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SPECIFICATION NO. SPEC/E-15/2/03

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RAIL MANTRALAYA

SPECIFICATION
FOR
TRANSFORMER-RECTIFIER SET
FOR
REGENERATION ON WCG-2 LOCOMOTIVES

SPECIFICATION No.SPEC/E-15/2/03

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SPECIFICATION FOR TRANSFORMER-RECTIFIER SET FOR REGENERATION ON WCG-2 LOCOMOTIVES

0. FOREWORD

0.1 This specification covers the requirement of the transformer-rectifier unit for regenerative braking to be fitted on WCG2 locomotive, as a part of the braking system.

0.2 This specification contains clauses for ratings and expected performance of the equipment. Any deviation from this specification, calculated to improve the performance, utility and scope of the equipment, proposed by the manufacturer, will be given due consideration, provided full particulars and justification thereof are furnished in the tender.

1. SCOPE

1.1 This specification covers the manufacture, supply and tests on the transformer-rectifier set for regeneration on WCG2 class of locomotives. The tenderer shall check the suitability of the equipment offered by him, based on the details furnished below, to ensure reliable and troublefree operation, and shall furnish complete technical details and test results for the same.

2. CAPACITY AND RATING

2.1 The regenerative braking transformer equipment, at full load voltage of 20 V, shall deliver a continuous DC output of 600 Amps for each of the two parallel paths of regenerative circuits, comprising of three traction motor fields and stabilising resistance connected in series, as shown in Enclosure A.

2.2 The equipment shall be designed with low percentage impedance of the order of 5-6%.

2.3 The transformer-rectifier set shall be equipped with two pairs of DC output terminals to facilitate connections for each of the two parallel paths.

2.4 The rectifier shall be so arranged as to by pass any excess current in the motor field circuit, due to resultant effect of the motoring current in the armature, without affecting the excitation transformer winding. This aspect is explained in the principle of operation (Annexure 1).

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2.5 The rectifier rating shall be such as to permit satisfactory operation under continuous current of 1000 Amps dc flowing through each of the traction motor field circuits.

2.6 The rectifiers shall be designed for consideration of short circuit across the excitation transformer with stabilising resistance in circuit.

2.7 The transformer-rectifier set shall be provided with class B insulation and designed for natural air cooling.

2.8 The input supply will be 3-phase, 400 V ± 10% with a frequency of 50 Hz ± 5%.

3. SERVICE CONDITIONS

3.1 The equipment covered in this specification shall be suitable for service in a temperature of the cooling air inside the locomotive being 65°C, relative humidity ranging upto 100%, at an altitude of 1000 metres above mean sea level and in dusty atmospheric conditions.

3.2 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 service, as indicated below :-

a) Maximum vertical acceleration - 1.0 g

b) Maximum longitudinal acceleration - 3.0 g

c) Maximum transverse acceleration - 0.5 g

d) Maximum frequency - 10 Hz with amplitude of 2.5 mm.

('g' being the acceleration due to gravity)

3.2.1 The vibrations are of sine wave form and the frequency of vibration is between 1 Hz and 50 Hz. The amplitude 'a', expressed in millimetres, is given as a function of 'f', by the equations :-

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

$a = \frac{250}{f^2}$ for values of f exceeding 10 Hz and upto 50 Hz.

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3.2.2 In the direction corresponding to longitudinal movement of the vehicle, the equipment is subjected for 2 minutes to 50 Hz vibrations of such a value that the maximum acceleration is equal to 3g (amplitude a = 0.3 mm).

3.3 The equipment shall be suitable for continuous operation on 3-phase, 50 Hz supply obtained from a 180 kVA DC motor - AC alternator set, with the limits of output voltage of 400V ± 10%, and frequency of 50 Hz ± 5%, for full load range.

4. GENERAL DESIGN FEATURES

4.1 Principle of Operation

4.1.1 The principle of operation of the equipment, as a part of the regenerative braking system of the locomotive, is given at Annexure 1.

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

4.3 Protection shall also be provided in each of the DC output parallel circuits against an over-load current exceeding 1000 Amps in the form of fuse or over-load relay.

4.4 Overload protection for equipment on AC side shall also be provided.

4.5 Visual indication shall be provided on the equipment for rectifier element failures. Rectifier rating shall be so selected that not more than two parallel paths are provided and each path shall be suitably protected with quick acting fuses.

4.6 All protective arrangements provided shall be suitable for repeated operations and finally ensure isolating the equipment in case of over-load and/or short circuits.

4.7 The positive terminals provided on the transformer-rectifier set shall be dimensionally bigger than the negative terminals, so that the connections coming on them cannot be inter-changed. In addition, the terminal board should bear clear marking of their potential.

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5. ENCLOSURES AND MOUNTING

5.1 The equipment shall be provided in a robust dust-proof sheet steel enclosure.

5.2 The enclosure shall be so arranged that, when it is opened, the terminals are readily accessible. Furthermore, 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. The cabinet shall be floor-mounted. The approximate space available for mounting the complete unit is as under :-

Length	-	950 mm
Width	-	850 mm
Height	-	1550 mm.

5.3 It shall be desirable to keep the weight of the unit as low as possible, without sacrificing any of the desired features. Under no circumstances, the weight shall exceed 1200 kgs.

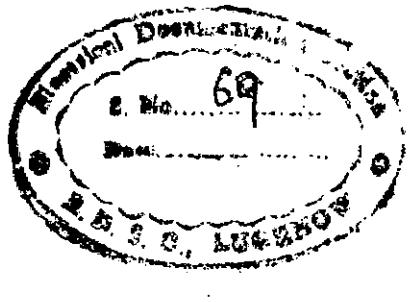
5.4 Arrangement for lifting the whole cubicle shall also be made by providing shackles.

5.5 The equipment shall be painted in light-greay colour with IS-1650 : 1960 - Colours for painting and decorative finishes.

6. TERMINAL BOARD AND WIRING

6.1 The unit shall be completely wired and the terminal brought out to a terminal board located inside the cubicle on the front side. The cables used for internal wiring shall be tinned multi-stranded copper. Special care shall be taken in the design to provide a minimum creepage distance of 45 mm between the terminals. The terminal 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 an earth connection.

6.2 All the terminals of the unit shall be brought out on a special terminal board with legible indications marked on the plate. The terminal arrangement shall be subject to the approval of the user railway prior to manufacture.



6.3 Suitable spring washers, nuts for terminal connections shall be provided on all the terminals, including earth.

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

7. <u>SCHEDULE OF PARTICULARS? DRAWINGS AND TECHNICAL DOCUMENTS</u>

7.1 Full particulars of the transformer-rectifier set shall be furnished along with the general outline dimensioned drawing of the equipment and its mounting arrangement. Details of the electrical circuitry and the various components shall also be advised.

7.2 Technical documents regarding make, rating, resistance/inductance/capacitance values of the various components shall also be furnished.

7.3 All necessary technical documents and literature, which would be useful for proper maintenance and repair of the equipment, shall also be furnished.

7.4 Calculations showing the temperature rise of the equipment under full load and normal operating conditions shall be furnished. The magnetising characteristics and load current characteristics with input, output and efficiency curves at various loads shall also be furnished.

7.5 Rectifier details shall be furnished as per Annexure 2.

8. <u>TYPE AND ROUTINE TESTS</u>

8.1 These sha ll be carried out in consultation with the Chief Electrical Engineer, Central Railway, Bombay, and the inspection of the equipment during manufacture and after assembly shall also be arranged by him.

9. <u>PROTOTYPE</u>

9.1 One prototype equipment shall be supplied for trial purpose. Order will be confirmed, when the prototype is found satisfactory.

10. GUARANTEE

10.1 The whole equipment shall be guaranteed for a period of 24* months from the date of supply or 18* months from the date of installation on the locomotive, whichever is earlier. Defective components/equipment shall be replaced without any extra charge and without loss of time.

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(*) to be fixed by Central Railway.

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PRINCIPLE OF OPERATION

The transformer-rectifier set is utilised to supply power to the excitation fields of traction motors during regenerative braking of the locomotive.

The simplified circuit for both regeneration and motoring, with TFEX connected, is shown in Enclosure "A". The field is connected in series with TFEX and this combination is connected across stabilising resistance. The distribution of currents and their directions were shown with arrows. The direction of field current is same both in regeneration and motoring.

During Regeneration: The excitation current flows from +ve terminal of TFEX (ground side) through the stabilising resistance motor field coils to the -ve side of TFEX. The regenerated current flows through the stabilising resistance in the same direction as the excitation current.

Hence, if -

E = Terminal voltage of TFEX in volts

R_s = Stabilising resistance in ohms

R_f = Field resistance in ohms (3 motors)

I_a = Armature current (either in regeneration or in motoring) in Amps

I_f = Field current in Amps (through R_f)

then, at any time during regeneration,

$$E = R_s (I_a + I_f) + R_f I_f$$

and $$I_f = \frac{E - I_a R_a}{R_s + R_f}$$

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Thus, if the terminal voltage E of the TFEX is constant, necessary stabilisation is provided by the stabilising resistance for any change in the regenerated current, by corresponding change in field current in the opposite sense.

During Motoring: Since the motoring current is in opposition to the current already flowing through stabilising resistance 'R_s', the voltage drop across 'R_s' is reduced, thereby increasing the field current (R_s and E being constant). Thus, with the increase in motoring current, the field is strengthened.

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Continued increase in motoring current will reduce the voltage drop across R_s and will try to reduce the current through it to Zero.

$$E = -R_s (I_a - I_f) + R_f I_f$$

$$E + R_s I_a = I_f (R_s + R_f)$$

$$I_f = \frac{E + R_s I_a}{R_s + R_f}$$

In this case, 'I_f' is more than in previous case and will tend to reduce the motoring current I_a, thus providing necessary stabilisation.

Increase in the field current I_f due to motoring current I_a will flow through the rectifiers alone without affecting the excitation transformer winding, as explained below :-

Assume -

I_f = Field current flowing through each of the two parallel paths of traction motor fields, induced due to excitation transformer.

I_{fm} = Increase in field current flowing through each of the two parallel paths due to the armature current I_a during motoring.

As explained in Figure B of Enclosure A, the field current I_f increases with increase in the motoring current I_a and flows in the same direction through excitation transformer rectifier set. Thus, I_f and I_{fm}, as assumed above, will have the same direction. Current I_f will be flowing in each of the field circuit due to the $2I_f$ current induced in the excitation transformer secondary winding and would pass through the rectifier bridge, as shown in RED in Fig. C of Enclosure A, whereas the increased field current I_{fm} will only pass through the rectifier alone, as shown in BLUE in Fig. C of Enclosure A, without affecting the excitation transformer secondary windings.

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A. TECHNICAL DATA OF RECTIFIER DIODES

The following technical data concerning diodes shall be furnished:-

1. Type and Make
2. Rated average forward current at an ambient temperature of 65°C with forced air cooling for half wave single phase/for single phase bridge connection.
3. Recommended crest working reverse voltage at rated junction temperature.
4. Rated repetitive peak inverse voltage at rated junction temperature.
5. Rated non-repetitive peak inverse voltage at rated junction temperature.
6. Test voltage at manufacturer's works.
7. Peak forward voltage drop characteristics at ambient and rated junction temperatures.
8. Graph of peak inverse current versus peak inverse voltage at rated junction temperature.
9. Overload characteristic curves (peak values).
10. Maximum peak surge current characteristic at rated condition.
11. I^2t value curve or equivalent.
12. Fuse characteristics, if provided.
13. Rated junction temperature and short time temperature limits for the junction.
14. Temperature limit of cell/body/heat sink at rated current.
15. Thermal resistance of the cell (°C/Watt).
16. Thermal resistance of the heat sink (°C/Watt), with forced cooling m/sec.
17. Transient thermal impedance curves for heat sink and cell.

18. Mounting torque in kg-m.

19. Recommended conductive grease.

20. Weight in kg of cell and heat sink.

B. TECHNICAL DATA OF RECTIFIER ASSEMBLY

1. Number of cells in series in each string.

2. Number of strings in parallel per arm.

3. Number of cells per rectifier unit.

4. Detailed characteristics of protective devices against overloads.

5. Devices used for protection against surge voltages -

   - Main surge arrestor
   - Main RC network and earthing condenser
   - Diode hole storage and potential divider circuit
   - DC damping network

6. Diagram showing connections between cells in each cubicle.

7. Weight of complete equipment with its auxiliaries.

C. DESIGN CALCULATIONS

Detailed calculations for arriving at number of cells in series and in parallel, to meet the specified duties, shall also be furnished.

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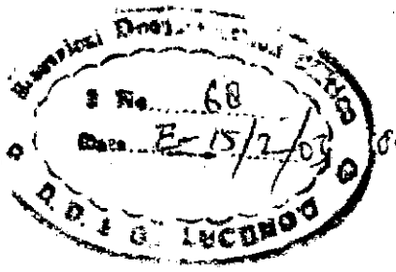

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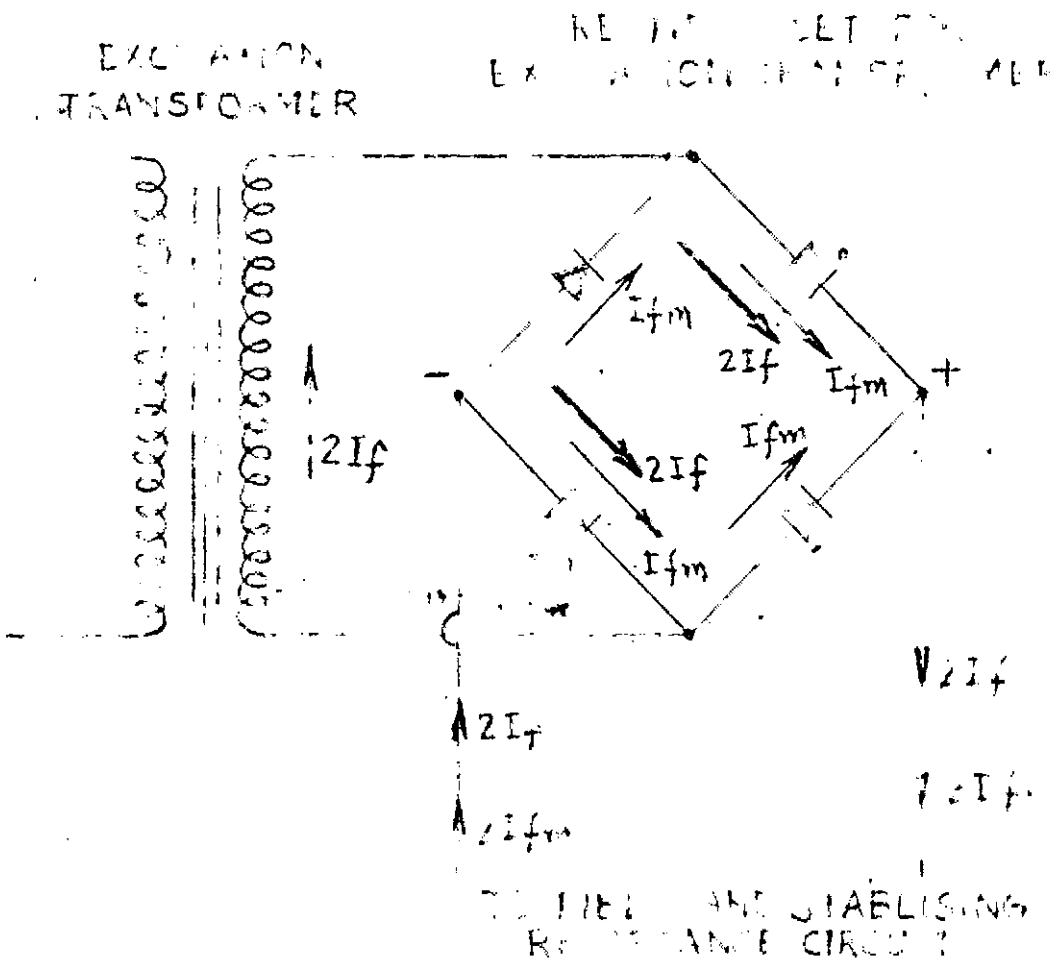
EXCITATION
TRANSFORMER
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FIG: C

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