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MILITARY STANDARD

DEFINITIONS APPLICABLE TO SPEED-GOVERNING OF ELECTRIC GENERATOR SETS

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OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON 25, D. C.

Supply and Logistics 17 March 1958

Definitions Applicable to Speed-Governing of Electric Generator Sets

MIL-STD-178A

1. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force, effective 17 April 1958.

2. In accordance with established procedure, the Corps of Engineers, the Bureau of Ships, and the Air Force have been designated as Army-Navy-Air Force custodians of this standard.

3. Recommended corrections, additions, or deletions should be addressed to the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics), Washington 25, D. C.

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1. SCOPE

This standard covers definitions of terms applicable primarily to complete prime mover driven generators and to mechanical and electrical speed-governing of generator sets where the ratio of prime mover speed to generator speed remains constant. Within certain limitations, which are obvious, this stand may also be used for generator sets where the ratio of prime mover speed to generator speed varies.

2. REFERENCED DOCUMENTS

2.1 The following standard, of the issue in effect on date of invitation for bids, forms a part of this standard.

STANDARD

FEDERAL

FED-STD-5 — Standard Guides for Preparation of Item Descriptions by Government Suppliers.

3. DEFINITIONS

3.1 Average. Average is the quantity found by dividing the sum of all quantities by the number of quantities. Example: the average of 3, 5, and 10 is 6. For the purposes of this standard the terms average and mean are used synonymously.

3.2 Base speed. Base speed is the speed represented by the midpoint of the steady-state speed regulation band at rated power output (see also, mean governed speed (3.7) and midspeed (3.9)).

3.3 Deadband. Deadband is the total speed change within which the speed-governing system makes no measurable correction to the setting of the governor-controlled devices, such as fuel-metering equipment.

3.4 Hunting. Hunting is a state of unstability of speed which is evidenced by forced oscillation of the speed about a mean value where the amplitude of the oscillation (periodic maximum deviation from the mean value) exceeds the specified limits for the steady-state governing speedband. An observed condition of hunting is described by the frequency and amplitude of the oscillation. The amplitude is expressed in percent of rated speed.

3.5 Load detector. A load detector is a device which senses load, or a quantity proportional thereto, and delivers a signal output proportional to load.

3.6 Mean. Mean is the quantity found by dividing the sum of all quantities by the number of quantities. Example: The mean of 3, 5, and 10 is 6. For the purposes of this standard the terms mean and average are used synonymously.

3.7 Mean governed speed. Mean governed speed (see figure 1) is the average speed that occurs in a given period during which a generator set is operating under any sustained condition of electrical load with the speed-governing system in control. It is the arithmetic mean of all the instantaneous values of speed occuring during the period under consideration.

3.8 Mean speed-power curve. The mean speed-power curve is the relationship between mean governed speed and power output of the generator set.

3.9 Midspeed. Midspeed is the average speed obtained from the maximum instantaneous speed and the minimum instantaneous speed included in the observed speedband (see figure 1), of a generator set when operating under conditions of steady-state electrical load.

3.10 Momentary overspeed. Momentary overspeed (see figure 2) is the maximum in-

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crease in speed above the midspeed occurring at the second operating condition incident to a sudden decrease between two given steady-state electrical loads. It is expressed in percent of rated speed, thus:

(a) For a load decrease equal to rated power output:

$$So = \frac{n_{max} - n_0}{n_r} (100)$$

Where:

n_r = rated speed.

n_0 = midspeed at zero power output.

n_{max} = maximum momentary speed incident to a sudden and complete loss of load from conditions at rated speed and a steady-state electrical load equal to rated power output.

(b) For a load decrease less than rated power output:

$$So = \frac{n_{max} - n_1}{n_r} (100)$$

Where:

n_r = rated speed.

n_1 = midspeed at the second steady-state electrical load.

n_{max} = maximum momentary speed incident to a sudden reduction between two steady-state loads.

3.11 Momentary underspeed. Momentary underspeed (see figure 3) is the maximum momentary decrease in speed below the midspeed occurring at the second operating condition incident to a sudden increase between two given steady-state electrical loads. It is expressed in percent of rated speed, thus:

$$Su = \frac{n_1 - n_{min}}{n_r} (100)$$

Where:

n_r = rated speed.

n_1 = midspeed at the second steady-state electrical load.

n_{min} = minimum momentary speed incident to a sudden increase between two steady-state electrical loads.

3.12 **Observed speedband.** Observed speedband is the speed-time envelope having upper and lower speed values represented by the maximum and minimum instantaneous speeds which occur during a sample time interval throughout which the specified conditions prevail and so chosen that a representative section of the actual instrument trace of the speed-time function is covered. The observed speedband is described narratively by stating the deviation of these upper and lower speed values from the midspeed, where the amplitude of deviation is expressed in percent of rated speed.

3.13 **Power output.** Power output is the net electrical power that is obtained from the generator set. It is the electrical power output at the generator terminals after deductions have been made for the electrical power used by any auxiliaries that by agreement are considered to function in effect as essential parts of the basic generator set.

3.14 **Prescribed speedband.** Prescribed speedband is a speed-time envelope having upper and lower speed limits which represent, respectively, the values of the maximum and minimum instantaneous speeds to be used when determining the instant of termination of recovery time interval. The values of these limits are specified by means of an amplitude which is taken with respect to the midspeed of the observed speedband. This amplitude is expressed in percent of rated speed.

3.15 **Rated Power output.** Rated power

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output is the manufacturer's stated or guaranteed net electrical power (kw.) output that is obtainable continuously from the generator set when it is functioning at rated speed under the specified operating conditions.

3.16 **Rated speed.** For alternating-current generator sets, rated speed applies to the speed which produces rated frequency. For direct-current generator sets, rated speed applies to the identification plate design value of speed for rated power output.

3.17 **Recovery time.** Recovery time is that time which elapses between the instant when load starts to change and the instant when the speed reaches a certain state of recovery following a given sudden change in the steady-state electrical load on a generator set. It is the time in seconds from instant of change from the initial load condition to the instant when the decreasing oscillation of speed finally enters a prescribed speedband.

3.18 **Speed.** The term speed as used herein refers to rotational speed (usually in revolutions per minute).

3.19 **Speed changer.** The speed changer is that portion of a speed governing system which provides means for changing the mean governed speed of the operating generating set while the generator set is in operation.

3.20 **Speed control mechanism.** The speed control mechanism includes all equipment, such as relays, servo-motors, pressure or power amplifying devices, levers, linkages, valves and associated interconnections, between either or both the speed detector and load detector and the fuel-metering equipment in the case of internal combustion engine generator sets, the valves in the case of turbine generator sets, and the basic motor in the case of motor-generators.

3.21 **Speed detector.** A speed detector is a device which senses speed, or a quantity proportional thereto, and delivers a signal output proportional either to speed or to the deviation of speed from a reference value.

3.22 **Speed deviation.** Speed deviation is a maximum departure of speed from midspeed of the initial observed speedband which occurs during transient response resulting from stated upsetting conditions. Speed deviation is expressed in percent of rated speed. Speed deviations above midspeed of the initial observed speedband are positive and speed deviations below midspeed of the initial observed speedband are negative. When used without further qualifications, operation with adjustments set for rated conditions and step changes in generator load impedance is implied.

3.23 **Speed drift.** Speed drift is the total amount of variation of the mean governed speed with time under steady-state operating conditions. For specified conditions and period of time, speed drift is expressed in percent of rated speed.

3.24 **Speed-governed system.** A speed-governed system is a generator set or a motor-generator as defined in Standard FED-STD-5, less the speed-governing system.

3.25 **Speed-governing system.** The speed-governing system generally consists of a speed detector or such combinations as the speed and load detectors, and the necessary mechanism required to transmit the speed corrective action from either or both detectors to the fuel-metering equipment of an internal combustion engine generator set, the valves in the case of a steam turbine generator set, or the basic motor in the case of a motor-generator. It may also include such devices as a speed changer and a speed regulation changer.

3.26 **Speed regulation changer.** The speed regulation changer is that portion of the

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speed governor system which provides means for changing the steady-state speed regulation of the generator set.

3.27 **Stability.** Stability is that property of the speed-governing system which causes it to develop restoring forces among its electrical and mechanical elements.

3.28 **Steady-state electrical load.** Steady-state electrical load on a generator set is any electrical power demand having a constant mean value although it may have either or both the following:

(a) Random deviations not exceeding a specified value such as plus or minus 0.25 percent of rated power output.

(b) Periodic deviations not exceeding a specified value such as plus or minus 0.1 percent of rated power output.

3.29 **Steady-state governing speedband.** Steady-state governing speedband is a speed-time envelope having upper and lower speed values represented by the maximum and minimum instantaneous speeds which occur under given steady-state operating conditions with the speed-governing system functioning. The limits for the steady-state governing speedband are defined by an amplitude which is taken with respect to the midspeed of the observed speedband. This amplitude is expressed in percent of rated speed.

3.30 **Steady-state incremental speed regulation.** Steady-state incremental speed regulation is the rate of change of speed with respect to power output under conditions of steady-state electrical load. It is represented by the slope of the tangent to the mean speed-power curve at the point of power output under consideration. When used with the qualification "steady-state incremental speed regulation referred to rated speed" it is implied that the tangent is established from a segment of a speed-power curve obtained with the mean governed speed for the point of power output under consideration set at rated speed by means of the speed changer. Steady-state incremental speed regulation is expressed in percent of rated speed when the difference in speed, expressed in percent of rated speed, between any two points on the defined tangent is divided by the difference in the corresponding power levels at these points expressed as a fraction of rated power output. It may be expressed mathematically in percent as follows:

$$R_i = \frac{P_r (n_2 - n_1)(100)}{n_r (P_1 - P_2)}$$

Where:

n_r = rated speed.

n_1 = rated speed corresponding to the larger power level P_1.

n_2 = speed corresponding to the lesser power level P_2.

P_r = rated power output.

3.31 **Steady-state operating conditions.** Steady-state operating conditions exist when the generator set is functioning with any influences that are variable coming within any limits that may have been specified for steady-state operation, or, if no limits have been specified, are as nearly constant as is practically possible.

3.32 **Steady-state speed regulation.** Steady-state speed regulation is the change in midspeed, expressed in percent of rated speed, when the power output of the driven generator is reduced from rated power output to zero power output with fixed settings of all adjustments of the speed-governing system. Unless otherwise indicated, the fixed settings of adjustments are such that base speed and rated speed coincide. Speed regulation is considered positive when the speed at zero power output is greater than the speed at rated power output.

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3.33 **Steady-state speed regulation band.** Steady-state speed regulation band is the band formed by the parallelogram of minimum area which circumscribes, between zero and rated power output, the group of mean speed-power curves, obtained in such manner as to establish the bounds of operation of the generator set under the controlling influence of the speed-governing system for given conditions of adjustment, limits of environmental conditions, and modes of operation of the generator set. It is designated in terms of speed spread (expressed in percent of rated speed) and slope (expressed in percent of 100 percent speed regulation). When the term is used without further qualification, operation in accordance with applicable specifications with adjustments set for rated conditions is implied.

4. ALPHABETICAL LISTING OF TERMS WHICH ACCORDING TO THIS DOCUMENT, ARE NONSTANDARD

4.1 Alphabetical listings of terms, which according to this standard are nonstandard are as follows:

(a) Droop control—see 3.26.

(b) Frequency of dither—see 3.27.

(c) Frequency regulation—see 3.32.

(d) Momentary overshoot—see 3.10.

(e) Momentary undershoot—see 3.11.

(f) Speed droop control—see 3.26.

(g) Speed governor actuating mechanism—see 3.20.

(h) Speed governor element—see 3.5 and 3.21.

(i) Steady speed regulation—see 3.32.

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Copies of this standard for Military use may be obtained as indicated in the foreword to the Index of Military Specifications and Standards.

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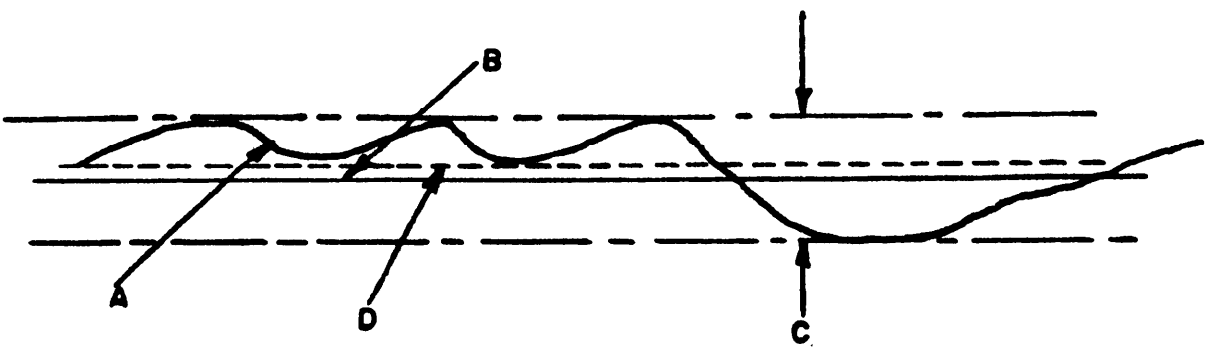

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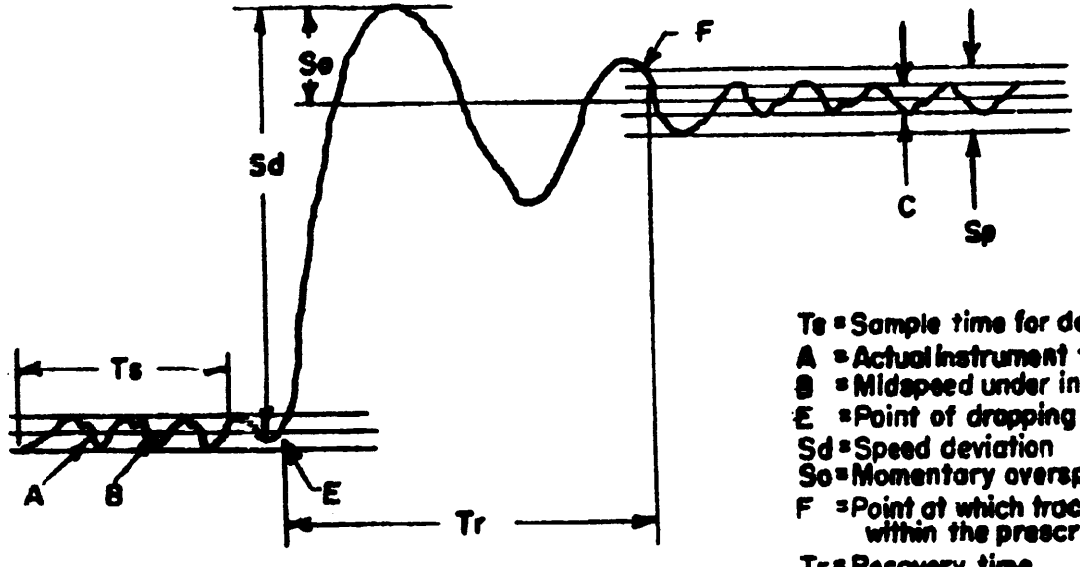
A = Actual instrument trace of function
B = Midspeed
C = Observed speedband
D = Mean governed speed

FIGURE 1. *Steady-state.*



Ts = Sample time for determining steady-state
A = Actual instrument trace of function
B = Midspeed under initial steady-state conditions
E = Point of dropping load
Sd = Speed deviation
So = Momentary overspeed
F = Point at which trace enters and remains within the prescribed speedband
Tr = Recovery time
C = Obeserved speedband under final steady-state conditions
Sp = Prescribed speedband under final steady-state conditions

FIGURE 2. *Drop load.*

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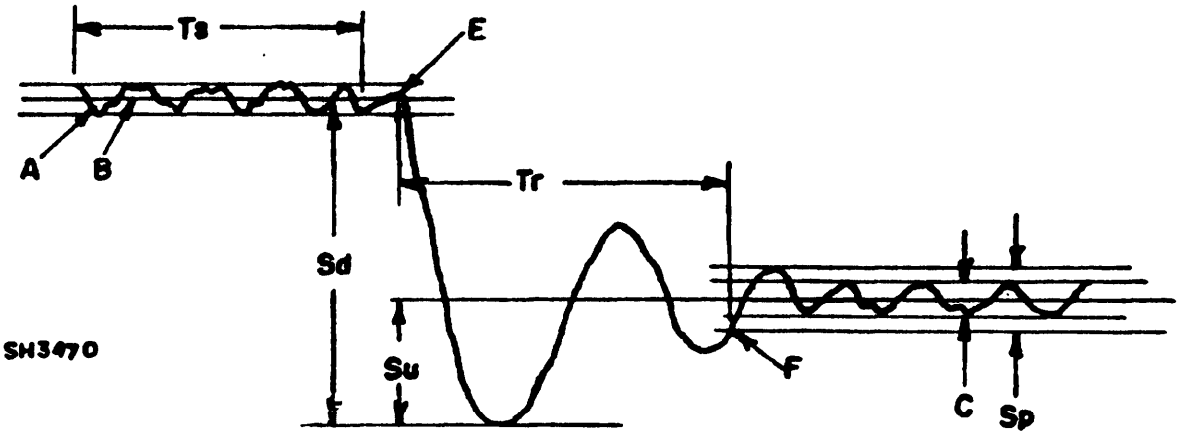

Ts = Sample time for determining steady-state
A = Actual instrument trace of function
B = Midspeed under initial steady-state condition
E = Point of load application
Sd = Speed deviation
Su = Momentary underspeed
F = Point at which trace enters and remains within the prescribed speedband
Tr = Recovery time
C = Observed speedband under finial steady-state conditions
Sp = Prescribed speedband under final steady-state conditions

FIGURE 3. *Add load.*

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