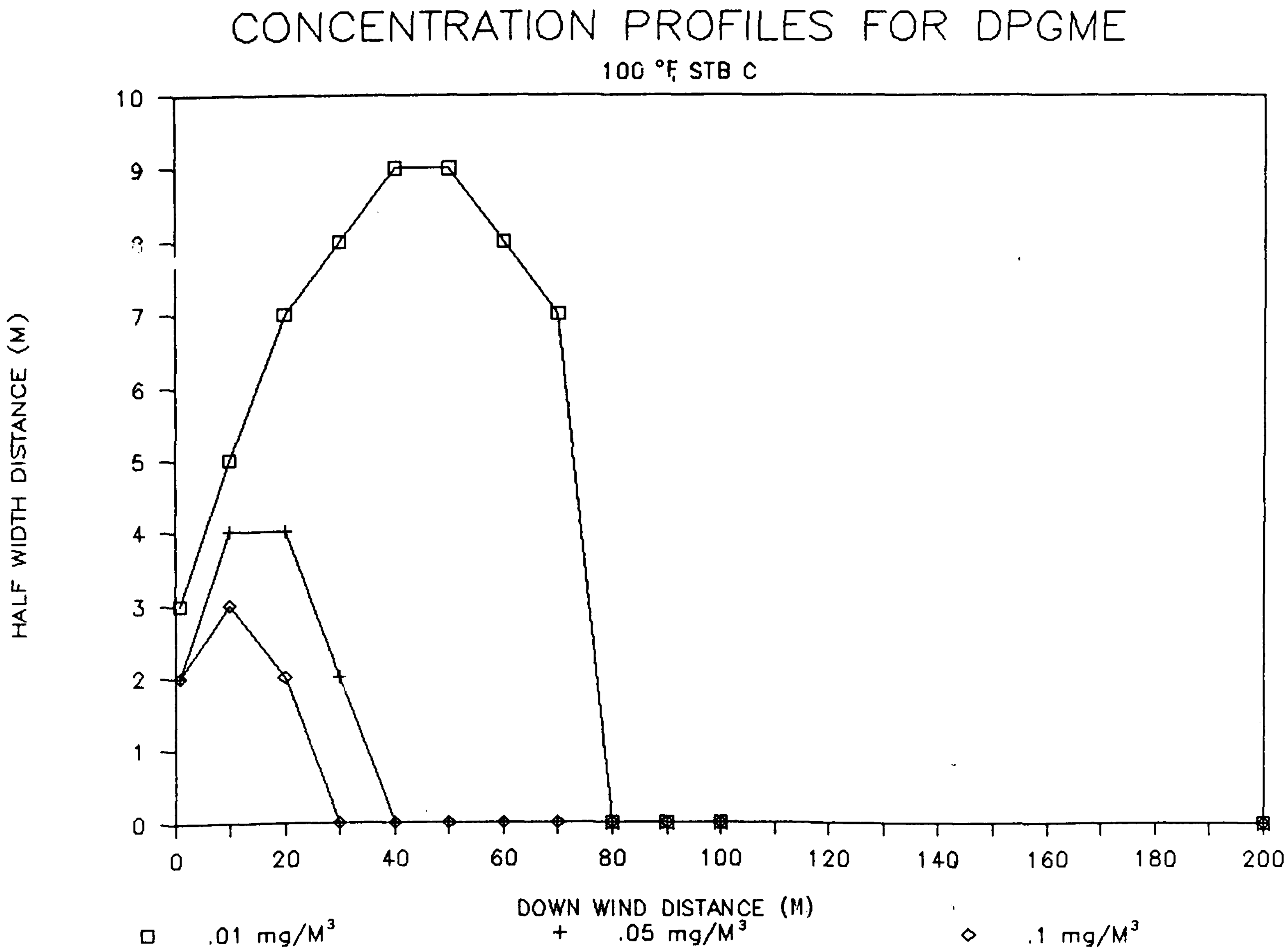

Figure C-15 - DPGME Vapor Half-Width Profiles vs. Downwind Distance Plots from an Evaporative Area Source = 0.324m² at 100 °F, Windspeed = 1m/s and Air STB = "C".

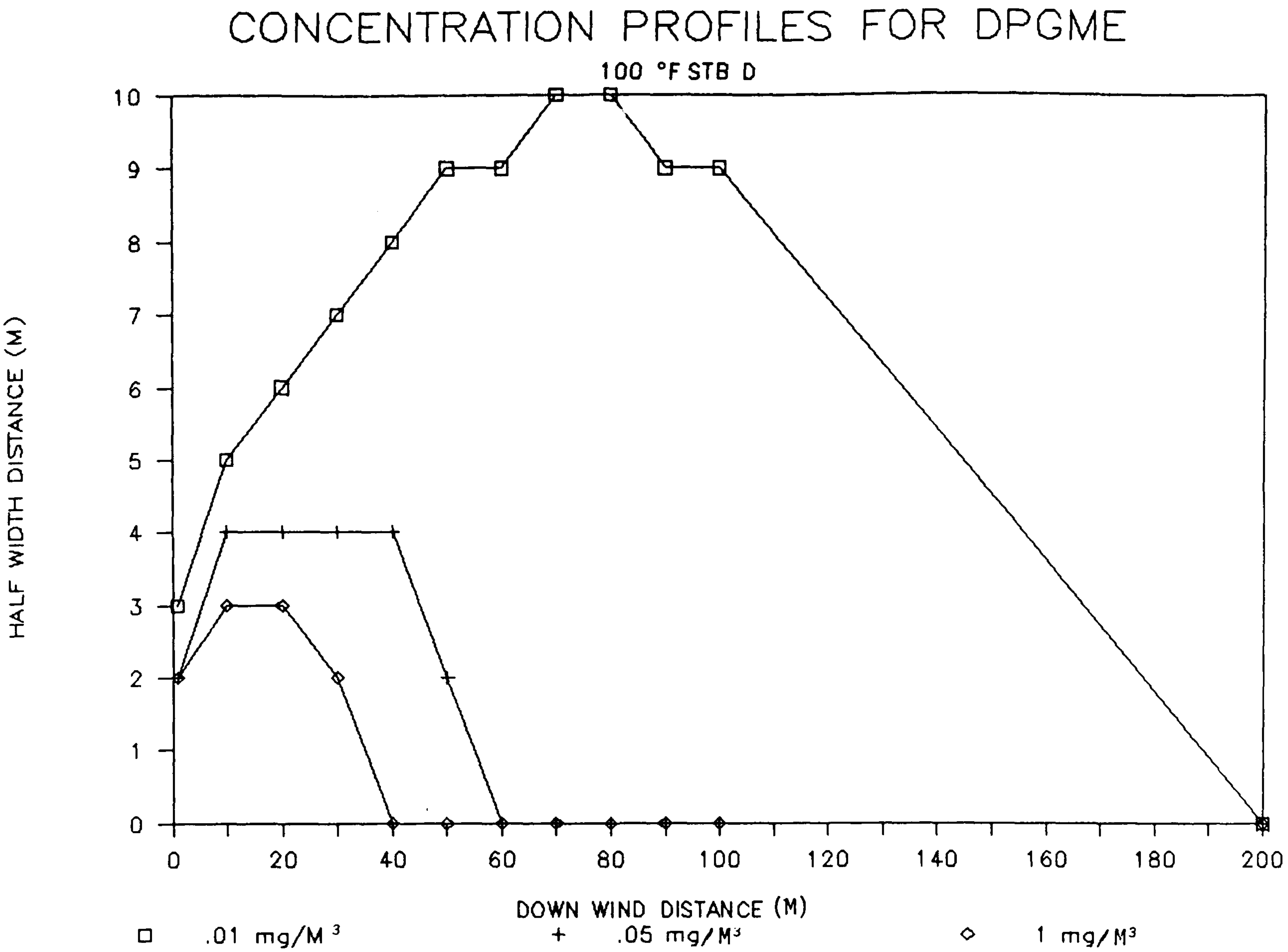

Figure **C-16** - DPGME Half-Width Profiles vs. Downwind Distance Plots from an Evaporative Area Source = 0.324m² at 100 °F, Windspeed = 1m/s and Air STB = "D".

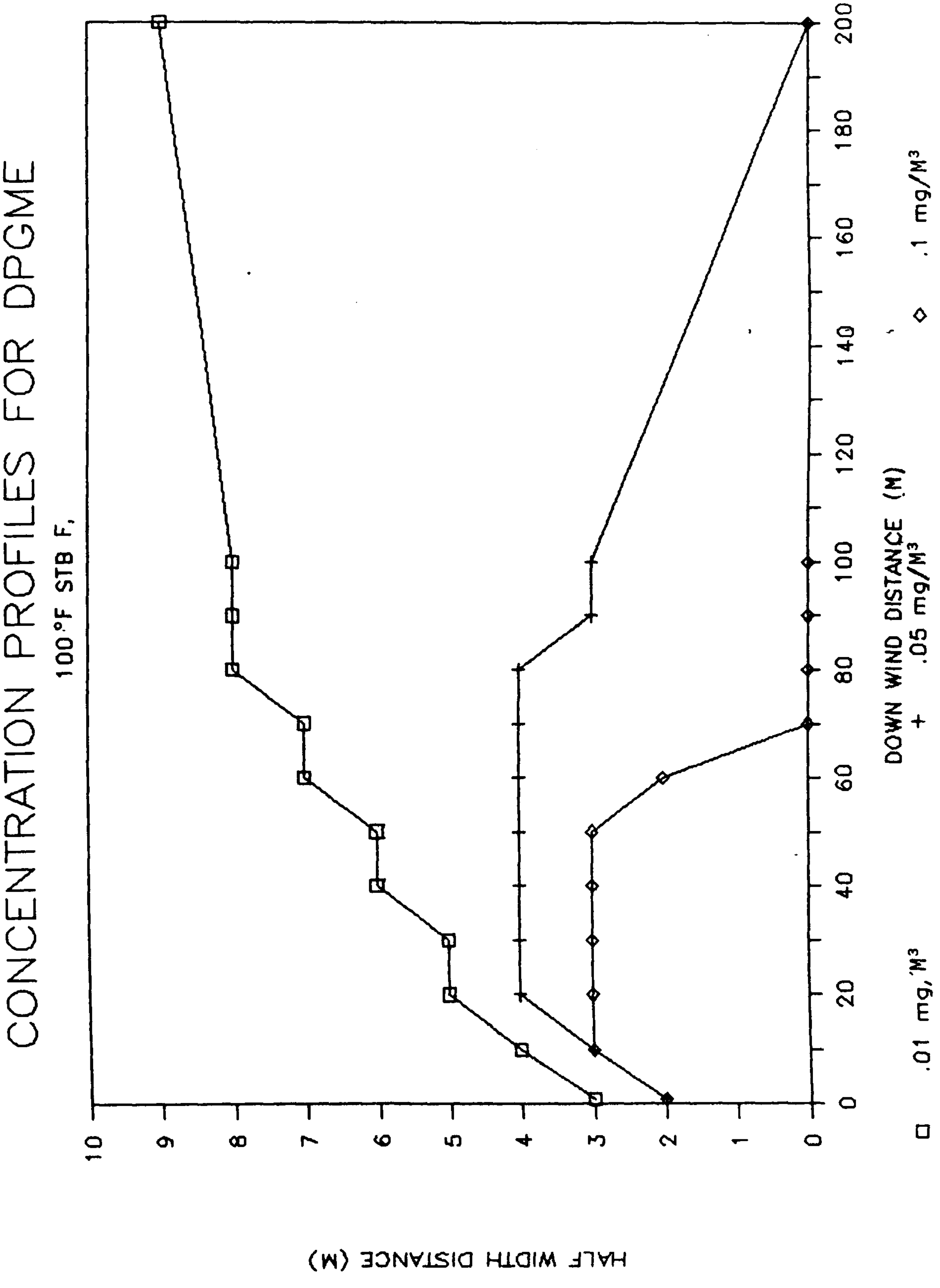

Figure C-17 - DPGME Half-Width Profiles vs. Downwind Distance Plots from an Evaporative Area Source = 0.324m² at 100 °F, Windspeed = 1m/s and Air STB "F".

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APPENDIX D

MIRAN TESTS

1. Background.

The MIRAN 1A is a long pathlength infrared spectrometer, and is currently planned to be used during CAM FOT&E testing to monitor and verify the MS vapor flux leaving a point source a given distance downwind. The MIRAN is relatively portable and a durable instrument, so it should perform well in the field. However, the MIRAN is approximately two orders of magnitude less sensitive to MS than the CAM, so there is a question of how far downwind from the source the MIRAN would have to be placed to reliably analyze the air for MS vapors.

2. Purpose.

The purpose of this test was to investigate how far downwind the MIRAN could consistently read a concentration of MS vapor in the air.

3. Test Equipment.

The following materials were used to conduct this test:

a. 1 - MS calibrated MIRAN 1A Infrared Analyzer
b. 1 - Heating Jacket
c. 1 - Zero Gas Activated Charcoal Filter Cartridge
d. 1 - 8 ft. Sample Hose (w/particulate filter) - 0.5" diameter
e. 1 - 200 ft extension cord
f. 1 - 9 in. by 12 in. baking pan
g. 1/2 gallon - MS
h. 1 - stand with a strip of plastic (wind direction indicator)
i. 1 - can of red paint to mark field grid
j. 1 - wind velocity meter
k. 1 - sling wet bulb thermometer

4. Test Procedure.

4.1 Field Test Grid.

The wind direction indicator was placed in the center of the field. The 9 in. by 12 in. pan was filled with liquid MS and placed next to the wind indicator. Next, paint was used to mark-off half circles at radii of 5 ft, 10 ft, and 15 ft downwind from the MS vapor source.

4.2 MS Vapor Monitoring Procedure.

Following the test procedures for the MIRAN outlined in Appendix E, the air was analyzed for MS vapors at 0 ft, 2 ft and 4 ft elevations initially 5 ft downwind from the vapor source. The MIRAN was allowed 5 minutes of monitoring time at each elevation. Next, the MIRAN sampled air at the same elevations 2 ft and 1 ft downwind from the source. Meter readings were recorded at all of the elevations and downwind distances and are provided in section 6.

5. Test Conditions.

a. Average Wind Velocity = 3.5 mph
b. Temperature = 98 °F
c. Relative Humidity = 50%

6. Test Results.

The meter readings (% transmissions) for the various distances and elevations downwind from the MS vapor source are listed below in table D-1.

TABLE D-1. Meter Readings and MS Vapor Concentrations Detected by the MIRAN 1A.

Downwind Distance (ft)	Elevation (ft)	Transmission Reading (%)	Approximate MS Vapor Concentration (mg/m^3)
5	0	0.0	*
5	2	0.0	*
5	4	0.0	*
2	0	0.03 - 0.1	14 - 713
2	2	0.0	*
2	4	0.0	*
1	0	0.2 - 0.4	4140 - 26750
1	2	0.2 - 0.34	4140 - 13375
1	4	0.1 - 0.2	713 - 4140

* Below detectable level of the instrument

7. Conclusion.

Based on the test results in section 6, a downwind distance no greater than 1 ft from the MS vapor source consistently monitored the vapor flux at these test conditions. At this short distance, moderate changes in wind direction had little effect on the ability of the MIRAN to indicate MS vapor was being evolved from the liquid source.

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APPENDIX E

MIRAN-1A FIELD USE PROCEDURES

1. Scope.

The following procedures apply to the field use of the MIRAN 1A infrared gas analyzer in monitoring ambient air for methyl salicylate (MS) vapors.

2. Assumptions.

a. Assume the MIRAN 1A has been calibrated with MS and that this data is available.

b. Assume the MIRAN 1A has undergone its initial checkout procedure (see MIRAN's Operation, maintenance and service manual referenced in Appendix H) and is in good operating condition.

3. Precautions.

a. Use the particulate filter whenever sampling to prevent dust and dirt from damaging optical components.

b. Avoid water condensation in the cell when the instrument is cold. Before use, purge the cell with dry air or inert gas, such as nitrogen or helium. Before purging, allow sufficient warm-up time to prevent water condensation on cold internal surfaces.

c. Before storage or transporting the instrument in a cold environment, purge the cell with a dry inert gas and close cell ports.

d. Use the heating jacket for the 20-m cell when possible. MS vapors tend to condense into a liquid on colder surfaces.

e. Cover the MIRAN and strip chart recorder (if used) from direct sunlight and rain.

4. Initial Tests.

The following tests indicates longterm changes in the MIRAN's performance, such as drift, and verifies proper instrument operation.

a. Close the intake (IN-OUT) and exhaust (OUT) port valves to the MIRAN.

b. Turn on the MIRAN and heating jacket and allow 5 to 15 min warm-up. Adequate warm-up is indicated by no detectable down scale drift on the 0.1A scale. Some random fluctuation due to noise is normal and should not be confused with drift. Drift is indicated by a consistent meter deflection in one direction over a period of a minute or two.

Set the following conditions:

RANGE = %T
PATH = 0.75 m
SLIT = 1 mm
WAVELENGTH = 3.5 µm
ZERO CONTROLS = X1, minimum (0,0)
RESPONSE TIME = 1.0 s

Record the instruments reading and compare it to previously recorded values from prior tests. This record will show long-term changes in instrument performance. Some degradation in infrared optical components should be expected. If the value from this test differs by more than plus or minus five percent from the previous test, then the instrument should be turned in for repair. After several years of normal service, the cell windows may have to be replaced. A continuous record of this test is useful in deciding whether instrument service is required. It will also show sudden performance changes as occur with exposure of NaCl windows to very wet samples or exposure of AgBr windows to ammonia or pyridine.

5. MS Vapor Monitoring Procedures.

a. Operation.

(1) Close the intake (IN-OUT) and exhaust (OUT) port valves to the instrument.

(2) Turn-on the power to the MIRAN and the cell heating jacket. If the instrument and heating jacket have cooled down since the initial quick tests, allow a 5 to 15 min warm-up.

(3) Set-up the instrument for MS with the following settings:

SLIT = 1.0 mm
WAVELENGTH = 8.3 µm
PATHLENGTH = 21.75 m
RESPONSE TIME = 1 s

(4) Connect the zero gas filter to the inlet (IN-OUT) port for the sample hose.

(5) Open the inlet (IN-OUT) and exhaust (OUT) port valves.

(6) Turn-on the ambient air pump and let it warm up for 5 minutes.

(7) Set the function switch to .25 A to adjust the MIRAN to zero on all absorbance ranges. Use the FINE ZERO control to carefully zero the instrument.

(8) Turn-off the ambient air pump and close the intake (IN-OUT) and exhaust (OUT) port valves.

(9) Remove the zero gas filter and connect the sampling hose (w/particulate filter) to the sample inlet (IN-OUT) port.

(10) Open the intake (IN-OUT) and exhaust (OUT) port valves and switch on ambient air pump.

(11) Read absorbance values from the instrument meter.

b. Shut-Down.

(1) Turn-off the ambient air pump and close the intake (IN-OUT) and exhaust (OUT) port valves to the MIRAN.

(2) Disconnect the sampling hose (w/particulate filter) and connect the zero gas filter to the sample inlet port.

(3) Open the IN-OUT and OUT port valves and switch on the ambient air pump.

(4) Allow the pump to run for five to ten minutes.

(5) Close the IN-OUT and OUT port valves and switch off the MIRAN and heat jacket.

6. Alternative Reading/Recording Methods.

A voltmeter (0-1 volt) can be connected to the chart recorder jacks located above the power plug for absorbance readings if desired. For relatively long monitoring times, a chart recorder can be connected to the MIRAN. Set up of the recorder is as follows:

a. Instrument Settings.

WAVELENGTH = 3.5 µm
SLIT = closed
PATHLENGTH = .75 m
RESPONSE TIME = 1 s
RANGE = 100%T
COARSE ZERO CONTROL = x10

b. Adjust the recorder zero setting for a reading of zero.

c. Open SLIT to 1 mm.

d. Set the instrument FINE ZERO CONTROL for a reading of 100% transmission. (If unable to do so, change COARSE ZERO to X1.)

e. Set the recorder attenuate control for recorder reading of 100.

The recorder readings should now correspond to the meter.

7. Power Supply.

The MIRAN and heating jacket require 25 watts at either 115 or 230 vac, 50-60 Hz and 400 watts respectively. By using an invertor, the MIRAN can be operated from a 12 volt battery. If a chart recorder is used, additional power will be required. The power going to the MIRAN should be filtered to avoid power surges and spikes.

8. QA/QC Procedure.

The MIRAN will undergo a QC/QC check at the beginning and end of each day's use. A 1 to 5 µL injection of a standard 10% MS/cyclohexane solution (by volume) will be challenged to the MIRAN in a closed loop calibration system and its response recorded. This calibration set-up and procedure will be conducted in accordance with the MIRAN 1A operation, maintenance and service manual.(See Appendix H for reference) The recorded response will be compared to the instrument's value according to its previously determined calibration curve, and if the value is within 5% of the calibrated value, the instrument will be judged ok and the test data obtained will be considered valid. If the response value does not fall in the designated range, the test will be repeated three times. Should the values obtained from the repeated tests be unacceptable, the instrument will undergo the initial test as stated in section 4. and be recalibrated if still operational.

APPENDIX F

BASIC MATERIALS LIST

Item Description	Dimensions	Quantity
Vehicle Vapor Source Pans	(See Figure 7)	90
Vehicle Sponge Pads	3.5 cm by 11.8 cm by 12.8 cm	150
Vapor Generator *	1.0 ft by 1.5 ft by 1.0 ft	2
Simulant Vapor Source for Vapor Generator	---------------	2
MIRAN 1A Infrared Gas Analyzer	3.0 ft by 1.0 ft by 1.0 ft	2
Glass Vapor Source Tray *	9.0 in. by 12 in. by 2.0 in.	30
Tray Pads (cut to fit) *	9.0 in. by 12 in. by 1.0 in.	30
Glass Vapor Source Dish	2.0 in. DIA x 0.5 in.	10
Dish Green Scrub Pad	2.0 in. DIA x 0.5 in.	10
Syringe	Hamilton, 50 µL	10
Hamilton Dispenser	Model# PB 600	2
Syringe Needle	26 gauge	20
MS ** gallons	------------	30
DPGME ** gallons	------------	40
Ethanol ** gallons	------------	10

* Item on loan from Detection Directorate
** Item to be provided by the Army Armor and Engineering Board

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APPENDIX G

KEY SIMULANT PROPERTIES

The following contains a summary of key simulant properties which should be considered when using these field simulants:

MS is methyl salicylate (oil of winter green) an H mode simulant and DPGME is Dipropylene glycol monomethyl ether, a G mode simulant. (See Table G-1) In general, avoid direct skin and eye contact with these chemicals. A water/weak acid decon was suggested for DPGME, ethanol works fairly well with MS. While no contraindication was expressed in the literature for the use of these chemical in open environment, it is recommended minimal contamination of terrain, due to the limited environmental fate studies conducted to date.

TABLE G-1. Key Properties for Methyl Salicylate (MS) and Dipropylene Glycol Monomethyl Ether (DPGME).

Key Simulant Properties	MS	DPGME
Molecular Weight (g/gmol)	152.14	148.2
Surface Tension (dynes/cm) @25 °C	41.7	------
Density (g/cm^3) @25 °C	1.18	0.95
Boiling Point (°C)	223.2	189.0
Vapor Pressure (mmhg)		
@ 60 °F	0.69	.28*/.38**
@ 80 °F	0.161	0.62**
@ 100 °F	0.354	1.28**
Diffusivity (m^2/s)		
@ 60 °F	0.0643	------
@ 80 °F	0.0643	------
@ 100 °F	0.0686	------
Human Exposure Criteria		
TLV - TWA	None	600 mg/m^3
TLV - STEL	-----	900 mg/m^3
ECOTOXICITY	No Data	No Data

Other Comments:

MS	DPGME
Avoid Eye and Skin Exposure. 30 mL ingested is lethal in adults.	Exposing DPGME to air in the presence of light can lead to the formation of nonvolatile, explosive

Table G-1. Continued

MS	DPGME
	peroxides. Water/weak acid wash off will decompose these peroxides. Avoid oxidating and reducing agents.

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* 20 °C

** Computed value

APPENDIX H

LIST OF KEY TERMS

In order to reduce confusion, a number of key terms used in this report are provided. Frequently the same term has very different meanings to different people and activities.

FOT&E	Follow on Operational Test and Evaluation
CAM	Chemical Agent Monitor
MIRAN	Miniature infrared gas analyzer
SHELTER	Portable collective protection system
SORT	Distinguish between contaminated and uncontaminated
SURVEY	The act of locating sources of contamination which can influence a designated area of interest (CAM 2+ Bar response in this case).
MONITOR	The act of monitoring rechecking and uncontaminated region for breaches of contamination.
KEY TERRAIN	A critical path or area of interest.
USE DOCTRINE	The method of equipment employment specified by the Chemical School, to accomplish a specified mission.
MAN/MACHINE INTERFACE	Ability of personnel to use equipment under realistic conditions.
USER	Personnel selected to use equipment during FOT&E.
REFEREE	Trained test personnel, who record independent CAM data, collected just after user performs his task (User check).
HAZARD ZONE	The area around a contamination source which represents a hazard to unprotected personnel (CAM 2+ Bar Range).

AREA OF INFLUENCE	The area over which a contamination source can influence the actions taken by personnel. Depending on individual protective posture, it could be the hazard zone.
SIMULANT	A chemical interference which causes the CAM to respond as if an agent were present.
MS	Methyl salicylate, H mode simulant
DPGME	Dipropylene glycol monomethyl ether, G mode simulant