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SUPERSESSION DATA
(SEE 6.6)

MILITARY STANDARD

AIRCRAFT ELECTRIC POWER CHARACTERISTICS

FSC MISC

DEPARTMENT OF DEFENSE
Washington, DC 20301

AIRCRAFT ELECTRIC POWER CHARACTERISTICS

MIL-STD-704B

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to the Commanding Officer, Naval Air Engineering Center, ESSD (Code 93), Lakehurst, N.J. 08733.

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1. GENERAL

1.1 Scope. This document defines standards for aircraft electric power characteristics present at utilization equipment power-input terminals, maintained during operation of the generation, distribution and utilization equipments, and systems applications aspects of utilization equipment.

1.2 Purpose. The purpose of this standard is to provide voltage and frequency limits and conditions for aircraft electric power to be used as criteria for system performance.

2. REFERENCED DOCUMENTS

2.1 The issues of the following documents in effect on date of invitation for bids, form a part of this standard to the extent specified herein.

SPECIFICATIONS

Military

MIL-E-6051	Electromagnetic Compatibility Requirements, Systems

(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.)

STANDARDS

Industry

DO-160 (RTCA)	Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments;
IEEE STD-100-1972	IEEE Standard Dictionary of Electrical and Electronic Terms

2.1.1 Addresses for documents referenced herein, not obtainable from the Government, are as follows:

RTCA	Radio Technical Commission for Aeronautics 1717 H. Street, N.W. Washington, D.C. 20006
IEEE	Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street New York, N.Y. 10017

3. DEFINITIONS

3.1 Definitions of terms not explicitly treated are as given by IEEE Standard Dictionary of Electrical and Electronic Terms.

3.2 AC power characteristics. The designation ac power characteristics relates to alternating voltage and to frequency in single-phase and three-phase wye-connected neutral or ground return systems.

3.3 AC voltage. The term ac voltage refers to the gross, root mean square (rms) phase to neutral value unless otherwise designated.

3.3.1 Nominal AC voltage. The nominal ac voltage magnitude is 115/200 volts (line-neutral)/(line-line). An alternative nominal ac voltage standard is 230/400 volts (line-neutral/line-line) when specifically authorized.

3.4 Crest factor. The crest factor of the ac voltage waveform is defined as the ratio of the peak to rms values.

3.5 DC power characteristics. The designation dc power characteristics applies to voltages in a direct-current two-wire or ground return system.

3.5.1 Nominal dc voltage. The nominal dc voltage magnitude is 28 volts. An alternative standard is 270 volts when specifically authorized.

3.6 Distortion. AC distortion is the rms value of the ac waveform exclusive of the fundamental. AC distortion includes the components resulting from amplitude modulation as well as harmonic and non-harmonic components. In a dc system, distortion is the rms value of the superimposed alternating voltage.

3.6.1 Distortion factor. The ac distortion factor is the ratio of the ac distortion to the rms value of the fundamental component. The dc distortion factor is the ratio of the dc distortion to the average dc voltage.

3.6.2 Distortion spectrum. The distortion spectrum quantifies ac distortion and dc distortion in terms of the amplitude of each frequency component. The distortion spectrum includes the components resulting from amplitude and frequency modulation as well as harmonic and non-harmonic components of the ac waveform.

3.7 Electrical power characteristics. The electrical power characteristics include values and limits of voltage and frequency parameters, and include related characteristics pertinent to electromagnetic compatibility requirements as well as those designated in ac and dc subcategories. These characteristics are representative of steady and transient states experienced in system operation during all phases of aircraft operation.

3.8 Electric power system. The aircraft electric power system is that group of connected generation, distribution, protective and conversion equipments active in supplying electric power to utilization equipments. The terms main or primary electric power system generally refer to the engine-driven generator, its accompanying electronic power-converter if any, plus associated distribution wiring and control.

3.9 Electromagnetic compatibility. The capability of systems and associated equipment to perform at specified levels in the total electromagnetic environment.

3.10 Emergency mode. The emergency mode is that condition of the electric system whereby a limited electric source, often independent of the main generation equipment is used to power a selected, reduced complement of distribution and utilization equipment.

3.10.1 Emergency power characteristics. The emergency power characteristics are those existing at the utilization equipment terminals during operation in the emergency mode.

3.11 Frequency. Frequency is equal to the reciprocal of the alternation period of the fundamental of the ac voltage. The unit of frequency is the number of alternations per second of the ac voltage and is designated hertz (Hz.).

3.11.1 Nominal frequency. The nominal frequency is 400 Hz.

3.11.2 Frequency drift. Frequency drift is the slow and random variation of the controlled frequency level within steady state limits due to such influences as environmental effects and aging.

3.11.2.1 Frequency drift rate. The frequency drift rate is the time rate of frequency change due to frequency drift.

3.11.3 Frequency modulation. Frequency modulation is defined as difference between maximum and minimum values of 1/T, where T is the period of one cycle of the fundamental of the phase voltage. When applicable, the rate at which 1/T values repeat cyclically is called the frequency modulation rate.

3.11.4 Frequency transient. The frequency transient is the locus of values defined by the reciprocals of sequential alternation periods of the ac voltage, in instances when the frequency departs from the steady-state value.

3.12 Overvoltage and undervoltage. Overvoltage and undervoltage are those voltages which exceed the combined steady state and surge limits and are usually terminated by the action of protective devices. Although generally short lived, they differ from surges in the sense that, if left unchecked, they would continue indefinitely at their fixed magnitude or until some breakdown in operation was precipitated. Overvoltage and undervoltage can exist indefinitely at values slightly exceeding steady state limits but within the trip limits of the generator protection circuits. They are generally due to loss of regulator control, to unbalance, or to faults, i.e. causes other than those producing surge voltages. On ac systems, they apply on all three phases or only one or two phases.

3.13 Ripple amplitude. The ripple amplitude is the maximum value of the difference between the average and the instantaneous values of a pulsating unidirectional wave. (See 2.1, IEEE Standard.)

3.14 Steady state. A steady state condition of the characteristics is one in which the characteristic shows only negligible change throughout an arbitrarily long period of time.

3.15 Utilization equipment. Utilization equipment is that which receives power from the electric power system. It may be an individual unit, a set of equipments or a complete subsystem reciving power through common equipment terminals or power converters.

3.15.1 Utilization equipment terminals. Utilization equipment terminals through which the electric power system is connected to the utilization equipment are attached to the equipment or are immediately adjacent to the equipment itself. Power interconnections within the utilization equipment are excluded.

3.16 Voltage phase difference. The voltage phase difference is the difference in electrical degrees between the fundamental components of any two phase voltages taken at consecutive zero or dc level crossings of their instantaneous values traced in the negative to positive directions.

3.17 Voltage surge. The voltage surge is defined as a transient departure of the peak values of voltage from the peak instantaneous value of the steady state voltage, persisting for periods in excess of 500 microseconds, followed by recovery to within peak values corresponding to steady state. Surges are caused by load changes, switching or power interruptions elsewhere in the system, and are not expected to activate protective equipment.

3.18 Voltage spike. The spike is a transient of total duration normally less than 500 microseconds and is superimposed on the otherwise unaltered instantaneous voltage. Spikes may be characterized here in the time domain in terms of voltage with parameters of duration, risetime and energy. They may also be characterized equivalently in terms of Fourier component amplitudes as a function of frequency. Spikes are not expected to activate protective equipment.

3.19 Voltage unbalance. Voltage unbalance is defined as the maximum difference among phase voltage magnitudes at the utilization equipment terminals.

3.20 Reference ground. The primary aircraft structure is the reference ground for both the ac and dc electrical power systems in metal structure aircraft. In composite structure aircraft, reference ground is additionally designated for specific systems. In some instances, it may be possible to utilize as ground the negative polarity wiring of the dc system, the neutral of the three-phase ac system, or one "side" of a single-phase ac system.

3.21 Power sensitivity. Power sensitivity of utilization equipment is the ratio of incremental output changes to incremental input changes for specified output performance quantities and specified voltage or frequency input-power changes. (See IEEE STD, 2.1)

4. GENERAL REQUIREMENTS

4.1 System equipment compatibility. The characteristics defined in this standard shall be maintained at the U/E terminals during the operation of all expected combinations of power source, distribution and utilization equipment. System operating modes outside the conditions defined by this standard will be permitted only when specifically authorized.

4.2 Power interruption. Due to conditions of bus transfer, voltage may be between zero and the steady state limits for a period no greater than fifty milliseconds, and within the limits of Figures 4 and 7 following this interruption, for ac and dc systems, respectively. Interruptions resulting from out-of-tolerance frequency, overvoltage and undervoltage or overcurrent may be followed by bus transfer, or by power restoration delays as determined by the particular application. (See 5.1.4 and 5.2.3)

4.3 Conformance tests. Tests for conformance of the aircraft electric system to the characteristics stipulated in this standard shall be defined as part of the procurement specifications to which this document is applicable, and shall be subject to the approval of the procuring activity.

5. DETAIL REQUIREMENTS

5.1 AC power characteristics. AC power characteristics are those of a single-phase or three-phase wye-connected neutral or ground return system having a nominal voltage of 115/200 volts and a nominal frequency of 400 Hz. An alternate standard is a nominal 230/400 volts when specifically authorized. The voltage magnitude limits for the 115/200 volts standard shall apply proportionally to the 230/400 volts standard.

5.1.1 Steady state.

5.1.1.1 AC voltage magnitude. The steady state phase-voltage shall be within 108.0 to 118.0 volts. The voltage in the emergency mode shall be within the range of 102.0 to 124.0 volts.

5.1.1.2 Voltage unbalance. Voltage unbalance applied to the terminals of equipment using a three-phase supply shall be less than 3 volts.

5.1.1.3 Voltage phase difference. The voltage phase difference shall be within 120° ±2°.

5.1.1.4 Phase sequence. The phase sequence is A-B-C corresponding to phase wire markings. See Fig. 1.

5.1.1.5 AC waveform distortion. The distortion factor for the phase voltage waveform shall not exceed 0.05 nor shall the limits of the ac distortion spectrum exceed the envelope shown in Fig. 2. The crest factor shall not exceed 1.41 ±0.10, nor shall the dc component exceed ±0.10 volts. Excepting the conditions of spikes and surges, the waveform shall be within the band V ($\pm 0.071 + \sin \theta$), where V is the maximum value of the equivalent sine wave and θ is the phase angle.

5.1.1.6 Amplitude modulation. The amplitude modulation components (sidebands) resulting from all modulating influences shall not exceed 0.62 volts rms over the range 400 ±60 Hz. (See 6.5)

5.1.1.7 System frequency. The system frequency shall be 400 ±5 Hz. For helicopters, the frequency shall be 400 ±20 Hz. The system frequency in the emergency mode depends on the tolerable limits among the individual equipments operating in this mode, but shall not exceed 400 ±40 Hz. Below 360 Hz, frequency/voltage ratio shall be greater than 2.9.

5.1.1.8 Frequency modulation. Modulated frequency deviation shall not exceed the limits specified in Fig. 3.

5.1.1.9 Frequency drift. Frequency drift shall not exceed the steady state limits, nor occur at a rate of change exceeding 15 Hz per minute.

5.1.2 Transient.

5.1.2.1 Voltage surge. Voltage surges shall not exceed the limits shown in Figure 4.

5.1.2.2 Voltage spike.

a. The system electromagnetic compatibility aspects of voltage spikes shall be controlled by MIL-E-6051.

b. Utilization equipment shall be capable of withstanding voltage spikes as defined in 5.4.5.1. (See also 6.2.)

5.1.3 Frequency transient limits (frequency surge). The frequency transient shall be within 400 ±25 Hz., returning to within 400 ±20Hz. in one second, to within 400 ±10 Hz. in 5 seconds, and to within 400 ±5 Hz. in 15 seconds. The rate of frequency change shall not exceed 500 Hz./second for any period greater than 15 milliseconds.

5.1.4 Overvoltage and undervoltage. The ac overvoltage values shall not exceed the upper limit shown in Figure 5. The ac undervoltage shall not exceed the lower limit of Figure 5 except that zero voltage can exist indefinitely. The voltage may remain within the limits of 118 to 125 volts or 100 to 108 volts for the allowed duration of conditions resulting in voltages within these limits. Interruption following the period of these overvoltages or undervoltages shall be as specified in 4.2. (See also 3.12, 3.17 and 3.18.)

5.1.5 Out-of-tolerance frequency (over- and under-frequency). The frequency limits shall not exceed 400 ±25 Hz. for more than 5 seconds, or for an interval specifically authorized, but in no instance be allowed to exceed 480 Hz. Interruptions following this interval shall be as specified in 4.2. (See also 5.1.3.)

5.2 DC power characteristics. DC power characteristics are those of a direct-current, two-wire or ground return system having a nominal voltage of 28 volts. An alternate standard is a nominal 270 volts when specifically authorized.

5.2.1 Steady state.

5.2.1.1 DC voltage magnitude. The dc voltage shall be within 22.0 to 29.0 volts. The dc voltage for the alternative 270 volts (nominal) system shall be within 250 to 280 volts. The voltage range for operation in the emergency mode shall be within 18.0 to 29.0 volts. For the 270 volts (nominal) system, the voltage range for operation in the emergency mode shall be within 240 to 290 volts.

5.2.1.2 DC distortion. The dc distortion factor shall not exceed 0.02 nor shall the dc distortion spectrum exceed the limits shown in Fig. 6. The ripple amplitude shall not exceed 1.5 volts (peak). For the 270 volts (nominal) system, the distortion factor shall not exceed 0.03 nor the dc distortion spectrum exceed the limits shown in Fig. 6, nor the ripple amplitude exceed 6.0 volts. (See 6.4.)

5.2.2 Transient.

5.2.2.1 Voltage surge. The maximum value of the dc voltage surge shall not exceed the limits shown in Fig. 7. For the 270 volts (nominal) system, the maximum value of the dc surge shall not exceed the limits shown in Fig. 9.

5.2.2.2 Voltage spike. The requirements of 5.1.2.2 also apply to this paragraph.

5.2.3 Overvoltage and undervoltage. The dc overvoltage values shall not exceed the upper limit shown in Figure 8. The dc undervoltage shall not exceed the upper limit shown in Figure 8 except that zero voltage can exist indefinitely. The voltage may remain within the limits of 29 to 31.5 volts or 20.0 to 22.0 volts for the allowed duration of conditions resulting in voltages within these limits. For the 270 volts (nominal) system, the dc overvoltage values shall not exceed the upper limits shown in Figure 10, and the dc undervoltage shall be restored to its steady state limits within 5 seconds after exceeding the lower limit of Figure 9. Interruption following the period of these overvoltages or undervoltages shall be as specified in 4.2 (See also 3.12, 3.17 and 3.18.)

5.3 Ground support power characteristics. Power supplied by ground support generation systems shall result in power at the utilization equipment terminals at least within the limits specified in 5.1 and 5.2, but excepting 5.1.3. (See 4.1.)

5.3.1 AC voltage.

5.3.1.1 AC voltage magnitude. The voltage range at the point of connection to the aircraft shall be within 116 to 119 volts including unbalance. (See 4.1.)

5.4 System operation of utilization equipment.

5.4.1 Power types. Utilization equipment shall operate from one or more of the types of power defined below, as required by the equipment specifications:

Nominal Classification	115v 400Hz	28vdc	230v 400Hz	270vdc
Limits	104-122v** 380-420Hz	22-29.5**	208-244v 380-420Hz	245-285vdc

** See DO-160 (2.1)

5.4.2 Equipment performance. The utilization equipment shall function as follows:

a. Unless otherwise specified, all performance requirements must be met when the utilization equipment is supplied one or more power types specified in 5.4.1 above, when operated in a system, and when operated within the appropriate limits specified in 5.1 and 5.2, which must be within the limits of the equipment specification.

b. Performance in the emergency mode shall be as required by the equipment specification.

c. Utilization equipment need not maintain required performance when supplied voltages between the applicable surge limits and the associated overvoltages and undervoltages of 5.1.4 and 5.2.3, and frequencies between applicable steady state limits and the transient limits of 5.1.3, unless otherwise required. (See 3.12.)

d. Exposure to the voltages and frequencies stipulated above in this paragraph 5.4.2 shall not result in an unsafe condition, nor impair the ability of utilization equipment to maintain performance requirements in subsequent operation. After such exposure the utilization equipment shall be automatically restored to specified operating performance unless otherwise required.

5.4.3 Precision power. The electric power system shall not be used directly as a source of reference voltages or frequencies, or timing signals unless specifically authorized by the procuring activity.

5.4.4 Partial power failure. The failure of one or more phases of a polyphase equipment, or the loss of power to any or all pairs of power-input terminals of equipments which require both ac and dc power, shall not result in an unsafe condition.

5.4.5 Power sensitivity tests. Tests for utilization equipment sensitivity to the appropriate power conditions shall be as defined in the system procurement specification. Detail equipment tests will not be invoked unless specifically called out. (See 6.3.)

5.4.5.1 Voltage spike. Subsequent to the application of the spike waveforms, as specified below, to the power-input terminals of utilization equipment functioning according to corresponding detail specification, this equipment shall meet 5.4.2. The spike waveform, produced by a generator with a source impedance of 50 ±5 ohms, shall satsify the following requirements:

Open-circuit voltage: ±600 volts peak.
Risetime: 0.9 ±0.2 microseconds
Falltime: 10.0 ±1.0 microseconds
Pulsewidth (50% amplitude points): 5.0 ±0.1 microseconds.
Repetition rate (aperiodic): Not greater than 50 Hz.
Source energy capability: Not less than 0.01 j.

See Fig. 11 for waveform example.

6. NOTES. The material in this section is not a mandatory part of this standard.

6.1 Total system characteristics. This standard specifies selected characteristics of electric power in a total aircraft system. These characteristics are the result of the mutual influences of the electric power generation, distribution and load equipment. Load equipment should be designed to minimize any deleterious reactions and effects it may have on power quality. It is not the intent of this standard to specify the manner in which these characteristics are attained. Further detail specifications contain additional limits and constraints which are the responsibility of the designer to recognize in the context of the total system limits.

6.2 Spikes. The random and periodic occurrance of voltage spikes superimposed on other voltage characteristics specified by this standard is acknowledged. Their impact on equipment may range from temporary degradation of performance to destruction of equipment. The predominance of their high frequency behavior, however, makes necessary the recognition of their potential influence as a form of electromagnetic interference. MIL-E-6051 is the primary instrument by which their interference behavior is controlled and electromagnetic compatibility assured. No spike suppression is explicitly imposed on specific induction devices or elements such as relays and solenoids.

Spike measurements on operating systems have led to the following estimates:

Magnitude: Within the range of + and -250 volts.
Duration: Not less than 100 nanoseconds.
Risetime: Not less than 2 nanoseconds.
Energy: Not greater than 0.01 joules.
Ringing Frequency: Not greater than 10 MHz.

These may be considered worst case on the basis of present knowledge. They are not to be misconstrued with values that may be derived for a spike susceptibility test for individual utilization equipments. Problems with spikes of less than 10 volts amplitude occur frequently.

6.3 Power sensitivity and system conformance tests. Power sensitivity tests for individual utilization equipment must be developed further and adapted to a new standard to serve as a companion to MIL-STD-704B.* The RTCA document DO-160 represents significant progress already accomplished in this direction. It is also necessary to develop conformance testing methods and standards based on MIL-STD-704B with allowance for individual aircraft requirements. (*See 3.21.)

6.4 DC distortion: individual equipment vs. system effects. Tests have disclosed that individual dc generator and T/R unit tests into dummy loads demonstrate higher frequency-component amplitudes than are indicated by Fig. 6. It is important to recognize this fact in connection with 5.2.1.2, 5.4.5 and 6.3.

6.5 Amplitude modulation. Amplitude modulation effects are predominantly identified with periodic load changes. The peak-peak change

* In the context of this standard, and in the absences of correlation between individual equipment performance and that in a system, the inclusion of such tests is intended to indicate qualification and compatibility for subsequent system application.

requirement, based on a sine wave modulating influence, is consistent with previous requirements for amplitude modulation. The resultant rms level is below that indicated by the ac distortion (Fig. 2) derived as the covering envelope of measured spectral values. The off-carrier sideband components, however, are not required to fall off, in proportion to their frequency departure from the carrier, as in other standards, a situation that would cause inordinate increase in load-feeder size to safeguard against the eventuality of such low-amplitude sidebands. There is no reliable data to indicate the presence of fall-off in sideband amplitude.

6.6 Supersession data. MIL-STD-704B supersedes MIL-STD-704A dated 9 Aug 1966, for new designs. MIL-STD-704A may be used for existing applications or reordered equipment. Users of MIL-STD-704 are reminded that existing applications may require a continued use of MIL-STD-704A dated 9 Aug 1966, and that the MIL-STD-704A issue with its associated amendments should be retained.

6.7 International Standardization Agreement. Certain provisions of this standard are subject to international standardization agreements: NATO STANAG 3456, NATO STANAG 3516, ASCC Air Standard 12/10, and Air Standard 12/19. When amendment, revision or cancellation of this standard is proposed, that will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental offices, if required.

6.8 Changes from the previous issue. Asterisks are normally used to identify changes from the previous issue of a Military document. Because of the extensiveness of this revision, this practice has not been followed in this issue.

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

Preparing activity:
Navy - AS
(Project No. MISC-0952)

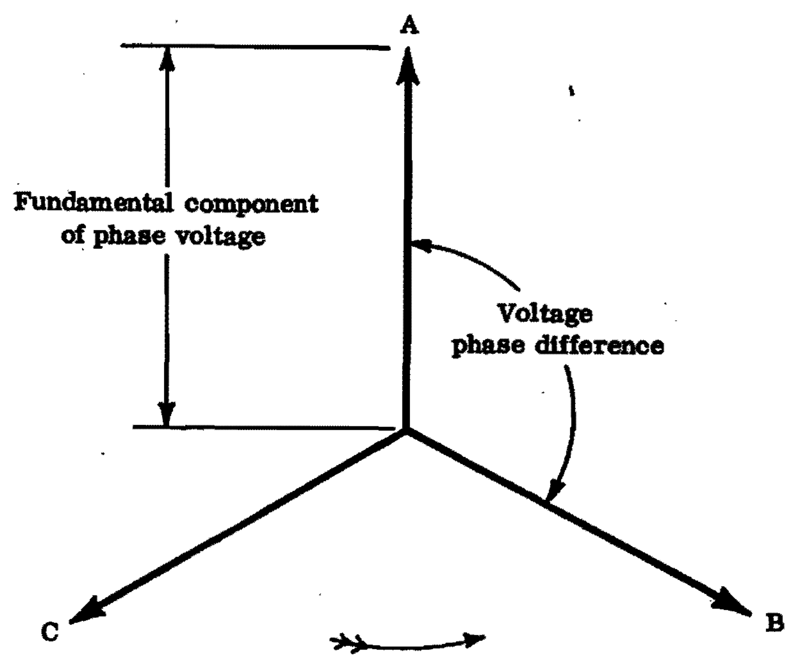


Fig. 1. Phasor diagram showing required phase sequence relationship. (See 5.1.1.4)

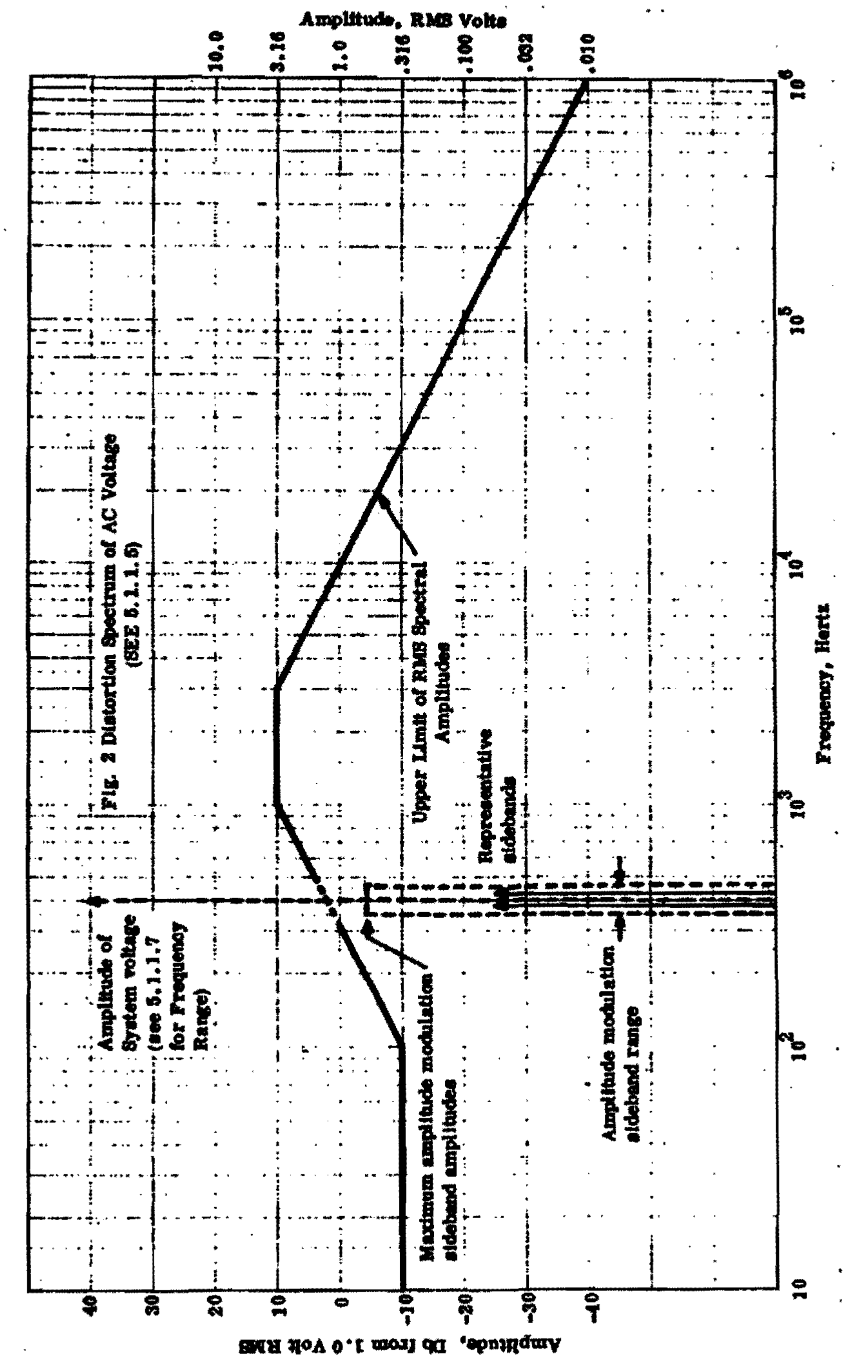


Fig. 2 Distortion Spectrum of AC Voltage (SEE 5.1.1.5)

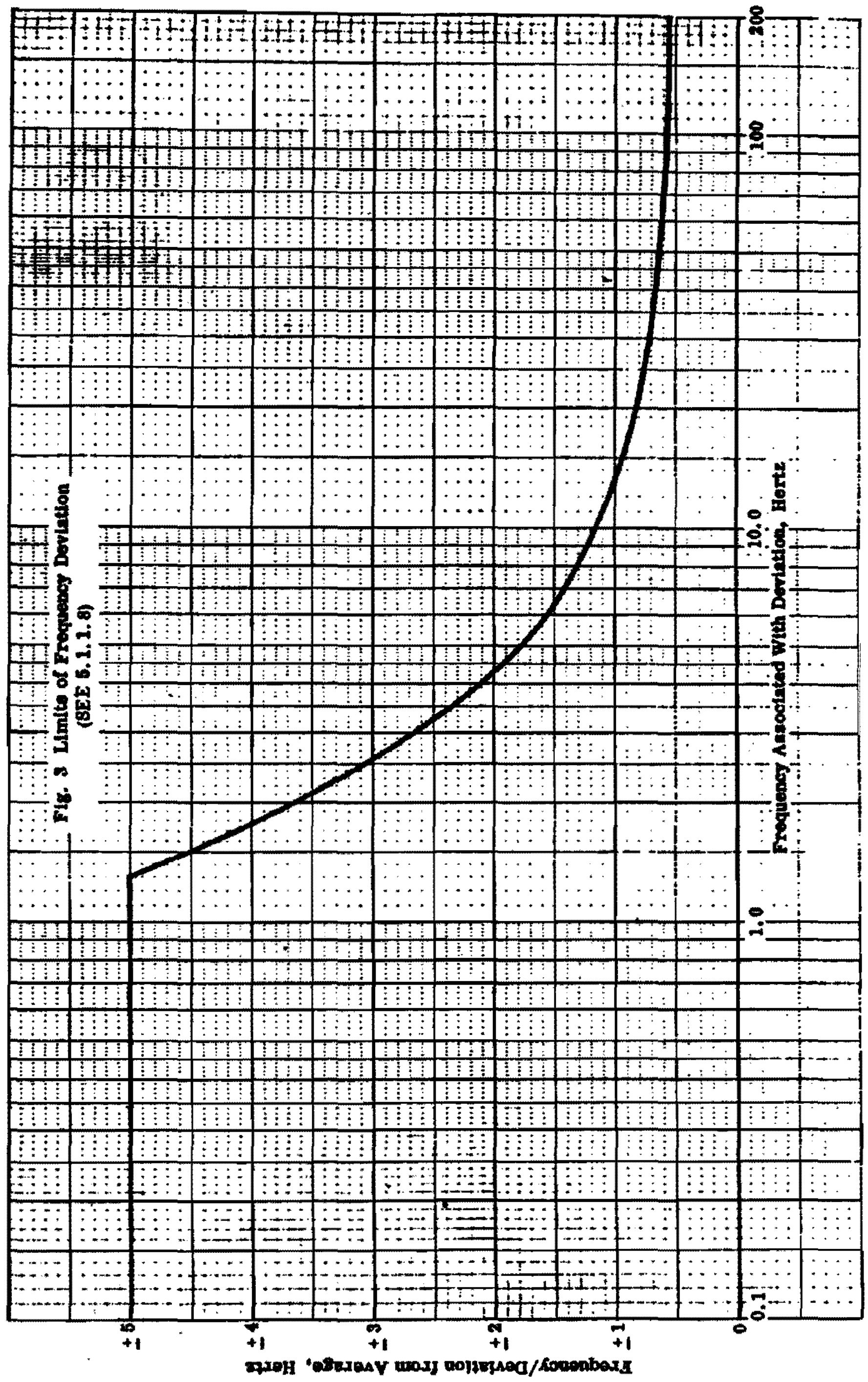


Fig. 3 Limits of Frequency Deviation
(SEE 5.1.1.8)

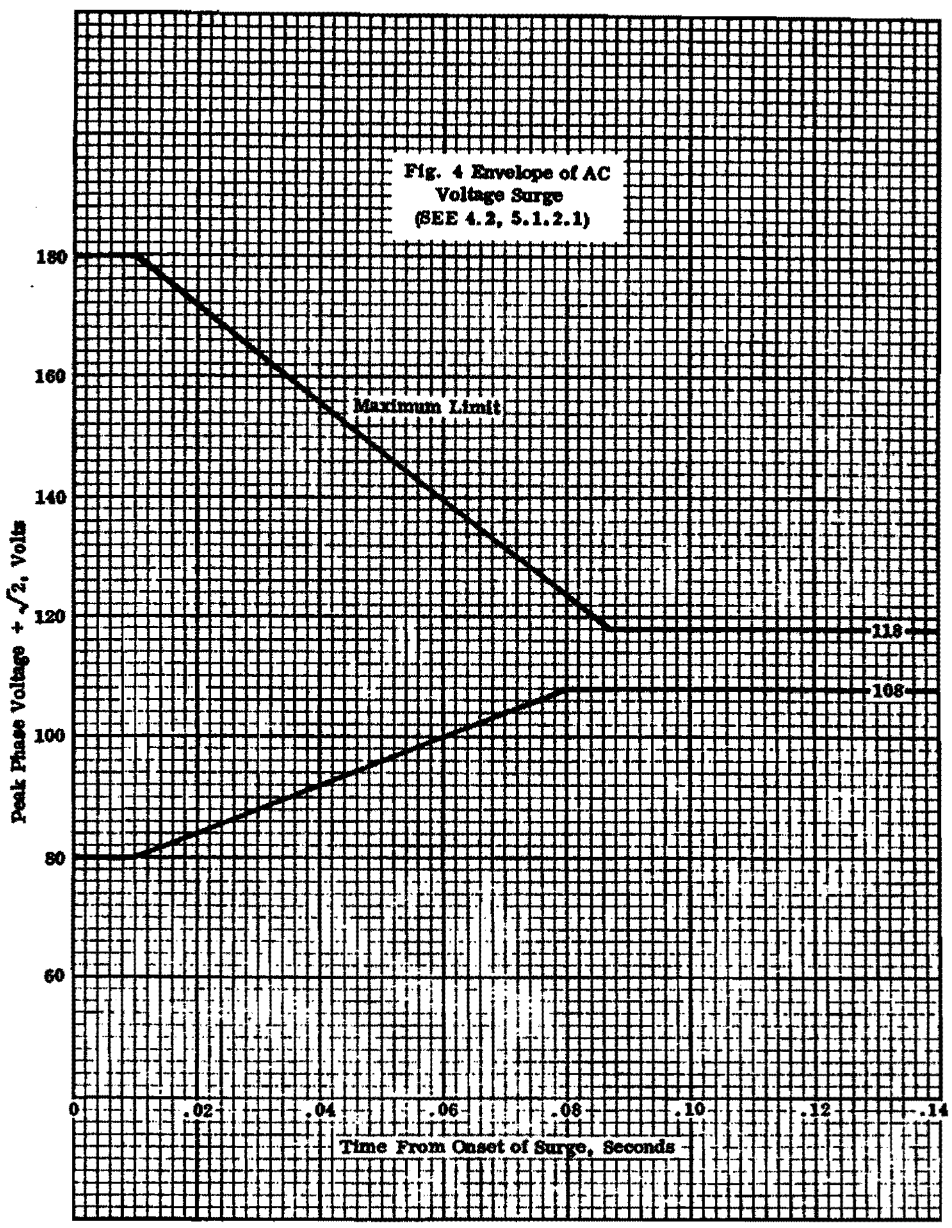


Fig. 4 Envelope of AC Voltage Surge (SEE 4.2, 5.1.2.1)
Maximum Limit
118
108
180
160
140
120
100
80
60
Peak Phase Voltage + √2, Volts
0
.02
.04
.06
.08
.10
.12
.14
Time From Onset of Surge, Seconds

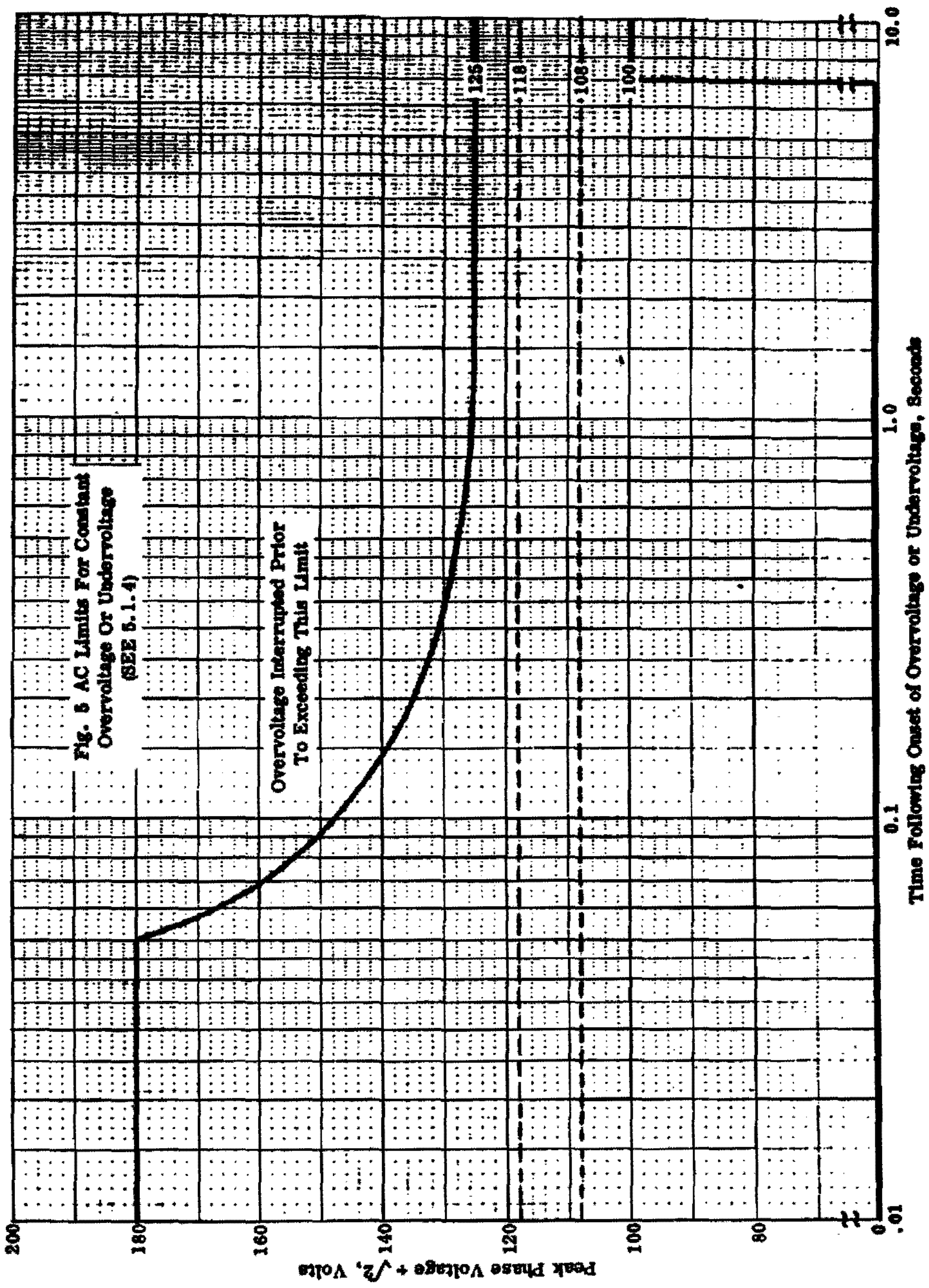


Fig. 5 AC Limits For Constant Overvoltage Or Undervoltage (SEE 5.1.4)

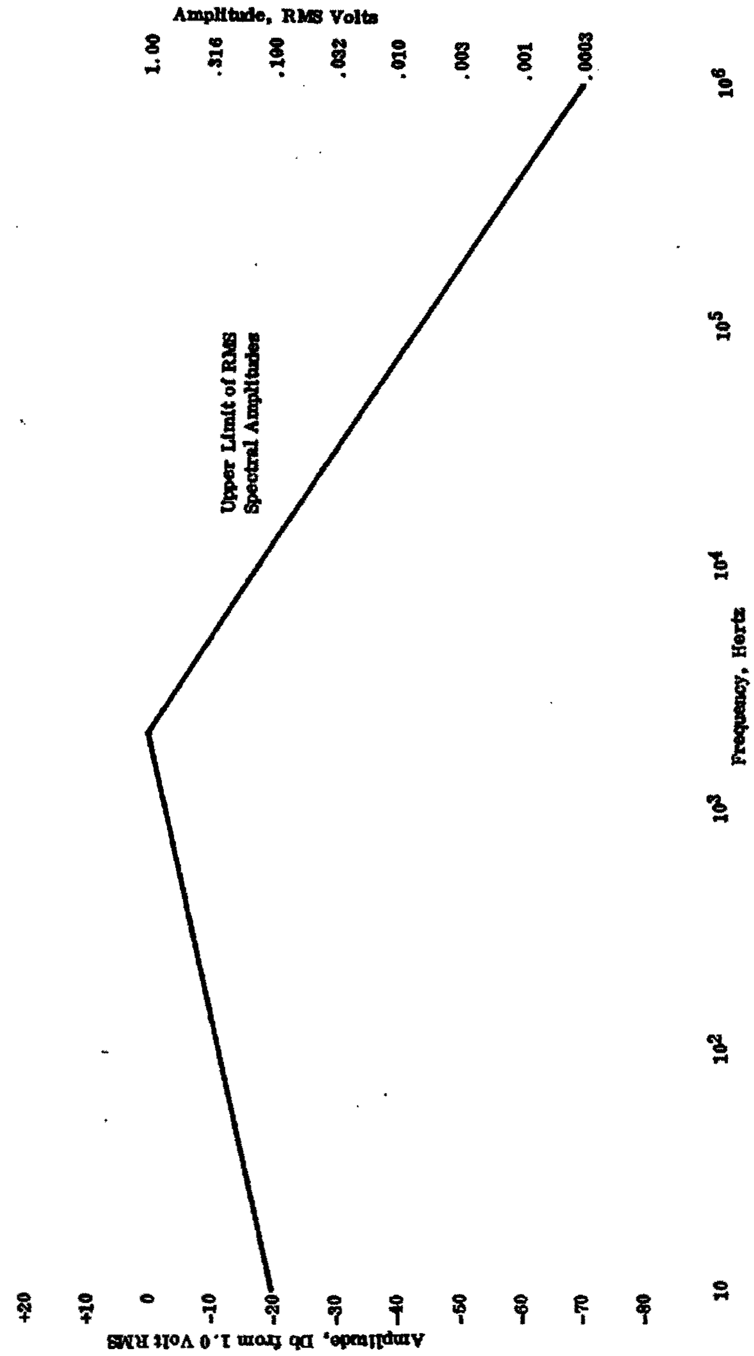


Fig. 6 Distortion (Ripple) Spectrum of DC Voltage
(SEE 5.2.1.2)

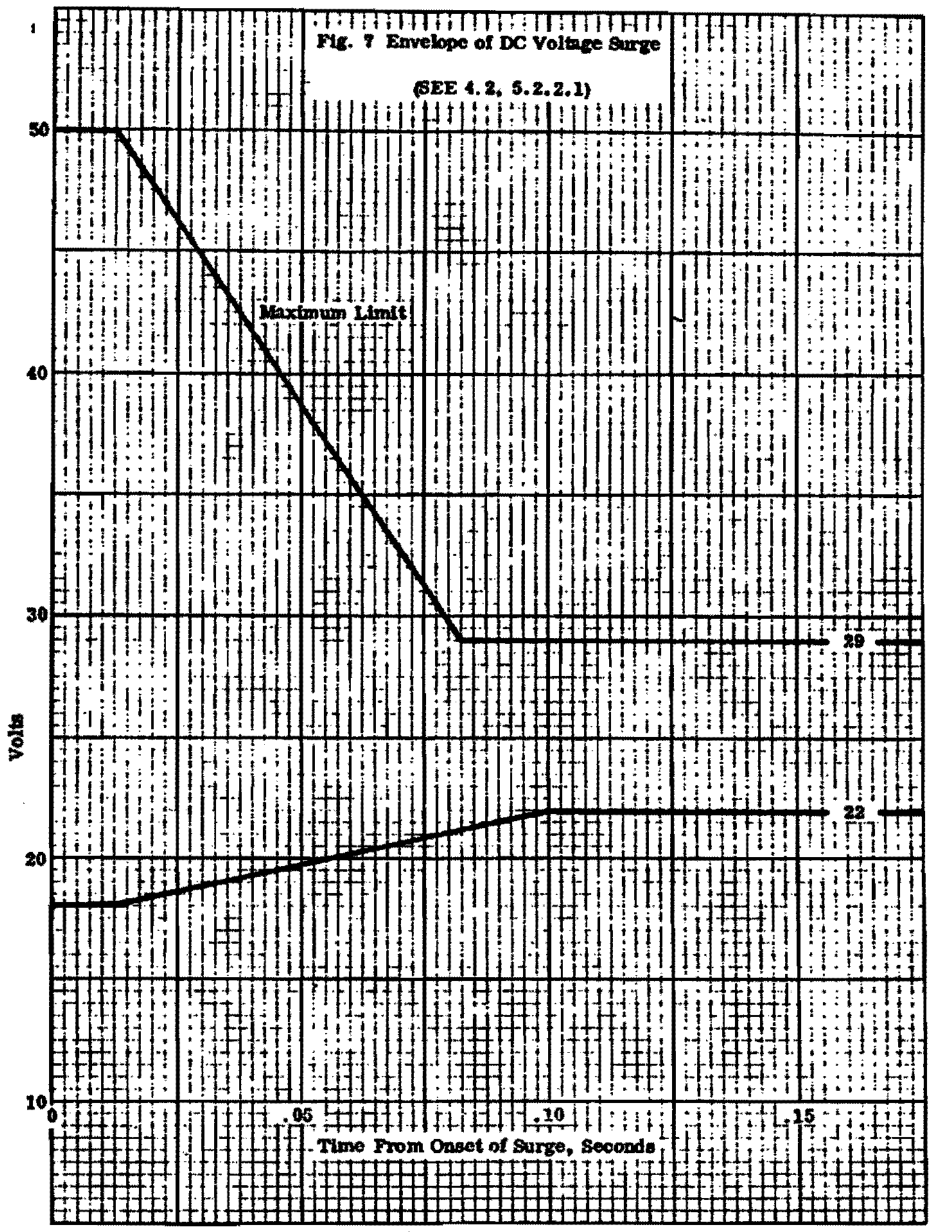


Fig. 7 Envelope of DC Voltage Surge
(SEE 4.2, 5.2.2.1)
Maximum Limit
50
40
30
20
10
29
22
Volts
0
.05
.10
.15
Time From Onset of Surge, Seconds

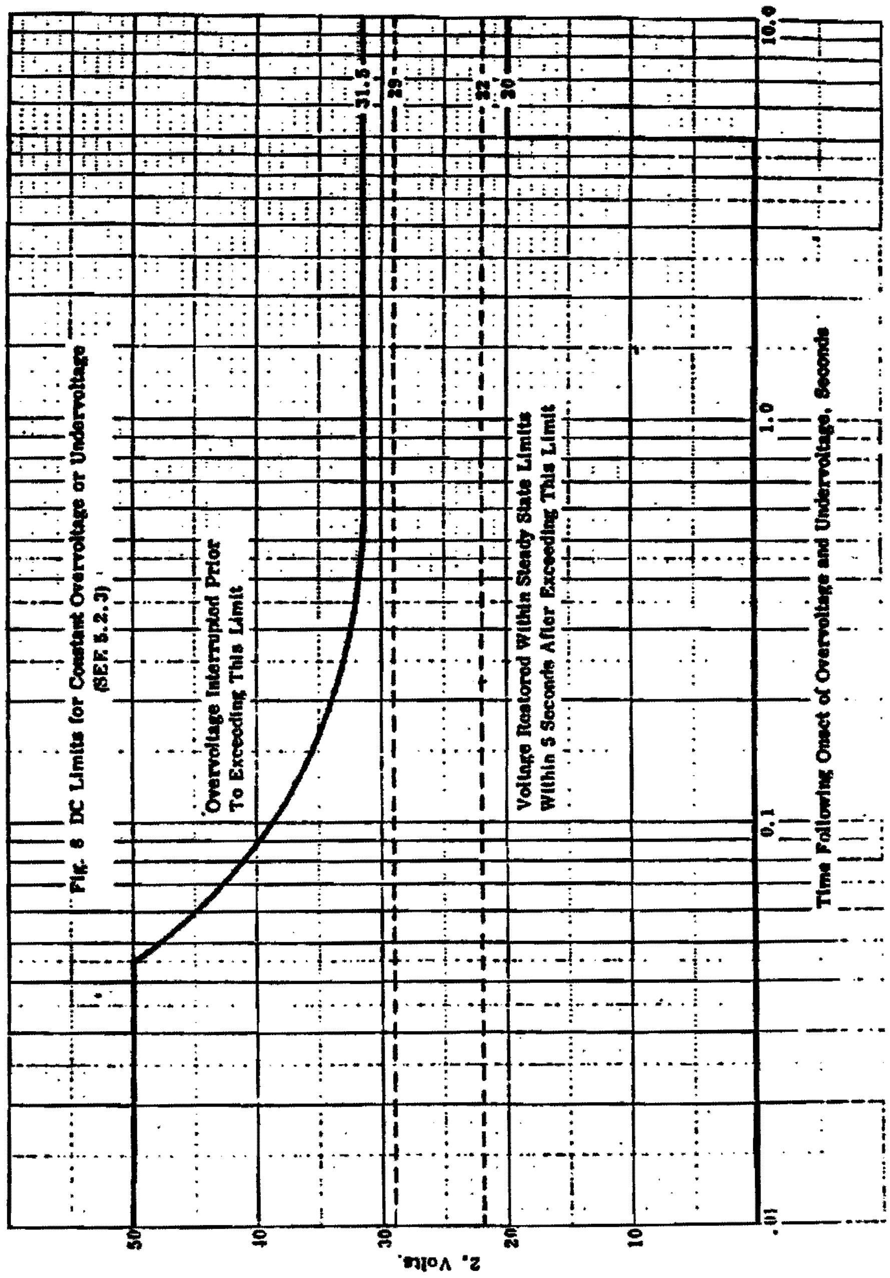
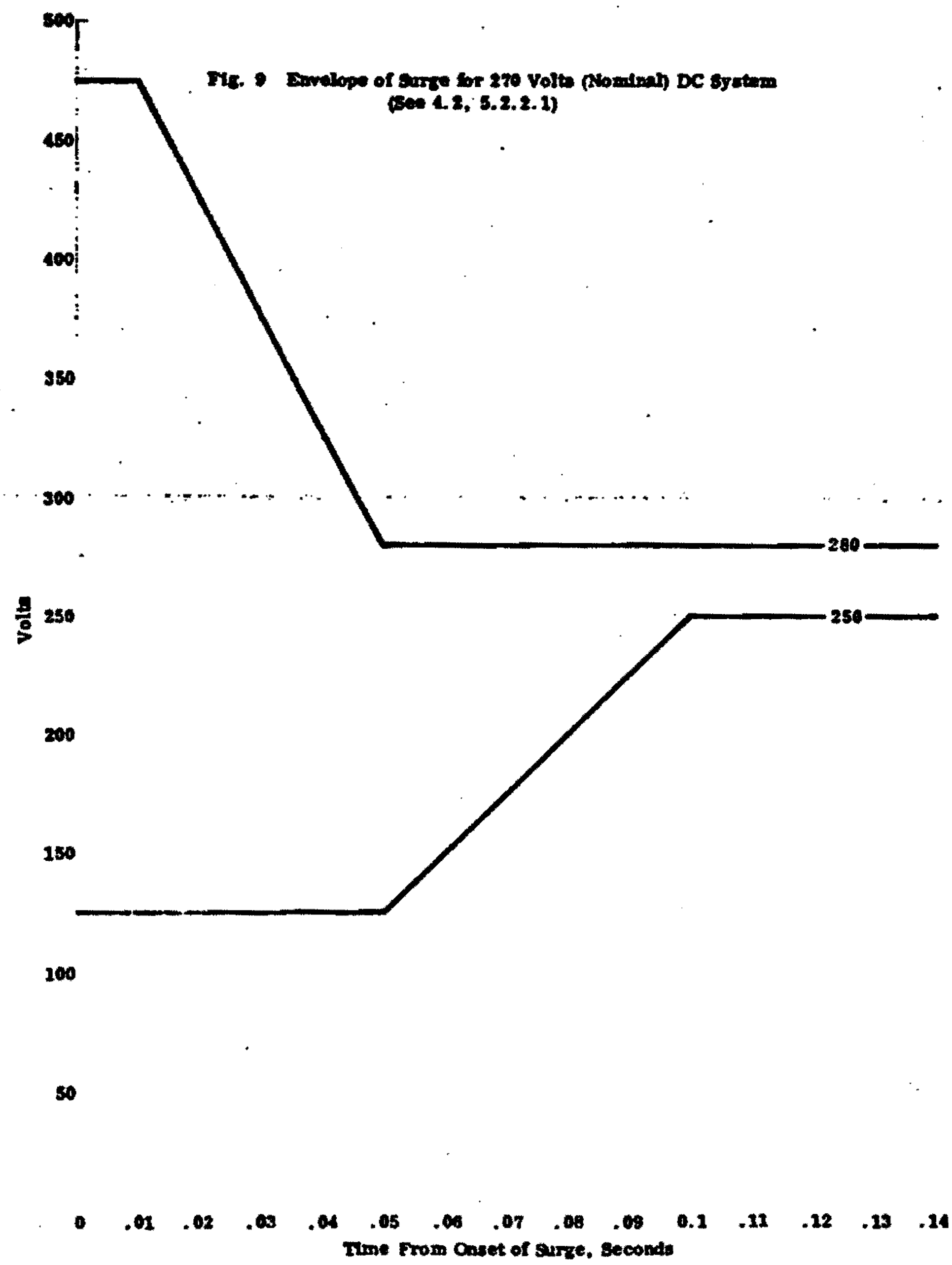


Fig. 8 DC Limits for Constant Overvoltage or Undervoltage
(SEE 5.2.3)

Fig. 9 Envelope of Surge for 270 Volts (Nominal) DC System
(See 4.2, 5.2.2.1)



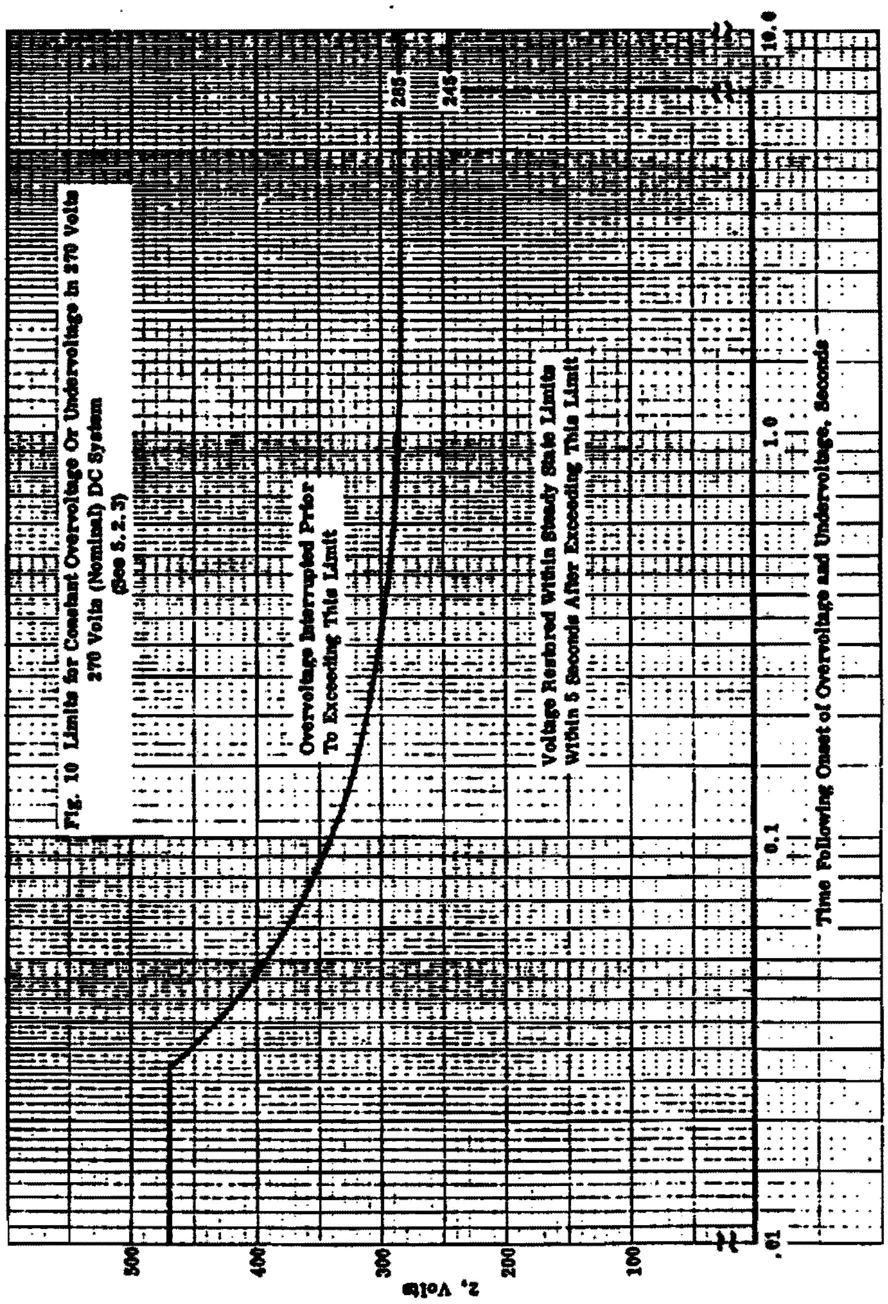


Fig. 10 Limits for Constant Overvoltage Or Undervoltage In 270 Volts
270 Volts (Nominal) DC System
(See 5.2.3)

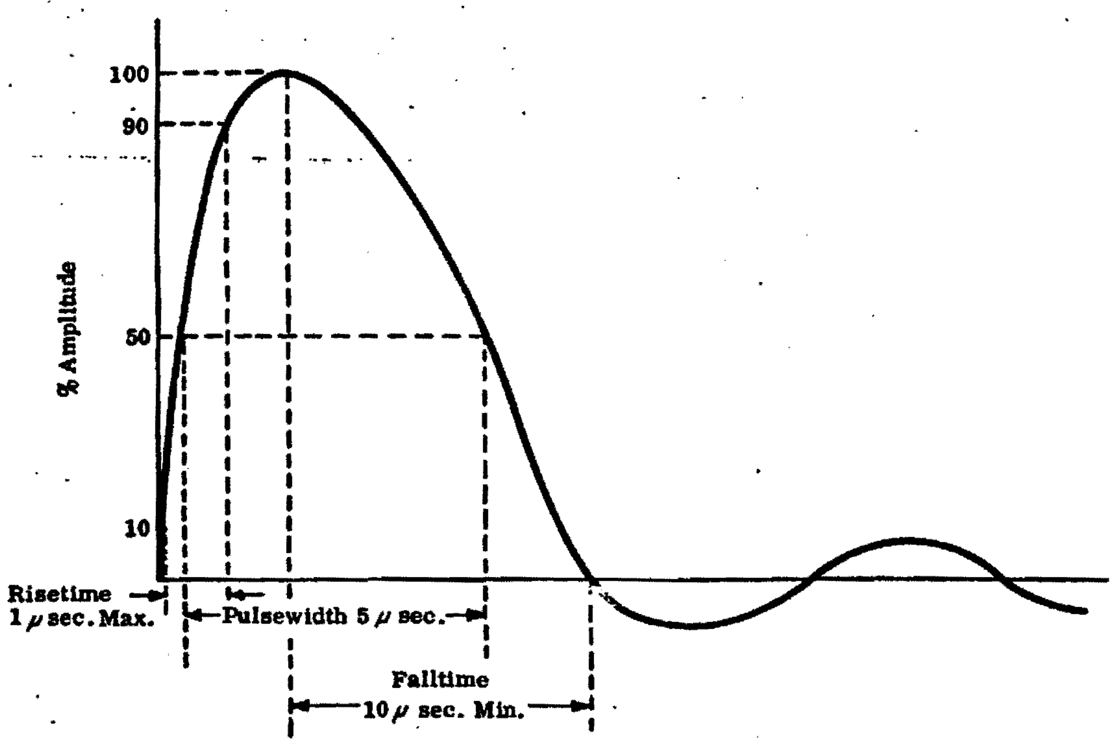


Fig. 11. Example for spike waveform showing time parameters. (See 5.4.5.1)