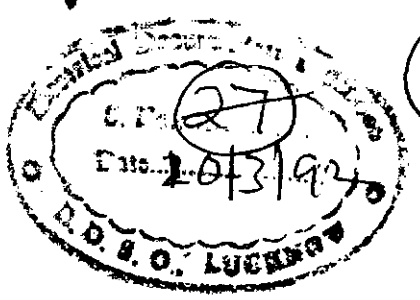
Doc. Copy

SPEC. NO. SPEC/E-5/27

27

158



158

TECH. SPECIFICATION FOR THYRISTOR EQUIPMENT OF 5000 H.P. WAG7/WAP4 CLASS ELEC. LOCOMOTIVES

SPECIFICATION No. SPEC/E-5/27.

Government of India
Ministry of Railways
(Railway Board)

INDIAN RAILWAYS

Technical Specification

for

Thyristor Equipment

of

5000 H.P. WAG-7/WAP-4 Class

Electric Locomotive

December 1990

Issued by

Research Designs & Standards Organisation

Lucknow - 226 011

CONTENTS

ANNEXURES

SPECIFICATION FOR THYRISTOR EQUIPMENT FOR 5000 HP WAG-7 CLASS ELECTRIC LOCOMOTIVE.

---

1 SCOPE & DEFINITIONS

1.1 SCOPE

1.1.1 Indian Railways have electrified around 9000 route kilometers of track. Further electrification is in progress. The power supply system adopted is of 25.0 KV., 50 Hz., single phase except for a small section of around 400 route kilometers with 1500V DC supply system. The equipment to be supplied will be provided on 25.0 KV., 50 Hz., single phase AC electric locomotives.

1.1.2 Currently the electric locomotives manufactured at Chittaranjan Locomotive Works, Chittaranjan are rated for 3250 HP using conventional tap changer control, silicon diode rectifier, DC series traction motors. Speed potential of freight locomotive is upto 75 km/h., maximum starting tractive effort of 33.5t and continuous running tractive effort of 20.6t at a speed of 50.5 km/h. Speed potential of passenger Locomotive (WAP-3) is 140 Km/h.

1.1.3 Taking into consideration the present increased trailing load of 4700t of BOX-N wagon under design the performance parameters of the required locomotive is 44t starting tractive effort and 5000HP continuous. In view of the above, an upgraded version of electric locomotive, designated as WAG-7 is under consideration.

Also for increasing the trailing load to 26 coaches and the speed upto 120 km/h AC WAP-4 class locomotive with a starting tractive effort of 26.3t is also under consideration.

63715

1.1.4 The use of thyristor controlled equipment has been considered on these WAG-7 and WAP-4 locomotives due to stepless control, use of fixed ratio transformer elimination of tap changer, field weakening without the use of resistors and contactors, etc. The existing DC series traction motor type HS 15250 will be suitably modified as a compound traction motor HS 15250CB to suit thyristor convertors, the details of which are given under equipment data in Chapter-V. The traction motor type HS 15250CB will be a fully suspended type.

1.15 This specification is for design, manufacture, testing, installation, commissioning and field trials of thyristor convertors with associated equipment as detailed below for use in the proposed 5000 HP, 25 KV, 50 Hz, AC single phase electric locomotive.

The convertor is to be complete with the followi associated equipment :-

.1 Surge absorbers to protect the thyristor convertors.

.2 Power factor correction units.

.3 Assymetrical half-controlled bridges operating in two step sequence control complete with micro-processor based control and protection system.

.4 Microprocessor based control system for thyristo controlled bridges of traction circuit and power factor correction units, microprocessor based continuous system health monitoring, fault diagnostic system and indications/alarms etc detailed in Chapter-IV.

.5 Continuous wheel slip/slide detection system and slip/slide control.

.6 Master controller-cum-weak field controller detailed in Chapter-IV.

.7 Sensors for control function.

.8 Interface units for fault retrieval system, display, display control, key board, printer, etc.

.9 Solid state switches, relays, contactors, power supply, etc., required for thyristor control convertors and controls.

The offer shall be for sets of equipment for mounting on WAG-7/WAP-4 locomotives and complete loco sets as spare. List of components required for maintenance for a period of 3 years is to be furnished with cost by the tenderer.

1.2 Definitions.

1.2.1 'Tenderer'/'Supplier' means the firm/company submitting the offer for supply of electrical equipment conforming to this specification. To qualify as a tenderer/supplier, the firm/company shall provide satisfactory evidences acceptable to the Purchaser in that they -

(i) have the requisite capacity to develop the design on the basis of manufacturing thyristor control for traction or industrial application which is performing well.

..... 3

(ii) have manufactured programmable logic controllers or the like

1.2.2 'Purchaser' means the President of the Republic of India.

1.2.3 RDSO means, Research Designs & Standards Organisation, Ministry of Railways, Manak Nagar, Lucknow, India - 226 011.

1.24 'Inspecting Officer' means person, firm or department nominated by the purchaser to inspect the equipment on his behalf or the representative of the Inspecting Officer so nominated.

1.2.5 CLW means Chittaranjan Locomotive Works, Chittaranjan, West Bengal, India-713 331 or their successors.

1.2.6 Contractor means any firm or company with whom the order for supply of electric equipment has been placed or intended to be placed.

1.2.7 'Sub-supplier'/Vendor means any person, firm or company from whom the contractor may obtain any material, sub-assemblies or assemblies used for the manufacture of the electrical equipments so mentioned

1.2.8 IEC means International Electro-Technical Commission.

1.2.9 'IR' means Indian Railways.

1.2.10 'BG' means 1676mm gauge, referred to as Broad Gauge.

1.2.11 'IRS' means Indian Railways Standards.

1.2.12 'IS' means Indian Standards.

1.2.13 'BS' means British Standards.

1.2.14 'IEEE' means the Institute of Electrical and Electronics Engineers, Inc., U.S.A.

163716

CHAPTER - II

2 POWER SUPPLY SYSTEM AND OPERATING CONDITIONS.

2.1 Traction Power Supply System.

The basic features of 25.0 KV, AC, single phase, 50 Hz system are as follows :-

- General : 25.0 KV is the nominal voltage of the system. The design, calculations and guaranteed performance shall be based on a line voltage of 22.5 KV, AC.
- Supply voltage variation : 19.0 KV to 27.5 KV
  Occasional maximum : 30 KV
  Instantaneous minimum : 17.5 KV
- Variation in frequency : ± 3 % (48.5 to 51.5 Hz).

The voltage is subjected to wide fluctuations which are inherent in any traction system. The traction substations are provided with 12.5 MVA/(-20 MVA, 132 KV/25 KV single phase transformers. As per supply conditions, average power factor is not to be less than 90%, failing which heavy penalties are imposed. Indian Railways are also considering the 2 x 25 KV AT system for traction power supply.

2.2 Climatic and Environmental Conditions.

The environmental and service conditions are given below :-

- Maximum temperature (atmospheric) : Under Sun .. 70°C
  Under Shade .. 50°C
  Inside Loco .. 55°C
- Minimum : 0°C
- Humidity : 95 to 100% during rainy season.

- Reference site condition	:	Ambient	.. 47°C
		Inside loco	.. 55°C
		Humidity	.. Upto 90 %
		Altitude	.. 160m above mean sea level.
- Rainfall	:	Very heavy in certain areas. The locomotive equipment shall be designed suitably.	
- Atmosphere during hot weather	:	Extremely dusty and desert terrain in certain areas. The dust concentration in air may reach a high value of 1.6 mg/M^3.	
- Coastal area	:	The equipment shall be designed to work in coastal area in humidity and salt laden and corrosive atmosphere. The maximum values of the condition will be as follows :-	
		.1 Maximum pH value	.. 8.5
		.2 Sulphate	.. 7 mg/Litre
		.3 Max. concentration of chlorine	.. 6 mg/Litre
		.4 Max. conductivity	.. 130 micro Siemens/CM
- Vibration	:	The equipment sub-system and their mounting arrangement shall be designed to withstand satisfactorily the vibrations and shocks encountered in service as specified in IEC-571 Publication for electronic equipment and relevant IECs as applicable to other equipments.	

63717

2.3 Signal and Telecommunication Installations.

2.3.1 The track over which the locomotive will run is equipped with different types of track circuits, axle counters, block instruments, point machine, etc. On the communication network, train control circuit and teleprinter circuits, VHF and microwave circuits are employed. Broad details of such signalling and telecommunication equipment used are

given in Annexure-A. The design of power electronics and control electronics offered for providing on the locomotive shall be such as not to cause unacceptable levels of interference on these circuits as detailed in para 2.3.2.

2.3.2 The following are the maximum acceptable level as measured on the current drawn by the locomotive :-

.1 Psophometric current shall be as low as possible. It shall not exceed the limit of 10 Amps under any circumstances. Offer with lower values may be given preference.

.2 Interference current due to second harmonic should be less than 2 Amps.

.3 The interference ~~trials~~ in the audio frequency range (1 KHz to 3 KHz) and in the high frequency range (above 3 KHz) shall be mutually agreed between purchas and manufacturer.

p.t.o. ...

CHAPTER - III

3.0 POWER CIRCUIT AND OPERATING REQUIREMENTS OF EQUIPMENT TO BE SUPPLIED.

3.1 Power Circuit.

A simplified power circuit diagram is enclosed as Annexure-D (GKEL No. 3979)). The locomotive will be provided with two current collectors (pantographs), but at a time only one will be used. The provision for raising both the pantographs is also provided. Pantograph type AM-12 of M/s. Faively make is the standard adopted.

Spark Gap ET-1 of 210mm is provided before vacuum circuit breaker and the spark gap ET2 with a gap between 70 to 90mm along with the gapless lightning arrester provided as shown in circuit diagram will be according to RDSO Specification No. Spec./E-1/2/05.

The vacuum circuit breaker (VCB) type 20 CB of M/s. GEC make or similar or an air blast ckt. breaker will be provided and its operating parameters are furnished under equipment data in chapter-V.

The main transformer is a fixed ratio transformer with four (4) secondary windings for traction motors, two auxiliary windings for feeding the separately excited shunt windings of traction motors (TMs are separately excited DC compound motors) and tertiary winding for auxiliary power supply. As shown in the figure at Annexure-D, each secondary winding is connected to a controlled bridge convertor and the output of two traction convertors are connected in a wayso as to get a 2-step sequence control to feed such a group of three traction motors mounted in the same bogie and connected in parallel. The half controlled bridges will be operated in sequence for traction motor voltage control. The series field of traction motor is connected in series with the traction motor armature.

Separately excited shunt fields of the traction motors on one bogie are operated in series and fed from a fully controlled rectifier bridge. Weak field operation and dynamic breaking shall be obtained by controlling the output of fully controlled bridge feeding shunt fields. A reverser is used for changing the direction of locomotive. Traction motor contactors (L1 through L6) are provided for isolation of a defective traction motor. Each traction motor is to be provided with smoothing reactor to limit ripple current below 28% at full load.

The locomotive is provided with dynamic braking with a suitable changeover switch. Shunt field should be so regulated that maximum braking effort is obtainable, with the use of shunt field only. The maximum value of braking effort shall not exceed 20t for WAG-7 and 16.3t for WAP-4.

3.2 Voltage control.

The voltage control for traction motors shall be obtained by controlling the firing angle of thyristors in half control bridges and the two bridges are operated in sequence. -12-1990

The shunt field windings control shall be obtained by fully controlled field excitation convertors.

3.3 Modes of operation.

There will be four modes of operation as explained below :-

(1) Starting;

(2) Continuous running at any selected position;

(3) Weak field operation;

(4) Dynamic braking.

3.3.1 Starting mode.

In 'starting' mode, the voltage control is achieved by one half controlled bridge of each bogie traction motor group convertors. The voltage across traction motors is increased by increasing the conduction angle of thyristors. The firing of the Bridge No. 1 shall be advanced first and subsequently bridge No. 2 of the same group is fired, keeping the DC voltage linear with respect to master controller angular position. There will be nominated number of steps for the master controller corresponding to limiting the traction motor voltages in equal steps, at least three steps for each half control bridge and one at half the voltage, i.e., full conduction of one bridge for each bogie. The conduction angle of thyristors should gradually change automatically for smooth variation in voltage/current to obtain stepless control. The acceleration shall be under current control mode within set voltage.

3.3.2 Continuous running.

It should be possible to run the locomotive continuously at any preset condition according to the position of the master controller.

Wheel slip/slide should be detected and automatically reduced the conduction angle by microprocessed control to arrest the slip/slide.

3.3.3 Weak field operation mode.

The control logic should be such that changeover to weak field operation mode is effected only after the starting mode and full traction motor rated voltage is achieved. The weak field operation shall be achieved by controlling the shunt field current. The weak field mode shall have 5 control positions, setting the % weak field between the maximum and minimum. The maximum weak field is 40%. The change from max. to min. shall be stepless.

The traction motor isolation is achieved by opening the respective traction motor isolating contactor (L1-6). The feed to the shunt field of isolated traction motor will remain in circuit. However, if one group of three motors are all isolated, the separately excited fields also should be isolated.

3.3.4 Dynamic brake.

The master controller will be moved from traction position to braking side and the shunt field excitation will be controlled by controlling the firing angle of fully controlled field excitation bridge. The master controller may be provided with seven steps, one of which will be for changing connections from traction to braking and the balance six for field control.

In case of excessive braking effort leading to slide conditions, the firing angle should automatically be reduced in order to reduce the excitation and thereby overcome the situation.

1637.9

3.4 Control scheme.

The control will be of flexible nature, main control being set by the driver and within the driver's control command 'automatic control' being achieved by the microprocessor. The control function should be based on a constant armature current till conduction angle as set by the notch position of master controller is achieved and locked until change is ordered by the driver.

All the controlled bridges should be controlled through the master controller through a synchronous control command by the microprocessor.

..... 10

The control system should be so designed as to operate the locomotive with one bogie, i.e., three traction motors isolated condition.

There should be a built-in wheel slip/slide protection in microprocessor control scheme under which correction will be applied only to the affected bogie motors which is under slip/slide till normal operation is restored. Necessary indication should be available on driver's desk. Facility shall also exist for automatic sanding operation in case of wheel slip/slide.

In case the interference level goes beyond the limit the vacuum circuit breaker shall trip with an indication to driver. Microprocessor based control should also control power factor such that it is above 0.95 beyond the speed of 25 km/h.

The control shall be suitable for multiple unit operation upto 2 locomotives. Equipment for such operation forms part of the scope of supply.

3.5 Protection scheme.

The total protection scheme for thyristor equipment, power factor control, etc., should be a part of the design and is to be envisaged and provided by the supplier. The protection scheme shall be ensured through microprocessor control system.

Standard protection like over voltage, over current, over temperature, monitoring of proper functioning of the cooling system and necessary interlock with circuit breaker to trip in case of inadequate cooling, earth fault protection in power circuit, earth fault protection in the auxiliary circuit, harmonic current beyond the limit values, power device failures, excessive rate of rise of voltage and current, i.e., $\frac{dv}{dt}$ and $\frac{di}{dt}$ protection, gate drive protection to thyristor, etc., are expected to be covered in the scheme. Details of proposed protection to be provided are to be listed out in the offer. The major faults shall be displayed to the driver through microprocessor based equipment and shall isolate faulty equipment automatically.

3.6 Monitoring control.

The microprocessor based system should continuously monitor the health of the power convertors and protection system, for their proper functioning. At each fresh start, i.e., at the time of switching

..... 11

on the battery supply, the microprocessor should check the soundness of various cards and confirm through indications for n ormal condition and fault in case any card is defective. Similarly, faults located during monitoring while on run should be indicated to the driver alongwith an advise for further course of action to be taken by him, in case no automatic corrective action has been taken by the control itself.

The harmonic disturbance shall also be monitored by monitoring device for detecting 100 Hz component in the traction current drawn by the locomotive. This device should be cut off power to the thyristor equipment in the event of values exceed a predetermined level.

63720

3.6.1 For prevention of mal-functioning of signalling system a monitoring device should be installed in the thyristor control locomotive. The detector should be capable of detecting unbalance of control angle in positive and negative half cycle both under steady, state and dynamic conditions and DC component/even harmonic content in the primary current of locomotive. The detecting device (should cut off power to the thyristor) in the event of value exceeding a pre-determined level.

3.6.2 To detect uncontrolled in rush of current in the event of thyristor failure and initiate corrective measures, a thyristor failure detection device should be installed in the locomotive.

3.7 Overspeed control.

When the loco is moved light at terminals, overspeeding due to accident at movement of master controller to full position is to be avoided. The acceleration should be monitored and whenever it exceeds 0.7m/ sec^2 the control logic is to ensure that power is shut off to traction motors beyond 20 km/h.

3.8 Fault diagnostics.

The microprocessor based fault diagnostic system should provide a complete protection scheme for the offered system. It should not only detect the fault but also carry out isolation of the faulty equipments to the extent possible with indication to the driver according to a set scheme. The set scheme will be finalised after mutual agreement between RDSO and the supplier.

In addition to the above, the fault diagnostic unit should indicate the driver the defects occurring in the locomotive on other circuitry as detailed in Chapter-IV para 4.11.1. The operation part like isolation of such defective equipments, etc will be done by the driver.

.....12/-

3.9 Multiple operation.

The control scheme and control wire should be so designed to permit the operation, fault diagnostic features upto two locomotives in multiple operation.

3.10 Auxiliary Motors

The three phase auxiliary motors to be used for cooling system for the convertors offered shall have its own protection system for isolation in case of fault and necessary interface with main equipments and protection system. The auxiliary motors shall be suitable for 380V $\pm$ 22$\frac{1}{2}$ % , 50 Hz $\pm$ 3% , phase voltage unbalance of 5%, in three phase power supply.

...13/-

CHAPTER - IV

4.0 OPERATION PARAMETERS OF EQUIPMENTS TO BE SUPPLIED.

The performance specification and operating requirements for the equipments to be supplied are detailed as under :-

4.1 Power factor correction unit.

Microprocessor controlled thyristorised power factor correction unit suitable for light load, to normal load trains should be provided. The power factor shall be measured continuously and corrected so that it is close to unity above train speed of 20 km/h.

4.2 Harmonic filter unit.

The harmonic filter unit shall be suitable to limit the disturbances to the lowest possible and below the specified values indicated in Clause 2.3.2.

4.3 Half controlled rectifier bridges.

The half controlled thyristoriesed rectifier bridges to be supplied shall be complete with surge arrester and other protections on both AC & DC side, fault diagnostic system, cooling system, etc.

There shall be two half-controlled bridges operating in sequence to feed three traction motors of one bogie. Similar arrangement shall be provided for other bogie provided with three traction motors. Each bogie shall have its control independent so that half power is available in case of one bogie isolation.

Each half controlled bridge shall be suitable for a continuous rating of 3 x 1350A DC after derating for higher ambient specified in the specification. In case of several devices in parallel to get required current rating, the continuous rating of the convertor with one string isolated shallbe furnished.

In the circuit configuration, 25% safety margin in the rating of both voltage and current under worst condition is to be ensured. This should be established in the offer with calculation.

A minimum thermal margin of 5°C for junction temperature under worst operating condition for the power devices is required.

....14/-

The over-voltage protection shall be provided by blocking the triggering pulses to thyristors. The over current protection shall be achieved by tripping of the main vacuum circuit breaker. In case of overloading of any traction motor, the respective traction motor contactor will isolate the faulty motor. The design and setting of rectifier bridge over current should be such that the rectifier should be capable of withstanding traction motor flash over current, etc. for a period of 100 ms till it is cleared by the main vacuum circuit breakers. In case of internal fault such as device failure, the faulty string should be isolated automatically permitting normal operation of locomotive with the remaining strings in parallel, in case the offered convertors is fuse free the detailed protection scheme, reliability its isolation, safety factors, etc., should be supported by calculations and service performance for tradion application. In case the strings are provided with fuse, it should be so matched that the remaining devices withstand the surge current with current unbalance to avoid any damage to healthy devices.

The convertors should be complete with various protections required for the power devices and details furnished in the offer. Modular construction is to be adopted as far as possible. The semiconductor devices should conform to IEC-146, other components to relevant IEC specifications and assembled converter to IEC-411-1.

4.4 Fully controlled rectifier bridges for field excitation.

Fully controlled rectifier bridges should be suitable for 375 Amps continuous rating for feeding three series connected shunt fields of traction motors in one bogie The fully controlled thyristorised rectifier bridge should be controlled by microprocessor and complete with all protections and cooling system. The input voltage to this convertors is fed from the trasnformer winding having a voltage of 140 volts corresponding to 22.5KV on primary. There will be two such windings each feeding fields of three traction motors.

The minimum safety factors as given for main half controlled bridges should be ensured for these field convertors also.

It is preferred to have cooling system of field excitation convertor common to main convertor feeding the same group of motors in one bogie.

.....15/-

4.5 Master controller.

The composite mater controller for powering and braking shall have minimum 17 positions, 0 to 10 preferably in traction powering and 0 to 7 positions in opposite direction for braking. The total rotation of the master controller angle for both traction and braking modes shall be limited to 180° max. The powering positions shall be for 0 to 7 full field operation with 4th position for half voltage and 8 to 10 for weak field operation. Braking positions shall be 0 to 7 with position 1 for change over connections to braking mode. The position of master controller shall decide the max. conduction angle with constant armature current, voltage maintained within the set limits and sequence operation of series connected half controlled rectifier bridges and shunt field excitation current. The master controller shall be provided with micro-switch contacts of 5 Amps rating with L/R of 40 mS at 110V DC for control functions. A min. of 12 contracts-6 normal and 6 reverse- shall be provided. Suitable interlock between forward/ reverse movement & the master controller shall be provided.

Smoothing reactors.

Suitable smoothing reactors (SL1-6) to limit the ripple current to 25% to 30% over the range of 0.25 to 1.2 rated current for traction motor is provided along with the transformer. Each smoothing reactor is rated for 750V, 900 A continuous. The duty cycle per coil is

900 A - continuous - followed by

1350 A - 2 minutes - followed by

1200 A - 10 minutes - followed by

960 A - 1 hr.

Max. voltage - 1250 V DC (rectified)

Ripple frequency - 100 Hz

4.7 Sensors.

Suitable sensors, i.e., current transformers, potential transformers, DC current transformer (DCCT), DC potential transformers (DCPT), temperature sensors, relays, contactors for electronic

..... 16/-

control, etc., as required for thyristor equipment, power factor correction unit, filter circuit, etc., are to be supplied with the equipment.

4.8 Auxiliary motors.

Three phase auxiliary motor/blower, pump set, etc., as required for offered cooling system willalso be supplied with the equipment. The calculation for their adequacy and rating, etc., are to be submitted with tender offer. The total load for the offered auxiliary machines shall be within 6 KW. The auxiliary motors shall be suitable for 380V ± 22½ % and phase unbalance voltage of 5%.

4.9 Speed sensors.

Suitable speed sensors for various control function viz slip/slide etc. shall also form part of the supp

4.10 Slip and slide control unit.

Slip and slide control unit must be provided for fast detection and corrective action of wheel slip and slide. Details of the same should be included in the offer. Creep control provision is preferred.

4.11 Microprocessor based control, fault indication, monitoring and display system.

A proven control scheme in the offer is preferred. The control philosophy should be such that it should be possible to move the master controller from one position to another. The corresponding conduction angle achieved through a built-in change rate of 60A per second in the traction motor current as long as the control bridge is continuing the control during starting mode. During weak field operation on the rate of current change should not be more than 30A/sec.

The electronic components should preferably of MIL, Grade 'B' and assembled equipment should be tested as per IEC-571 for satisfactory operation. The dry heat test with equipment energised and loaded shall be conducted at 85°C instead of 70°C mentioned in IEC 571.

In case the MIL Grade 'B' components are not used, the screening procedure, burn-in procedure followed for components and assembled PCBs with temperature limits and duration in hours, specification followed for procurement of components, quality assurance measures adopted, etc., should be submitted in detail

.... 17/-

Provision of suitable redundancy so as to improve reliability will be necessary. The calculation for reliability and redundancy should be indicated in the offer.

The offered equipment shall have built in automatic diagnostic system and trouble shooting upto card level. The details of indications for fault location should also be listed. Following functions are expected from this system :-

(i) Fault, its status indication and logging.

(ii) Continuous monitoring of locomotive operation and detection of abnormal condition and initiation of corrective action and logging.

(iii) Detection of harmonic contents and tripping of locomotive in case it exceeds the limit values with necessary indications.

(iv) On system offered shall display adequate information from the stored memory, in case of any fault, to enable the driver/shed maintenance staff to proceed with the trouble shooting.

(v) Continuous monitoring of power factor and correction.

4.11.1 Additional scheme for which monitoring and indication is to be arranged through a microprocessor based fault monitoring system.

Micro processor based control should ensure that it is not possible for the driver to start the train unless sufficient compressed air pressure is available for operation of the pneumatic controls and brake power. Ten such inputs may be taken as the maximum for the purpose of design.

The fault monitoring and indication will be basically for voltage inputs/pressure inputs/temperature inputs. The nature of voltage inputs are like low battery voltage, blowing out of a fuse operation of relay, etc.

Successive points will be monitored for availability of the voltage signals. When the voltage signal vanishes, two consecutive points at which the signal is available and not available will be picked up and used for processing the defect observed and indication to the driver.

..... 18/-

Approximately one hundred (100) such inputs are envisaged. The inputs may be in a number of groups which would be decided only after finalisation of the control functions. Additional capacity should be built in to enable coverage of 20 more inputs as required in future.

4.11.2 Fault display unit

Suitable fault display unit with key board shall be fluorescent type element to achieve good readability. The functions of key board shall be as under :-

(i) Setting of clock

(ii) Brightness control arrangement

(iii) Locomotive number

(iv) Test pattern for checking display

(v) Confirmation of fault memory

(vi) Confirmation of status memory.

4.11.3 Status memory

The status memory shall have the following categories :-

(i) Fault in high voltage circuit

(ii) Fault in control system

(iii) Fault in battery charger, battery and light circuit.

(iv) Fault in three phase auxiliary invertor

(v) Fault in auxiliary motors

(vi) Fault in cooling system

(vii) Fault in penumatic circuit

(viii) Miscellaneous.

4.11.4 Fault memory

This shall record at least last 100 faults. The fault shall be presented with locomotive number, date, time of failure, nature of defect and values of traction motor voltage and current and speed of the locomotive at the instant of fault occurrenc

..... 19/

In case the number of faults exceeds 100 numbers, the last 100 faults should be available. Suitable provision shall be made to get a printout of faults with all details mentioned above.

Resetting of memory shall be possible only in Maintenance Depot.

4.11.5 Printers and interface equipment.

Suitable interface equipment if required to take printout from the memory shall be provided.

At least 3 printers (132 column Dot Matrix) suitable to take printout should be included in the offer.

4.11.6 AC supply available in the locomotive for auxiliary motors may be used for power supply for electronic cards, as far as possible.

4.12 Additional sensors

For the scheme envisaged by the supplier, if provision of sensors in equipment other than those in the scope of supply is envisaged, provision of such sensors should be detailed and manner in which these sensors are to be provided in other equipments should be explained in detail in the offer.

4.13 Test equipment

Instruments/equipments required for testing, commissioning, performance monitoring and maintenance of equipment offered should also be supplied. The test equipment offered shall include special microprocessor based testing equipment for various PCBs provided. Cost of such equipments should be indicated separately. Two sets of equipment are to be supplied.

4.14 Spares

For equipment covered in the scope of supply, one number spare should be supplied. In addition, the list of recommended spares including spare PCBs with cost for satisfactory operation and maintenance of the equipment for a perid of 3 years shall be indicated and quoted separately for supply.

4.15 Training

A proposal for training of Indian Railway Engineers and Technicians in the manufacturer's works and also in Railway systems where similar equipments of the manufacturer are in service, should be quoted along with details of number of persons to be trained and duration of training. The training scheme should be such that the Railway personnel get sufficient knowledge for satisfactory maintenance of the equipment in service and also tackle problems connected with deficiencies in design as they surface in service.

4.16 . Size and weight of equipments.

The size and weight of offered equipments should be minimum possible. The approximate size and weight for each equipment is indicated in Annexure 'F' and under no case it should exceed these values.

p.t.o. ... 21/-

CHAPTER - V

RELEVANT OPERATING PARAMETERS OF ASSOCIATED EQUIPMENT OUTSIDE THE SCOPE OF SUPPLY

5 The relevant ratings/operating parameters of some of the important associated equipment which are not included in the scope of supply are given below :-

5.1 Current collector pantograph.

Type make	:	AM-12 Faively
Max. extension	:	2.46m.
Min. air pressure allowing complete extension of pantograph (Panto shall start lowering if and when pressure drops to 3.5 kg/cm^2)	:	4.6 kg/cm^2
Raising time from the moment the air is fed to the moment when the panto reaches an extension of about 1.5m.	:	6-10 seconds.
Rated current	:	400 Amps.
Lowering time	:	Equal or less than 10 seconds.
Weight of pantograph	:	205 kg.
Weight of insulator	:	80 kg.
ELECTRICAL		
- Dry flashover	:	Not less than 130 KV rms for one minute.
- Wet flashover	:	Not less than 80 KV rms for one minute.
- Dry withstand	:	120 KV rms for 1 minute.
- Wet withstand	:	80 KV rms for 1 minute.
- Impulse (1/50 micro-second wave)	:	200 KVP.

163725

.....22/-

- Upward force static : 7 kg. force.
- aerodynamic at 160 km/h : 5 kg. force.

5.2 Transformer (TFP)

Capacity, voltage & current ratings (approximately)

Winding	Capacity (KVA)	Nominal Voltage (Volts)	Current (Amps.)
Primary (AB)	5800	22500	257.8
Secondary windings (a_1, b_1, a_2, b_2 a_3, b_3, a_4, b_4 - 4 windings)	5400	4 x 500	4 x 2700
Auxiliary (cd)	300	850	353
Field excitation (ef)	100	140	2 x 360
Insulation	130 KV		
Percentage impedance voltage drop	AB/a_1 b_1	6%	
	AB/a_2 b_2	6%	
	AB/a_3 b_3	6%	
	AB/a_4 b_4	6%	
	AB/cd	5%	
	AB/ef	1.5% at 100 KVA.	

5.3 (a) Vacuum Circuit Breaker.

Type / Make : 20CB6B2/GEC

Rated voltage : 25000 V

Short circuit current : 10 KA rms

Making current : 25.5 KA (Peak)

..... 23/-

Rated breaking capacity	: 250 MVA at 25 KV, 50 Hz single phase
Control voltage	: 110 V DC
Maximum permissible voltage	: 30 KV
Operating range of coil	: 70 V DC (Min.) 125 V DC (Max.)
Max. Permissible temp. coil	: 170°C
Air pressure range	: 5 to 11Kg/cm^2
Regulator set at	: 5 Kg/cm^2
Maximum permissible closing time	: 130 ms.
Maximum permissible first to final make of each bottle	: 10 ms.
Total maximum opening time	: 45 ms.
Movement time/arcing time	: 12 ms (Max.)
Actual arcing time in bet. (R-C network value across ao-a1 C = 25 mfd, 560V R = 4.7 ohm type H2342	: 7-12 ms

5.3(b) Air Blast Circuit Breaker

Type	-DBTF 301 250, Air blast
Current	- 400 amp
Voltage	- 26 KV
Maximum pressure	- 10 kg 1 cm^2
Minimum pressure	- on 4 kg/cm^2 off 3.5 kg/cm^2
opening time	- 80 millisecs.

163726

.....24/-

5.4 Traction Motor (M_1 - M_6)

Type		: HS 15250 CB compound motor.
Mounting		: Nose suspended/ fully suspended
Rating -	One hour	: 750 V, 960A,870rpm, 670 KW
	Continuous	: 750 V, 900A 895 rpm, 630 KW
	Weak field	: 40%
Max. permissible ripple at continuous current of 900A		: 28%
Resistance in Ohm at 110°C (Approx.)		
Armature		: 0.0127
Series field coil		: 0.0050
Com. pole coil		: 0.0078
Total motor resistance		: 0.0255
Shun field		: 0.03452
Starting current		: 1350 A for 2 mts.
Short time rating		: 1200 A for 10 mts.
Weight complete with pinion, gear & gear box.		: 3450 kg.

....25/-

5.5 Traction motor contactors (L_1 - 6)

The contactors are used to trip off power to traction motors and isolate the faulty traction motor. Brief specification of these contactors are as follows :-

Rated Voltage	:	1000 V DC
Rated current	:	1000 A
Nominal air pressure	:	5 kg/cm^2
Nominal control voltage	:	110 V (variation 70V to 130V)
Rupturing capacity	:	2000 A (Approx.)

Under traction motor flash over/short circuit conditions, the main vacuum circuit breaker is tripped.

5.6 Reverser, powering/braking changeover switches.

Type	:	LFG 24F_1, LFG 23 F_1
Rated voltage	:	1250 V DC
Rated current	:	1000 A
Number of contacts	:	12
Contact pressure	:	10 kg/cm^2
Air pressure nominal	:	5 kg/cm^2
Control voltage	:	110 V DC (variation 70 to 130V DC)
Auxiliary contacts	:	Cam operated
Rated current	:	5 A

C63727

.....26/-

5.7 Auxiliary power supply

Three phase power supply of 380V ± 22½ % and phase voltage unbalance of 5% at 50 Hz ± 3 % with centre (neutral) or star point being available for protection of earth fault in the auxiliary supply system.

The three phase supply may be from static invertor or ARNO machine. The maximum permissible auxiliary load for the new equipment shall not be more than 6 KW. The offered auxiliary machines, therefore, should be suitable for 380 V ± 22½ % and frequency of 50 Hz ± 3 % phase voltage unbalance 5 %.

p.t.o. 27/-

CHAPTER - VI

TESTING. INSTALLATION AND COMMISSIONING AND MAINTENANCE MANUAL.

6.1 Testing, Installation and Commissioning.

The offered equipments are to be tested as per relevant IEC specification or equivalent international standards prior to despatch. The individual equipment, systems and sub-systems, as may be necessary, shall be subjected to type tests and routine tests in accordance with relevant IEC specifications and as modified by Test programme to be drawn up by the supplier/manufacturer in consultation with RDSO. The tests of the equipment shall be carried out by the manufacturer in his premises at his own responsibility and cost and in the presence of and to the satisfaction of the representative of RDSO. Only equipment passing all prescribed tests will be despatched.

6.2 In framing and finalisation of test programme for individual equipment, establishment of suitability from long term reliability angle as well as environmental conditions will be of paramiount consideration. Wherever the relevant standard test procedure for type and routine tests prescribed by IEC or similar National/International standards do not adequately cover this requirement, RDSO will lay down the details of special tests to establish satisfactory performance over the entire range of variable system conditions like voltage, frequency, temperature and humidity.

6.3 RDSO may also, in addition, require evaluation of test results on raw materials and components of critical nature, so as to ensure that they meet the performance and reliability stipulations. This may extend to components/equipments/raw material not manufactured in the manufacturer's Works, but purchased by them. Results of tests conducted by the manufacturer are to be made available as required by RDSO.

6.4 Tests will be conducted to determine the levels of interference with the traction power supply and signal and telecommunication equipments to prove that these are within acceptable limits.

6.5 The equipment, systems and sub-systems are to be guaranteed for satisfactory performance for 5 (five) years. Broadly, it may be stated that all aspects of design will be covered by the guarantee.

....28/-

6.6 If any problems are experienced or feed-back information is obtained, during the trials and tests, which warrants a re-check of the design/ manufacture/quality of the equipments and components, action shall be taken, as may be necessary by the manufacturer to carry out the required investigations and to incorporate the improvement considered most appropriate without any extra cost or liability to the purchaser. Such improvements shall be carried out on all the equipments and shall be evaluated for their validity for a further period of time as may be agreed to mutually in each case.

6.7 Modifications found necessary as a result of the test/trial shall be incorporated by the supplier at his own cost on the equipment in a manner approved by the purchaser. Drawings incorporating the modifications found necessary as a result of test and trial shall be submitted to RDSO for final approval.

6.8 The training of Indian personnel at the manufacturer's Works and Design office and suppliers of equipment/material to the extent necessary for maintenance and operation of locomotives employing similar system/or on any special training kit available will be arranged by the tenderer. The terms and conditions will be mutually agreed upon with the Indian Railways.

6.9 The manufacturer/supplier is expected to supply sufficient number of spare sub-assemblies as unit exchange spares, tools, testing instruments, and other special jigs and fixtures, which will be required by the Indian Railways for maintenance and operation. These may include special training kits for trouble shooting by the driver and maintenance staff.

6.10 The equipment supplied will be installed as per the installation guidelines and under the guidance of tenderer by Indian Railway Engineers in India. However, inspection, testing, commissioning, etc., shall be done by tenderer's Engineers.

6.11 Maintenance Manual, Operating and trouble shooting instructions.

6.11.1 The manufacturer/supplier will furnish 'as-made' drawings/tracings, manual of instructions for operation and maintenance of the equipment, trouble shooting instructions and such other technical information as may be required for maintenance and operation of the equipment in India. These will be required to be supplied in advance of the despatch of the equipment from the manufacturer's

.... 29/-

Works. Terms and conditions in this regard will be mutually agreed upon after placement of contract.

6.11.2 The manufacturer/supplier will be required to station in India competent Engineers/Supervisors alongwith the required spare parts during the service trials and for such further period of time as may be required by the Indian Railways until the Indian Railway Engineers and staff concerned with operation and maintenance of these equipments get fully familiar with the equipment and their use under actual service conditions.

RG379

p.t.o. . 30/-

CHAPTER - VII

7 GENERAL DESIGN CONSIDERATIONS AND DATA SUBMISSION

7.1 The offered design shall be based on the requirements given and of sound, proven and reliable engineering practices. The entire key design shall be submitted by the supplier before manufacture with technical data and calculations to RDSO for evaluation, check and approval.

7.2 Approval of design means approval of general design features. For this purpose, detailed drawings will be required to be submitted to RDSO for approval before commencing manufacture. Notwithstanding the approval from RDSO, the supplier shall be wholly and completely responsible for satisfactory performance of offered equipment. All necessary data, design calculations, and drawings required by RDSO for examination of manufacturer's proposal shall be furnished by the successful tenderer.

7.3 The design data calculations and drawings are to be furnished in three parts :-

(i) Along with the tender documents while submitting the offer;

(ii) Confirmation of compliance of the requirements while submitting offers and furnishing the details at the detailed design stage after placement of the contract;

(iii) Details to be furnished at the detailed design stage.

7.3.1 Details to be furnished along with the offers :-

(1) Weight, size and centre of gravity and mass movement to inertia of the equipment;

(2) Number of cubicles per loco and arrangements of thyristors and diodes, continuous rating, duty cycle with (N -1) strings in circuit, where 'N' is the number of parallel paths per arm, estimated traction motor flashover current and convertor capability to withstand such fault current for such duration till it is cleared by the protection system;

(3) Estimated harmonic content of the 2nd and higher order of harmonics in traction current. Values estimated less than 10 milli Amps should not be furnished.

(4) Estimated maximum psophometric current;

..... 31/-

(5) Calculation for matching the rating of the thyristor equipment with the requirements of traction motor;

(6) Calculation of selection of the semiconductor devices; Number of devices required in series and parallel and the safety margins available;

(7) Calculation of cooling system - estimated maximum loss and the parameters of the cooling system and estimated minimum safety margin in junction temperature of devices;

(8) Table of fault diagnostic features and corrective action exercised by the microprocessor based fault diagnostic system;

(9) Proposed numbers of controls, additional if any, to the requirements as stipulated in the specification;

(10) Estimated power factor and efficiency curves against speed.

7.3.2 Details to be confirmed in the quotation and furnished later for technical scrutiny :-

(1) Height of equipments and cubicles is to be within 1800mm;

(2) List of protection arrangements proposed to be provided for a thyristor equipment and the manner in which it is proposed to be achieved;

(3) Confirmation of confining to the limits stipulated against interference with signalling and telecommunication equipment;

(4) Estimated reliability prediction.

7.3.3 Detailed design calculations to be furnished after placement of contract :-

(1) Schematic diagrams for power circuits;

(2) Thyristor control circuit and protection circuit;

(3) Block diagram for control scheme with description of the control scheme as a whole;

(4) Isolating and indication arrangements provided for faulty arrangement;

.... 32/-

(5) Details of display unit, monitoring unit, fault diagnostic scheme offered, sensors used, cab equipment for drivers;

(6) Characteristics of power thyristors, diodes, heat sink, and associated components used in power convertors;

(7) Details of convertor cooling arrangement along with characteristics of coolant under operating conditions.

.....33/-

I. DETAILS OF MAIN SIGNAL & TELECOMMUNICATION EQUIPMENTS USED ON 25 KV AC ELECTRIFIED SECTIONS OF INDIAN RAILWAYS.

A. Track circuiting installation.

	Types	Working frequency	Remarks.
1.	AC 83⅓ Hz track circuit	83⅓ Hz	AC vane type of relays are used. Two supplies at 83⅓ Hz at 90° out of phase required for local end control supplies are transmitted from central location in the section using lead and aluminium sheathed cables. Both single and double rail type of track circuits are used.
2.	H.F. jointless track circuits	20 kHz 40 kHz	
3.	A.F.Track circuits	175 kHz 225 kHz 270 kHz	
4.	High voltage impulse track circuits		Similar to Jeuomont impulse track circuits.
5.	Long jointless track circuit	2580 Hz 2820 Hz	
6.	DC Track circuit (single rail)	D.C.	9 Ohm AC immunised relays tested for minimum 50 Hz immunity of 50 Volts are used.

63731

p.t.o. ... 34/-

B. Electrical & Block Signalling Equipment.

1. Block instruments.

Types	Working frequency	Remarks.
(a) Daido single line token-less block instru-ments	(i) Carrier, 2000, 2500 Hz Mod. Frequency 65 & 85 Hz.	Block circuit in RE area are pro-vided on PE insula-ted quada in lead sheathed or aluminium sheathed main tele-communication cables. Intrinsic screening factors of lead sheathed cables at 50 Hz + 800 Hz are 0.4 in range 50 V - 450 V/km and 0.06 in range 0-10 V/km res-pectively. The screening factors for cables are 0.1 and 0.016 at 50 Hz and 800 Hz respect-ively in the range of 50 to 450 V/km field strength.
	(ii) Carrier 1800, 2700 Hz Mod.Frequency 65 & 85 Hz.	

2. Point machines

(a) Point operation.	DC, 24V DC, 110V Single phase AC, 50 Hz, 220V Three phase AC, 50 Hz, 380V
(b) Point detection	DC, 12V DC, 24V DC, 60V

3. Signal

(a) Control	DC, 12V DC, 24V DC, 60V
(b) Signal lighting	110V, AC stepped down to 12V, AC for signal lamp.

..... 35/-

	Type	Working frequency	Remarks.
	(c) Route indicator lighting	110V, AC	
	(d) Shunt signal lighting	110V, AC	
4.	Retarder operation and control	(a) 50 Hz, AC	
		(b) - do -	
		(c) Doppler Radar speed check at 10.7 GHz.	
5.	Axle counter	5 k Hz	
6.	AWS	50 KHz & 100 KHz	

C. TELECOMMUNICATION CABLING INSTALLATIONS

1.	Control circuits	(a) Speech - VF band (b) Signalling - 50 Hz, interrupted at $3\frac{1}{2}$ cycles per sec.	
2.	VF Telegraphy	150 Hz, 1620 Hz	
3.	Teleprinter	150 Hz, 1620 Hz	
4.	Trunk circuit	Speech VF Band and signalling - 17 Hz, 50 Hz, 150 Hz.	
5.	Gate control	Speech VF Band and signalling - 17 Hz	
6.	Block Bell and Train wire	150 Hz	
7.	Carrier circuits	1 + 3 stackable carrier equipment 3.9 Hz to 11 kHz.	Speech communication plus data transmission.

'63732

.....36/-

Annexure - A

D. RADIO COMMUNICATION

1.	HF Communication	2-16 MHz (SSB & DSB working)	For speech communication and data transmission.
2.	VHF Links	68-87 MHz 146-163 MHz	
3.	UHF	437-445 MHz 462-470 MHz	
4.	Microwave	7124-7425 MHz	

E. MISCELLANEOUS

1.	Clock network	Square wave pulses in 5 sec.
2.	PA equipment	VF band
3.	CCTV	3 MHz

II. Particulars of the existing communication and signalling circuits in 1500V DC traction areas of Western and Central Railways.

A. Communication

(i)	Telephone lines (Overhead line and underground cables)	Speech and dial pulses, etc.
(ii)	Telegraph lines (Morse & Teleprinter overhead line and underground cable)	Manual or machine telegraph signal.
(iii)	Carrier lines (overhead line underground cable)	Stackable carrier with a max. of 3 channels including voice and VFT (3.9 KHz to 3.9 MHz)
(iv)	Multichannel VHF, UHF and microwave radio communication	(a) Microwave Link 7125-7425 MHz band. (b) UHF - 450-470 MHz. (c) VHF - 70-88 MHz 144-158
(v)	Clock-time pulse line (underground cable).	One pulse every 5 sec. or slower. Max.pulse amplitude 50 V (across 600 Ohms).

.... 37/-

(vi)	Control circuit (overhead lines and underground cable)	Speech & code selection pulse at 3.5 Hz and magnato ringing. Max. and Min. signalling pulse amplitude 200V and 5 dB respectively (across 600 Ohms).
(vii)	Paging and Talk back system	Speech band, Max. speech voltage 100 RMS (Across 600 Ohms)
(viii)	Closed circuit TV circuit	Video signals.
(ix)	Frequency spectrum of harmonics of line current at maximum line current and maximum psophometric current (AC/DC traction).	
(x)	A graph of psophometric current versus speed and load.	
(xi)	Details of on-board filters/techniques used and their contribution for reducing psophometric current (AC/DC traction).	

B. Signalling

(i)	Track circuits	50 and 83⅓ Hz AC track circuit. Voltage across rails is about 1.0 Volts.
(ii)	Signalling track relays	(a) AC Vane type VT1 (b) Siemens motor type
(iii)	Impedance bond	Type P1, B2 and Siemen 1000 Amp. per rail.
(iv)	Rail/OHE mast connection	Direct
(v)	Signalling line relays (used with transformers rectifier either built in or separate)	(a) 'Q' series (WSF) (b) K-50 series (Siemen) (c) ALIB type (d) BL 18 type.
(vi)	Signal and point control and detection lines.	DC or 50 Hz 110V AC

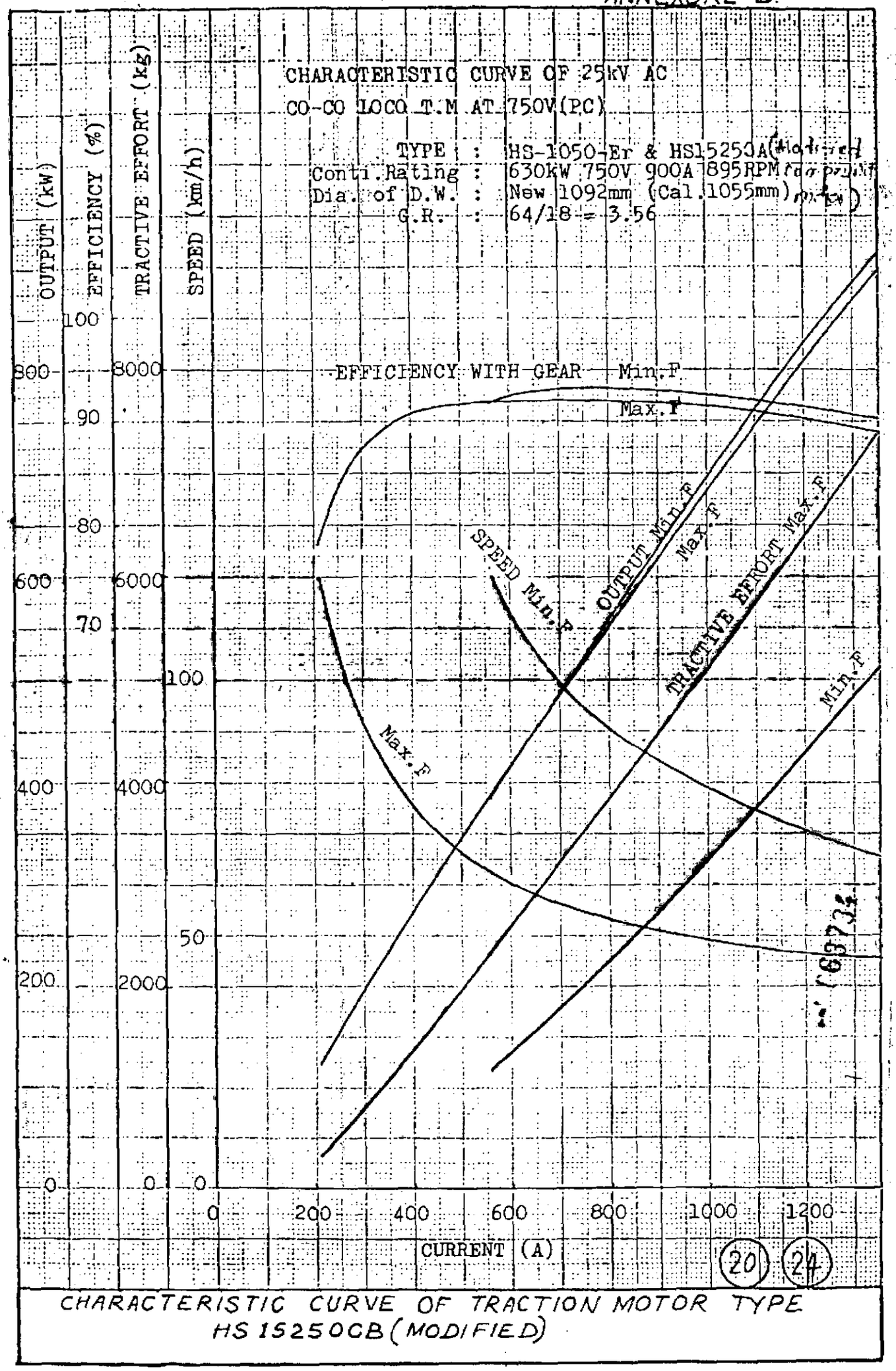
R63733

.....38/-

(vii)	Point machine	(a) Siemens (b) CRS 5A, 5B (c) Type HA (d) Type M. 63
(viii)	Signalling cable	Unscreened, armoured (unearth laid)
(ix)	Axle counter	5 KHz 'RDSO' design.
(x)	AWS system	Siemens 1-100

.....39/-

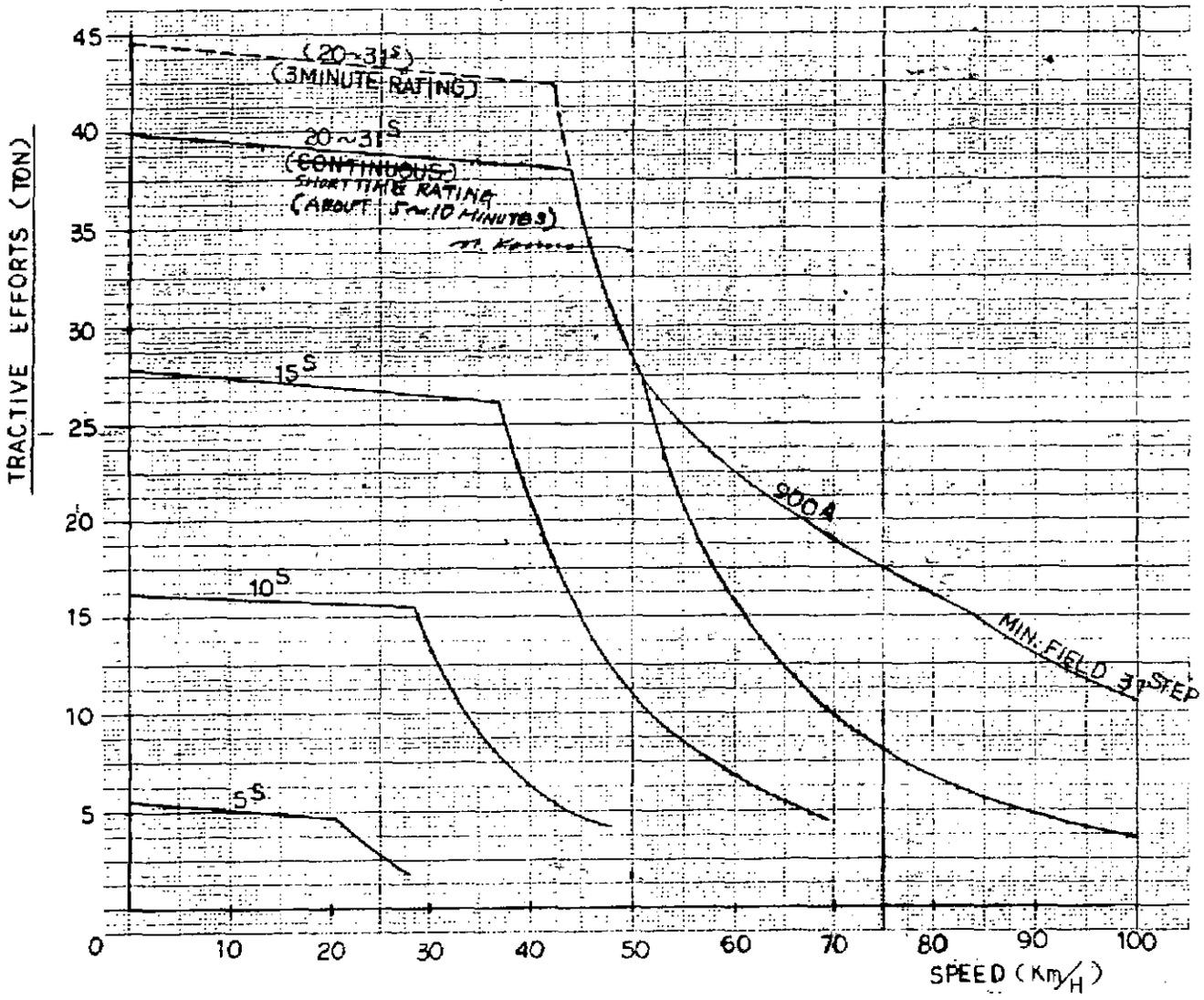
ANNEXURE-B.



CHARACTERISTIC CURVE OF TRACTION MOTOR TYPE HS 15250CB (MODIFIED)

20 24

NOTCHING CURVES ON POWERING



LINE VOLTAGE ; 22.5KV.

TRACTION MOTOR; 630KW, 750V,
900A/353A, 895 RPM.

GEAR RATIO ; 64/18 = 3.56

WHEEL DIA. ; NEW 1092 mm (CAL. 1055 mm)

TRACTIVE EFFORT V/S SPEED CURVE FOR THE PROPOSED LOCOMOTIVE.

6. Master controller.

The master controller base plate size shall preferably be within 200mm (L) x 200 mm (W) and 150mm (H) including the height of operating handle. Space for reverser handle and brake handle shall be left blank. Approximately, expected weight is 6 to 7 kg per master controller.

7. Electronic cubicle.

The electronic cubicles shall be two per locomotive (one for each bogie control). Each control cubicle shall not exceed 700 mm (L), 300 mm (W), 1550 mm (H) and weight not exceeding 300 kg.

The dimensions and weights indicated above are approximate. Lighter and compact equipment are preferable. The actual weight and size and mounting details of the offered equipment are to be indicated by the manufacturer.

Annexure - F

SIZE AND WEIGHT OF EQUIPMENT

1. Main smoothing reactor.

The size of main smoothing reactor should be as small as possible and shall have independent winding for each traction motor. The offered smoothing reactor shall be with closed magnetic circuit to avoid flux linkage to other equipment used for track circuits, axle counters, etc.

The total weight should not exceed 3 tonnes.

2. Main thyristor controlled convertor.

It is preferable to have oil cooled convertor and as small as possible. Non-chlorine coolant may also be considered and should be as small as possible.

The construction shall be modular and interchangeable.

In case offer is with air cooling system, the maximum size shall not exceed 3000mm (L) x 630mm (W) x 1700 mm (H), The air cooled convertor offer will have lower preference.

The weight of the convertor including field excitation convertor etc complete with cooling system, protections etc should not exceed 5.0 tonnes, including PFC cubicles.

3. Power factor correcting unit.

The power factor correcting unit consists of resistor, capacitor, inductance, thyristors, protections, etc.

The thyristor switches used for the power factor correction equipment of each group may be provided in the respective cubicle of main convertor to share the cooling system and hence to reduce weight and size.

4. Fault display limit.

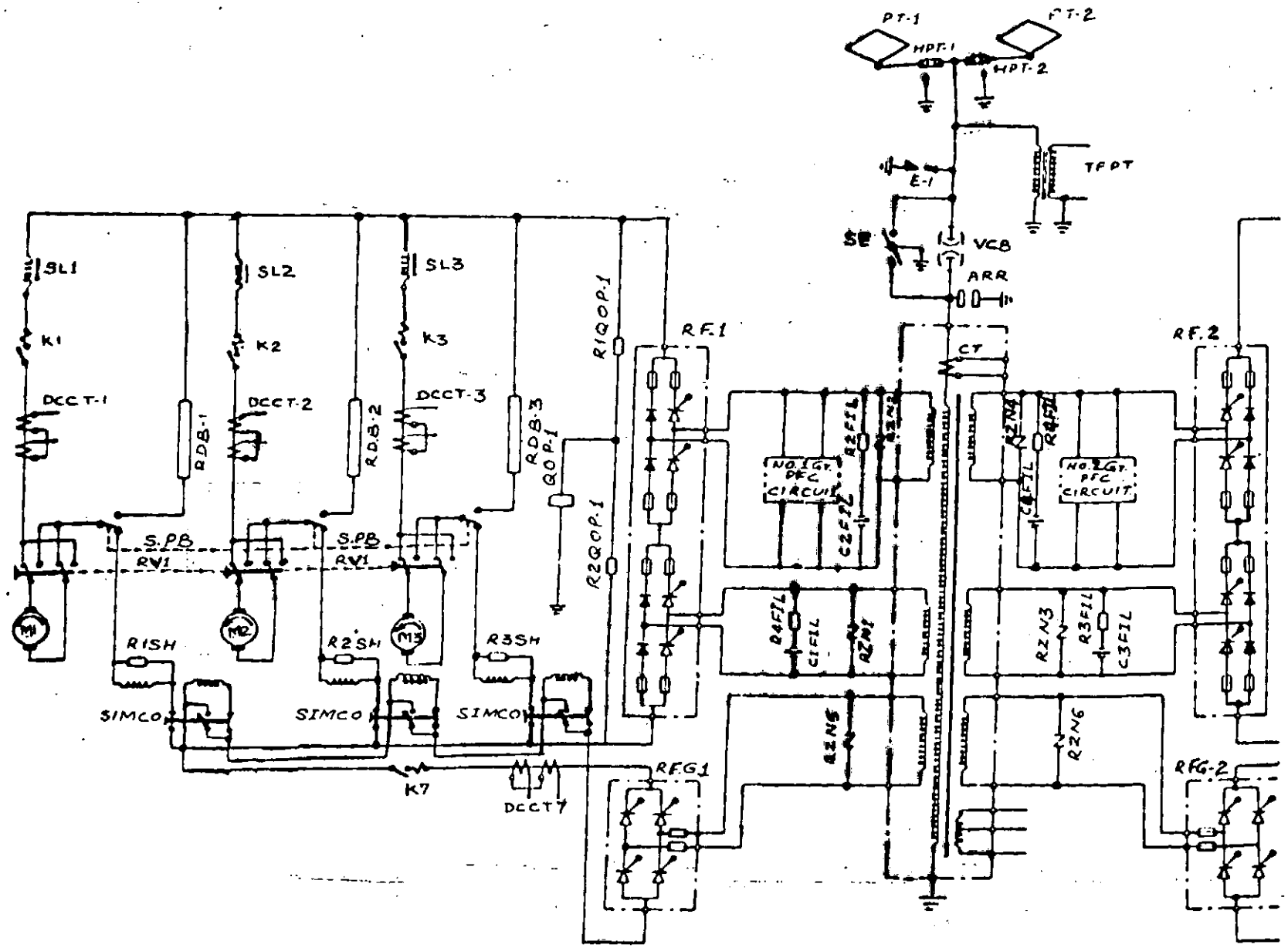
The fault display unit complete including key board shall preferably be within 350(L) x 250(W) x 200(D) and weight approximately 7 kg.

5. Power supply.

The power supply complete with transformer, electronics, protection and control, etc., for the offered control and other electronic circuits shall be within 1000(L) x 650(W) x 1700(H) and weight not exceeding 200 kg.

The actual weight and size and detailed specification to be advised by the manufacturer.

ANNEXURE-D

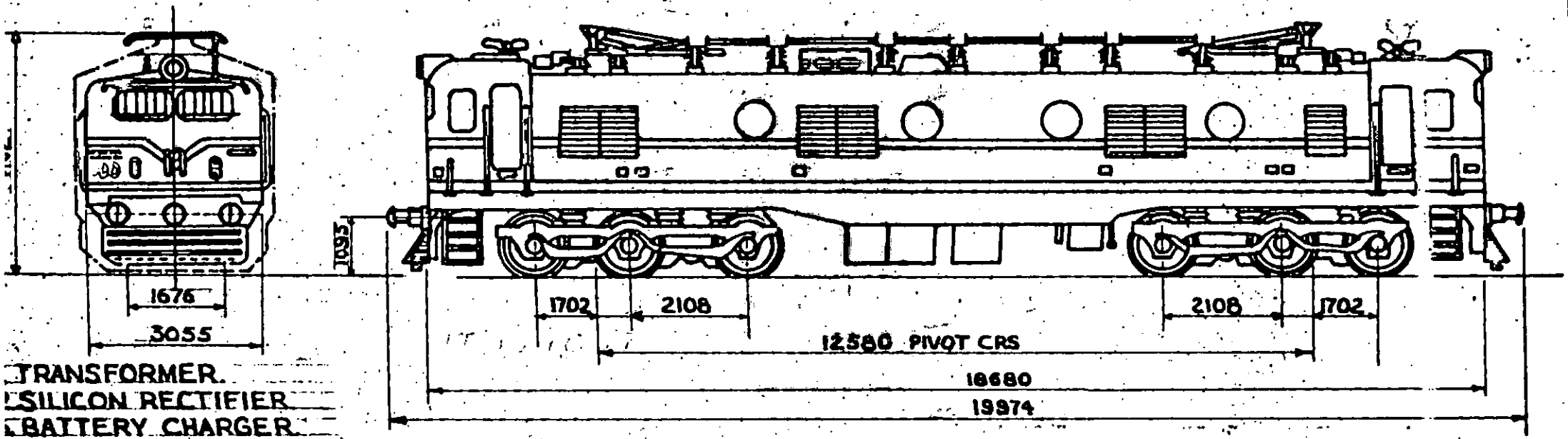


SYMBOL	DESCRIPTION
ARR	LIGHTNING ARRESTOR
C.FIL	AC FILTER CAPACITOR
CT	CURRENT TRANSFORMER
DCCT	DC CURRENT TRANSFORMER
HPT	PANTOGRAPH DISCONNECTING BAR
K	LINE SWITCH
M	TRACTION MOTOR
PT	PANTAGRAPH
QOP	GROUND RELAY
RDB	BRAKE RESISTOR
RF	MAIN RECTIFIER
R.FIL	AC FILTER RESISTOR
RQOP	GROUND RESISTOR
R.SH	FIELD RESISTOR
RV	REVERSER
R2NR	SURGE ABSORBER
SE	EARTH SWITCH
SL	MAIN SMOOTHING REACTOR
S.MCO	MOTOR CUT SWITCH
S.PB	POWER BRAKING
RFG	FIELD EXCITATION RECTIFIER
VCB	VACUUM CIRCUIT BREAKER.

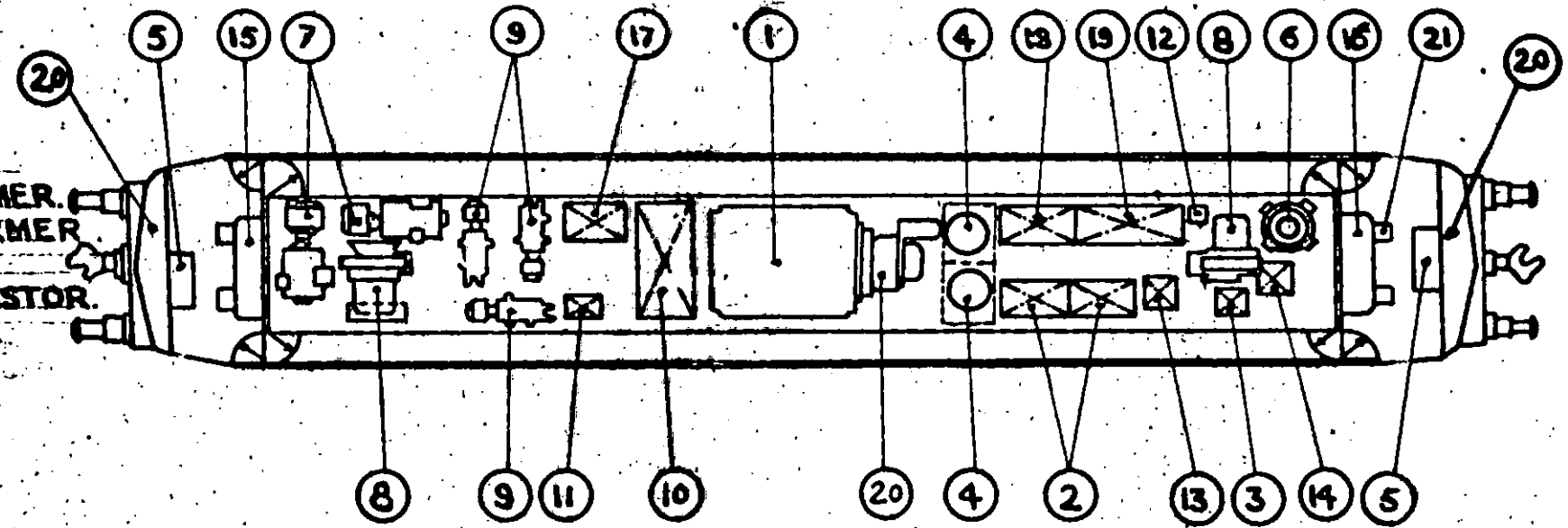
PROPOSED POWER CIRCUIT FOR WAG-7 THYRISTORISED LOCO

SK.EL-3979

163735



1. TRANSFORMER.
2. SILICON RECTIFIER.
3. BATTERY CHARGER.
4. SMOOTHING REACTOR.
5. MASTER CONTROLLER.
6. ARNO.
7. EXHAUSTER.
8. T.M. BLOWER.
9. COMPRESSOR.
10. BRAKE RESISTOR.
11. EXCITATION TRANSFORMER.
12. HEADLIGHT TRANSFORMER.
13. DAMPING NETWORK.
14. ARNO STARTING RESISTOR.
15. PNEUMATIC CABINET.
16. AUXILIARY CABINET.
17. Ba-1 PANEL.
18. Ba-2 PANEL.
19. Ba-3 PANEL.
20. DRIVER'S DESK.



EQUIPMENT LAYOUT ON EXISTING WAG-5 ELECTRIC LOCOMOTIVE.