SPECIFICATION P-133:95

CHARGER FOR STATION BATTERIES

DESIGN DEPARTMENT (NTDC)

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CHARGER FOR STATION BATTERIES

0.0 **FOREWORD**

0.1 This specification has been prepared by the Design T&G Department of WAPDA.

0.2 This specification is intended only for the procurement of material and does not include provisions of a contract.

0.3 This specification is mainly based on IEC Publication 146. However, if any requirements indicated herein differ from those of IEC Publication 146, the requirements indicated herein shall prevail.

0.4 This specification is subject to revision as and when require.

1.1 **SCOPE**

0.2 This specification describes a fully automatic, constant voltage type, semi-conductor rectifier equipment, intended to be permanently connected across the nominal 110V or 220V battery (lead-acid or nickel – cadmium type) and DC load of a substation in the floating battery system.

2.0 **DEFINITIONS**

2.1 **Nominal Voltage**

It is the voltage by which the DC power system of a sub-station, and hence, the charger is designated.

2.2 **Rated Direct Voltage**

It is mean value of the direct voltage (indicated by a moving coil voltmeter) between DC terminals of a charger under the given AC voltage

and specified service conditions, and can assume any selected value in an intended range of operating voltages.

2.3 **Rated Direct Current**

It is the mean value of the maximum direct current (indicated by a moving coil ammeter) which the charger is capable of carrying continuously at rated direct voltage under the specified service conditions.

2.4 **Float (and Float Voltage)**

It is the operation of a charger in parallel with a battery and a load. The charger operates at such a constant voltage (called the float voltage) that the battery draws the current from the charger which is just sufficient to maintain the battery in a fully charged condition.

2.5 **Boost (and Boost Voltage)**

It is that state of operation of the charger during which the battery is given initial charge, periodic equalizing charge or quick recharges subsequent to a discharge during AC supply failure, at an increased constant voltage (called the boost voltage).

3.0 **SERVICE CONDITIONS**

The chargers shall be suitable for indoor installation and be capable of delivering continuously the rated output under the following service conditions:

3.1 Ambient Temperature

Maximum	50°C
Maximum mean over 24 hours.	45 °C
Mean in any year Minimum	-10°C

3.2 **Humidity**

Relative humidity may range from 0 to 100 percent. The maximum value of temperature and humidity, however, do not occur simultaneously. In monsoon high humidity may persist over long periods with temperature ranging from 30°C to 40°C.

3.3 **Altitude**

Upto 1000 meters above sea level.

3.4 **AC Supply Fluctuations**

Voltage	+ / - 10%
Frequency	+/ - 5%

4.0 **TECHNICAL CHARACTERISTICS**

4.1 **Ratings**

The chargers shall be designated as types A & B by their voltage and current ratings which shall be as follows:

		TYPE A	**TYPE B**
i.	Nominal direct voltage	110 Volts	220 Volts
ii.	Rated direct voltage		
	Float	110–132 Volts	220–264 Volts
	Boost	121-143 Volts	242-286 Volts
iii.	Rated direct current	25 Amps.	40 Amps.
iv.	Rated AC Supply voltages	240 Volts	415 Volts
		Single phase	Three phase

v.	Rated supply frequency	50 Hz	50 Hz
vi.	Duty Clause 46.2 of IEC 146)	1	1

4.2 **Temperature Rise**

The maximum temperature rise of the windings of converter transformer and filter choke shall not exceed 65 °C. The temperature limitations shall apply under both float and boost operations of the charger.

4.3 **Insulation**

4.3.1 **Dielectric Strength**

All circuits connected to the AC mains or to DC terminals shall be able to withstand safely an AC test voltage of 2kV rms 50 Hz for one minute applied between all terminals and earth, and between terminals of electrically separate circuits.

4.3.2 **Insulation Resistance**

The insulation resistance between each winding of converter transformer, screen, core and frame, measured at 100V DC immediately after the application of AC test voltage mentioned in clause 4.3.1 shall be not less than 20 megaohms.

4.4 **Regulation**

4.4.1 **Steady State**

The output voltage shall be automatically and continuously held constant to within +/- 1 % (one percent) of the voltage setting regardless o foutput

current varying from no-load to 100 percent rated direct current with a simultaneously variation of +/- 10% in AC supply with a simultaneous variation of +/- 10% in AC supply voltage and +/- 5% in supply frequency. This regulation shall be maintained under both float and boost operations and at each tap setting on the transformer primary (clause 5.2.9.1). The temperature stability of the regulating unit shall not exceed variation of +/- 0.05%.

4.4.2 **Dynamic**

Following sudden acceptance or rejection of 80% of rated load with simultaneous variation of +/-10% in input AC voltage and +/- 5% in frequency, the overshoot/undershoot of output voltage must not exceed 10% of rated output voltage and it must return to steady state limit within 5 cycles. This feature shall be verifiable with the help of a storage oscilloscope.

5.0 **DESIGN AND CONSTRCUTION**

5.1 **General**

5.1.1 The charger shall be designed to give fully automatic voltage stabilization and current limitation to provide proper charging characteristics to the battery.

5.1.2 They shall be completely solid-state and employ no mechanical relays except for boost charging system and the alarms. All semi-conductor devices shall be made of silicon and have non-ageing characteristics.

0.2.1 The charger circuitry shall be of modular design and the printed circuit cards shall have plug-in or slide in type construction. The internal layout of the charger shall be so designed that no healthy component is needed to be detached for extracting any faulty component i.e every component/ module shall be directly accessible to the maintenance personnel. To meet

this requirement multi-layer design shall be avoided. The silicon rectifier diodes and thyristors may be assembled to one sub-assembly which can be easily replaced.

0.2.1 All the major components, whether inside or outside the cabinet, shall be adequately labeled and the test points to be used in the event of trouble shooting shall be suitably identified. These test points shall be readily accessible for the maintenance and troubleshooting even during operation of the charger. Wave – forms and /or quantitative analog levels of signals at each test point shall be given on the drawings as well as in the trouble shooting manual. A functionally laid out directional point to point testing sequence shall be given in the instructions manual.

0.2.1 All components especially the converter transformer and the thyristor stack shall be adequately rated for continuous operation at the maximum output under the specified service conditions and shall not normally require replacement during the life of the charger. Minimum safety margin for power semi-conductors shall not be less than 2.5 times of their characteristics values i.e. peak inverse voltage, peak forward voltage and max. forward current.

0.2.1 In choosing material and their finishes due regard shall be given to the service conditions specified. Tropical grad materials which are heat and moisture resistant shall be used and iron or steel shall be painted or galvanized. Small iron and steel parts of the instruments and electrical equipment, the core of electromagnets and electrical equipment, the core of electromagnets and the metal parts of relays shall be effectively treated to prevent rusting.

5.1.7 There shall be no fan or moving parts in the charger.

0.2.1 A 240 volts A.C. lamp fixture shall be provided inside the cabinet with a door-operated control switch such that the lamp will be lighted on opening the door. In addition, a 240 volt A.C 3-pin socket outlet shall be provided

inside the cabinet at a suitable place to provided inside the cabinet at a suitable place to make available A.C. supply for the testing equipment.

5.1.9 Auxiliary apparatus s instruments, fuses, circuit breakers etc., fitted in the charger shall comply with the appropriate IEC recommendations for the apparatus.

5.1.10 Light emitting diode (LED) type of signal lights of suitable rating (at least 8 mm dia) will be provided on the front panel.

5.2 **Design**

5.1.9 The chargers shall consist of a double wound converter transformer designed to suit the intended duty, a single or three phase (as the case may be) non-uniform thyristors stack using hermetically sealed silicon rectifier diodes and silicon controlled rectifiers (thyristors) in double way connection and mounted on suitable heat sinks, trigger equipment for thyristors, and the required protective, control and indicating devices.

5.2.2 The control equipment for firing of thyristors shall be so designated that instantaneous firing pulses are applied to thyrisotr gates at the same angle and amplitude as required ensuring adequate gate trigger voltage and current for reliable thyristor operation . Rectifier design shall include soft start feature in order to limit AC inrush current.

5.2.3 The forward and reverse characteristics including turn-on and turn-off time properties of the thyristors shall be perfectly matched so as to avoid unequal current distribution or unequal current distribution or unequal voltage division in the arms of thyristor stack.

5.2.4 In selecting silicon rectifier diodes and thyristors ample allowance shall be provided in the characteristics values for repetitive maximum inverse voltages and the factor of safety shall be such as to ensure that there will

never be a failure on these accounts. Similarly the circuits having semi-conductor and other devices which normally fail under thermal mode shall be designed with ample protection against such failure.

5.2.5 The electronic components used shall be of high grade commercial quality as designated in relevant IEC standards. These shall have minimum safety margin of 30% in voltage and current ratings and 100% in power rating.

5.2.6 The rated direct voltage of the chargers shall be adjustable manually over the specified range of float and boost operations. Once the desired float and boost voltages have been selected, the regulating unit shall be capable of maintaining the output voltage at the p reset level on float and boost settings within specified regulation (clause 4.4.) automatically frequency, output current and the ambient temperature change separately or simultaneously.

5.2.7 **Float and Boost Charging System**

5.2.7.1 The chargers shall be provided with a system which allows initial charging as well as recharging of the battery in service under boost mode. Provisions shall be made for the initiation and cut-off of the boost charging mode manually as well as automatically, and a select or switch shall be provided to select the desired feature (clause 5.3.5).

5.2.7.2 Automatic boost facility shall be such that, when selected, the charger is switched on to boost mode automatically upon restoration of the AC supply after an AC mains failure, provided, the charging current drawn by the battery exceeds a preset limit (adjustable between 2 to 10 amperes). The charger shall automatically return to normal (float) mode after charging the battery in boost mode when the charging current drawn by the battery drops below a preset limit (adjustable between 0 to 5 amperes). Provision shall be made so that return to the mode can also be carried out manually.

5.2.8 **Current Limiter**

5.2.8.1 The charger shall be provided with an adjustable current limiter in order to restrict the output current of the charger to the preset value indicated in clause 5.2.9.4. This electronic control shall inherently protect the charger against direct short circuit and continuous overload without tripping, whether the charger is operating in float or boost mode.

5.2.8.2 The properties of the current limiter shall be such that, it shall automatically operate to rapidly reduce the output voltage of the charger and the current shall be limited to maximum 110% of the preset value irrespective of the boost or float voltage setting and input voltage variations within +/- 10%. The charger shall resume normal functioning and automatically supply the correct output voltage when the overload conditions are removed.

5.2.9 **Adustments**

5.2.9.1 **Coarse Adjustment**

The provisions shall be made for the coarse adjustment of the rated direct voltage in the form of the taps on the converter transformer primary to compensate for any voltage difference form rated C supply voltage. The taps shall be provided and marked on for the following input voltgages:

Single Phase Supplies	**3-Phase Supplies**
250 V	430 V
240 V (Principal Tap)	415 (Principal Tap)
230 V	400 V
220 V	280 V

The output voltage regulation at each tap setting shall be in accordance with clause 4.4.

5.2.9.2 **Float Voltage Adjustment**

It shall be possible to adjust the output voltage on float operation (auto/manual) within 100 – 120% of the nominal voltage. Potentiometer (s) shall be provided for setting these values by a continuous adjustment.

5.2.9.3 **Boost Voltage Adjustment**

It shall be possible to adjust the output voltage on boost opration (auto/manual) within 110-130% of the nominal voltage. Potentiometer (s) shall be provided for setting these values by a continuous adjustment.

5.2.9.4 **Current Limiter Adjustment**

The automatic current limiter shall be adjustable to limit the output current of the charger between 50 to 110% of the rated direct current.

0.2.1.1 Means for settings shall be very simple and readily accessible. All adjustment controls shall however become inaccessible when the door of the cabinet is closed. The controls shall be easily identified and so located that there is no possibility of any accidental alteration of the setting. Panel mounted controls shall be accepted only if the provision has been made to lock them after the desired settings have been obtained.

5.2.10 **Ripple Control**

The output of the charger shall be smoothed by means of a filter network comprising of at least one inductor and a capacitor of suitable values. The output shall be filtered to less than 3% (rms) of the direct voltage when delivering rated current to the resistive load. The capacitor shall be fused.

Fuse shall be installed at an accessible place inside the cabinet. A lamp shall be provided

5.2.11 **Protection and Isolation**

Circuit breakers of appropriate rating shall be provided to protect and isolate the chargers both on AC and DC sides against over current in the event of internal and external short circuits and wrong battery connections. Circuit breakers shall be mounted on front panel of the charger cabinet. The rating of circuit breakers shall be clearly marked on them.

Independent circuit breakers shall be provided on battery and load circuits. Fuses shall be provided on input and output sides of semiconductor bridge to protect it form overloading. A.C. main supply to the charger shall be controlled by electromagnetic contractor of adequate rating. It shall pick up when switched onto A.C. supply and drop out in case of or over voltage at charger output.

5.2.12 **Surge Protection**

The chargers (particularly the thyristor stacks) shall be protected against transient surge voltages of internal and external origins both on AC and DC sides by a built-in surge suppression circuitry.

5.2.13 **Parallel Operation**

5.2.13.1 The charger shall be suitable for parallel operation both under boost and float conditions. A blocking diode shall be provided on the DC side of the chargers to prevent any reverse flow of power.

5.2.13.2 It shall be ensured that under any fault conditions at the charger. DC load must not be disconnect from the battery bank in order to avoid the outage of protection.

5.2.14 **Load voltage Limitation**

A suitable device shall be used in the load line of the chargers (clause 5.3.4) to limit the voltage to the DC load to maximum 110% of the nominal voltage under all operating conditions including the failure of the said device.

5.2.15 **Measuring Instruemnts**

A DC voltmeter and 2 DC ammeters (1 for battery circuit and 1 for DC load circuit) of moving coil type shall be provided for the continuous indication of output quantities. The DC voltmeter shall be connected to the battery side of the DC breaker. In addition to this an AC voltmeter of moving iron type shall be provided to read off input supply voltage. The AC voltmeter shall be accompanied by a phase selector switch in case of below 2% and measuring range commensurate with the charger rating.

5.2.16 **Alarms and Annuciations**

The chargers shall be fitted with the following fault detection arrangements. Besides operating the alarms as mentioned below, each arrangement shall have a spare contact for remote indication. These arrangements shall be mounted inside the cabinet.

1. Mains under voltage & single-phasing
(for 3-phase sets only)

Chargers working on 3-phase supply shall be equipped with a phase supervision device for the three phase mains in order to indicate a reduced or loss of output voltage on any one or more phases on secondary side of converter transformer by operating audible alarm and visual indication.

2. Charger Failure

A detection unit shall be fitted for sensing the charge failure. It shall operate an audible alarm provided on the charger and give an independent signal light (in red), on the front panel upon failure of charging current whether it is due to AC mains failure, internal charger failure or any other reason which causes the output voltage of the charger to fall below the battery voltage or due to opening of charger – battery link, except in case of switchover from boost to float charging mode.

3. Over Voltage on the Battery Bus

Adequate arrangement shall be made for sensing abnormal rise in the output voltage of the charger and or the charger and or the battery voltage owing to charger control init (regulator) failure or any other reason. It shall be such that the charger stops to supply the charging current by disconnecting the A.C. main supply when the voltage on battery bus exceeds & nominal direct votage). Besides, it shall operate the audible alarm of the charger and give an independent signal light (red) on the front panel. The correct voltage returns.

4. Under Voltage on Battery Bus

Arrangement shall be made for sensing under voltage on battery bus due to failure of regulator unit or any other reason. A separate indication shall appear on the front panel of the charger when the voltage on battery bus falls below a preset value which shall be adjustable from 80% to 100% of nominal direct voltage.

5. Capacitor Fuse Failure

A detection unit shall be fitted for sensing the blow off of capacitor fuse. It shall operate an audible alarm and give an independent signal light (Red) on the front panel of the battery charger.

6. Over Voltage on Load Terminal

A detection unit shall be fitted for sensing the abnormal (from the pre-set value) rise the output voltage on the load terminal. It shall operate an audible alarm and give an independent signal light (red) on the front panel. It shall be such that the charger stop to supply the current. The battery shall operate the load under such conditions.

7. Lamp Check

A lamp test facility shall be provided for all the indication lamps

8. Acknowledgment

A switch shall be provided to acknowledge the fault which shall put the alarm off leaving the indication intact. Upon removal of fault alarm circuit shall automatically be ready for next operation.

5.2.17 **Acoustic Noise Level**

The overall audio noise level of a completely assembled rectifier shall not exceed 60 dBs at a distance of one meter from the equipment.

5.2.18 **D.C. Grounding**

It shall be ensured that normal working of the charger shall not be affected due to any single polarity DC grounding.

5.3 **Construction**

5.3.1 The charger equipment alongwith its accessories shall be accommodated in at least 2mm thick strong steel cabinet suitable for floor mounting.

5.3.2 The cabinet shall be adequately ventilated for self cooling by natural convection of the ambient air. It shall, however, be made completely vermin-proof.

5.3.3 All components shall be easily accessible from the front of the cabinet which may be constructed as a hinged door. The door shall have a handle with provision for locking. Entries of cables for connection to AC main and station DC panel shall be provided through suitable cable glands.

5.3.4 Besides AC terminals, the chargers shall have two positive terminals (i.e. one for battery and the other for DC load) and two negative terminals (one for battery and other for load) on the output side. The positive terminal shall be marked "+B" and "+L" for battery and load respectively and coloured black. AC terminals shall be marked "AC". All the markings shall be durable.

5.3.5 Following components shall be mounted on the front panel of the chargers. Each component shall be labeled permanently.

i. (a) A two position main switch for charger input ON/OFF with signal light (green)

1. Float
2. Boost
3. Automatic (Float/Boost0

ii. The above settings may alternatively be achieved by separate toggle switches as follows:

1. ON/OFF
2. Float/Boost
3. Automatic/Manual

iii. Signal lights, (yellow) to indicate boost, float, auto and manual operation.

iv. A miniature circuit breaker for charger output.

v. Two miniature circuit breakers for charger outputs (1 for battery and 1 for load output)

vi. Two Nos. 96 x 96 mm flush fitted DC ammeters (1 for battery and 1 for load circuit. Ammeter on battery circuit shall have 40-0-40 amperes range for 110 Voltage battery charger and 60-0-60 amperes range for 220 volts battery charger).

vii. A 96 x 96 mm flush fitted AC voltmeter.

viii. A 96 x 96 mm flush fitted AC voltmeter. This shall accompany a phase selector switch in case of 3-phase set.

ix. Signal lights as per clauses 5.2.16.

x. Test switch for A.C and D.C indication lights.

xi. Switch to acknowledge A.C and D.C faults.

5.3.6 All wiring terminations shall be shrouded to avoid accidental short circuit or earthing of the battery. Where wiring is taken trough sheets, the holes shall be fitted with glands or similar protection. The wiring along metal surfaces shall be carried through insulated cable ducts/trays properly fixed to the metal surface. The connections to various components of power circuit such as relays, instruments, circuit breakers and input & output shall be carried out via terminal.

5.3.7 An instructions manual alongwith a circuit diagram for the complete charger equipment shall be placed at a suitable place inside the cabinet. In

addition wiring diagram shall be pasted permanently at a suitable place inside the cabinet.

5.3.8 All interior and exterior surfaces of the cabinet shall be thoroughly cleaned to prepare the metal surface for painting. Three coats of paint shall be applied to give enhanced corrosion protection. The first coat shall be primer of zinc chromate and iron oxide or nay other primer which has equivalent weather resistance and rust inhibiting properties. The second coat shall be based on a synthetic resin with suitable properties for resistance to weathering. The third finish coat shall also be based on a synthetic resin and shall have a hard durable surface and excellent weathering properties. The total paint thickness shall be at least 0.12 mm. Finish colour shall be light grey.

5.3.9 Provision shall be made for earthing of the cabinet and a connector shall be provided to accommodate 95 sq.mm earthing conductor. Cabinet assembled from bolted panels shall use suitable washers to ensure electrical continuity of the structure.

6.0 RATING PLATE

6.1 A rating plate shall be fixed on front side of the cabinet which shall contain the following minimum information marked legibly in English. The rating plate shall be of durable material with silver background and marking imprinted or etched or embossed in black. The markings shall be non-fading.

1. Manufacturer’s name or trade mark with type designation.
2. Wapda contract No. and date
3. Serial No.
4. Name of equipment i.e “Adjustable Rectifier Equipment.
5. Rated direct current
6. Nominal voltage of the charger
7. Rated AC supply voltage and indication for number of supply phases.

8. Rated frequency
9. Range of adjustment for:

    i. Float voltage
    ii. Boost Voltage
    iii. Current Limiter
10. Power factor at 110-220V/25-40A applicable
11. Efficiency at 110-220V/25-40A
12. Duty class i.e. “100% continuous”.

6.2 The rating plates for the sub assemblies e.g. thyristor stack, converter transformer etc., shall bear the following indications:

a. Identification reference/manufacturer’s type designation.
b. Serial No.
c. Number of input phases
d. Rated input voltage and frequency
e. Rated input current
f. Rated ouput voltage
g. Rated output current
h. Efficiency for the convertor transformer
i. PIV and PFV ratings for thyrisor bridge.

7.0 **LOSSES**

7.1 The manufacturer shall design the battery charger for minimum losses and the overall efficiency shall not be less than 80% at full load.

7.2 In the evaluation of battery charger tenders, following rates shall be used for the capitalization of losses.

US $ 1.75/-per watt of overall losses at 25% rated direct current.

The capitalized cost of losses shall be added to the CIF/Ex-works price of battery charger to obtain adjudication price. The losses to be taken shall be

the total guaranteed losses at 25% rated direct current at rated D.C and A.C voltages and reference ambient conditions.

7.3 A penalty at twice the rate of the capitalized cost shall be payable by the contractor for the losses in excess of the guaranteed figures.

8.0 TESTS

8.1 General

8.1.1 The performance tests shall comprise type and routine tests on separate components, sub assemblies and complete chargers and a proper test certificate will be issued for each charger. The tests are intended to prove that the equipment complies with this specification and shall be performed in accordance with the best modern approved methods and latest applicable standards.

8.1.2 **Type Tests**

The components and sub assemblies of one charger and a complete charger in the group of chargers having same type, characteristics and rating shall be subjected to type tests. The certified tests results of all the type tests carried out by the manufacturer (s) shall be supplied. If a component or assembly is equal or similar to one previously tested the manufacture may submit a certified report of any previous tests at least equal to the requirements laid down herein in lieu of actual tests.

8.1.3 **Routine Tests**

All semiconductor devices and stacks, converter transformers and other components to be used in the chargers shall be subjected to manufacturer's routine shop tests before assembly into the charger. All the chargers shall be routine tested before delivery. The certified test results of all the tests carried out by the manufacturer shall be supplied.

8.2 **Tests for Complete Charger**

8.2.1 Following type and routine tests shall be carried out in accordance with the relevant clauses of IEC 146 (1973) or described hereunder:

8.2.1.1 **Type Tests**

i. Visual inspection
ii. Insulation test
iii. Checking properties of protective devices.
iv. Checking properties of current limiter
v. Checking properties of alarm and annunciations.
vi. Checking properties of smoothing circuit
vii. Noise level test.
viii. Verification of characteristics as per clauses 4.4.2 with help of oscilloscope.

8.3 **Test Method**

8.3.1 **Insulation**

The insulation test shall be performed to verify that the equipment complies with the requirements laid down in clause 4.3 of htris specification. The test will be performed as under:

a. Test voltage will be applied between the DC terminals connected with each other and the housing for one minute. The AC terminal will be connected for one minute. The AC terminal will be connected with each other and with the housing.
b. Test voltage will be applied between housing and the AC terminals connected with each other for one minute. The DC terminal will be connected with the housing.

c. The insulation resistance will be measured at 1000 volt D.C (1000 V.D.C megger) to check conformity to the specified requirements of clause 4.3.2.

8.3.2 **Power Loss**

The power loss measurement test shall be performed for the load conditions given in clause 11.1.2 (item xiv) of this specification and at nominal voltage. The efficiency shall be determined by measuring input and output power by wattmeters of accuracy not below class 1 connected at input and output (load terminal) sides of the charger. The output power will be measured when the charger is set at maximum float voltage.

8.3.3 **Voltage Regulation**

The test for checking the voltage regulation shall be made to verify that the requirements of regulation stipulated in clause 4.4 of this specification are fulfilled. The accuracy of voltmeters and ammeter used for measurements of voltage and current shall be not below 0.5%. To verify the requirement of clause 4.4.2 a storage oscilloscope shall be used.

8.3.4 **Visual Inspection**

The chargers shall be inspected visually for checking conformance with clause 5 & 6 of this specification and the approved drawings.

8.3.5 **Checking Properties of Smoothing Circuit**

The rms value of ripple voltage in the output at any setting shall be measured by an oscilloscope connected at the output (battery terminal) of the charger when it is supplying to a purely resistive load. The ratio of the AC rms to DC voltage called the ripple factor will be determined to verify the requirements of clause 5.2.10 of this specification.

8.3.6 **Checing Properties of Alarm Annuciations**

Tests shall be performed to verify that the requirements of clause 5.2.16 in regard to the properties of alarms and annunciations are fulfilled. The tests shall be performed under conditions equivalent to those stated in clause 5.2. 16 for various alarms and annunciations.

8.3.7 **Checking Properties of Current Limiter**

The properties of current limiter shall be checked on a variable resistive load connected at the battery terminal to verify that the requirements of clause 5.2.8 are met.

8.3.8 **Protective Devices**

Checking the co-ordination of protective devices shall be done so far as is possible without stressing the components of the equipment above their rated overload currents. Tests shall be performed to check the operations of protective devices (circuit breakers relays etc.)

8.3.9 **Temperature Rise**

The temperature rise test shall be performed to verify the requirements of clause 4.2 of this specification at 50°C ambient. The temperature rise of the windings of transformer and filter choke shall be determined by measuring the resistance of winding and using the formula:-

$$T2 = R2/R1\ (235 + T1) - 235$$

Where

R1 = Resistance of winding in cold state