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Electric Power, Aircraft, Characteristics and Utilization of

RATIONALE

This document has been superseded by DO-160G and MIL-STD-704F requirements used in conjunction with newer standards.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE AE-7C Systems Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. GENERAL

1.1 Scope: The 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 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 utilization restrictions and requirements stated in section 6 and 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 neutral of the ac in the power generation and power utilization systems.

3.3 Transients: A transient is the short term changing condition of a characteristic beyond the steady-state limits, returning 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. Transients so generated usually consist of a train of spikes.

3.4 Total harmonic content: The total harmonic content of a complex wave is the total rms value 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. It is frequently nonsinusoidal.

3.6 Frequency modulation repetition rate: The frequency modulation repetition rate is the reciprocal of the period of the modulation waveform.

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 to utilization equipment, a phase being considered the line-to-neutral circuit at the equipment terminals. All ac voltage values are rms values, unless otherwise stated herein.

3.10 Voltage modulation: Voltage modulation is the cyclic variation or random variation, 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 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 subject 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” utilization 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 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 ground operation, 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 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 as a result of 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(s) of emergency power for essential utilization equipments.

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 sum of the individual power source ratings with a paralleling factor applied.

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

3.25 Equivalent step function: An equivalent step function is a mathematical function which is used in this standard to evaluate actual surges found to exist in power systems (see 7.3) and to provide a definitive basis for comparison of those surges with the requirements of this standard.

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 wye-connected system, having a nominal voltage of 115/200 Volts and a nominal frequency of 400 Hertz (Hz). 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 performance specified in section 6 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.

5. DETAIL REQUIREMENTS, AIRCRAFT ELECTRIC POWER SYSTEM CHARACTERISTICS

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 displacement: The displacement between any adjacent phases shall be within the limits of 120 deg ±2 degrees. 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: For normal electric system operation the 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 ± 0.10 (see 7.6.7)

(b) Total harmonic content: 5% of the fundamental (rms) when measured with a distortion meter as distortion of the fundamental frequency

(c) Individual harmonic content: 4% of the fundamental (rms) when measured with a harmonic analyzer

5.1.3.6 Voltage modulation:

5.1.3.6.1 Magnitude: The modulation of voltage under conditions of steady state loading and frequency modulation (see 5.1.5.2) 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).

5.1.3.6.2 Frequency characteristics: The frequency components of the voltage modulation envelope wave form shall not exceed the limits specified on Fig. 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 Fig. 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 Fig. 2, 3, and 4. Transient spikes shall be controlled such that the stress levels shall not exceed the limits defined by Fig. 18 and paragraph 7.6.8.

5.1.4.1 Normal electric-system operation: When switching loads from 10% up to 85% and down to 10% of rated system capacity, the equivalent stop function of the ac voltage transient surge shall be within limits 5 and 6 of Fig. 2, 3, and 4. For other normal system operations including switching loads from 20% up to 170% and down to 20% of rated system capacity, the equivalent step function of the ac voltage transient surge shall be within limits 2 and 3 of Fig. 2, 3, and 4 (see 3.19). This latter inrush condition exists when the load or group of loads being switched includes motor loads.

5.1.4.1.1 Bus switching: Under conditions of bus transfer, switching or synchronization, the interruption of the ac supply shall not exceed 50 milliseconds, during which time the voltage may be any value between zero and the applicable steady state limits. Upon completion of the interruption the equivalent step function of the voltage transient shall be within limits 2 and 3 of Fig. 2, 3 and 4.

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 within limits 1 and 4 of Fig. 2, 3 and 4 (see 3.20). The abnormal steady-state limits (ASSL) of limits 1 and 4 may continue for the duration of the flight (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 Hz for normal steady-state operation.

(b) Emergency power sources - The voltage shall be maintained within the limits of Table I at frequencies between 360 to 440 Hz. Below 360 Hz the frequency/voltage (F/V) ratio shall not fall below 2.9.

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 Hz 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 Hz per minute (see 3.8).

5.1.5.2 Frequency modulation: Variations of primary system frequency due to frequency modulation during any 1 minute period shall be within a band about the mean frequency defined by Fig. 19.

5.1.6 Frequency transient: Frequency transients shall be within the limits of Fig. 5 for all operations of the aircraft electric system.

5.1.6.1 Normal electric-system operation: When switching loads from 10% up to 85% and down to 10% of rated system capacity, the frequency transient shall be within limits 5 and 6 of Fig. 5 (see 3.19). For other normal system operations, including switching loads from 20% up to 170% and down to 20% of rated system capacity, the frequency transient shall be within limits 2 and 3 of Fig. 5.

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 Fig. 5 (see 3.20). The ASSL of limits 1 and 4 may continue for the duration of the flight (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. Fig. 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.

5.2.1.1 Engine start: Aircraft employing dc electric engine starters normally experience low dc system voltages during the starting cycle. Equipment which is required to operate or be left switched on during this period shall be so identified by the detailed specification which shall also define the applicable power supply voltage levels.

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 Fig. 7.

5.2.3 Transient voltage: Transient surge voltages, when converted to their equivalent step functions, shall be within the limits of Fig. 8, 9, and 10 for all operations of the aircraft electric system. Transient spikes shall be controlled such that the stress levels shall not exceed the limits defined by Fig. 17 and paragraph 7.6.8.

5.2.3.1 Normal electric-system operation: For normal system operations including switching loads from 20% up to 170% and down to 20% of rated system capacity, the equivalent step function of the dc voltage transient surge shall be within limits 2 and 3 of Fig. 8, 9, and 10. This inrush condition exists when the load or group of loads being switched includes motor loads.

5.2.3.1.1 Bus switching: Under conditions of bus transfer, switching and synchronization, the interruption of the dc supply shall not exceed 50 milliseconds, during which time the voltage may be any value between zero and the applicable steady state limits. Upon completion of the interruption, the equivalent stop function of the dc voltage transient shall be within limits 2 and 3 of Fig. 8, 9 and 10.

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 within limits 1 and 4 of Fig. 8. 9 and 10 (see 3.20). The abnormal steady state limits (ASSL) of limits 1 and 4 may continue for the duration of the flight (see 3.21).

6. DETAILED REQUIREMENTS, UTILIZATION OF AIRCRAFT ELECTRIC POWER

The utilization equipment shall function as specified 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 voltage supply interruption associated with bus switching (see 6.3 (a)).

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. Equipment using both ac and dc power shall give specified performance when subjected to simultaneous ac and dc power variations defined in section 5.

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 dc input of 5 amperes or less may obtain the dc power by means of integral static conversion in lieu of requiring aircraft dc power.

6.3 Normal electric-system operation: During the transient and steady-state conditions associated with 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:

(a) Shall provide 100% 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 voltage supply interruption associated with bus switching (see 5.1.4.1.1 and 5.2.3.1.1) except as defined by the detailed equipment specification.

(b) Shall remain safe.

(c) Shall, 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:

(1) Automatically recover to 1O0% performance.

(2) Remain unaffected in reliability.

6.4 Abnormal electric-system operation: During the transient and steady state conditions associated with 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) Shall, after abnormal operation of the electric system and with return of the electric system to normal operation:

(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 the transient and steady-state conditions associated with operation from the emergency electric power source (see 5.1.3, 5.1.3.4, 5.1.4,5.1.5(b), 5.1.6, 5.2.1, and 5.2.3), if required by the equipment detail specification, utilization equipment:

(a) Shall have 100% performance or the specified degraded performance.

(b) Shall remain safe.

(c) Shall 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 as specified in section 5, utilization equipment:

(a) Shall not be required to perform.

(b) Shall 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, a voltage transient shall be considered as a rectangular pulse of the appropriate voltage persisting for its corresponding duration as defined by the limits of Fig. 2, 3, 4, 8, 9, 10, 17, and 18. (See para 7.6.8.) For 3-phase ac utilization equipment, the transient shall be applied to all phases simultaneously.

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 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: Transient voltage spikes generated by utilization equipment shall not exceed the stress level limits defined by Fig. 17 and 18 and paragraph 7.6.8.

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 aircraft 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.

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 load 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 Fig. 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 within the limits specified on Fig. 12.

6.9.5 Phase failure: One or more phases of the 3-phase power can fail. Loss of one or more phases shall not result in an unsafe condition. During failure of the one or more phases, 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, unless specified in the equipment detail specification.

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% 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.

6.13 Power requirements data: Power requirements data, when required, shall be to the format of Fig. 20.

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 Hz 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 Fig. 13, 14, and 15. Fig. 13 shows the method used to convert an overvoltage transient to its equivalent step function and Fig. 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 Fig. 2, 3, and 4.

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 Fig. 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 Fig. 13, 14, and 15.

(b) Determine the peak dc voltage or the peak rms ($V_P / \sqrt{2}$) ac 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 Fig. 13, 14, and 15.

(e) Locate the applicable step function curve on Fig. 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, and

(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 checklist: The equipment detail specification may use the checkoff list illustrated on Fig. 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% i.e., phases are loaded so that the maximum va differential between phases is not more than 15% 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 convertor)

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

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

(b) DC generators driven by:

(1) Wide range, variable speed transmissions (piston engines).

(c) Inverters

(d) Transformer-rectifiers

(e) Batteries

(f) AC generators driven by:

(1) Wide range variable speed prime mover (Turbo Jet Engine, etc.) and utilizing a frequency changer in the power system.

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 between 15% and 85% of the power-system capacity.

7.6.6 System power factor: System power factor is a minimum of 80% lagging.

7.6.7 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 ± 0.05 and are degraded to 1.41 ± 0.10 by the character of the loads.

7.6.8 Transient spike voltage conditions:

7.6.8.1 Source impedance: Where the values for the source impedance for transient spike voltages are not defined by the detailed specification or other reference specification, it shall be 50 ohms maximum for significant frequency components of the transient.

7.6.8.2 Load impedance: Where the value for the load impedance into which the utilization equipment generates transients is not defined by the detailed specification or other reference specification, it shall be 50 ohms minimum for significant frequency components of the transient.

Paragraphs 7.6.8.1 and 7.6.8.2 do not apply to impedances at power frequencies.

7.6.8.3 Figures 17 and 18 are not intended to represent actual spikes, but rather to define stress levels for purpose of design and/or test.

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. (Also, the limits are influenced by the abnormal voltage protection devices and the trip level variation of these devices over environmental extremes).

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

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	18.0 - 30.0V
Emergency source voltage		-2.0 - +0V
Line drop - cat. “B” util. equipment	-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 - 30.0V

7.9 Higher than reference voltages: Where it is desired to generate and to use power of higher voltages than the standard voltages defined herein, these higher voltages should be chosen as nominal 230/ 400 volts ac or nominal 112/224, or 140/280 volts dc.

7.10 Helicopter applications: In helicopter applications special problems may exist with frequency modulation, frequency transients and harmonic distortion. The airframe manufacturer should be consulted on design problems of utilization equipment.

PREPARED BY

704 AD HOC SUBCOMMITTEE OF SAE COMMITTEE A-2,
AEROSPACE ELECTRICAL AND ELECTRONIC EQUIPMENT

TABLE I

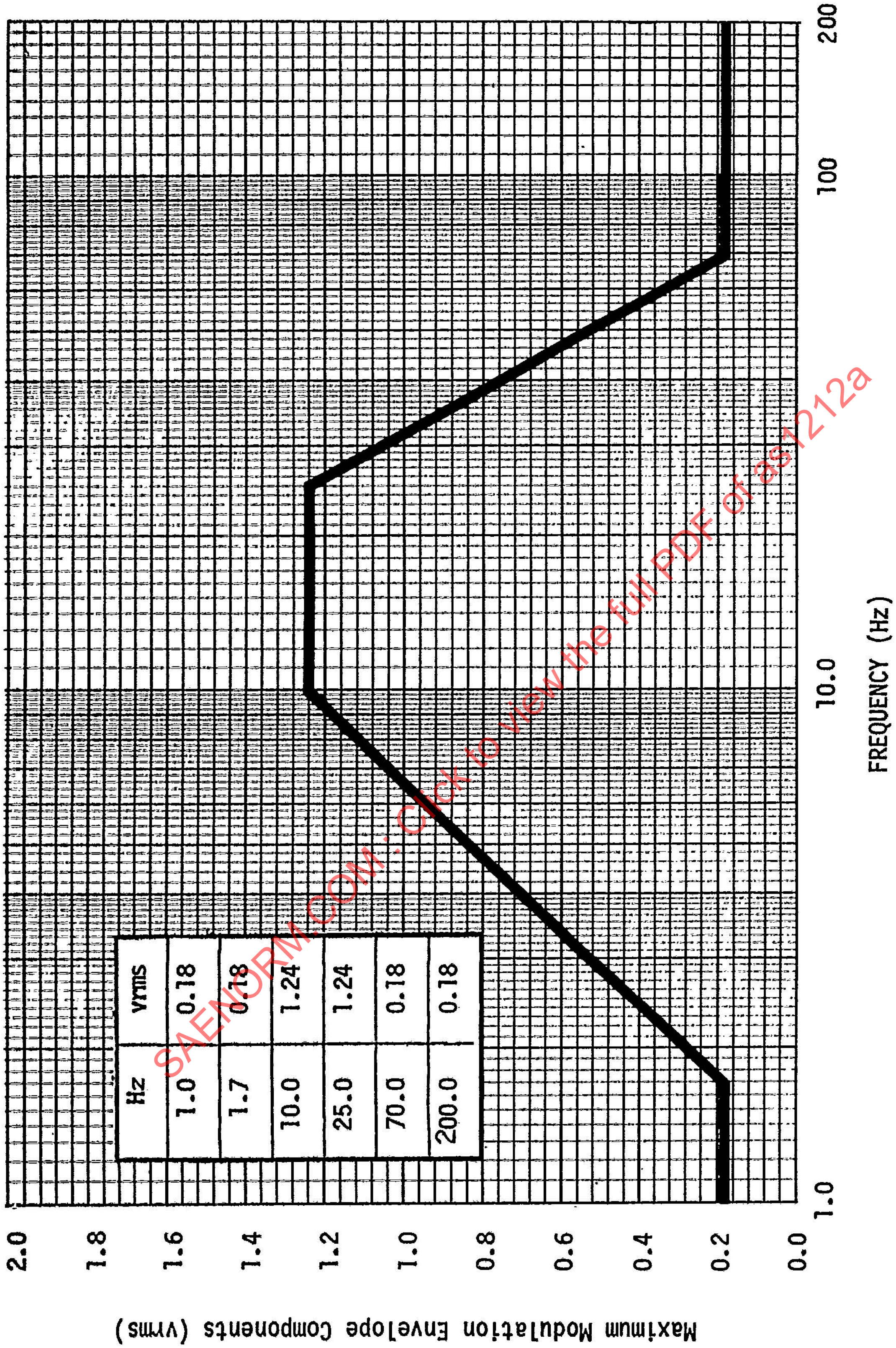
STEADY-STATE AC VOLTAGE LIMITS UNDER DIFFERENT
MODES OF ELECTRIC SYSTEM OPERATION

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

TABLE II

STEADY-STATE DC VOLTAGE LIMITS UNDER DIFFERENT
MODES OF ELECTRIC SYSTEM OPERATION

EQUIP. CATEGORY	NORMAL (NSSL)	ABNORMAL (ASSL)	EMERGENCY (ESSL)
A	25 - 28.5	23.5 - 30	17 - 30
B	24 - 28.5	22.5 - 30	16 - 30
C	23 - 28.5	21.5 - 30	15 - 30



Hz	Vrms
1.0	0.18
1.7	0.18
10.0	1.24
25.0	1.24
70.0	0.18
200.0	0.18

FIGURE 1. Frequency Characteristics of AC Voltage Modulation Envelope

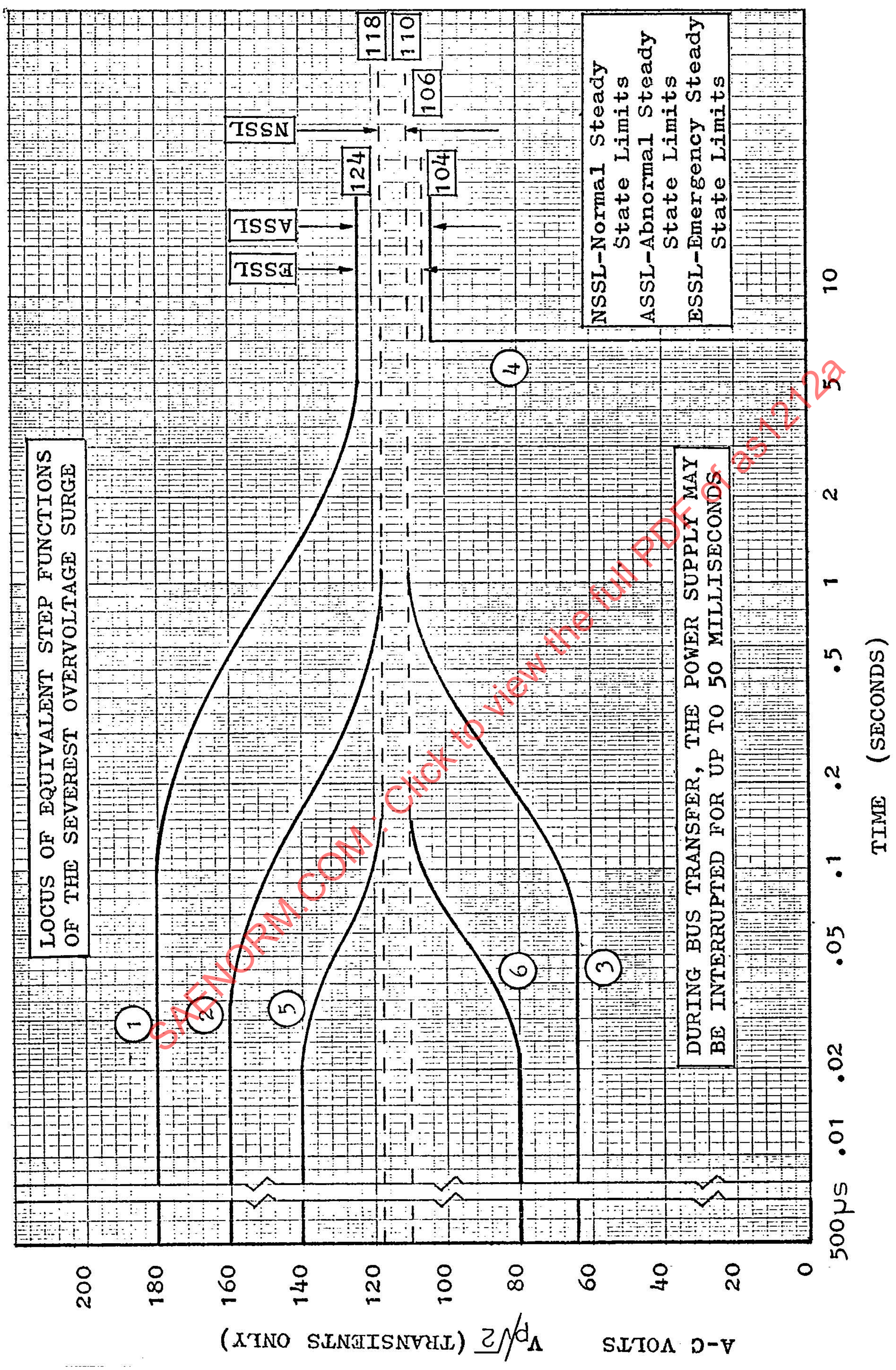


FIGURE 2. Transient Surge AC Voltage Step Function Loci Limits For Category A Equipment

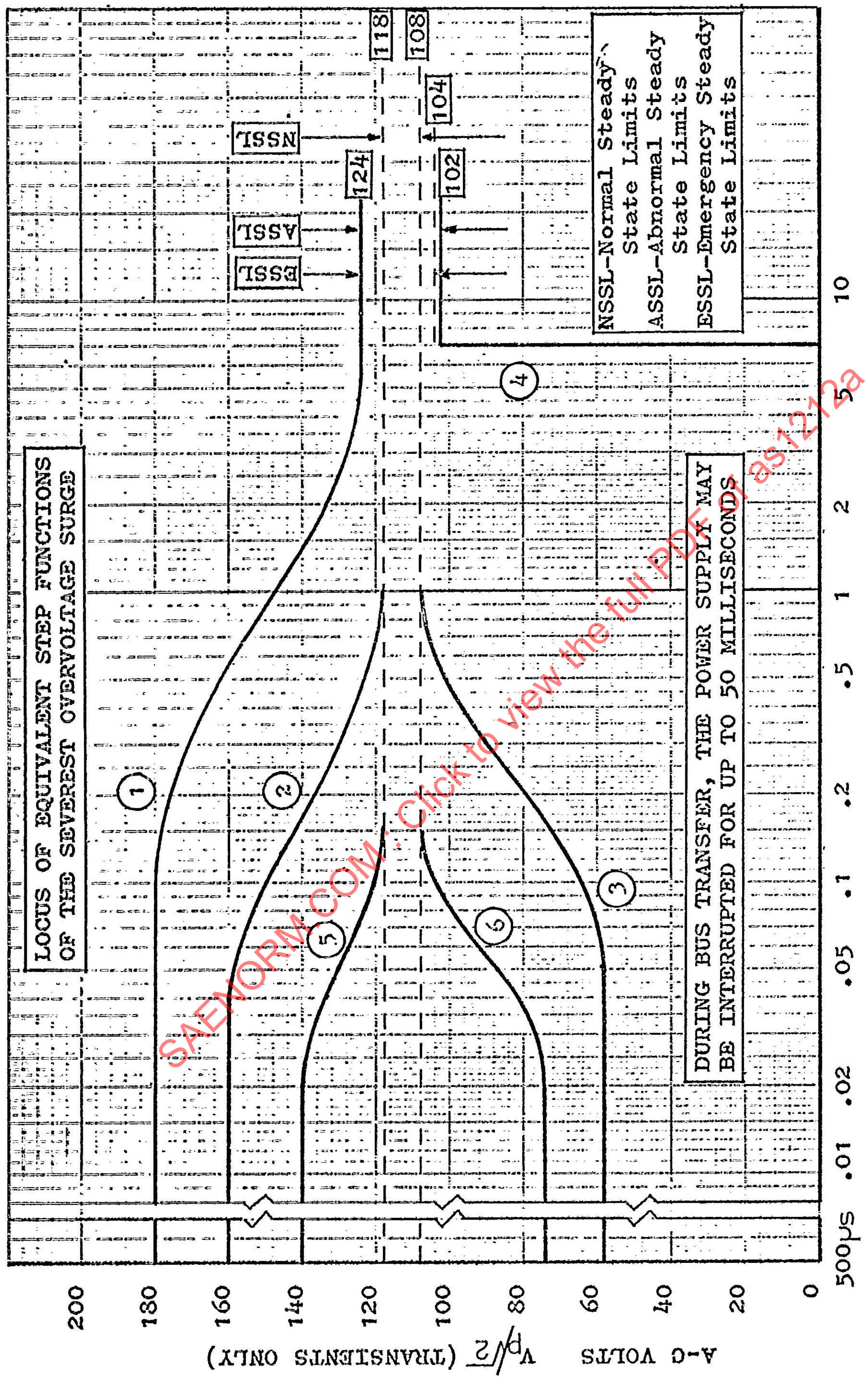


FIGURE 3. Transient Surge AC Voltage Step Function Loci Limits For Category B Equipment

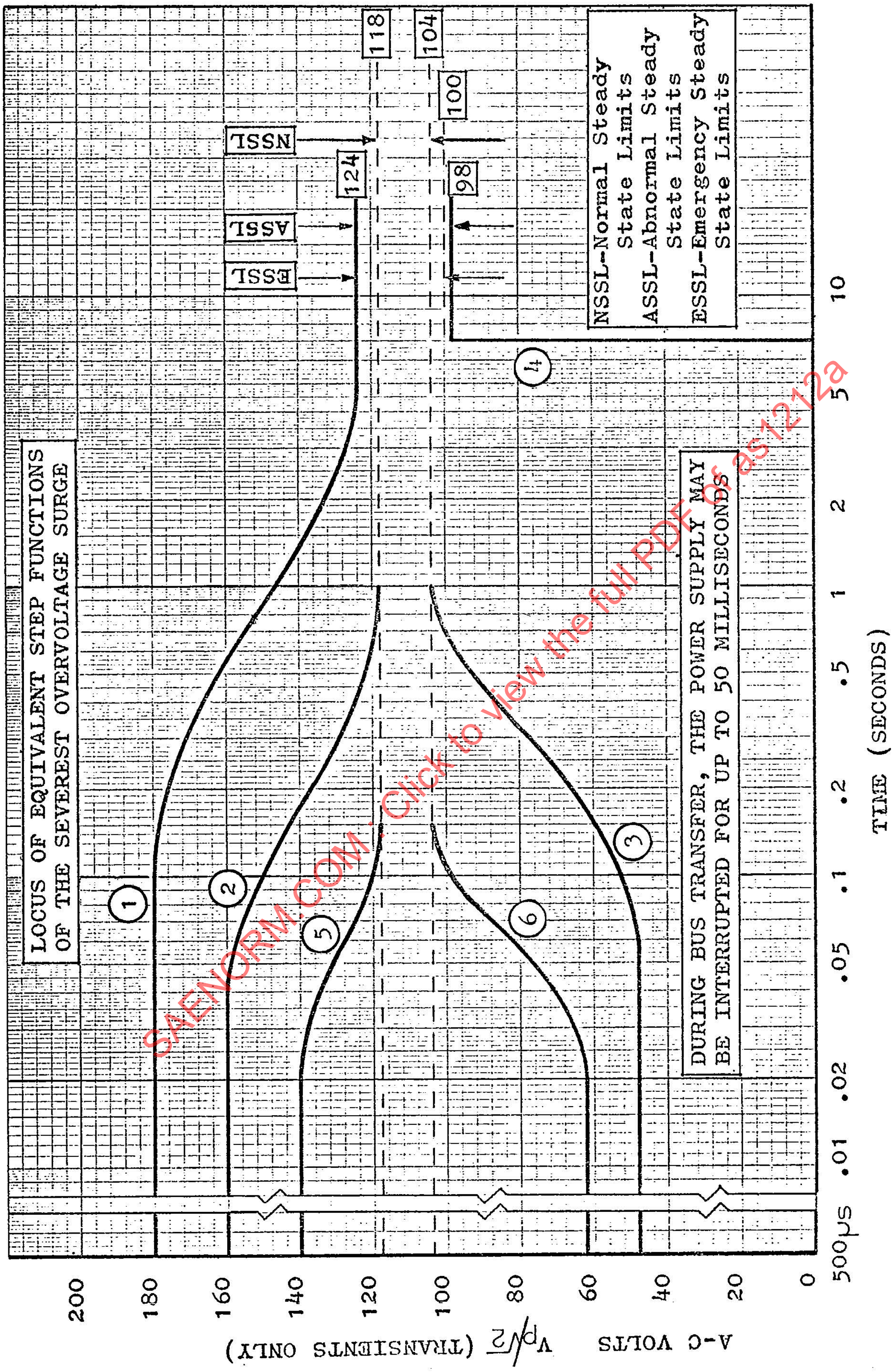


FIGURE 4. Transient Surge AC Voltage Step Function Loci Limits For Category C Equipment

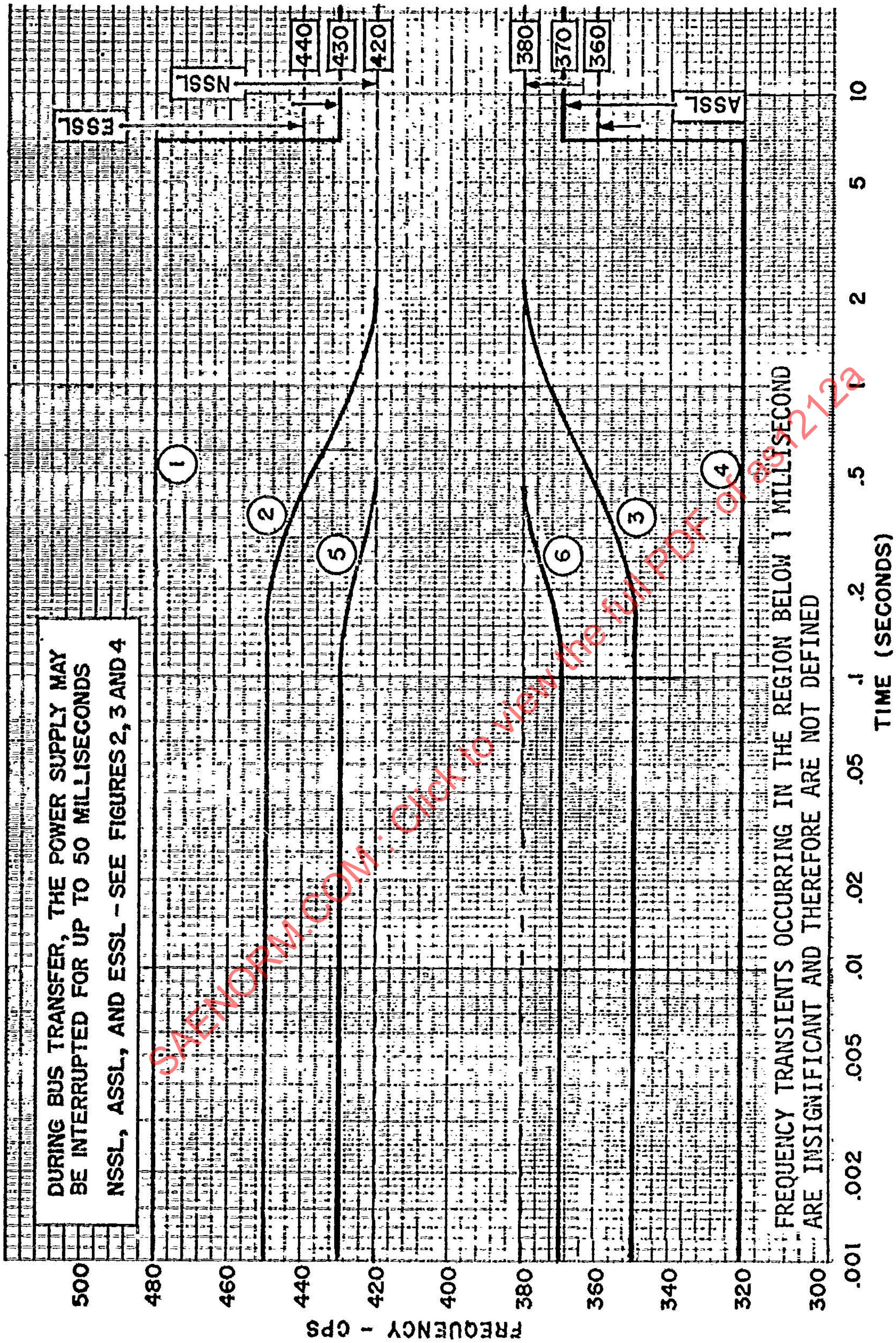


FIGURE 5. Transient Frequency Limits

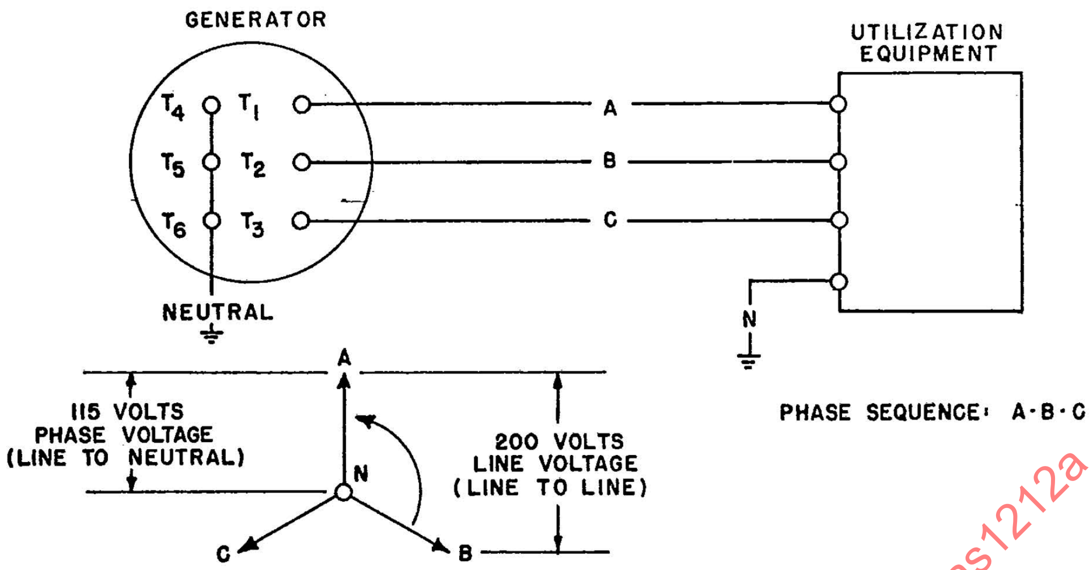
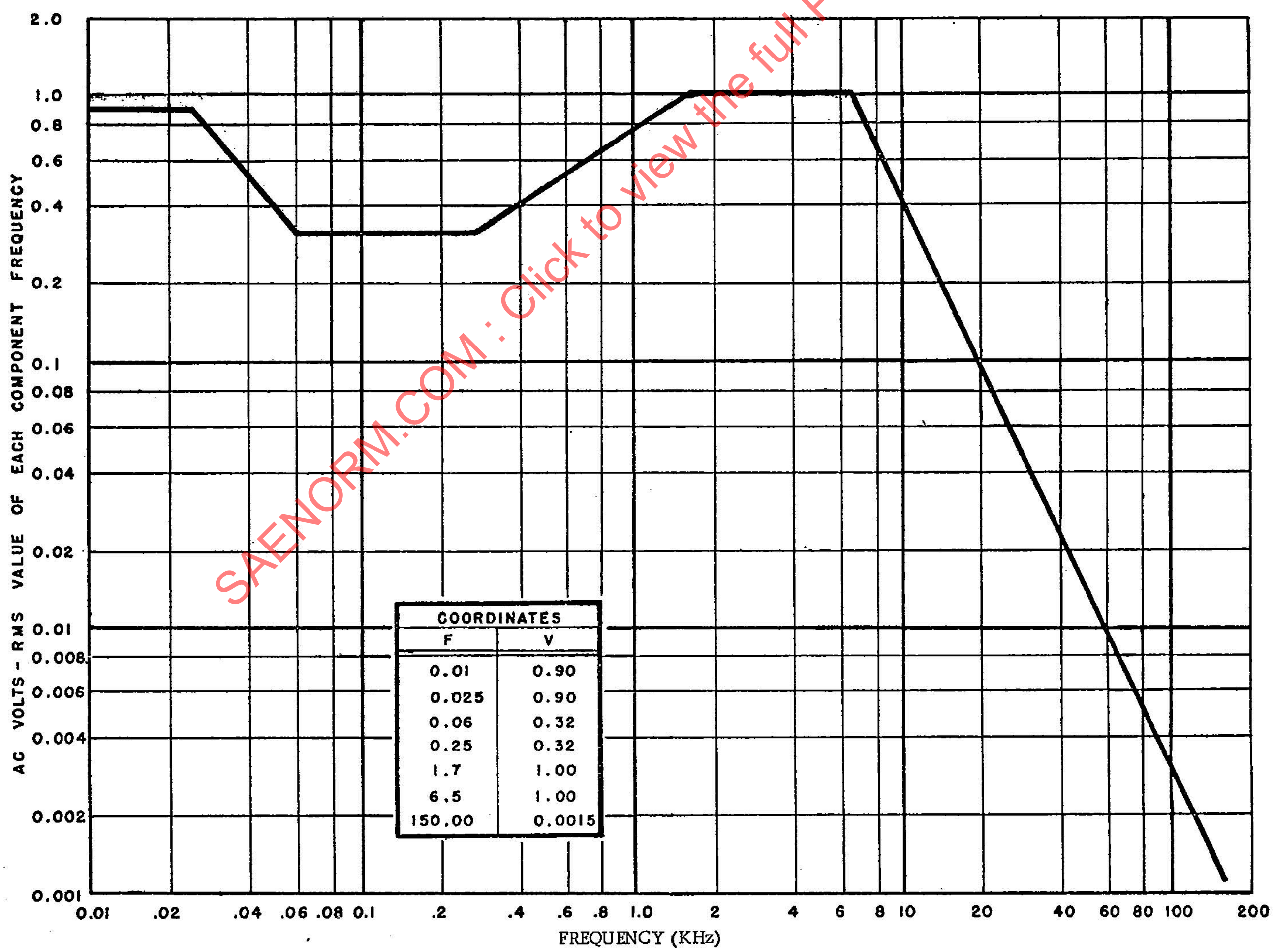


FIGURE 6. Diagram of Phase Sequence and Line Designations



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

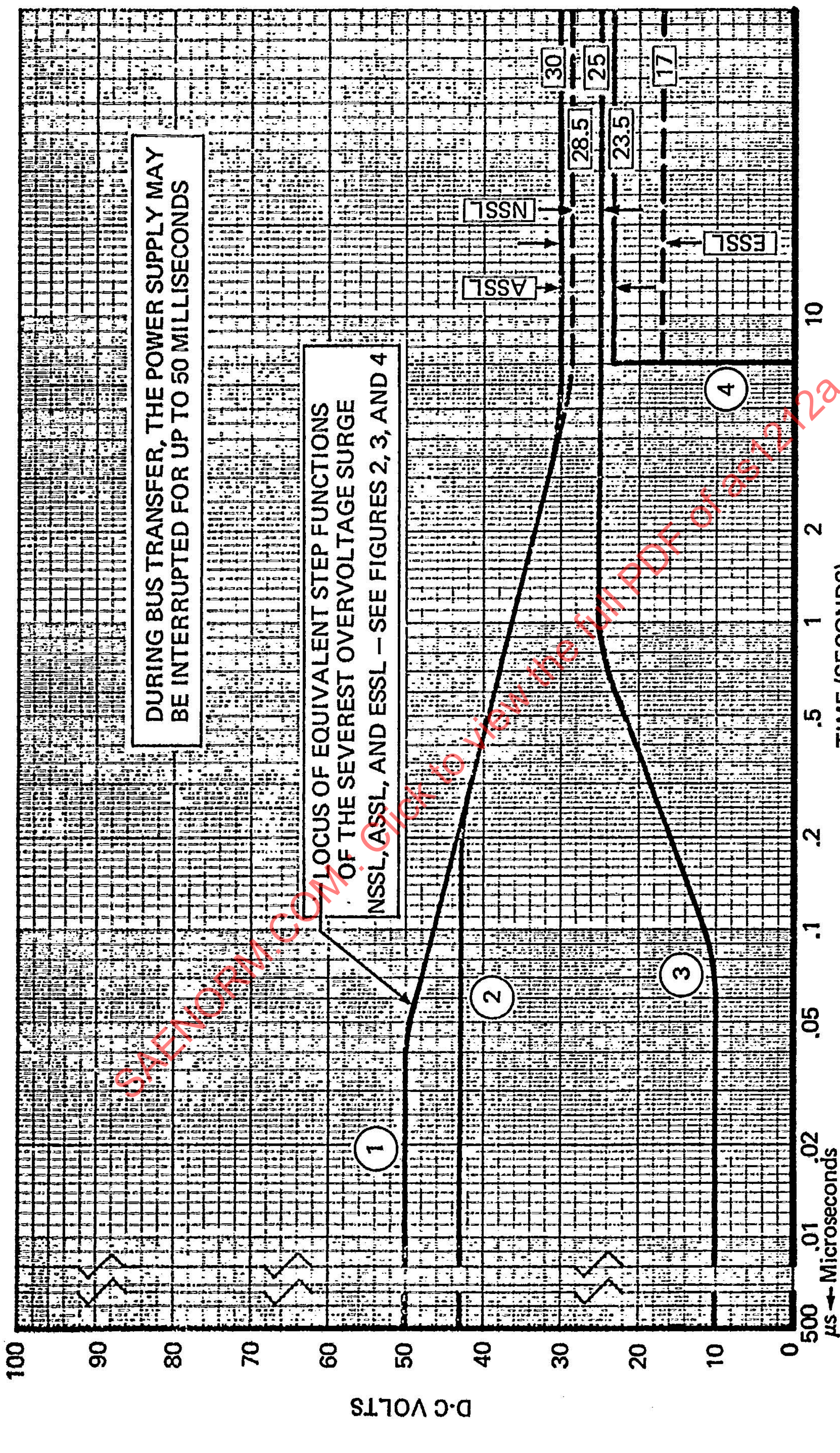


FIGURE 8. Transient Surge DC Voltage Step Function Loci Limits For Category A Equipment

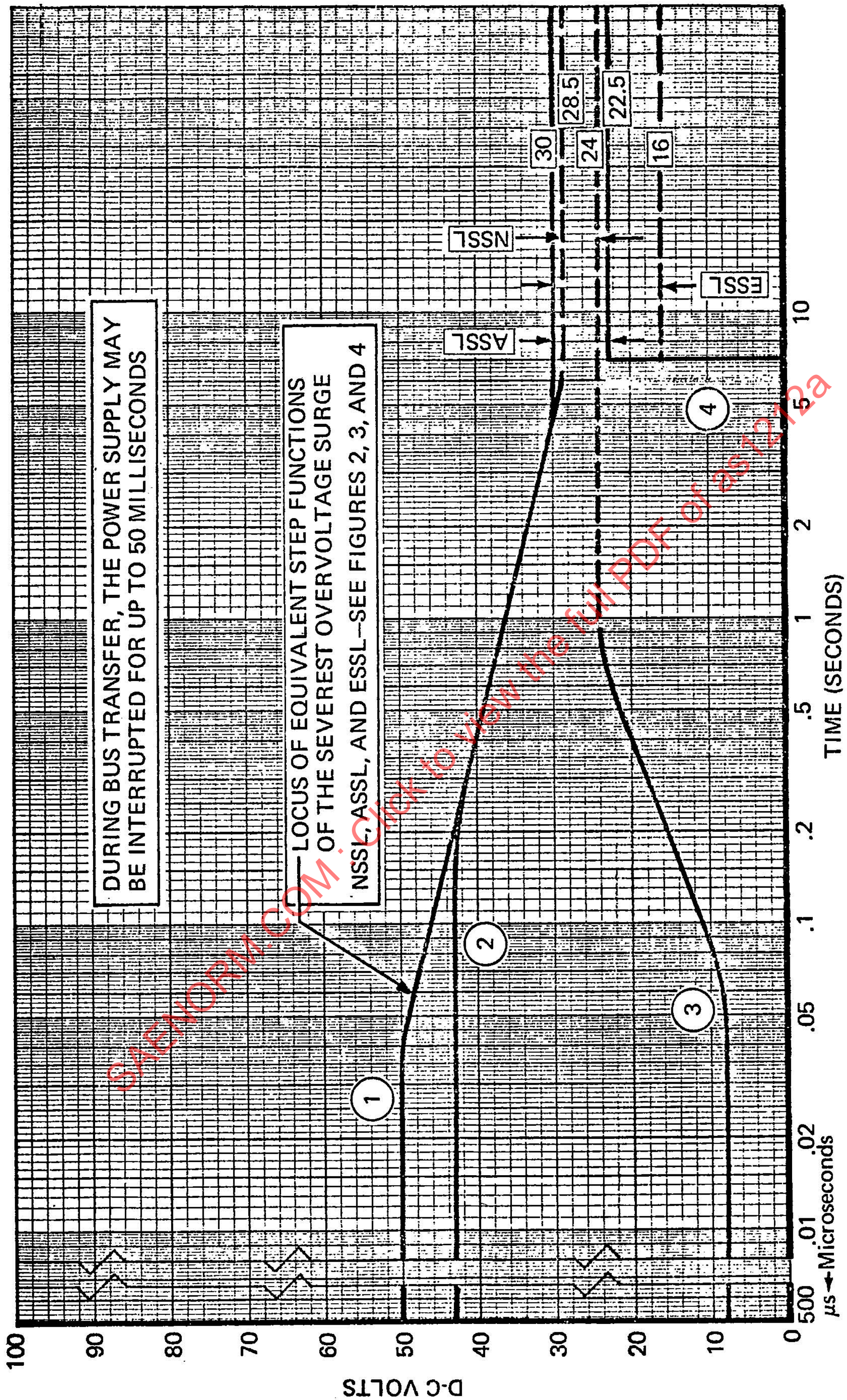


FIGURE 9. Transient Surge DC Voltage Step Function Loci Limits For Category B Equipment

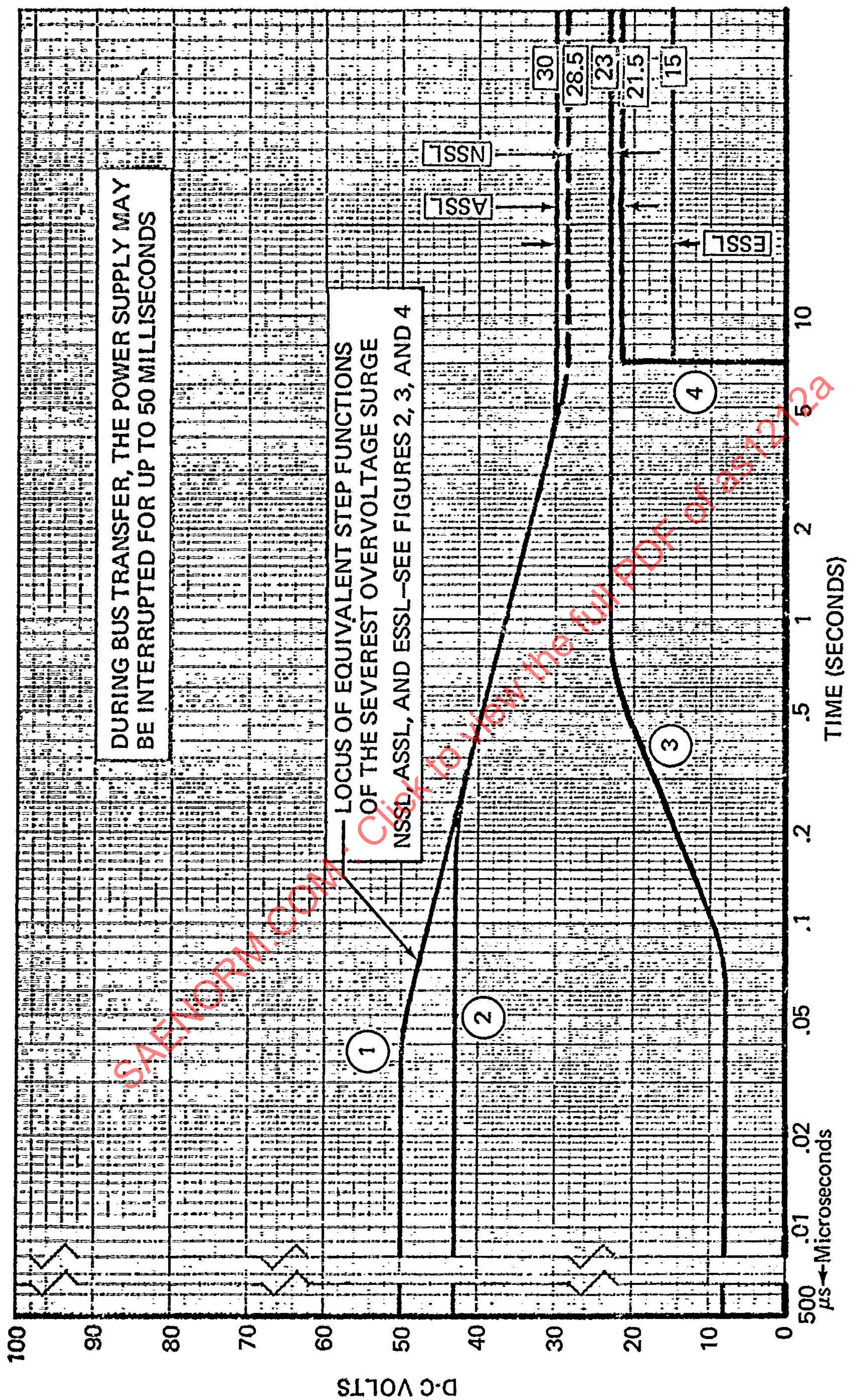
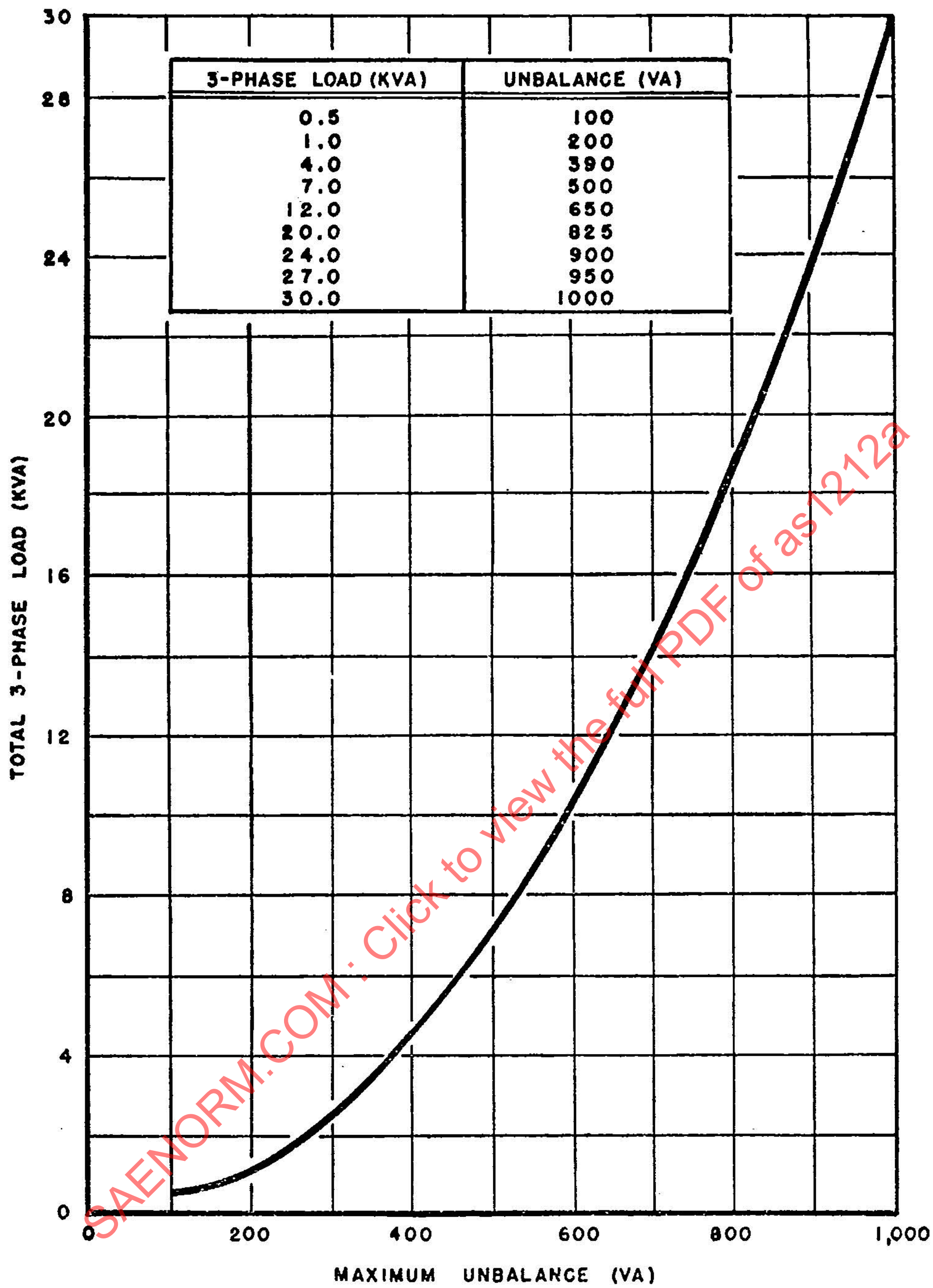


FIGURE 10. Transient Surge DC Voltage Step Function Loci Limits For Category C Equipment



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