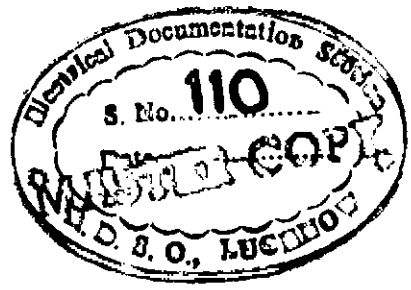
GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)



INDIAN RAILWAYS
TECHNICAL SPECIFICATION
FOR
TRANSFORMER RECTIFIER EQUIPMENT
FOR
REGENERATIVE BRAKING ON WCG 2A LOCOMOTIVE

JUNE 1983

ISSUED BY

RESEARCH DESIGNS AND STANDARDS ORGANISATION
MANAK NAGAR/ LUCKNOW
PIN - 226011.

E-15/2/04

TECH SPEC/E-15/2/04

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SPECIFICATION FOR TRANSFORMER RECTIFIER EQUIPMENT FOR REGENERATIVE BRAKING ON WCG-2A LOCOMOTIVES.

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0. Foreword

0.1 This specification covers the requirement of the transformer rectifier unit for regenerative braking to be fitted on WCG-2A locomotive as a part of the braking system.

0.2 The complete detailed design of transformer rectifier and control system shall have approval of RDSO before their manufacture/prototype development is undertaken.

0.3 Any deviation from this specification calculated to improve the performance, utility and efficiency of equipment proposed by the manufacturer will be given due consideration, provided full particulars with justification there of are furnished in the tender. The deviation from this specification shall be brought out in the tender documents indicating justification thereof.

1.0 Scope

This specification covers the following details of Transformer Rectifier(TREX) set to be connected across 3 phase 415V output of MA set for regenerating braking purpose on 1500 Volt DC locomotive class-WCG2A.

i) General Requirement.
ii) Capacity and Ratings.
iii) Service Conditions
iv) General Design Feature.
v) Limits of temperature rise.
vi) Enclosure and Mountings.
vii) Terminal Board and wiring
viii) Finish.
ix) Schedule of Particulars, Drawings and calculations.
x) Technical documents.
xi) Tests.
xii) Gurantee.

2.0 General Requirement:

2.1 While hauling the trains on the down gradients, it is economical to control them by regenerative braking on the locomotive. During eregeneration the traction motors fields are separately excited by giving them variable dc low voltage(high current) supply from Transformer Rectifier set and traction motors work as generators and feed the generated voltage back to overhead catenary system.

3.0 Capacity and Rating

3.1 Input supply: The power to the transformer rectifier set shall be supplied from 250 KVA alternator at a voltage of 415 ± 7% and frequency 50 Hz ± 3%.

3.2 Output: At maximum ambient temperature of 55°C transformer rectifier equipment at full load voltage of 50 volts shall deliver a continuous d.c.output of 1000 Amps in each of the two parallel paths of fields excitation. Each of the two parallel paths consists of 3 fieEds(in series)and one stablising resistance in series. The resistance value of each field is 11.84 mili ohm and resistance value of stabilizing resistance is 0.01 ohm. Circuit diagram for regeneration braking is attached.

as such I step of 2 V and 3.3 Provision shall be made for varying the output dc voltage from 22 V to 50 V in 14 equal steps through contacts of the master controller on the locomotive. With the variation of voltage, current will vary in equal steps from 500 Amps to 1000 Amps. in each of the two parallel paths.

3.4 Suitable magnetic amplifier or electronic control with thyristors, to meet the requirements of clause 3.3 is also to be supplied with the unit.

3.5 The equipment shall have an overload capacity of 25% for 1 hour, starting from cold.

3.6 The equipment shall be designed with low percentage impedence of the order of 5-6 per cent.

4.0 Service Conditions

4.1 The equipment shall be suitable for service in the ambient temperature varying from 5-55°C with relative humidity ranging upto 100% and at an altitude of 1000 m above the mean sea level and in dusty and corrosive atmospheric conditions.

4.2 The equipment and its mounting arrangement shall be of robust design for traction duty and shall withstand satisfactorily the vibrations and shocks normally encountered in traction service, as indicated below:

a) Maximum vertical acceleration - 1.0 g

b) Maximum longitudinal acceleration - 3.0 g

c) Maximum transverse acceleration - 2.0 g

(g being acceleration due to gravity)

.....3/-

4.3 The vibration are of the sine wave and the frequency of the vibrations is between 1 Hz and 50 Hz. The amplitude 'a' expressed in mm is given as a function of 'f' by the equation:

$$a = \frac{25}{f}$$ for values of 'f' from 1 Hz to 10 Hz.

$$a = \frac{250}{f2}$$ for values of 'f' exceeding 10 Hz and upto 50 Hz.

4.4 In the direction corresponding to longitudinal movement of the vehicle the equipment is subjected for two minutes to 50 Hz vibrations of such a value that the max. acceleration is equal to 3 g (amplitude a = 0.3 mm)

5.0 General Design Features

5.1 As low voltage dc supply is required for fields excitation of traction motors, the regenerative braking equipment design may incorporate transductor control or thyristor control or any other suitable principle of operation.

5.2 The equipment shall be suitable for feeding inductive nature of load of traction motor field winding without any adverse effects. The inductance at rated current of each field is 3.2 milli henry and resistance(hot) of each field is 0.01184 ohm at 115 °C.

5.3 The step-down transformer and the rectifier unit shall be suitable for the duty specified and ripple in the output voltage shall be kept to the minimum. Preferably, 3 phase to six phase transformation may be used on the transformer and it shall be star connected. In case electronic control with thyristor is used the ripple contents in the output circuit shall not exceed the ripple content as obtained with 6 phase connection rectifier system with 50 Hz (Maximum 4% for inductive load).

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5.4 The rectifier and other semi-conductor equipment shall be suitably derated for satisfactory operation under the service conditions stipulated in clause 4 surrounding air temperature of 55 °C and excessive temperature rise within the cubicle due to losses in the unit, and for stipulated voltage and load variation. The calculations for determining complete rating of the main rectifier and other electronic control equipment, if any, shall be furnished alongwith the tender.

5.5 The supply for the control circuit of the equipment shall be available from the loco battery. The noamal loco battery voltage is 110 V dc but range is from 77 volt to 121 volt dc.

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5.6 On input side of the equipment adequate protection shall be provided against over current and over voltage due to any reason beyond the stipulated values.

5.7 Adequate protection of the equipment shall be provided against surges caused by hole storage phenomenon in the rectifiers and switching surges in the circuit. The calculations for the protection system shall also be furnished.

5.8 Protection shall also be provided for individual rectifier elements against short circuit of one element. Visual indication shall be provided on the equipment for rectifier element failure. The rating will be sufficient in each circuit. Indication may also be provided for normal/healthy operation of the rectifier elements. One set of these indication shall also be provided for remote display.

5.9 The rectifier for each of the six phases shall consist of required number of diodes in parallel.

5.10 It is suggested that string fuse shall be provided so that the failed diode is isolated under diode failure condition. The normal operation shall be possible with $(n-1)$ strings operation without any restriction.

5.11 Suitable filters shall be provided in the case of thyristor circuits, if used, to avoid radio and telecommunication interference.

5.12 The parts which are likely to be replaced in service/ maintenance sub as fuses, printed circuits cards etc. shall be of plug in type, suitable for traction duty as per relevant IECs/IS ad shall be accessible from the front.

5.13 The equipment shall be either natural aircooled or forced air cooled type, but the dimension limits indicated in clause 7 have to adhered with the maximum temperature rise limits and without sacrificing any desirable feature.

5.14 The rectifier unit shall be suitably designed to meet general requirements as indicated in RDSO Specn. No.SPEN-E-16/12, suitably modified for three phase applications.

5.15 All the electronic components/equipments viz diode, resistance etc shall be derated to 50% . Thus the rating of the electronic components/equipments shall be twice of the requirement.

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6.0 Limits of Temperature Rise

6.1 The maximum temp. rise permissible for the winding of natural air cooled/forced air cooled transformer and transductors/thyristor shall not be more than the values specified below:

For insulation Class B = 55°C
Class F = 75 °C
Class H = 105 °C
Class C = 150 °C

6.2 Insulation of Class C or H with H Class varnish shall be preferred for transformer winding so that the given dimension limits may be adhered with the satisfactory performance under prevailing Indian Railway conditions.

6.3 The diode junction temp. shall be below 10°C of specified max. junction temp, under worst conditions.

7.0 Enclosure and Mounting

7.1 The cabinet shall be floor mounted. The space available for mounting the complete unit on the locomotive is length 1200 mm, width 850 mm and height 1575 mm.

7.2 The equipment shall be provided in robust dust proof sheet steel enclosure.

7.3 The enclosure shall be so arranged that when it is opened, the terminals are readily accessible. Further more, sufficient space shall be left in the interior of the enclosure for accommodation of external connections from the point of entry into the enclosure upto the terminals.

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7.4 It shall be desirable to keep the weight of the unit within 1500 kg. without sacrificing any of the desired features.

7.5 Suitable arrangement for lifting the whole cubicle shall be provided.

8.0 Terminal Board and Wiring

8.1 The unit shall be completely wired and the terminals brought out to a terminal board located inside the cubicle on the front side. The cables used for internal wiring shall be tinned stranded copper. Special care shall be taken in the design to provide adequate creepage distance between the terminals. The terminals shall be clearly marked for input and output and their arrangement shall be such as to ensure against accidental short circuiting of input and output terminals. A separate terminal shall be provided for making on earch connection.

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8.2 Suitable spring washers and nuts(zinc plated) for terminal connection shall be provided on all the terminals including earth terminals.

8.3 All components including bolts, nuts and washers screws etc. of the unit shall be suitably protected against corrosion and rust by zinc plating.

9.0 Finish

9.1 The equipment shall be finally finished and painted light grey in colour with IS:1650:1960-Colours for building and decorative finishes.

9.2 The positive terminals provided on the Transformer Rectifier set shall be dimensionally bigger than the Negative terminals so that the connections coming on them can not be interchanged. In addition, the terminals should bear clear marking of their potential and input and output.

10.0 Schedule of Particulars,Drawings and Calculations:

10.1 Full particulars of the Transformer Rectifier shall be furnished by the tenderer alongwith general outline dimensioned drawings of the converter and its mounting arrangement. Details of the electrical circuitry and the various components shall also be included alongwith a brief write-up on the principle of operation. Detailed design,calculations shall also be submitted.

10.2 The details of circuitry, rating of each element and details of output obtainable with the offered system shall be given by the suppliers.

11.0 Technical Documents

11.1 Technical documents regarding make, ratings resistance/inductance/capacitance values, and brief specification of the various components shall be furnished by the tenderer.

11.2 All necessary technical documents and literature which would be useful for proper maintenance and repairs ofthe equipment shall be furnished.

12.0 Type test and Routine Test

12.1 Type and routine test shall be carried out as per test programme(Annexure-I).

12.2 Certain specifical tests to ensure reliability of the equipment may be finalised mutually viz. the supplier and RDSO/Railways at the time of placement of order.

12.3 The tests will be conducted in the presence of Railways/RDSO's representative. Any modification in the test conditions required by the suppliers shall be subjected to the prior approval of the Railway/RDSO.

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13.0 Gurantee

13.1 The whole equipme nt shall be guranteed for a period of 24 months from the date of supply or 18 months from the date on commissioning on the locomotive, whichever is earlier. Defective equipment/components shall be replaced without any extra charge and without loss of time. The diodes in the rectifier shall be guranteed for 60 months from the date of commissioning.

13.2 Supplier's representative shall be available all the time during the commissioning and will assist in the commissioning of equipments.

ANNEXURE-I

Test programme for Excitation Transformer - Rectifier set.

Generally the transformer shall comply with the IEC 70 but temperature limited to IEC-20°C.

(a) Transformer	TYPE TEST	Routine tests.
1. Measurement of resistance	The resistance of each winding shall be measured by DC volt-ammeter method at ambient temperature and recorded at 75°C.	As for type test.
2. Measurement of transformation ratio:	The no load transformer ratios shall be measured by voltmeter method between windings.	As for type test.
3. No load test	The primary no-load current and no-load losses shall be measured at primary supply voltage, at rated frequency, other windings being open. Then characteristic curves of no-load losses for the primary supply shall be drawn.	The primary no-load currents and no-load losses shall be measured at primary supply voltage of 415 V, at rated frequency other windings being opened
4. Short circuit test	The copper losses at short circuit voltage shall be measured with the secondary short circuited and the magnetic amplifier at the rated frequency, which gives the rated current on the primary shall be applied. From the results the resistance and reactance shall be calculated and referred to the secondary Measured rectance shall not deviate ± 15% from design value.	As for type test. Measured reactance shall not deviate ± 10% from that of type tested one.
5. Temperature rise test	The temperature rise test shall be carried out for the first transformer by the loading back method or short-circuit method. In the former method, two transformers shall be connected back to back between primary and secondary till a steady temp. is attained with the rated continuous current, the value of temp.rise of each winding shall be measured by resistance method and shall exceed IEC limits - 20°C.	---

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Type tests	Routine tests
6. Di-electric test The di-electric test shall be conducted with the following voltages after the heat rum test. Between windings and earth - 2500 Volts 50 c/s for one minute. Between primary and secondary - 2500 V, 50 c/s for one minute.	Same as type test.
7. Inducted voltage test ----	The test is carried out in accordance with para 708 under section VII of IEC Publication 76.
(b) Silicon Rectifier Assembly - The tests for Silicon diodes would be conducted as per RDSO Spec. No.E-16/13 (copy attached).	As per RDSO Spec. E-16/13,
(c) Rectifier assembly	
1. Temperature rise test With the natural/forced ventilation as applicable a continous DC current of 2000 A for a period of one hour or until the steady state temperature is measured at the base of all cells with a thermofil unit. The temperature rise curve is plotted for the hottest cell with the aid of thermo elements. The temperature at the base must be the specified junction temperature. The stipulated temperature rise above an ambient of 55 °C shall be within the specified value. The test is carried out at a low voltage.	Same as type test.

contd....

Type tests	Routine tests
2. <u>Current distribution</u> The current distribution at 2000 A continuous load in parallel connected diodes/ strings is to be recorded and the imbalance shall not exceed 10%.	Same as type test.
3. <u>Short circuit test</u> With normal ventilation, the value of peak short-circuit current as obtained by shorting across the bus bar with the offered transformer that protection system may clear the fault within clearing time.	----
4. <u>Insulation test</u> The test voltage according to IEC 146 clause 252.6 = 1.5 kV AC 50 c/s applied for 1 minute.	Same as type test.
5. <u>Vibration test</u> As per IS: 7288/ IEC 146.	---
(d) <u>Test on complete set:</u>	
1. <u>Load test</u> ---- L 15 steps of the control and	As far as possible, the exact load conditions available on the loco shall be created and load current on the DC side shall be measured at each of the/ recorded. The current values shall be corresponding to the voltage. For the thyristor version current will very smoothly with voltage.

(e) <u>Tests for control circuits</u>

The tests for control circuit shall be decided at the time of placing order and will be according to the IEC/IS relevant to the control equipment offered.

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I1 – GENERATED CURRENT
If – FIELD CURRENT SUPPLIED BY THE EX
E – EXCITATION VOLTAGE – EX OUTPUT
Rs – STABILISING RESISTANCE
3Rf – FIELD RESISTANCE OF THREE MOTOR

SCALE

CIRCUIT DIAGRAM ... ON WDG A LOCO

No.SPEC. E-16/12

BHARAT SARKAR
RAIL MANTRALAYA
(RAILWAY BOARD)

RELIABILITY ASSURANCE SPECIFICATION FOR SINGLE PHASE POWER CONVERTORS FOR TRACTION APPLICATION

SPECIFICATION NO.SPEC/E-16/12
FEBRUARY 1981

Issued by

ANUSANDHAN ABHIKALP AUR MANAK SANGATHAN
LUCKNOW-226011

RELIABILITY ASSURANCE SPECIFICATION FOR SINGLE PHASE POWER CONVERTORS FOR TRACTION APPLICATION

INTRODUCTION

The power convertor design, assembly and manufacture shall be as per IS:7788 latest 'Specification for Single Phase Traction Power Convertors' and as modified by the tender specification. In addition, it shall also comply with this Reliability Assurance Specification. This Reliability Assurance Specification elaborates certain special requirements from the point of view of detailed design, specification of components and assembly over and above those covered in IS:7788.

This Reliability Assurance Specification also lays down the code of practice for assembly, layout, wiring, etc. with a view to ensure the highest level of reliability and durability under the severe service conditions of traction application.

1. Bus-Bars

1.1 The busbars shall be of electrolytic copper as per IS:613.

1.2 The bus-bars shall be tin-plated. The tin-plating shall be done after bending, drilling holes, etc. and bare copper shall not be used anywhere. The pure tin-plating shall be as per IS:1359 and thickness of the plating shall not be less than 8 micro-meters.

1.3 Joints in bus-bars shall be avoided as far as possible. In case joints are to be provided, the joints shall be away from the bent portion.

1.4 Sharp bends

1.4.1 Sharp bends in the bus-bars must be avoided. The inner radius of cold bend should be as large as possible, but not less than the following :

	(in radius 'R')
Annealed electrolytic copper	2 x T
Hard drawn electrolytic copper	3 x T

'T' - Thickness or diameter of the flat or rod

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1.4.2 The above limits of bend radius shall apply not only to thick bus-bars, but also to thin wires, such as resistor and capacitor leads, etc.

1.4.3 Where it is not possible to accommodate the radius specified above, specific approval for deviation shall be obtained from RDSO.

1.5 The bus bars shall be provided with the following colour code to identify ac, dc, positive and negative connections :

ac		Yellow
dc	Positive	Red
	Negative	Black

1.6 All power connections to the busbars and busbar joints shall be directly made without any insulating support.

1.7 Busbar supports shall be made with insulators and not by making use of insulating members of the assembly.

2. Welding

2.1 Butt welding shall be used for fabrication of frame work. Fillet welding must be avoided as far as possible. There should be no undercuts in fillet welds.

3. Fasteners

3.1 Hexagonal nuts only shall be used. Socket headed screws will be used only at the locations where use of hexagonal nuts is not feasible. All the nuts will be suitable for tightening with a spanner only and not with screw drivers.

3.2 The minimum size of screws or bolts shall be M-6. Any bolt or screw of size less than M-10 shall be of high tensile steel(preferably clause 8.8) as per IS:1367.

3.3 All the nuts, which are not normally required to be opened for repair or maintenance shall be locked. Locking may be done in case of small nuts either with drop of Araldite or Locktite compound. Nylock nuts are not to be used for locking.

3.4 All bolted connections shall be provided with spring washers.

3.5 Tightening of the bolts shall be done to the maximum extent to avoid fatigue failures.

4. Components

4.1 General

4.1.1 Only components of rating, make and type approved by RDSO/Railways shall be used for assembly.

4.1.2 No deviation from the rating, type and make of the approved device list shall be made without prior approval of RDSO/Railways. For any deviation in the rating type and make of any component, full details, alongwith reasons for deviation, shall be furnished to RDSO/Railway for approval.

4.1.3 All bought-out components shall be subjected to lot acceptance tests as per the laid down specification. The manufacturers will establish strict quality control so as to achieve the highest reliability of the components.

4.1.4 All the electrical and electronic components shall be subjected to 100% screening tests before using them for assembly, in addition to lot acceptance tests. The screening tests for the various components are detailed in APPENDIX-I.

4.1.5 Complete records of the lot acceptance tests, screening tests and routine tests shall be kept separately. These records shall be made available for the scrutiny of the representative of RDSO/Railway.

4.1.6 Reliability cannot be tested, but has to be built in by attention to design, manufacturing process and stage inspection. It is, therefore, necessary that the manufacturer lays down detailed quality assurance programme for the manufacture of devices and the assembly of the convertors. Copies of quality assurance programmes, details of the tests at various stages of inspection, check lists, etc. shall be furnished at the time of evaluation of detailed design. Any changes made in these programmes shall be advised to RDSO/Railways.

4.2 Silicon Diodes

4.2.1 Stud type of devices are not acceptable. Diodes with soldered junction and soldered external seal construction are also not acceptable.

4.2.2 Quality assurance testing, end of line screening etc. of the devices shall be governed by 'Quality Assurance Testing of Silicon Diodes' No.Spec/E-16/13 issued by RDSO.

4.2.3 Flexible leads of the devices shall be fully insulated either with silicon rubber or PTFE sleeving.

4.2.4 In case of flat base devices, a suitable cover of ether silicon rubber or PTFE shall be provided over the device to avoid occurance of external flash overs by foreign matters.

4.2.5 Surface finish and flatness of the surface of the device in contact with heat sink shall be as under :

Surface Finish	Less than 1.524 micrometer
Surface Flatness	Total Indicator Reading (TIR) to be held from 0.0005 to .001 mm

4.2.6 The size of the base mounting studs shall be not less than M-6.

4.3 Heat Sink

4.3.1 Heat sinks shall be of extruded construction. Sand cast heat sinks are not acceptable. For any other type, specific approval of RDSO/Railway shall be taken.

4.3.2 The area of device seat on the heat sink shall have proper surface finish and flatness to minimise mounting resistance due to surface problems. Flatness and surface finish shall be as under :

Surface Flatness	Total Indicator Reading (TIR) to be held from 0.0005 to .001 mm
Surface Finish	Less than 1.524 micrometer.

4.3.3 Current collection through the heat sink is to be avoided. In case it is not possible, then the heat sink device mounting surface and current collection contact area shall be suitably treated to prevent electrical corrosion. Full details of the proposed treatment shall be furnished to RDSO/Railway at the time of detailed evaluation of design for approval.

4.3.4 To aid radiation heat transfer and give corrosion protection, the heat sink surface shall be suitably treated in black colour either by painting or anodising or any other process. Full details, along with the test results, shall be furnished at the design evaluation stage for approval.

4.3.5 Device seat and power connection area on the heat sink shall be free from treatment, foreign materials, oxides and films, etc.

4.4 Resistances

4.4.1 Vitreous enamelled non-inductive wire wound resistor as per IS:3373 Part II(latest) shall only be used.

4.4.2 The resistances shall be of stud mounted type and provided with lug terminals Pattern 2 of IS:3373.

4.4.3 The declared wattage rating of the resistors at the specified ambient temperature will be at least two times the calculated maximum wattage in the circuit of application under the worst loading conditions. In case of potential deviding resistors across diodes, the wattage raring shall be corresponding to maximum leakage current limit of the device.

4.4.4 The resistors shall be preferably mounted in the vertical position. In case two resistances are mounted close to each other, the distance between the resistances(edge to edge) shall be at least two times the diameter of the bigger resistance.

4.5 Capacitors

4.5.1 Capacitors of reputed and approved make shall only be used. The type of capacitor selected out of the standard range of reputed manufacturers, shall be suitable for particular circuit application.

4.5.2 Metal can capacitors with self healing features shall be only used. Full technical details and calculations for selecting a particular capacitor shall be furnished at the time of detailed evaluation of the design.

4.5.3 Capacitors with main terminals mounted on porcelain insulators shall be only used. The creepage distance and clearance between the terminals shall comply with Table 5 of S:7780.

4.5.4 The connection to the capacitors shall be provided by inculated type 'slip on' connectors.

4.5.5 The maximum working voltage across any capacitor shall not exceed 5 % of the rated repetitive voltage. In case of hole storage capacitors, the voltage rating of the capacitors shall be the same as the PIV rating of the device.

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4.5.6 The capacitors shall be suitable for case temperature from -20°C to +85°C. The case temperature rise shall not exceed 10°C under the design current and voltage rating of the convertor.

4.6 *Fuses*

4.6.1 Fuses suitable for semiconductor application complying with IEC 269-4 shall be used.

4.6.2 Fuses with built in signalling arrangement are not to be used. Separate signalling fuses shall be used.

5. Assembly of the heat sink and device

5.1 In case of disc type of devices, the design of the clamping system shall be such that the required clamping force is applied perpendicular to the disc surface. The clamp shall be provided with a mechanical force gauge to indicate what force is applied as well as to indicate that the set force for a particular device has been applied. Individual clamp arrangement shall be provided for each assembly and not a common clamp for the stack.

5.2 In case of flat base devices, pressure plate or mounting spring with safety bracket shall be provided between the base and the mounting studs, so that the spring pressure plate becomes flat when proper mounting pressure is applied.

5.3 Mounting arrangement of the device shall be such that the pressure is uniformly distributed over the total contact area. The pressure shall be applied in a staggere fashion such as tightening of opposite corners to one half of the recommended torque and then finally apply the necessary remaining torque in the same staggered fashion.

5.4 Recommended optimum mounting pressure for the offered device type shall be determined by suitable tests and full details of which shall be furnished to RDSO/Railway.

5.5 In order to optimise the contacts between mating surfaces of the device and heat sink, suitable thermal compound shall be used to fill up the voids between the mating surfaces before assembly. The thermal compound shall have low thermal resistance and shall seal the joint against moisture.

6. Cables

6.1 Single strand solid wires shall not be used for inter-connection between equipments/sub-assemblies. All inter-connections shall be with multi-stranded flexible insulated cables.

6.2 Bare copper multi-stranded cables insulated with fibre glass/rubber sleeving etc. shall not be used.

6.3 Minimum size of the cable shall be 2.5 sq.mm.

6.4 PTFE (Poly Tetra Fluor Ethylene) insulated cables as per specification at APPENDIX-II shall be used for all inter-connections to the snubber circuits and signalling fuses.

6.5 Elastomeric cables as per RDSO's specification No. E-13/93(as amended from time to time) shall be used for all other locations.

6.6 The voltage grade shall be 3kV (ac) for damping and snubber circuits and 750 V for ventilation blower and other auxiliary circuits.

7. Terminal Boards

7.1 The design of the terminal board shall have the approval of RDSO/Railway. The design shall general comply with the following:

i) The size of the connection studs shall have adequate current ratings and the minimum size shall not be less than M.5.

ii) The studs shall be cadmium plated steel as per BS:3382-61(Part-I).

iii) Provision of insulation barriers between the terminals.

iv) Method making the electrical connection shall be such that the contact tightening force is not passed through the insulating board.

7.2 Not more than 2 terminations shall be provided at one stud. In case more connections are required, the terminals may be extended by providing copper connection strips.

7.3 Copper strips shall be used for interconnections at the terminal board instead of small cable loops.

7.4 Separate terminal boards shall be provided for 110 V dc and 380 V ac circuits.

7.5 Positive and negative terminals shall be separately located. Four spare terminals shall be provided in each terminal board for emergency use.

7.6 Terminal boards shall be installed in the vertical position to avoid that dust collection and accidental short circuits.

8. Cable Terminations

8.1 Soldered joints

8.1.1 Soldered cable terminations and connections shall be normally avoided. In case soldered connections are unavoidable, full details shall be furnished to MMRCO/Railway for prior approval.

8.1.2 Soldered joints shall be made by trained staff with 100% tin solder with suitable soldering equipment, which maintains the bit temperature constant.

8.1.3 Only pure resin is to be used as a flux. use of acidic/corrosive flux is prohibited.

8.1.4 Visual inspection of each soldered joint shall be carried out by trained inspector for checking the soundness of the joint and the proper wetting of the surfaces being joined.

8.2 Cable Sockets

8.2.1 All cable ends shall be socketed with crimped type socket.

8.2.2 Pre-insulate sockets shall only be used. The crimping is to be done in such a way that the insulation of the cable gets crimped with the insulated sleeve to prevent failures due to flexing action of the unsupported lenth.

8.2.3 The crimped sockets shall be of proper dimensions for a particular size of the cable.

8.2.4 Proper tools and dies shall be used for crimping and frequent checks shall be carried out by examination of cut samples and millivolt drop to ensure quantity of the crimping.

8.2.5 Pull out tests shall be made on 1% of crimped joints to check quality of crimping tools and dies. The pull out force shall not be less than 80% of the U.T.S. of the wire.

9. <u>Wiring Layout</u>

9.1 The quality of workmanship and layout of the wiring shall be of the highest standard so asto ensure long life of wiring as well as to prevent deterioration/damage of insulation in service. For the layout of wiring the following guidelines will be kept in view :

a) Complete separation of low, medium and high voltage wires shall be ensured

b) Only wires of same potential will be bunched together. The cables of different voltages shall be separately bunched and routed.

c) As far as possible, all wires,which are temporarily energised, shall be bunched separately and no permanently energised wire should be included in this bunch.

d) The positive and negative wires in dc circuit shall be seperately bunched.

e) Sharp bends shall be avoided in the wiring layout. The closed insulated minimum radius of the bend shall be at least 10 times the outer diameter of the cable.

f) Wherever the cables/wires travel through holes, orifices, cut ways, etc., suitable rubber grommets shall be provided. The grommets shall be provided such that they do not get dislodged during vibrations, [illegible]ts and bumpings experienced in service.

g) All the cable runs shall be suitably supported by insulated stiffeners or laid-in cable ducting.

h) The cable bunches shall be neatly tied up with string at adequate intervals. In order to have neatness and easy maintenance, the number of wires in each bunch shall not exceed ten.

9.2 Cable Marking

All wires shall be numbered and provided with cable ferrules of approved style and design at either end of cable terminations. The marking shall be indelible and unalterable. The use of metallic lables/tags, etc. is prohibited. Separate series of numbering shall be followed for low, medium and high voltage cables and the adopted scheme shall have the approval of the purchaser.

APPENDIX-I

SCREENING METHODS FOR THE COMPONENTS

1. Resistors, fixed, wire wound, vitreous enamelled (Power Type)

(a) Short time overload

Test -- The resistors shall be subjected to an over-voltage which will result in 10 times rated wattage for 5 seconds. DC resistance shall be measured after the resistor has cooled down to room temperature.

Specification -- There shall be no evidence of arcing, burning or charring. Change in resistance value shall not exceed 2% at 25°C.

(b) Life Test

Test -- DC resistance shall be measured at 25°C. Resistor will be loaded with rated power in an ambient of 70°C for a period of 100 hours. No forced ventilation is to be provided.

Specification -- Change in resistance value shall not exceed 3%. No evidence of mechanical damage.

2. Capacitors

(a) Thermal Shock

Test --

Step No.	Time	Temp.	No. of cycles
1	30 mts	-20°C	
2	5 mts	+25°C	
3	30 mts	+85°C	5 cycles.
4	5 mts	+25°C	

Specification -- The capacitor shall withstand the extremes of high and low temperature without any visible damage.

(b) Life Test (operating burn-in)

Test -- Each capacitor shall be subjected to the maximum rated voltage and case temperature for a period of 100 hours.

Specification -- The change in the capacitance shall not exceed ±5% at 25°C. The capacitance value shall be within the specified tolerance even after the burn-in.

Appendix-II

Technical Specification for PTFE Cables

1.	Operating Conditions:	Temperature -20°C to +150°C Voltage rating (r.m.s.) as approved based on application data.
2.	Specification:	The wire shall fully confirm type EE of MIL-W-16878D regarding design, construction and testing.
3.	Material of the Conductor:	High conductivity annealed and tinned/silver plated multi-stranded copper wire as per IS: 8130.
4.	Insulation:	Polytetrafluoroethylene(PTFE).
5.	Construction:	The insulation shall be extruded or tape wrapped on sintered. The insulation thickness shall be sufficient to withstand electrical, thermal and mechanical stresses without deterioration under extreme operating conditions.
6.	Colour:	Black/Orange.

No.SPEC. E-16/13

BHARAT SARKAR

RAIL MANTRALAYA

(RAILWAY BOARD)

(DRAFT)

QUALITY ASSURANCE TESTING OF DIODES

FOR

SINGLE PHASE TRACTION POWER CONVERTORS.

SPECIFICATION NO.SPEC/E-16/13

FEBRUARY - 1981

ISSUED BY

ANUSANDHAN ABHIKALP AUR MANAK SANGATHAN

LUCKNOW-226 011

DRAFT - QUALITY ASSURANCE TESTING OF DIODES FOR SINGLE PHASE TRACTION POWER CONVERTORS.

....

INTRODUCTION

High reliability of the equipment is the pre-requisite for traction application. Traction application calls for devices of the rectifier to work under arduous service conditions of thermal cycles, dusty and salt laden atmosphere, high humidity, voltage transients and continuous vibrations and shocks. Therefore, devices are required to be of high reliability for traction application.

After the device has been properly selected to meet with the duty requirements, reliability of the device is the responsibility of the manufacturer. It is at the manufacturing stage the reliability is built into the device-beginning to end. It is, therefore, incumbent upon the manufacturer to ensure that the complete manufacturing process is designed and controlled as to maintain quality of the devices in volume production.

The purpose of this Quality Assurance Test Programme is to lay down detailed procedure for lot inspection and type approval for user's inspection as required vide clause 10 of IS-7788 as well as audit checks ensure periodical monitoring of the quality of the production and use of reliable devices for assembly of the traction rectifier sets.

1. Type Approval of the devices

1.1 Any new device proposed or uprated by a manufacturer shall be subjected to the type tests as per APPENDIX -A. The devices shall not be used for assembly of the convertors, till type approval is accorded for the device by RDSO/Railway. All facilities for carrying out the type and investigation tests shall be provided by the manufacturer. The tests shall be conducted in the presence of RDSO/Railways nominated representatives.

1.2 The sampling plan for type tests shall be as under. Samples shall be selected by RDSO/Railways' representative.

Lot quantity (Nos.)	Sample rate of the lot	
Upto 200	20%	Subject to minimum of 40 devices
200 to 500	12%	
500 to 1000	10%	
Above 1000	7.5%	

1.3 In case of bulk orders, the lot offered for type testing and inspection shall be at least 50% of the total order.

....2/-

1.4 The programme of the type tests on the samples selected shall be as per APPENDIX -A.

2. Validity of the Type approval:

2.1 The type approval for a particular device shall be normally for a period of two years. Complete type tests as per item I will repeated before the validity of the approval is renewed. However, at the discretion of the RDSO/Lucknow, conducting of complete type test programme may be waived off or modified programmed may be repeated.

3. Manufacturer's Quality Assurance Programme:

3.1 It is at the manufacturing stage, from beginning to end, that the reliability is to be introduced into the devices. It starts with the choice of suppliers for the components and continues with incoming inspection, in line process controls, processing after construction, end of line screening and testing and quality assurance testing. It is, therefore, incumbent upon the manufacturer to lay down quality control programme to monitor the manufacture and testing of the semiconductors. The manufacturer shall finish the quality assurance programme proposed to be followed at the time of the placement of the order. Any changes made subsequently will be advised. Audit checks shall be carried out from time to time by the representative of RDSO/Railways to ascertain the implementation of the quality assurance programme.

4. Routine Tests

4.1 Routine tests including screening and burn-in tests shall be carried out on all devices as per APPENDIX-A by the manufacturer. The manufactuer will kept separate records for these routine tests carried out on the devices, which will be made available for inspection of the representatives of RDSO/Railways.

4.2 A certificate, as per the following proforma shall be furnished for each cubicle or for the lot of the spare diodes supplied in respect of routine tests.

> Certified that all the diodes type No. as per the enclosed serial numbers used for the assembly of the cubicle S.No._____ against contract/Order No._____ dt._____ have been subjected to the laid down routine tests and comply with the declared limits of the various finalised parameters of the device.
>
> Quality Control Engineer

.....3/-

5. Audit Check of the Routine Tests:

5.1 Ten percent of the devices from each cubicles offered for inspection, picked up at random by the representative of the Inspecting Authority, shall be subjected to routine tests, as indicated in APPENDIX-A in presence of the representative of the inspecting authority.

5.2 In case any device, out of 10% sample lot devices, does not comply with the declared parameters, the following procedure shall be followed:-

(a) In case more than one loco set is offiered for inspection, then 20% of the devices will be taken as sample from each of the balance cubicles and subjected to routine tests. In case any device from this lot out of these samples also does not comply with the declared parameters, then the whole offered lot shall be taken as rejected.

(b) The manufacturer shall rescreen the whole batch and re-assemble the cubicles with the devices complying with the specification. These cubicles will again be subjected to the 10% check as detailed in 5.1 above.

(b) In case all the sample devices as per 5.2(a) above meet with the specification, then the particular cubicle will only be taken as rejected. Rescreening shall be done by the firm before offering it for reinspection.

5.3 In case of failure of the devices during 10% audit checks occures for more than two occasions in a year, the approval for the device may be taken as withdrawn.

6. Periodical sampling life tests

6.1 Routine tests to be carried out on 100% devices are mainly constitute electrical parameter screening for elimination of the ends of long tailed distribution. These tests, however, do not ensure total electrical and mechanical reliability of the device. It is, therefore, necessary to carry out periodical sampling life tests so as to verify that the complete manufacturing process ensures quantity of the devices. Following sampling plan shall be followed for this purpose.

....4/-

(a) Two devices from each cubicle will be selected as sample by the representative of the inspecting authority.

(b) After every six months, the 10 devices out of the lot selected will be subject to the following tests in addition to all the routine tests in the presence of representative of RDSO/Railways.

i) Thermal cycling (Test No.9)
ii) Load test (Test No.12)
iii) Blocking life (Test No.15)

6.2 In case any device, out of these 10 samples, does not pass the above test, then further acceptance of any lot shall not be done, till the matter is investigated by the firm and necessary improvements in the manufacturing process implemented. The devices will be subjected to type test again before clearance for further supplies is accorded by RDSO/Railway.

APPENDIX-I

TEST PROGRAMME FOR SILICON DIODES

1. General

1.1 The type, routine and ingestigational tests on the silicon diodes shall be conducted as per latest IS:7788 with clarifications furnished hereunder. Some additional tests, not included in IS:7788, are also to be conducted as type or routine or special tests, as claried below:

1.2 Based on this general type and routine test programme, the manufacturer shall submit particular test programme, applicable for the offered device, indicating limit values of various parameters and test conditions such as voltage and current, base temperature, duration of test, reference temperature, etc. The details of the empirical relations proposed to be used for working out the final values of the parameters shall be indicated in the test programme.

1.3 The detailed proforma for recording readings, test results, observations, conclusions, etc. shall be submitted along with the particular test programme.

2. Summary of the Tests

Sl. No.	Nature of test	Reference clause of IS:7788 - 1975	
		Type test	Routine test
1.	Forward characteristic	10.1.2.1	
2.	Forward voltage drop		10.1.2.1 or 10.1.2.2
3.	Reverse characteristic	10.1.3.	
4.	Reverse current		10.1.4
5.	Reverse voltage	10.1.5	10.1.5
6.	Reverse recovery charge	10.1.6	
7.	Thermal resistance	10.1.7.1	10.1.7.1
8.	Transient thermal impedance	10.1.7.2	
9.	Thermal cycling	10.1.8	
10.	Surge forward limit current	10.1.9.1	10.1.9.2
11.	Surge forward current	10.1.10	
12.	Load	10.1.11	

contd.....2

13.	Deterioration	10.1.12	
14.	Encapsulation	10.1.13	10.1.13
15.	Blocking life	As per clause 4.1 below	As per clause below
16.	Environment tests		
16.1	Damp heat	-do- 4.2	
16.2	Corrosion	-do- 4.3	
17.	Shock and vibration	-do- 4.4	
18.	Robustness of the termination	-do- 4.5	
	INVESTIGATION TESTS		
19.	Operating life	-do- 5.1	
20.	X-ray examination	-do- 5.2	

3. Additional details of the tests covered by IS:7788

Following additional details shall apply for the tests covered by IS:7788-1975

3.1 Test No.2 Forward voltage drop (FVD)

The FVD grouping shall be classified based on 50 mV peak group corresponding to rated device current rating. It will be verified that the characteristic is within the specified FVD group.

3.2 Tests No.3 & 4 - Reverse Characteristics

In case of type test as per Clause 10.1.3, full reverse characteristic shall also be exhibited on the oscilloscope.

In case of routine test as per Clause 10.1.4, reverse characteristics shall be verified on the oscilloscope and shall be free from defects. The leakage current corresponding to PIV rating of the device shall be recorded.

....3/-

3.3 Test No.9 - Thermal Cycling

The test shall be conducted as per Clause 10.1.8 of IS:7788-1975. The test shall be conducted for 20,000 cycles and no parameters shall change. The test shall be further continued till any of the parameters exceed the limit value/abnormal variation is noticed or the device fails.

All the parameters that may be affected by the test i.e. forward voltage drop, reverse leakage current, thermal resistance, etc. shall be measured and recorded at the beginning of the test and thereafter every 5000 cycles till no change in parameters is noticed. The moment any change is noticed, the parameters shall be checked after every 1000 cycles till the change in any parameter is found beyond limit or device fails. The test will be considered satisfactory in case there is no change in the values recorded for the device under test in the beginning.

3.4 Test No.10 - Surge forward current

The test will be carried out with 50% reverse voltage applied between current pulses.

3.5 Test No.12 - Load Test

The forward characteristic, reverse characteristic thermal resistance, etc. shall be measured at the beginning and at the end of the test. The test will be considered, satisfactory in case there is no change in the value of the parameters recorded for the device under test at the beginning.

3.6 Test No.14 - Encapulation Test

The test shall be carried out with Helium gas detector method for the type test.

4. Additional tests not covered by IS: 7788

4.1 Blocking life

Type Test - This test shall be carried out by applying rated peak reverse voltage (either full or half wave rectified) on the devices in an ambient temperature equal to the maximum rated junction temperature for a period of 30 days.

Leakage current shall be measured at the beginning of the test and then checked after every 7 days. The test will be considered satisfactory in case no change of leakage current, takes place.

.....4/-

Routine Test - This test shall be carried out on every device in the same way as type test, but for a period of 24 hours.

4.2 Environmental tests

4.2.1 Test No. 16.1 - Damp heat

This test will be carried out as per IS:9000 (Pt:IV) 1979 with the following details:

Conditioning	Temperature of 55 ± 2°C and relative humidity of 93% +2 −3
	The device shall be placed with the base facing upwards.
Severities	21 days.
Final measurements	
Visual inspection -	Condition of the plating of the base, flexible lead, etc.
Electrical	Insulation resistance before and after the test.

4.3 Corrosion

This test shall be carried out as per Clause 26 of IEC 571. The duration of the test shall be 48 hours. The device shall be subjected to visual examination for corrosion of the plating, etc. at the end of the test.

4.4 Vibration test

This test shall be carried out generally as per Clause 28 of IEC 571(Rules for electronic equipment [redacted] used on rail vehicles), with the following severities:

4.5 Robustness of the termination

The details of the test will be mutually finalised. The manufacturer shall declare the tensile strength of terminal and the proof load will be at least 2 times the declared terminal strength.

5. Investigation Tests:

5.1 Operating life test

This test will be carried out on the devices under the following operating conditions:

.....5/-

i) Loaded to the maximum rated forward current.
ii) Maximum repetitive peak voltage applied.
iii) At rated case temperature.

The test will be carried out for a period of 30 days. All the parameters, viz. forward voltage drop, reverse leakage current and thermal resistance shall be recorded at the beginning of the test and then checked after every 7 days. The test will be considered satisfactory in case there is no change in any of the parameters for device under test.

5.2 X-ray examination

The purpose of this test is to detect faulty construction or the presence of foreign particles after encapsulation. This test will be carriedout after shock/ vibrations test. The method of conducting test shall be mutually decided. The devices under test shall be serialised and then X-ray followed.

Annexure-I

Type Test Plan

The samples selected for type testing as per Clause 1.2 shall be subjected to the various tests as per the following plan:

GROUP A

(On all devices of the sample lot of 40)

Visual and mechanical inspection
verification of dimensions
electrical performance
(Test Nos 1,2,3,4,5,6,7,10)

Encapsulation Test No.14

Group B
(10 devices)
Transient thermal impedance(18)
Surge forward Current(11)

- B1 (5 devices): Load test(12)
- B2 (5 devices): Thermal cycling(9)
  Terminal strength (18)

Group C
(25 devices)

- C1: 10 devices deteriotation
- C3: 5 devices Investigation test - Operating life(19)
- C2: 10 devices Blocking test.

Group D
(5 devices)

- D1: Damp heat (16.1)
- D2: Corrosion (16.2)

Group E
(5 devices)
Vibration & Shock(17)
Investigation Test
X-ray Examination (20)

NOTE: The above figures show the minimum number of devices to be subjected to various tests. The actual number of devices shall be determined by the sample lot in the same proportion.