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ELECTRIC POWER, AIRCRAFT, CHARACTERISTICS AND UTILIZATION OF

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DEPARTMENT OF DEFENSE
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Electric, Power, Aircraft, Characteristics and Utilization of

MIL-STD-704A

1. This military standard is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to Commander, Naval Air Systems Command, Attn: AIR-52021, Washington, D. C. 20360.

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ELECTRIC POWER, AIRCRAFT, CHARACTERISTICS AND UTILIZATION OF

1. GENERAL

1.1 Scope. This standard delineates the characteristics of electric power supplied to airborne equipment at the equipment terminals and the requirements for the utilization of such electric power by the airborne equipment.

1.2 Purpose. The purpose of this standard is to foster compatibility between aircraft electric systems or ground support electric systems and airborne utilization equipment to the extent of confining the aircraft and ground support electric power characteristics within definitive limits and restricting the requirements imposed on the electric power by the airborne utilization equipment.

1.3 Basis for characteristics. The characteristics and limits delineated and specified in this standard are based on the notes and assumptions stated in section 7 of this standard.

2. REFERENCED DOCUMENTS

2.1 Not applicable.

3. DEFINITIONS

3.1 Average value. The average root mean square (rms) value of phase quantities is the arithmetical sum of the phase rms values divided by the number of phases.

3.2 Ground. The primary aircraft structure is the referenced ground for the negative of the dc and the neutral of the ac in the power generation and power utilization systems.

3.3 Transients. A transient is the changing condition of a characteristic. These usually go beyond the steady-state limits and return to the steady-state limits within the specified time period.

3.3.1 Surges. A surge is a variation from the controlled steady-state level of a characteristic, resulting from the inherent regulation of the electric power supply system and remedial action by the regulator.

3.3.2 Spikes. A spike is a variation from the surge level or from the controlled steady-state level of a characteristic which reaches its greatest amplitude in an extremely short time. It results from very high frequency currents of complex wave form produced when loads are switched. A spike generally lasts less than 50 microseconds and tapers off to the surge level or to the steady-state limits.

3.4 Total harmonic content. The total harmonic content of a complex wave is the total rms voltage remaining when the fundamental component is removed.

3.5 Frequency modulation. Frequency modulation is the cyclic or random variation, or both, of instantaneous frequency about a mean frequency during steady-state electric-system operation. The frequency modulation is normally within narrow frequency limits and occurs as a result of speed variations in a generator rotor owing to the dynamic operation of the rotor coupling and drive speed regulation.

3.6 Frequency modulation rate. The frequency modulation rate is the rate of change of frequency owing to frequency modulation when plotted against time.

3.7 Frequency drift. Frequency drift is the slow and random variation of the controlled frequency level within the steady-state limits occurring, for example, as a result of environmental effects and wear on the electric power-drive system.

3.8 Frequency drift rate. The frequency drift rate is the rate of change of frequency owing to frequency drift when plotted against time.

3.9 AC phase voltage. The ac voltage values stated herein shall be for any phase of those supplied utilization equipment, a phase being considered the line-to-neutral circuit at the equipment terminals. All ac voltage values are rms values.

3.10 Voltage modulation. Voltage modulation is the cyclic variation or random variations, or both, about the mean level of the ac peak voltage during steady-state electric-system operation such as caused by voltage regulation and speed variations. The modulation envelope is formed by a continuous curve connecting the successive peaks of the basic voltage wave.

3.11 Voltage modulation frequency characteristics. The frequency characteristic of voltage modulation is defined as the component frequencies which make up the modulation envelope wave form.

3.12 Ripple. Ripple is the cyclic variation of voltage about the mean level of the dc voltage during steady-state dc electric-system operation.

3.13 Unsafe condition. An unsafe condition is any condition within an aircraft that jeopardizes the safety of the aircraft or the personnel aboard.

3.14 Aircraft operational period. The operational period of an aircraft is defined as the time interval between the start of preparation for flight and the post flight engine shutdown with consequent deactivation of the aircraft electric system.

3.15 Utilization equipment. Utilization equipment will be considered as comprising either an individual unit, set, or a complete system to which the electrical power is applied.

3.16 Category "A" utilization equipment. Category "A" equipment are those utilization equipments whose installation in aircraft will be controlled so that line drops will be limited to 2 volts ac line drop or 1 volt dc, or both. The line drop is the voltage difference between the point of voltage regulation and the power input terminals of the equipment. Use of this category should be held to a minimum, and its use will be subjected to approval by the procuring activity.

3.17 Category "B" utilization equipment.- Category "B" equipment are those utilization equipments destined for aircraft for which the line drops will be less than 4 volts ac or 2 volts dc, or both. When a detail equipment specification does not designate a category, the equipment will be considered a category "B" equipment. This category will include the majority of aircraft electric equipments and is the preferred category.

3.18 Category "C" utilisation equipment.- Category "C" equipment are those equipments which are intermittently operated. During operation, voltage limits include allowance for 8 volts ac line drop or 3 volts dc line drop, or both.

3.19 Normal electric-system operation. Normal operation of the primary electric system is all the functional electric-system operations required for aircraft operation, aircraft mission, and electric-system controlled continuity. These operations occur at any given instant and any number of times during flight preparation, takeoff, airborne conditions, landing, and anchoring. Examples of such operations are switching of utilization equipment loads, engine speed changes, bus switching and synchronization, and paralleling of electric power sources. Switching of utilization equipment loads is a type of system operation which occurs the greatest number of times.

3.20 Abnormal electric-system operation. Abnormal operation of the electric system is the unexpected but momentary loss of control of the electric system. The initiating action of the abnormal operation is uncontrolled and the exact moment of its occurrence is not anticipated. However, recovery from this operation is a controlled action. This operation occurs, perhaps, once during a flight, or as a result of battle damage, or it may never occur during the life of an aircraft. An example of an abnormal operation is the faulting of electric power to the structure of an aircraft and its subsequent clearing by fault protective devices.

3.21 Abnormal limits. Abnormal limits accommodate the trip bands of protective equipment in the primary power generating system.

3.22 Emergency electric-system operation. Emergency operation is defined as that condition of the electric system during flight when the primary electric system becomes unable to supply sufficient or proper electric power, thus requiring the use of a limited independent source of emergency power.

3.23 Primary power system. The primary power system is the electric system whose generators are driven by the aircraft propulsion engines. Power conversion systems (not part of utilization systems) powered by the primary generators are part of the primary power system.

3.24 Power-system capacity.- The power-system capacity is considered to be the capacity of the power sources rated under the prescribed operating and environmental conditions in the aircraft.

(a) For parallel systems, this is the total of the individual power source ratings taking into consideration the paralleling factor.

(b) For nonparrallel systems, this is the individual power source rating.

4. GENERAL REQUIREMENTS

4.1 Power systems. Characteristics of aircraft power at the input terminals of utilization equipment shall be within the limits specified in section 5 under the conditions of power utilization specified in section 6. The electric power system shall be so designed as to ensure that the characteristics of electric power at the utilization equipment terminals conform to the requirements specified herein, and shall be so installed and protected that the failure of any power source and its disconnection from the system will not result in subsequent impaired performance of the remaining power sources.

4.1.1 AC power. The ac power system shall be a 3-phase, 4-wire "Y" system, having a nominal voltage of 115/200 and a nominal frequency of 400 cycles per second (cps). The neutral point of the source of power is connected to ground (see 3.2), and the ground is considered the fourth conductor.

4.1.2 DC power. The dc power system shall be a 2-wire, grounded system having a nominal voltage of 28 volts. The negative of the power source is connected to ground and the ground is considered the second wire.

4.2 Utilization equipment. Utilization equipment shall maintain specified performance when using power with characteristics which are specified in section 5 without degrading the power characteristics beyond their limits. When use of power is required having other characteristics or closer tolerances than specified herein, the conversion to other characteristics or closer tolerances shall be accomplished as a part of the utilization equipment. Utilization equipment designed for a specific aircraft application may deviate from these requirements only upon approval of the procuring activity.

5. DETAIL REQUIREMENTS

5.1 AC power system characteristics.

5.1.1 Line-to-neutral. Characteristics of line-to-neutral power shall be as specified herein.

5.1.2 Line-to-line. Characteristics of line-to-line power shall be as a result of line-to-neutral characteristics being as specified.

5.1.3 Steady-state voltage. The steady-state phase voltage shall be within the limits specified in table I. These limits are applicable during operation over the steady-state frequency ranges (see 5.1.5). Modes of electric-system operation and utilization equipment categories shown in table I and subsequent are defined in section 3.

5.1.3.1 Individual phase. The steady-state rms voltage for an individual phase shall be within the limits specified in table I.

5.1.3.2 Three phase. The steady-state voltage average for the three individual phases shall be within the limits specified in table I.

5.1.3.3 Phase displacements. The displacement between any adjacent phases shall be within the limits of 120° ±4°. This angle shall be the relative displacement between the zero voltage points on the wave forms of the three phases.

5.1.3.4 Unbalance. Maximum spread in phase voltages shall not exceed 3 volts between the phase with the highest voltage and the phase with the lowest voltage for all aircraft operations. This spread shall not exceed 4 volts when the source of power is the emergency power source.

5.1.3.5 Wave form. The voltage wave form shall be within the following limits:

(a) Crest factor: 1.41 ±0.15 (see 7.6.8).

(b) Total harmonic content: 8 percent of the fundamental (rms) when measured with a distortion meter as distortion of the fundamental frequency.

(c) Individual harmonic content: 5 percent of the fundamental (rms) when measured with a harmonic analyzer.

(d) Deviation factor: In any event, the wave form shall not deviate from corresponding points of the fundamental by more than 5 percent of the peak value of the fundamental.

5.1.3.6 Modulation.

5.1.3.6.1 Magnitude. The modulation of voltage shall not exceed 3.5 volts when measured as the peak-to-valley difference between the minimum voltage reached and the maximum voltage reached on the modulation envelope over a period of at least 1 second (see 3.10). A sketch of voltage modulation is shown on figure 1.

5.1.3.6.2 Frequency characteristics. The frequency components of the voltage modulation envelope wave form shall be as specified on figure 1 (see 3.11).

5.1.4 Transient voltage. Transient surge voltages, when converted to their equivalent step functions, shall be within the limits of figures 2,3, and 4 for all operations of the aircraft electric system (see 7.3). The most severe phase transient shall be used in determining conformance to figures 2, 3, and 4.

5.1.4.1 Normal electric-system operation. When switching loads from 10 percent up to 85 percent and down to 10 percent of rated system capacity, the equivalent step function of the ac voltage transient shall be within limits 5 and 6 of figures 2, 3, and 4. For other normal system operations including switching loads from 20 percent up to 170 percent and down to 20 percent of rated system capacity, the equivalent step function of the ac voltage transient shall be within limits 2 and 3 of figures 2, 3, and 4 (see 3.19). This latter condition exists when the load or group of loads being switched includes motor loads. Limit 3 includes a period of zero voltage which occurs under conditions of bus switching or transfer.

5.1.4.2 Abnormal electric-system operation. The equivalent step functions of the ac voltage transients which result from abnormal electric-system operation shall be less than limits 1 and 4 of figures 2, 3, and 4 (see 3.20). The abnormal steady state limits (ASSL) of limits 1 and 4 may continue indefinitely (see 3.21).

5.1.5 Steady-state frequency. The ac power system frequency shall be as follows:

(a) Primary power sources - The frequency shall be maintained at 400 ±20 cps for normal steady-state operation.

(b) Emergency power sources - The frequency shall be maintained at 400 ±40 cps with the voltage within the limits of table I, except that below 360 cps the frequency/voltage (F/V) ratio shall not fall below 3.4.

5.1.5.1 Drift. The range of variation of the controlled frequency level within the steady-state frequency limits owing to drift shall be not more than 10 cps for any one period of steady-state primary electric-system operation (see 3.7). Frequency variation owing to drift shall not occur at a rate greater than 15 cps per minute (see 3.8).

5.1.5.2 Modulation amplitude. Variations of primary system frequency owing to frequency modulation during any 1-minute period shall be within a band of ±4 cps about a mean frequency (see 3.5). The mean frequency may drift within the limits defined by 5.1.5.1.

5.1.5.3 Modulation rate. Rates of frequency change owing to frequency modulation shall be not greater than 25 cps per second (see 3.6).

5.1.6 Transient frequency. Frequency transients shall be contained within the limits of figure 5 for all aircraft operations.

5.1.6.1 Normal electric-system operation. When switching loads from 10 percent up to 85 percent and down to 10 percent of rated system capacity, the frequency transient shall be within limits 5 and 6 of figure 5 (see 3.19). For other normal system operations, including switching loads from 20 percent up to 170 percent and down to 20 percent of rated system capacity, the frequency transient shall be within limits 2 and 3 of figure 5 where the rate of frequency change during the transient shall not exceed 250 cps per second for any period longer than 15 milliseconds. This latter condition exists when the load or group of loads being switched includes motor loads. In addition, excursions from the initial steady-state controlled frequency level shall not exceed 10 cps under conditions of limits 5 and 6, and 30 cps under conditions of limits 2 and 3.

5.1.6.2 Abnormal electric-system operation. Frequency transients as a result of abnormal electric-system operations shall be within limits 1 and 4 of figure 5 where the rate of frequency change during the transient shall not exceed 500 cps per second for any period longer than 15 milliseconds (see 3.20). In addition, excursions from the initial steady-state controlled frequency level shall not exceed 60 cps. The abnormal steady state limits (ASSL) of limits 1 and 4 may continue indefinitely (see 3.21).

5.1.7 Phase sequence. The electric distribution and utilization systems shall have a phase sequence of A, B, C corresponding to $T_1 - T_2 - T_3$ of the power source. Figure 6 diagrams this relationship.

5.2 DC power system characteristics.

5.2.1 Steady-state voltage. The steady-state voltage shall be within the limits specified in table II.

5.2.2 Ripple. The cyclic peak of ripple voltage to the mean level of the dc voltage shall be less than 2.0 volts (see 3.12 and 7.7).

5.2.2.1 Frequency characteristics. The frequency components of the ripple shall be within the limits of figure 7 when measured as conducted interference.

5.2.3 Transient voltage. Transient surge voltages, when converted to their equivalent step functions, shall be within the limits of figures 8, 9, and 10 for all operations of the aircraft electric system. Transient spike voltages shall be within the limits shown on figure 17. They shall not exceed ±600 volts nor depart from the normal wave form for more than 50 microseconds.

5.2.3.1 Normal electric-system operation. When switching loads from 10 percent up to 85 percent and down to 10 percent of rated system capacity, the equivalent step function of the dc voltage transient shall be within limits 5 and 6 of figures 8, 9, and 10 (see 3.19). For other normal system operations including switching loads from 20 percent up to 170 percent and down to 20 percent of rated system capacity, the equivalent step function of the dc voltage transient shall be within limits 2 and 3 of figures 8, 9, and 10. This latter condition exists when the load or group of loads being switched includes motor loads. Limit 3 includes a period of zero voltage which occurs under conditions of bus switching or transfer.

5.2.3.2 Abnormal electric-system operation. The equivalent step functions of the dc voltage transients which result from abnormal electric system operation shall be less than limits 1 and 4 of figures 8, 9, and 10 (see 3.20). The abnormal steady state limits (ASSL) of limits 1 and 4 may continue indefinitely (see 3.21).

6. UTILIZATION OF AIRCRAFT ELECTRIC POWER.

The utilization equipment shall be designed to give its specified performance when utilizing electric power having characteristics whose ranges are described herein. Specified performance is required under all system conditions except the abnormal condition and the zero voltage portion of limit 3 of figures 2, 3, 4, 8, 9, and 10.

6.1 Power types. The utilization equipment specification shall specify which of the types of power listed herein is required. The equipment may require one or both of these types of power. No other types of input power shall be used without written permission from the procuring activity.

6.2 Conversion. Equipment which requires conversion of input power to power with other characteristics shall accept the power as defined herein for modification and use. Modification and use shall be integral with the utilization systems or utilization equipment.

6.2.1 AC to 28 volts dc. Utilization equipment requiring ac input power of 500 va or more and 28 volt dc input power of 5 amperes or less shall obtain the dc power by means of integral static conversion in lieu of requiring aircraft dc power. When it is specifically known that the utilization equipment is designed primarily for use on aircraft having a dc generator system, this requirement for internal conversion shall not apply.

6.3 Normal electric-system operation. During normal operation of the primary electric system (see 5.1.3, 5.1.4.1, 5.1.5(a), 5.1.6.1, 5.2.1, and 5.2.3.1), utilization equipment shall:

(a) Provide 100 percent performance, except when the detail specification for a given utilization equipment defines specific regions of the electric system characteristics with corresponding degrees of performance degradation (see 7.5). No performance of utilization equipment is required during the zero voltage portion of limit 3 of figures 2, 3, 4, 8, 9, and 10.

(b) Remain safe.

(c) When degraded performance has been permitted for given regions of given characteristics, after operation in such regions with return to other regions of normal electric-system operation, the utilization equipment shall:

(1) Automatically recover to 100 percent performance.

(2) Remain unaffected in reliability.

6.4 Abnormal electric-system operation. During abnormal operation of the electric-system (see 5.1.3, 5.1.4.2, 5.1.6.2, 5.2.1, and 5.2.3.2) utilization equipment:

(a) Shall have no performance requirements, unless the detail specification for a given utilization equipment requires specific degrees of performance to be maintained within specific regions of the electric-system characteristics (see 7.5).

(b) Shall remain safe.

(c) May have momentary loss of function; however, this momentary loss shall not affect later equipment performance.

(d) After abnormal operation of the electric system and with return of the electric system to normal operation, utilization equipment shall:

(1) Recover automatically to specified performance, unless the detail specification for a given utilization equipment permits manual reset of equipment after the abnormal electric-system operation.

(2) Have negligible effect on reliability owing to the abnormal electric-system operation.

6.5 Emergency electric system operation. During operation from the emergency electric power source (see 5.1.3, 5.1.3.4, 5.1.5(b), and 5.2.1), if required by the equipment detail specification, utilization equipment shall:

(a) Have 100 percent performance unless the detail specification allows for degraded performance.

(b) Remain safe.

(c) Have specified performance with return to operation from the primary electric power system.

6.6 Other electric-system operation. If the electric system operates in regions of characteristics other than specified in section 5, utilization equipment shall:

(a) Not be required to perform.

(b) Not be required to perform after return of the electric system into the regions of characteristics specified in section 5.

6.7 Voltage transients. For the purpose of testing performance of utilization equipment during conditions of input voltage transients, voltage transients shall be considered as any voltage at its corresponding time on the limits of figures 2, 3, 4, 8, 9, and 10.

6.8 Influence on electric system. There shall be no influence by utilization equipment on the characteristics of power at the input to its terminals which would cause these characteristics to go beyond the limits specified in section 5.

6.8.1 Self-modulation. The modulation induced by varying loads within utilization equipment shall not, at the terminals of the utilization equipment, cause voltage modulation, ripple, or transients to go beyond the specified limits. This self-modulation is caused by variations in the current required by the equipment, in turn causing a varying voltage drop in the wiring of the power circuit to the equipment and a varying load on the power supply system.

6.8.1.1 Voltage spikes. Utilization equipment shall not cause spikes exceeding the limits of figure 17. The peak values of these spikes shall not exceed 600 volts and their departure from the normal wave form shall not exceed 50 microseconds. Voltage spikes occur during transient surge voltages whose step function limits are defined in figures 8, 9, and 10. However, these curves do not describe spike voltages since their values exceed the limits shown on these figures.

6.8.2 Three-phase loads. The phase load and power factor unbalance of three-phase utilization equipment shall not cause the phase displacement and voltage unbalance to go beyond the limits specified in 5.1.3.3 and 5.1.3.4 at the equipment terminals under the worst aircaft line drop conditions.

6.9 AC power.

6.9.1 Three phase. For loads rated less than 500 va, 3-phase power shall be used when practicable. For steady-state ac input demands of 500 va or more, 3-phase power shall be required. The average of three phases steady-state voltage limits in table I are applicable only when a phase of the three phases is not utilized as a single-phase load.

6.9.2 Single phase. For steady-state ac input demands less than 500 va, it is allowable for the equipment to require single-phase power. Equipment which is inherently single-phase in power consumption shall present, if practicable, a 3-phase demand by being internally segregated into three single-phase loads. Single-phase power shall be used only on a line-to-neutral basis.

6.9.3 Phase balance. Equipment requiring three-phase power shall require equal phase volt-amperes and power factor insofar as practicable. The phase volt-ampere difference between the highest and lowest phase values, assuming balanced voltages, shall be less than the limits specified on figure 11.

6.9.4 Power factor. Equipment utilizing ac power shall be designed to present as near a unity power factor as practicable for all modes of equipment operation. The fully loaded equipment shall present a power factor on the worst phase not less than the limits specified on figure 12.

6.9.5 Phase failure. One phase of 3-phase power can fail. Failure of one phase shall not result in an unsafe condition. During failure of the one phase, no equipment performance is required unless specified in the equipment detail specification.

6.10 Power failure. For those equipments which require both ac and dc power, one of these power sources may fail. Failure of one power source shall not result in an unsafe condition. During the loss of the one power source, no equipment performance is required.

6.11 Standby power. For those modes of equipment operation in which performance is not required, but power is required to maintain equipment standby readiness, the standby power requirements should be kept to a minimum.

6.12 Power tolerance. Input power requirements shall not vary by more than ±10 percent of an established limit between production units of a given utilization equipment. The specified tolerance limits do not include changes in equipment power demands as a result of engineering changes made during production.

7. NOTES

7.1 Reference voltage. For the measurement of input power and calibration of utilization equipment, the following reference voltages shall be used:

(a) 115 volts line-to-neutral for the 115/200-volt ac system.

(b) 28 volts line-to-ground for the 28-volt dc system.

7.2 Reference frequency. For the measurement of input power and calibration of utilization equipment, the reference frequency of 400 cps shall be used.

7.3 Conversion of a transient surge voltage to its equivalent step function. An equivalent step function is a reasonable rms value of a transient surge voltage function at the peak rms voltage of the actual transient. The equivalent step function shall be determined as described on figures 13, 14, and 15. Figure 13 shows the method used to convert an overvoltage transient to its equivalent step function and figure 14 shows the conversion of an undervoltage transient. Figure 15 shows an example of an overvoltage transient which exceeds the loci limits of limit 2 of figures 2, 3, and 4. The step functions which terminate at the loci limits of figures 2, 3, 4, 8, 9, and 10 shall be used in transient surge voltage evaluation of utilization equipment.

7.3.1 Conformance of an equivalent step function to their loci limits. Under normal and abnormal electric-system operation, transient surge voltages are produced which may affect the performance of utilization equipment. When the equivalent step function falls within the limits of the applicable loci limit of figures 2, 3, 4, or 8, 9, and 10, the actual transient surge voltage is considered to meet the requirements of this standard. To accomplish this, the following transient surge voltage analysis procedure shall be used:

7.3.1.1 Transient surge voltage analysis procedure.

(a) Record or plot the actual transient surge voltage on rectangular coordinate paper as shown on figures 13, 14, and 15.

(b) Determine the peak rms ($V_p/\sqrt{2}$) voltage of the actual transient surge voltage from item (a).

(c) Determine the time (T_1) to reach the peak voltage from item (a).

(d) Determine the equivalent duration (T_p) of the peak voltage from item (a) as explained on figures 13, 14, and 15.

(e) Locate the applicable step function curve on figures 2, 3, 4, or 8, 9, and 10. To accomplish this the following considerations must be made:

(1) AC or dc system

(2) A, B, or C equipment category

(3) Type of operation causing the transient surge voltage such as fault condition (limits 1 and 4), bus switching (limits 2 and 3), and normal equipment switching (limits 5 and 6).

(f) From the applicable step function curve determine the maximum allowable duration of the equivalent step function voltage which is a voltage equal to the voltage determined in item (b).

(g) From the time obtained in item (f) subtract $T_1/2$. T_1 was determined under item (c).

(h) A transient which meets the following two conditions qualifies to the requirements of this standard:

(1) Item (g) results in positive time.

(2) The time determined under item (d) is less than the time determined under item (g).

7.4 Line drop compensation. Upon specific approval from the procuring activity, the categories "A" and "B" utilization equipment may incorporate means to compensate for line drop. It is preferred that the means consist of taps brought out to the input power connection for selection at time of installation.

7.5 Equipment detail specification. The equipment detail specification may use the checkoff list illustrated on figure 16 to specify considerations applicable to this standard. The notes detail the qualifying aspects for each item.

7.6 Assumptions.

7.6.1 Smallest primary electric system. The smallest primary electric system is 1,500 va ac, 50 amps dc.

7.6.2 Electric-system balance. Balance in the electric system is within 15 percent, i.e., phases are loaded so that the maximum va differential between phases is not more than 15 percent of 1/3 the 3-phase va capacity.

7.6.3 Generating-system characteristics. No generating-system characteristic is considered unless it is usual and normal for the generating system to be tied to the bus at the time the characteristic becomes evident.

7.6.4 Electric-system characteristics. Characteristics covered in this standard are based on the electric power source being:

(a) AC or dc generators driven by:

(1) Constant speed drives (speed control in hydraulic or mechanical torque converter).

(2) Constant speed turbines (speed control on air or gas turbine).

(3) Narrow range, variable speed transmissions (turboprops, helicopter rotors, etc.).

(4) Wide range, variable speed transmissions (piston engines) dc generators in parallel with batteries).

(b) Inverters

(c) Transformer-rectifiers

(d) Batteries

Components of the power system are to meet the requirements of their detail specifications, and the system is to provide the characteristics specified in this standard.

7.6.5 Normal loading. Normal loading of an electric system is b ,ween 15 percent and 85 percent of the power-system capacity.

7.6.6 Initial warmup. Initial warmup (first 5 minutes) is not inclusive with takeoff, climb, cruise-combat, and landing aircraft operations.

7.6.7 System power factor. System power factor is 85 percent lagging.

7.6.8 Crest factor. The crest factor limits specified in this standard assume that the crest factor limits at the terminals of electric power sources do not exceed 1.41 ±0.10 and are degraded to 1.41 ±0.15 by the character of the loads.

7.7 Ripple voltage measurement. The ripple voltage shall be measured with a peak reading vacuum tube voltmeter in series with a 4.0-microfarad capacitor. The higher of the two values measured when the voltmeter is successively connected for each of two polarities shall be considered the ripple voltage.

7.8 Contributing factors that establish the steady-state voltage limits. Tables I and II delineate the normal, abnormal, and emergency voltages which utilization equipment will be exposed to during steady-state operation. The voltage limits are determined by taking into account the generating system bus voltage range; which includes regulation, generator symmetry, and load balance; and voltage drops to the utilization equipment.

7.8.1 Contributing factors to the AC voltage limits. The steady-state ac voltage limits shown in table I are based on the factors shown in the following example:

FACTORS	LIMITS	
	Primary system	Emergency system
Generating system voltage at point of regulation	112 - 118V	108 - 122V
Line drop - cat. "B" util. equipment	-4.0 +0V	-4 +0V
Cat. "B" util. equip., Normal steady-state limits (NSSL)	108 - 118V	
U-V and O-V trip bands	-6.0 +6.0V	
Cat. "B" util. equip., abnormal steady-state limits (ASSL)	102 - 124V	
Cat. "B" util. equip., emergency steady-state limits (ESSL)		104 - 122V

7.8.2 Contributing factors to the dc voltage limits. The steady-state dc voltage limits shown in table II are based on the factors shown in the following example:

FACTORS	LIMITS	
	Primary system	Emergency system
Generating system voltage at point of regulation	26.0 - 28.5V	
Battery voltage		18.0 - 24.0V
Line drop - cat. "B" util. equipment	-2.0 +0V	-2.0 +0V
Cat. "B" util. equip., normal steady-state limits (NSSL)	24.0 - 28.5V	
U-V and O-V trip bands	-1.5 +1.5V	
Cat. "B" util. equip., abnormal steady-state limits (ASSL)	22.5 - 30.0V	
Cat. "B" util. equip., emergency steady-state limits (ESSL)		16.0 - 24.0V

TABLE I. Steady-state ac voltage limits under different modes of electric system operation

EQUIP. CAT.	INDIVIDUAL PHASE			AVERAGE OF THE THREE INDIVIDUAL PHASES		
	NORMAL (NSSL)	ABNORMAL (ASSL)	EMERGENCY (ESSL)	NORMAL (NSSL)	ABNORMAL (ASSL)	EMERGENCY (ESSL)
A	110 - 118	104 - 124	106 - 122	111.5 - 116.5	105.5 - 122.5	108 - 120
B	108 - 118	102 - 124	104 - 122	109.5 - 116.5	103.5 - 122.5	106 - 120
C	104 - 118	98 - 124	100 - 122	105.5 - 116.5	99.5 - 122.5	102 - 120

TABLE II. Steady-state dc voltage limits under different modes of electric system operation

EQUIP. CAT.	NORMAL (NSSL)	ABNORMAL (ASSL)	EMERGENCY BATTERY ONLY (ESSL)	ENGINE START	LANDING
A	25 - 28.5	23.5 - 30	17 - 24	17 - 28.5	21 - 28.5
B	24 - 28.5	22.5 - 30	16 - 24	16 - 28.5	20 - 28.5
C	23 - 28.5	21.5 - 30	15 - 24	15 - 28.5	19 - 28.5

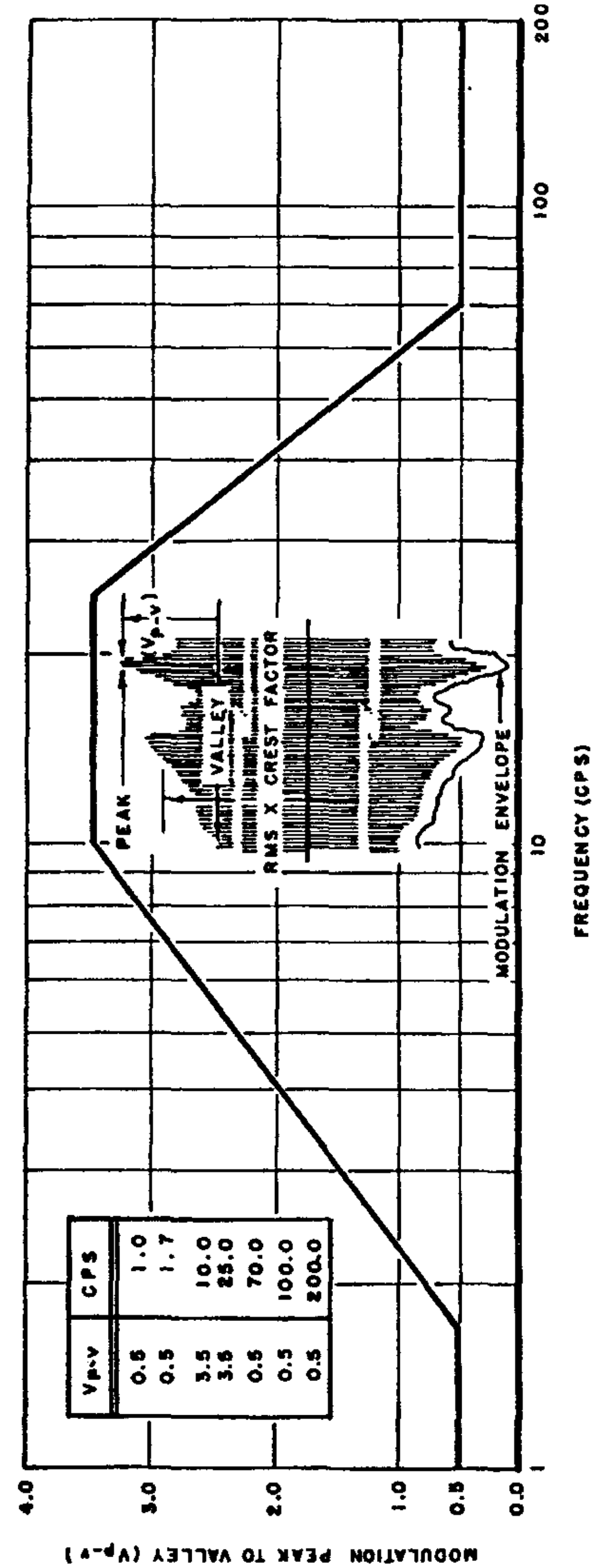


FIGURE 1. Frequency characteristics of ac voltage modulation envelope

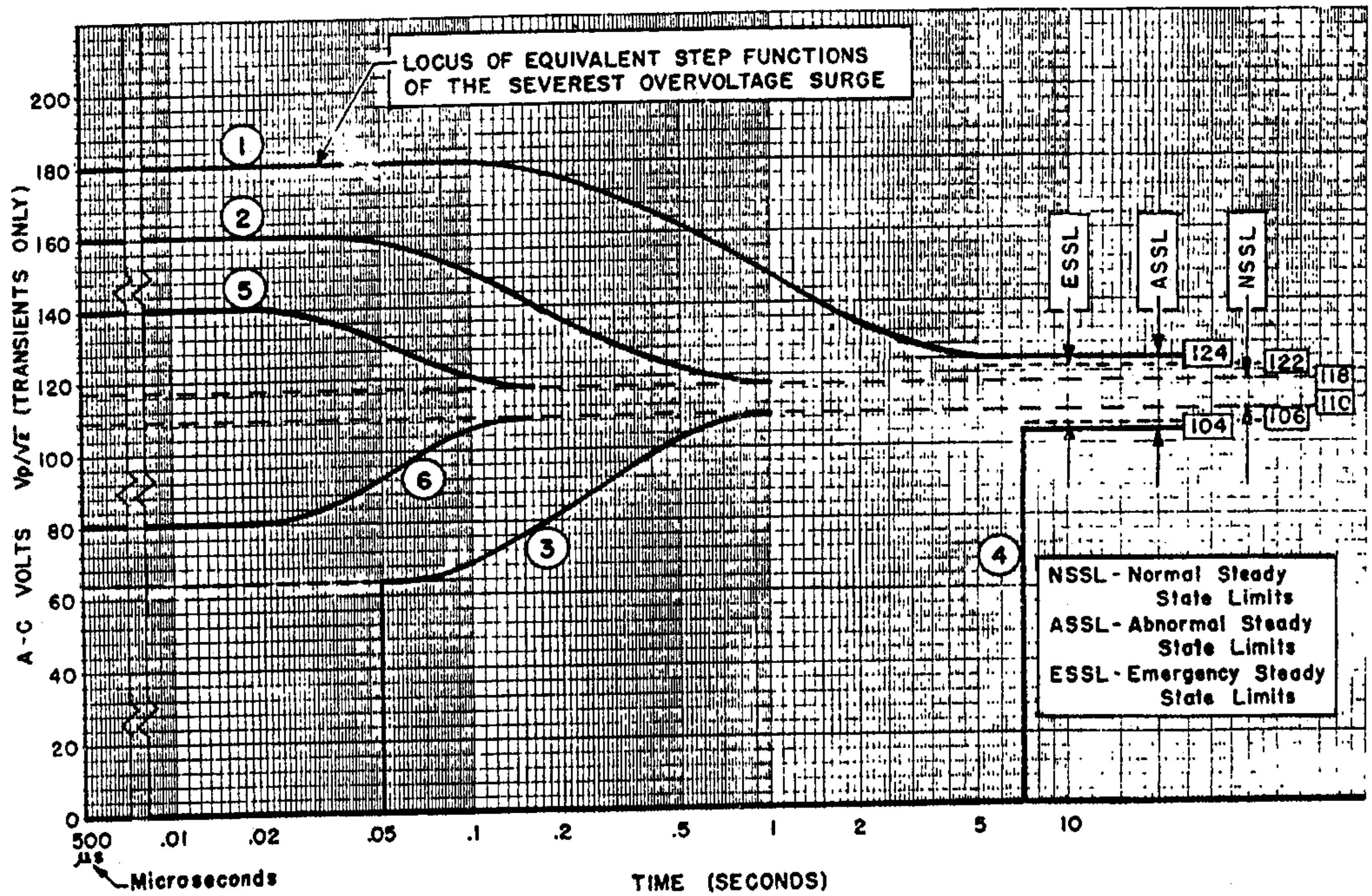


FIGURE 2a. Transient surge ac voltage step function loci limits for category A equipment

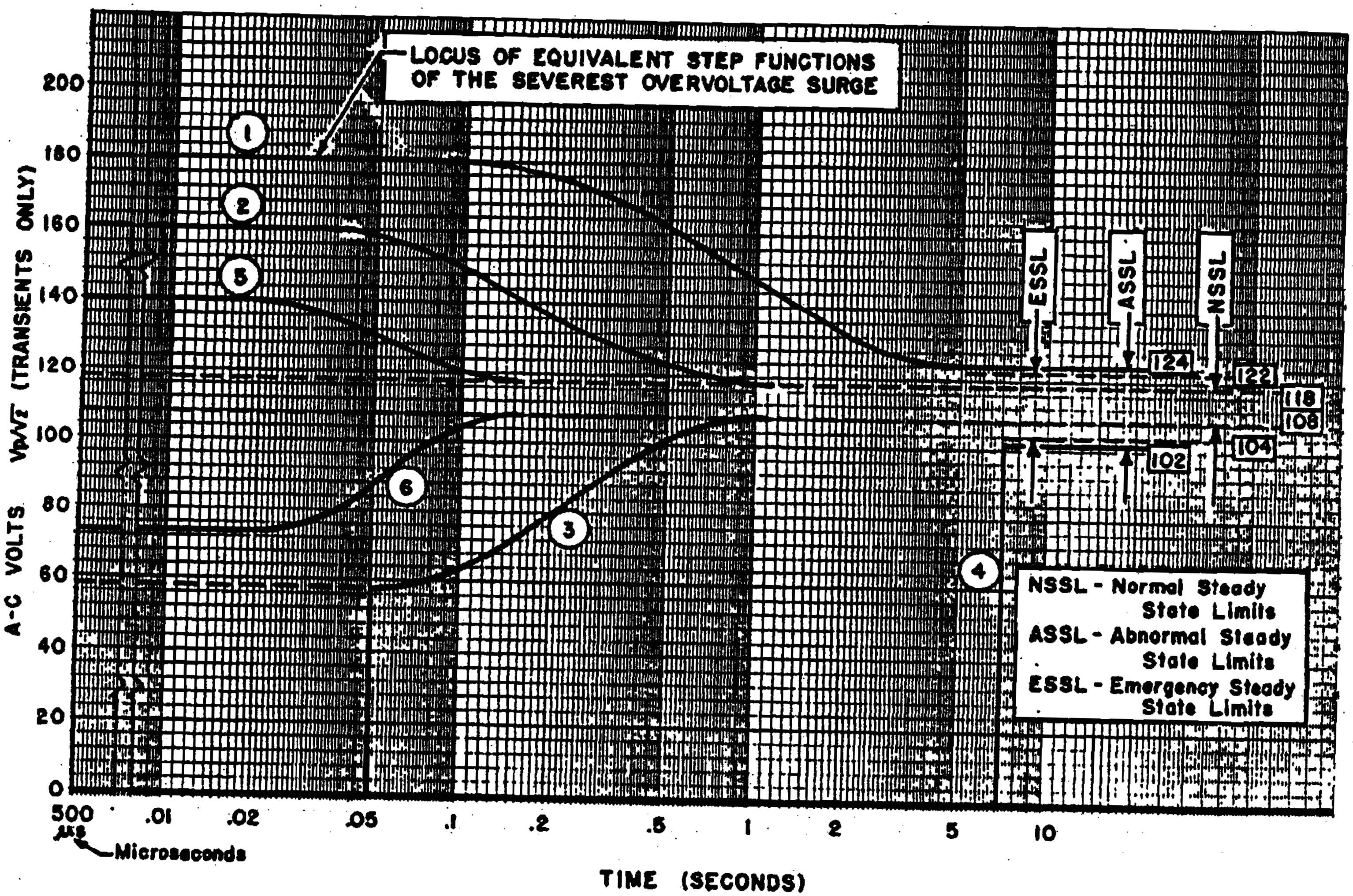


FIGURE 3. Transient surge ac voltage step function loci limits for category B equipment

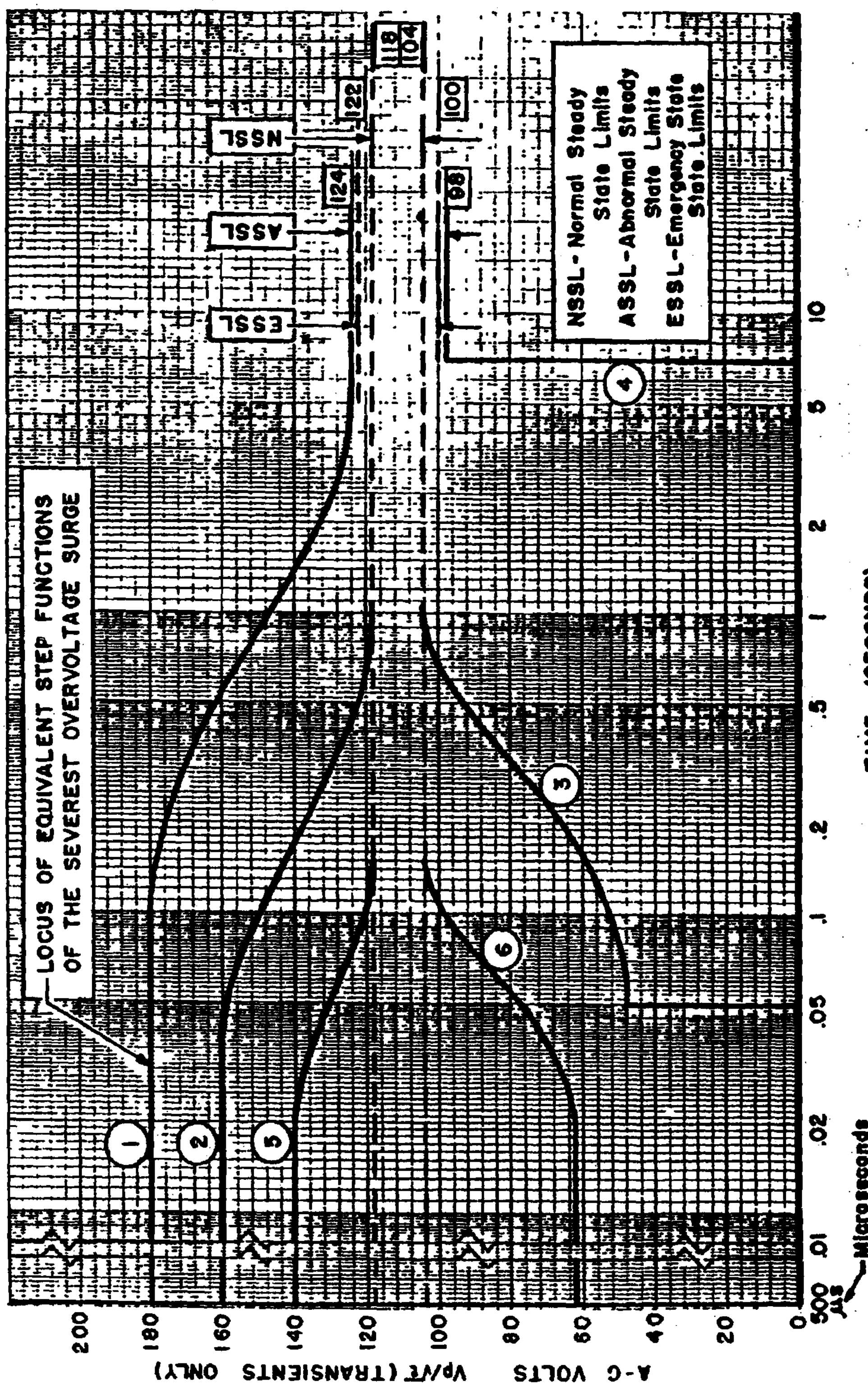


FIGURE 4. Transient surge ac voltage step function load limits for category C equipment

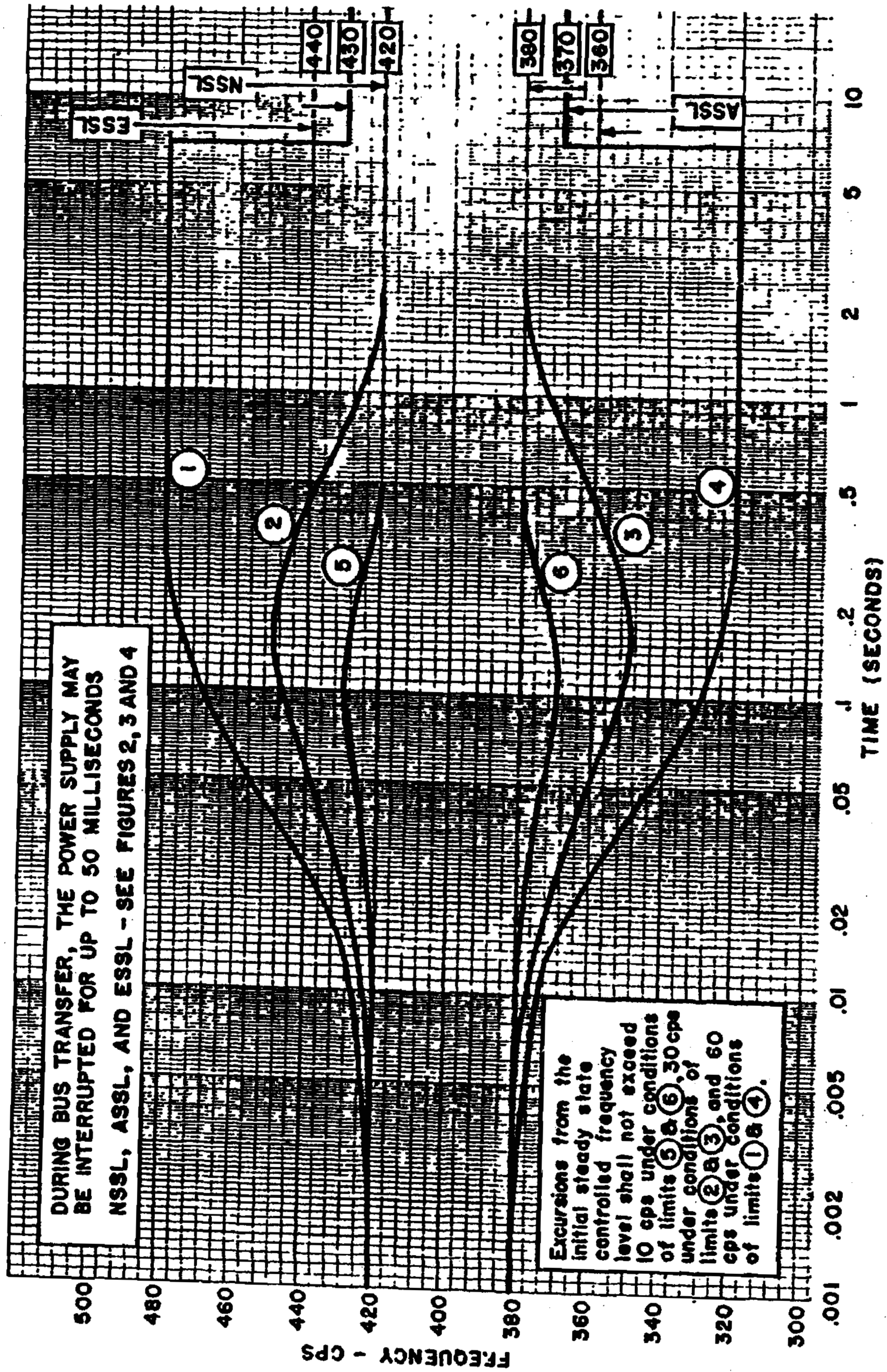


FIGURE 3. Transient frequency limits

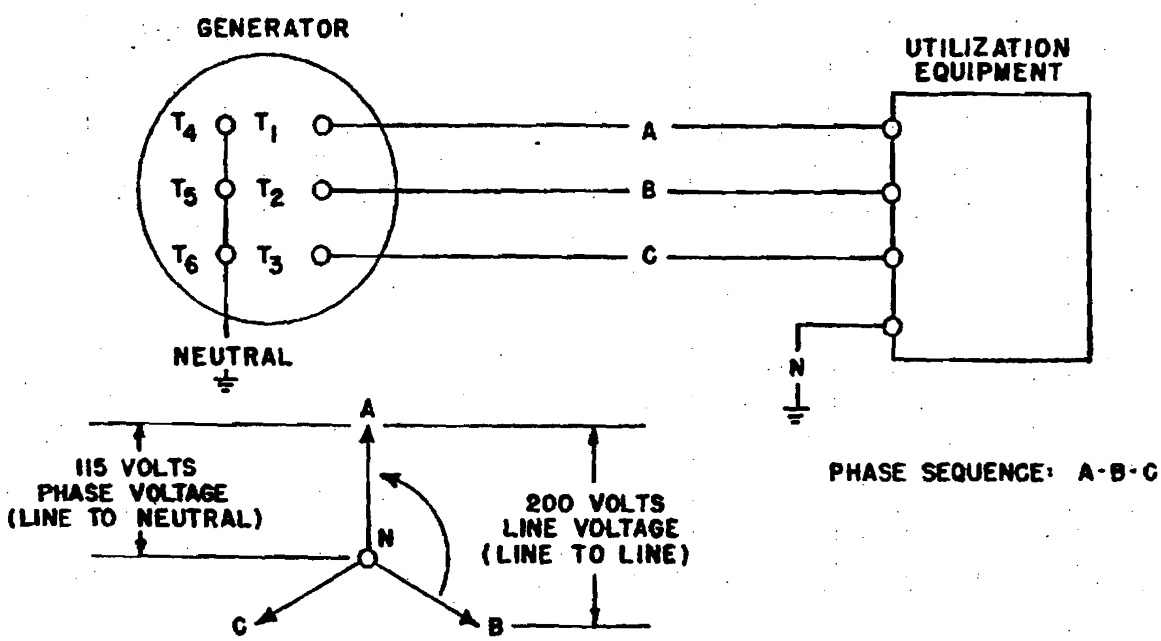
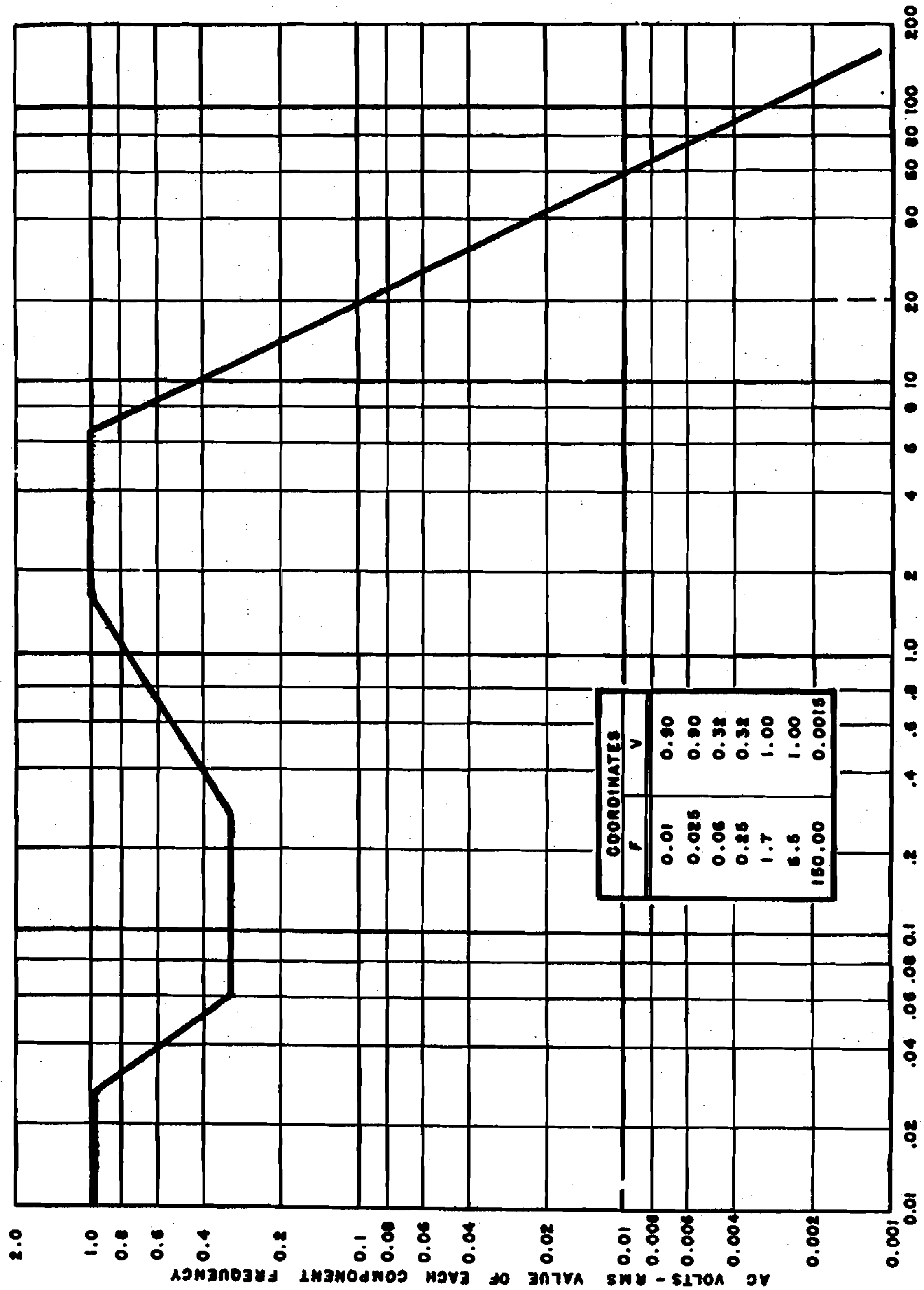


FIGURE 6. Diagram of phase sequence and line designations



COORDINATES	
F	V
0.01	0.90
0.025	0.90
0.06	0.32
0.25	0.32
1.7	1.00
6.5	1.00
150.00	0.0015

FIGURE 7. Frequency characteristics of ripple in 28 volt dc electric systems

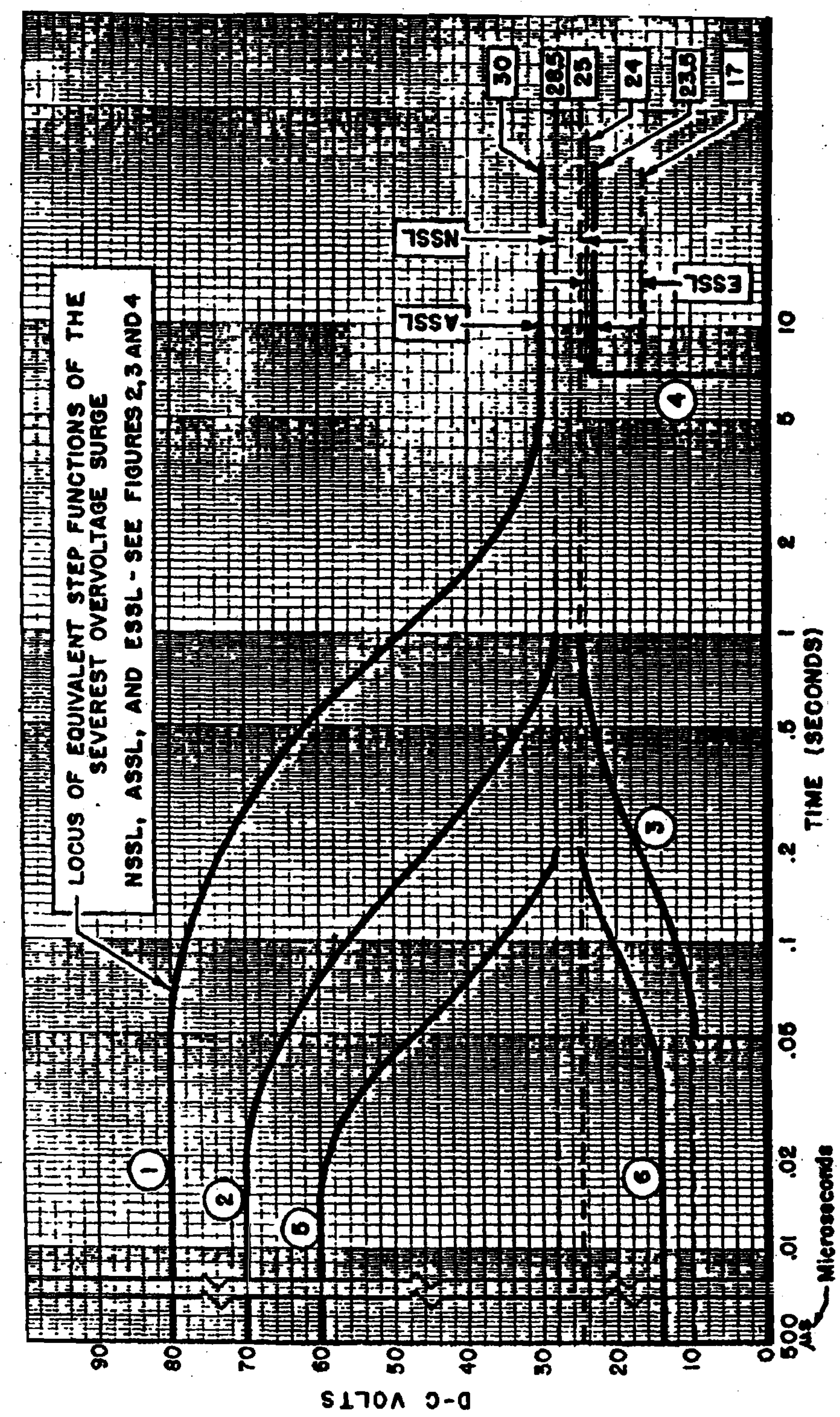


FIGURE 8. Transient surge dc voltage step function load limits for category A equipment

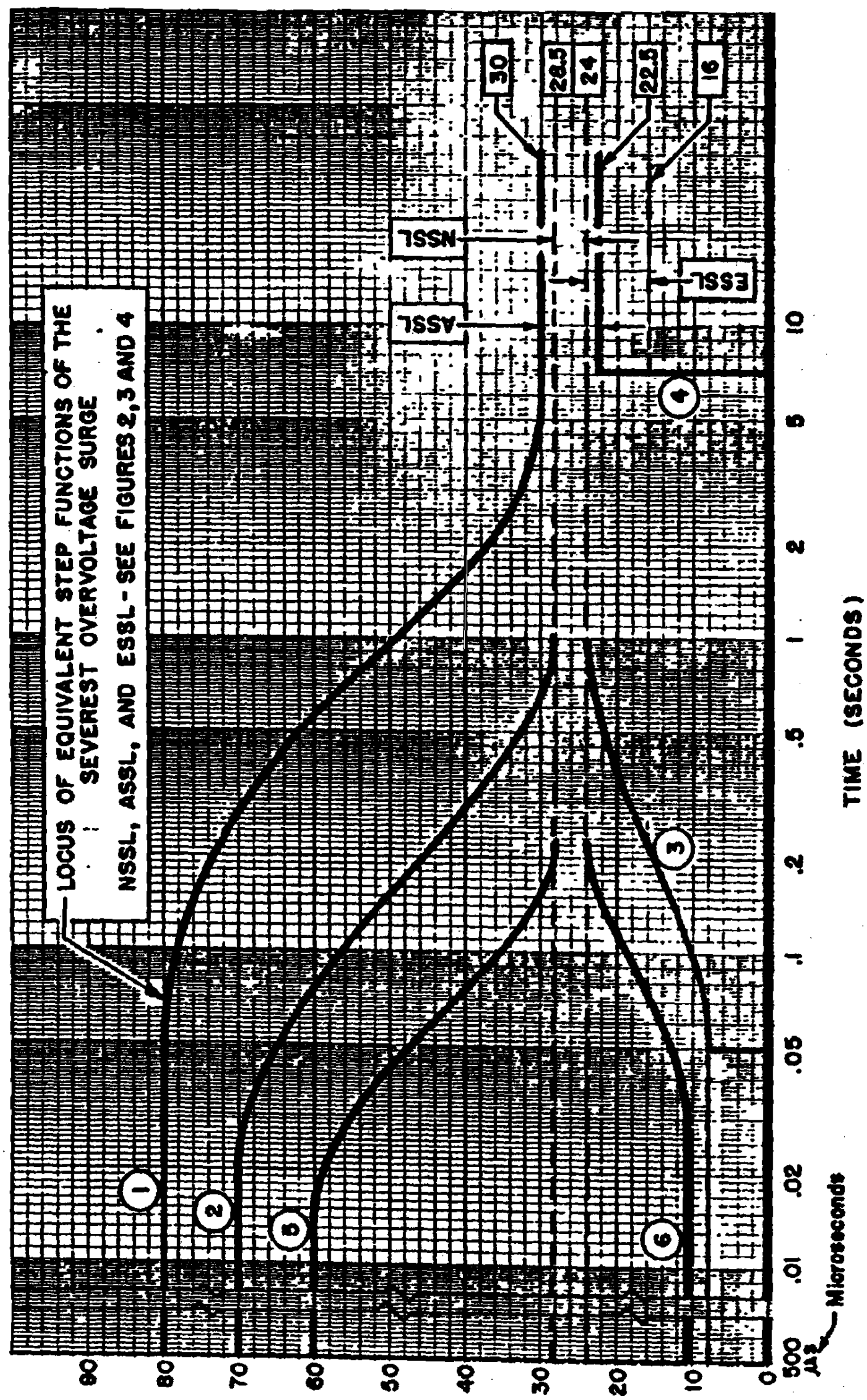


FIGURE 9. Transient surge dc voltage step function loci limits for category B equipment

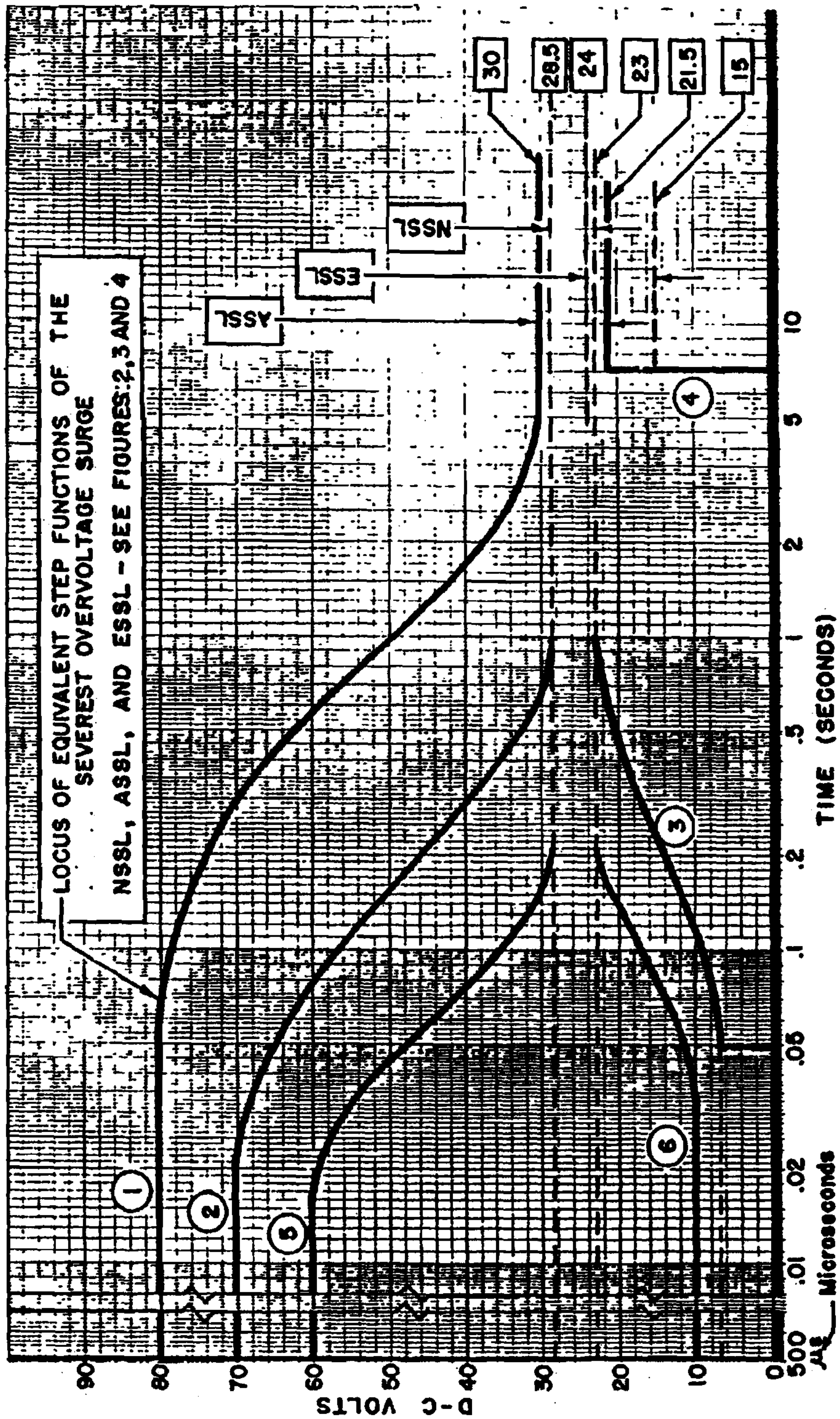
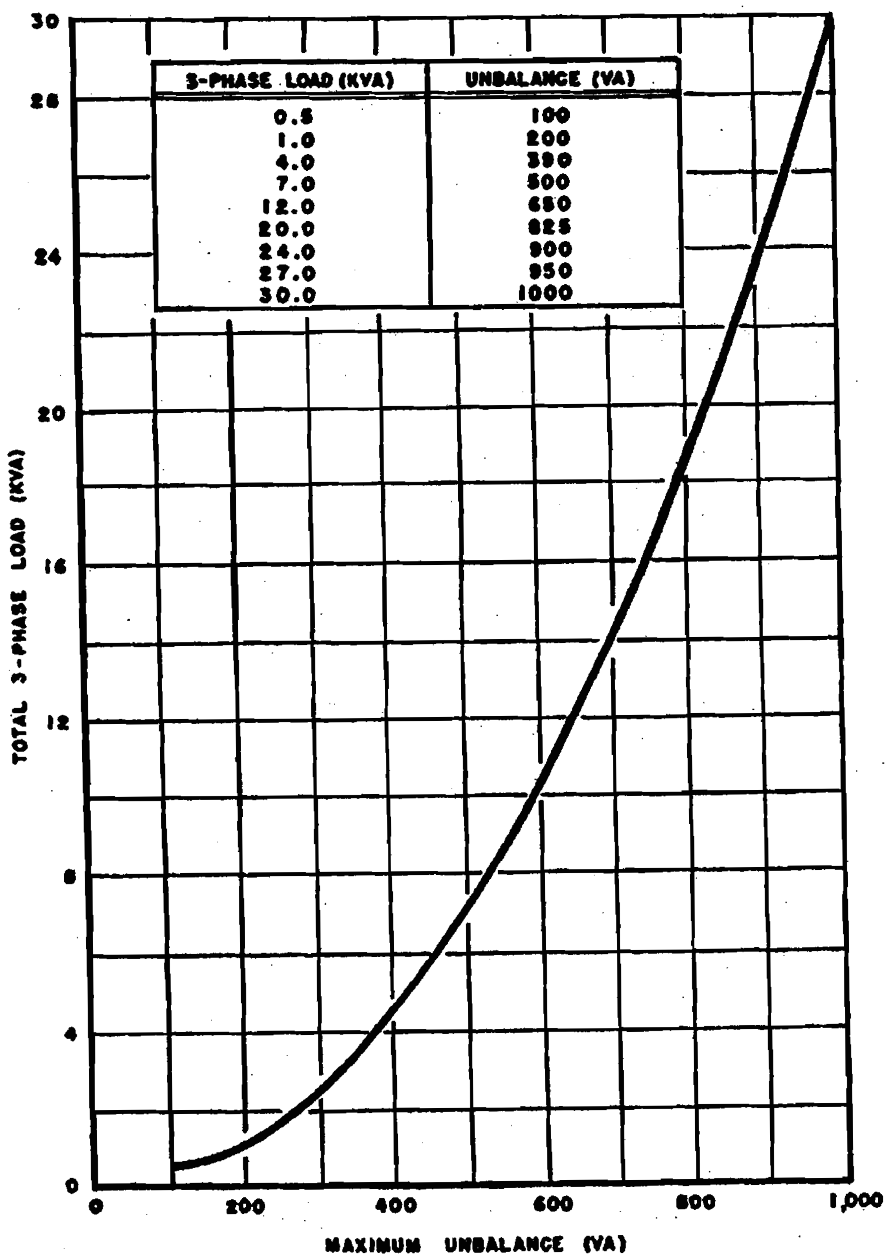


FIGURE 10. Transient surge dc voltage step function loci limits for category C equipment



3-PHASE LOAD (KVA)	UNBALANCE (VA)
0.5	100
1.0	200
4.0	390
7.0	500
12.0	650
20.0	825
24.0	900
27.0	950
30.0	1000

FIGURE 11. Unbalance limits for 3-phase utilization equipment

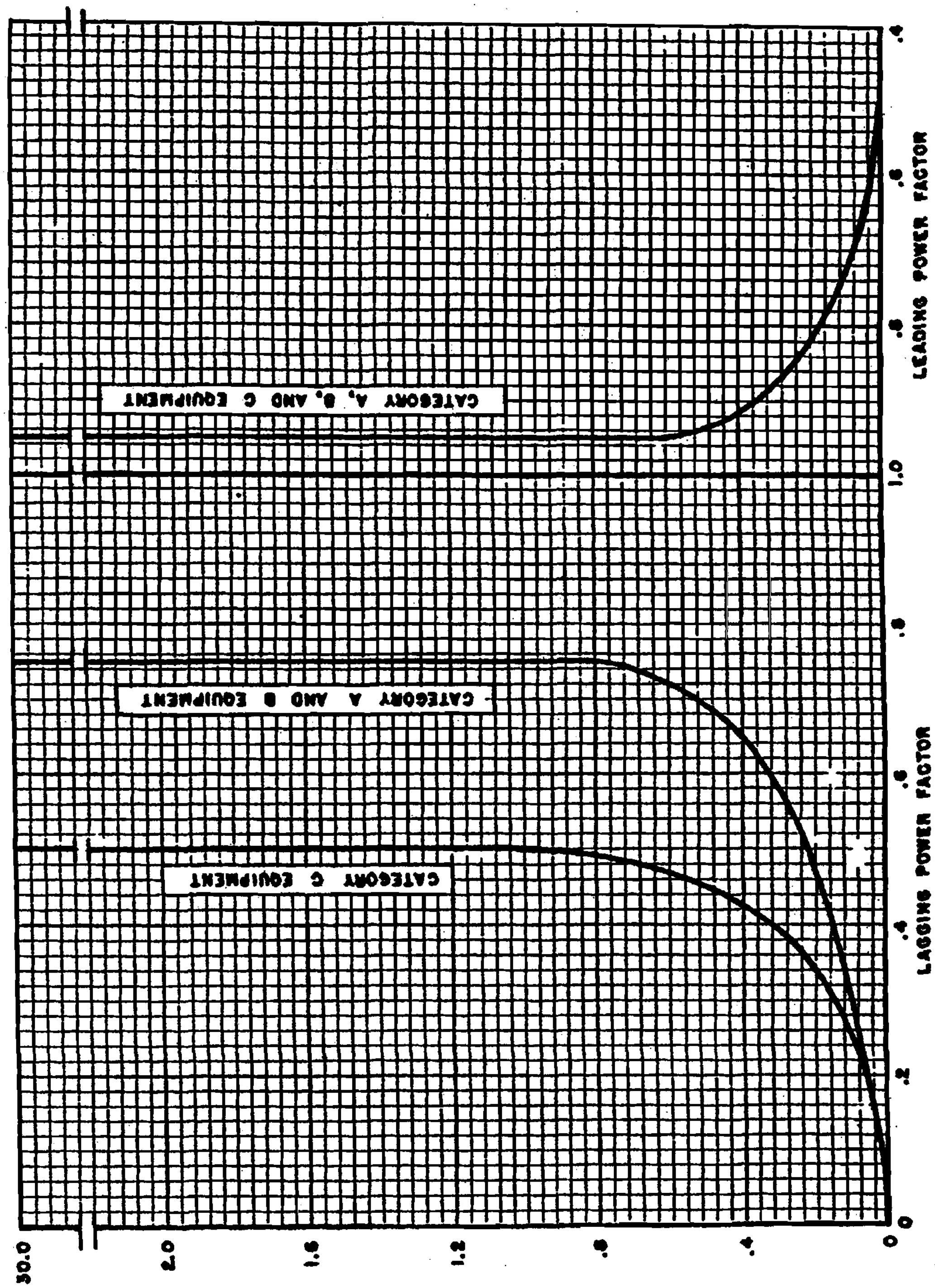
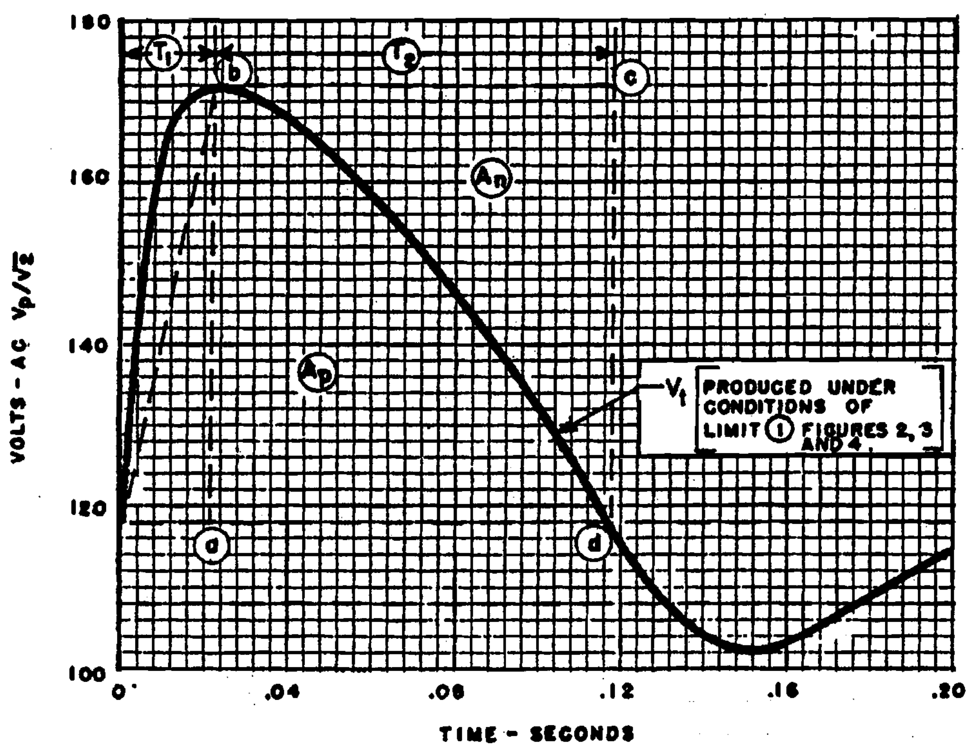


FIGURE 12. Power factor limits for utilization equipment



CONVERSION IS BASED ON EXCESS VOLT-SECONDS OVER THE NORMAL VOLT-SECOND INPUT

V_t = VOLTAGE TRANSIENT SURGE

T_1 = TIME TO REACH PEAK VOLTAGE

T_2 = POST-PEAK TRANSIENT TIME

A_p = AREA WITHIN abda

A_n = AREA WITHIN bcdb

T_p = EQUIVALENT DURATION OF THE PEAK VOLTAGE

T_s = DURATION OF THE STEP FUNCTION AT THE PEAK VOLTAGE

T_1 = 0.022 SECOND

T_2 = 0.118 − 0.022 = 0.096 SECOND

$A_p + A_n$ = 648 SQUARES

A_n = 259 SQUARES

A_p = 648 − 259 = 389 SQUARES

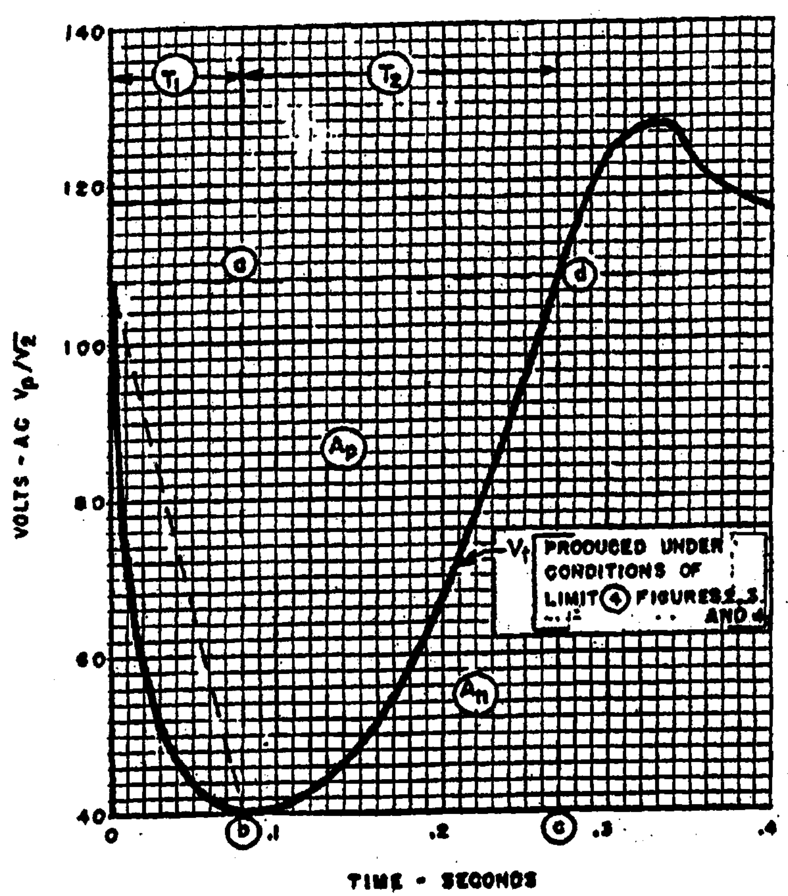
$$T_s = \frac{T_1}{2} + T_p = \frac{T_1}{2} + T_2 \frac{A_p}{A_p + A_n}$$

$$= \frac{.022}{2} + .096 \frac{389}{648}$$

$$= .011 + .096\,(.60)$$

$$= .011 + .0575 = 0.0685 \text{ SECOND}$$

FIGURE 13. Conversion of an overvoltage transient surge to its equivalent step function



CONVERSION IS BASED ON DEFICIT VOLT-SECONDS UNDER THE NORMAL VOLT-SECOND INPUT

V_t = VOLTAGE TRANSIENT SURGE
T_1 = TIME TO REACH PEAK VOLTAGE
T_2 = POST-PEAK TRANSIENT TIME
A_p = AREA WITHIN abdc
A_n = AREA WITHIN bcdb
T_p = EQUIVALENT DURATION OF THE PEAK VOLTAGE
T_s = DURATION OF THE STEP FUNCTION AT THE PEAK VOLTAGE

T_1 = 0.08 SECOND
T_2 = 0.27 − 0.08 = 0.19 SECOND
$A_p + A_n$ = 646 SQUARES
A_n = 218 SQUARES
A_p = 646 − 218 = 428 SQUARES

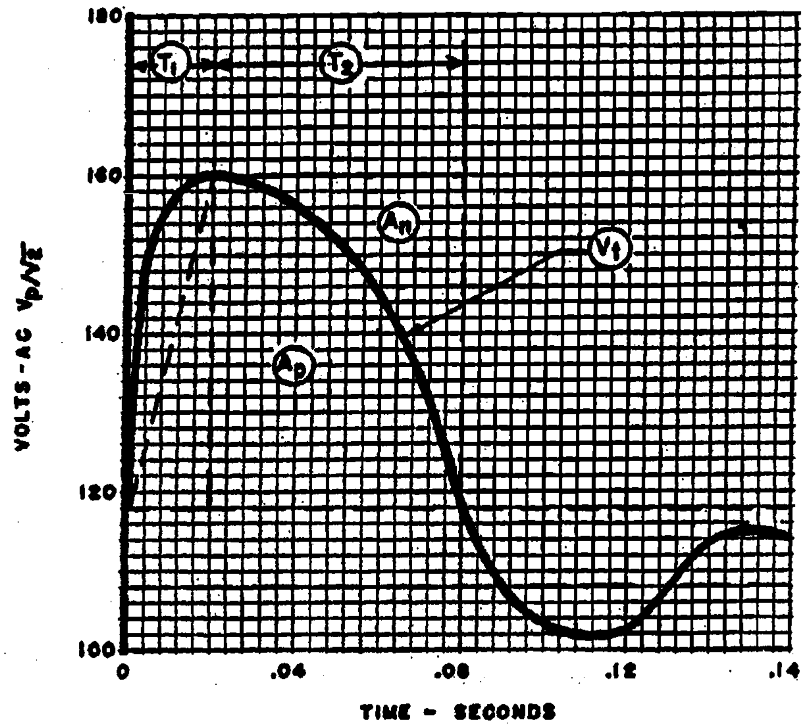
$$T_s = \frac{T_1}{2} + T_p = \frac{T_1}{2} + T_2 \frac{A_p}{A_p + A_n}$$

$$= \frac{.08}{2} + .19 \frac{428}{646}$$

$$= .04 + .19(.663)$$

$$= .04 + .126 = 0.166 \text{ SECOND}$$

FIGURE 14. Conversion of an undervoltage transient surge to its equivalent step function



NOTE: SEE FIGURE 13. FOR THE DEFINITION OF THE SYMBOLS.

V_t = VOLTAGE TRANSIENT SURGE PRODUCED UNDER CONDITIONS OF LIMIT (2) OF FIGURES 2, 3 AND 4.

THIS TRANSIENT HAD A PEAK RMS VOLTAGE OF 160 VOLTS AC; IT REACHED THIS PEAK VOLTAGE IN 0.02 SECONDS, AND ENTERED THE STEADY STATE LIMITS IN 0.08 SECONDS.

T_1 = 0.02 SECOND

T_2 = 0.08 - 0.02 = 0.06 SECOND

$A_p + A_n$ = 315 SQUARES

A_n = 88.5 SQUARES

A_p = 315 - 88.5 = 226.5 SQUARES

$$T_p = T_2 \frac{A_p}{A_p + A_n} = .06 \frac{226.5}{315}$$

$$= .06\,(.72) = .0431 \text{ SECOND}$$

THIS IS THE EQUIVALENT DURATION OF THE PEAK VOLTAGE. WHEN THIS TIME IS ADDED TO $T_1/2$, THE DURATION OF THE EQUIVALENT STEP FUNCTION RESULTS.

THE EQUIVALENT STEP FUNCTION FOR THIS TRANSIENT IS 160 VOLTS FOR ($T_s = \frac{.02}{2} + .0431$) 0.0531 SECONDS. THE LIMIT IS 0.040 SECONDS FOR 160 VOLTS AS LIMIT (2) OF FIGURES 2, 3 AND 4 SHOWS. THEREFORE, THE TRANSIENT IS OUTSIDE THE LIMITS OF THIS STANDARD.

FIGURE 15. An example of an overvoltage transient surge which exceeds the limits of figures 2, 3, and 4

ITEM	NO	YES	NOTE
1. MIL-STD-704 POWER REQUIRED (AC)			
2. MIL-STD-704 POWER REQUIRED (DC)			
3. OTHER TYPE POWER REQUIRED			
4. CATEGORY "A" EQUIPMENT			
5. CATEGORY "B" EQUIPMENT			
6. CATEGORY "C" EQUIPMENT			
7. DURING NORMAL OPERATION, REGIONS AND DEGREES OF DEGRADED PERFORMANCE ARE PERMITTED			
8. DURING ABNORMAL OPERATION, REGIONS AND DEGREES OF PERFORMANCE ARE REQUIRED			
9. MANUAL RESET IS PERMITTED AFTER ABNORMAL OPERATION			
10. FULL EQUIPMENT PERFORMANCE IS REQUIRED FOR THE FOLLOWING AIRCRAFT OPERATING CONDITIONS:			
START AND WARMUP			
TAKEOFF AND CLIMB			
CRUISE AND CRUISE-COMBAT			
LANDING			
EMERGENCY			
11. EQUIPMENT PERFORMANCE IS REQUIRED WITH LOSS OF POWER FROM ONE PHASE			
12.			

NOTES:

FIGURE 16. Standard MIL-STD-704 power utilization checklist

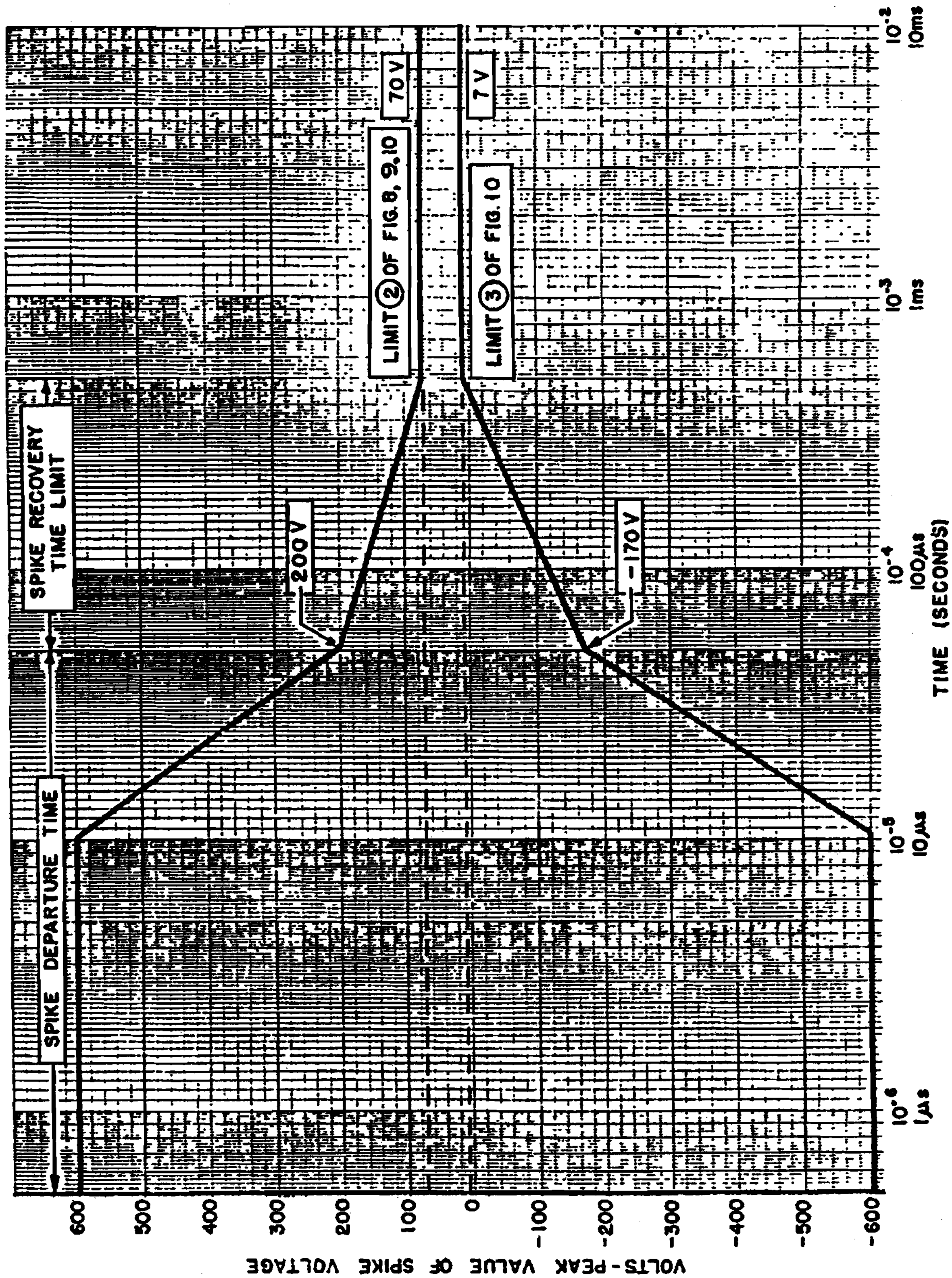


FIGURE 17. Envelope of spike voltages for dc equipment

8. International standardization agreement. Certain provisions of this standard are the subject of international standardization agreements ASCC Air Standard 12/10, STANAG No. 3456. When amendment, revision, or cancellation of this standard is proposed, the departmental custodians will inform their respective Departmental Standardisation Offices so that appropriate action may be taken respecting the international agreement concerned.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

Custodians:
Army - MO
Navy - AS
Air Force - 11

Reviewer activities:
Army - MO
Navy - AS
Air Force - 11

International interest (see 8)

Preparing activity:
Navy - AS

Project No. MISC-0232