7 October 1969

Materiel Test Procedure 6-2-166*
Aberdeen Proving Ground

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

LASER RANGEFINDERS

1. OBJECTIVE

The objective of this procedure is to evaluate the performance and safety characteristics of laser rangefinders under a variety of expected operating conditions.

2. BACKGROUND

The development of the laser over the past few years has continually led to its employment in a variety of applications. Its effectiveness as a useful tool lies in its many unique properties, including: the narrowness of its emission frequency (monochromaticity) its brightness and power density, and the pulse shortness of which it is capable. These and other qualities are found in upwards of 50 different laser types, each varying according to wavelength, temperature, energy conversion efficiency, excitation means, power output and other characteristics.

Of particular interest to the Army is the use of the laser as the transmitting element in range-finding instruments, suitable for field use. Ranging applications may be conveniently classified on the basis of distance between target and instrument. A typical value, routinely measured, is 20 km, more or less, since earth-bound systems are limited by atmospheric conditions.

In general, range-finding lasers are optically excited instruments with active elements such as ruby or yttrium aluminum garnet crystals. They are operated in a "Q-switched" mode in order to generate narrow, high-powered pulses. In this mode a resonant cavity condition is interrupted which reduces stimulated-emission losses and causes an intense laser action upon restoration of resonance. Besides generating an intense pulse, this technique limits the output power to a single, precisely timed pulse. This limiting is of paramount importance since the time required for the pulse to travel to the target and return is the primary measurement. The measurement is generally carried out by a crystal clock, a binary-coded decimal counter, and a readout.

In addition to the active element, Q-switch, optics, counter and timing circuits the rangefinder includes a detector, usually, a photomultiplier tube with a variable gain control to minimize false signals caused by background light.

When built to military specifications, laser rangefinders must be lightweight and portable, yet durable and reliable. Speed of measurement and good resolution are also factors to be considered. As these instruments are

* Supersedes Interim Pamphlet 35-64

evolved in the continuing technological progress associated with lasers the testing of the instruments must provide valid evaluations of their characteristics and capabilities.

See the Glossary for a definition of terms.

3. REQUIRED EQUIPMENT

a. Photo-detector(s), as required.
b. Light Modulator(s), as required.
c. Power Measuring Device(s)(radiation)
d. Optical Filters, as appropriate.
e. Attenuator(s)(electric).
f. Oscilloscope(s), with appropriate plug-in units.
g. Standard Time Interval Counter.
h. Pulsed Radiation Source, for producing radiation of specified wavelengths.
i. Oscilloscope Cameras, with Film, as required, including:

   1) Single frame camera
   2) Continuous motion camera
   3) Cine motion (frame-by-frame) camera

j. Selected Ranging Targets, as required.
k. Precision Optical Mounts, as required.
l. Still Camera with Film.
m. Motion Picture Camera with Film.
n. Controlled Environmental Facilities.
o. Safety Goggles, of required optical density.
p. Suitable Laboratory Facilities.
q. Selected Range Test Sites; as required.
r. Battery Recharging Facility.
s. Secured Storage Facility, for classified materials and equipment.
t. Maintenance Support Facility.
u. Personnel Protective Clothing.
v. Equipment, as required by the referenced MTP's.
w. Meteorological Equipment.

4. REFERENCES

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M. Cherni, R. H. and Foster, L. E., Instrumentation for Engineering Measurement, John Wiley and Sons, Inc., New York 1962.
N. MTP 3-2-503, Safety Evaluation of Electronic and Electrical Equipment.
O. MTP 4-2-804, Laboratory Vibration Tests.
P. MTP 5-2-506, Shock Test Procedures.
Q. MTP 6-2-135, Infrared Equipment.
R. MTP 6-2-165, Lasers.
S. MTP 6-2-500, Physical Characteristics.
T. MTP 6-2-502, Human Factors Engineering.
U. MTP 6-2-503, Reliability.
V. MTP 6-2-504, Design for Maintainability.
W. MTP 6-2-509, Electromagnetic Compatibility.
X. MTP 6-2-514, Electrical Power Requirements.
Y. MTP 10-2-109, Telescopes.
Z. MTP 10-2-503, Surface Transportability (General Supplies and Equipment)
AA. USATECOM Laser Safety Guide, 25 November 1968.
AB. TB MED 279, Control of Hazards to Health from Laser Radiation, 24 February 1969.

5. SCOPE

5.1 SUMMARY

This document outlines procedures for conducting engineering tests of laser rangefinders, in order to evaluate their capabilities, and safeness for use as reliable instruments. The following are to be performed in the evaluation:

a. Preparation for Test, including:

1) Initial Inspection - A study to determine the arrival condition of each test item.
2) Physical Characteristics - A study to determine the physical characteristics of each test item.
3) Electrical Characteristics - A study to verify the

electrical characteristics and power requirements for each test item.

b. Operational Checkout - A check to verify that the test item systems are functioning properly and that the various indicator values respond to the necessary adjustments.

c. Operational Performance - An evaluation of the performance characteristics of the test item including:

1) Laboratory Tests of Transmitter Performance, as follows:

a) Output Pulse Power - A determination of the pulse power characteristics.
b) Output Pulse Description - A determination of the output pulse rise time and pulse width.
c) Output Beam Divergence - A determination of the angular spread of the output beam.

2) Laboratory Tests of Receiver Performance, as follows:

a) Signal Detectability - A determination of the minimum signal level able to be detected.
b) Detector Pulse Response - A determination of the response characteristics of the receiver detector.
c) Range Counter Pulse Response - A determination of the response characteristics of the receiver range [illegible]nter.
d) Range Counter Accuracy - A study of the accuracy [illegible] range counter response to pulses of varying time separation.

3) Field Tests, as follows:

a) Maximum Range Capability - A determination of the maximum effective range of the test item.
b) Optical Collimation Accuracy - An evaluation of the accuracy with which the sighting, transmitting and receiving optics have been collimated.

4) Aiming and Sighting Capability - A determination of the characteristics of the test item aiming and sighting system.

d. Power Requirements - An evaluation of the test item's overall response to variations in input power in its various configurations.

e. Electromagnetic Compatibility - A study to determine mutual electromagnetic interferences between test item components, during operation, and the susceptibility of the test item to interference from external sources and the effects of its operation on nearby equipment.

f. Environmental Tests - A study to evaluate the capability of the test item to withstand environmental extremes with little or no degradation of performance.

g. Transportability - A study to evaluate the effects of transport on the test item.

h. Reliability Evaluation - A study to evaluate the test item capability for meeting specified reliability criteria.

i. Maintenance Evaluation - A study to evaluate the test item with regard to its design for maintainability and to determine its maintenance requirements and the ease with which maintenance operations can be performed.

j. Human Factors Evaluation - A study of the man-item relationships involved in the maintenance and operation of the test item.

k. Safety Evaluation - An evaluation of the safeness of the test item in its various configurations and the resultant safety hazards to personnel during handling, operation and maintenance of the test item.

5.2 LIMITATIONS

This MTP shall be limited to laser rangefinders with pulsed solid-state transmitters.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Training

Personnel must have adequate training, and all applicable technical publications must be available to them.

6.1.2 Safety Precautions

a. Use references 4AA and AB as safety guides for personnel during the conduct of testing.

b. Take the necessary measures to ensure that safety and security are maintained at all test sites to protect personnel from inadvertent exposure to laser radiation.

c. Avoid night operations or operations in deep twilight, if possible.

d. Be sure that all personnel involved with laser testing receive a laser eye examination by an opthalmologist before the start of the test and on a regular basis thereafter. The examination will include, but not be limited to:

1) Visual acuity determination
2) Visual field plotting
3) Slit lamp examination of iris and ocular media

e. Be sure that test personnel are equipped with laser safety glasses of appropriate optical density as described in reference 4AA.

f. Maintain a check list and a log of all safety precautions taken during the testing.

6.1.3 Initial Inspection

Upon receipt of each test item at the test site:

a. Visually inspect the test item packages and record the following:

1) Evidence of packaging damage or deterioration.
2) Identification markings, as follows:

a) Name of manufacturer
b) Number and date of contract
c) Date of manufacture
d) Other markings pertaining to the contents

b. Weigh and measure the individual packages and record the following for each:

1) Weight
2) Linear dimensions
3) Cubage

c. Record the following furnished with each test item:

1) Technical literature
2) Tools
3) Repair/replacement parts

d. Unpack the test item, visually inspect it, and record the following, as applicable:

1) Evidence of defects in manufacturing, materials, and workmanship.
2) Evidence of wear and damage.

e. Photograph all test item damage and use sketches in reporting the condition of the test item.

f. Record the presence of identification and instruction plates, including:

1) Nomenclature, model and serial numbers
2) Warnings, precautions
3) Operating instructions
4) Adjustments and calibrations
5) Connector and receptacle markings

g. Record whether any parts are missing (identify).

6.1.4 Physical Characteristics

a. Determine the physical characteristics of the test item as described by the applicable sections of MTP 6-2-500.

b. Assemble a characteristics data sheet consisting of a photograph of the test item together with a listing of physical and performance characteristics.

6.1.5 Electrical Characteristics

Determine the electrical characteristics and electrical power requirements as described in the applicable sections of MTP 6-2-514.

6.2 TEST CONDUCT

6.2.1 Operational Checkout

Perform the following for a minimum of three test items.

a. Prepare each test item for operation as specified in the applicable technical literature.
b. Verify the operability of the test item using the specified checkout procedures, including operation with each applicable power supply configuration.
c. Record the test item indicator values as specified in the checkout procedures.
d. Make any adjustments necessary to bring indicator values within specified tolerances and record the adjustments.

NOTE: Pre-set parameter values, critical to performance characteristics should not be changed.

e. Record any operational discrepancies such an unusual noises from components in test item auxiliary systems etc.

6.2.2 Operational Performance

a. Evaluate the operational performance of a minimum of three test items using each of the power supply configurations.

NOTES:
1. The performance tests conducted in the laboratory determine the basic system parameters of the test item and verify its capability for safe operation.
2. The performance of the test item can be defined in terms of its ranging capability, measuring accuracy, and target resolution, each of which encompasses several basic parameters.
3. Subtests are to be conducted concurrently, whenever possible, so as to reduce the time required to collect the necessary data.
4. Measurement and recording of laser parameters are discussed in references 4E, 4F, 4K, and 4R.

b. Record the following for each major component in the instrumentation system used to measure and record the data:

1) Nomenclature
2) Model number
3) Serial number
4) Manufacturer

c. Set up and calibrate the instrumentation system components as described in the applicable technical literature and record the required calibration data.

d. Record the following characteristics for each test item transmitter power measuring device used in the performance evaluations.

1) Type (photo-detector, photomultiplier tube, silicon photodiode, calorimeter etc.)
2) Wavelength range.
3) Maximum power rating.
4) Maximum energy rating.
5) Sensitivity.
6) Rise time.
7) Decay time.
8) Aperture diameter.
9) Accuracy.

6.2.2.1 Laboratory Tests of Transmitter Performance

6.2.2.1.1 Output - Pulse Power - Perform the following:

a. Determine the test item transmitter output pulse power as described in the applicable sections of MTP 6-2-165.

NOTE: Selection of the power-measuring device for monitoring the laser output is dependent on the output characteristics themselves.

b. Pulse the transmitter in rapid sequence over a time period as specified in the test plan.

c. Measure and record the stability of the output power level.

6.2.2.1.2 Output Pulse Description - Perform the following:

a. Determine and record the output pulse characteristics of the test item transmitter as described in MTP 6-2-165.

b. Repeat step a until a minimum of ten determinations have been made.

c. Replace the transmitter active element and repeat steps a and b.

d. Record any difficulty encountered in changing the active element.

6.2.2.1.3 Output beam Divergence - Determine the output beam divergence (angular spread) of the test item transmitter as described in the applicable sections of MTP 6-2-165.

6.2.2.2 Laboratory Tests of Receiver Performance

6.2.2.2.1 Signal Detectability - Perform the following:

a. Expose the test item receiver to radiation at the transmitter wavelength from a controllable external source or from the rangefinder transmitter.

NOTE: When the test item transmitter is used as a radiation source vary the "range" or "reflectivity" of the target receiver or change the transmittance of the intervening space with the appropriate optical filters.

b. Decrease the flux density of the radiation at the receiver until the signal level is just enough to consistently trigger the range counter.

c. Measure and record the signal flux density using an appropriate proven measuring device.

d. Repeat steps a through c until a minimum of ten measurements have been made.

6.2.2.2.2 Detector Pulse Response - Perform the following:

a. Apply pulsed signals, from a controllable signal source (as in paragraph 6.2.2.2.1), to the detector input of the test item receiver at the wavelength of the test item transmitter.

b. Measure and record the detector pulse response including:

1) Pulse rise time
2) Pulse amplitude
3) Pulse delay
4) Pulse rise time degradation

NOTE: Slow detector pulse rise time severly affects the resolution capability of the test item and the overall repeatability of ranging information.

c. Repeat steps a and b until minimum of ten sets of measurements have been made.

d. Record the following for the test item detector:

1) Type
2) Sensitivity (radiant)
3) Bandwidth
4) Maximum power
5) Operating voltage
6) Aperture diameter

6.2.2.2.3 Range Counter Pulse Response - Perform the following:

a. Apply pulsed signals to the input of the range counter (through the test item receiver section).

b. Decrease the pulse amplitude and determine and record the minimum pulse energy required to trigger the range counter.

c. Repeat steps a and b until a minimum of ten determinations have been made.

6.?.2.2.4 Range Counter Accuracy - Perform the following:

a. Apply pairs of start-stop pulsed signals, separated in time by one μ sec, simultaneously, to the test item range counter and to a 100 MHz standard time interval counter, for a specified time.

b. Record the reading from each counter readout.

c. Repeat steps a and b for pulsed signals which are separated by 5 μ sec, 10 μ sec, 20 μ sec, 30 μ sec, etc., (increasing the interval by 10 μ sec until maximum interval is achieved.

d. Record the time interval between pulses for each determination.

e. Record any apparent test item range counter instability.

6.2.2.3 Field Tests

a. Select a suitable site for the performace of field tests.

b. Select targets for field tests as specified in the test plan.

c. Ensure that there is strict adherence to range safety during all phases of field testing.

d. Conduct field tests under the following conditions:

1) Clear daylight
2) Fog or haze
3) Rain, if applicable
4) Clear darkness, if applicable

e. Measure and record the following for each field test:

1) Ambient air temperature
2) Barometric pressure
3) Relative humidity

f. Record the weather condition for each field test.

NOTE: Field tests shall require no direct test item instrumentation since they provide data to verify the laboratory data (basic parameters).

6.2.2.3.1 Maximum Range Capability - Perform the following:

a. Determine and record the maximum range at which each of three targets, selected as specified in the test plan, may be detected by the test item.

b. Repeat step a until a minimum of five determinations have been made for each target.

c. Record the target identity for each determination.

6.2.2.3.2 Optical Collimation Accuracy - Perform the following:

a. Position the test item at a distance of 5000 meters from a selected highly reflective target.
b. Measure the range from the test item to the target and record the range counter readout.
c. Progressively increase the distance between the test item and the target and repeat step b until ranging become erratic.

NOTE: At long ranges target discrimination is affected by the accuracy with which the sighting, transmitting, and receiving optics are collimated.

6.2.2.3.3 Target Discrimination - Perform the following:

a. Position a minimum of 15 closely speced targets at ranges and angular directions from the test item as specified in the test plan.

NOTE: Generally, lateral discrimination is dependent on the diameter of the test item laser beam at the target while range (depth) discrimination is dependent upon the length, in space of the laser output pulse.

b. Determine the range to each target using the test item and record the test item readout.
c. Repeat step b until a minimum of three determinations have been made for each target.
d. Record the designation of identifying number for each target during each observation.

6.2.2.4 Aiming and Sighting Capability

Determine the characteristics of the test item aiming and sighting system using the criteria of MTP 10-2-109 (for telescopic system) or MTP 6-2-135 (for infrared system) as appropriate.

6.2.3 Power Requirements

a. While performing the procedures of paragraph 6.2.2, subject the test item, as a unit, to the applicable procedures of MTP 6-2-514 to determine the test item's sensitivity to input power variations.

NOTE: 1. Input power frequency and voltage variations within the established tolerance limits for the item may cause output and ranging parameters to deteriorate below acceptable limits.
2. Ensure that no critical combination of voltage and frequency are omitted.

b. Maintain a log of the test item operating time throughout the test to determine any test item performance degradation due to battery usage, etc.

6.2.4 Electromagnetic Compatibility

a. While performing the procedures of paragraph 6.2.2, subject the test item to the applicable procedures of MTP 6-2-509 to determine the electromagnetic compatibility of its transmitter and receiver components.

b. Determine and record the interference effects of electromagnetic radiation emanating from the test item on nearby equipment.

c. Determine and record the effects of electromagnetic radiation on the test item where radiation is emanating from an external source.

6.2.5 Environmental Tests

a. Subject the test item to the simulated environments of AR 70-38 as described in the applicable sections of MIL-STD-810B to include the following:

1) High temperature tests (Method 501).
2) Sunshine tests (Method 505, Procedure II). This procedure will be modified to use peak solar radiation of 360 Btu/ft^2/hr and peak air temperature of 110°F in accordance with AR 70-38, intermediate conditions.
3) Low temperature tests (Method 502). For this procedure a storage temperature of -50°F and an operating temperature of -35°F will be used unless otherwise specified.
4) Humidity tests (Method 507, Procedure V).
5) Fungus tests (Method 508).
6) Salt fog tests (Method 509).
7) Dust tests (Method 510).
8) Rain tests (Method 506). Procedures of MTP 2-2-815 are also acceptable.

b. Verify the operability of the test item, at the conclusion of each of the environmental tests, by conducting an operational checkout as described in paragraph 6.2.1.

6.2.6 Transportability

Determine the effects of transportation on the test item by subjecting it to the applicable procedures of MTP 10-2-503 and/or the following:

6.2.6.1 Vibration Test

a. Determine the effects of vibration on the test item by subjecting it to the applicable procedures of MTP 4-2-804.

b. Verify the operability of the test item, at the conclusion of the vibration test, by conducting the operational checkout described in paragraph 6.2.1.

6.2.6.2 Shock Test

a. Determine the effects of shock on the test item by subjecting it to the procedures of MTP 5-2-506 using the criteria on AR 705-35, as applicable.

b. Verify the operability of the test item, at the conclusion of shock testing, by conducting the operational checkout described in paragraph 6.2.1.

6.2.7 Reliability Evaluation

Evaluate the reliability of the test item using criteria of MTP 6-2-503.

6.2.8 Maintenance Evaluation

Determine the maintainability of the test item using the criteria of MTP 6-2-504, including the following:

a. Evaluate the test itme design with respect to part replacement.

b. Record the following for authorized maintenance operations:

1) Skill level required
2) Number of man-hours expended
3) Difficulties encountered

6.2.9 Human Factors Evaluation

Perform a human factors evaluation of the test item using the criteria of MTP 6-2-502, and the following:

a. Accessibility of connectors and receptacles.
b. Ease of making connections between components.

6.2.10 Safety Evaluation

Determine the test item safety hazards resulting from transport, operations and maintenance in accordance with criteria of MTP 3-2-503.

NOTE: Hazards to test personnel due to the operation of the test item transmitter shall be eliminated, as far as possible, in accordance with the procedures of reference 4AA.

6.3 TEST DATA

Data to be recorded are described in paragraphs 6.1 and 6.2.

6.4 DATA REDUCTION AND PRESENTATION

Data obtained during the conduct of the various subtests shall be evaluated in accordance with the procedures contained in the MTP's applicable to those subtests.

Calculations shall be performed as specified by the applicable MTP's and all photographs, motion pictures and illustrative material shall be suitably identified, particularly oscilloscope trace photos.

Sketches, such as block diagrams, shall be used to describe the various instrumentation setups, when necessary.

Where multiple sets of data are taken, average values for the various parameters shall be calculated and used in the subsequent plots or presentations.

Specific requirements for the presentation of performance results are as follows:

a. Transmitter Performance

1) Plot transmitter output pulse power vs time.
2) Plot output power vs storage voltage at a fixed temperature.
3) Plot output power vs temperature at normal voltage control setting.
4) Correlate photographic data records with measured data, wherever possible to show output pulse variations.
5) Prepare a comparison table showing the output pulse characteristics of the test item transmitter for each active element used.
6) Show any variation in transmitter performance from test item to test item.

b. Receiver Performance

1) Show (by table) any abnormal change in signal characteristics across the detector section of the test item receiver.
2) Show (by data record) any change in the detector pulse response characteristics including pulse rise time degradation vs time.
3) Show (by data record) any change in the range counter response characteristics due to changes in transmitter pulse characteristics.
4) Compare the range counter readings with those read from the standard interval counter to show time measuring accuracy.
5) Present data to show any range counter instability, if applicable.

c. Maximum Range Capability:

1) Relate the output pulse power data, the beam divergence data and signal detectability data so as to define the maximum range capability of the test.
2) Compare the expected maximum range capability to the actual maximum capability as determined from the field tests.

d. Range Measuring Accuracy:

1) Relate the transmitter, output pulse characteristics, the receiver pulse response characteristics and the range counter accuracy so as to define the test item's range measuring accuracy.
2) Compare the expected ranging accuracy to the actual accuracy as determined from the field tests.

e. Lateral Target Discrimination

1) Calculate the item laser beam diameter for each target used in target discrimination tests as follows (using the known ranges):

$$D_L = \frac{R\theta}{1000}$$

where: D_L = laser beam diameter in meters

R = target range in meters

θ = beam divergence angle in m radians

2) Correlate target data (lateral discrimination) with the beam diameter at each target.

f. Target Range Discrimination:

1) Calculate the distance in space occupied by the transmitter pulse, for each target, as follows:

$$D_R = 300t$$

where: D_R = pulse length (in space) in meters
t = time length of pulse in microseconds

2) Compare target range data with known range and correlate the results with the calculated value for the pulse length.

g. Optical Collimation Accuracy:

Present tabular data to show the optical collimation accuracy for the test item sighting, transmitting and receiving optics.

h. Meteorological Effects on Test Item Performance:

Compare data taken under various conditions and correlate applicable performance degradation to the various conditions.

i. Effects of Power Supply Changes:

Correlate abnormal performance results with power supply changes made during the testing period, if applicable.

Prepare a Safety Release Recommendation based on the data collected in paragraph 6.3.2.10 in accordance with USATECOM Regulation 385-6.

GLOSSARY

1. Angstrom (A°): Unit of measure of wavelengths equal to 10^{-10} meter or 0.1 nanometer (millimicrons).

2. Beam Divergence: Angle of beam spread in milliradians (1 milliradian = 3.4 minutes of arc).

3. Closed Installation: Any location where lasers are used which will be closed to personnel during laser operation such as remote firing and TV monitored operations.

4. C. W. Laser: Continuous wave laser as distinguished from a pulsed laser.

5. Decibel (db): The unit used to express a beam intensity ratio. The decibel is equal to 10 times the logarithm of the beam intensity ratio as expressed by the following equation:

$$n(db) = 10 \log_{10} \frac{(P_1)}{(P_2)}$$

where P_1 and P_2 designate two amounts of power or energy density and n the number of decibels corresponding to their ratio.

6. Electromagnetic Radiation: The propagation of varying electric and magnetic fields through space at the speed of light.

7. Emergent Beam Diameter: Diameter of the laser beam at the exit aperture of the system.

8. Energy Density: The intensity of electromagnetic radiation per unit area per pulse expressed as joules per square centimeter.

9. Gas Laser: A class of laser in which the laser action takes place in a gas medium usually a C. W. Laser.

10. Hazard Evaluation Survey: Evaluation of the hazards to personnel working or remaining in the vicinity of laser equipment.

11. Joule (j): A unit of energy. Used in describing a single pulsed output of a laser. It is equal to one watt-second or 0.239 gram-calories.

12. Joule/cm^2 (j/cm^2): Unit of energy density used in measuring the amount of energy per area of absorbing surface or per area of a laser beam. It is a unit for predicting damage potential of a laser beam.

13. Laser: Light amplification by stimulated emission of radiation.

14. Laser Light Region: A portion of the electromagnetic spectrum which includes ultraviolet, visible, and infrared light.

15. Maser: Microwave amplification by stimulated emission of radiation. When used in the term optical maser, it is often interpreted as molecular amplification by stimulated emission of radiation.

16. Maximum Permissible Power or Energy Density: The intensity of laser radiation that, in light of present medical knowledge, is not expected to cause detectable bodily injury to a person at any time during his lifetime.

17. Open Installation: Any location where lasers are used which will be open during laser operation to operating personnel and may or may not specifically restrict entry to casuals.

18. Optical Density (OD): A logarithmic expression of the attenuation afforded by a filter. Alternatively, OD may be expressed as one-tenth the attenuation in db.

19. Optically Pumped Laser: A class of laser which derives its energy from a noncoherent light source such as a xenon flash lamp. This laser is usually pulsed.

20. Output Power and Output Energy: Power is used primarily to rate C. W. lasers since the energy delivered per unit time remains relatively constant (output measured in watts). However, pulsed lasers which have a peak power significantly greater than their average power produce effects which may best be categorized by energy output per pulse. The output power of C. W. lasers is usually expressed in milliwatts (mw = 1/1000 watts), pulsed lasers in kilowatts (1000 watts), and q-switched pulsed lasers in megawatts (MW = million watts) or gigawatts (GW = billion watts). Pulsed energy output is usually expressed in joules.

21. Power Density: The intensity of electromagnetic radiation present at a given point. Power density is the average power per unit area usually expressed as milliwatts per square centimeter.

22. Pulsed Laser: A class of laser characterized by operation in a pulsed mode, i.e., emission occurs in one or more flashes of short duration (pulse length).

23. Pulse Length: Duration of laser flash. May be measured in milliseconds (msec = 10^{-3} sec), microseconds (μ sec = 10^{-6} sec), or nanoseconds (nsec = 10^{-9} sec).

24. Q-Switched Laser: (also known as Q-spoiled) A pulsed laser, capable of extremely high peak powers, for very short durations (pulse length of several nanoseconds).

25. Semiconductor or Junction Laser: A class of laser which normally produces relatively low power outputs. This class of laser may be "tuned" in wavelength and has the greatest efficiency.

26. Solid-State Laser: A class of laser which utilizes a solid crystal such as ruby or glass. This class most commonly is used as an optically pumped, pulsed laser.

27. Metric and Exponential Systems: The following explanation of the metric system and the exponential method of expressing numbers is presented as a source of reference:

(1) Metric System Abbreviations:

meter - m
centimeter - cm
millimeter - mm
micron - μ
nanometer - nm
angstrom - Å

Equivalent Units

1 m = 100 cm = 1,000 mm = 39.37 inches
1 cm = 0.3937 inches; 1 inch = 2.54 cm
1 μ = 10^{-6} meters = 10^{-4} cm
1 msec = 1/1,000 seconds = 1 x 10^{-3} seconds
1 μsec = 1/1,000,000 seconds = 1 x 10^{-6} seconds
1 nsec = 1 x 10^{-9} seconds
1 milliradian = 10^{-3} radians =0.057 degrees = 3.4 arc-minutes

(2) Exponential System: For convenience in writing and manipulation, unwieldy numbers are written as factors of appropriate powers of 10. The following examples will illustrate:

2,380,000,000 = 2.38×10^{9}
238 = 2.38×10^{2}
0.238 = 2.38×10^{-1}
0.000000238 = 2.38×10^{-7}