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CHEMICAL BIOLOGICAL CENTER

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

ECBC-TR-301

**TEST RESULTS OF PHASE 3 LEVEL A SUITS TO CHALLENGE
BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS:
SUMMARY REPORT**

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EXECUTIVE SUMMARY

As part of the Domestic Preparedness Program, four Occupational Safety and Health Administration Level A* suit designs were tested to assess their capability to protect in a chemical warfare (CW) agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation by sarin (GB) and mustard (HD). From these data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor (PF) is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated physiologically-derived breakthrough times and PFs are presented.

* Level A protection consists of a completely encapsulating, gas/vapor proof chemical resistant suit; a self-contained breathing apparatus (SCBA) or positive-pressure supplied-air respirator with escape SCBA, chemical resistant gloves and boots.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in March 2000 and completed in September 2000.

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TEST RESULTS OF PHASE 3 LEVEL A SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: SUMMARY REPORT

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance emergency and hazardous material response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, people who are responding to an incident will use personal protective equipment to protect them from exposure to chemical agents or biological agents. The specific personal protective equipment (PPE) that would be used by emergency responders depends upon the situation that they encounter and the PPE the responders currently possess. This information can be used by these emergency responders to establish work rules for safe work limits for Level A suits they currently possess, and can be used in deciding which Level A suits to purchase in the future. Level A protective suits are required when the greatest level of skin, respiratory, and eye protection is required, or when entering an unknown environment. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or supplied air lines.

2. OBJECTIVES

This study evaluated four different common and commercially available Level A suits. These four different suits met the Occupational Safety and Health Administration (OSHA) description of Level A as defined in 29 Code of Federal Regulations (CFR) 1910.120, Appendix B. These suits were evaluated to assess how well they resist vapor permeation* from liquid contamination by chemical agents Sarin (GB) and mustard (HD) and droplet penetration by a corn-oil aerosol from 0.4 to 0.6 μ in diameter (used to simulate the 0.4 to 5 μ military standard for the possible biological or chemical particulate threat). This information is intended for emergency responders as an aid in evaluating Level A suits when they choose to include military chemical and biological agent protection as a criterion. The information supplements data and information provided by the suits' manufacturers. The suits are tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors are beyond the intended scope of this test program. These tests are conducted to assess percutaneous protection** only.

* Throughout this report the term permeation is used even though for some of the tests the precise mechanism of agent transfer is not determined and penetration is likely to be involved also.

** Inhalation and ocular protection are typically provided by the use of a SCBA or air-supplied respirator that covers the eyes, nose and mouth.

3. TESTING AND DATA ANALYSIS

3.1 Testing Overview.

The Level A suits that are tested in this test program are listed in Table 1.

Table 1. Level A Suits Tested

Model	Manufacturer	Address
Lakeland Deluxe Level A 10640	Lakeland Industries, Inc.	Somerville, AL
Lakeland Economy Level A 10660	Lakeland Industries, Inc.	Somerville, AL
Mar Mac Commander 9400FB	Mar Mac Manufacturing, Inc.	McBee, SC
Giat UNISCAPH Gas Tight Suit	Centech Group, Inc.	Fairfax, VA

Tests include the measurement of vapor permeation of both GB and HD through material swatches. Tests are also conducted to measure the total aerosol leakage into the suits through seams, seals, etc., when worn as part of a complete PPE system.

3.2 Liquid Challenge/Vapor Permeation Testing (Agent Swatch Testing).

3.2.1 Liquid Challenge/Vapor Permeation Testing Procedures.

This testing is conducted to measure the actual permeation of chemical agents GB and HD through suit swatches over a 24-hr period. The test is intended to assess how well the suit materials and seams resist agent permeation. For each suit design, all swatches were taken from a single suit. The amount of agent applied and duration of exposure do not represent any particular threat that responders would possibly encounter, but serve as a common point of reference for all test results.

The test methodology was taken from TOP 8-2-501¹ and is described in Appendix A. Three swatches are taken from each of six different areas of the suit – 18 total swatches per suit design for GB and 18 more for HD. Swatches are also taken from silicone rubber (M45 mask formulation) slabs. For each test, six swatches taken from a suit and one silicone swatch are placed in test cells, one swatch per test cell. Laboratory personnel apply a predetermined liquid agent challenge (10 g/m²) to the top surface of each swatch. Agent droplets are applied to the surface of the first swatch at time zero. Agent is then applied to the surface of each succeeding swatch at 3-min intervals. The upper chamber of each test cell is sealed. A 1.0 L/min airflow, from the test cabinet, is maintained in the lower test cell chamber beneath each swatch.

¹ *Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants* (Swatch Testing); Test Operations Procedure (TOP) 8-2-501; U.S. Army Dugway Proving Ground: Dugway, UT, UNCLASSIFIED Report (AD-A322329).

During the 24-hr test period, gas samples are taken on a sequential basis by a laboratory MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL) with stream selection system (a miniaturized gas chromatograph with flame photometric detector and sampling system) from the airstream beneath each swatch. Gas sampling by the MINICAMS™ begins for the first swatch approximately 3 min following agent application. Subsequent 3-min cycles of the MINICAMS™ are composed of 2 min of desorption of collected agent vapor from the pre-concentrator tube (PCT) onto the GC column followed by 1 min of gas sampling (collection of agent vapor from the next swatch by the PCT). Sampling is done sequentially through six swatches (three from one sampling area followed by three from a second sampling area), the silicone swatch,* and then three blank gas samples are taken from the test chamber to purge the sampling line before repeating the sampling sequence. The six swatches, the silicone swatch, and three blanks are all sampled for the first time within the first 30 min of the test. Then the sampling sequence begins anew.

The MINICAMS™ first determines the amount of agent vapor in each gas sample. Using this result, the amount (ng) of agent vapor present in the airstream that passes beneath the swatch over the time from the previous gas sample to the current gas sample is determined by the MINICAMS™ permeation software. This amount of agent vapor is presumed to be the amount of agent vapor that has permeated the swatch over that time interval. Given the area of the test swatch, the MINICAMS™ permeation software determines the M_f at each elapsed time for each swatch, where the cumulative mass of agent permeating the swatch per unit area at any elapsed time during the 24-hr test is defined as M_f .

3.2.2 Liquid Challenge/Vapor Penetration Testing Analysis.

Each suit yielded M_f data for 18 swatches for each of the two agents. For this report, the average (of three swatches) cumulative permeation (M_f) for each suit area (for example gloves) is calculated. This average is then presented, at each of the reported elapsed times, as representative of the suit's permeation resistance at that sampling area. The reported elapsed time for each sampling area is the sum of the elapsed times for the three swatches divided by three.

To estimate M_f at each elapsed time for a suit, the simplifying assumption is that the exposure is uniform over the entire suit. This permits the use of the weighting factor scheme developed by Belmonte² to determine the weighted average M_f over the entire suit at each average elapsed time. The average elapsed time is the sum of the reported elapsed times for all the sampling areas divided by the number of sampling areas. The weighting factors shown in Table 2 were assigned roughly on the basis of surface area assigning a minimum assigned value of 5%. Swatches were not necessarily taken from exactly the same locations for all suits because

* Originally, it was intended to use silicone swatches as references or controls, but it was soon found that permeation through the silicone varies too widely for it to be used for that purpose. Silicone swatches were used anyway, because they serve as a reliable source of agent vapor to assure the tester that the MINICAMS™ is responding properly during tests when little or no agent permeates the actual test swatches.

² Belmonte, R.B., *Test Results of Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report; ERDEC-TR-513*; U.S. Army Edgewood Research, Development and Engineering Center: Aberdeen Proving Ground, MD, 1998; UNCLASSIFIED Report (AD-A353013).

their configurations differed. Note that not all suits have the same components. The weighted average M_f at any average elapsed time is calculated using an equation similar to the following (using the Lakeland Deluxe suit weighting factors in Table 2 for this example):

Weighted average $M_f = 0.5(\text{suit material } M_f) + 0.15(\text{suit seam } M_f) + 0.15(\text{visor material } M_f) + 0.1(\text{glove material } M_f) + 0.05(\text{boot seam } M_f) + 0.05(\text{zipper/material seam } M_f)$

Table 2. Weighting Factors For Each Sampling Area by Suit

Suit Model	Suit Material	Suit Seam	Visor Material	Glove Material	Hood Seam	Boot Seam	Zipper/Material Seam
Lakeland Deluxe Level A 10640	50	15	15	10	-	5	5
Lakeland Economy Level A 10660	50	15	15	10	-	5	5
Mar Mac Commander 9400FB	50	-	15	10	15	5	5
Giat UNISCAPH Gas Tight Suit	50	15	15	10	-	5	5

3.2.3 Relationship Between Liquid Challenge/Vapor Permeation Test Results and Skin Exposure.

The permeation test is designed to distinguish among these material swatches according to their permeation resistance to chemical agents. It is not intended to specifically replicate threat scenarios that may be encountered in actual use. As previously reported by Belmonte,² it is instructive to estimate the agent dosage ($C_{it,skin}$) that would result from such a standard agent challenge as a relative indication of possible physiological effects. This is done by converting the weighted average M_f s to equivalent agent dosages. This relationship was developed by Fedele (written communication, Dr. P. Fedele, R&T Directorate, ERDEC, July 1997) and was reported by Belmonte.² For suit materials impermeable to airflow, the equation is:

$$\text{Agent Dosage (mg - min/m}^3\text{)} = \frac{M_f \text{ (ng/cm}^2\text{)}}{P_s, \text{ Permeability of skin to agent vapor (cm/min)}}$$

where skin permeability (P_s) is 2 cm/min for HD and 0.1 cm/min for GB. The agent dosage can then be compared to doses that are known to cause certain levels of toxicity. Skin permeability is assumed to be constant over all regions of the body.

² Belmonte, R.B., *Test Results of Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report; ERDEC-TR-513*; U.S. Army Edgewood Research, Development and Engineering Center: Aberdeen Proving Ground, MD, 1998; UNCLASSIFIED Report (AD-A353013).

3.2.4 Evaluation Criteria for Liquid Challenge/Vapor Permeation Test Results.

When analyzing the test results, it is useful to determine whether the data indicate that the Level A suit provides percutaneous protection over some period of time. Mustard vapor can produce erythema (reddening of the skin, certain body regions) at dosages of approximately 100 mg-min/m^3 , and can produce vesication (skin burns and blisters, certain body regions) at 200 mg-min/m^3 .

Sarin vapor can produce incapacitation (twitching, convulsions or loss of consciousness) at unprotected, percutaneous, whole-body dosages of approximately 8000 mg-min/m^3 and can be lethal at unprotected, percutaneous dosages of 15000 mg-min/m^3 where exposed persons are healthy, young, fit, and well-nourished males of approximately 70-kg mass. People who are smaller, less fit, etc., may exhibit adverse effects at lower doses ($C_{i\text{-skin}}$). The conservative simplifying assumptions were that the suit would be exposed to a uniform liquid GB challenge over its entire surface, and that this would result in a uniform exposure of all body regions to GB vapor. This is conservative because the areas likely to receive more exposure (hands, arms, chest, back) would also be those less sensitive. Therefore, the amount of agent per unit area (weighted average M_f) necessary to permeate the suit to produce a predetermined physiological effect was estimated by using each of the above dosages and the appropriate skin permeability (P_s). These values are used in the graphs of weighted average M_f versus time given in Appendixes C through G and summarized in Table 3. The breakthrough dosages are assumed to be the HD dosage that produces erythema (100 mg-min/m^3) and the GB dosage that produces incapacitation (8000 mg-min/m^3). A physiologically-derived breakthrough time is the time when the weighted average M_f equals the breakthrough dosage criterion.

Table 3. Agent Breakthrough Criteria

Agent	Breakthrough Dosage (mg-min/m^3) ^a	Physiological Effect	Skin Permeability (P_s), (cm/min)	Breakthrough M_f , (ng/cm^2) ^a
HD	100	Erythema	2	200
HD	200	Vesication	2	400
GB	8000	Incapacitation	0.1	800
GB	15000	Lethality	0.1	1500

^a These breakthrough criteria are not to be construed as safe threshold values, they are being used only to rank suits.

3.3 Aerosol Simulant Tests.

3.3.1 Test Procedures.

The testing is conducted to determine leakage of a challenge corn-oil aerosol (physical simulant of a biological or chemical agent aerosol) into a suit ensemble while people of different sizes are wearing appropriately sized ensembles. Volunteers dressed in Level A suits with SCBA enter a chamber with aerosol simulant and remain for 40 min. Instrumentation measures any aerosol leakage (penetration) into the suit through gaps between ensemble

components (vapor permeation through materials cannot be measured by this technique). During the test, the people in the suits perform standardized movements. A brief description of the test and movements made by the people during the test are given in Appendix B. Four different ensembles, listed in Table 1, were tested. Eight suits of each design were worn by 12 volunteers on each of two days, for a total of 24 trials for each suit design. However, because it was not possible to retain the same 12 volunteers throughout the entire course of testing, this variable (the differences among wearers) was not held constant across all suit designs.

From this test a protection factor (PF) is derived. In simplest terms, PF is a measure of the challenge concentration outside the suit divided by the concentration inside the suit ensemble. For example, if the concentration of aerosol inside the suit ensemble is found to be 1/10th the value of the average concentration outside the suit ensemble, the PF is equal to 10.

3.3.2 Aerosol Simulant Analysis.

Samples of aerosol are taken continuously at the visor and upper arm within the suit and their concentrations are measured by laser photometry, recorded in a computer file and displayed continuously on a computer monitor. These sampling locations were selected as being the most likely locations for aerosol leakage to occur because suits tend to leak through outlet valves and zippers. So this is thought to be worst case and the PF is a worst case PF.

The PF data are presented based upon predetermined PF pass levels, ranging from 2 to 100,000 (i.e., at each pass level the number of failing and passing suits is recorded). The higher the percentage of test occasions that passes at a given PF, the greater the probability that the suit will provide that level of protection in use.

The exercises can reveal weaknesses in suit designs. Heavy work can affect the performance of a suit. For example, outlet valves could begin leaking due to moisture escaping from the suit.

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
Ct	Vapor exposure, product of vapor concentration (mg/m^3) and time (minutes)
$C_{It_{\text{skin}}}$	Vapor exposure to skin
cm^2	Square centimeters
$^{\circ}\text{F}$	Temperature in degrees Fahrenheit
delta p	Differential pressure
DoD	Department of Defense
ECBC	U.S. Army Edgewood Chemical Biological Center
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
g	Gram
GB	Sarin, Isopropylmethylphosphonofluoridate
HD	Sulfur Mustard; 2,2'-Dichlorodiethylsulfide
L	Liter
M_f	Cumulative mass permeation through the fabric
m^2	Square meters
m^3	Cubic meters
mg	Milligram
μL	Microliter
ng	Nanogram
NBC	Nuclear, Biological and Chemical
OSHA	Occupational Safety and Health Administration
PCT	Pre-concentrator tube
PF	Protection Factor
PPE	Personal Protective Equipment
P_s	Skin permeability
RH	Relative Humidity
SCBA	Self-Contained Breathing Apparatus
TOP	Test Operations Procedure

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APPENDIX A

MODIFIED STATIC DIFFUSION TEST PROCEDURE

MODIFIED STATIC DIFFUSION TEST

This test procedure was adapted from Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT, 3 March 1997, UNCLASSIFIED Report (AD A322329). The test procedure was entitled "Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; $\Delta p = 0$, Single Flow Test)". The following procedure was used:

1. Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.
2. From each suit, three each 1 and 15/16-in diameter material swatches will be taken for mustard (HD) and a like number taken for sarin (GB). Depending upon the suit configuration, 3 seam swatches (same diameter) will be taken plus 3 swatches of other flat components such as visor, gloves, suit/visor interface and zipper/material interface for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number, which will be placed on the bag. A list of serial numbers will be kept with the swatches. Alternatively, the swatches for each day's test will be cut from the suit and placed in the environmental chamber for conditioning. Sample identification will accompany each swatch.
3. The environmental chamber will be controlled at a temperature of 90 ± 2 °F, and the maximum achievable relative humidity (RH) without occurrence of condensation (normally $50\% \pm 10\%$ RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. The TOP 8-2-501 specifies that a system control and data acquisition system will be used, but this system will not be used due to budget constraints. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. The TOP 8-2-501 specifies that differential pressure monitoring will be done but differential pressure gages will not be used due to budget constraints.
4. The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min, which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller. If the flows don't match, the test cell will be disassembled, adjustments made, the test cell reassembled and flows rechecked.

5. The TOP 8-2-501 specifies that positive control and negative control swatches will be used, but they will not be used due to budgetary and schedule limitations. The swatches will be preconditioned for at least 2 hr and will be monitored by MINICAMS™ for at least one cycle prior to agent application. Eighty-mil silicone will be used, one for each test (six suit swatches and one silicone swatch).

6. Agents GB and HD will be used. The contamination density will be 10 g/m² (8 each 1 µL HD droplets or 10 each 1 µL GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a repeating dispenser.

7. Seven swatches will be tested at once. MINICAMS™ with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three sampling intervals following the silicone during which chamber air will be sampled. Each swatch will be sampled once every 30 min. The MINICAMS™ will be standardized weekly with a range of agent standards (diluted in isopropanol). Concentrations will normally range from 1 ng/µL to 100 ng/µL.

8. The test length will be 24 hr.

9. The test cells will be aerated and o-rings replaced between uses. No other cleaning method will be used.

10. The data to be reported are cumulative permeation (ng/cm²) at various elapsed times (minutes) for each swatch. The elapsed time for each swatch is the time from agent contamination. All recorded data will be placed in laboratory notebooks and one technical report per suit will be drafted at the conclusion of this effort.

APPENDIX B

AEROSOL SIMULANT TEST PROCEDURE

To properly test suits with statistical significance, eight suit ensembles of each model are provided to the Mask Fit Test Facility for examination. Each ensemble is new and inspected as received. The suit ensembles include relevant accessory equipment such as respirators that are worn with the suits, gloves, boots, and any other equipment that is necessary for chemical agent use. The suit ensembles are run on at least 10 different subjects with at least 22 trials. The eight suits are reused to achieve the 22 or more trials. Sampling of suits is done at the visor and upper arm for each trial.

Exercise routine for all suits is as follows:

Phase 1 (Pre-Operational):

- 1) standing still, normal breathing
- 2) bending forward and touching toes
- 3) jogging in place
- 4) raising arms above head and looking upward
- 5) bending knees and squatting
- 6) crawling on hands and knees
- 7) torso twists with hands folded on chest
- 8) standing still, normal breathing

Phase 2 (Operational):

- 1) climb step ladder
- 2) move 3 lb boxes from table to floor
- 3) rest
- 4) roll walls and ceiling
- 5) bag clothes
- 6) rest
- 7) loosen bolts
- 8) move 3 lb boxes from floor to table

Note: The phase 1 (pre-operational) exercises are performed for 1 min each for a total of 8 min. The phase 2 (operational) exercises are performed for 4 min each for a total of 32 min. Hence, the overall total exercise time is 40 min.

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APPENDIX C

LAKELAND DELUXE LEVEL A

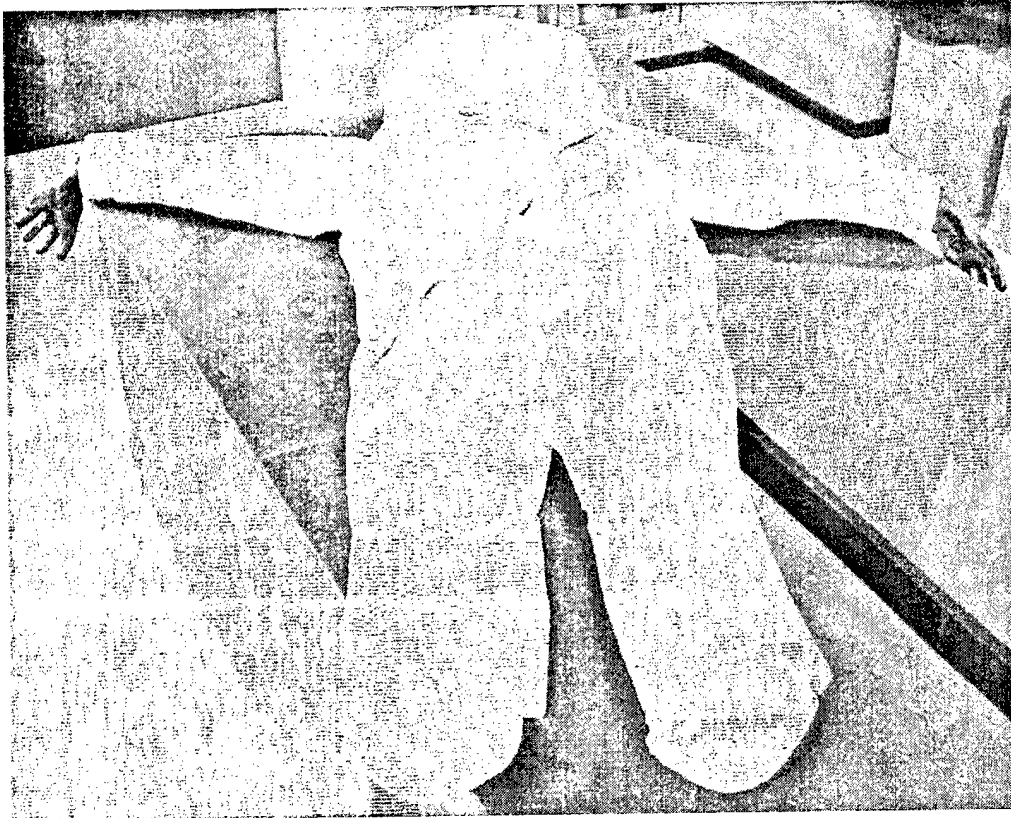


Figure C - 1: Lakeland Deluxe Level A - Front View

Table C - 1. Lakeland Deluxe Level A - Average HD Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Material	Time (min)	Suit Arm Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _r
15	13	6	2	3	2	15	5	13	13	5	5	10	8
45	54	36	17	34	23	46	19	43	43	36	48	40	39
75	73	67	27	64	37	76	29	73	73	66	70	70	55
106	85	97	37	95	48	106	37	103	104	97	92	101	67
136	109	128	45	125	58	137	46	133	134	127	236	131	90
166	168	158	56	155	70	167	56	163	164	157	689	161	147
197	270	188	68	186	85	197	67	193	195	188	1511	192	245
227	411	219	83	216	102	228	79	223	225	218	2631	222	378
257	581	249	99	246	123	258	93	253	256	248	3923	252	535
288	771	279	119	277	148	288	108	283	286	279	5294	283	708
318	1166	310	140	307	177	319	125	313	316	309	6665	313	985
348	1569	340	165	338	209	349	143	343	347	339	8049	344	1267
379	1781	370	192	368	246	380	162	373	377	370	9454	374	1456
409	1994	401	220	398	287	410	183	403	407	400	10841	404	1645
440	2207	431	250	429	330	440	204	433	438	430	12232	435	1836
470	2604	462	282	459	377	471	227	463	468	461	13438	465	2110
500	3182	492	315	489	425	501	251	493	498	491	14558	495	2471
531	3754	522	348	520	474	531	275	523	529	522	15666	526	2828
561	4138	553	381	550	524	562	300	553	559	552	16824	556	3095
591	4514	583	415	580	575	592	325	583	589	582	17965	586	3356
622	5061	613	449	611	626	623	350	613	620	613	18924	617	3695
652	5605	644	482	641	680	653	374	643	650	643	19954	647	4035
682	6145	674	514	671	733	683	398	673	680	673	21059	678	4378
713	6510	705	545	702	783	714	421	703	711	704	22082	708	4627
743	6697	735	576	732	834	744	445	733	741	734	23025	738	4784
774	7056	765	606	762	886	774	468	763	771	764	24048	769	5031
804	7584	796	636	793	935	805	491	793	802	795	25069	799	5362
834	8110	826	666	823	982	835	513	823	832	825	25998	829	5687
865	8634	856	694	853	1028	866	535	853	863	856	26928	860	6011
895	9161	887	721	884	1075	896	556	883	893	886	27858	890	6335
925	9688	917	747	914	1120	926	578	913	923	916	28789	920	6660
956	10037	948	774	944	1164	957	599	943	954	947	29717	951	6895
986	10212	978	800	975	1207	987	620	973	984	977	30794	981	7050
1017	10389	1008	825	1005	1248	1018	641	1003	1014	1008	31868	1012	7206
1047	10561	1039	850	1036	1289	1048	662	1033	1045	1038	32782	1042	7351
1077	10734	1069	875	1066	1329	1078	683	1063	1075	1068	33854	1072	7504
1108	10913	1100	900	1096	1367	1109	703	1093	1105	1099	34928	1103	7660
1138	11090	1130	924	1127	1404	1139	723	1123	1136	1129	36008	1133	7815
1168	11263	1160	947	1157	1439	1170	744	1153	1166	1159	37247	1163	7976
1199	11432	1191	970	1187	1474	1200	764	1183	1196	1190	38481	1194	8134
1229	11600	1221	993	1218	1508	1230	784	1213	1227	1220	39551	1224	8283
1260	11768	1252	1016	1248	1540	1261	803	1243	1257	1250	40632	1255	8433
1290	11933	1282	1038	1278	1573	1291	821	1273	1287	1281	41891	1285	8590
1320	12094	1313	1059	1309	1605	1322	840	1303	1318	1311	43142	1315	8743
1351	12253	1343	1079	1339	1636	1352	859	1333	1348	1342	44385	1346	8896
1381	12413	1373	1100	1369	1666	1382	877	1363	1378	1372	45621	1376	9048
1411	12571	1404	1120	1400	1695	1413	895	1393	1409	1402	46867	1407	9200
		1434	1140	1430	1725			1423		1433	47932		

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The average time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average M_r = 0.5(Suit Matl M_r) + 0.15(Suit Seam M_r) + 0.15(Visor Matl M_r) + 0.1(Glove M_r) + 0.05(Boot Seam M_r) + 0.05(Zipper Seam M_r).

Table C - 2. Lakeland Deluxe Level A - Average GB Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Material	Time (min)	Suit Arm Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _i
13	0	13	0	4	0	3	5	4	0	12	25	8	2
44	7	43	6	34	5	34	72	35	97	43	255	39	30
74	18	73	15	64	15	64	127	65	275	73	529	69	67
104	29	103	20	94	22	94	176	95	438	103	765	99	98
135	38	133	24	124	29	125	221	126	597	134	1000	129	129
165	46	163	28	154	36	155	265	156	755	164	1239	160	159
195	54	193	31	184	42	185	308	186	912	195	1484	190	189
226	61	223	35	214	48	216	351	217	1066	225	1738	220	218
256	68	253	38	244	53	246	393	247	1218	255	2005	250	248
286	74	283	41	274	57	277	434	277	1368	286	2291	281	278
317	80	313	44	304	62	307	473	308	1515	316	2596	311	309
347	86	343	47	334	66	337	509	338	1659	346	2920	341	340
377	92	373	50	364	70	368	551	368	1800	377	3287	371	373
408	97	403	52	394	74	398	598	399	1940	407	3706	402	410
438	103	433	55	424	77	428	643	429	2080	437	4171	432	448
468	109	463	56	454	80	459	687	459	2218	468	4696	462	489
499	114	493	58	484	83	489	727	490	2355	498	5277	492	533
529	120	523	60	514	86	519	761	520	2490	529	5905	522	577
559	124	553	61	544	89	550	792	550	2621				
590	129	583	63	574	92			581	2747				
620	134	613	64	604	95			611	2870				
650	138	643	66	634	97			641	2988				
681	142	673	67	664	100			672	3104				
711	146	703	69	694	103			702	3217				
741	150	733	70	724	105			732	3327				
772	154	763	72	754	108			763	3433				
802	158	793	73	784	111			793	3536				
832	162	823	75	814	113			823	3637				
863	165	854	76	844	116			854	3736				
893	169	884	77	875	119			884	3832				
923	172	914	79	905	121			914	3926				
954	176	945	80	935	124			945	4018				
984	179	975	81	966	126			975	4107				
1014	182	1005	81	996	129			1005	4194				
1045	185	1036	82	1026	131			1036	4279				
1075	188	1066	83	1057	134			1066	4362				
1105	191	1096	84	1087	136			1096	4443				
1136	194	1127	84	1117	139			1127	4522				
1166	197	1157	85	1148	141			1157	4600				
1196	199	1187	86	1178	144			1187	4675				
1227	202	1218	86	1208	146			1218	4748				
1257	204	1248	87	1239	149			1248	4820				
1287	207	1278	88	1269	151			1278	4891				
1318	209	1309	88	1299	153			1309	4960				
1348	212	1339	89	1330	156			1339	5028				
1378	214	1369	90	1360	158			1369	5094				
1409	217	1400	91	1390	161			1400	5160				
		1430	91	1421	163			1430	5225				

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The average time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_T = 0.5(\text{Suit Matl } M_T) + 0.15(\text{Suit Seam } M_T) + 0.15(\text{Visor Matl } M_T) + 0.1(\text{Glove } M_T) + 0.05(\text{Suit/Visor Interface } M_T) + 0.05(\text{Zipper/Matl Interface } M_T)$.

Note 4: Sampling for glove material and zipper seam was ended prematurely due to equipment failure.

Lakeland Deluxe Level A 10640

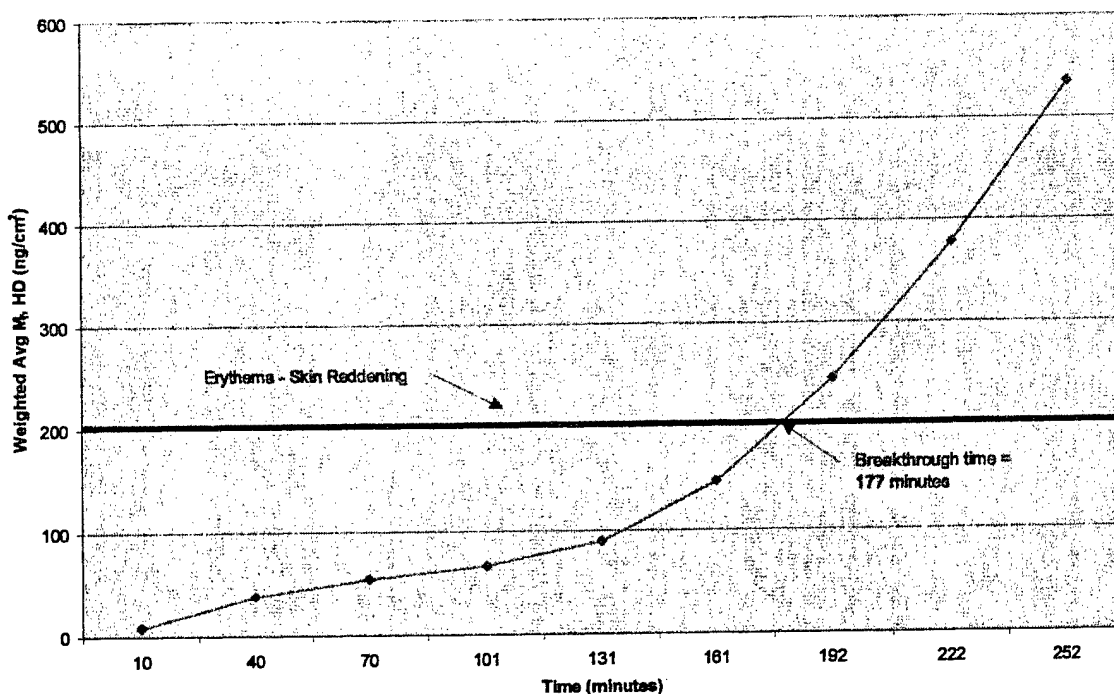


Figure C - 2: Lakeland Deluxe Level A - Weighted Average HD Permeation

Lakeland Deluxe Level A 10640

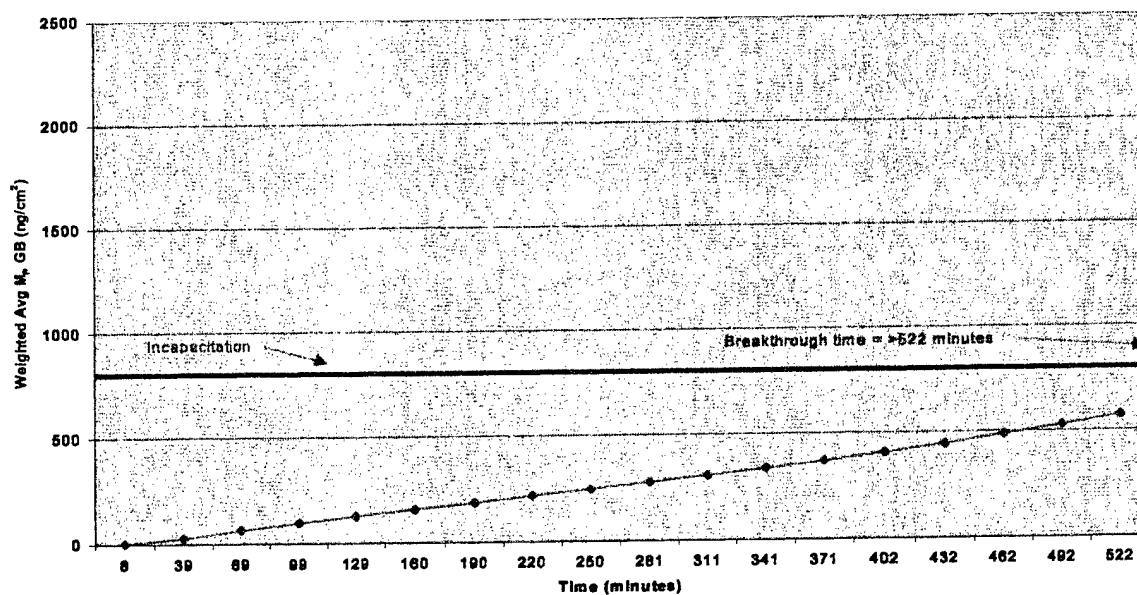


Figure C - 3: Lakeland Deluxe Level A - Weighted Average GB Permeation

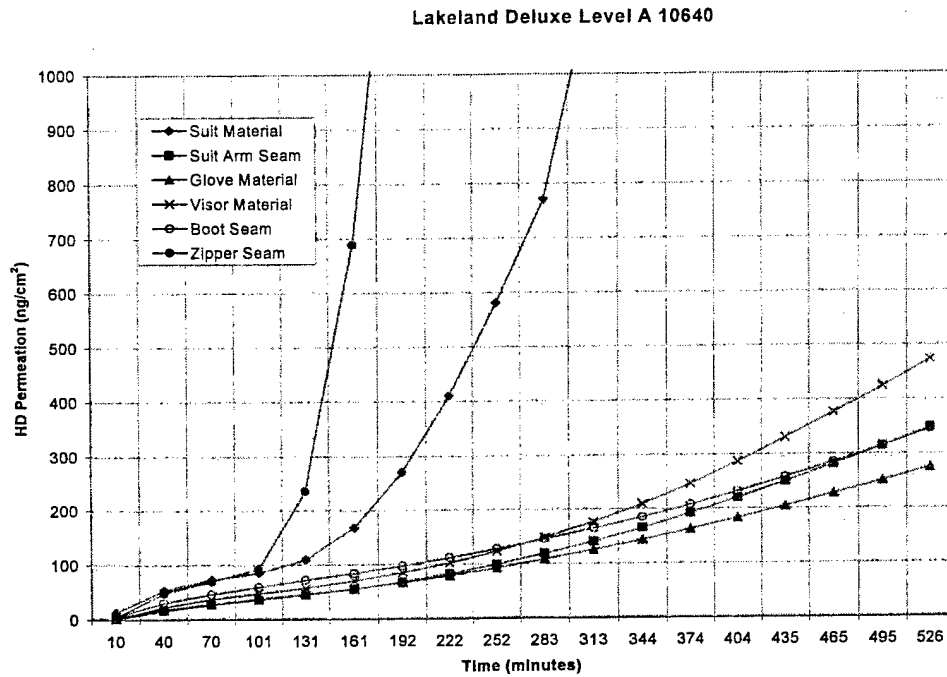


Figure C - 4: Lakeland Deluxe Level A - HD Permeation by Sampling Area

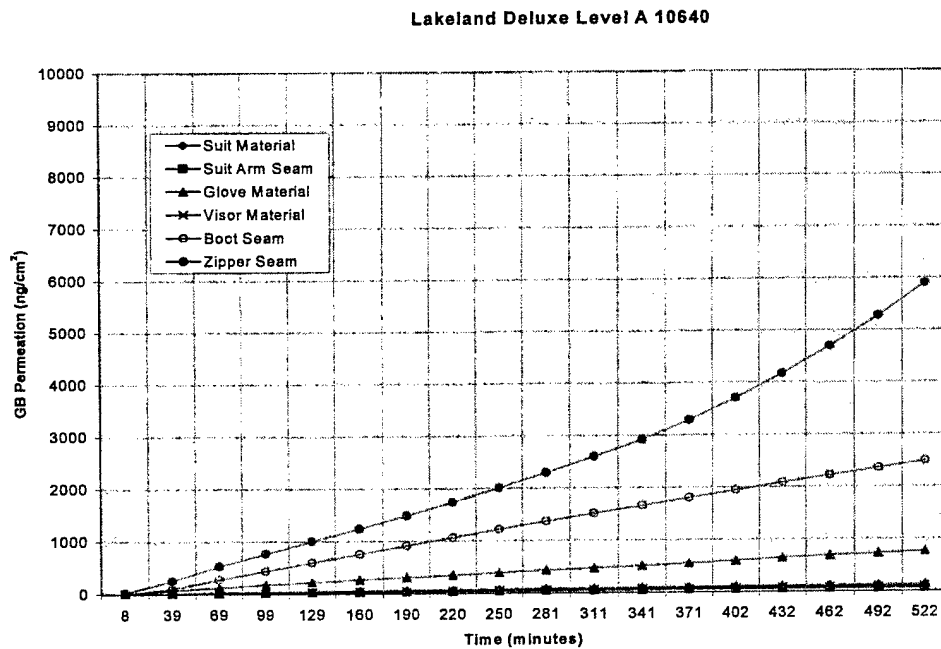


Figure C - 5: Lakeland Deluxe Level A - GB Permeation by Sampling Area

Table C - 3: Lakeland Deluxe Level A - System Test (Aerosol Simulant) Results

PF	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	.00	100.00	0	.00	100.00
2	0	.00	100.00	0	.00	100.00
5	0	.00	100.00	0	.00	100.00
10	0	.00	100.00	0	.00	100.00
50	0	.00	100.00	0	.00	100.00
100	1	2.27	97.73	0	.00	100.00
150	1	4.55	95.45	1	2.38	97.62
500	4	13.64	86.36	6	16.67	83.33
1000	8	31.82	68.18	2	21.43	78.57
1667	6	45.45	54.55	4	30.95	69.05
2000	3	52.27	47.73	2	35.71	64.29
5000	14	84.09	15.91	11	61.90	38.10
6667	3	90.91	9.09	2	66.67	33.33
10000	3	97.73	2.27	4	76.19	23.81
20000	1	100.00	.00	7	92.86	7.14
50000	0	100.00	.00	3	100.00	.00
100000	0	100.00	.00	0	100.00	.00
No. of Trials	44			42		

Table C - 4. Lakeland Deluxe Level A - Overall Test Results

Physiologically-derived breakthrough time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema				
GB	HD	500	5000	10000	
>522	177	86	16	2	Pre-Operational
		83	38	24	Operational

APPENDIX D

LAKELAND ECONOMY LEVEL A

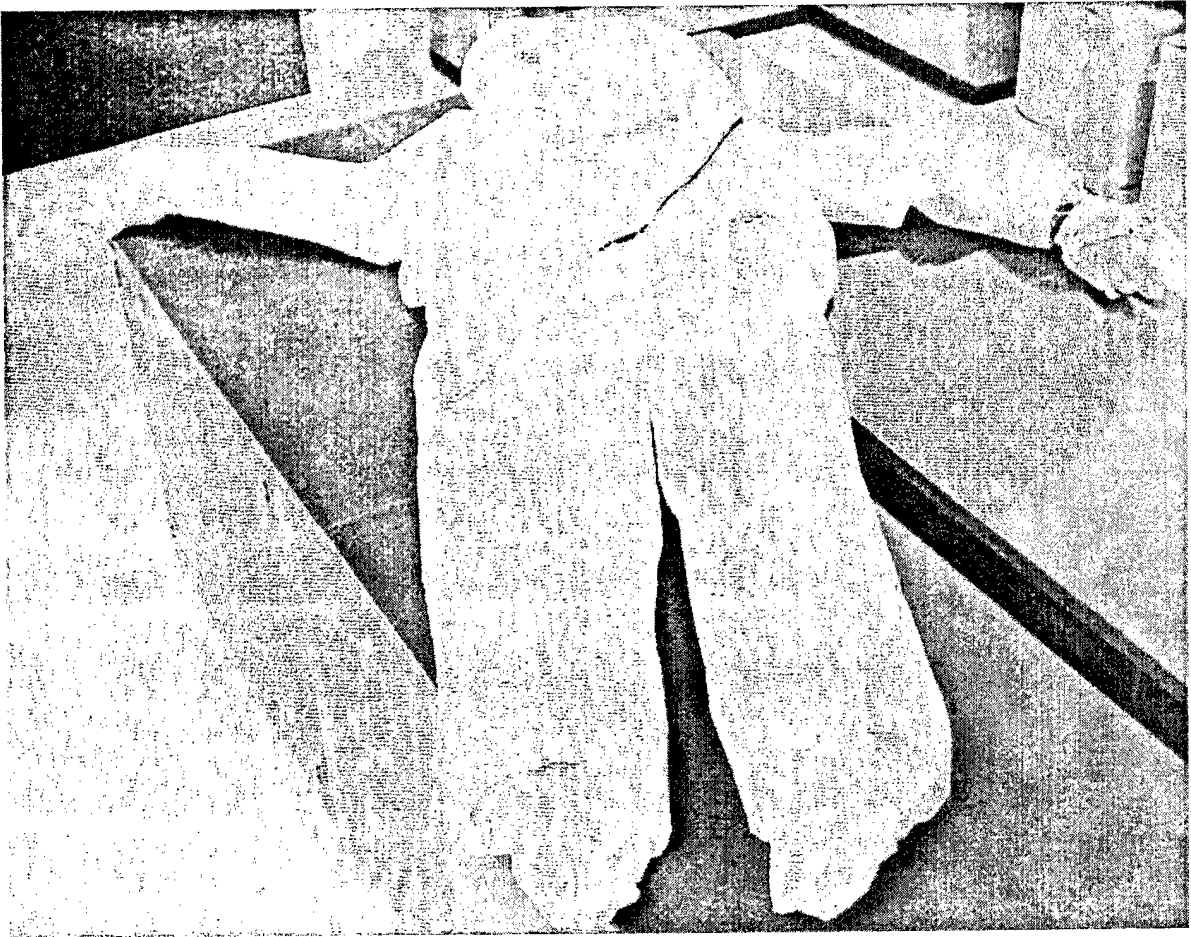


Figure D - 1: Lakeland Economy Level A - Front View

Table D - 1. Lakeland Economy Level A - Average HD Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Leg Material	Time (min)	Suit Arm Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _i
4	3	14	27	4	1	13	3	5	9	13	30	9	8
34	37	44	104	35	21	44	16	35	105	43	165	39	52
64	77	74	140	65	35	74	47	65	176	73	318	69	94
94	121	104	174	95	46	104	153	95	241	103	476	99	145
124	163	134	210	126	58	135	390	125	310	133	617	129	207
154	213	164	251	156	74	165	773	155	386	163	761	159	290
184	271	194	300	186	94	195	1271	185	472	193	911	189	391
214	337	224	356	217	118	226	1824	215	569	223	1063	220	504
244	409	254	416	247	148	256	2384	245	676	253	1211	250	622
274	482	284	485	277	181	286	2945	275	794	283	1356	280	743
304	558	314	560	308	219	317	3508	305	923	313	1498	310	868
334	638	344	640	338	259	347	4074	335	1058	343	1637	340	996
364	723	374	723	368	301	377	4638	365	1200	373	1774	370	1127
394	806	404	807	399	346	408	5201	395	1341	403	1909	400	1259
424	888	434	890	429	395	438	5767	425	1475	433	2042	430	1389
454	969	464	968	459	451	468	6335	455	1603	463	2171	460	1520
484	1044	494	1045	490	520	499	6916	485	1725	493	2294	491	1649
514	1116	524	1122	520	604	529	7504	515	1846	523	2415	521	1780
544	1185	554	1196	550	707	559	8086	545	1963	553	2531	551	1911
574	1251	584	1269	581	835	590	8661	575	2075	583	2644	581	2043
604	1315	614	1338	611	991	620	9348	605	2180	613	2754	611	2189
634	1379	644	1405	641	1198	650	10186	635	2283	643	2862	641	2356
664	1440	674	1471	672	1466	681	11069	665	2383	673	2968	671	2535
694	1498	704	1535	702	1782	711	11967	695	2478	703	3073	701	2721
724	1555	734	1596	732	2154	741	12867	725	2569	733	3175	731	2914
754	1609	764	1655	763	2589	772	13773	755	2655	763	3275	762	3115
784	1662	794	1711	793	3095	802	14692	785	2737	793	3376	792	3327
814	1713	824	1765	823	3669	832	15595	815	2813	823	3474	822	3545
844	1763	854	1817	854	4311	863	16487	845	2887	853	3571	852	3772
874	1812	884	1867	884	5032	893	17378	875	2957	883	3668	882	4010
904	1858	914	1915	914	5824	923	18257	905	3023	913	3764	912	4255
934	1904	944	1962	945	6682	954	19127	935	3086	943	3858	942	4508
964	1949	974	2006	975	7602	984	19981	965	3146	973	3949	972	4769
994	1994	1004	2046	1005	8580	1014	20811	995	3204	1003	4038	1002	5034
1024	2037	1034	2087	1036	9615	1045	21620	1025	3261	1033	4128	1033	5305
1054	2079	1064	2126	1066	10685	1075	22421	1055	3314	1063	4216	1063	5580
1084	2120	1094	2165	1096	11795	1105	23194	1085	3365	1093	4305	1093	5857
1114	2161	1124	2202	1127	12951	1136	23924	1115	3413	1123	4395	1123	6136
1144	2200	1154	2239	1157	14142	1166	24635	1145	3460	1153	4484	1153	6418
1174	2238	1184	2275	1187	15371	1196	25327	1175	3506	1183	4571	1183	6702
1204	2276	1214	2309	1218	16621	1227	25995	1205	3550	1213	4658	1213	6987
1234	2313	1244	2343	1248	17897	1257	26647	1235	3592	1243	4746	1243	7274
1264	2349	1274	2376	1278	19217	1287	27298	1265	3632	1273	4836	1273	7566
1294	2384	1304	2407	1309	20568	1318	27934	1295	3671	1303	4925	1304	7861
1324	2419	1334	2438	1339	21926	1348	28558	1325	3707	1333	5013	1334	8156
1354	2454	1364	2468	1369	23311	1378	29166	1355	3743	1363	5103	1364	8452
1384	2488			1400	24753	1409	29768			1393	5193		
1414	2522			1430	26251					1423	5286		

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_t = 0.5(\text{Suit Leg Matl } M_t) + 0.15(\text{Suit Arm Seam } M_t) + 0.15(\text{Visor Matl } M_t) + 0.1(\text{Glove Material } M_t) + 0.05(\text{Boot Seam } M_t) + 0.05(\text{Zipper Seam } M_t)$.

Table D - 2. Lakeland Economy Level A - Average GB Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Leg Material	Time (min)	Suit Arm Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _f
14	0	5	2	5	0	14	0	5	0	14	1	10	0
45	78	35	54	35	0	44	0	36	1718	44	73	40	137
75	236	65	131	65	0	74	0	66	4805	74	222	70	389
105	394	95	201	95	0	104	0	96	7440	104	369	100	618
136	541	125	268	125	0	134	1	127	9798	134	495	130	826
166	674	155	331	155	1	164	2	157	11858	164	605	160	1010
196	792	185	391	185	1	194	2	187	13677	194	699	190	1174
227	894	215	449	215	1	224	3	218	15281	224	783	220	1318
257	986	245	505	245	1	254	4	248	16707	254	859	251	1447
287	1071	275	558	275	1	284	4	278	18016	284	928	281	1567
318	1152	305	609	305	1	314	4	309	19217	314	990	311	1678
348	1232	335	658	335	1	344	4	339	20335	344	1048	341	1785
378	1309	365	705	365	1	374	4	369	21429	374	1101	371	1887
409	1379	395	750	395	1	404	4	400	22463	404	1151	401	1983
439	1448	425	792	425	1	434	4	430	23435	434	1198	431	2075
469	1515	455	833	455	1	464	4	460	24373	464	1241	461	2164
500	1578	485	871	485	1	494	4	491	25256	494	1283	491	2247
530	1639	515	909	515	1	524	4	521	26086	524	1323	522	2327
560	1698	545	947	545	1	554	4	551	26878	554	1362	552	2404
591	1757	575	985	575	1	584	4	582	27660	584	1399	582	2480
621	1817	605	1021	605	1	614	4	612	28414	614	1434	612	2554
651	1873	635	1054	635	1	644	4	642	29125	644	1467	642	2625
682	1927	665	1085	665	1	674	4	673	29799	674	1499	672	2692
712	1979	695	1113	695	1	704	4	703	30440	704	1528	702	2756
742	2030	725	1139	725	1	734	4	733	31054	734	1556	732	2817
773	2079	755	1164	755	1	764	4	764	31635	764	1582	762	2875
803	2126	785	1186	785	1	794	4	794	32182	794	1607	793	2931
833	2172	815	1208	815	1	824	4	824	32696	824	1630	823	2984
864	2216	845	1227	845	1	854	4	855	33184	854	1652	853	3034
894	2259	875	1246	875	1	884	4	885	33647	884	1673	883	3083
924	2301	905	1264	905	1	914	4	915	34085	914	1693	913	3130
955	2342	935	1281	935	1	944	4	946	34499	944	1712	943	3174
985	2382	965	1298	965	1	974	4	976	34893	974	1730	973	3218
1015	2422	995	1314	995	1	1004	4	1006	35264	1004	1747	1003	3259
1046	2459	1025	1329	1025	1	1034	4	1037	35611	1034	1763	1033	3298
1076	2496	1055	1344	1055	1	1064	4	1067	35948	1064	1779	1064	3337
1106	2533	1085	1358	1085	1	1094	4	1097	36273	1094	1795	1094	3374
1137	2567	1115	1372	1115	1	1124	4	1128	36580	1124	1809	1124	3410
1167	2601	1145	1386	1145	1	1154	4	1158	36871	1154	1823	1154	3444
1197	2634	1175	1399	1175	1	1184	4	1188	37151	1184	1837	1184	3477
1228	2665	1205	1412	1205	1	1214	4	1219	37415	1214	1850	1214	3508
1258	2696	1235	1424	1235	1	1244	4	1249	37670	1244	1863	1244	3539
1288	2726	1265	1436	1265	1	1274	4	1279	37919	1274	1875	1274	3569
1319	2756	1295	1448	1295	1	1304	4	1310	38160	1304	1887	1304	3598
1349	2786	1325	1460	1325	2	1334	4	1340	38393	1334	1899	1335	3627
1379	2816	1355	1472	1355	2	1364	4	1370	38617	1364	1911	1365	3656
1410	2847	1385	1485	1385	4	1394	4	1401	38838	1394	1922	1395	3685
		1415	1497	1415	6	1424	4	1431	39059	1424	1934		

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_f = 0.5(\text{Suit Leg Matl } M_f) + 0.15(\text{Suit Arm Seam } M_f) + 0.15(\text{Visor Matl } M_f) + 0.1(\text{Glove Material } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper Seam } M_f)$.

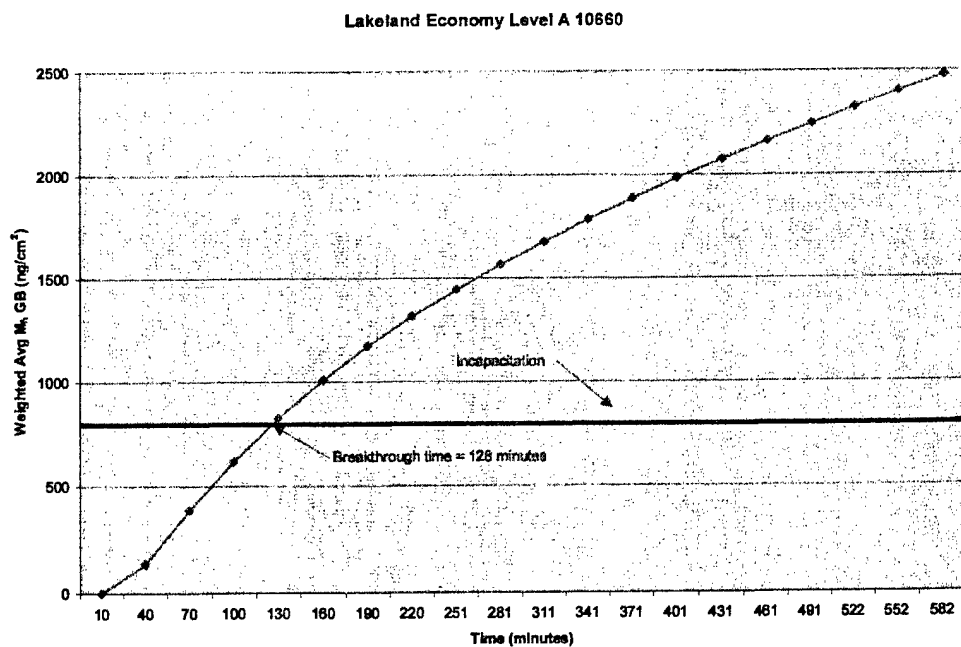


Figure D - 2: Lakeland Economy Level A - Weighted Average HD Permeation

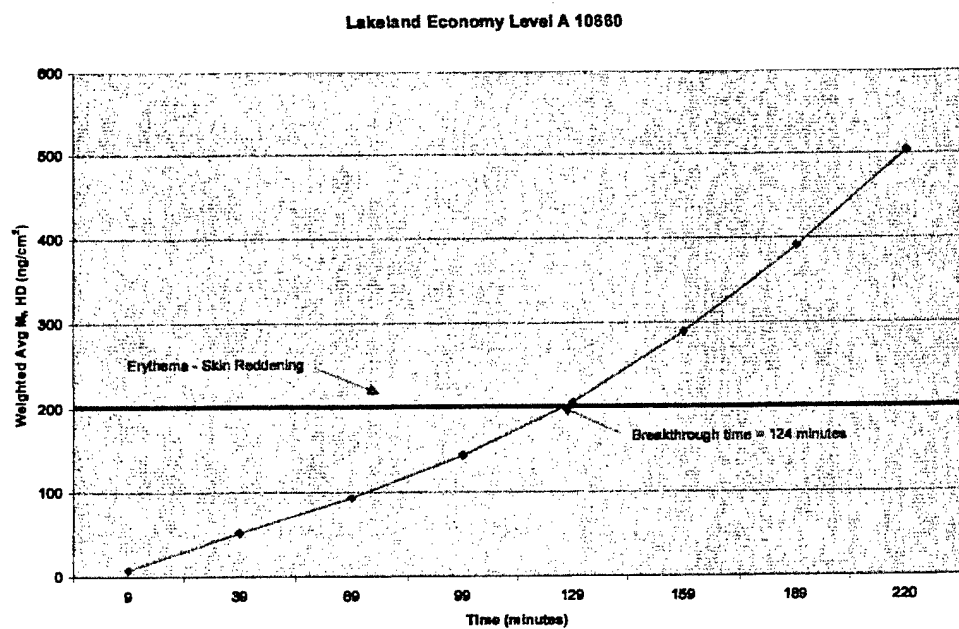


Figure D - 3: Lakeland Economy Level A - Weighted Average GB Permeation

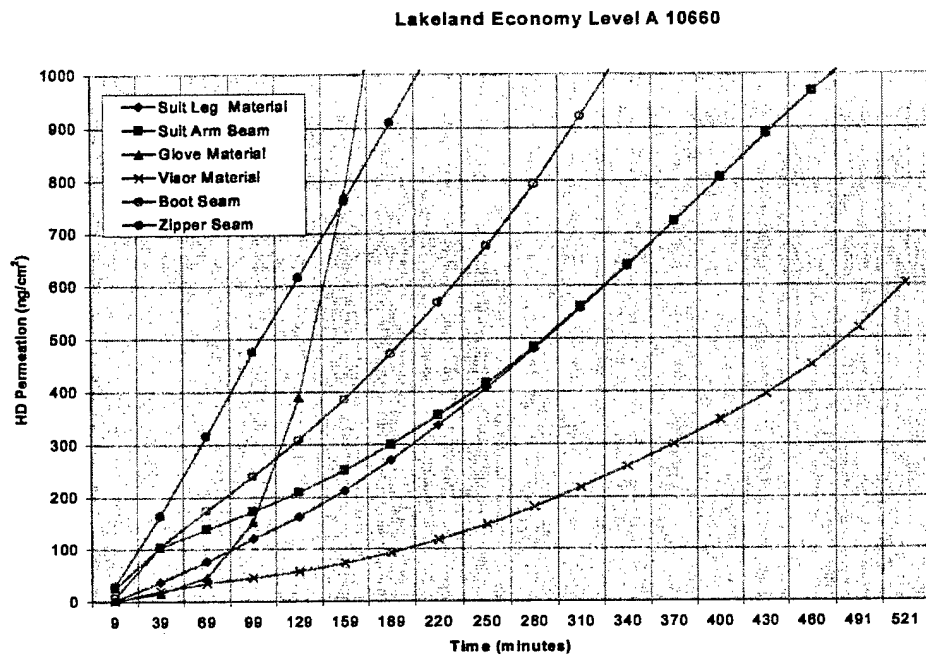


Figure D - 4: Lakeland Economy Level A - HD Permeation by Sampling Area

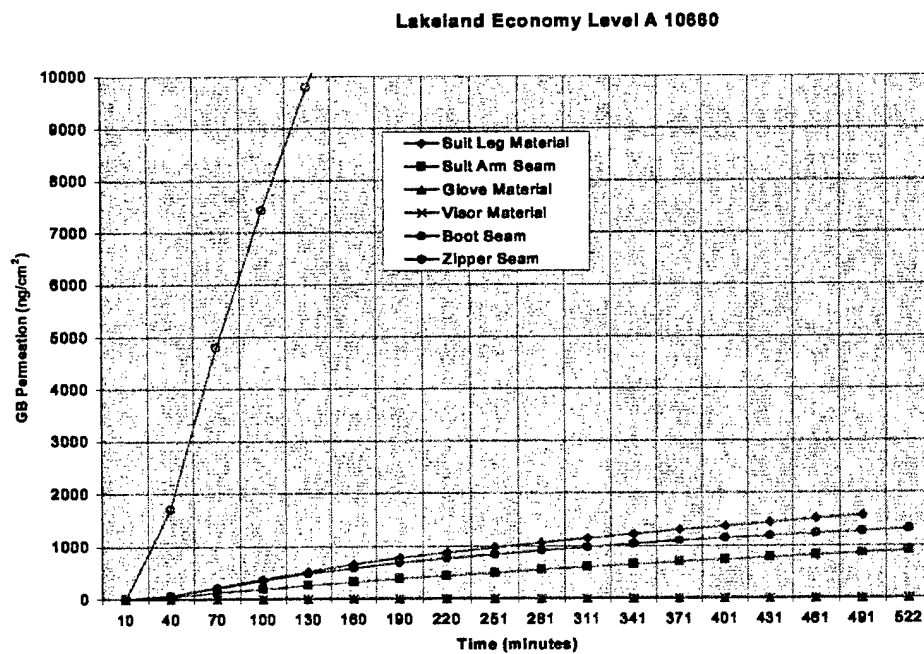


Figure D - 5: Lakeland Economy Level A - GB Permeation by Sampling Area

Table D - 3. Lakeland Economy Level A - System Test (Aerosol Simulant) Results

PF	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	.00	100.00	0	.00	100.00
2	0	.00	100.00	0	.00	100.00
5	0	.00	100.00	0	.00	100.00
10	0	.00	100.00	0	.00	100.00
50	0	.00	100.00	1	2.27	97.73
100	0	.00	100.00	0	2.27	97.73
150	0	.00	100.00	1	4.55	95.45
500	0	.00	100.00	0	4.55	95.45
1000	0	.00	100.00	0	4.55	95.45
1667	1	2.27	97.73	0	4.55	95.45
2000	0	2.27	97.73	0	4.55	95.45
5000	13	31.82	68.18	0	4.55	95.45
6667	9	52.27	47.73	0	4.55	95.45
10000	10	75.00	25.00	4	13.64	86.36
20000	8	93.18	6.82	11	38.64	61.36
50000	2	97.73	2.27	18	79.55	20.45
100000	1	100.00	0.00	9	100.00	0.00
No. of Trials	44			44		

Table D - 4. Lakeland Economy Level A - Overall Test Results

Physiologically-derived breakthrough time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema				
GB	HD	500	5000	10000	
128	124	100	68	25	Pre-Operational
		95	95	86	Operational

APPENDIX E

MAR MAC COMMANDER



Figure E - 1: Mar Mac Commander - Front View

Table E - 1. Mar Mac Commander - Average HD Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Leg Material	Time (min)	Hood Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _t
14	2	5	9	12	3	3	0	5	1	14	35	9	5
44	12	35	81	42	13	33	9	35	15	44	170	39	30
74	19	65	105	72	23	63	20	65	23	74	275	69	45
105	25	95	113	102	32	93	31	96	30	104	373	99	57
135	30	125	121	132	38	123	39	126	38	134	509	129	70
165	36	155	130	162	45	153	47	156	46	164	809	159	91
196	41	185	141	192	51	183	56	187	55	194	1526	189	134
226	46	215	159	222	59	213	67	217	69	224	2820	219	207
256	52	245	188	252	68	243	81	247	87	254	4610	250	307
287	58	275	230	282	77	273	98	278	108	284	6165	280	399
317	65	305	283	312	88	303	118	308	133	314	7908	310	502
347	72	335	346	342	100	333	141	338	164	344	10366	340	643
378	78	365	417	372	112	363	168	369	200	374	12960	370	793
408	85	395	493	402	126	393	198	399	242	404	15647	400	950
438	93	425	571	432	139	423	230	429	288	434	18025	430	1092
469	101	455	650	462	153	453	263	460	339	464	20458	460	1237
499	108	485	729	492	167	483	297	490	397	494	23013	490	1388
529	115	515	809	522	182	513	331	520	459	524	25339	521	1529
560	123	545	891	552	196	543	364	551	525	554	28050	551	1690
590	131	575	974	582	210	573	398	581	595	584	31107	581	1868
620	139	605	1055	612	224	603	432	611	668	614	33994	611	2038
651	147	635	1136	642	239	633	469	642	743	644	36692	641	2198
681	155	665	1217	672	254	663	507	672	823	674	39670	671	2374
711	163	695	1298	702	269	693	544	702	907	704	42760	701	2554
742	172	725	1380	732	284	723	580	733	994	734	45887	731	2738
772	180	755	1462	762	300	753	617	763	1084	764	49268	761	2933
802	189	785	1543	792	315	783	653	793	1179	794	52532	792	3124
833	197	815	1625	822	329	813	690	824	1277	824	55776	822	3313
863	205	845	1706	852	344	843	726	854	1377	854	59222	852	3513
893	214	875	1787	882	359	873	762	884	1480	884	62770	882	3718
924	223	905	1870	912	374	903	796	915	1586	914	66481	912	3931
954	232	935	1953	942	389	933	831	945	1699	944	70303	942	4150
984	242	965	2034	972	403	963	864	975	1816	974	74101	972	4369
1015	251	995	2118	1002	417	993	897	1006	1939	1004	77926	1002	4589
1045	261	1025	2202	1032	430	1023	928	1036	2067	1034	81811	1032	4812
1075	271	1052	2276	1062	444	1053	959	1066	2200	1061	85328	1062	5016
1106	281	1079	2348	1092	458	1083	989	1097	2336				
1136	291	1103	2408	1122	470	1113	1016	1127	2478				
1166	302	1127	2462	1152	483	1143	1041	1157	2626				
1197	312	1151	2516	1179	492	1170	1057	1188	2776				
1227	323	1175	2570	1208	498	1197	1065	1218	2930				
1257	335	1199	2624	1233	504	1224	1072	1248	3086				
1288	346	1220	2665	1260	509	1251	1078	1279	3243				
1318	357	1241	2700	1287	514	1278	1085	1309	3402				
1348	367	1262	2732	1314	519	1305	1091	1339	3563				
1379	378	1283	2763	1341	524	1332	1097	1370	3725				
1409	389	1304	2794	1368	528	1359	1102	1400	3889				
		1322	2811	1395	532	1386	1108	1430	4052				

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_t = 0.5(\text{Suit Matl } M_t) + 0.15(\text{Hood Seam } M_t) + 0.15(\text{Visor Matl } M_t) + 0.1(\text{Glove Matl } M_t) + 0.05(\text{Boot Seam } M_t) + 0.05(\text{Zipper Seam } M_t)$.

Note 4: Sampling for zipper seam was ended prematurely due to equipment failure.

Table E - 2. Mar Mac Commander - Average GB Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Leg Material	Time (min)	Hood Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _t
13	0	6	0	4	0	13	0	4	0	15	0	9	0
43	26	36	40	34	4	43	26	34	164	45	166	39	39
73	66	66	146	64	8	73	63	64	373	76	570	69	110
103	91	97	273	94	11	103	82	94	450	106	1074	99	173
133	115	127	373	124	13	133	90	124	511	136	1625	130	231
163	137	157	444	154	15	163	92	154	565	167	2189	160	284
193	159	188	503	184	17	193	94	184	615	197	2738	190	334
223	180	218	557	214	19	223	97	214	662	227	3262	220	382
253	200	248	606	244	21	253	99	244	706	258	3761	250	427
283	218	279	651	274	23	283	101	274	746	288	4229	280	469
313	236	309	693	304	24	313	103	304	783	318	4667	310	508
343	252	339	733	334	26	343	105	334	817	349	5090	340	546
373	267	370	770	364	27	373	106	364	849	379	5495	370	581
403	282	400	806	394	28	403	107	394	879	409	5883	401	615
433	295	430	840	424	29	433	108	424	907	440	6261	431	647
463	307	461	873	454	30	463	108	454	933	470	6625	461	678
493	319	491	905	484	31	493	109	484	957	500	6967	491	707
523	330	521	935	514	32	523	110	514	979	531	7299	521	735
553	340	552	963	544	32	553	110	544	1001	561	7621	551	761
583	349	582	990	574	32	583	110	574	1021	591	7933	581	787
613	358	612	1016	604	32	613	110	604	1041	622	8237	611	811
643	367	643	1041	634	32	643	110	634	1059	652	8531	641	835
673	375	673	1064	664	32	673	110	664	1077	682	8820	672	858
703	383	703	1087	694	32	703	110	694	1093	713	9103	702	880
733	390	734	1109	724	32	733	110	724	1109	743	9381	732	902
763	397	764	1130	754	32	763	110	754	1123	773	9654	762	923
793	404	794	1150	784	32	793	110	784	1138	804	9921	792	943
823	410	825	1170	814	32	823	110	814	1151	834	10182	822	963
853	416	855	1189	844	32	853	110	844	1164	864	10439	852	982
883	422	885	1208	874	32	883	110	874	1176	895	10699	882	1002
913	427	916	1227	904	32	913	110	904	1187	925	10964	912	1021
943	432	946	1245	934	32	943	110	934	1198	955	11233	943	1040
973	438	976	1263	964	32	973	110	964	1209	986	11503	973	1060
1003	442	1007	1281	994	32	1003	110	994	1219	1016	11776	1003	1079
1033	447	1037	1298	1024	32	1033	110	1024	1229	1046	12051	1033	1098
1063	452	1067	1315	1054	32	1063	110	1054	1238	1077	12326	1063	1117
1093	456	1098	1331	1084	32	1093	110	1084	1247	1107	12600	1093	1136
1123	460	1128	1347	1114	32	1123	110	1114	1255	1137	12876	1123	1154
1153	464	1158	1362	1144	32	1153	110	1144	1263	1168	13148	1153	1172
1183	467	1189	1377	1174	32	1183	110	1174	1270	1198	13420	1183	1190
1213	470	1219	1391	1204	32	1213	110	1204	1277	1228	13693	1214	1208
1243	473	1249	1405	1234	32	1243	110	1234	1283	1259	13962	1244	1226
1273	477	1280	1418	1264	32	1273	110	1264	1290	1289	14228	1274	1243
1303	479	1310	1431	1294	32	1303	110	1294	1296	1319	14494	1304	1260
1333	482	1340	1444	1324	32	1333	110	1324	1301	1350	14758	1334	1277
1363	485	1371	1457	1354	32	1363	110	1354	1307	1380	15019	1364	1293
1393	487	1401	1469	1384	32	1393	110	1384	1312	1410	15275	1394	1309
1423	490	1431	1481	1414	32	1423	110	1414	1318				

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_t = 0.5(\text{Suit Matl } M_t) + 0.15(\text{Hood Seam } M_t) + 0.15(\text{Visor Matl } M_t) + 0.1(\text{Glove Matl } M_t) + 0.05(\text{Boot Seam } M_t) + 0.05(\text{Zipper Seam } M_t)$.

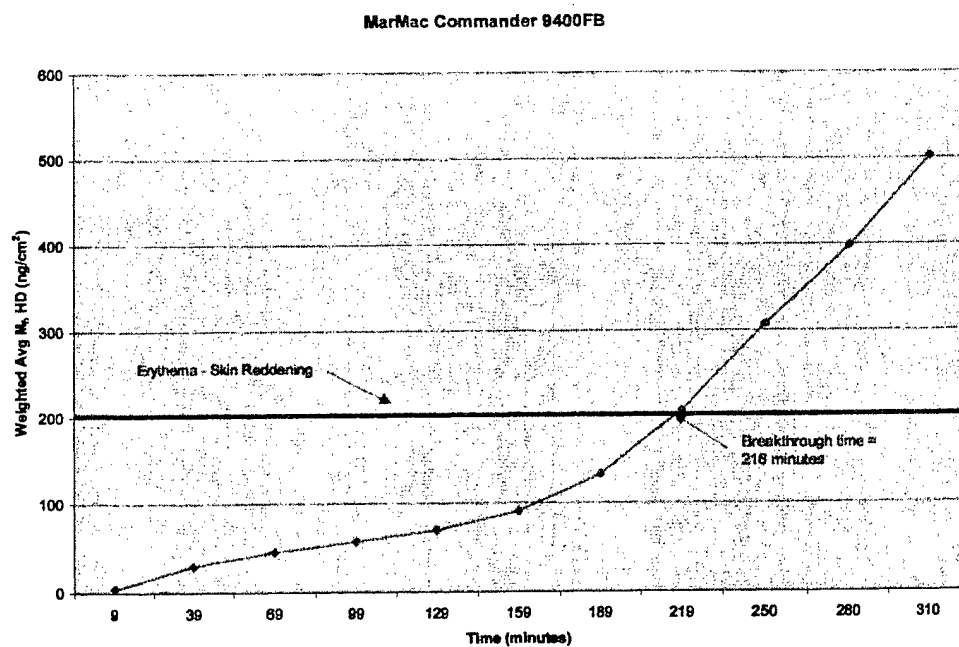


Figure E - 2: Mar Mac Commander - Weighted Average HD Permeation

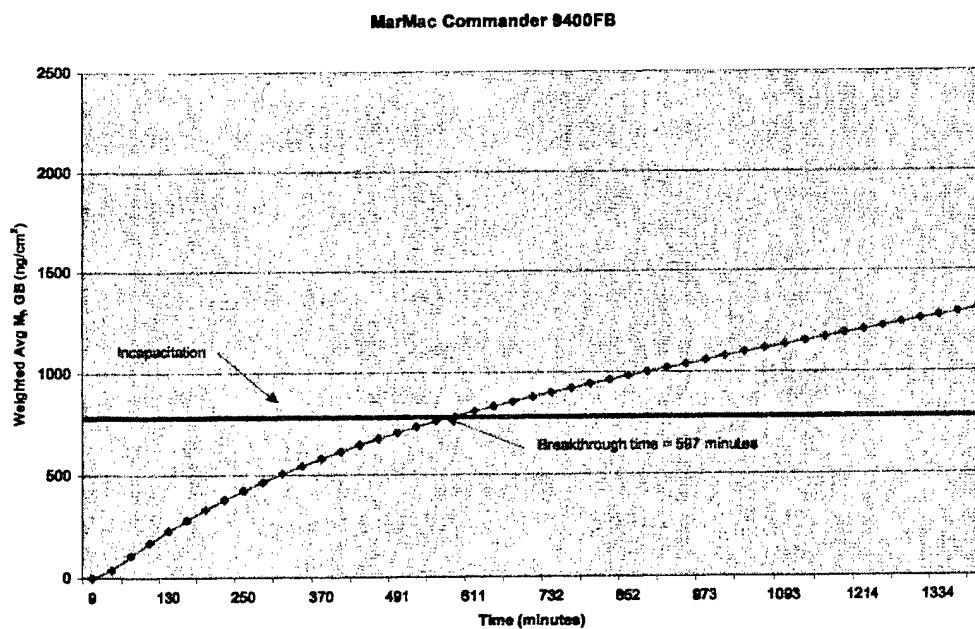


Figure E - 3: Mar Mac Commander - Weighted Average GB Permeation

MarMac Commander 9400FB

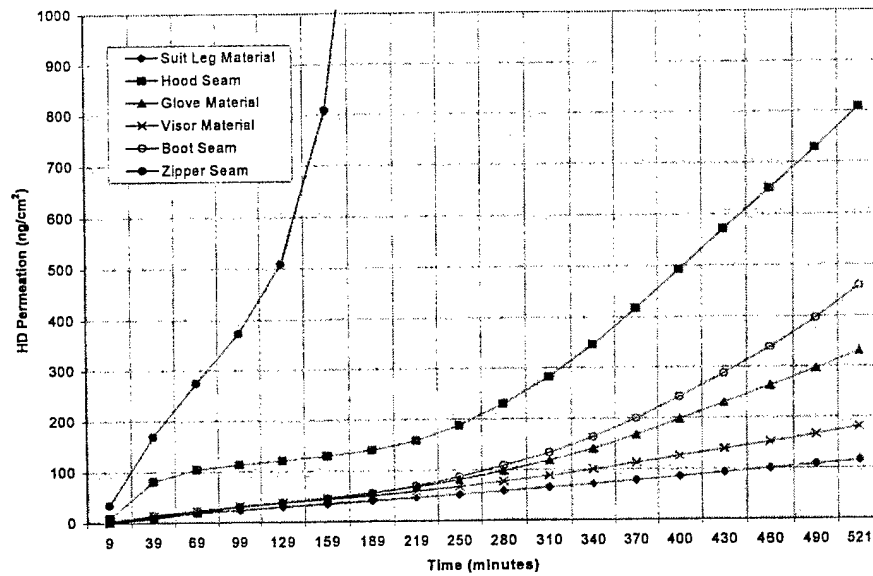


Figure E - 4: Mar Mac Commander - HD Permeation By Sampling Area

MarMac Commander 9400FB

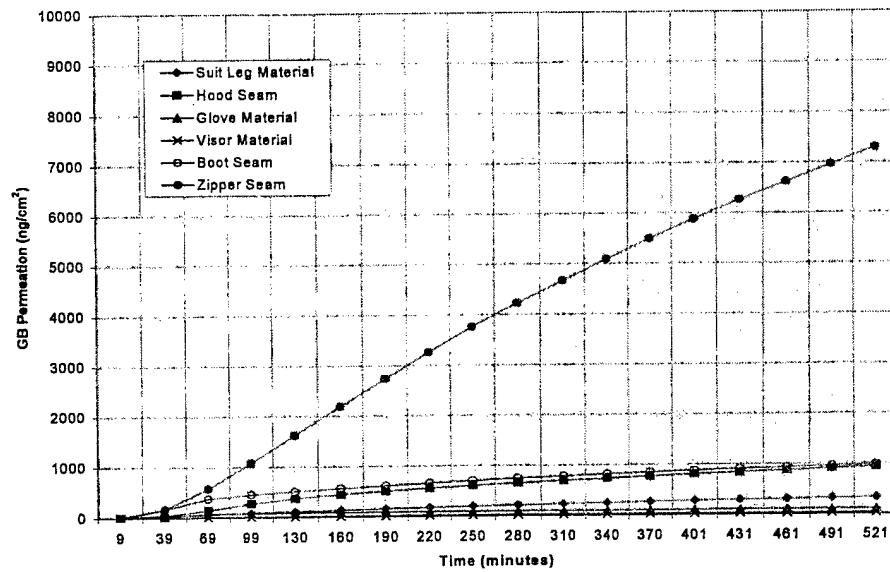


Figure E - 5: Mar Mac Commander - GB Permeation By Sampling Area

Table E - 3. Mar Mac Commander - System Test (Aerosol Simulant) Results

PF	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	.00	100.00	0	.00	100.00
2	0	.00	100.00	0	.00	100.00
5	0	.00	100.00	0	.00	100.00
10	0	.00	100.00	0	.00	100.00
50	0	.00	100.00	0	.00	100.00
100	0	.00	100.00	0	.00	100.00
150	0	.00	100.00	0	.00	100.00
500	0	.00	100.00	0	.00	100.00
1000	0	.00	100.00	0	.00	100.00
1667	1	2.13	97.87	0	.00	100.00
2000	0	2.13	97.87	1	2.13	97.87
5000	17	38.30	61.70	10	23.40	76.60
6667	9	57.45	42.55	11	46.81	53.19
10000	8	74.47	25.53	8	63.83	36.17
20000	9	93.62	6.38	15	95.74	4.26
50000	2	97.87	2.13	2	100.00	0.00
100000	1	100.00	0.00	0	100.00	0.00
No. of Trials	47			47		

Table E - 4. Mar Mac Commander - Overall Test Results

Physiologically-derived breakthrough time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema				
GB	HD	500	5000	10000	
597	216	100	62	26	Pre-Operational
		100	77	36	Operational

APPENDIX F

GIAT UNISCAPH



Figure F - 1: Giat UNISCAPH - Front View

Table F - 1. Giat UNISCAPH - Average HD Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _f
5	1	3	0	5	3	14	21	12	1	14	3	9	3
36	16	33	7	35	25	44	100	42	8	45	14	39	23
66	31	63	12	65	36	74	175	72	14	75	24	69	41
96	41	93	17	95	47	104	252	102	19	106	35	99	56
127	52	123	20	125	60	134	331	132	23	136	227	129	82
157	69	153	24	155	76	164	411	162	26	167	982	160	138
188	101	183	27	185	94	194	494	192	29	197	2310	190	232
218	154	213	31	215	115	224	579	222	32	228	3756	220	342
249	231	243	35	245	139	254	666	252	35	258	5286	250	469
279	327	273	39	275	166	284	756	282	38	288	6987	280	615
310	434	303	44	305	194	314	847	312	41	319	8706	310	767
340	549	333	48	335	225	344	942	342	44	349	10425	341	924
371	669	363	53	365	257	374	1037	372	47	380	12145	371	1084
401	798	393	58	395	290	404	1128	402	50	410	13892	401	1250
432	926	423	63	425	324	434	1217	432	54	441	15646	431	1415
462	1050	453	69	455	357	464	1306	462	57	471	17373	461	1576
493	1173	483	74	485	391	494	1395	492	60	502	19020	491	1734
523	1292	513	80	515	426	524	1483	522	63	532	20592	522	1886
554	1411	543	85	545	460	554	1569	552	66	563	22151	552	2036
584	1528	573	90	575	493	584	1653	582	69	593	23655	582	2183
615	1643	603	95	605	525	614	1740	612	72	624	25118	612	2326
645	1754	633	100	635	559	644	1827	642	74	654	26643	642	2472
676	1862	663	105	665	592	674	1914	672	77	685	28222	672	2618
706	1969	693	110	695	625	704	1999	702	80	715	29682	703	2757
737	2075	723	115	725	658	734	2082	732	82	746	31087	733	2893
767	2178	753	120	755	690	764	2165	762	85	776	32599	763	3033
798	2276	783	125	785	723	794	2245	792	87	807	34155	793	3172
828	2373	813	130	815	756	824	2327	822	90	837	35644	823	3307
859	2468	843	135	845	788	854	2410	852	92	868	37011	853	3436
889	2561	873	140	875	820	884	2491	882	94	898	38431	884	3566
920	2654	903	144	905	851	914	2571	912	97	929	39903	914	3698
950	2746	933	149	935	882	944	2649	942	99	959	41379	944	3830
981	2838	963	153	965	912	974	2726	972	101	990	42926	974	3965
1011	2930	993	158	995	941	1004	2805	1002	103	1020	44484	1004	4101
1042	3019	1023	162	1025	971	1034	2882	1032	105	1051	46038	1034	4235
1072	3110	1053	166	1055	1000	1064	2958	1062	108	1081	47586	1065	4369
1103	3202	1083	170	1085	1029	1094	3032	1092	110	1112	49140	1095	4504
1133	3292	1113	174	1115	1057	1124	3106	1122	112	1142	50689	1125	4637
1164	3382	1143	178	1145	1086	1154	3179	1152	114	1173	52236	1155	4771
1194	3472	1173	182	1175	1115	1184	3253	1182	116	1203	53794	1185	4905
1225	3562	1203	186	1205	1145	1214	3329	1212	117	1234	55360	1215	5040
1255	3651	1233	190	1235	1175	1244	3405	1242	119	1264	56917	1246	5173
1286	3738	1263	194	1265	1204	1274	3482	1272	121	1295	58468	1276	5306
1316	3824	1293	198	1295	1233	1304	3560	1302	123	1325	60021	1306	5438
1347	3908	1323	202	1325	1263	1334	3638	1332	125	1356	61574	1336	5570
1377	3994	1353	206	1355	1291	1364	3715	1362	127	1386	63128	1366	5701
1408	4079	1383	209	1385	1320	1394	3791	1392	129	1417	64685	1396	5833
		1413	213	1415	1348	1424	3867	1422	130				

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_f = 0.5(\text{Suit Matl } M_f) + 0.15(\text{Suit Seam } M_f) + 0.15(\text{Visor Matl } M_f) + 0.1(\text{Glove Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper Seam } M_f)$.

Table F - 2. Giat UNISCAPH – Average GB Permeation

Average Cumulative Permeation (ng/cm ²)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Visor Material	Time (min)	Glove Material	Time (min)	Boot Seam	Time (min)	Zipper Seam	Average Time (min)	Weighted Average M _f
5	9	12	5	4	6	13	11	3	2	14	36	9	9
35	102	42	25	34	63	43	47	33	35	44	184	39	78
65	190	72	39	64	87	73	67	63	61	74	331	69	138
95	277	102	51	94	101	103	78	93	78	104	477	99	194
125	364	132	61	124	110	133	87	123	92	134	627	129	250
155	451	162	69	154	118	163	94	153	104	164	782	159	305
185	538	192	77	184	125	193	100	183	116	194	950	189	360
215	625	222	85	214	132	223	105	213	127	224	1136	219	416
245	711	252	93	244	138	253	111	243	138	254	1343	249	473
275	796	282	100	274	144	283	116	273	148	284	1575	279	530
305	879	312	108	304	150	313	121	303	158	314	1833	309	588
335	961	342	115	334	155	343	126	333	168	344	2124	339	646
365	1040	372	122	364	161	373	130	363	178	374	2447	369	705
395	1119	402	128	394	166	403	134	393	187	404	2804	399	765
425	1195	432	134	424	171	433	138	423	196	434	3193	429	825
455	1271	462	140	454	175	463	141	453	205	464	3615	459	886
485	1344	492	146	484	180	493	145	483	214	494	4072	489	948
515	1416	522	152	514	184	523	149	513	222	524	4564	519	1011
545	1486	552	157	544	189	553	152	543	230	554	5086	549	1075
575	1555	582	162	574	194	583	156	573	238	584	5639	579	1139
605	1621	612	169	604	198	613	159	603	246	614	6222	609	1203
635	1686	642	175	634	202	643	162	633	254	644	6829	639	1268
665	1749	672	181	664	206	673	165	663	261	674	7455	669	1333
695	1810	702	187	694	210	703	168	693	269	704	8097	699	1399
725	1870	732	193	724	214	733	171	723	276	734	8752	729	1463
755	1928	762	198	754	218	763	174	753	283	764	9419	759	1528
785	1984	792	204	784	222	793	177	783	290	794	10094	789	1592
815	2039	822	210	814	226	823	179	813	298	824	10776	819	1656
845	2092	852	215	844	230	853	182	843	305	854	11468	849	1719
875	2145	882	220	874	234	883	185	873	311	884	12182	879	1783
906	2197	912	226	904	238	913	187	903	318	915	12899	909	1847
936	2247	942	232	934	241	943	190	933	324	945	13618	939	1910
967	2297	972	237	964	245	973	192	963	331	976	14340	969	1973
997	2345	1002	242	994	249	1003	195	993	337	1006	15068	999	2035
1027	2392	1032	247	1024	253	1033	198	1023	343	1036	15800	1029	2097
1058	2438	1062	252	1054	257	1063	200	1053	349	1067	16528	1060	2159
1088	2483	1092	256	1084	261	1093	203	1083	355	1097	17254	1090	2219
1119	2526	1122	261	1114	265	1123	205	1113	361	1128	17976	1120	2279
1149	2569	1152	265	1144	269	1153	208	1143	367	1158	18690	1150	2338
1179	2611	1182	270	1174	273	1183	210	1173	373	1188	19395	1180	2396
1210	2652	1212	274	1204	277	1213	213	1203	378	1219	20095	1210	2453
1240	2692	1242	278	1234	281	1243	216	1233	384	1249	20792	1240	2510
1271	2731	1272	282	1264	285	1273	218	1263	389	1280	21486	1271	2566
1301	2769	1302	286	1294	289	1303	221	1293	395	1310	22168	1301	2621
1331	2807	1332	290	1324	293	1333	223	1323	400	1340	22839	1331	2675
1362	2843	1362	294	1354	297	1363	226	1353	405	1371	23502	1361	2728
1392	2878	1392	297	1384	301	1393	228	1383	411	1401	24154	1391	2780
1422	2913	1422	301	1414	306	1423	231	1413	416	1431	24800	1421	2831

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average $M_f = 0.5(\text{Suit Matl } M_f) + 0.15(\text{Suit Seam } M_f) + 0.15(\text{Visor Matl } M_f) + 0.1(\text{Glove Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper Seam } M_f)$.

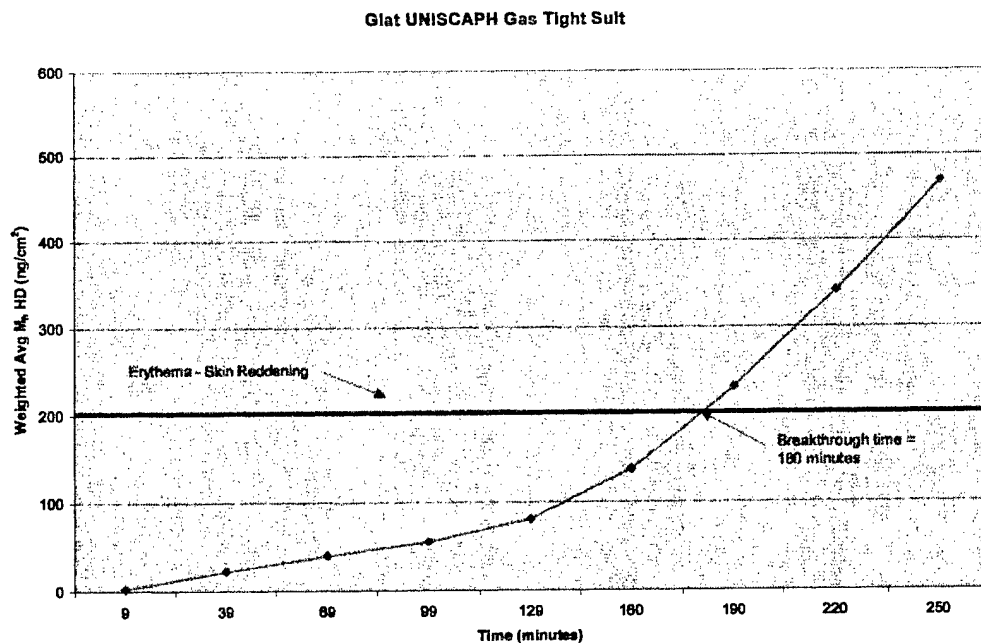


Figure F - 2: Giat UNISCAPH - Weighted Average HD Permeation

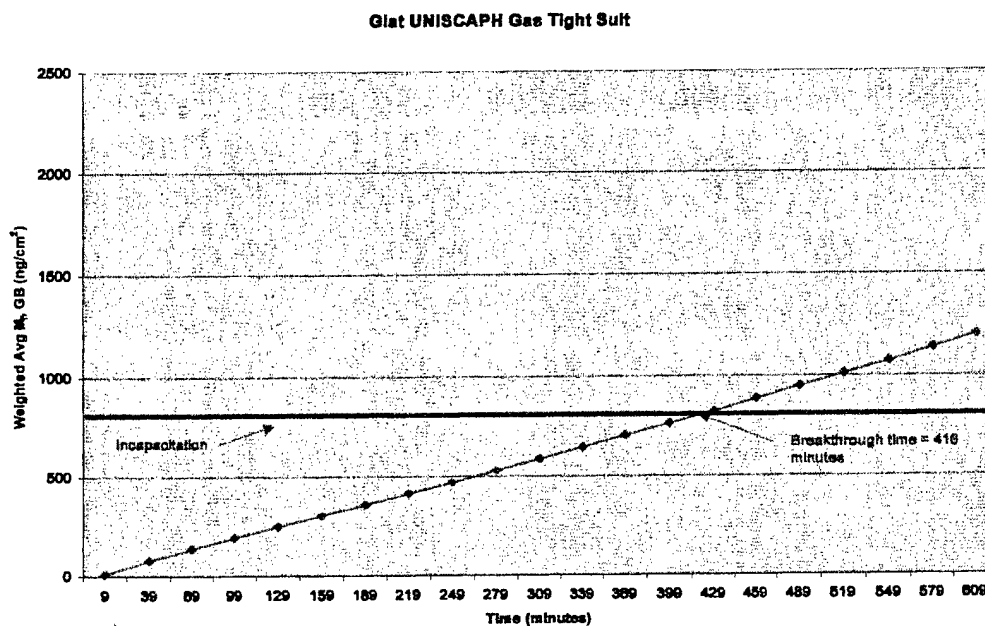


Figure F - 3: Giat UNISCAPH - Weighted Average GB Permeation

Giat UNISCAPH Gas Tight Suit

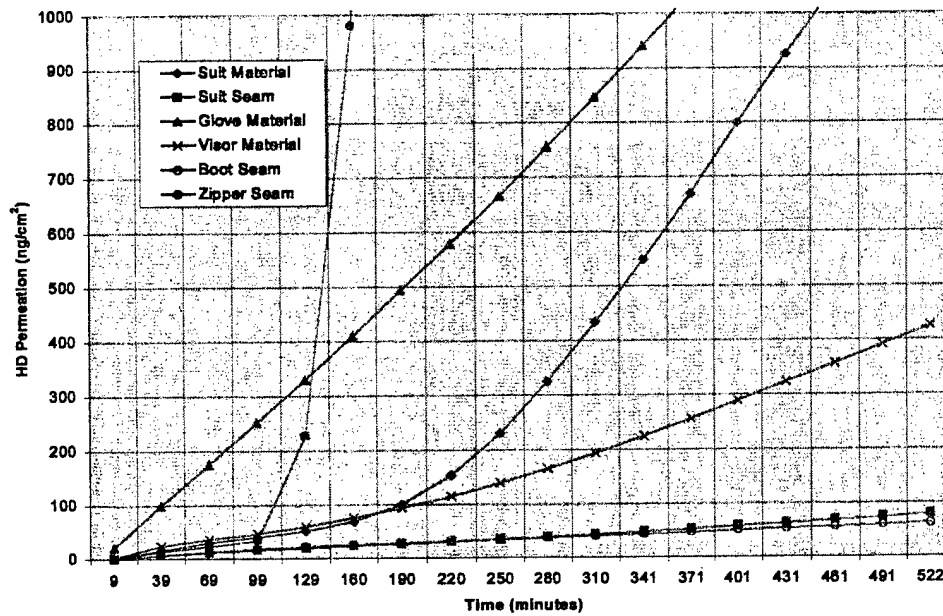


Figure F - 4: Giat UNISCAPH - HD Permeation by Sampling Area

Giat UNISCAPH Gas Tight Suit

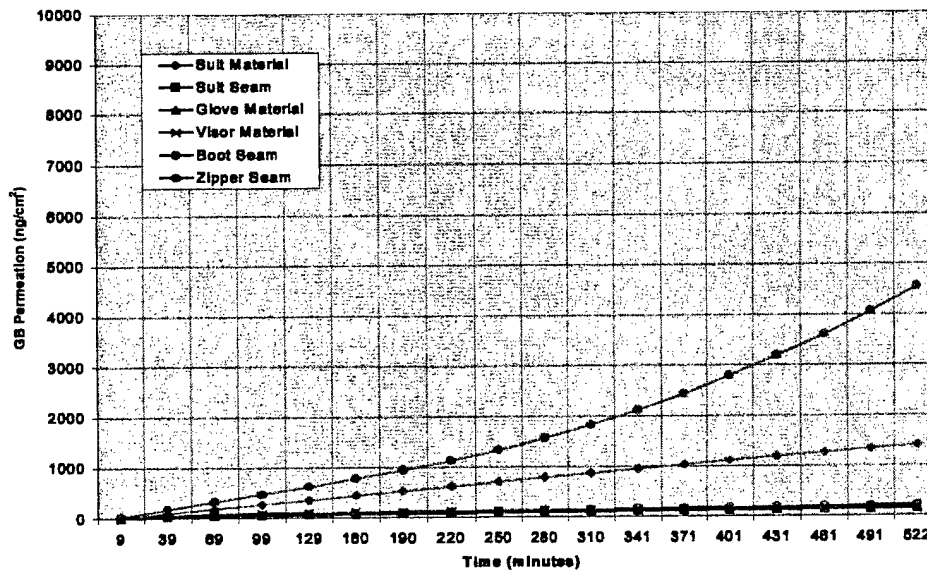


Figure F - 5: Giat UNISCAPH - GB Permeation by Sampling Area

Table F - 3. Giat UNISCAPH - System Test (Aerosol Simulant) Results

PF	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	.00	100.00	0	.00	100.00
2	0	.00	100.00	0	.00	100.00
5	0	.00	100.00	0	.00	100.00
10	0	.00	100.00	0	.00	100.00
50	0	.00	100.00	0	.00	100.00
100	0	.00	100.00	0	.00	100.00
150	0	.00	100.00	2	4.35	95.65
500	6	13.04	86.96	10	26.09	73.91
1000	11	36.96	63.04	8	43.48	56.52
1667	14	67.39	32.61	3	50.00	50.00
2000	7	82.61	17.39	2	54.35	45.65
5000	8	100.00	.00	15	86.96	13.04
6667	0	100.00	.00	2	91.30	8.70
10000	0	100.00	.00	2	95.65	4.35
20000	0	100.00	.00	1	97.83	2.17
50000	0	100.00	.00	1	100.00	.00
100000	0	100.00	.00	0	100.00	.00
No. of Trials	46			46		

Table F - 4. Giat UNISCAPH - Overall Test Results

Physiologically-derived breakthrough time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema				
GB	HD	500	5000	10000	
416	180	87	0	0	Pre-Operational
		74	13	4	Operational

APPENDIX G

OVERALL TEST RESULTS

Summary of HD Permeation Results

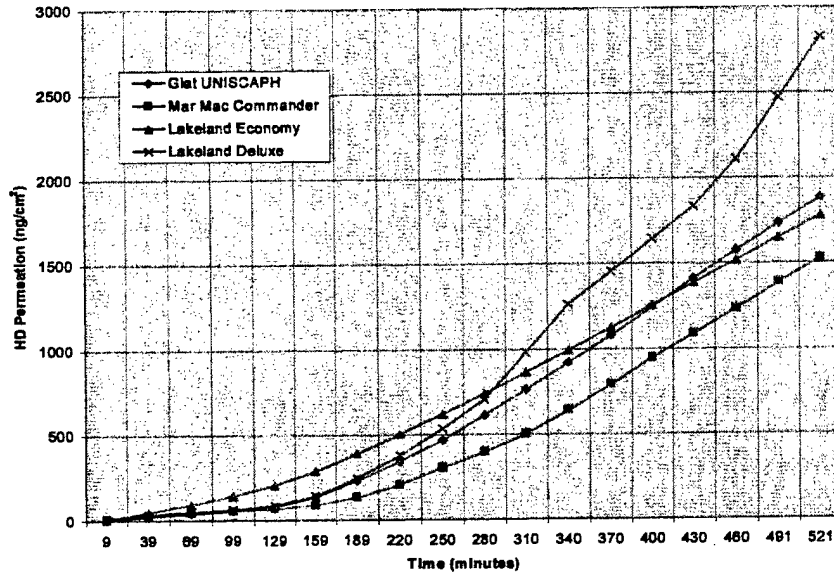


Figure G - 1: Weighted Average HD Permeation

Summary of GB Permeation Results

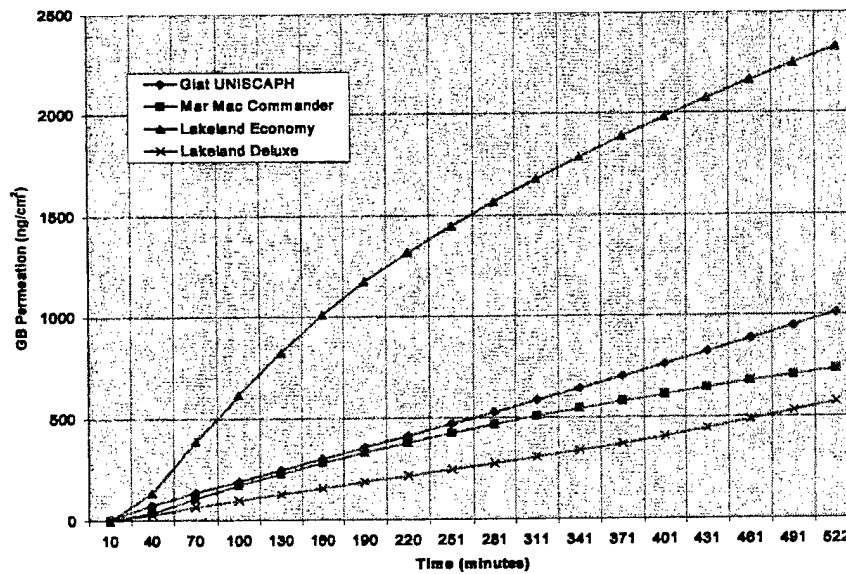


Figure G - 2: Weighted Average GB Permeation

Table G - 1. Summary of Overall Results for all Level A Suits

Test Item	Physiologically-derived breakthrough time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
	Incapacitation	Erythema				
	GB	HD	500	5000	10000	
Lakeland Deluxe Level A 10640	>522	177	86	16	2	Pre-Operational
			83	38	24	Operational
Lakeland Economy Level A 10660	128	124	100	68	25	Pre-Operational
			95	95	86	Operational
Mar Mac Commander 9400FB	597	216	100	62	26	Pre-Operational
			100	77	36	Operational
Giat UNISCAPH Gas Tight Suit	416	180	87	0	0	Pre-Operational
			74	13	4	Operational