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ELECTRICAL POWER SUPPLY SYSTEMS BELOW 650 VOLTS

PART 6: 28 VOLT DC ELECTRICAL SYSTEMS IN MILITARY VEHICLES

AMENDMENTS ISSUED SINCE PUBLICATION

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Revision Note

This Standard has been revised to align equipment tests with the requirements of Def Stan 59-41(Part 3) and has been structured to conform with Def Stan 00-00(Part 2)/1.

Historical Record

INTERIM Def Stan 61-5(Part 6) - dated 19 September 1968
Def Stan 61-5(Part 6) - Issue 1 dated 17 September 1973
Def Stan 61-5(Part 6) - Issue 2 dated 30 November 1974
Def Stan 61-5(Part 6) - Issue 3 dated 18 July 1979
Def Stan 61-5(Part 6) - Issue 4 dated 5 December 1984

ELECTRICAL POWER SUPPLY SYSTEMS BELOW 650 VOLTS

PART 6: 28 VOLT DC ELECTRICAL SYSTEMS IN MILITARY VEHICLES

PREFACE

This Defence Standard supersedes Def Stan 61-5 (Part 6) Issue 4 dated 5 December 1984

i This Defence Standard applies to 28V dc Electrical Systems in Military Vehicles, for Ministry of Defence use.

ii The 61-5 series Defence Standards comprises the following:

Def Stan 61-5(Part 1) - Terminology and Definitions
Def Stan 61-5(Part 2) - Ground Generating Set Characteristics
Def Stan 61-5(Part 3) - Distribution and Protection Requirements
Def Stan 61-5(Part 4) - Power Supplies in HM Ships
Def Stan 61-5(Part 6) - 28 Volt DC Electrical Systems in Military Vehicles

iii This Standard has been prepared by RARDE(CH) in collaboration with "Defence Electrical and Electronic Standardization Committee" (DELSC) L4 who will be responsible for amending or updating as the need arises.

iv This Standard has been agreed by the authorities concerned with its use and shall be incorporated whenever relevant in all future designs, contracts, orders etc and whenever practicable by amendment to those already in existence. If any difficulty arises which prevents application of the Defence Standard, the Directorate of Standardization shall be informed so that a remedy may be sought.

v Any enquiries regarding this Standard in relation to an invitation to tender or a contract in which it is invoked are to be addressed to the responsible technical or supervising authority named in the invitation to tender or contract.

vi This Standard has been devised for the use of the Crown and of its contractors in the execution of contracts for the Crown and, subject to the Unfair Contract Terms Act 1977, the Crown will not be liable in any way whatever (including but without limitation negligence on the part of the Crown its servants or agents) where the Standard is used for other purposes.

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0 Introduction

The purpose of this Defence Standard is to ensure electrical compatibility between military (ground) vehicular power supplies and installed utilization equipment requiring a nominal 28V supply.

1 Scope

This Standard defines the characteristics for all military vehicle nominal 28V electrical systems, whether these are derived direct from a propulsive engine driven generator, a separate auxiliary power unit (APU), a transformer rectifier unit (TRU) or converter.

In addition, it also defines the number of tests required to demonstrate compliance with the requirements of this Standard in annexes B, C and D.

By application of these tests and compliance with the defined limits, the electrical compatibility of utilization equipment, including radio and other non-automotive electronic/electrical systems, with the vehicle supplies should be ensured.

2 WARNING

This Standard calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and in no way absolves either the supplier or the user from statutory obligations relating to health and safety at any stage of manufacture or use.

3 Related Documents

3.1 The following documents and publications are referred to in this Standard:

Def Stan 00-35	Environmental Handbook for Defence Material
Def Stan 59-41 (Part 1)	Electromagnetic Compatibility: General Requirements
Def Stan 59-41 (Part 3)	Electromagnetic Compatibility: Technical Requirements, Test Methods and Limits

3.2 Related Documents are available from the following addressees:

DOCUMENT	SOURCE
IEC Publications	BSI Sales Department Linford Wood MILTON KEYNES MK14 6LE
Defence Standards	Directorate of Standardization Stan 1 Kentigern House 65 Brown Street GLASGOW G2 8EX

4 Definitions

The following definitions are to be used for the purposes of this Standard, in preference to those in Def Stan 61-5(Part 1).

NOTE: Due to common usage of the terms transient, spike and surge, as defined in previous issues of this Standard, the term spike is still used instead of specifying the equivalent definition for a transient (spike) in Def Stan 59-41, Part 1.

4.1 Military vehicle. For the purposes of this Standard a 'Military Vehicle' is one intended for service with the British Armed Forces whose electrical distribution system has been designed for the installation of radio and/or other non-automotive electrical/electronic equipment.

4.2 Generating system. All equipments necessary to provide a nominal 28V supply at the main distribution point.

4.3 Utilization equipment. Any individual unit, or group of units, to which electrical power is supplied from the vehicle generating system via the main distribution point.

4.4 Steady state condition. The condition in which circuit parameters remain essentially constant, occurring after all initial transients and fluctuating conditions have subsided. It is the condition where, during normal system operation, only inherent or natural changes occur, ie no fault occurs and no deliberate change is made to any part of the system. For this reason, the steady state condition is defined by upper and lower voltage limits in this Standard.

4.5 Ripple. All regular and irregular variations of voltage about a nominal dc voltage level during steady state operation of a dc system.

4.6 Transient. A changing condition which departs from the steady state limits and returns to the steady state limits within a specified time period. transients are generally subdivided into surges and spikes as defined below.

4.6.1 Surge. A surge is any transient variation from the controlled steady state level lasting for a period >5ms. The recovery time of a surge is the interval between the time the voltage deviates from the steady state limits and the time it returns to, and remains within, those limits (see figure 1). A surge is usually the result of inherent regulation of the generating system and remedial action by the regulator, initiated by a change in demanded power, or power feed-back from a regenerative system.

4.6.2 Spike. A spike is a high frequency oscillatory variation from the surge or the steady state limits lasting <5ms. It generally results from the switching of reactive loads. Such action often generates a train of spikes, each of which attains a high amplitude in less than 1µs. An individual spike typically lasts less than 50µs but the train may take several milliseconds to decay to the surge or steady state limits.

4.7 Starting disturbance. This is an undervoltage variation from the prevailing steady state level. It is caused by engine starter engagement and cranking of the engine. A voltage profile illustrating an idealized 'Initial Engagement Surge' and 'Cranking Level Voltage' is shown in figure 2. The duration of the initial engagement surge is measured from the instant at which the voltage falls below the relevant lower steady state limit, to the instant that the cranking level voltage is maintained above a specified minimum value, for the appropriate mode of starting. Cranking extends from the end of the engagement surge until the starter is disengaged.

4.8 Auxiliary power unit (APU). This is an auxiliary (non-propulsive) power unit (or Generating Unit, Electric (GUE)) which is primarily used to provide electric power for non-automotive systems.

4.9 Vehicle electrical system functional conditions

4.9.1 Generator plus batteries. This applies when the electrical system is fault free and the generator is on-line maintaining the nominally fully charged status of the batteries.

4.9.2 Battery only. This applies when the electrical system is fault free and is being supplied by the batteries only.

4.9.3 Battery starting. This applies when starting the engine(s) using the on-board batteries.

4.9.4 Generator assisted starting. This applies when starting an engine from the on-board batteries which are being augmented by a separate engine driven generator, eg an APU.

4.9.5 Slave starting. This applies when an engine is being started from an adjacent vehicle utilizing an inter-vehicle slave lead. This is generally a standard requirement for military vehicles.

4.9.6 Generator only condition. This applies as a consequence of the need to meet a generating system single fault design requirement, which automatically results in degradation of the electrical performance. A malfunction of the regulator system or failure of the vehicle batteries are considered to be the most arduous single fault design conditions to be met. As it is difficult and impractical to specify a regulator system fault, only the second of these conditions is simulated for the tests specified in annexes B, C and D. Simulation is achieved by disconnection of all vehicle batteries from the generating system hence, this condition is referred to as the 'generator only condition; rather than the 'single fault condition'.

NOTE: When subjected to tests simulating the above vehicle electrical system conditions, utilization equipment shall function as follows:

(a) operate normally during conditions described in **4.9.1** and **4.9.2;**

(b) survive during conditions described in **4.9.3, 4.9.4, 4.9.5** and **4.9.6** and continue to operate thereafter, without the need for operator intervention.

5 Climatic Conditions

5.1 The characteristics defined in this Standard shall apply over the range of climatic conditions in Def Stan 00-35 as specified by the Project Manager for the vehicle.

5.2 It is not essential that vehicle testing (annex B) be carried out over the full range of climatic conditions, provided that adequate utilization and generating system equipment level tests (annexes C and D) are carried out over an appropriate range of climatic conditions, to the satisfaction of DGDQA.

6 Vehicle Electrical System Characteristics

6.1 General. All equipment shall be so designed and installed that the maximum voltage drop between the regulator sensing point and utilization equipment terminals shall not exceed 2V when operating under all steady state conditions. The following characteristics apply at the designated main distribution terminals.

6.2 Generator plus battery condition

6.2.1 Steady state voltage. The voltage limits, including ripple peaks, shall be 25V and 30V.

6.2.2 Ripple. The peak-to-peak ripple voltage shall be less than 4V.

NOTE 1: In this Standard, the ripple voltage amplitude is specified over a nominal bandwidth of dc to 10kHz.

NOTE 2: The control of ripple current versus frequency is separately exercised by the application of test DCE01 of Def Stan 59-41 (Part 3).

6.2.3 Surges. All surges resulting from system operation shall be within the limits shown in figure 3.

6.2.4 Spikes. All spike voltages, resulting from system operation, shall not exceed the following absolute values:

(a) +130V and/or -100V;

(b) +90V and/or -60V for a period of not longer than 10µs;

(c) +70V and/or -40V for a period of not longer than 5ms.

NOTE: This does not conflict with the maximum permitted level of exported transient (spike) voltages at utilization equipment terminals (see Def Stan 59-41(Part 3)) as the conditions of test and measurement differ.

6.3 Battery only condition

6.3.1 Steady state voltage. The voltage limits, including utilization equipment ripple peaks, shall be 22V and 27V.

6.3.2 Ripple. The peak-to-peak ripple voltage shall be less than 4V.

NOTE 1: In this Standard, the ripple voltage amplitude is specified over a nominal bandwidth of dc to 10kHz.

NOTE 2: The control of ripple current versus frequency is separately exercised by the application of test DCEO1 of Def Stan 59-41(Part 3).

6.3.3 Surges. Surges, by definition, are not applicable to the battery only condition. Transients, however, can occur as a result of heavy load switching, which may depart from the steady state limits.

NOTE 1: Any non-regenerative switching action resulting in a surge voltage which departs from the steady state limits will, by definition, transfer the system into a fault condition for the duration of the excursion. During this excursion, therefore, the surge limits of the Generator Only Condition shall apply.

NOTE 2: For a regenerative switching action the surge limits for the Generator Plus Battery Condition shall apply.

6.3.4 Spikes. All spike voltages, resulting from system operation shall not exceed the following absolute values:

(a) +130V and/or -100V;

(b) +90V and/or -60V for a period of not longer than 10µs;

(c) +70v and/or -40V for a period of not longer than 5ms.

NOTE: This does not conflict with the maximum permitted level of exported transient (spike) voltages at utilization equipment terminals (see Def Stan 59-41(Part 3)) as the conditions of test and measurements differ.

6.4 Generator Only Condition

6.4.1 Steady state voltage. The voltage limits, including ripple peaks, shall be 15V and 40V.

6.4.2 Ripple. The peak-to-peak ripple voltage shall be less than 14V.

NOTE 1: In this Standard, the ripple voltage amplitude is specified over a nominal bandwidth of dc to 10kHz.

NOTE 2: The control of ripple current versus frequency is separately exercised by the application of test DCE01 of Def Stan 59-41(Part 3).

6.4.3 Surges. All surges resulting from system operation shall fall within the limits shown in figure 4.

6.4.4 Spikes. All spike voltages, resulting from system operation shall not exceed the following absolute values:

(a) +280V and/or -220V;

(b) +130V and/or -70V for a period of not longer than 10µs;

(c) +110V and/or -50V for a period of not longer than 5ms.

NOTE: This does not conflict with the maximum permitted level of exported transient (spike) voltages at utilization equipment terminals (see Def Stan 59-41(Part 3)) as the conditions of test and measurement differ.

6.5 Battery starting condition

6.5.1 Steady State voltage. The voltage limits shall be 22V and 27V.

6.5.2 Starting disturbances

6.5.2.1 Initial engagement surge. During the engagement the voltage shall not fall below 1V. The duration shall not exceed 1s.

6.5.2.2 Cranking level voltage. During cranking the voltage level shall be greater than 10V.

NOTE: During cranking no electrical equipment is expected to operate, other than the possible exception of a fuel pump and the ignition system, hence the duration of cranking does not require definition.

6.6 Generator assisted starting condition

6.6.1 Steady state voltage. The voltage limits, including ripple peaks, shall be 25V and 30V.

6.6.2 Starting disturbances

6.6.2.1 Initial engagement surge. During the engagement the voltage shall not fall below 6V. The duration shall not exceed 1s.

6.6.2.2 Cranking level voltage. During cranking the voltage level shall be greater than 15V.

NOTE: During cranking no electrical equipment is expected to operate, other than the possible exception of a fuel pump and the ignition system, hence the duration of cranking does not require definition.

6.7 Slave starting. In this condition it is expected that no equipment will be operating in the vehicle being started and the limits apply only to the slave vehicle supplying the power through the inter-vehicle slave lead. Should the parameters depart from those specified for self-starting, the slave vehicle will be deemed to have transferred to a fault condition during cranking.

7 Test Methods

Methods of testing vehicles, utilization equipment and generating equipment, together with limits, are given in annexes B, C and D respectively.

8 Influence of Equipment on Vehicle Electrical System

When the system is functioning in a fault-free condition (see **4.9.1** and **4.9.2)** neither the utilization nor the generating system equipments shall cause the vehicle electrical system characteristics to exceed the appropriate limits specified in **6.2** and **6.3.**

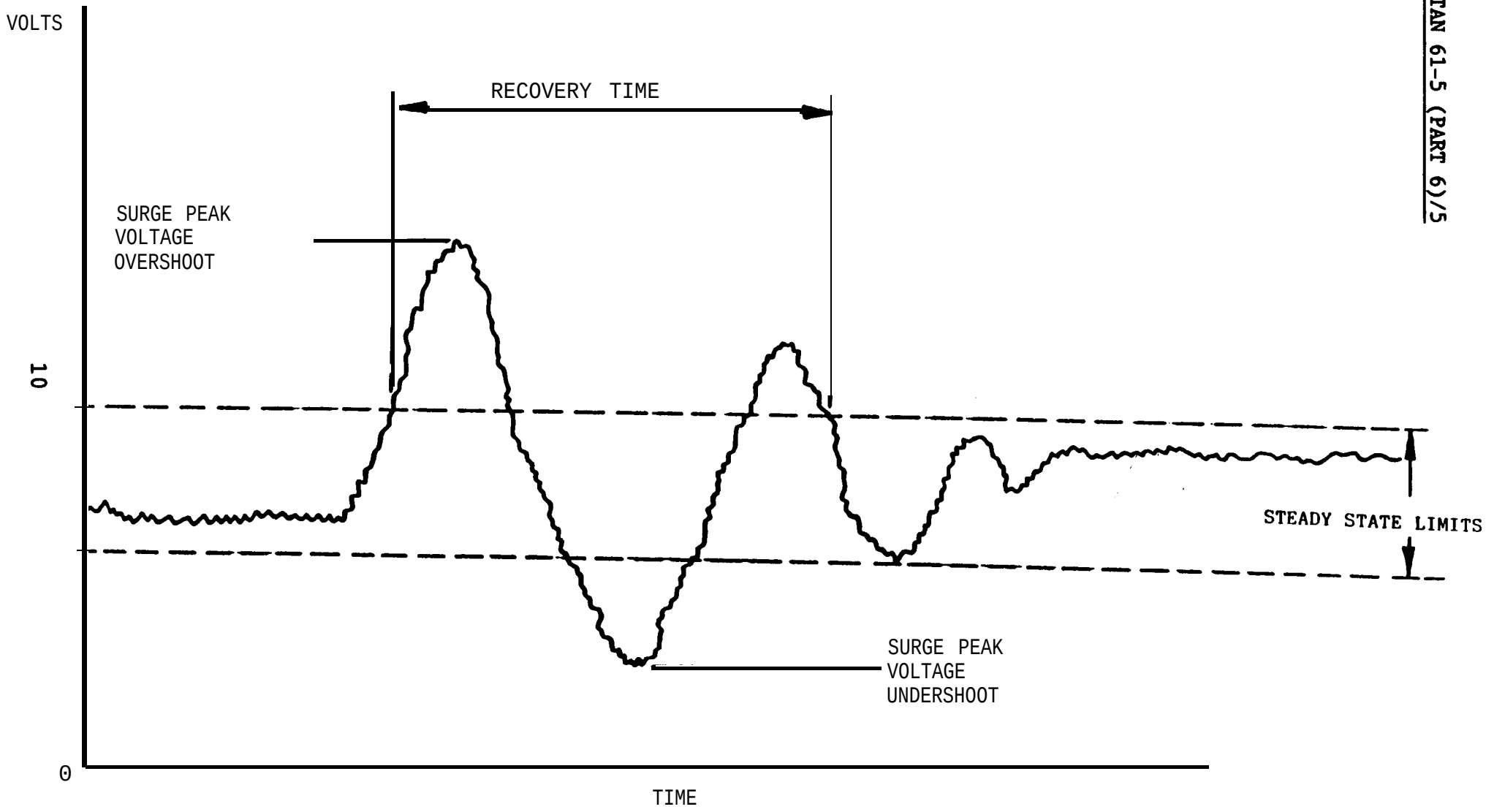

FIGURE 1 ILLUSTRATIVE SURGE WITH RECOVERY TIME

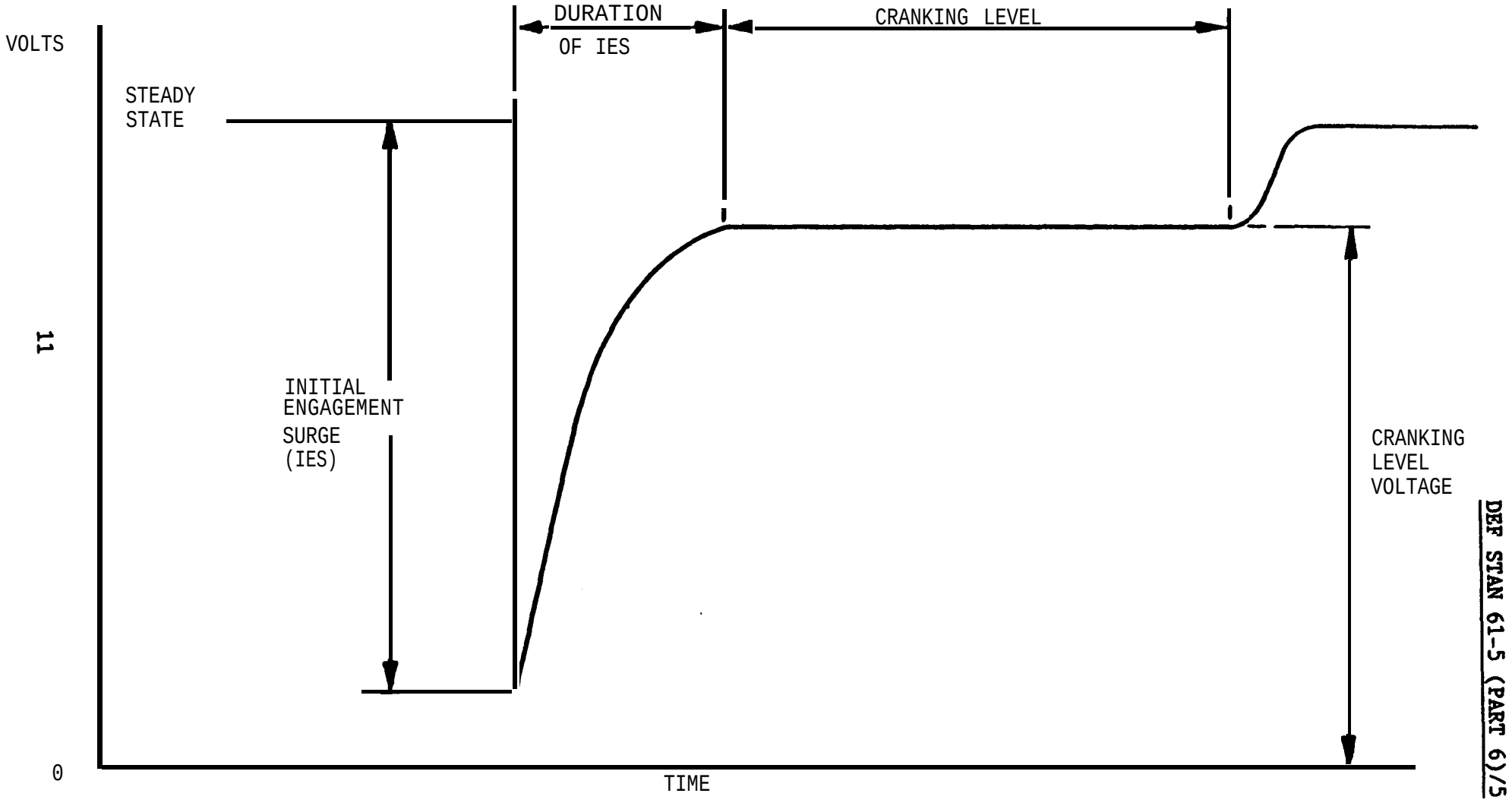

FIGURE 2. STARTING DISTURBANCES

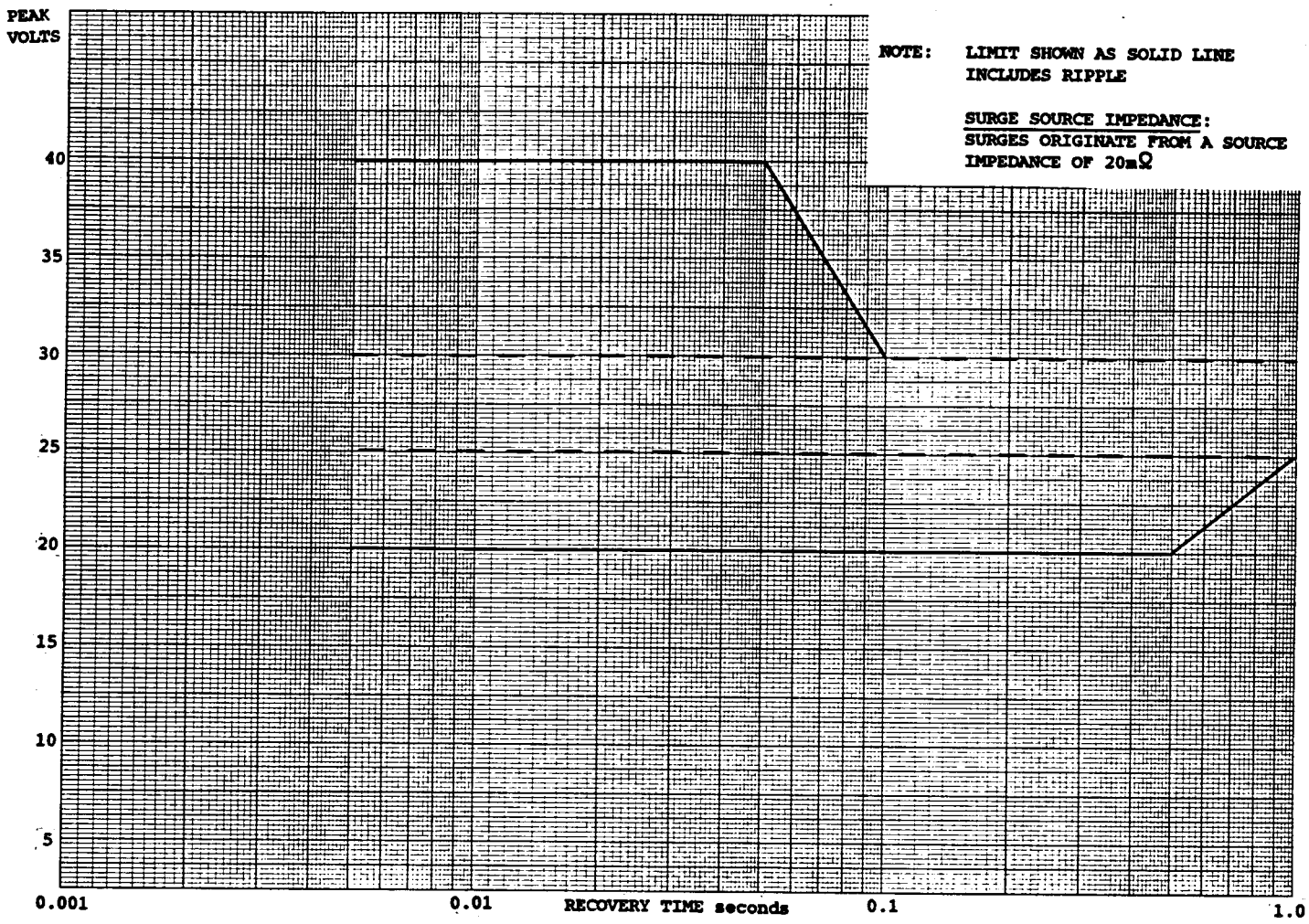

Fig 3 Surge Limit Generator Plus Battery Condition

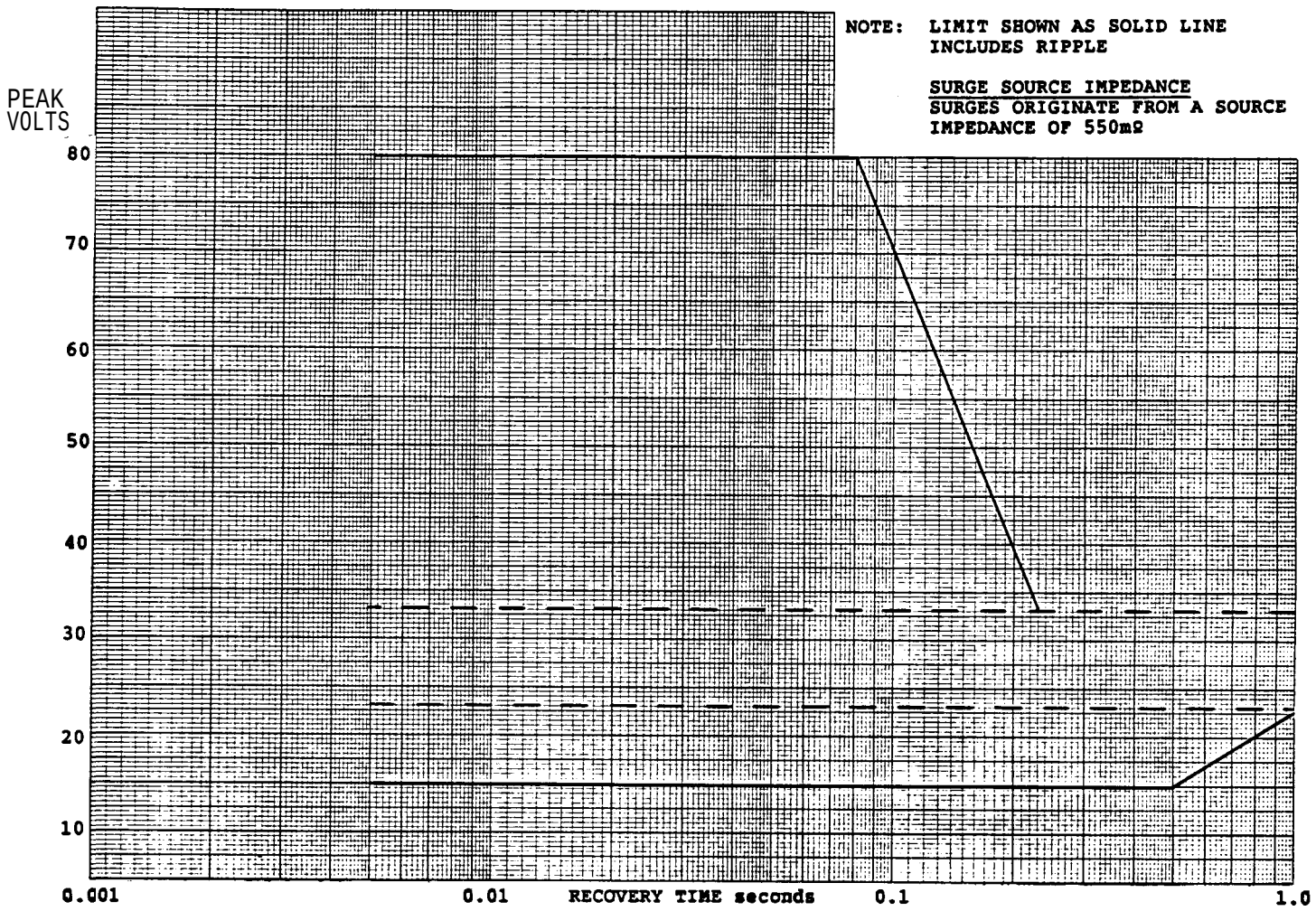

Fig 4 Surge Limit Generator Only Condition

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Implementation of QSTAG 307

QSTAG 307

(Amendment 2)

Characteristics of 28V DC Electrical Systems in Military Vehicles

Substance of Agreement

The armies of the United States, United Kingdom, Australia and the Canadian Forces agreed to a Design Standard to establish the characteristics of 28V electrical systems in military vehicles.

NOTE: A 'military vehicle' is defined by the United States and Australia as any military ground vehicle, with the exception of those primarily of commercial design.

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Recommended Vehicle Electrical System Tests

B.1 Introduction

This annex defines the minimum number of tests and conditions necessary to demonstrate compliance with the limits detailed in clause **6** of this Standard. These tests and required limits are summarized in table **B.1.**

B.2 Monitoring Points

The monitoring points shall be determined by the QA authorities and shall be of sufficient number to ensure that the results obtained are fully representative of all conditions of operation of the vehicle electrical system. Monitoring points shall include:

(a) the main distribution terminals (generator system output);

(b) at least one secondary distribution point, eg Turret Distribution Box, Radio Junction Box and the Regulator Sensing Point.

B.3 Engine Speed

All tests with the exception of the spike test shall be conducted for the following engine speed conditions:

(a) tickover speed sufficient to guarantee generator is on-line and capable of supplying power;

(b) minimum speed sufficient to provide maximum continuous rated power (current) output;

(c) mid-range speed (typical cruising speed);

(d) maximum permitted continuous speed.

NOTE: Nominal fixed speed engines shall be run at their design on-line speed only.

B.4 Test Equipment

This shall consist of an oscilloscope and a 10kHz low pass filter. The oscilloscope shall have an input impedance equivalent to a resistance of not less than 1Mohm, shunted by a capacitor of not greater than 50pF and have a 3dB bandwidth of not less than 50MHz. Circuit details of a suitable filter together with performance requirements are given in figures B.1a and B.lb. The oscilloscope shall be capable of a measurement accuracy of better than 5%.

B.5 Battery Condition

The vehicle batteries should be as new and, prior to the tests, charged to between 40% and 80% by running the vehicle generator. Measurement of the level of charge by determination of the sg of the cells is adequate.

B.6 Test Procedure

B.6.1 Ripple

B.6.1.1 Method of Measurement. Connect the oscilloscope and 10kHz low pass filter to each selected monitor point in turn using the defined lead length for the filter. Then with the system successively in the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition, measure the ripple amplitude at each monitor point as follows:

(a) with the generator under maximum utilization equipment load;

(b) with the generator supplying power to selected individual equipments/ sub-systems which are expected to produce relatively high levels of ripple (eg rotating machines, static inverters etc).

NOTE 1: Sweep times greater than 1s are not required.

NOTE 2: For multi-engined vehicles, measurements at **B.6.l.l(a)** and **B.6.l.l(b)** shall be carried out on the generating systems individually. Where generating systems are designed to run in parallel to increase total power output, the maximum equipment load measurements shall also be made during combined generating system operating. The appropriate design authority should be consulted to establish whether there are any design limitations on the combined output before applying the maximum equipment load.

B.6.2 Surges

B.6.2.1 Method of Measurement

B.6.2.1.1 Connect the oscilloscope and 10kHz low pass filter to each selected monitor point in turn using the defined lead length for the filter. Then with the system successively in the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition, measure the surges at each monitor point produced by:

(a) switching ON and OFF each utilization equipment likely to produce a significant surge;

(b) switching an external load from 10% to 85% to 10% of system rated capacity.

NOTE 1: For multi-engined vehicles, surge measurements shall be carried out on the generating systems individually. Where generating systems are designed to run in parallel to increase total power output, surge measurements related to the rated capacity of the combined generating system shall also be carried out. The appropriate design authority should be consulted to establish whether there are any design limitations on the combined output before applying the maximum combined load.

NOTE 2: On vehicles where it is not possible to limit the load to 10% of the maximum continuous rated load, the minimum load to sustain engine running shall be used.

B.6.2.1.2 Record trace of the 'worst case' surge and retain for reference.

B.6.3 Spikes

B.6.3.1 Additional measuring equipment. The use of a memory voltmeter is recommended to confirm that the true peak level has been captured by the oscilloscope. The combined impedance of the oscilloscope and the memory voltmeter should not be less than the minimum values stated for the oscilloscope alone.

B.6.3.2 Method of measurement

B.6.3.2.1 During this test all equipment (including roof/maintenance lights), other than the one actually being operated, shall be in the OFF position.

B.6.3.2.2 Connect the oscilloscope without the 10kHz filter to the selected monitoring point using the shortest possible lead length. Ensure the vehicle is in the Battery Only (Fault Free) Condition. Operate the equipment capable of being supplied from the batteries, switching each equipment ON and OFF at least 10 times and measure the maximum voltage amplitude and the duration of the spike. In the event of a train of spikes being present measure the overall duration.

NOTE: 20 operations should give a reasonable probability that spikes of maximum amplitude and duration are obtained.

B.6.3.2.3 With engine speed set at the mid-range value or its fixed speed value as appropriate, repeat the tests in both the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition again ensuring that all equipment not under test is switched OFF.

B.6.3.2.4 Record the trace of the 'worst case' spike in each limit category and retain for reference.

B.6.4 Starting disturbances

B.6.4.1 Method of measurement

B.6.4.1.1 Connect the oscilloscope and 10kHz filter to the main distribution point, using the defined lead length for the filter, and measure the starting disturbances for each engine with the vehicle in the Battery Starting Condition.

B.6.4.1.2 On multi-engined vehicles, measurements are also to be made in the Generator Assisted Starting Condition.

NOTE: Separate testing for slave starting is not required.

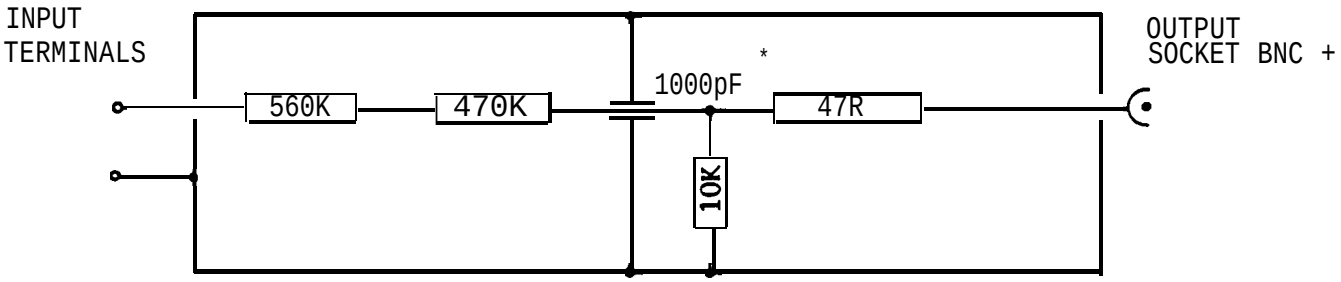
B.6.4.1.3 Record trace of engagement surge and cranking level and retain for reference.

Table B.1

Vehicle Electrical Systems

Summary of Tests and Limits

CONDITION	STEADY STATE	RIPPLE	SURGE LIMITS	SPIKE LIMITS	STARTING DISTURBANCES		GENERATOR LOADING	ENGINE SPEEDS (Other than fixed) speed motors)
					INITIAL ENGAGEMENT SURGE	CRANKING LEVEL VOLTAGE		
GENERATOR plus BATTERY (Fault free condition)	25V to 30V incl. ripple peaks	< 4V peak to peak	Fig. 3	a) +130V/-100V peak b) +90V/-60V peak for 10µs max. c) +70V/-40V peak for 5ms max.	-	-	a) Max (equip load). b) Selected equipment loads.	1) Tick Over. Gen. on line. 2) Min. speed for max. rated Gen. O/P continuous current. 3) Mid range. (Avg between 2 & 4) 4) Max permitted.
BATTERY ONLY	22V to 27V incl ripple peaks	< 4V peak to peak	N/A	As above	-	-	a) Max (equip load) b) Selected equipment loads.	N/A
GENERATOR ONLY (Single fault condition	15V to 40V incl ripple peaks	< 14V peak to peak	Fig. 4	a) +280V/-220V peak b) +130V/-70V peak for 10µs max. c) +110V/-50V for 5ms max.	-	-	a) Max (equip load) b) Selected equip loads	1) Tick over. Gen on line 2) Min speed for max rated Gen O/P continuous current. 3) Mid range. (Avg between 2 & 4) 4) Max. permitted.
BATTERY STARTING	22V to 27V	-	-	-	Fig 2 >= 1V for 1 sec max duration.	Fig 2 >= 10V	-	-
GENERATOR ASSISTED STARTING	25V to 30V	-	-	-	Fig 2 >= 6V for 1 sec max duration.	Fig 2 >= 15V	-	-



* 1000pF lead thro' capacitor value adjusted on test to give 3dB bandwidth of 10kHz ± 10%.

\+ 3 metres of 50Ω coax cable used between filter and cro input.

NOTE 1: Filter to be used and calibrated with 3 metre coaxial cable.

NOTE 2: If longer cable is required capacitor must be adjusted to give correct bandwidth.

Fig B.1a Suggested Circuit Arrangement of 10kHz Filter

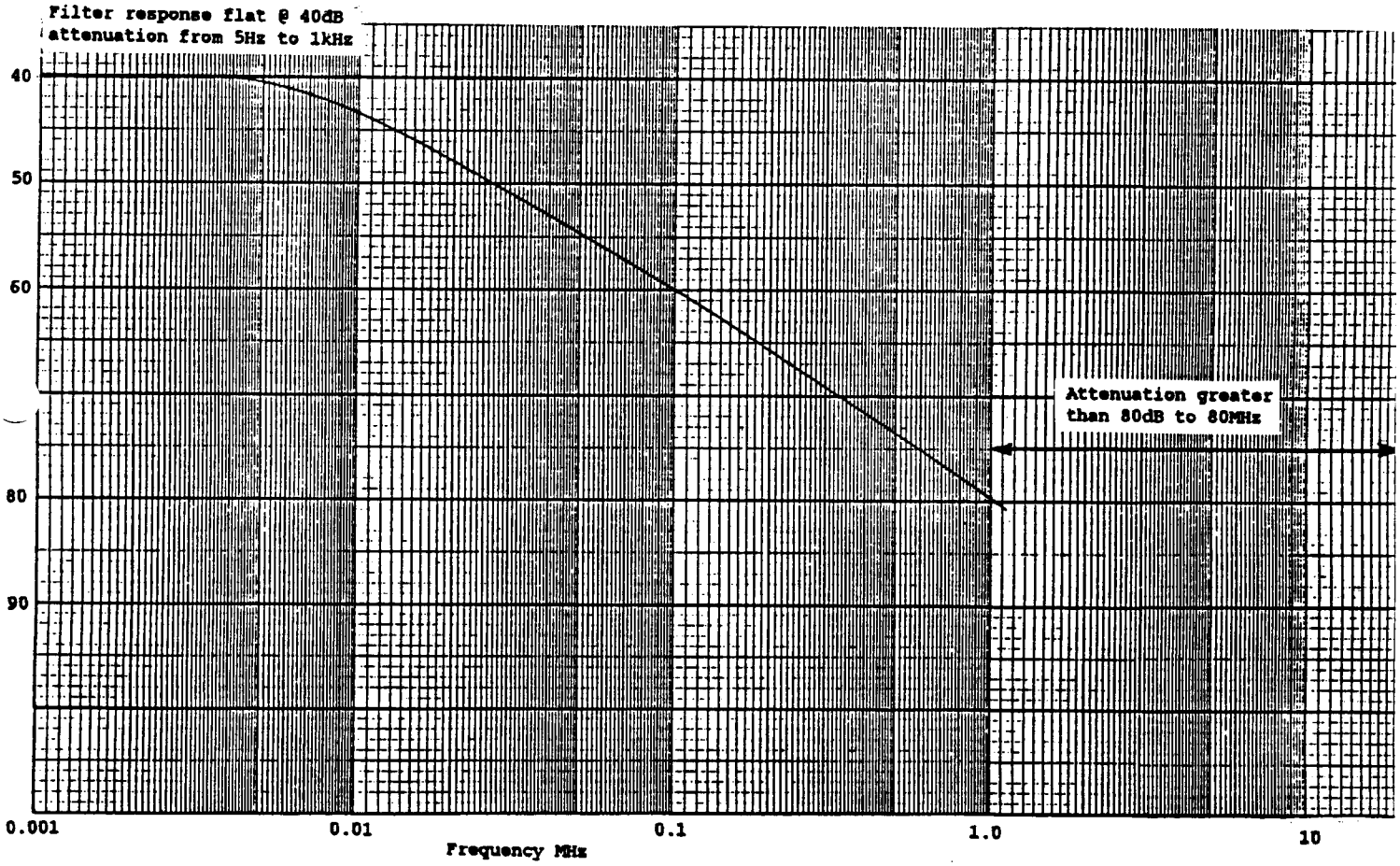


Fig B.1b Typical Frequency Response of 10kHz Filter + 3m Cable

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Recommended Utilization Equipment Tests

C.1 Introduction

C.1.1 This annex defines the minimum number of tests to demonstrate that utilization equipments should be compatible with vehicle electrical systems whose characteristics are defined in clause **6** of this Standard. These tests and required limits are summarized in table C.1.

C.1.2 It is the responsibility of the appropriate authority to specify the following:

(a) how the equipment shall function during and after these tests;

(b) the climatic conditions under which these tests are carried out.

NOTE: Any protection devices necessary for the equipment under test to meet the limits shall be included with the equipment under test.

C.2 Test Equipment

This shall consist of an oscilloscope and a 10kHz low pass filter. The oscilloscope shall have an input impedance equivalent to a resistance of not less than 1Mohm, shunted by a capacitor of not greater than 50pF, and have a 3dB bandwidth of not less than 50MHz. Circuit details of a suitable filter and performance requirements are given in annex B, figures B1a and B.1b. The oscilloscope shall be capable of a measurement accuracy of better than 5%.

C.3 Tests with Voltage Surges Imported into Equipment

C.3.1 For these tests, simulated overvoltage and undervoltage surges shall be applied to the equipment, whilst it is operating at a nominal battery voltage of 26.4V. It is intended that the vehicle electrical system shall be represented in both the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition.

C.3.2 The voltage surge sources specified in **C.3.3** and **C.3.4** shall have the amplitude stated before connection of the equipment. The nominal supply voltage shall be maintained, both before and after each surge, for a period sufficient to establish correct functioning of the equipment under test. The test shall be applied five times at intervals of not less than 1s.

C.3.3 The Generator Plus Battery (Fault Free) Condition test surges shall be:

(a) an overvoltage surge rising to +40V, +5/-0%, lasting for 50ms, from a source impedance no greater than 20mohms;

(b) an undervoltage surge falling to +20V, +0/-5%, lasting for 500ms, from a source impedance no greater than 10mohms.

C.3.4 The Generator Only (Single Fault) Condition test surges shall be:

(a) an overvoltage surge rising to +100V, +5/-0%, lasting for 50ms, from a source impedance no greater than 550mohms;

(b) an undervoltage surge falling to +15.4V, +0/-5% lasting for 500ms, from a source impedance no greater than 550mohms.

C.3.5 To generate the required voltage and source impedance, the use of nominal 100Ah lead acid batteries together with an appropriate series resistor is recommended. Before use all batteries should be fully charged, cell tested and left to stabilize.

NOTE: The following are suggested connections:

15.4 Volts ..... 7 cells, 20 Volts ..... 9 cells,
40 Volts ..... 18 cells, 100 Volts ..... 45 cells.

C.3.6 Recommended circuits for overvoltage and undervoltage surges are shown in figures C.1 and C.2 respectively.

C.3.7 In general, equipment shall continue to operate normally for the Generator Plus Battery (Fault Free) Condition overvoltage and undervoltage surge tests. When subjected to the Generator Only (Single Fault) Condition overvoltage and undervoltage surge tests, equipment need not function correctly but shall survive and continue to operate correctly without the need for any manual reset. The Project Office may, however, impose other conditions.

C.4 Tests for Ripple Exported from Utilization Equipment

C.4.1 The vehicle system is to be simulated by a lead acid battery of adequate capacity for the equipment under test, connected in series with an inductor of 5µH, ± 10%, for the Generator Plus Battery (Fault Free) Condition, or an inductor of 50µH ± 10% for the Generator Only (Single Fault) Condition as shown in figure C.3.

C.4.2 Connect the oscilloscope and the 10kHz low pass filter, using the defined lead length for the filter, across the equipment power input terminals. Then operate the equipment over its specified range of functions, measure and record the maximum peak-to-peak ripple voltage.

C.4.3 The ripple limits quoted in clause **6** of this Standard are those for the vehicle electrical system. Due to the additive effect of ripple from various sources it is not possible to allow any one equipment to export more than a proportion of the peak-to-peak limits. The proportion for each utilization equipment should be less than 75%.

C.4.4 The peak-to-peak ripple voltage shall not exceed 3V for the Generator Plus Battery (Fault Free) Condition or 10V for the Generator Only (Single Fault) Condition.

NOTE 1: Sweep times greater than 1s are not required.

C.4.4 (Contd)

NOTE 2: Frequency content of the ripple (low frequency emissions) is controlled by applying test DCE01 of Def Stan 59-41(Part 3) and extending the low frequency limit to a value specified by the Project Office. A frequency of 50Hz is suggested.

C.5 Tests for Ripple Imported into Utilization Equipment

This test is covered by Def Stan 59-41(Part 3), test DCS01.

C.6 Tests for Spikes Exported from and Imported into Equipment

These tests are covered by Def Stan 59-41(Part 3) tests DCE03 and DCS04.

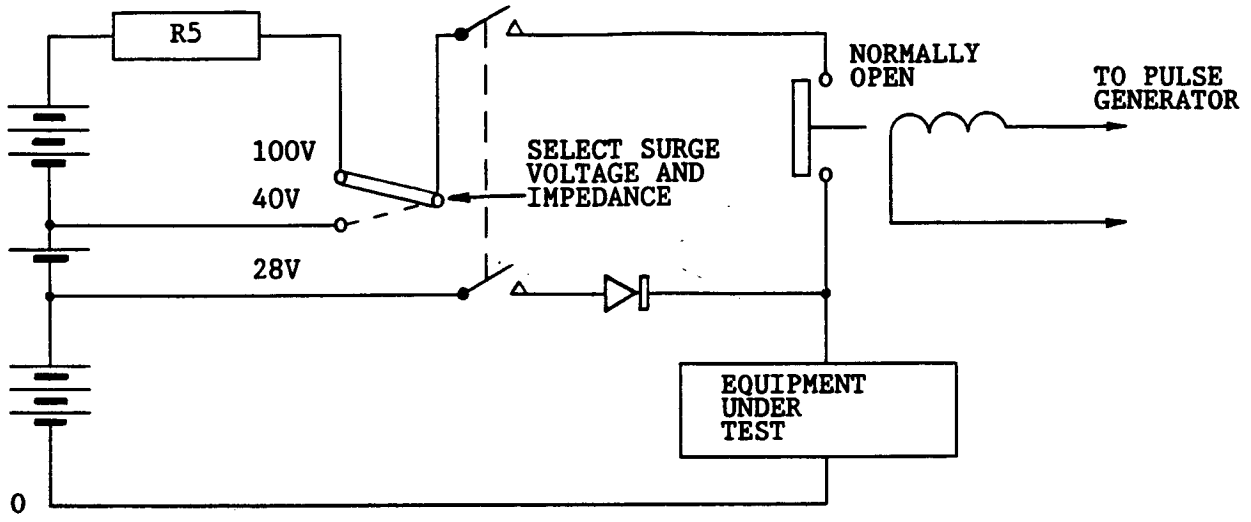
NOTE: In Def Stan 59-41(Part 1) a spike is referred to as a transient.

Table C.1

Utilization Equipment

Summary of Tests and Limits

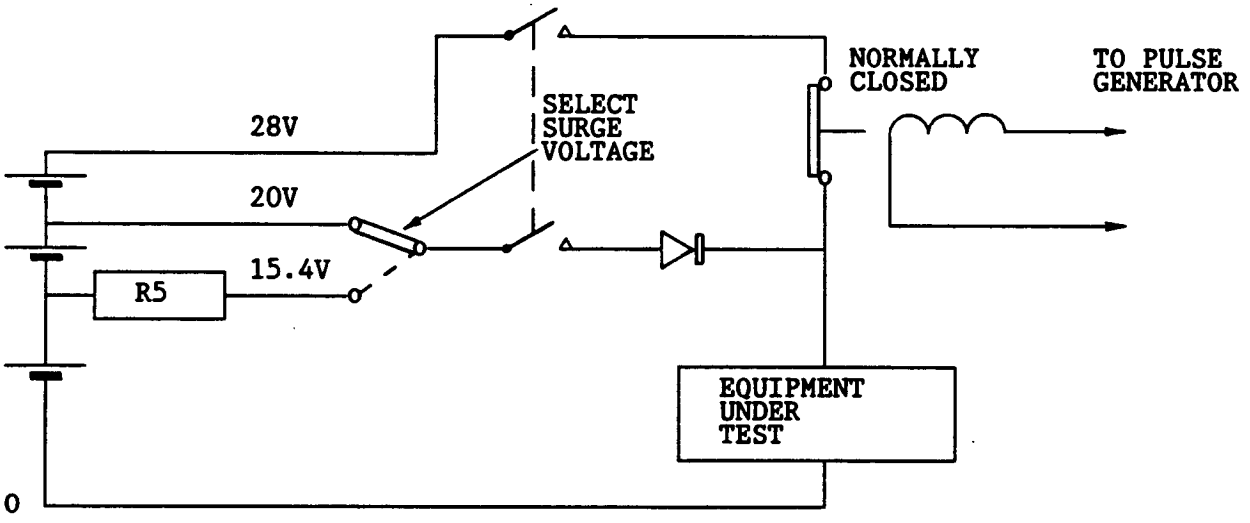
CONDITION	RIPPLE			SPIKES	SURGES
	EXPORTED		IMPORTED	IMPORTED AND EXPORTED	IMPORTED
	AMPLITUDE	FREQUENCY COMPONENTS	FREQUENCY COMPONENTS		
GENERATOR PLUS BATTERY	Max 3 volts peak to peak (DC to 10kHz) Test circuit in Fig C.3.	DEF STAN 59-41 Part 3 DCE01	DEF STAN 59-41 Part 3 DCS01	DEF STAN 59-41 Part 3 DCE03 and DCS04	40V for 50ms 20V for 500ms Test circuit in Fig C.1 and C.2
GENERATOR ONLY (Single fault condition)	Max 10 volts peak to peak (DC to 10kHz) Test circuit in Fig C.3	As above	As above	As above	100V for 50ms 15.4V for 500ms Test circuit in Fig C.1 and C.2



NOTE: Pulse generator produces 5 surges of 50ms duration at intervals of 1s between the commencement of each surge.

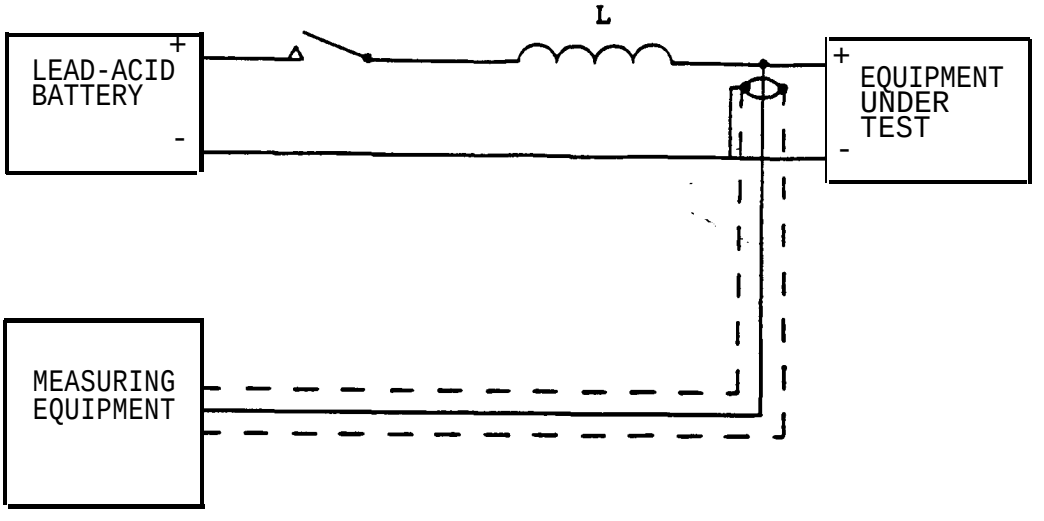
The value of the series resistor has been calculated assuming a battery source impedance of 1mohm per cell.

Fig C1 Imported Overvoltage Surge Test Circuit



NOTE: Pulse generator produces 5 surges of 50ms duration at intervals of 1s between the commencement of each surge.

Fig C2 Imported Undervoltage Surge Test Circuit



NOTE: L = 5μH for the simulated 'Generator Plus Battery' Condition or 50μH for the simulated 'Generator Only' Condition.

Fig C3 Utilization Equipment Exported Ripple Test Circuit

Recommended Generating Equipment Tests

D.1 Introduction

D.1.1 This annex defines the minimum number of tests necessary to demonstrate that a generating system should comply with the limits in clause **6** of this Standard, when installed in a vehicle. The tests and limits are summarized in table D.1.

NOTE: Any protection devices necessary to meet the limits shall be incorporated within the generating system.

D.1.2 It is the responsibility of the Project Office or appropriate authority to specify the following:

(a) how the equipment shall function during and after these tests;

(b) the climatic conditions under which these tests are carried out.

D.1.3 All tests shall be conducted for the following minimum number of engine speed conditions:

(a) minimum operating speed equivalent to an engine speed that would be sufficient to guarantee that the generator would be on-line and thus capable of supplying all intended design automotive loads;

(b) minimum speed which generates maximum rated continuous current;

(c) speed equivalent to maximum engine speed;

(d) speed midway between (b) and (c).

Nominal fixed speed engine generators shall be run at their design on-line speed only.

D.2 Test Equipment

This shall consist of:

(a) an oscilloscope with an input impedance equivalent to a resistance of not less than 1Mohm shunted by a capacitance of not greater than 50pF and having a 3dB bandwidth of not less than 50MHz;

(b) a 10kHz low pass filter. A suitable circuit and performance requirements are given in annex B, figures B.1a and B.1b;

(c) DC ammeters;

(d) non-inductively wound loads.

All test equipment shall be capable of a measurement accuracy of better than 5%.

D.3 Battery Load

Throughout all tests, batteries equivalent to those required in the intended vehicle shall be connected across the generating system output unless stipulated otherwise. At no time during testing shall the charging current be greater than 5% of the load current.

D.4 Load Range and Regulation Tests

D.4.1 Prior to testing, the regulator output shall be set to 28.5V, ± 0.5V. The generator shall then be run at speeds appropriate to those detailed in **D.1.3.** At each speed several incremental loads shall be applied up to that appropriate for maximum design rated current output. the voltage at the regulator sensing point for the test circuit shown in figure D.1 and the load current shall be recorded for each test condition.

D.4.2 Between any two load and speed conditions the voltage variation should not be greater than 50mV, ± 5mV.

D.5 Surge tests

D.5.1 Connect the oscilloscope and 10kHz low pass filter, using the defined lead length for the filter, to the regulator sensing point for the test circuit shown in figure D.2. With the system successively in the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition, measure the surges produced by switching a non-inductively wound load from 10% to 85% and 85% to 10% of the maximum continuous rated capacity. Record worst case surges.

D.5.2 All surges shall be less than the appropriate vehicle limits for each test condition.

NOTE: For multi-engined vehicles, surge measurements will normally be carried out on the generating systems individually. The Design Authority may, however, require additional tests on a paralleled system.

D.6 Exported Ripple Tests

D.6.1 Connect the oscilloscope and 10kHz low pass filter, using the defined lead length for the filter, to the regulator sensing point for the test circuit shown in figure D.2. Measure the peak-to-peak ripple amplitude successively in the Generator Plus Battery (Fault Free) Condition and the Generator Only (Single Fault) Condition for all generator speeds defined in **D.1.3,** with loads of 10%, 50% and 85% of the maximum continuous rated output applied.

D.6.2 Due to the additive effect of ripple from various sources it is not possible to allow any one equipment to export more than a proportion of the vehicle peak-to-peak limits. The proportion for generating equipment should be less than 90%. Therefore, the peak-to-peak ripple shall not exceed 3.6V for the Generator Plus Battery (Fault Free) Condition and not exceed 12.6V for the Generator Only (Single Fault) Condition.

NOTE 1: Sweep times greater than 1s are not required.

D.6.2 (Contd)

NOTE 2: Frequency content of the ripple (low frequency emissions) are controlled by applying test DCE01 of Def Stan 59-41(Part 3) and extending the low frequency limit to a value specified by the Project Office. A frequency of 50Hz is suggested.

D.7 Imported Ripple Tests

Electronic regulators shall be subjected (independent of generators) to the appropriate conducted and radiated EMC susceptibility tests in Def Stan 59-41(Part 3).

D.8 Exported Spikes Test

This test is covered by Def Stan 59-41(Part 3), test DCE03.

D.9 Imported Spike Test

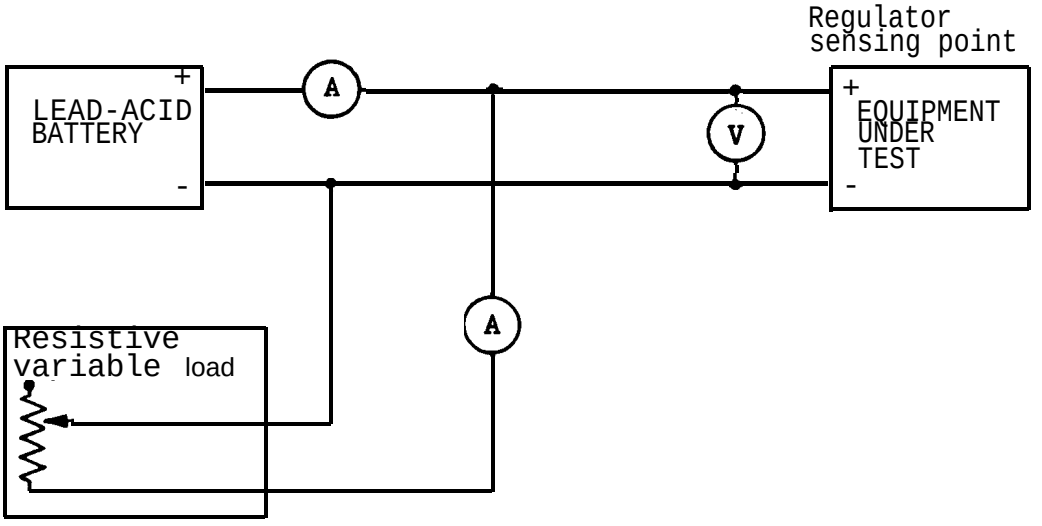
Electronic regulators shall be subjected (independent of generators) to be imported transient (spike) test DCS04 of Def Stan 59-41(Part 3).

Table D.1

Generating Equipment

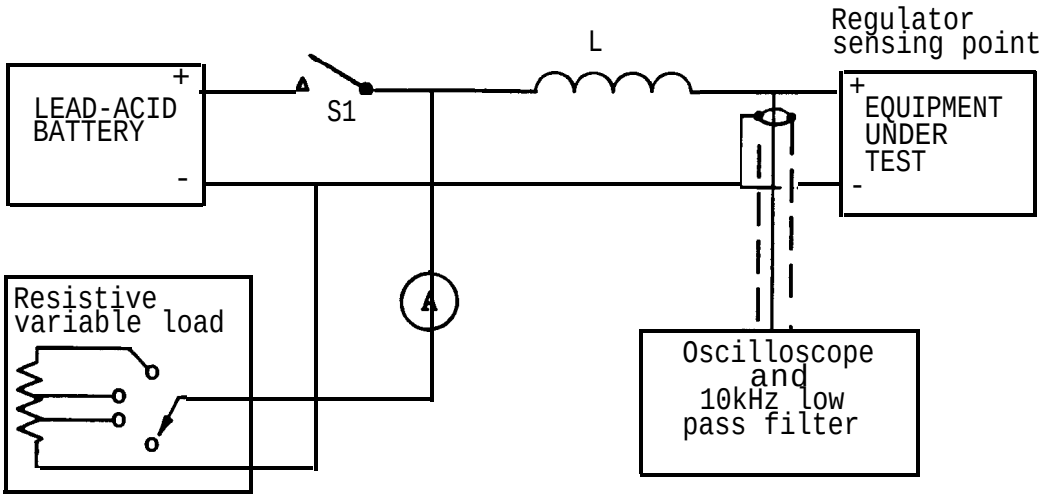
Summary of Tests and Limits

CONDITION	RIPPLE EXPORTED PEAK	RIPPLE EXPORTED FREQUENCY COMPONENTS	SURGES	SPIKES IMPORTED AND EXPORTED	GENERATOR LOAD RANGE AND REGULATION	ENGINE TEST SPEEDS (other than fixed speed generator motors)
GENERATOR PLUS BATTERY	Max 3.6 volts peak to peak Frequency range DC to 10kHz Test circuit in Fig D.2	DEF STAN 59-41 Part 3 DCE01	Limits as in Fig. 3. Test circuit Fig. D.2.	DEF STAN 59-41 Part 3 DCE03 and DCS04	Load applied in increments up to design max. rated current O/P at each engine test speed. Test circuit in Fig. D.1.	1) Tick over-Gen On line. 2) Min. speed for max rated Gen. O/P continuous current. 3) Mid range. (Avg. between 2 and 4). 4) Max. permitted speed.
GENERATOR ONLY (Single fault condition)	Max 12 volts peak to peak. Frequency range DC to 10kHz. Test circuit in Fig D.2.	DEF STAN 59-41 Part 3 DCE01	Limits as in Fig. 4. Test circuit in Fig. D.2	As above	As above	As above
ELECTRONIC REGULATORS	DEF STAN 59-41 Part 3 Appropriate susceptibility tests.		-	-	-	-



NOTE: Charging current not to exceed 5% of the load current.

Fig D.1 Generating Equipment Regulation Test Circuit



NOTE 1: S1...open - 'generator only' condition
S1...closed - 'generator plus battery' condition

S2...Load selection

NOTE 2: L=5μH for the simulated 'Generator Plus Battery Condition.
or 50μH for the simulated 'Generator Only Condition'.

Fig D.2 Generating Equipment Surge and Exported Ripple Test Circuit

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The following Defence Standard file reference relates to the work on this Standard - D/D Stan/319/01/08.

Contract Requirements

When Defence Standards are incorporated into contracts users are responsible for their correct application and for complying with contract requirements.

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Defence Standards are revised when necessary by the issue either of amendments or of revised editions. It is important that users of Defence Standards should ascertain that they are in possession of the latest amendments or editions. Information on all Defence Standards is contained in Def Stan 00-00 (Part 3) Section 4, Index of Standards for Defence Procurement - Defence Standards Index published annually and supplemented periodically by Standards in Defence News. Any person who, when making use of a Defence Standard encounters an inaccuracy or ambiguity is requested to notify the Directorate of Standardization without delay in order that the matter may be investigated and appropriate action taken.

DEF STAN 61-5 (PART 6)/5

ELECTRICAL POWER SUPPLY SYSTEMS BELOW 650 VOLTS

28 VOLT DC ELECTRICAL SYSTEMS IN MILITARY VEHICLES

AMENDMENT 1 (REVISED TEXT)

1. ANNEX C : Page C-3 : paragraph C-6

Delete: tests DCE03 and DCE04.

Substitute : tests DCE03 and, DCS06 and DCS07 as appropriate.

2. ANNEX C : Page C-4 : Table C.1 : "spikes" column

Delete: DCE03 and DCS04

Substitute: DCE03, DCS06 and DCS07 as appropriate.

3. ANNEX D : Page D-3 : paragraph D.9

Delete: test DCS04 of Def Stan 59-41(Part 3).

Substitute: tests Def Stan 59-41(Part 3) DCS06 and DCS07 as appropriate.

4. ANNEX D : Page D-4 : Table D.1 : "spikes" column

Delete: DCE03 and DCS04

Substitute: DCE03, DCS06 and DCS07 as appropriate.

5. Make a note of this amendment on the Amendment Record.

D/D Stan/319/01/18 27 Jul 94

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