SPECIFICATION NO. MP.0.24.02.20 (Rev. 00)

(For official use only)

भारत सरकार
रेल मंत्रालय

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION OF ALTERNATOR MOUNTED RECTIFIER ASSEMBLY FOR AC/DC DIESEL-ELECTRIC LOCOMOTIVES

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TECHNICAL SPECIFICATION OF ALTERNATOR MOUNTED RECTIFIER ASSEMBLY FOR AC/DC DIESEL-ELECTRIC LOCOMOTIVES

0.0 INTRODUCTION

0.1 Power rectifiers are used in the AC/DC diesel-electric locomotives to convert the variable voltage variable frequency output of traction alternator to DC supply to feed the DC traction motors. With the introduction of 3100HP AC/DC locomotives, BHEL make conventional rectifiers of type AR5400A/B were initially introduced. These rectifiers take cooling air from FTTMB plenum chamber and use capsule type diodes that require frequent maintenance and are more prone to failure due to high vibration/shock levels. The presence of smoke, oil fumes etc. inside the locomotive also has a severe detrimental effect on the diodes. In spite of many modifications and preventive measures taken from time to time, failures in these rectifiers although reduced considerably, could not be arrested completely. At present, most of the AC/DC diesel-electric locomotives of Indian Railways are fitted with these types of rectifiers.

0.2 To reduce maintenance and to avoid the problems due to vibration and entry of oil, dust etc. normally observed in conventional rectifiers, self-cooled rectifiers with pig tail type diodes were developed. These rectifiers take the cooling air supply from their own top mounted blower. Although self-cooled rectifiers have negligible failure of diodes, problems of commutator flashover and sparking in DC blower motors have been a big problem in various sheds. Additionally, DC blower motors require frequent maintenance for trouble free operation.

0.3 As a further improvement in the earlier designs, alternator mounted rectifiers using pigtail type diodes and cooling air from alternator fan have been developed with following advantages:

a) Saves loco floor space, which is critical in diesel-electric locomotives.
b) Separate blower motor is not needed therefore no associated problems.
c) Use of pigtail type diodes improves reliability and requires negligible maintenance of diode/heat sink.

0.4 Till date, a large number of alternator mounted rectifiers have been fitted on various AC/DC locomotives homed at different sheds and overall performance of these rectifiers has been found satisfactory. Considering the above advantages and comparative performance feedback of various types of rectifier designs, it has been decided to use the alternator-mounted rectifiers in most of the future BG and MG diesel-electric locomotives.

1.0 SCOPE

This specification covers the technical requirements of design, manufacture, testing and supply of alternator-mounted rectifiers with associated protection and indication equipment to be used on AC-DC diesel-electric locomotives.

2.0 SCOPE OF SUPPLY

2.1 Pig tail type diodes complete with heat sink, mounting arrangement, accessories and ducting for inlet and outlet cooling air for rectifier assembly.

2.2 All resistors and capacitors used as diode matching components for hole storage, surge suppression and voltage smoothening.

2.3 Cell failure indicating device or rectifier fuse protection with signalling fuse indication.

2.4 All AC and DC bus bars, insulators and hardware for mounting.

2.5 Anti vibration mounting pads.

3.0 GOVERNING SPECIFICATIONS

Assistance has been taken from the following specifications:

a) IEC: 60411
b) IEC: 60146
c) IEC: 60571
d) IS: 7788
e) IEC: 747-2 (Part 2)

4.0 ENVIRONMENTAL CONDITIONS

4.1 The rectifier assembly shall be required to work continuously at full load under following atmospheric conditions:

Maximum temperature (Atmospheric)	(i) 70 ºC (under sun). (ii) 47 ºC (in shade) (Temperature inside locomotive may reach 60 ºC.)
Minimum temperature (Atmospheric)	-20 ºC.
Humidity	Up to 100% during rainy season
Altitude	Max. 1200 meter above mean sea level

Refernce site conditions	(i) Ambient temp. 47 °C (ii) Temp. inside engine compartment 55 °C (iii) Altitude 160 m.
Annual rainfall	Between 1750 mm to 6250 mm.
Dust	Extremely dusty and desert terrain in certain areas. The dust content in air may reach as high a value as 1.6 mg / m³.
Atmospheric conditions in coastal areas in humidity salt laden and corrosive atmosphere	(a) Maximum PH value : 8.5 (b) Sulphate : 7 mg / liter. (c) Max. concentration of chlorine : 6 mg / liter (d) Maximum conductivity : 130 micro siemens / CM.

4.2 The rectifier shall be suitable for rugged service normally experienced for rolling stock where locomotives are expected to run up to a maximum speed of 160 kmph in varying climatic conditions existing throughout India.

4.3 The engine room of the locomotive may have oil fumes. The manufacturer shall take due account of this aspect in the design of the rectifier.

5.0 GENERAL REQUIREMENT

5.1 The rectifier assembly shall be suitable for rectifying the 3-phase AC output of traction alternator used in AC/DC diesel-electric locomotives such as BHEL make traction alternator type TA10102EV or equivalent throughout the range of operation of these alternators as per V-I characteristics of the locomotive.

5.2 The rectifier shall be used on AC/DC diesel-electric locomotives such as WDM3C, WDM3D, WDM3A etc. with gross horse-power varying from 2300 HP to 3300 HP. Main electrical parameters of these locomotives are as below:

(a) <u>FOR 3300 HP LOCOMOTIVES</u>

- Maximum starting current: 4400 Amps DC
- Maximum voltage: 1100 VDC
- Low voltage continuous ratings: 585 VDC, 3600 ADC, 1050 RPM
- High voltage continuous rating: 1075 VDC, 1938 ADC, 1050 RPM

Alternator output V-I characteristic curve (DC) at rated engine output for 3300 HP locomotive is attached at **annexure – A.**

(b) FOR 3100 HP LOCOMOTIVES

- Maximum starting current: 4400 Amps DC
- Maximum voltage: 1100 VDC
- Low voltage continuous ratings: 525 VDC, 3700 ADC, 1050 RPM
- High voltage continuous rating: 1100 VDC, 1760 ADC at 1050 RPM

Alternator output V-I characteristic curve (DC) at rated engine output for 3100 HP locomotive is attached at **annexure – B.**

(c) FOR 2300 HP LOCOMOTIVES

- Maximum starting current: 4400 Amps DC
- Maximum voltage: 900 VDC
- Low voltage continuous ratings: 383 VDC, 3700 ADC, 1000 RPM
- High voltage continuous rating: 900 VDC, 1587 ADC at 1000 RPM

Alternator output V-I characteristic curve (DC) at rated engine output for 2300 HP locomotive is attached at **annexure – C.**

5.2.1 Rectifier shall be designed to withstand maximum voltage, maximum current and continuous loads mentioned above with sufficient margin.

5.3 Output of the rectifier shall normally be fed to 6 nos. DC traction motors type TM4906, TM4907, TM5002 (BHEL make) or TM7362, TM7362A (CGL make) or equivalent. Various combinations of traction motors such as 2S-3P at starting & 6P at high speed operation and field weakening may be used as per the traction requirement of the target locomotive. Design of the rectifier shall take care of these motor combinations.

5.4 Supplier is required to ensure that interface dimensions of the proposed rectifier with the traction alternator are exactly matching. Locations and sizes of fixing bolts shall also match exactly to avoid difficulty during installation. However, overall rectifier design shall be flexible enough so that it can be easily fitted with similar alternators in future with minimum modifications required.

5.5 The rectifier shall be mounted on top of the traction alternator. Therefore this design is more prone to vibration/shocks as compared to other designs of rectifiers. All the components such as diodes, heat sinks, fuses, micro switches, snubber capacitors/resistors etc. and their mounting arrangement shall be designed to withstand vibrations and shocks as specified in IEC-60571. Size of rectifier mounting bolts shall be M16 with bolt strength class 10.9. Sufficient numbers of suitable anti-vibration pads shall be used at rectifier-alternator interface surfaces and at all the other critical locations. All the bolts shall be used with suitable washers. The equipment shall withstand the buffing shocks encountered during normal traction application.

5.6 Alternator fan provides cooling air for the rectifier by suction through common alternator-rectifier cooling duct. Same air of this duct is used to cool the alternator windings after cooling the rectifier. Two additional ducts are also provided in the alternator assembly to cool the alternator windings independently. Common cooling duct of the rectifier shall be designed for optimal cooling air flow distribution to rectifier and alternator windings.

5.7 Rectifier covers shall be designed to keep entry of oil, dust, smoke etc. to the minimum possible. Opening for the cooling air shall be only from the top side of the rectifier. Preferably it shall be provided with suitable wire mesh to prevent entry of foreign objects into the rectifier and alternator. Design of front and rear covers and their fixing arrangement shall be made keeping in view ease in opening and closing during routine maintenance. All the components shall be easily accessible.

5.8 A fuse shall be connected in series with each diode for more reliable operation of loco in case of abnormal high currents in the rectifier due to any fault. In this case, the corresponding fuse shall blow and therefore disconnect the affected diode circuit. Loco operation shall continue at full load with remaining diodes.

6.0 DESIGN, MOUNTING AND DIMENSIONS

6.1 The rectifier assembly shall be of sheet metal constructed with a strong framework. Maximum allowable envelope size of the rectifier assembly is shown in the attached drawing at **annexure – D**.

6.2 DC terminals shall be provided such that the connection with DC bus of the locomotive can be made without resorting to complicated cabling. The terminations of all the three AC bus bars inside the assembly shall be made vertically downwards so as to exactly match the corresponding output terminals of the alternator. AC terminals shall be designed to minimize the obstruction for the cooling air. Location of positive and negative DC bus bars shall be such that negative bus bar comes at the front side (driver cab side) and positive bus bar comes at the engine side to facilitate making connection during load box testing. Design of the bus bar insulators shall be such that to avoid loosening and cracking/creepage. Preferably insulators with grooves and sleeve shall be used. For bus bars, annealed copper bars with conductivity greater than 99.99% as per IS : 613 – 1984 shall be used. All the mounting hardware shall be supplied by the manufacturer. High tensile & blackodise fasteners only from the approved suppliers shall be used.

6.3 The rectifier assembly shall consist of a 3-phase diode bridge. The rectifier shall be designed for continuous as well as starting duty cycle rated currents as specified in **clause-7** with adequate margin of safety and shall be capable of working at 100% load factor. It shall have adequate margin to withstand internal short circuits due to string

failure condition and short circuit across DC output due to traction motor flash-over. The diodes in the rectifier assembly shall be fitted complete with suitable heat sinks and hole storage resistors/capacitors. Additional protection against voltage and current surges may be provided, if felt necessary by the manufacturer for reliable operation of the rectifier.

6.4 The rectifier shall have sufficient voltage rating to withstand the top corner voltage of the alternator and switching surges encountered in the diesel electric locomotives. Transient voltage surges may be equal to 200% of the maximum no-load voltage. However, a voltage safety factor of 2 should be taken for design of the rectifier.

6.5 A multi string type rectifier bridge shall be preferred. The locomotive should be able to operate even if one string has failed. A suitable cell check device or fuse shall be provided for indicating cell failure depending upon the rectifier design. High-speed fuses, only from the reputed suppliers, should be used. Only auto re-setting type fuses shall be used. The fuse should be selected so that:

a) It protects the diodes in case of short circuit across DC bus bars / generation of transient currents.

b) (N-1) operation of rectifier may be possible in case of a string/diode failure.

6.6 Design and layout of heat sinks should be such that to dissipate maximum thermal energy generated in diodes at all the locations keeping in view the direction and quantity of cooling air flow. There should be complete electrical isolation between parts at different voltages (such that between positive and negative DC bus bars).

6.7 The current unbalance should be kept at minimum. For this, only one forward voltage drop (FVD) group shall be used and entire series shall be restricted to only two consecutive FVD groups. The peak mV drop difference between two FVD groups shall be limited to 50 mV (peak) corresponding to maximum diode current rating. Further, in a particular arm, only one FVD group shall be used.

6.8 The voltage and current unbalance of 20% shall be assumed for design calculations.

6.9 The devices used in the rectifier assembly shall preferably be of a standard type of a reputed make such that, in case of urgency, the purchaser can interchange these devices with commercially available devices of another make. Flat square base or stud type devices shall be used instead of capsule types.

6.10 The layout of components inside the rectifier assembly shall provide for easy accessibility and replacement of the failed components during maintenance without having to remove large number of other healthy components. Each component shall be clearly marked to indicate type, nomenclature and rating.

6.11 All electrical connections shall be made by a standard method with crimped terminals, nuts, bolts and plated spring steel washers to ensure good electrical connection and facilitate maintenance. Proper routing of LT wires shall be done to avoid rubbing with rectifier body or bus bars. Preferably glass insulation sleeve shall be provided over the wires.

6.12 All electrical components including insulators, cables etc. used in the assembly shall be suitable for 1.5 KV insulation level. Insulators used shall be of type EP3 as per IS : 10192 - 1982 .

6.13 Adequate creepage distance shall be maintained for all live parts to avoid internal flashover, keeping sufficient allowance for the pollution of air with oil and dust inside the engine room of the locomotive.

6.14 All components used in the rectifier assembly should be procured only from approved suppliers.

7.0 RATINGS

7.1 RECTIFIER ASSEMBLY

S.N.	PARAMETER	RATING
1	Continuous current (DC)	3800 Amps.
2	Starting current (DC)	4700 Amps. (for 2 minutes)
3	Max. output volt (DC)	1400 volts
4	Max. input volt (3-phase AC)	888 volts

7.2 The rectifier assembly shall be suitably rated to withstand the maximum fault level as brought out in **Annexure - E** for the fault clearance time of 100 milliseconds.

7.3 DIODES AND FUSES

The ratings of diodes and fuses used in the rectifier assembly may be such as to suit the rating of the rectifier given in **clause 7.1** in N and N-1 conditions. Diodes and fuses shall also be suitably rated to withstand the maximum fault level as brought out in **Annexure - E** for the fault clearance time of 100 milliseconds

8.0 INFORMATION TO BE FURNISHED BY THE SUPPLIER

Technical information will be supplied by the manufacturer as detailed in the attached **Annexure - F**.

9.0 QUALITY ASSURANCE PROGRAMME, INSPECTION & TEST CERTIFICATE

9.1 The manufacturer shall submit his internal quality assurance programme to the purchaser. The manufacturer shall, on demand by the purchaser or any other inspecting agency nominated by the purchaser, make the records of checks carried out during internal quality assurance exercise, available for scrutiny. The QAP proposed by the manufacturer for the rectifier assembly offered shall be submitted with the offer.

9.2 Inspection tests shall be similar to the routine test programme given in this specification. Final acceptance of the rectifier assembly shall be made at the purchaser's premises.

9.3 The manufacturer shall afford the inspector all reasonable facilities and necessary assistance to check that the rectifier assembly is being supplied in accordance with this specification.

9.4 Three copies of test certificates shall be supplied giving the following details:

a) Railway, Unit, Order Number
b) Supplier's name
c) Batch number
d) Results of all acceptance tests.

10.0 WARRANTY

The rectifier assembly shall be warranted for satisfactory and trouble-free operation for a period of three years from the date of receipt or two years from the date of putting into service, whichever is earlier.

10.1 All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement for rectification of failures reported under warranty.

10.2 Warranty period of the rectifier assembly may be extended as per mutual agreement between RDSO and supplier if it has undergone major design modifications during the warranty period.

11.0 MAINTENANCE MANUAL

The manufacturer shall supply free copies of the approved maintenance manual for overhaul/test purposes at the rate of one copy per two loco sets.

12.0 FAILURES DURING WARRANTY PERIOD UNDER MAINTENANCE CONTRACT

12.1 In case of any failures, the details of failure and action taken to arrest re-occurrence of similar failure in future with failure analysis report etc. is to be submitted to RDSO.

12.2 In case of repeated failures, necessary changes in the design of rectifiers put in service or in production line are to be made by the manufacturer. Investigation tests, if considered necessary, are to be arranged/conducted by the manufacturer.

13.0 TESTS, FIELD TRIAL AND PRODUCT APPROVAL

13.1 The type and routine tests shall generally conform to RDSO test programme no. MPTP – 035, (Rev. 00).

13.2 Type test will be performed on one prototype unit of given design to verify that product meets the specified design requirements. However, routine tests shall be carried out on each equipment.

13.3 The supplier shall submit detailed type and routine test programs to RDSO for its approval. RDSO may also decide to carry out some special tests on the rectifier unit, which are not covered by the test programme.

13.4 The prototype unit will be tested by RDSO representative(s) at the manufacturer's premises or at mutually decided venue where all the facilities should be made available for carrying out the prototype test and the total cost of the tests shall be borne by the manufacturer.

13.5 In case a rectifier assembly is found suitable in type tests, field trial on the locomotive shall be carried out on a limited number of prototypes for six months. All the modifications required due to defects noticed or design improvements found necessary as a result of the test / trial shall be carried out by the tenderer in the least possible time. Total cost of such modifications/design changes shall be borne by the manufacturer.

13.6 In case of successful completion of field trial, the rectifier assembly shall be approved for a restricted period to be decided by the purchaser. Final approval shall be given only after extensive use on the locomotives.

13.7 If mutually agreed between manufacturer and RDSO, witnessing of routine test may be waived for sets manufactured after the prototype. The routine test of equipment, for which witnessing has been waived, shall be accepted after successful scrutiny of test results submitted to RDSO.

13.8 The purchaser reserves the right to repeat the type test of the rectifier assembly should it be felt necessary by the purchaser to do so. The device (type & make) used in the rectifier assembly shall not be changed without fresh type clearance of the device as well as the rectifier by the RDSO.

14.0 MARKING AND PACKING

14.1 All major components of the rectifier assembly such as diodes, fuses etc. shall bear for identification a serial no. and manufacturer's name. Rectifier assembly shall be provided with a suitable rating plate giving usual information including the following:

a) Manufacturer's name
b) Type of rectifier
c) Serial no. of rectifier assembly
d) Date of manufacture
e) Nominal and short time ratings

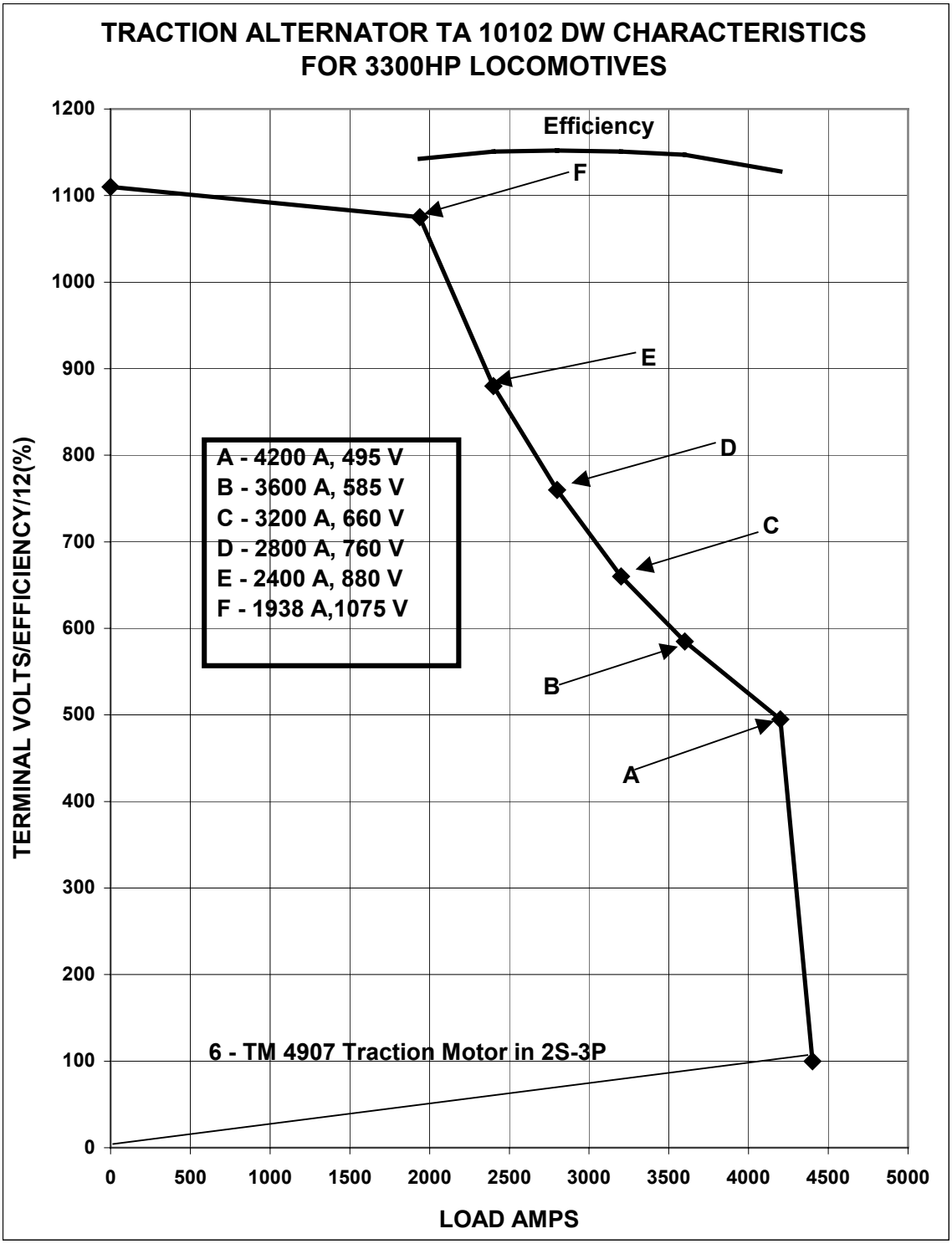
14.2 The rating plate shall be clearly visible when rectifier assembly is installed in position. Identification numbers shall also be suitably stamped on non-interchangeable matched components to facilitate assembly and to prevent mixing up.

14.3 The rectifier assembly shall be suitably packed in wooden water proof boxes to prevent damage during transit and handling.

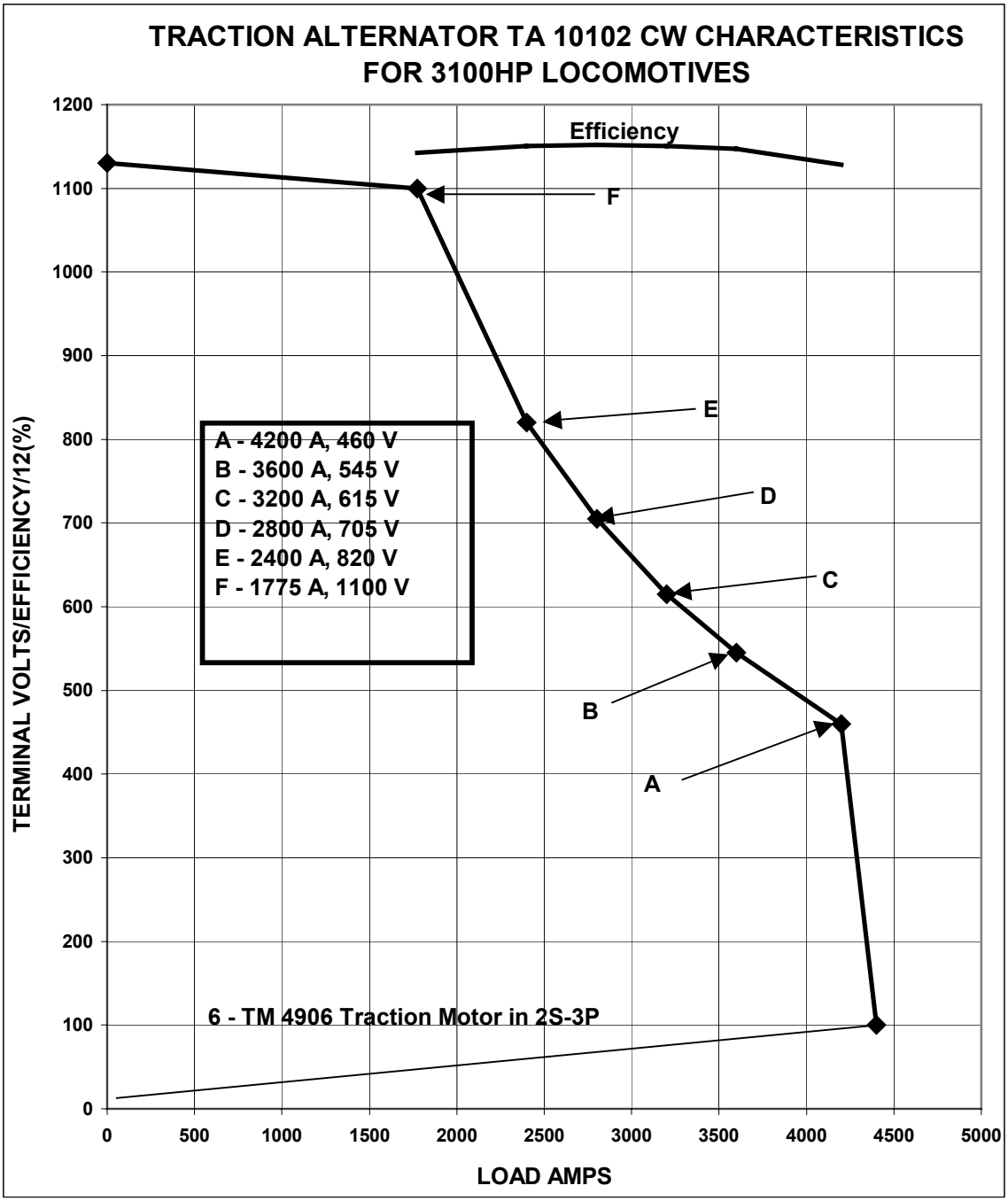
15.0 INFRINGEMENT OF PATENT RIGHTS

Indian Railways shall not be responsible for infringement of patent rights arising due to similarity in design, manufacturing process, components used in design, development and manufacturing of rectifier assembly and any other factor that may cause such dispute. The responsibility to settle any issue lies with the manufacturer.

ANNEXURE - A


TRACTION ALTERNATOR TA 10102 DW CHARACTERISTICS
FOR 3300HP LOCOMOTIVES
Efficiency
F
E
D
C
B
A
A - 4200 A, 495 V
B - 3600 A, 585 V
C - 3200 A, 660 V
D - 2800 A, 760 V
E - 2400 A, 880 V
F - 1938 A,1075 V
6 - TM 4907 Traction Motor in 2S-3P
TERMINAL VOLTS/EFFICIENCY/12(%)
LOAD AMPS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

ANNEXURE - B

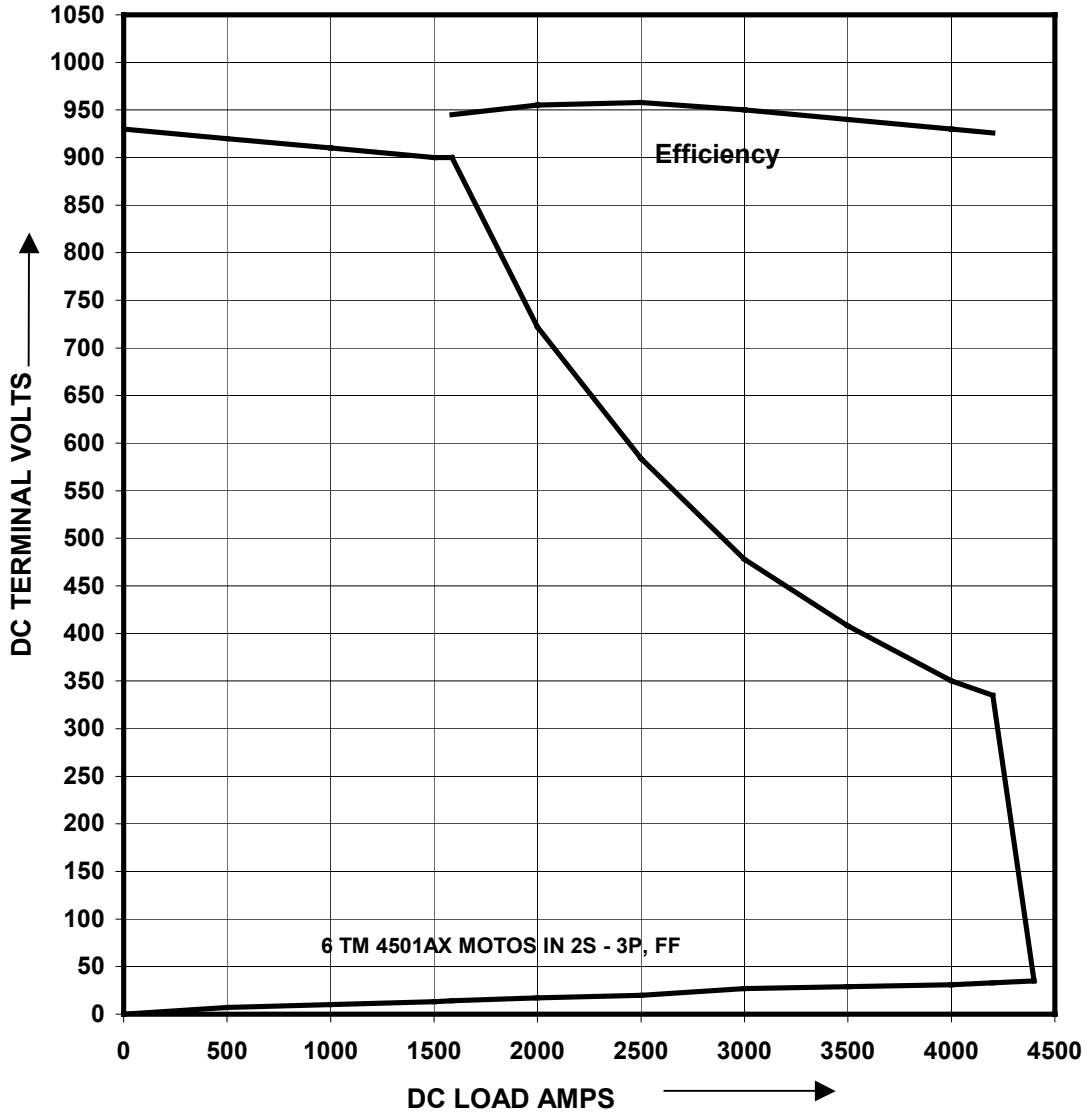

TRACTION ALTERNATOR TA 10102 CW CHARACTERISTICS
FOR 3100HP LOCOMOTIVES
TERMINAL VOLTS/EFFICIENCY/12(%)
LOAD AMPS
Efficiency
F
E
D
C
B
A
A - 4200 A, 460 V
B - 3600 A, 545 V
C - 3200 A, 615 V
D - 2800 A, 705 V
E - 2400 A, 820 V
F - 1775 A, 1100 V
6 - TM 4906 Traction Motor in 2S-3P
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

ANNEXURE - C

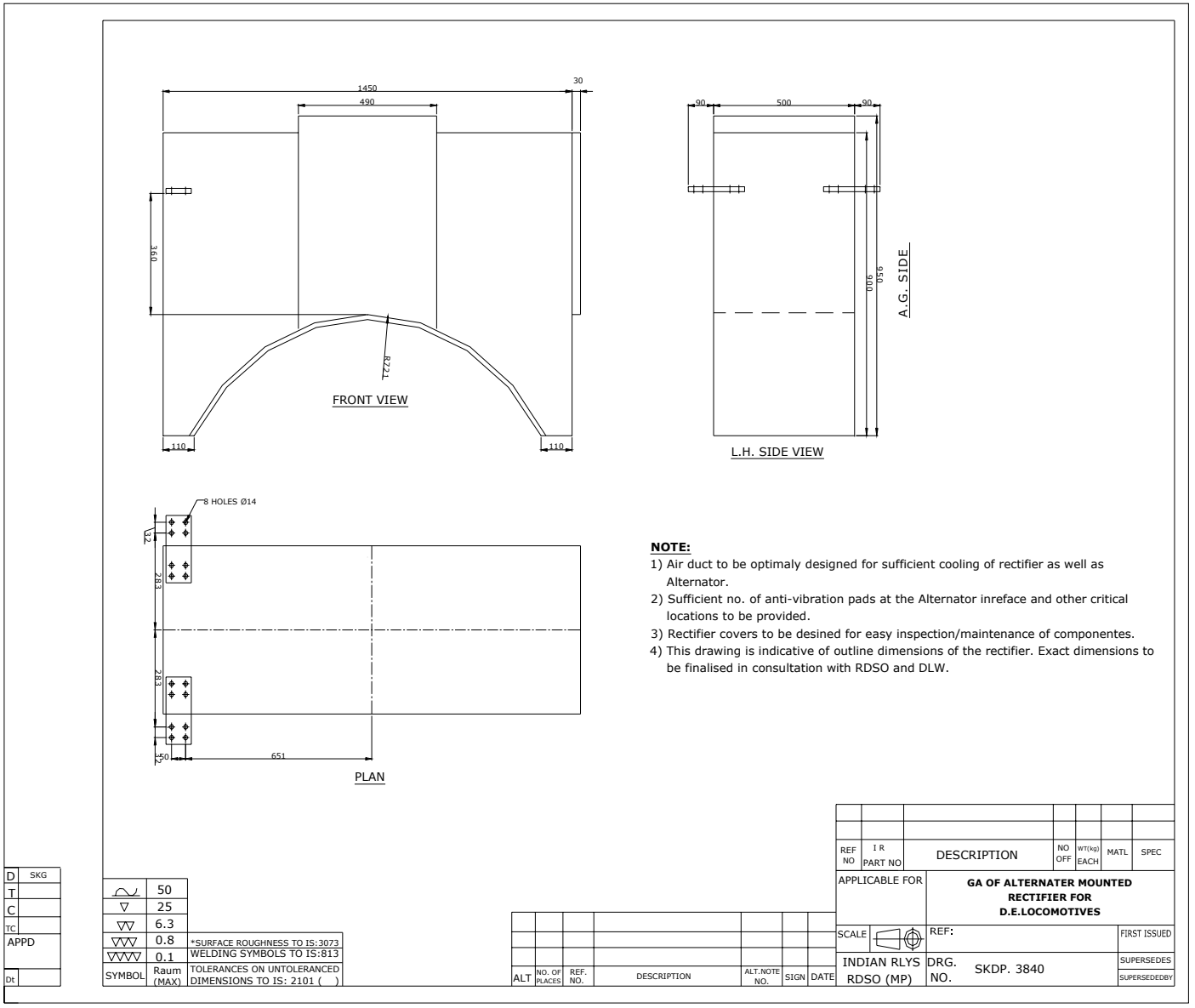
TRACTION ALTERNATOR TA10102 DW/EV CHARACTERISTICS FOR 2300HP LOCOMOTIVES

INPUT TO TRACTION : 2050 HP AT 1000 RPM

HV CONT. RATING : 900V, 1587A, 1428KW, 1000RPM
LV CONT. RATING : 383V, 3700A, 1417KW, 1000RPM



ANNEXURE – D



NOTE:

1) Air duct to be optimaly designed for sufficient cooling of rectifier as well as Alternator.
2) Sufficient no. of anti-vibration pads at the Alternator inreface and other critical locations to be provided.
3) Rectifier covers to be desined for easy inspection/maintenance of componentes.
4) This drawing is indicative of outline dimensions of the rectifier. Exact dimensions to be finalised in consultation with RDSO and DLW.

D	SKG
T	
C	
TC	
APPD	
Dt	

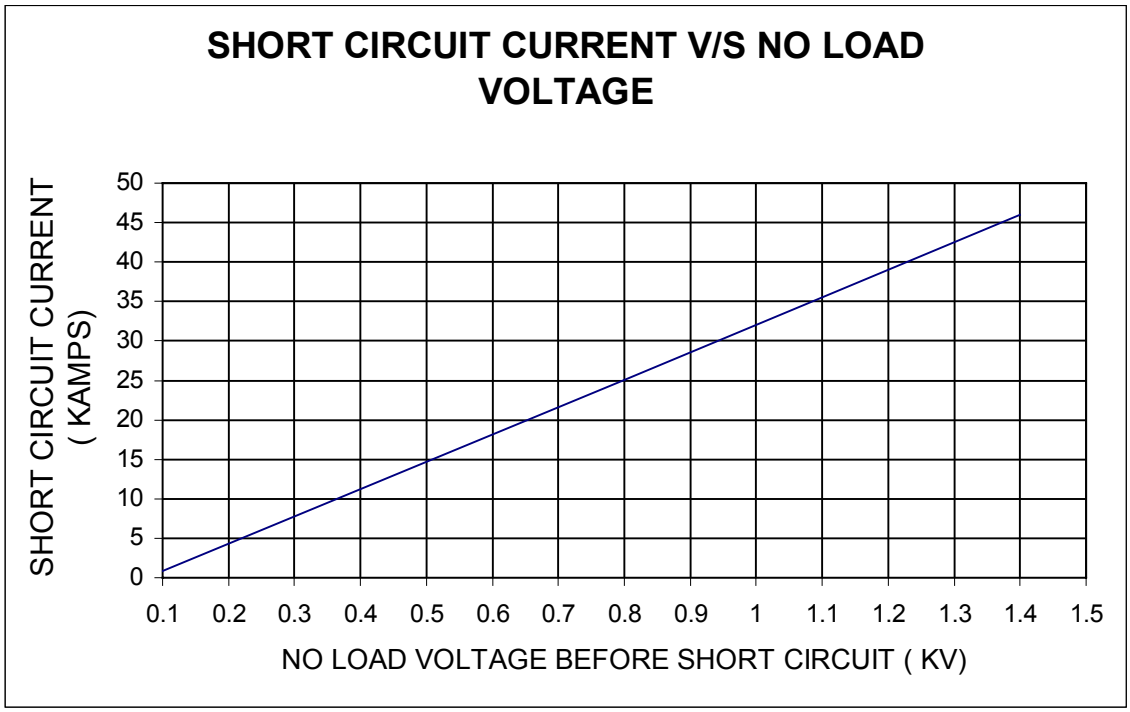
	50	
▽	25	
▽▽	6.3	
▽▽▽	0.8	*SURFACE ROUGHNESS TO IS:3073
▽▽▽▽	0.1	WELDING SYMBOLS TO IS:813
SYMBOL	Raum (MAX)	TOLERANCES ON UNTOLERANCED DIMENSIONS TO IS: 2101 ( )

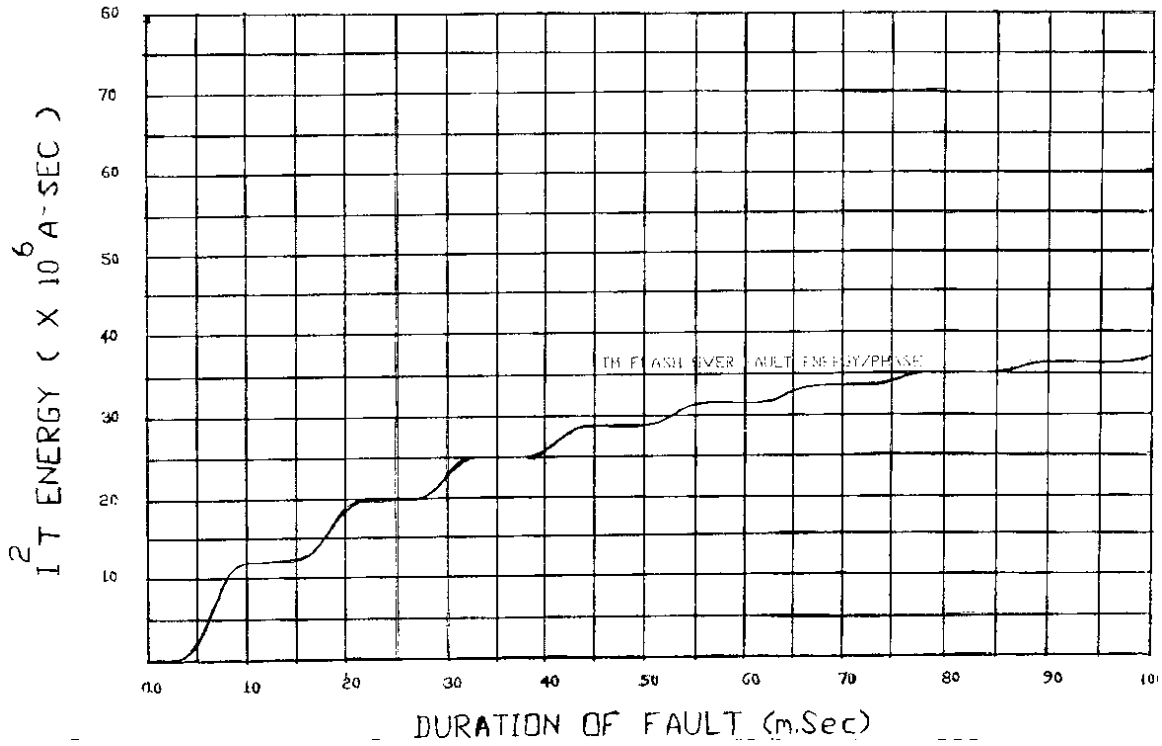
ALT	NO. OF PLACES	REF. NO.	DESCRIPTION	ALT.NOTE NO.	SIGN	DATE

REF NO	I R PART NO	DESCRIPTION	NO OFF	WT(kg) EACH	MATL	SPEC

APPLICABLE FOR	**GA OF ALTERNATER MOUNTED RECTIFIER FOR D.E.LOCOMOTIVES**	
SCALE	REF:	FIRST ISSUED
INDIAN RLYS RDSO (MP)	DRG. NO. SKDP. 3840	SUPERSEDES
		SUPERSEDEDBY

ANNEXURE – E


SHORT CIRCUIT CURRENT V/S NO LOAD VOLTAGE
SHORT CIRCUIT CURRENT (KAMPS)
50
45
40
35
30
25
20
15
10
5
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5
NO LOAD VOLTAGE BEFORE SHORT CIRCUIT (KV)


I^2T ENERGY (X 10^6 A-SEC)
60
70
60
50
40
30
20
10
0.0 10 20 30 40 50 60 70 80 90 100
DURATION OF FAULT (m.Sec)

ANNEXURE - F

INFORMATION TO BE FURNISHED BY MANUFACTURER

a) Drawings, Specifications etc.

a.1 Outline general arrangement and detailed assembly drg. of the rectifier cubicle including layout and schematic drg. of the rectifier assembly.

a.2 Drawing of heat sink, diode, separately & in assembled condition and of insulated hardware used for assembly.

a.3 Detailed drawing of all major equipment used in assembly.

a.4 Component drawings for fabrication of rectifier assembly.

a.5 Manufacturing assembly drawings

a.6 Complete list and specification of parts, components and raw materials proposed to be imported and their manufacturer's address.

a.7 Complete list and specification of parts, components and raw material proposed to be procured from indigenous sources and their manufacturer's address.

a.8 Complete technical data of silicon rectifiers including silicon diodes and matching components.

a.9 Full particulars of the rectifier protective system including indication devices and the supervisory unit.

a.10 Type and routine tests reports on the rectifier assembly, diodes and other major equipment.

a.11 Complete description of the design features with explanatory notes.

b) Technical data of diodes

b.1 Type and make. .....
b.2 Type of junction .....
b.3 Rated average forward current
with forced air cooling :
b.3.1. At 70 deg. C ambient and rated junction temp :
i. For single phase 180 deg. conduction.....
ii. For three phase 120 deg. conduction .....
With Base temperature.....and frequency...
b.3.2. At 55 deg. ambient and rated junction temp :
i. For single phase 180 deg. conduction.....
ii. For three phase 120 deg. conduction. .....
With Base temperature.....and frequency....

b.4 Recommended crest working reverse voltage at rated junction temp .....

b.5 Rated repetitive peak inverse voltage at rated junction temp.....

b.6 Rated non-repetitive peak inverse voltage at rated junction temp .....

b.7 Test reverse voltage at works at rated junction temperature .....

b.8 Peak forward voltage drop characteristics at ambient and rated junction temp. (enclose curve)

b.9 Forward Watt loss vs forward current curve. (enclose curve).

b.10 Graph of peak inverse current vs peak inverse voltage at rated junction temp. (enclose curve)

b.11 Overload characteristics : Surge limit current with no reverse voltage and surge forward current with 50 % reverse voltage (enclose curve)

b.12 Max. peak surge current without inverse voltage at rated junction temp :
i) One cycle, (50Hz) .....
ii) Five cycles, (50Hz).....
(Enclose Peak Surge Current Vs Pulse Base Width Curve)

b.13 Max. peak surge current with rated PIV applied at rated junction temp :
i) One cycle (50Hz) .....
ii) Five cycles (50Hz) .....
(Enclose Peak Surge Current Vs Pulse Base Width Curve)

b.14 I^2t value (Survival rating) for 25 Deg. C and rated junction temperature separately :
i) For 10 milliseconds .....
ii) For time corresponding to five half cycles of fault current .....
iii) For time corresponding to the time of isolation of fault .....
(Enclose I^2t content Vs Pulse Base Width Curve).

b.15 Resistance of diode on rated condition :
i) Forward .....
ii) Reverse .....

b.16 Average forward current vs cooling air temp curve (at specific cooling, enclose curve)

b.17 Rated junction temp. and short time temp. limits for the junction.

b.18 Temp. limit of cell body/heat sink at rated current .....

b.19 Thermal resistance of the cell base to heat sink (deg./watt) .....

b.20 Thermal resistance curve of the heat sink (deg. / Watt) vs forced air and natural cooling vs heat dissipation in watts. (Enclose curve)

b.21 Transient thermal impedance curves for heat sink and cell.

b.22 Hydraulic loss coefficient of heat sink vs Phase velocity (enclose curve)

b.23 Vibration resistance for diode at 50 Hz.....

b.24 Mounting torque in Kg-m.....

b.25 Weight in Kg. of cell and heat sink.....

b.26 Storage temp :
- i) max. .....
- ii) min. .....

b.27 Service life (min) .....

c) Technical data of Rectifier Assembly

c.1 Number of cells in series in each string.

c.2 Number of strings in parallel per arm.

c.3 Number of cells per rectifier unit.

c.4 Total no. of cells per loco.

c.5 Continuous current rating of rectifier for 30 sec, 1, 3 & 8 min.

c.6 Fuse data :
- i) Rated voltage
- ii) Rated current
- iii) Rated power
- iv) I^2t ratings (enclose curve)
- v) Additional characteristics of fuse (enclose curves)

c.7 Devices used for protection against surge voltages :
- i) Main surge arrester.
- ii) Main RC network and earthing condenser.
- iii) DC damping network

c.8 Data and characteristics of thermal switch used for detecting abnormal temp. rise of device.

c.9 Detailed characteristics of additional protective devices against overloads (if any).

c.10 Devices used for hole storage condenser and resistance :
- i) Capacitance .....
- ii) Resistance .....

c.11 Device for checking defective cells in the rectifier cell check devices or string fuse.

c.12 Diagram showing connections between cells in the cubicles

c.13 Weight of complete equipment with its auxiliaries.

c.14 Cooling air requirement .....cfm with..... mm.wg static pressure at inlet.

d) Design Calculations

d.1 Calculation of the number of cells in series based on :
- i) repetitive voltage
- ii) switching surge

d.2 Calculation of the number of cells in parallel based on :
- i) specific continuous current
- ii) starting duty cycle
- iii) short circuit current

d.3 Calculation of fuse selection based on :
- i) continuous rating
- ii) traction motor flashover / output short circuit
- iii) string failure

d.4 Temperature rise for :
- i) continuous rating
- ii) starting duty cycle
- iii) continuous rating & starting duty cycle with one parallel string eliminated

d.5 Cooling air at continuous rating with air inlet temp. of 25 Deg.C & 60 Deg.C