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CHEMICAL BIOLOGICAL CENTER

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

ECBC-TR-338

# PROTECTION FACTOR TESTING OF THE 3M BREATHE EASY (BE-10) POWERED AIR PURIFYING RESPIRATOR (PAPR)


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September 2003

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Aberdeen Proving Ground, MD 21010-5424


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This report describes the results of the performance testing of the 3M Breathe Easy (BE-10) Powered Air Purifying Respirator. A series of tests were performed to determine the corn-oil protection factors using human subjects.

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## Executive Summary

The work described in this report was authorized under the TSA Project No. 209 for the U.S. Army Soldier and Biological Chemical Command (SBCCOM). This work was conducted during December 2001 and includes information contained in an earlier report under the Domestic Preparedness Evaluation Program. Protection Factor (PF) testing of the Improved 3M BE-10 PAPR was completed on December 15, 2001 at the Mask Fit Test Facility using 24 different military volunteers. The BE-10 PAPRs were pre-screened on the TDA-99M prior to PF testing to determine quality. All 12 PAPRs passed this testing while on the Smartman and being breathed at 25 liter per minute. The purpose of this testing (the TDA testing and the PF testing) was to see if the 3M BE-10 PAPR could be used by a civilian/First Responder population in the event of a chemical or biological terrorist attack.

Each volunteer performed five trials of 10 1-min exercises while wearing the 3M BE-10 PAPR. Air sampling occurred at the oro-nasal region. Two methods of oro-nasal sampling were used: Standard U.S. Army oro-nasal sample and 3M oro-nasal cannula sample. After performing several tests it became evident that the U.S. Army method was less labor intensive and showed no significant difference with the 3M method. The 3M representatives agreed to continue sampling only with the U.S. Army method.

Precise PF values were calculated for each exercise by an instrument called a Laser Photometer (rear light-scattering). The instrument can measure leakage into the mask by shining a laser over the cross-sectional area of the sample. If corn oil is present, the laser will refract and register a voltage peak. This voltage peak is then compared to the chamber reading and converted by the instrument into a PF value.

Because this civilian mask is a PAPR, the U.S. Army requires that it meet 100% pass rates at the 10000 PF level. The 3M BE-10 PAPR met and surpassed this requirement achieving 100% pass rates at the 10000 and 20000 PF levels, respectively.

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## PREFACE

The work described in this report was authorized under the TSA Project No. 209 for the U.S. Army Soldier and Biological Chemical Command (SBCCOM). The work was started and completed in December 2001.

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# PROTECTION FACTOR TESTING OF THE 3M BREATHE EASY (BE-10) POWERED AIR PURIFYING RESPIRATOR (PAPR)

## 1. INTRODUCTION

The 3M Breathe Easy (BE-10) Powered Air Purifying Respirator (PAPR) was tested to determine its capability to protect first responders (i.e., firemen and policemen) from a chemical or biological attack. The complete unit includes the blower/filtration unit, appropriate respirator headpiece assembly, breathing tube assembly, rechargeable battery and appropriate filters. The PAPR is designed to protect the wearer from airborne contaminants (particulates such as dusts, mists and fumes), organic vapors, acid gases, and other inorganic gases. It is specifically designed not to handle atmospheres containing < 19.5 % oxygen and contaminant concentrations above Immediately Dangerous to Life and Health (IDLH) levels. Testing was conducted through a test service agreement (TSA) between the 3M Company and the U.S. Army Edgewood Chemical Biological Center (ECBC).

## 2. BACKGROUND

The BE10 was originally marketed by RACAL as the BE20. Earlier testing, as part of the Domestic Preparedness (DP) Program, indicated there might be a problem with leakage around the exhalation valve. The valves of the BE10 and BE20 were compared, and it was found that there is a difference in the design of the ring nut that secures the valves to the PAPR lens. The ECBC personnel considered this as a possible leak point. There was also concern about a flashing problem that occurred in the blower housing where the filter cartridges are mounted. The 3M company provided a gasket to ECBC as a mod kit and a gasket for the ring nut. The PAPR was subsequently retested. This report discusses the second Protection Factor (PF) test performed on this PAPR.

## 3. OBJECTIVE

The PF test used a corn oil aerosol to simulate chemical and biological airborne agents. Human subjects wore the 3M BE-10 PAPR inside the corn oil aerosol chamber to determine the device's overall PF.

## 4. PROTECTION FACTOR TESTING

### 4.1 Testing Facilities.

Testing occurred in Building E5604, Aberdeen Proving Grounds – Edgewood Area, MD, on Saturday, December 15, 2001. A challenge aerosol concentration of 20 - 40 mg/m$^3$, polydispersed corn oil aerosol having a mass median aerodynamic diameter

(MMAD) of 0.4 to 0.6 μm (the U.S. Army Standard) was generated in a 10-ft × 20-ft × 32-ft test chamber. The test chamber challenge aerosol was generated by atomizing liquid corn oil at room temperature using a Laskin nozzle. The Laskin nozzle produced a coarse aerosol cloud, which was directed into an impaction plate to remove the larger particles and yield an aerosol in the desired size range. The concentrated aerosol from the generator was diluted with filtered ambient air to control the challenge aerosol concentration in the exposure chamber.

A 6-decade, 45° off-axis light-scattering laser photometer, sampling at a flow rate of 1 – 2 L/min, was used to quantify concentration of the challenge and the in-mask corn oil aerosols. For a given particle size, the quantity of scattered light is proportional to the aerosol concentration. The photometer converted the quantity of scattered light to a voltage, which was then digitized and recorded by a microcomputer.

4.2 Preparation of Test Items.

A total of 12 3M BE-10 PAPR units were received at the PF Testing Facility for use in the test. All units were then checked for quality with a TDA-99M. The units were configured with a SMARTMAN breathing at 25 L/min. All units passed this prescreening process.

A sample port must be fitted somewhere in the unit so it can connect to the laser photometers. It was initially decided that 3M cannula probes were going to be used in the oro-nasal region. After the first few trials, this probe became too labor intensive and it was determined by ECBC personnel and 3M representatives that U.S. Army oro-nasals probes were just as adequate. The U.S. Army standard probes were used from this point forward.

4.3 Test Procedure.

On test day, 24 military volunteers were chosen for the test. Upon their arrival at the testing facility, some anthropometric data was taken from them including facial length, facial width and head breadth. This data can be found in Appendix A. The ECBC personnel then went over an orientation for the volunteers, which explained the test and a volunteer agreement for each volunteer to sign.

The volunteers were then trained on the 3M BE-10 PAPR and how it should be donned properly. Once ready, a group of 8 volunteers prepared to enter the chamber. They were expertly donned with the 3M BE-10 PAPR units by 3M representatives and were instructed to enter the chamber.

Once inside the chamber, the volunteers were instructed to complete the following 10 1-min exercises to stress the seal of the mask:

- Normal Breathing
- Deep Breathing
- Move Head Side to Side
- Move Head Up and Down

- Recite the "Rainbow" Passage
- Sight the Rifle
- Reach for the Floor and Ceiling
- On Hands and Knees, Look Left and Right
- Facial Expressions
- Normal Breathing

Once all exercises were completed the volunteers were instructed to exit the chamber. They then removed the equipment and completed a comfort survey. That complete cycle is considered 1 trial. Each volunteer completed 5 trials for a total of 120 trials for the complete test.

## 5. DATA ANALYSIS

The PAPR's performance was quantified in terms of a PF. The PF was calculated by determining the ratio of the challenge aerosol concentration to the in-mask aerosol concentration as quantified by integrating the peak voltage output from the photometer over a time interval. A PF was calculated for each individual exercise ($PF_i$):

$$PF_i = \frac{Challenge\,Concentration}{In-mask\,Concentration}$$

Each $PF_i$ for that trial were then used to calculate an overall PF for a volunteer ($PF_o$) as follows:

$$PF_o = n\left(\sum_{i=1}^{n}\frac{1}{PF_i}\right)^{-1}$$

where $n$ is the number of exercises. The $PF_o$ is affected most by the smallest $PF_i$. Under the conditions of this test and the sensitivity of the photometer, the maximum PF that can be reported is 100,000. In Appendix B, the $PF_i$ is listed under each exercise and the $PF_o$ is listed under Average Fit (AVEFIT).

## 6. RESULTS AND DISCUSSION

The test data are summarized below in Tables 1 and 2. Table 1 represents the two trials done with the 3M cannula probe while Table 2 shows the results from the remaining trials using the U.S. Army oro-nasal probe. The first column lists each range of protection factor (PF) computed. The second column is the number of test trials falling within each calculated PF range. The third column presents the cumulative-percentage of test trials that resulted in a PF below the upper limit of the range and the fourth column presents the percentage of trials that exceed the lower limit of the range shown.

**Table 1. Trials Using Cannulus Probes**

| *PF* | *Frequency* | *Cumulative %* | Pass % |
|---|---|---|---|
| 0.0 | 0 | .00% | 100.0% |
| 10.0 | 0 | .00% | 100.0% |
| 50.0 | 0 | .00% | 100.0% |
| 100.0 | 0 | .00% | 100.0% |
| 200.0 | 0 | .00% | 100.0% |
| 500.0 | 0 | .00% | 100.0% |
| 1000.0 | 0 | .00% | 100.0% |
| 1667.0 | 0 | .00% | 100.0% |
| 2000.0 | 0 | .00% | 100.0% |
| 5000.0 | 0 | .00% | 100.0% |
| 6667.0 | 0 | .00% | 100.0% |
| 10000.0 | 0 | .00% | 100.0% |
| 20000.0 | 0 | .00% | 100.0% |
| 50000.0 | 0 | .00% | 100.0% |
| 100000.0 | 4 | 100.00% | 0.0% |

**Table 2. Trials Using U.S. Army Standard Probes**

| *PF* | *Frequency* | *Cumulative %* | Pass % |
|---|---|---|---|
| 0.0 | 0 | .00% | 100.0% |
| 10.0 | 0 | .00% | 100.0% |
| 50.0 | 0 | .00% | 100.0% |
| 100.0 | 0 | .00% | 100.0% |
| 200.0 | 0 | .00% | 100.0% |
| 500.0 | 0 | .00% | 100.0% |
| 1000.0 | 0 | .00% | 100.0% |
| 1667.0 | 0 | .00% | 100.0% |
| 2000.0 | 0 | .00% | 100.0% |
| 5000.0 | 0 | .00% | 100.0% |
| 6667.0 | 0 | .00% | 100.0% |
| 10000.0 | 0 | .00% | 100.0% |
| 20000.0 | 0 | .00% | 100.0% |
| 50000.0 | 6 | 5.36% | 94.6% |
| 100000.0 | 106 | 100.00% | 0.0% |

Because this civilian mask is a Powered Air Purifying Respirator (PAPR), the U.S. Army requires that it meet 100% pass rates at the 10000 PF level. The 3M BE-10 PAPR met and surpassed this requirement achieving 100% pass rates at the 10000 and 20000 PF levels, respectively. A major problem encountered in this testing was the battery on the PAPR. If not properly attached to the waist belt, it is easily disconnected and falls off. Three test subjects dropped their batteries during testing and that data was eliminated from the final analysis.

# APPENDIX A

# ANTHROPOMETRIC DATA

| | Face | | |
|---|---|---|---|
| Subject | Length (mm) | Width (mm) | Head Breadth (mm) |
| 1 | 122 | 134 | 190 |
| 2 | 119 | 137 | 194 |
| 3 | 123 | 133 | 198 |
| 4 | 111 | 124 | 187 |
| 5 | 120 | 146 | 191 |
| 6 | 132 | 145 | 203 |
| 7 | 123 | 136 | 203 |
| 8 | 115 | 137 | 190 |
| 9 | 119 | 146 | 199 |
| 10 | 120 | 150 | 203 |
| 11 | 122 | 140 | 204 |
| 12 | 130 | 137 | 201 |
| 13 | 113 | 131 | 199 |
| 14 | 129 | 146 | 198 |
| 15 | 110 | 129 | 193 |
| 16 | 108 | 135 | 183 |
| 17 | 127 | 143 | 207 |
| 18 | 111 | 124 | 176 |
| 19 | 127 | 147 | 196 |
| 20 | 129 | 135 | 186 |
| 21 | 122 | 152 | 208 |
| 22 | 126 | 144 | 207 |
| 23 | 111 | 131 | 192 |
| 24 | 121 | 136 | 185 |

# APPENDIX B

# RAW DATA

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVEFIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 10:42:12 | 3M-1 | 1 | 1 | 1 | 69733.9 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 18725.8 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:55:35 | 3M-9 | 1 | 1 | 2 | 43850.9 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 7681.5 | 55983.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:55:32 | 3M-11 | 1 | 1 | 3 | 78879.2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 27191.6 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:04:24 | 3M-3 | 1 | 1 | 4 | 74803.3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 25375.3 | 70049.3 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:01:12 | 3M-6 | 1 | 1 | 5 | 80584.3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 29331.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 10:42:13 | 3M-2 | 2 | 1 | 1 | 62393.6 | 64584.0 | 69841.9 | 75465.0 | 79476.9 | 77258.6 | 84783.0 | 26381.8 | 62246.6 | 78840.2 | 75497.1 |
| 12/15/2001 | 12:55:33 | 3M-12 | 2 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:04:25 | 3M-2 | 2 | 1 | 4 | 64111.7 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 64978.7 | 16504.9 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:01:14 | 3M-2 | 2 | 1 | 5 | 74575.9 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 22680.1 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 10:42:15 | 3M-3 | 3 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:55:37 | 3M-6 | 3 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:55:34 | 3M-9 | 3 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:04:26 | 3M-10 | 3 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:01:15 | 3M-9 | 3 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 10:42:16 | 3M-4 | 4 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:55:38 | 3M-1 | 4 | 1 | 2 | 99922.7 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 99232.2 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:55:36 | 3M-6 | 4 | 1 | 3 | 93484.8 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 62243.6 | 100000.0 | 92384.2 | 99216.3 |
| 12/15/2001 | 14:04:27 | 3M-6 | 4 | 1 | 4 | 92501.9 | 100000.0 | 100000.0 | 100000.0 | 98690.6 | 100000.0 | 86729.6 | 83147.9 | 85338.1 | 91706.6 | 84789.9 |
| 12/15/2001 | 15:01:16 | 3M-11 | 4 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVEFIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 15:41:23 | 3M-5 | 5 | 1 | 1 | 29837.8 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 8665.0 | 7156.2 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-10 | 5 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-3 | 5 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-9 | 5 | 1 | 4 | 28870.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 40097.5 | 4572.5 | 30542.2 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 5 | 1 | 5 | 86332.6 | 90847.7 | 100000.0 | 85244.2 | 87833.1 | 84414.7 | 85151.2 | 80333.0 | 63819.9 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-6 | 6 | 1 | 1 | 58164.6 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 12206.2 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-2 | 6 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-2 | 6 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 6 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-10 | 6 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 7 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-11 | 7 | 1 | 2 | 71515.4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 20068.2 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 7 | 1 | 3 | 56733.3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 11592.4 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-4 | 7 | 1 | 4 | 43023.7 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 7021.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-14 | 7 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 8 | 1 | 1 | 57202.5 | 50579.3 | 45573.3 | 49941.0 | 57603.1 | 59198.3 | 62045.3 | 61888.0 | 66286.6 | 64391.8 | 62750.0 |
| 12/15/2001 | 15:41:23 | 3M-4 | 8 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-10 | 8 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 8 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-5 | 8 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVEFIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 12:15:26 | 3M-6 | 9 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:15:09 | 3M-8 | 9 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:22:29 | 3M-4 | 9 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:19:19 | 3M-10 | 9 | 1 | 5 | 85637.1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 37352.7 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:10:47 | 3M-9 | 9 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:15:27 | 3M-2 | 10 | 1 | 2 | 58222.8 | 100000.0 | 100000.0 | 92134.8 | 100000.0 | 100000.0 | 100000.0 | 16393.4 | 34894.0 | 88953.5 | 100000.0 |
| 12/15/2001 | 13:15:11 | 3M-12 | 10 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:22:30 | 3M-2 | 10 | 1 | 4 | 99911.1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 99118.5 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:19:21 | 3M-4 | 10 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:10:48 | 3M-10 | 10 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:15:28 | 3M-3 | 11 | 1 | 2 | 59599.2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 16433.5 | 37124.9 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:15:12 | 3M-9 | 11 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:22:31 | 3M-3 | 11 | 1 | 4 | 92118.4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 53891.2 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:19:22 | 3M-3 | 11 | 1 | 5 | 71863.6 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 42332.7 | 28145.1 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:10:49 | 3M-11 | 11 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:15:29 | 3M-10 | 12 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:15:13 | 3M-10 | 12 | 1 | 3 | 90655.2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 49241.5 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:22:32 | 3M-10 | 12 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:19:23 | 3M-11 | 12 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:10:50 | 3M-12 | 12 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVEFIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 15:41:23 | 3M-5 | 13 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-5 | 13 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 13 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 13 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 13 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 14 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 14 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-11 | 14 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-5 | 14 | 1 | 5 | 95250.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 66724.8 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 15 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 15 | 1 | 3 | 55263.6 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 10994.9 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-5 | 15 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 15 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-6 | 15 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-12 | 16 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-4 | 16 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-12 | 16 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-12 | 16 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-5 | 16 | 2 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVERT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 11:35:42 | 3M-2 | 17 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:35:37 | 3M-5 | 17 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:45:50 | 3M-12 | 17 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:41:56 | 3M-12 | 17 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:19 | 3M-5 | 17 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:35:43 | 3M-8 | 18 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:35:38 | 3M-7 | 18 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:45:51 | 3M-1 | 18 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:21 | 3M-12 | 18 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:35:44 | 3M-4 | 19 | 1 | 1 | 97592.2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 80210.7 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 12:35:40 | 3M-12 | 19 | 1 | 2 | 89660.4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 46442.5 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 13:45:52 | 3M-5 | 19 | 1 | 3 | 77008.1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 25090.1 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:41:58 | 3M-2 | 19 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:22 | 3M-4 | 19 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 11:35:45 | 3M-7 | 20 | 1 | 1 | 69289.1 | 92846.0 | 95803.5 | 96549.0 | 100000.0 | 93165.5 | 99054.3 | 24261.1 | 49858.9 | 100000.0 | 93870.5 |
| 12/15/2001 | 12:35:41 | 3M-6 | 20 | 1 | 2 | 95207.8 | 100000.0 | 92565.0 | 97327.4 | 100000.0 | 100000.0 | 100000.0 | 93932.2 | 83653.1 | 92137.0 | 95219.0 |
| 12/15/2001 | 13:45:53 | 3M-10 | 20 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 14:41:59 | 3M-11 | 20 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 20 | 1 | 5 | 84841.1 | 99192.2 | 88071.3 | 86615.7 | 89553.7 | 90383.6 | 92673.6 | 88918.8 | 62558.4 | 73429.5 | 90780.8 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe

| | | | | | | | EXERCISES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | TIME | MASK | SUBJ | CNCPT | TRIAL | AVEFIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12/15/2001 | 15:41:23 | 3M-5 | 21 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-9 | 21 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-2 | 21 | 1 | 3 | 98262.4 | 100000.0 | 100000.0 | 100000.0 | 94739.3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 94764.9 | 93803.6 |
| 12/15/2001 | 15:41:23 | 3M-6 | 21 | 1 | 4 | 51084.8 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 9456.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-6 | 21 | 1 | 5 | 72813.9 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 21125.4 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-11 | 22 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-4 | 22 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-6 | 22 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-7 | 22 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 22 | 1 | 5 | 78586.8 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 26847.2 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-12 | 23 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-1 | 23 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-11 | 23 | 1 | 3 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-8 | 23 | 1 | 4 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-2 | 23 | 1 | 5 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-10 | 24 | 1 | 1 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-11 | 24 | 1 | 2 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-3 | 24 | 1 | 3 | 43179.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 7062.4 | 100000.0 | 100000.0 | 100000.0 |
| 12/15/2001 | 15:41:23 | 3M-9 | 24 | 1 | 5 | 33596.9 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 100000.0 | 4912.8 | 70941.9 | 100000.0 | 100000.0 |

Concept 1 – U.S. Army Standard Probe
Concept 2 – Cannulus Probe