U. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

TACTICAL LUMINANTS

1. OBJECTIVE

The object of this MTP is to describe procedures for determining the ability and effectiveness of military illuminating pyrotechnics, ground and air launched, to illuminate the ground.

2. BACKGROUND

Historically, flares have been evaluated on the basis of the intensity of the light generated by the candle. This intensity determination, however, bears little direct relationship to the actual effectiveness of the complete flare system in terms of effectively illuminating ground targets.

Methods other than a Pyrotechnic Evaluation Range (PER) system assume flare light distribution to be isotropic. Employing these other methods, flares are evaluated statically in test tunnels and on towers where light intensity is measured, and dynamically by measuring their trajectory and burn time during actual firing. Light intensity data and trajectory data are then mathematically manipulated in a calculated estimate of the flare illumination area. These methods do not evaluate the effectiveness of the complete flare system in terms of actually illuminating a target. The PER range developed at Yuma Proving Ground permits measurement of the incident light reaching the ground (ref 4.I).

3. REQUIRED EQUIPMENT AND FACILITIES

a. A field sensor array (361 photocell sensors arrayed in a rectangular pattern, 19 rows by 19 rows, with a 450-foot separation between each sensor) with the sensors preset to a desired threshold. The level may vary from 0.05 foot-candle (for infantry use) to 0.2 foot-candle (for aerial attack).

b. Recording instruments, including at least one 35-mm double frame camera with frame number input on a magnetic tape recorder, and a 16-mm camera for customer review and documentary records.

c. Event camera for noting flare performance for normal use; a 16-mm movie camera with a 20-inch lens and color film is recommended. For detail, a 48-inch lens is the largest practical.

d. Tracking instrumentation (normally three cinetheodolites) operating from a common time base. The tracking and console recording cameras should have common frame numbering capabilities. Color film is recommended.

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e. Standard meteorological equipment for measuring surface winds, temperature and pressure and winds up to 500 feet above the maximum trajectory of the flare.

f. Test items sufficient to fire four groups of 6 to 12 each, and additional groups to evaluate salvo firing, sequence firing, etc.

g. Stopwatches.

4. REFERENCES

A. MTP 5-1-031, Cinetheodolites.
B. MTP 4-3-148, Flare, Aircraft.
C. MTP 4-3-514, Safety Hazards.
D. FM 20-60, Battlefield Illumination.
E. TM 9-1370-200, Military Pyrotechnics.
F. MTP 4-2-131, Pyrotechnic Signals.
G. MTP 4-2-130, Flares and Photoflash Items.
H. AMCP 706-186, Military Pyrotechnics Series: Safety, Procedures and Glossary.
I. Pickles, Kevin, CPT, Ord C, YPG Report 0040, Instrumentation Development for Determination of Methodology for Measuring Flare Illumination, USATECOM Project No. 9-CO-006-000-003, Yuma Proving Ground, Yuma, Arizona, June 1970.
J. Brooks, Mahner, YPG Report 0052, Methodology Study of Illuminating Pyrotechnic Test and Evaluation Second and Final Partial Report, USATECOM Project No. 9-CO-006-000-002, Yuma Proving Ground, Yuma, Arizona, October 1970

5. SCOPE

5.1 SUMMARY

The methods of adequately evaluating a flare system in a dynamic environment in relation to the system ability to illuminate the ground are delineated in this document. The combined use of the go, no-go and analog light sensors permits the ability to acquire multi-aspect measurements of a system light output while it is normally deployed. Valuable data concerning burn time, optimum functioning height, drift characteristics, multiple round performance, sequential performance, effective area illuminated and flare intensity are also obtained.

5.2 LIMITATIONS OF EXISTING PER

5.2.1 Illumination Data

a. Sensors currently limited to threshold detection between 0.05 and 0.2 foot-candle.

b. The PER range is currently unable to evaluate large aircraft flares (about 5 million candle power rating is maximum) and flares exposed to wind speeds in excess of 15 knots. The maximum wind speed is lower with high intensity flares.

c. The PER range is limited to 6μ second scans at 0.1-seconds intervals, thus prohibiting evaluation of photoflash cartridge.

d. The sensors are designed to duplicate the response of the human eye, this prohibiting evaluation of flares designed to support vision devices operating in the UV or IR spectra.

5.2.2 Space Position Data

a. The current cinetheodolites require six men for operation (2 per camera), take up to 5 seconds after deployment for acquisition, and up to 5 days (because of the need to read film) for data handling.

b. The use of cinetheodolites effectively limits tracking to one flare at a time.

c. Because of the extremely low contrast between the non-ignited flare system and the background, flare systems cannot be detected until after they are burning (which normally occurs several seconds after deployment).

5.2.3 Smoke Conditions

The capability to determine the presence of residual smoke, as well as quantitatively defining it, is beyond current techniques.

5.2.4 Test Scheduling

a. Testing is practical only when the ambient light level is less than 5 percent of the threshold value of the sensors.

b. Testing is not practical when there is a severe temperature or humidity change, or in winds in excess of 51 knots.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Calibration

The following steps should be completed prior to initiation of testing:

a. The sensor array should be calibrated at the desired threshold level, calibration should be performed at such time of day that the temperature differential from the time of calibration to time of use will be minimized.

b. The sunset-check calibration system should be checked prior to the test night(s).

c. Reference lights for tracking cameras and weapon aiming should be surveyed in, installed and checked for reliable operation.

d. The weapon should be located and installed. If possible, a site should be selected which will permit a full trajectory envelope over the center of the sensor array, with non-functioning projectiles impacting beyond the sensor array. Desirably, projectile debris should also impact beyond the range.

e. If aircraft parachute flares are to be tested a suitable target working array should be laid out in the field to indicate the drop area.

f. If possible, the complete system, including space position instrumentation, should be checked the night prior to test firing, using flares similar to those undergoing test. If aircraft are to be used, this check-out permits pilot familiarization as well as range check-out.

6.1.2 Safety Considerations

a. Personnel should not be in the field array during firing unless overhead cover is available. Besides the danger from non-functioning parachutes, all flare systems produce debris in the form of covers, fittings, fuzes, etc.

b. All personnel at the test site should be informed as to proper procedures to be followed if endangered by a rogue flare system, including current wind direction.

c. Personnel should not look directly at a burning flare at close range, or through any lens system unless proper filters are used.

d. Aircraft flight paths should be upwind of ground meteorological teams using balloons or rockets.

e. Normal pyrotechnic safety procedures should be used by munition handlers and gun crews.

6.2 TEST CONDUCT

6.2.1 Prior to Sunset

a. Check communications with all elements including range control tower.

b. Verify weapon azimuth and locate on range map.

c. Insure range reference lights are in place and working.

d. Insure all auxiliary equipment, including power sources are functioning correctly. Fuel and lubrication levels should be full. If necessary, additional fuel and lubricants should also be available.

e. Set up meteorological equipment.

f. Deliver flares to loading site.

6.2.2 During Sunset Period

a. Run sunset check (record board display and concurrent ambient light level).

b. Recalibrate or replace variant sensors (priority to center of pattern) as far as possible. If a significant number of sensors are off calibration, suspend testing until they can be recalibrated or replaced. Record changes.

c. Register tracking cameras on reference lights.

d. Take first winds aloft readings (check test plan for wind velocity limitations).

6.2.3 After Dark (ambient illumination 5% of field trigger level)

a. Post the console data board with the date, test round number, and flare type before each round is fired.

b. Fire flare groups to function at the following altitudes:

1) Low altitude: Equal to the flare burning time multiplied by its rate of descent ($T_b x V_y$).
2) High altitude: Equal to 9/10 of the square root of the product of the rated candlepower and the threshold illumination level in foot-candles ($.9(\sqrt{I_r B_t})$).
3) 2/3-altitude: The altitude equal to the sum of the low altitude (1) plus 2/3 of the difference between the high altitude (2) and the low altitude (1). ($A_{(1)} + 2/3(A_{(2)} - A_{(1)})$).

NOTE: If the performance of the flare at high altitude (2) warrants, an altitude of 20 percent greater than the high altitude ($1.2(T_b V_y)$) for the 2/3-altitude function requirement may be substituted.

4) 1/3-altitude: The altitude equal to the sum of the low altitude (1) plus 1/3 of the difference between the high (2) and the low altitude (1). $(A_{(1)}+1/3\ (A_{(2)}-A_{(1)}))$.

NOTE: If there is an operational constraint, such as a minimum burnout altitude, and this constraint would result in a functioning altitude more than 20 percent greater than the low altitude (1), this operational altitude should be substituted for the 1/3 altitude.

5) The functional altitude can be altered to meet the user's requirements.

c. Record the following data for each round:

1) Time of day.
2) Round number.
3) Type and lot number of munition.
4) Function altitude (planned), (QE, azimuth and charge).
5) Time to function (stopwatch).
6) Function time (input to console display).
7) Visible burning time (stopwatch).
8) Illumination pattern versus time (from console, record by film or magnetic tape) 5 scans per second.
9) Observed flare performance (normal, erratic, wild oscillations, flamer, sputtering, etc.) to supplement the tracking film.
10) Cinetheodolites tracking data, 5 frames/sec.

d. Record the following data at half-hour intervals.

1) Surface wind speed (fps) and direction.
2) Wind speed (fps) and direction aloft at 500-foot intervals, up to maximum ordinate (if pibals are used, readings at 216, 414, 612, 801, 990 and 1170 meters are acceptable).
3) Surface ambient temperature.
4) Surface pressure.
5) Ambient light level.

6.2.4 Post Test Procedure

Following completion of test night, prepare a data reduction work sheet. Include the following data:

a. Test rounds to be reduced.

b. Time interval required by round.

c. Observed burning time from console.

d. Operational data influencing test data:

1) Camera failure(s).
2) Delayed or divergent functioning.
3) Flares failing to function.
4) Observed erratic flare behavior.
5) Flare burning time from observers.

e. Special data requirements.

6.3 DATA REDUCTION AND PRESENTATION

a. Individual round, tabular data (programs available).

1) Heading information:

a) Test round number.
b) Type round.
c) Date round fired.
d) Type of group.

2) Column entries (1-, 2-, or 5- second intervals):

a) Tracking camera frame number.
b) Time after functioning (seconds).
c) Descent rate (ft/sec).
d) Average intensity (candlepower).
e) Intensity standard deviation (1 sigma).
f) X position (referenced to NW corner of PER) (ft).
g) Y position (referenced to NW corner of PER) (-ft).
h) Normalized height above center of range (ft AGL).
i) Number of sensors activated.
j) Area illuminated (sq ft).

3) The following data may also be desired:

a) X velocity component (ft/sec).
b) Y velocity component (ft/sec).
c) Horizontal velocity component (ft/sec).
d) True velocity component (ft/sec).
e) Horizontal angle (azimuth from grid north).
f) Vertical angle (generated counterclockwise from vertical down).
g) True altitude (ft above mean sea level).

b. Individual round graphical data (program available). Graphs should be on a common time scale for comparison purposes. Graphs utilizing space position data (i.e., intensity calculations) should be prepared only when space position is available for at least 1/3 of the burning period of the flare.

1) Individual pattern plots[1].
2) Time topography plots (see Figure 1).

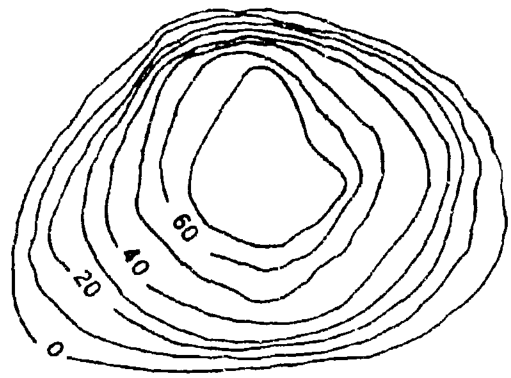

FIGURE 1. AREA EFFECTIVELY ILLUMINATED BY A TYPICAL 81-MM 500,000 CANDLEPOWER RATED FLARE TO 0.05 FOOT-CANDLE (CONTOURS IN SECONDS).

3) Area illuminated as a function of time[2], include integral area illuminated.[3]
4) Effective intensity (including ± 1 sigma) as a function of time (see Figure 2).
5) Space position (X, Y, Z coordinates) as a function of time.
6) The following may also be desired (programs not currently available).

   a) Searchlight effect showing successive 1/2-second scans for a 5-second period including tabular printout of the areas, radii, and area ratios of the portion continuously lit, the portion lit per scan, and the total area swept.[4]
   b) Area illuminated as a function of altitude.
   c) Effective intensity as a function of altitude.

[1]Brooks, Wahner, Methodology Study of Illuminating Pyrotechnic Test and Evaluation, Second and Final Partial Report, USATECOM Project No. 9-CO-006-000-002, Yuma Proving Ground, Yuma, Arizona, October 1970; Annex B, Incl 2.
[2]Ibid, Annex B, Incl 3.
[3]Ibid, Para 2.2.5d.
[4]Ibid, Annex D.

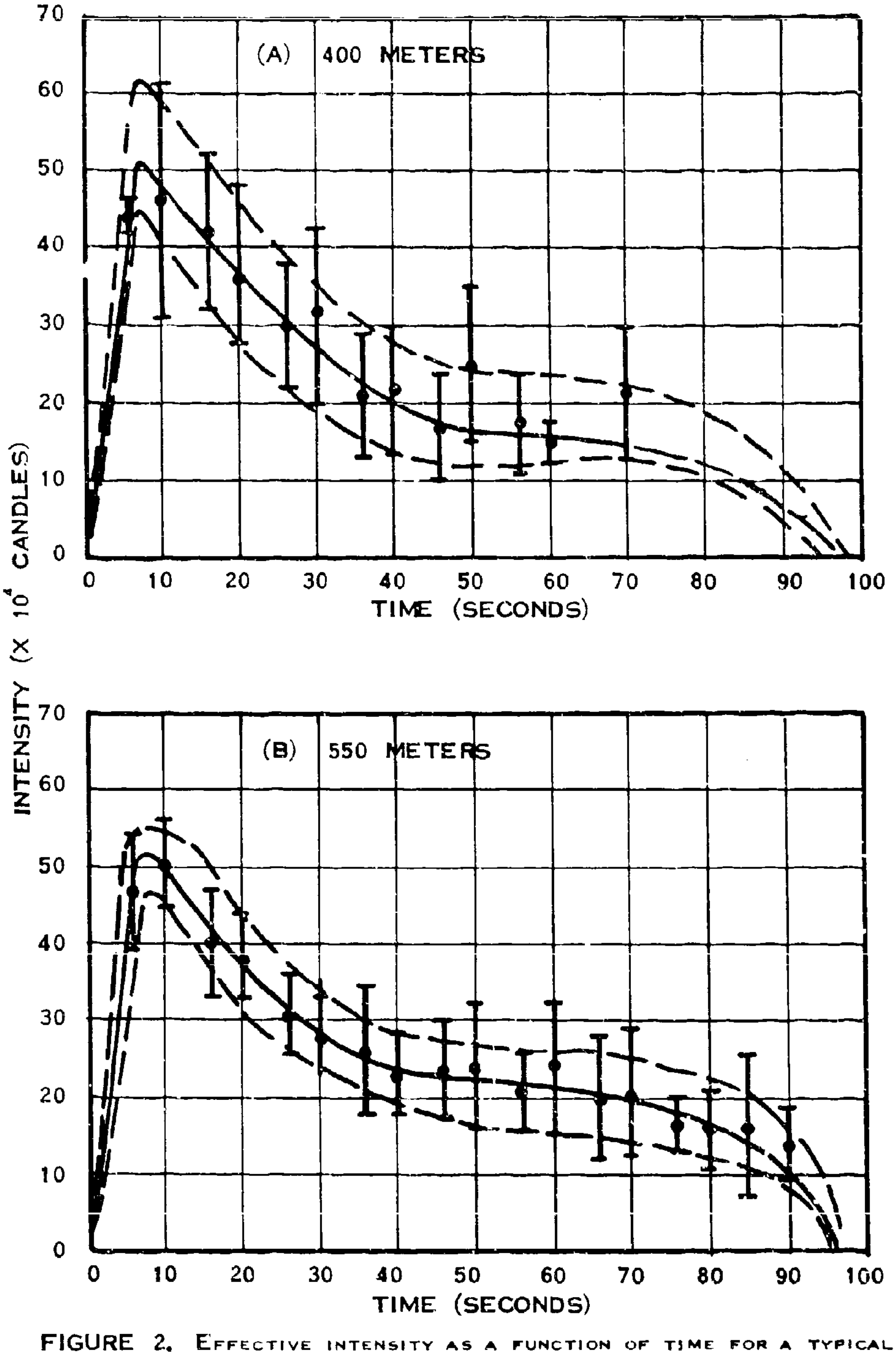

FIGURE 2. Effective intensity as a function of time for a typical 4.2-inch 850,000 candlepower rated flare of two functioning heights, (A) 400 meters and (B) 550 meters.

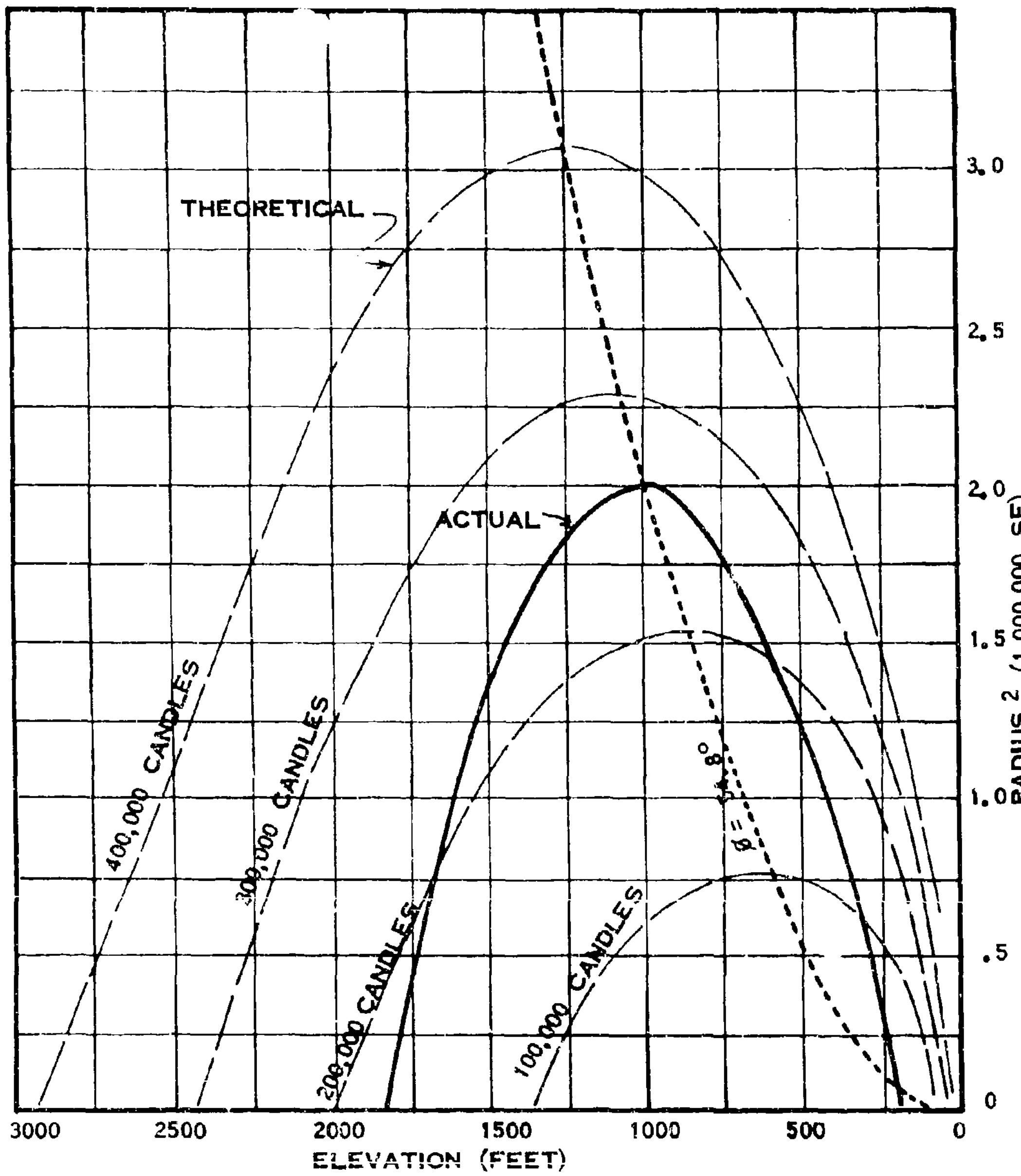

FIGURE 3. ACTUAL PERFORMANCE OF A TYPICAL 4.2-INCH 500,000 CANDLEPOWER RATED FLARE (FUNCTIONING AT 700M) COMPARED TO THE THEORETICAL CANDLES WITH ISOTROPIC OUTPUT AT VARIOUS INTENSITIES.

d) Comparison of actual illuminated area against theoretical as a function of altitude (see Figure 3).

c. Summary and composite graphs (currently requires manual plotting).

1) Composite of area illuminated as a function of time including ± one standard deviation and mean of representative rounds and plots of normalized rounds deviating from the average (see Figure 4).

a) On a common overlay, trace the normalized curves of the plots in b(3) above.
b) Calculate the mean and standard deviations of all the normalized curves at intervals not to exceed three times the original plotting interval.
c) On the composite, plot the calculated average and ± one standard deviation.

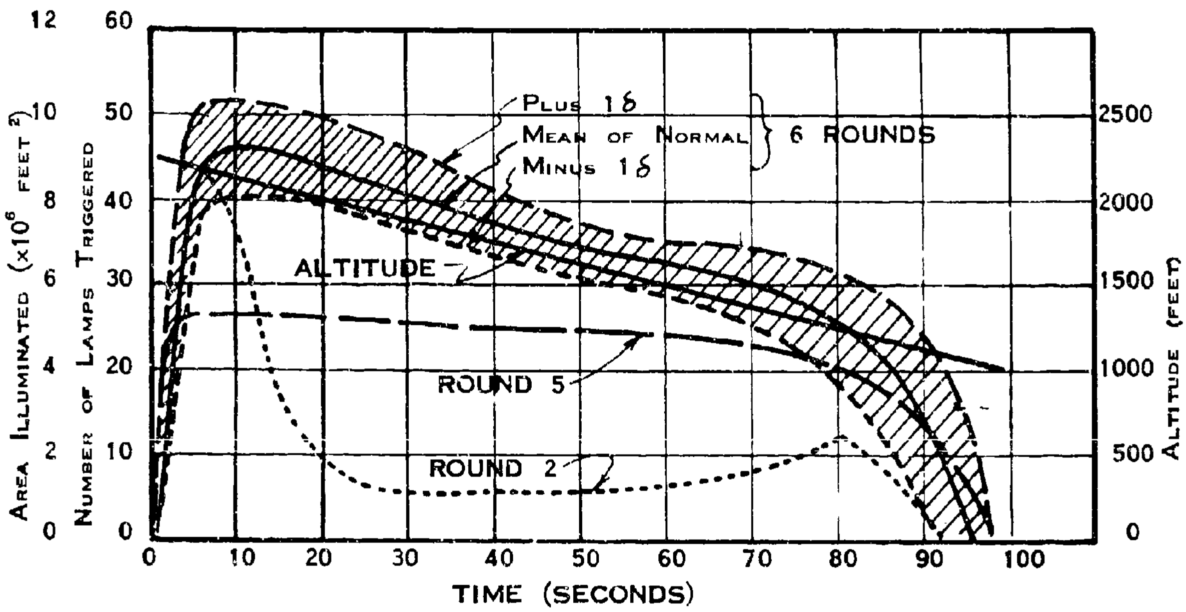

FIGURE 4. SUMMARY OF SIX TYPICAL 4.2-INCH ILLUMINATING ROUNDS PERFORMANCE (0.05 FOOT-CANDLE LEVEL) AT A 700-METER FUNCTIONING HEIGHT.

d) Fit curves through each set of points.
e) Recalculate the average and standard deviations of all normalized curves within the boundaries determined in (d).
f) Plot the recalculated averages and ± one standard deviation.
g) For the final curve, plot:

1 Curves fitted to the recalculated average.
2 Curves fitted to the recalculated ± one standard deviation.
3 Normalized curves of each variant round eliminated in step (e).

2) Summary of mean area/time curves for each group, labeled to indicate function altitude (above ground see Figure 5).

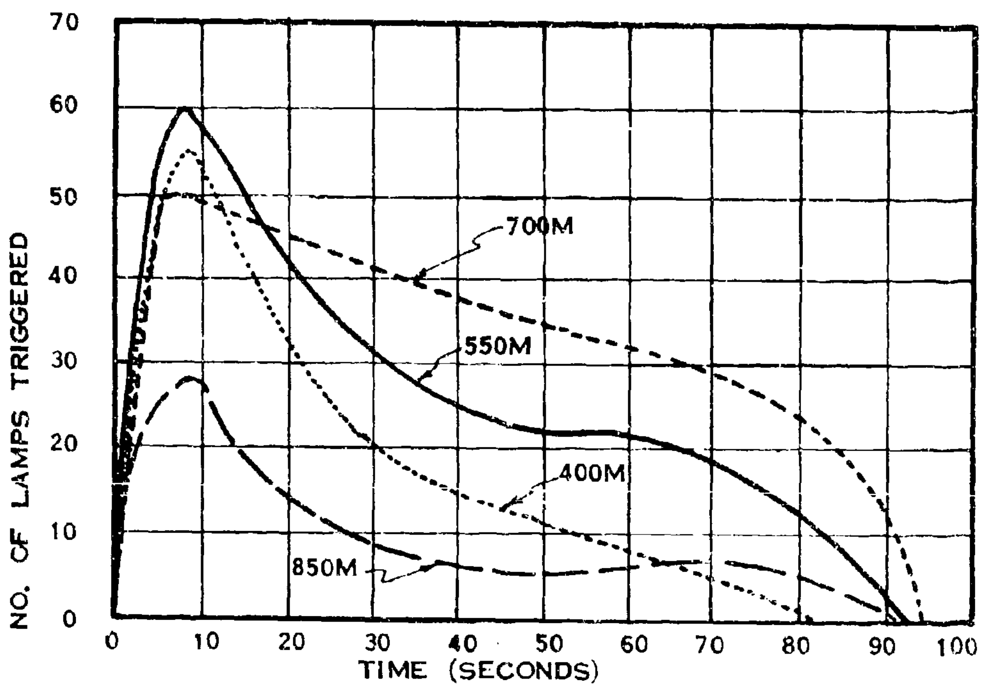

FIGURE 5. Performance curves of the 4.2-inch 850,000 candlepower rated round at various function heights.

3) Three dimension projection of area (vertical projection) burst height (horizontal projection) and time (diagonal projection (see Figure 6). This plot is optional.

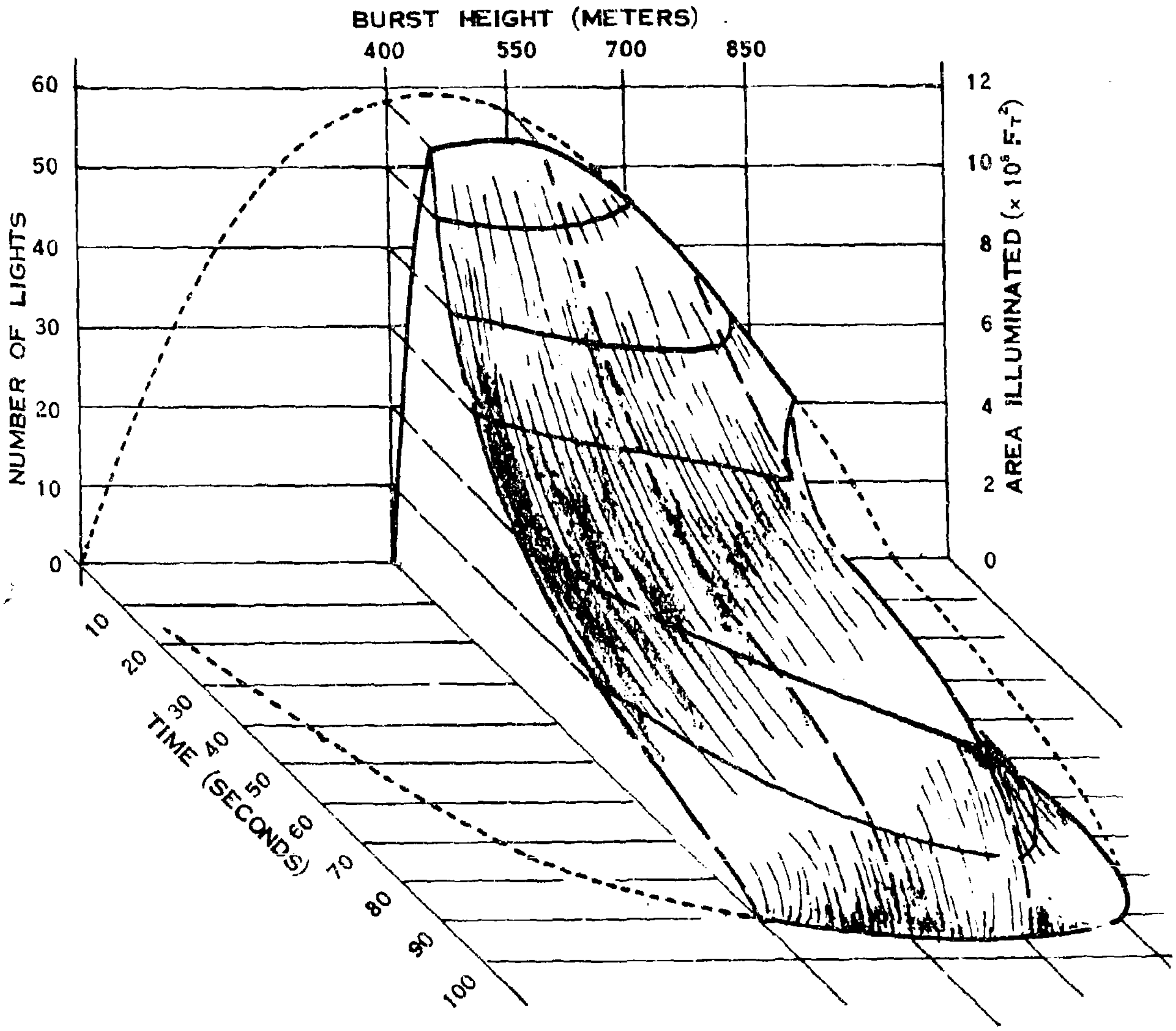

FIGURE 6. The Performance Envelope for the 4.2-inch Illuminating Cartridge.

4) Composite of effective intensity as a function of time, including mean and ± one standard deviation, determined as follows:

a) Determine rounds within the 2 sigma band in the illumination/time plot ((1) above).
b) From the tabular data, extract the average intensity for these rounds, sorted by 5-second intervals.
c) At each interval, calculate and plot the mean and ± one standard deviation.
d) Fit curves to these points (see Figure 2).

5) Summary of mean intensity/time curves for each group, labeled to indicate function altitude (see Figure 7). This plot is optional and dependent on (4) above.

d. Supplementary data:

1) Deviations of rounds from average performance should be noted and explained. Tracking photographs or supplementary coverage should be used as much as possible.
2) Limitation to test conduct should be described (i.e., flares could not be fired at intervals of less than X minutes because of the time required for smoke to dissipate)

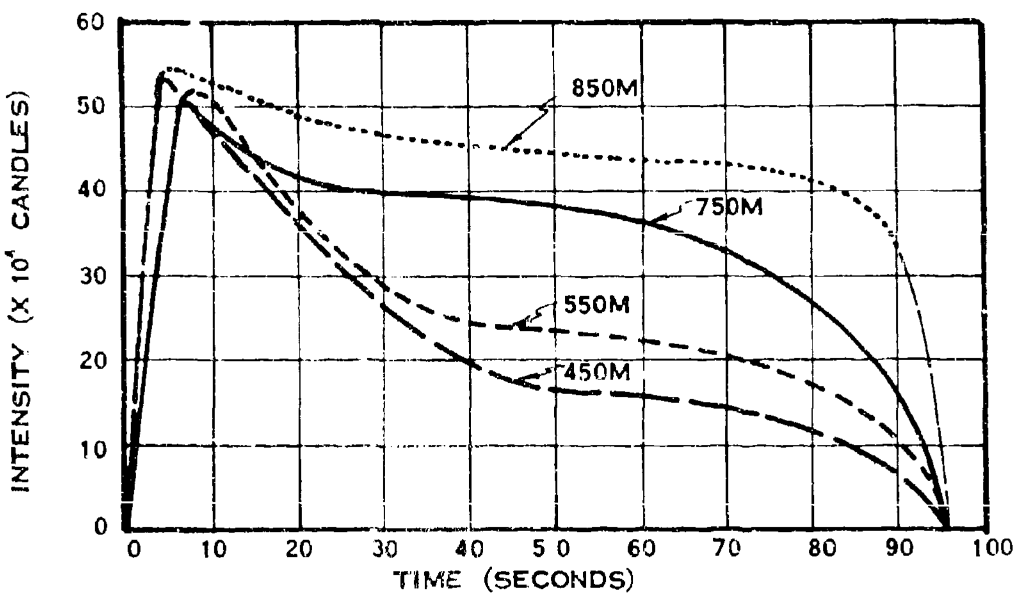

FIGURE 7. Apparent intensity curves for the 4.2-inch Illuminating Cartridge for various function heights.

3) Differences in data should be noted (i.e., observers noted all rounds normal while PER data indicate rounds X and Y were substandard).
4) Additional information which may be of value to user or developers should be included (i.e., gun crew members, located at X/Y could see surface objects in front of the flare, but not underneath it).
5) Improvements required in instrumentation or methodology should be described (i.e., color temperature measurements, if available, might have explained the irregular shape of the illumination/time curve).

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13. ABSTRACT

Provides detailed testing procedures and sample characteristic diagrams for tactical luminants utilizing a pyrotechnic evaluation range.

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