TECHNICAL REPORT ARLCD-TR-77054

THE EFFECTS OF CHANGES IN FLARE INTENSITY ON THE RECOGNITION PROBABILITY OF VEHICULAR SIZE TARGETS

ROBERT B. DAVIS
JESSE F. TYROLER

APRIL 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED.
The findings in this report are not to be construed as an official Department of the Army position.

DISPOSITION
Destroy this report when no longer needed. Do not return to the originator.
THE EFFECTS OF CHANGES IN FLARE INTENSITY ON THE RECOGNITION PROBABILITY OF VEHICULAR SIZE TARGETS

Robert B. Davis
Jesse F. Tyroler

Explosive Division
Feltman Research Laboratory
Picatinny Arsenal, Dover, NJ 07801

US Army ARRADCOM
ATTN: DRDAR-TSS
Dover, NJ 07801

Energetics Materials Division
Dover, NJ 07801

Approved for public release; distribution unlimited.

This information was prepared at the request of the Army Materials and Mechanics Research Center, Watertown, MA.

Flare illumination  Terrain model
Recognition probability  Critical illumination level
Target recognition
Search

The present specifications on minimum acceptable flare intensity are made without any quantitative information on how reductions in intensity influence an observer's ability to recognize targets. A study was conducted, using the Pyrotechnic Terrain Model, to examine the relationship between changes in the intensity of flares and target recognition. Four separate cases were examined having different illumination requirements for recognition. Using these data, three types of illumination flares at
20. (Cont'd)

three ranges were evaluated to show the decrease in recognition and recognition areas with decreasing intensities.
ACKNOWLEDGMENT

The assistance of Mr. Gene D. Venable and Mr. Henry Widmann in the collection of data and preparation of this report is sincerely appreciated by the authors.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Tests</td>
<td>2</td>
</tr>
<tr>
<td>Procedures</td>
<td>2</td>
</tr>
<tr>
<td>Discussion of Results</td>
<td>3</td>
</tr>
<tr>
<td>Flare Applications</td>
<td>4</td>
</tr>
<tr>
<td>Fixed Position</td>
<td>4</td>
</tr>
<tr>
<td>Specific Areas</td>
<td>4</td>
</tr>
<tr>
<td>Search</td>
<td>4</td>
</tr>
<tr>
<td>Figures of Merit</td>
<td>4</td>
</tr>
<tr>
<td>Fixed Position</td>
<td>5</td>
</tr>
<tr>
<td>Specific Area</td>
<td>5</td>
</tr>
<tr>
<td>Search</td>
<td>6</td>
</tr>
<tr>
<td>Approximate Effects</td>
<td>6</td>
</tr>
<tr>
<td>Fixed Position</td>
<td>6</td>
</tr>
<tr>
<td>Specific Area</td>
<td>6</td>
</tr>
<tr>
<td>Search</td>
<td>8</td>
</tr>
<tr>
<td>Conclusions</td>
<td>8</td>
</tr>
<tr>
<td>Distribution List</td>
<td>17</td>
</tr>
<tr>
<td>Tables</td>
<td></td>
</tr>
<tr>
<td>1 Effect of flare intensity on area illuminated</td>
<td>9</td>
</tr>
<tr>
<td>2 Effect of flare intensity on target recognition</td>
<td>10</td>
</tr>
</tbody>
</table>
Figures

1 Recognition response to vehicular size targets against a medium green background at a simulated range of 490 m (1500 ft) and a target illumination angle of 124°

2 Recognition response to vehicular size targets against a dark green background at a simulated range of 654 m (2000 ft) and a target illumination angle of 90°

3 Recognition response to vehicular size targets against a medium green background at a simulated range of 980 m (3000 ft) and a target illumination angle of 110°

4 Recognition response to vehicular size targets against a dark green background at a simulated range of 1150 m (3500 ft) and a target illumination angle of 70°

5 Portions of the response curve normalized at the critical illumination level

6 Average curve of the four normalized response curves
INTRODUCTION

Few successful field tests have been conducted in the past to determine the level and duration of illumination required from flares for the detection, recognition, and identification of standard military targets. Tests utilizing flares suspended by parachutes as a source of illumination had many serious disadvantages such as flicker, nonreproducibility of light levels, movement of the flare during burning, smoke, and unpredictable flight paths caused by wind changes. As a result it is virtually impossible to reproduce any set of conditions in order to examine the effect on performance of a change in one parameter, and the data gained from such tests provide little quantified information and are consequently of little value. Furthermore, since the actual flares used are generally of a multimillion-candlepower type, electrical sources which can be utilized to simulate the characteristics of a flare are completely impractical.

To overcome these problems, to provide valid statistical data for use in the field, and to eliminate expensive field tests, a model terrain program was initiated. The model terrain presently being utilized is a Southeast Asian type scaled at 160:1. The system can simulate exactly all the known parameters in a flare including flicker, spectral distribution, wind drift, oscillations, etc. As a result, it is possible for the first time to investigate the effect of each parameter of flare illumination in an area of interest with a quantitative and statistically sound procedure.

The pyrotechnic illumination model, the basic vehicle which is used in this program, has been used successfully in programs determining the illumination levels required for recognizing a variety of military targets under various conditions. The following reports on these studies have been published:


TESTS

Procedures

The observers used for these tests were U.S. Army personnel having normal vision, either natural or corrected. They were given an orientation on the terrain model, the targets to be recognized, the method of target presentation, and the type of responses desired such as, "Large truck, side", or "Jeep, front". Subsequently they were "dark-adapted" for at least 30 minutes and positioned at the proper distance. The simulated flare was positioned in the desired orientation with respect to the observer and targets. The level of illumination was fixed, and the observer responded to the vehicular-size targets presented. After completing a series of observations, the illumination level was lowered approximately 20% and the same procedure followed until the illumination level was insufficient and recognition was no longer possible.

The illumination was measured with a Weston Model 1979 Illumination Meter which was modified for greater sensitivity. The illumination levels reported are given in terms of the footcandles on a surface at the target perpendicular to the source.

Four tests were conducted to determine the probability of recognition of military, vehicular-size targets. The specific conditions of these tests were:

1. Target illumination angle, 90°; simulated range, 660 m (2000 ft); background, dark-green, grassy area; observations from ground level.

2. Target illumination angle, 124°; simulated range, 490 m (1500 ft); background, medium-green, grassy area; observations from ground level.

3. Target illumination angle, 70°; simulated range, 1150 m (3500 ft); background, dark-green, grassy area; observations from ground level.

4. Target illumination angle, 110°; simulated range, 980 m (3000 ft); background, medium-green, grassy area; observations from ground level.
These four conditions were selected to ensure a distinctly different illumination-level requirement in all cases and also because they were easily accessible positions on the terrain model. A total of 14 observers were used for these tests. They performed more than 16,500 separate observations in compiling the data. The resulting curves of Percent Recognition versus Illumination Level are shown in Figures 1, 2, 3, and 4.

Discussion of Results

It can be seen that in these four distinctly different cases all the curves exhibit a characteristic behavior, i.e., as the illumination level is increased, recognition increases rapidly until a plateau is finally reached at approximately the 90-95% recognition level where further increases in illumination have little or no effect on increasing recognition. This point on the recognition vs illumination level curve in this report will be referred to as the "critical illumination level" and, of course, is a different illumination level for each case.

If these four curves are normalized and plotted with Percent Recognition as the ordinate and Fraction of Critical Illumination as the abscissa, Figure 5 is obtained. It can be seen that all four normalized curves are very similar. The average of these four curves is plotted in Figure 6 and can be represented by the function

\[ P = 1.25e^{-0.42F} + 0.031 \]

where \( P \) is the probability of recognition and \( F \) is the fraction of critical illumination at the target. This average curve is very significant and can be very useful for estimating some effects of variation in flare intensity on actual performance. For example, assume that Figure 6 approximates the percent recognition as a function of the fraction of critical illumination independent of the critical illumination level and the relative positions of target, observer, and flare (a reasonable assumption since it was true in the four distinctly different cases described). It can be concluded that if a target is illuminated by a flare from a fixed position relative to an observer and if the illumination level is above the critical illumination level, then changes in intensity in the flare (the illumination on the target being proportional to the intensity of the flare) will have little effect on the observer's ability to recognize the target. If the illumination is below the critical illumination level, changes in the probability of recognition will be roughly proportional to changes in intensity.
FLARE APPLICATIONS

There are three general categories into which the uses of illuminating flares fall and these can be useful in describing and defining specific figures of merit related to the effectiveness of each flare. They are:

Fixed Position

This situation would exist when a target is at a known location such as a bridge or bunker and that target must be illuminated to direct lethal fire or assess damage.

Specific Areas

In this situation an area must be illuminated to a level that if a target were present the observer would have a very high probability of recognition. This would be employed when securing an area against infiltration by enemy troops.

Search

This situation considers the probability of finding a target in a very large suspect area. This may arise when an aircraft searches for the location of enemy vehicles or positions.

FIGURES OF MERIT

In order to examine the effect of changes in intensity for each of these situations, it is necessary to specify both the flare type and the range of the observer from the target. An approach can be used similar to the one taken by Dr. M. Messinger in his notes on "The Time Fuze Accuracy Requirements for Illuminating Mortar Projectiles," dated April 1972, to determine a figure of merit for each flare application.

It has been shown in PATR 4184 that the illumination required for a 90% probability of recognition is a function of the relative angle of the observer, flare, and target as well as the range. Also, the illumination required for a 90% probability of recognition in a given target situation, $R$, is a function of the flare coordinates $x_f, y_f, h$; target coordinates $x_t, y_t$; and observer coordinates $x_o, y_o$ so that

$$ R = R (x_f, y_f, h, x_t, y_t, x_o, y_o). $$
Fixed position

In the case where it is necessary to illuminate a fixed position, if we assume that $L$ is the actual target illumination and $R$ is the critical illumination level, we define the step function $u(L - R)$ such that $u = 0.9$ when $L \geq R$ and $u = P$ when $L < R$, $P$ being the probability of recognition as shown in Figure 6 and defined by the empirical equation

$$P = \frac{0.42}{1.25e^{\frac{F}{R}} + 0.031}$$

where $F$ is the fraction of critical illumination at the target, $F = \frac{L}{R}$.

A figure of merit ($E_f$) relating to the effectiveness of a flare for the fixed position illumination case can be defined as

$$E_f = \int_T u(L - R) \, dt$$

where the integral is taken over the total burning time of the flare. By varying the intensity ($I$) in the illumination equation, $(L)$, of the search case, one may compare the relative figures of merit for a given observer, target and source location and be able to analyze the effects of flare variations on effectiveness.

Specific Area

For the case where it is necessary to illuminate a specific area above the critical illumination level such as in anti-intrusion, perimeter defense, etc., we define the step function $u(L - R)$ such that $u = .9$ when $L \geq R$ and $u = 0$ when $L < R$. A figure of merit for the area illumination case ($E_{a}$) can then be defined such that

$$E_{a} = \int_{-\infty}^{T} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} u(L - R) \, dx \, dy \, dt$$
Search

In the case where a large area is to be searched for targets and only a small portion of the suspect area can be illuminated, we again define a function \( u(L - R) \) such that when \( L \geq R \), \( u = 0.9 \) and when \( L < R \), \( u = P \) where \( P \) is again the probability of recognition as shown in Figure 6.

The figure of merit, \( E_s \), in this case can be considered to be the integral

\[
E_s = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{T} u(L - R) \, dx \, dy \, dt
\]

APPROXIMATE EFFECTS

Fixed Position

In this case, estimates of how changes in intensity of the flare affect recognition performance can be made fairly easily. If it is assumed that the position of the flare remains the same relative to the target, changes in the probability of recognition would be affected exactly as shown in Figure 6; that is, when the illumination is above the critical illumination level there would be little effect on the probability of recognition. When the illumination is below this level, it would correspond to the slope of this curve (Fig 6) which varies from 1/3 to 3/2. For most practical ranges, the illumination level would be below the critical illumination level and in these applications it can be roughly estimated that changes in the intensity would affect the performance proportionally.

Specific Area

In this report for a first approximation it will be assumed that the critical illumination level is dependent only on the range of the target from the observer, and the effect of changes in intensity for three illumination rounds at three ranges will be examined.
The following operational characteristics were used in this calculation for these three items:

<table>
<thead>
<tr>
<th>Type of round</th>
<th>Candlepower ((x \ 1000))</th>
<th>Ignition altitude (feet)</th>
<th>Ignition altitude (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 mm mortar</td>
<td>320</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td>81 mm mortar</td>
<td>500</td>
<td>1000</td>
<td>330</td>
</tr>
<tr>
<td>155 mm howitzer</td>
<td>1000</td>
<td>1800</td>
<td>590</td>
</tr>
</tbody>
</table>

PATR 4184 provides the approximate critical illumination levels as a function of range:

<table>
<thead>
<tr>
<th>Range (\text{feet})</th>
<th>Illumination level, (E_0) (\text{footcandles})</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>0.04</td>
</tr>
<tr>
<td>3000</td>
<td>0.40</td>
</tr>
<tr>
<td>5000</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The results are shown in Tables 1, 2, and 3. From these results it can be seen that for short ranges where the critical illumination level is low the change in area illuminated to the critical illumination level (approximately 90% probability of recognition) is roughly proportional to the change in intensity. As the range increases, the change in area becomes more sensitive to changes in flare intensity, as much as five times in the case of the 81 mm mortar. In addition as this sensitivity increases the flare becomes very ineffective for recognition purposes since it illuminates a smaller and smaller area to the critical value. For example, in the case of the 81 mm mortar flare at a range of 980 m (3000 ft), a 5% change in flare intensity results in a 25% change in the area effectively illuminated to the 90% probability of recognition. The area illuminated to the critical value for 90% recognition is only \(7.85 \times 10^4\) square feet at the 980 m (3000 ft) range as compared to an area of \(3.6 \times 10^7\) square feet illuminated to the critical level for the same flare at the 260 m (800 ft) range. It appears from these data then, that in the Specific Area case that percent changes in intensity influence the effectiveness at least proportionately and probably no more than double for practical ranges of the item.
Search

If the same rough assumptions are made as in the Specific Area Case and if the same operational calculations for the items are used, then the effect of changes in intensity on effectiveness is shown in Tables 4, 5, and 6. Again it appears from these data that in the Search Case changes in intensity influence the effectiveness at least proportionately and may generate changes in the effectiveness by as much as twice the percentage change in intensity.

CONCLUSIONS

Changes in recognition probability are roughly proportional to changes in intensity when the target is in a fixed, known position and the illumination is at the critical illumination level or lower.

In the case of illuminating an area to a high probability of recognition, fractional degradation in intensity of the candle can produce more than double the degradation in performance; however, this occurs in an area where the flare performance is poor anyway.

The possible change in effectiveness of recognizing a target anywhere in a large search area illuminated by a flare appears to range between one and two times the percentage change in intensity for all practical ranges and conditions of use.

For a rough estimate of the degradation of a flare for use in evaluating specifications, it can be expected that, generally, degradation in effectiveness is at least proportional to degradation in intensity and would probably not be more than twice the percentage degradation in intensity of a flare for any practical range. However, before any production specifications on flare intensity are written, rigorous calculations should be performed to show the expected degradation of the performance of the flare. These calculations should utilize the data on each type of flare, the angular relations and intensity requirements found in PATR 4184, and the mathematical approach formulated in this report.
### Table 1

Effect of flare intensity on area illuminated

<table>
<thead>
<tr>
<th>Decrease in intensity (%)</th>
<th>Round (feet)</th>
<th>60 mm Mortar</th>
<th>81 mm Mortar</th>
<th>155 mm Howitzer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range (meters)</td>
<td>800</td>
<td>3000</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>CIL (footcandles)</td>
<td>0.04</td>
<td>0.4</td>
<td>0.04</td>
</tr>
<tr>
<td>5</td>
<td>5.23</td>
<td>9.10</td>
<td>5.40</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>10.45</td>
<td>18.20</td>
<td>10.80</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>15.68</td>
<td>27.30</td>
<td>16.20</td>
<td>75</td>
</tr>
<tr>
<td>20</td>
<td>20.90</td>
<td>36.40</td>
<td>21.60</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>26.13</td>
<td>45.50</td>
<td>27.00</td>
<td>28.80</td>
</tr>
<tr>
<td>30</td>
<td>31.35</td>
<td>54.60</td>
<td>32.50</td>
<td>34.50</td>
</tr>
<tr>
<td>35</td>
<td>36.58</td>
<td>63.70</td>
<td>37.90</td>
<td>40.30</td>
</tr>
<tr>
<td>40</td>
<td>41.80</td>
<td>72.80</td>
<td>43.20</td>
<td>46.00</td>
</tr>
</tbody>
</table>

---

**a** Specific area case; at ignition altitude.

**b** There is no 90%-recognition area at a range of 1640 m (5000 ft) and a CIL of 1 footcandle.

**c** Critical illumination level.

**d** Under these conditions there is no 90%-recognition area.
<table>
<thead>
<tr>
<th>Decrease in intensity (%)</th>
<th>Round Range (feet)</th>
<th>60 mm Mortar</th>
<th>81 mm Mortar</th>
<th>155 mm Howitzer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>800 3000 5000</td>
<td>800 3000 5000</td>
<td>800 3000 5000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>260     980 1640</td>
<td>260       980 1640</td>
<td>260       980 1640</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CIL b (footcandles)</td>
<td>0.04 0.4 1.0</td>
<td>0.04 0.4 1.0</td>
<td>0.04 0.4 1.0</td>
</tr>
<tr>
<td></td>
<td>Decrease in target-recognition probability (%)</td>
<td>4.9 4.5 7.7^c</td>
<td>5.4 7.3 8.7^f</td>
<td>5.4 7.6^d 7.8^h</td>
</tr>
<tr>
<td>10</td>
<td>10.2 12.3 11.5^d</td>
<td>10.8       13.8 16.2</td>
<td>11.0       15.5^d 22.1^h</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20.2 22.6 29.8^d</td>
<td>20.6       27.0 35.0</td>
<td>21.0       30.3^e 43.0^i</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>40.6 46.0 56.5^f</td>
<td>41.4       52.9 60.2</td>
<td>41.9       54.3^f 76.1^i</td>
<td></td>
</tr>
</tbody>
</table>

^a Search case; at ignition altitude
^b Critical illumination level
^c Maximum recognition probability possible 80%, ^d 70%, ^e 60%, ^f 50%, ^g 40%, ^h 30%, ^i 20%, ^j 10%.
Fig 1 Recognition response to vehicular size targets against a medium green background at a simulated range of 490 m (1500 ft) and a target illumination angle of 124°.
Fig 2  Recognition response to vehicular size targets against a dark green background at a simulated range of 654 m (2000 ft) and a target illumination angle of 90°
Fig 3  Recognition response to vehicular size targets against a medium green background at a simulated range of 980 m (3000 ft) and a target illumination angle of 110°
Fig 4  Recognition response to vehicular size targets against a dark green background at a simulated range of 1150 m (3500 ft) and a target illumination angle of 70°
Fig 5  Portions of the response curve normalized at the critical illumination level
Fig 6  Average curve of the four normalized response curves

\[ P = \frac{.42}{F} + .031 \]
DISTRIBUTION LIST

Metals and Ceramics Information Center
ATTN: Mr. Harold Mindlin, Director
      Mr. James Lynch, Asst Director
505 King Avenue
Columbus, OH 43201

Commander
Defense Documentation Center (12)
Cameron Station,
Alexandria, VA 22314

Commander
US Army Foreign Science & Technology Center
ATTN: DRXST-SD3
220 Seventh Street NE
Charlottesville, VA 22901

Office of the Deputy Chief of Staff for Research, Development and Acquisition
ATTN: DAMA-ARZ-E
      DAMA-CSS
Washington, DC 20310

Commander
Army Research Office
ATTN: Dr. George Mayer
      Mr. J. J. Murray
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Materiel Development & Readiness Command
ATTN: DRCQA-E
      DRCQA-P
      DRCDE-D
      DRCMDMD-FT
      DRCLDC
      DRCMT
      DRCMM-M
Alexandria, VA 22333
Commander
US Army Electronics Command
ATTN: DRSEL-PA-E, Mr. Stan Alster (2)
Fort Monmouth, NJ 07703

Commander
US Army Missile Research & Development Command
ATTN: DRDMI-TB, Redstone Scientific Information Center (2)
   DRDMI-TK, Mr. J. Alley
   DRSMI-M
   DRDMI-ET, Mr. Robert O. Black
   DRDMI-QS, Mr. George L. Stewart, Jr.
   DRDMI-EAT, Mr. R. Talley
   DRDMI-QP
Redstone Arsenal, AL 35809

Commander
US Army Troop Support and Aviation Materiel Readiness Command
ATTN: DRSTS-PLE, Mr. J. Corwin
   DRSTS-Q
   DRSTS-M
4300 Goodfellow Boulevard
St. Louis, MO 63120

Commander
US Army Natick Research & Development Command
ATTN: DRXNM-EM
Natick, MA 01760

Commander
US Army Mobility Equipment Research & Development Command
ATTN: DRDME-D
   DRDME-E
   DRDME-G
   DRDME-H
   DRDME-M
   DRDME-T
   DRDME-TQ
   DRDME-V
   DRDME-ZE
   DRDME-N
Fort Belvoir, VA 22060
Director
US Army Industrial Base Engineering Activity
ATTN: DRXPE-MT, Dr. W. T. Yang
Rock Island, IL 61299

Commander
Harry Diamond Laboratories
ATTN: DRXDO-EDE, Mr. B. F. Willis
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Test & Evaluation Command
ATTN: DRSTE-TD
DRSTE-ME
Aberdeen Proving Ground, MD 21005

Commander
US Army White Sands Missile Range
ATTN: STEWS-AD-L
STEWS-ID
STEWS-TD-PM
White Sands Missile Range, NM 88002

Commander
US Army Yuma Proving Ground
ATTN: Technical Library
Yuma, AR 85364

Commander
US Army Tropic Test Center
ATTN: STETC-TD, Drawer 942
Fort Clayton, Canal Zone

Commander
Aberdeen Proving Ground
ATTN: STEAP-MT
STEAP-TL
STEAP-MT-M, Mr. J. A. Feroli
STEAP-MT-G, Mr. R. L. Huddleston
Aberdeen Proving Ground, MD 21005
Commander
US Army Cold Region Test Center
ATTN: STECR-OP-PM
APO Seattle, WA 98733

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT
Dugway, UT 84022

Commander
US Army Electronic Proving Ground
ATTN: STEEP-MT
Ft. Huachuca, AR 85613

Commander
Jefferson Proving Ground
ATTN: STEJP-TD-I
Madison, IN 47250

Commander
US Army Aircraft Development Test Activity
ATTN: STEBG-TD
Ft. Rucker, AL 36362

President
US Army Armor and Engineer Board
ATTN: ATZKOAE-TA
Ft. Knox, KY 40121

President
US Army Field Artillery Board
ATTN: ATZR-BDOP
Ft. Sill, OK 73503

Commander
Anniston Army Depot
ATTN: SDSAN-QA
Anniston, AL 36202
Commander
Corpus Christi Army Depot
ATTN: SDSCC-MEE, Mr. Haggerty
Mail Stop 55
Corpus Christi, TX 78419

Commander
Letterkenny Army Depot
ATTN: SDS-LE-QA
Chambersburg, PA 17201

Commander
Lexington-Bluegrass Army Depot
ATTN: SDSRR-QA
Lexington, KY 40507

Commander
New Cumberland Army Depot
ATTN: SDSNC-QA
New Cumberland, PA 17070

Commander
US Army Depot Activity, Pueblo
ATTN: SDSTE-PU-O
Pueblo, CO 81001

Commander
Red River Army Depot
ATTN: SDSRR-QA
Texarkana, TX 75501

Commander
Sacramento Army Depot
ATTN: SDSSA-QA
Sacramento, CA 95813

Commander
Savanna Army Depot Activity
ATTN: SDSSV-S
Savanna, IL 61074
Commander
Seneca Army Depot
ATTN: SDSSE-R
Romulus, NY 14541

Commander
Sharpe Army Depot
ATTN: SDSSH-QE
Lathrop, CA 95330

Commander
Sierra Army Depot
ATTN: SDSSI-DQA
Herlong, CA 96113

Commander
Tobyhanna Army Depot
ATTN: SDSTO-Q
Tobyhanna, PA 18466

Commander
Tooele Army Depot
ATTN: SDSTE-QA
Tooele, UT 84074

Director
DARCOM Ammunition Center
ATTN: SARAC-DE
Savanna, IL 61074

Naval Research Laboratory
ATTN: Dr. J. M. Krafft, Code 8430
     Library, Code 2620
Washington, DC 20375

Director
Air Force Materiel Laboratory
ATTN: AFML-DO, Library
     AFML-LTM, Mr. E. Wheeler
     AFML-LLP, Mr. R. Rowand
Wright-Patterson AFB, OH 45433
Weapon System Concept Team/CSL
ATTN: DRDAR-ACW
Aberdeen Proving Ground, MD 21010

Technical Library
ATTN: DRDAR-CLJ-L
Aberdeen Proving Ground, MD 21010

Technical Library
ATTN: DRDAR-TSB-S
Aberdeen Proving Ground, MD 21005

Benet Weapons Laboratory
Technical Library
ATTN: DRDAR-LCB-TL
DRDAR-LCB, Mr. T. Moraczewski
Watervliet, NY 12189

Director
US Army TRADOC Systems Analysis Activity
ATTN: ATAA-SL, Technical Library
White Sands Missile Range, NM 88002

Director
Army Materials and Mechanics Research Center
ATTN: DRXMR-P
DRXMR-PL (2)
DRXMR-M (2)
DRXMR-MQ
DRXMR-MI, Mr. Darch
DRXMR-L, Dr. Chait
DRXMR-RA, Mr. Valente
Watertown, MA 02172

Commander
Chemical Systems Laboratory
ATTN: DRDAR-CLR, Mr. Montaway
DRDAR-QAC, Dr. Moritz
Aberdeen Proving Ground, MD 21010