



British Rail

TECHNICAL TRAINING NOTE APT /7.1

TRACTION POWER & CONTROL SYSTEM
A.P.T. POWER CAR

CONTENTS:-

1. General
2. Components and Location
3. Operation

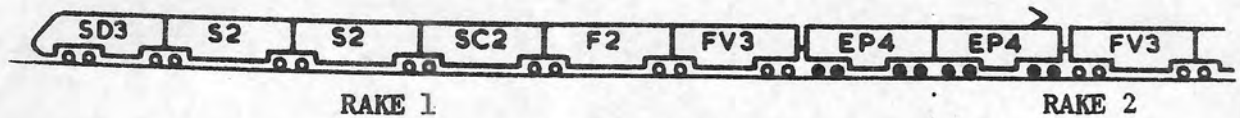
RAILWAY ENGINEERING SCHOOL,
BRITISH RAILWAYS, DERBY.

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APT	7.1		F2
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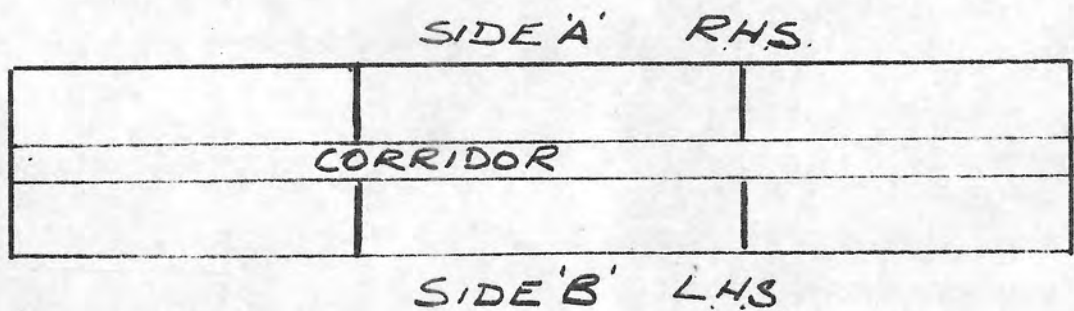
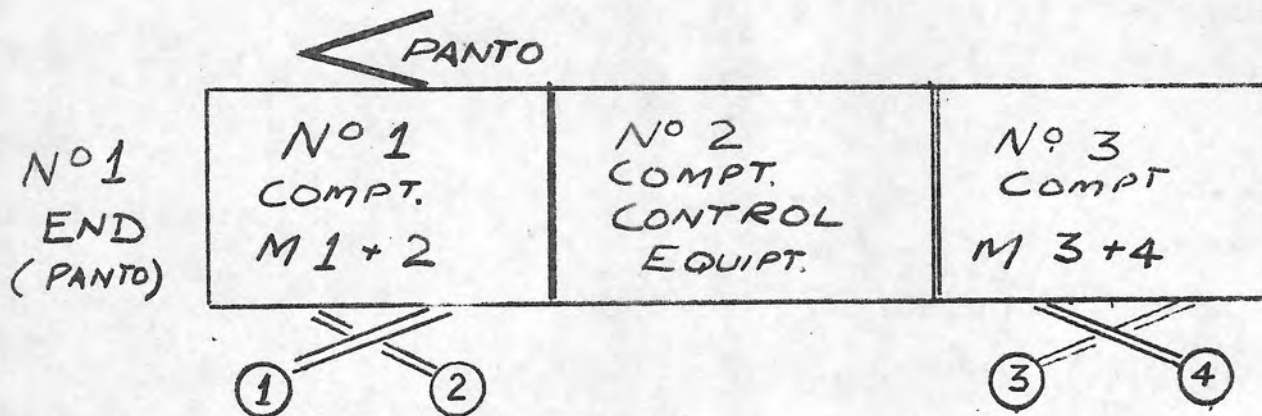
APT-P TRAIN FORMATION CODES

250 km/h (2+12) high-powered version (prototype)



OPERATORS CODE	DTS	TS	TS	TRB	TF	TBF	M	M	TBF
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DTS:-	Drg. Trailer Second	or	Second Drg. (3 axles)	SD3
TS :-	Trailer Second	or	Second (2 axles)	S2
TRB:-	Trailer Rest/Buffer	or	Second Catering (2 axles)	SC2
TF :-	Trailer First	or	First (2 axles)	F2
TBF:-	Trailer Brake First	or	First Van (3 axles)	FV3
M :-	Motor	or	Elect Power (4 axles)	EP4



TECHNICAL TRAINING NOTE APT/7 .1

TRACTION EQUIPMENT - APT POWER CAR

1. GENERAL

The following notes are intended to highlight:-

- a) What equipment is fitted
- b) Where the equipment is located
- c) What the equipment does and briefly,
- d) How it does it

and are based on the General Arrangement drawing AP-A0-0001.

The power car is supported on two bogies, each bogie has two axles which are individually powered by a separately - excited D.C. traction motor (i.e. four motors in total). [1000 H.P. each]

The body of the power car may be divided into three compartments:-

- a) No 1 compartment (under the pantograph) which houses No 1 and 2 traction motors.
- b) No 2 compartment (the centre) which houses the control equipment.
- c) No 3 compartment (far end) which houses No 3 and 4 traction motors and is a duplicate of No 1 compartment

There is a full length corridor which further divides the body into:-

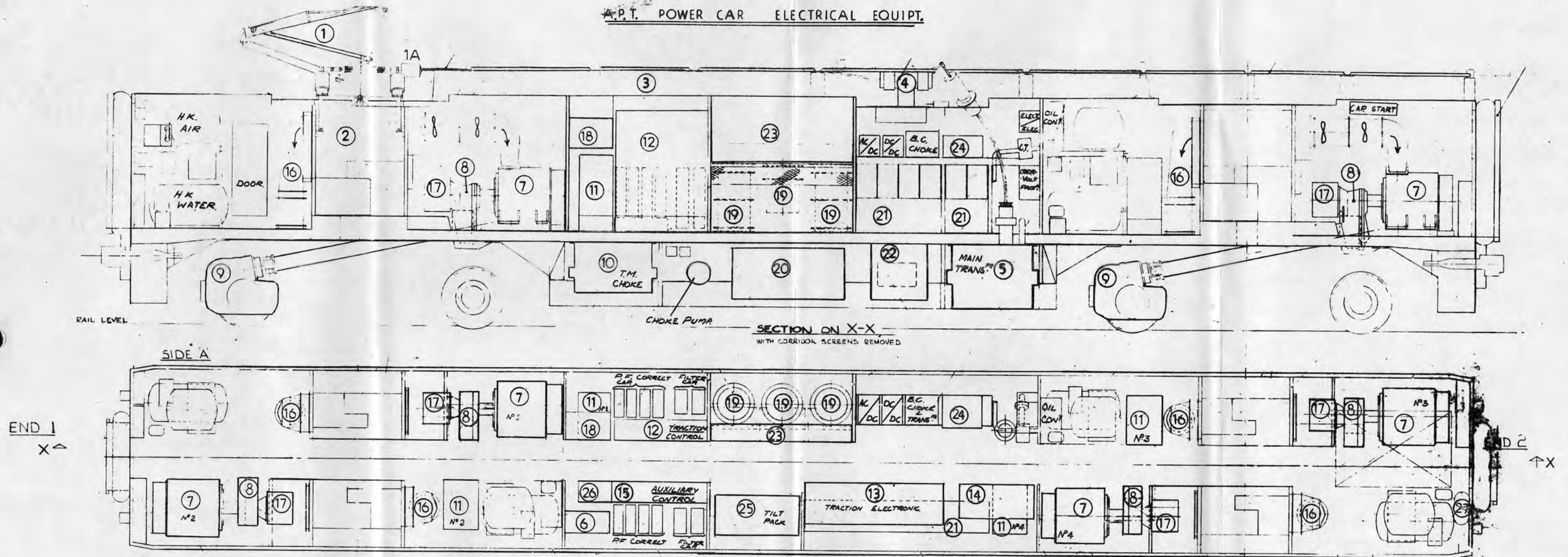
Side A on the right hand side
Side B on the left hand side

2. COMPONENTS AND LOCATION (Fig 2 Page 3)

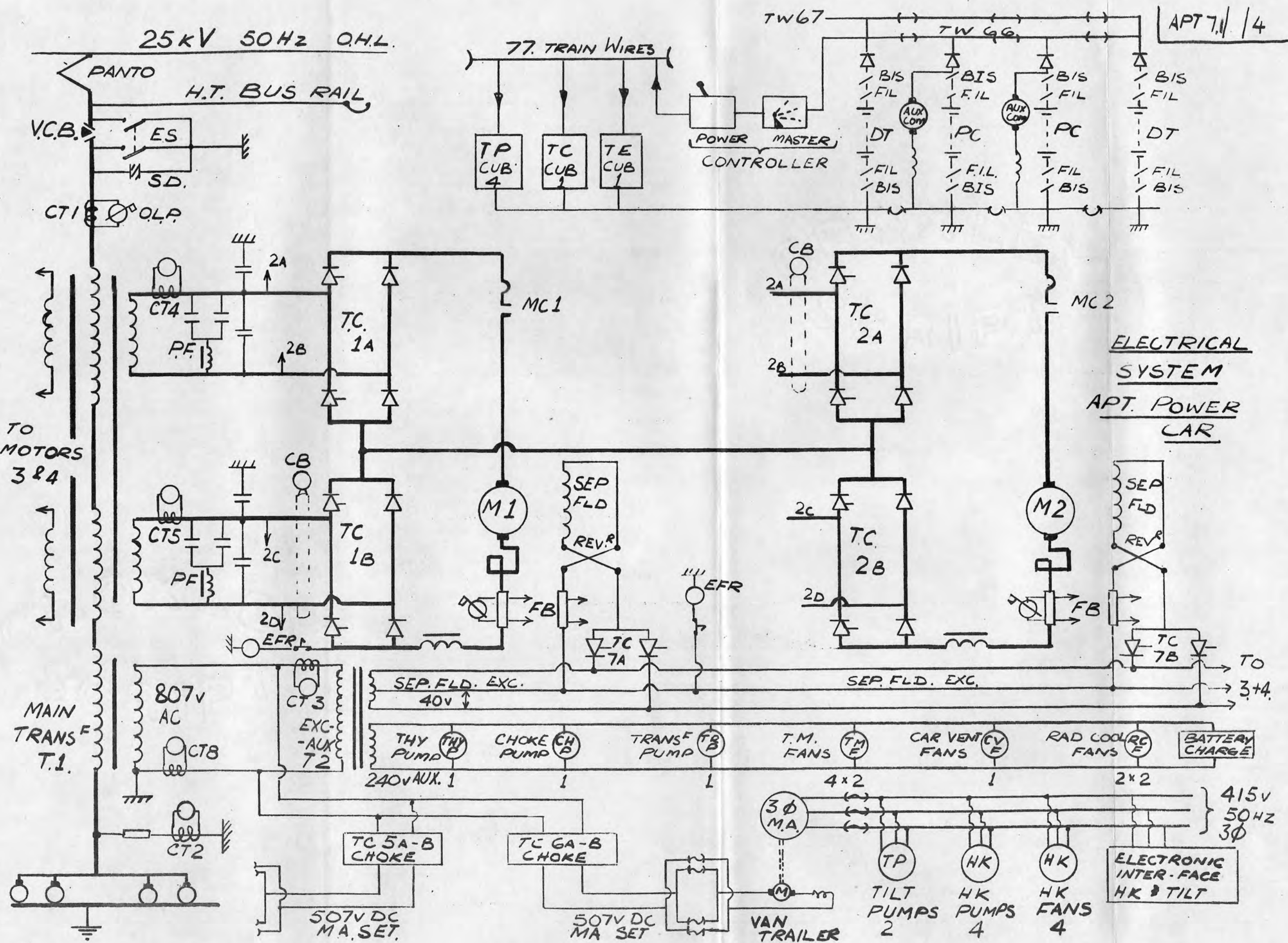
The following are the major parts of the equipment.

NOTE REF	ITEM	TYPE	LOCATION
1	PANTOGRAPH	FAIVELEY	ON ROOF NO 1 END
2	PANTOGRAPH ANTI TILT		BENEATH PANTOGRAPH
3	POWER HT BUS BAR		ON ROOF - FULL LENGTH
4	POWER CIRCUIT BREAKER	GEC VACUUM	ON ROOF REAR CENTRE
5	MAIN TRANSFORMER 25 kv	ASEA LTD	UNDERFRAME REAR CENTRE
6	EXCITATION AUX TRANSFORMER	ASEA LTD	NO 2 COMPT - FRONT LHS
7	TRACTION MOTORS (4 OFF)	ASEA LTD	NO 1 & 3 COMPT
8	TRACTION GEARBOX (4 OFF)		NO 1 & 3 COMPT
9	TRACTION FINAL DRIVE		NO 1 & 2 BOGIES
10	TRACTION CHOKE	ASEA LTD	UNDERFRAME FRONT CENTRE
11	TRACTION POWER CUBICLE	4 OFF	ADJACENT TO EACH MOTOR
12	TRACTION CONTROL CUBICLE	1 OFF	NO 2 COMPT RHS FRONT
13	TRACTION ELECTRONIC CUBICLE	1 OFF	NO 2 COMPT LHS CENTRE
14	AUXILIARY POWER CUBICLE	1 OFF	NO 2 COMPT LHS REAR
15	AUXILIARY CONTROL CUBICLE	1 OFF	NO 2 COMPT LHS FRONT
16	H.K. BRAKE RAD. & FAN	4 OFF	NO 1 & 3 COMPT L & RHS
17	H.K. BRAKE	4 OFF	NO 1 & 3 COMPT L & RHS
18	AIR COMPRESSOR	1 OFF	NO 2 COMPT RHS FRONT
19	COOLING FANS	3 OFF	NO 2 COMPT RHS CENTRE
	TRANSFORMER/CHOKE/THY/TILT		
20	COOLING RADIATOR	1 OFF	UNDERFRAME CENTRE
21	THYRISTOR CONVERTERS	2 OFF BANKS	NO 2 COMPT L & RHS
22	THYRISTOR COIL TANK AND PUMP	1 OFF	UNDERFRAME CENTRE
23	BATTERY	Ni-fe	NO 2 COMPT RHS
24	BATTERY CHARGER		NO 2 COMPT RHS
25	TILT CONTROL PACK		NO 2 COMPT LHS FRONT
26	FAULT INDICATION PANEL	1 OFF	NO 2 COMPT LHS FRONT
27	FIRE BOTTLES	2 OFF	NO 3 COMPT LHS REAR

A.P.T. POWER CAR ELECTRICAL EQUIPT.



NOTE REF	ITEM	TYPE	LOCATION	NOTE REF	ITEM	TYPE	LOCATION
1	PANTOGRAPH	FAIVELEY	ON ROOF NO 1 END	15	AUXILIARY CONTROL CUBICLE	1 OFF	NO 2 COMPT LHS FRONT
2	PANTOGRAPH ANTI TILT		BENEATH PANTOGRAPH	16	H.K. BRAKE RAD. & FAN	4 OFF	NO 1 & 3 COMPT L & RHS
3	POWER HT BUS BAR		ON ROOF - FULL LENGTH	17	H.K. BRAKE	4 OFF	NO 1 & 3 COMPT L & RHS
4	POWER CIRCUIT BREAKER	GEC VACUUM	ON ROOF REAR CENTRE	18	AIR COMPRESSOR	1 OFF	NO 2 COMPT RHS FRONT
5	MAIN TRANSFORMER 25 kv	ASEA LTD	UNDERFRAME REAR CENTRE	19	COOLING FANS	3 OFF	NO 2 COMPT RHS CENTRE
6	EXCITATION AUX TRANSFORMER	ASEA LTD	NO 2 COMPT - FRONT LHS	20	TRANSFORMER/CHOKE/THY/TILT		
7	TRACTION MOTORS (4 OFF)	ASEA LTD	NO 1 & 3 COMPT	21	COOLING RADIATOR	1 OFF	UNDERFRAME CENTRE
8	TRACTION GEARBOX (4 OFF)		NO 1 & 3 COMPT	22	THYRISTOR CONVERTERS	2 OFF	NO 2 COMPT L & RHS
9	TRACTION FINAL DRIVE		NO 1 & 2 BOGIES	23	THYRISTOR COIL TANK END PUMP	1 OFF	UNDERFRAME CENTRE
10	TRACTION CHOKE	ASEA LTD	UNDERFRAME FRONT CENTRE	24	BATTERY	Ni-fe	NO 2 COMPT RHS
11	TRACTION POWER CUBICLE	4 OFF	ADJACENT TO EACH MOTOR	25	BATTERY CHARGER		NO 2 COMPT RHS
12	TRACTION CONTROL CUBICLE	1 OFF	NO 2 COMPT RHS FRONT	26	TILT CONTROL PACK		NO 2 COMPT LHS FRONT
13	TRACTION ELECTRONIC CUBICLE	1 OFF	NO 2 COMPT LHS CENTRE	27	FAULT INDICATION PANEL	1 OFF	NO 2 COMPT LHS FRONT
14	AUXILIARY POWER CUBICLE	1 OFF	NO 2 COMPT LHS REAR		FINE BOTTLES	2 OFF	NO 3 COMPT LHS REAR



2.1 PANTOGRAPH (Fig 4 page 6)

The power supply to the train at 25 kV is collected by a modified Faiveley type pantograph mounted on the roof of each power car. The contact head has been modified from a plunger/spring assembly to a diamond frame secondary suspension unit for high speed current collection.

One pantograph only is raised and feeds both power cars in a two power car train by way of HT bus rails mounted on insulators along the roofs.

The pantograph is held down by a latch and the secondary suspension unit is folded by a set of springs in two 3" dia cylinders. Only when air at the correct pressure is applied to the main 8" dia cylinder will the tubular framework be raised by the tension in the two pull up coil springs.

2.2 PANTOGRAPH ANTI-TILT

Because the body of the power car tilts the pantograph is mounted on a non-tilting platform which is linked to the bogie.

2.3 POWER HT BUS BAR

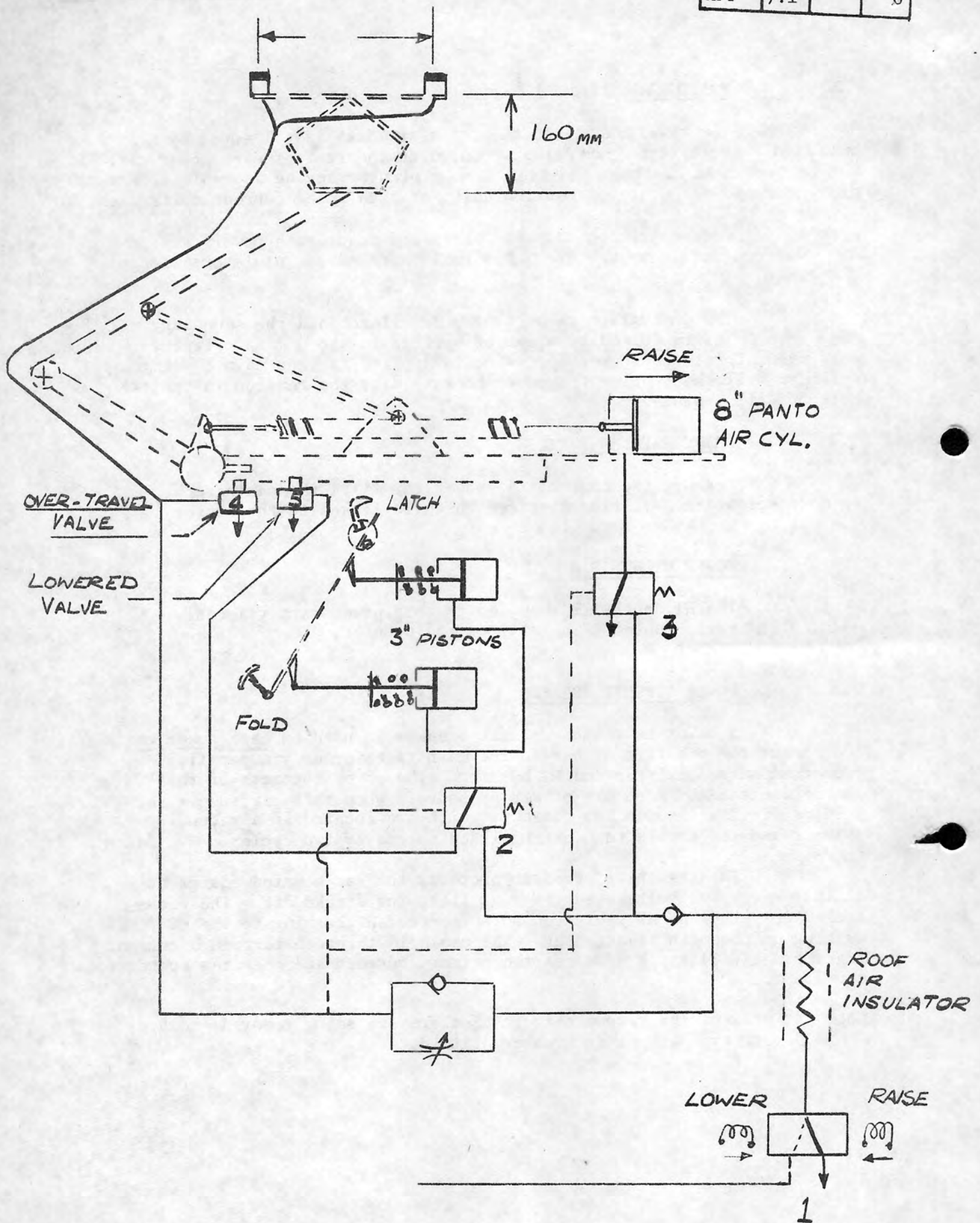
The HT supply is then fed to both power cars via roof mounted bus rail coupled by a latticed rod coupler.

2.4 POWER CIRCUIT BREAKER

A GEC type vacuum circuit breaker is used on each power car to connect the bus rail or bar to the main transformer via parallel connected surge diverter and HT bushing. The power contacts of the VCB are held closed by a supply of air pressure. When this air supply is lost, springs will open the contacts which are located in a vacuum chamber and the arc is then extinguished in one or two cycles.

The lightning arrestor protects the car mounted equipment against excessive voltage surges e.g. lightning strike etc. The cross-linked polyethylene HT cable connects the roof HT bushing to the HT bushing on the main transformer. The cable is threaded through a current transformer (CT) which measures the primary current and operates protection equipment.

Note At present the vacuum circuit breakers are being removed and Brown Boveri type air blast breakers fitted.



2.1.1 Alterations to the Standard Stone-Faiveley Pantograph

1. Redesigned Suspension Head

- a) Increased spacing between carbons
- b) Increased suspension travel 160 mm (30 mm std) obtained by four link arrangement with 8 mm dia torsion bar
- c) Saving in weight 6.5 Kg (9.5 Kg std)
2. Air cylinder mounted on frame and not on roof (because of tilt). No pull down springs in cylinder.
3. Auto-drop if carbons fracture) Air cannot be
4. Auto-drop if maximum raised height exceeded) isolated
5. Latch and Fold devices (the latter ensures pantograph is within loading gauge when panto down) Done by 2 x 3" dia air cylinders.

Operation

- 2.1.2 Raise Press pan up button to operate valve 1 so that air passes through to control valves 2 & 3 and via a choke to pressurise the "overtravel" and "auto-drop" line.

This pressure will now operate the control valves 2 & 3. At 30 psi the pressure is sufficient to unlatch and unfold the suspension lead which shoots open.

At 60 psi the main air cylinder will tension the two main springs to raise the framework.

2.1.3 Production

Should the carbons fracture or should the framework overtravel then the air will be lost at a greater rate than can be supplied through the choke and the two control valves 2 & 3 will changeover to exhaust the cylinders.

2.1.4 Lower

Press the pan down button to operate valve 1 so that air is exhausted from the pressurised "auto-drop" line. This will result in the control valve 3 dumping the air from the 8" main air cylinder thereby bring the framework down.

When the framework is lowered then valve 5 will exhaust to air from the 3" pistons which will now latch and fold the suspension head.

2.5 MAIN TRANSFORMER 25 kV T1 (4683 KVA)

This is mounted on the underframe near to No 2 bogie, and is oil and air forced cooled.

The neutral side of the primary winding is connected to earth via axle brushes. An alternative path to earth is provided via a resistor and protection relay, which detects loss of contact on all axles and opens the vacuum circuit breaker. There are five secondary windings. Four are used for power to the armatures of the traction motors and are each 573 V and are connected in series pairs.

The fifth winding (807 V - 1291 K VA) is used as a source of power for:-

- 1) The motor alternator sets. The 510 V d.c. for the motor drive is controlled by thyristor connectors TC 5A 5B and TC 6A 6B.
- 2) The excitation/auxiliary transformer

2.6 EXCITATION/AUXILIARY TRANSFORMER

This is located in the No 2 compartment, front and left hand side. It is supplied with 807 V a.c. input and has two output windings

- 1) 240 V single phase for a.c. auxiliary motors on the power car.
- 2) 40 V centre tapped for the separately excited fields of the traction motors.

Thyristor Converter TC No 7 for field 1 and 2 in parallel
 " " TC No 8 for field 3 and 4 " "

2.7 TRACTION MOTOR

The prototype APTs each have two power cars with four powered axles. To minimise unsprung weight, the axles are independently driven by body mounted motors which drive through a mechanical transmission.

The ASEA motors are force ventilated, six pole, fully compensated, separately excited d.c. traction machines. Principal data are:

Rated output	750 kW
Maximum speed	2 600 rev/min
Maximum voltage	900 V
Maximum accelerating current	1 800 A
Mass	1 950 kg

The armatures are connected in an all parallel arrangement, each under the control of two thyristor converter. e.g. 1A + b for motor 1. The fields are also in parallel but separately excited.

2.8

TRACTION DRIVE

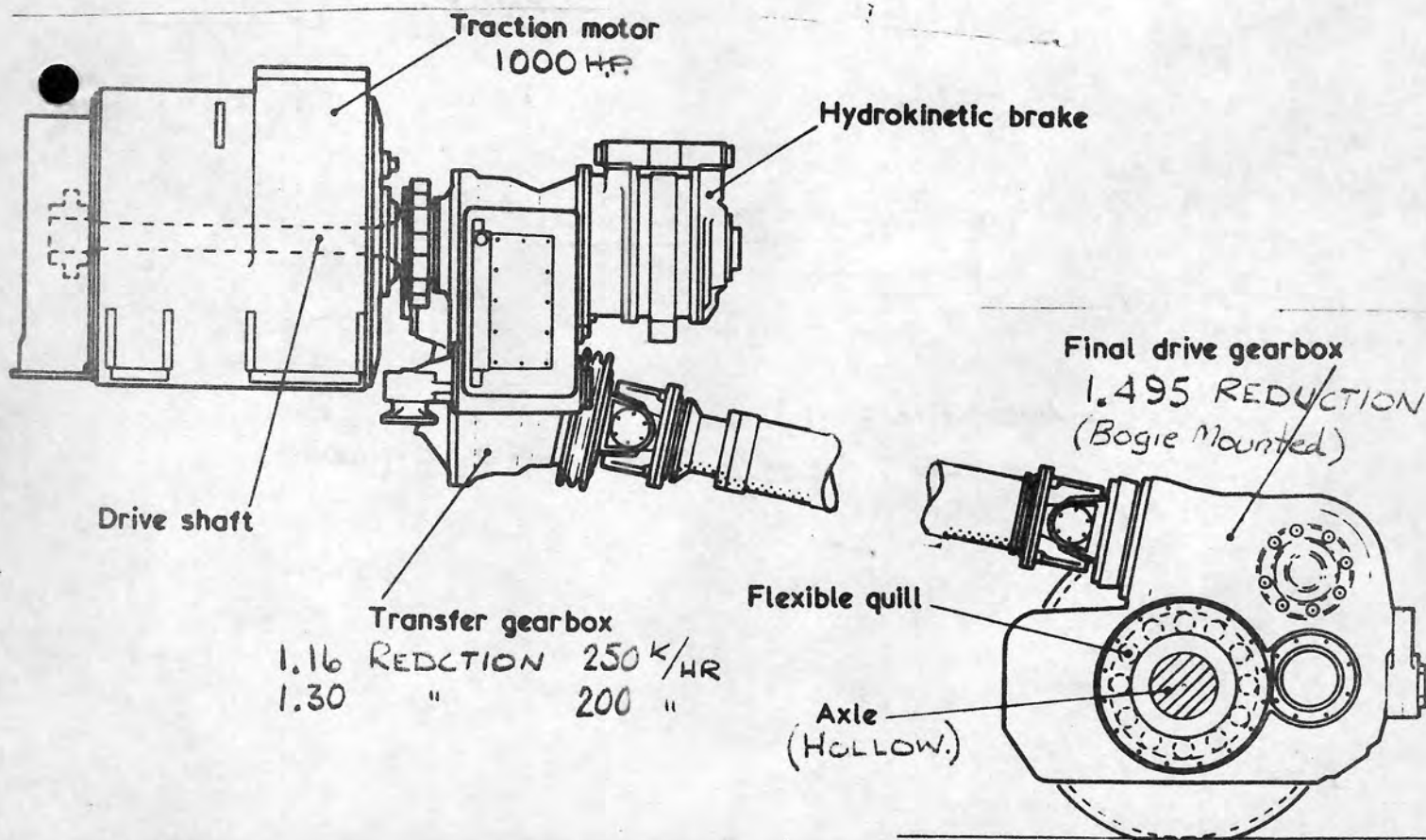
Each set of road wheels on the power car is driven by its own double reductions transmission system as follows:-

From the body mounted traction motor (1 000 HP) a drive shaft passes through the hollow armature to a layrub coupling on the transfer gearbox also body mounted.

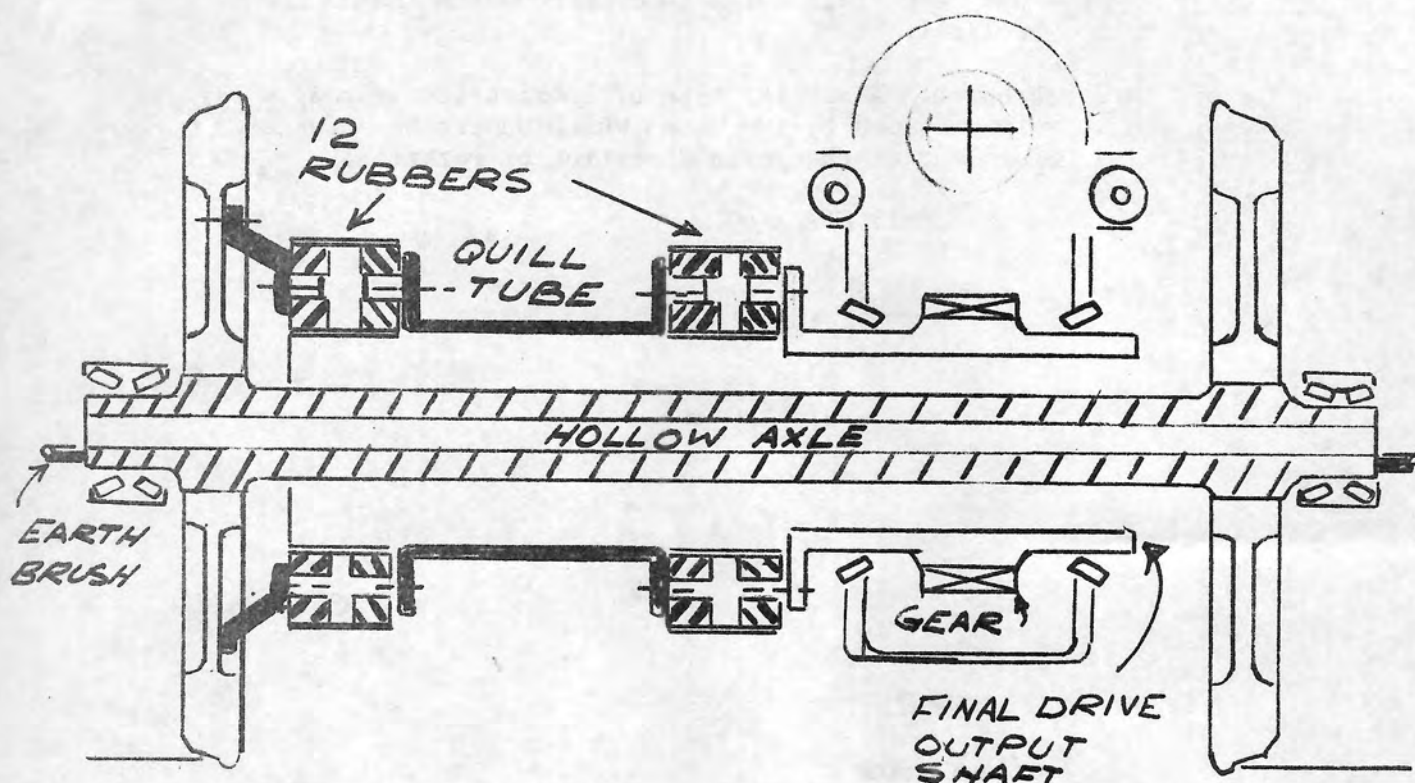
Then via a telescopic cardan shaft to a bogie mounted final drive gearbox and then via a quill tube surrounding the hollow axle to drive the wheel set.

Each gearbox has a similar type of lubrication system, spray and drain, and this is provided by two pumps which undertake a function (spray or drain) regardless of change in direction of rotation.

Lubricant is Shell OMALA 69.



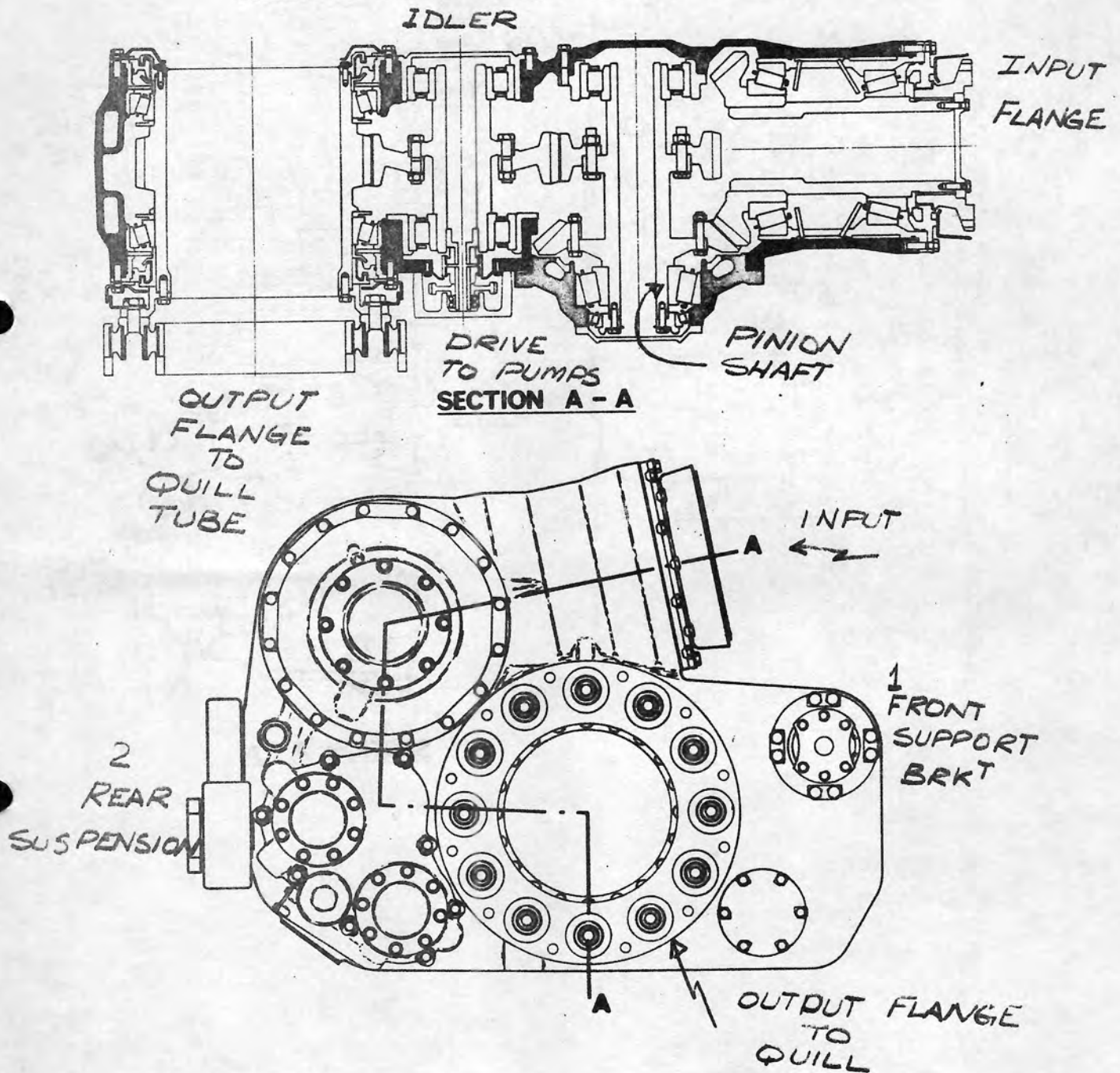
FINAL DRIVE G'BOX
BOGIE MOUNTED



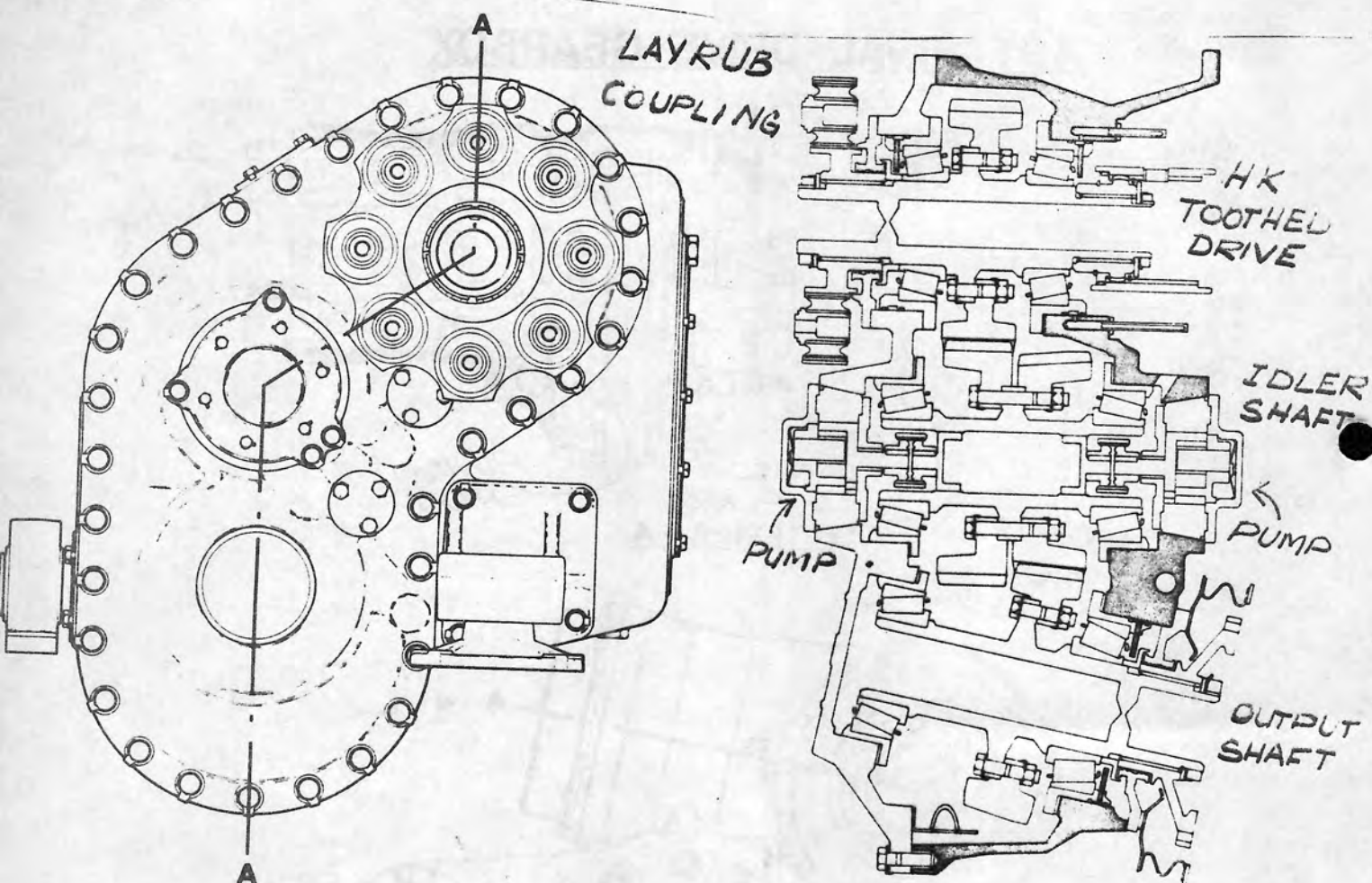
SUSPENSION OF FINAL DRIVE
GEAR BOX

NB. UNSPRUNG WEIGHT
PER AXLE = 1490 kg (approx)

APT FINAL DRIVE GEARBOX



APT TRANSFER GEARBOX



SECTION A - A

2.10 TRACTION CHOKE (1 off)

This is located on the underframe near to No 1 end (panto end) and contains six choke windings. It weighs 2 900 kg and is oil cooled

Chokes L1 - 4 are in series with respective traction motor armature

L5 - 6 are in series with respective motor alternator set drive motor.

Note the different arrangement of links for different train formation e.g. 2 power cars 2 M.A. sets the chokes are in series - 1 power car 2 MA sets they are split.

2.11 TRACTION POWER CUBICLE (4 off)

These are adjacent to each motor and contain 110 V motor contactor (EP type) and reverser E.P. type also, shunts, overload, relays.

2.12 TRACTION CONTROL CUBICLE (1 off)

This is in No 2 compartment front end RHS and contains sequencing relays for, Panto, VCB, APC etc. (110 V supply)

2.13 TRACTION ELECTRONIC CUBICLE (1 off)

This is in No 2 compartment front end LHS and contains :-
current control card
logic control card for thyristor firing circuits
speed and current control cards for the MA sets (all at 15 V)

2.14 AUXILIARY POWER CUBICLE

In No 2 compartment LHS rear and contains EP contactors, shunts, current balance CT earth fault CT for the two motor alternator set.

Note, Has the links for changing method of connection of chokes for 1 or 2 MA sets.

2.15 AUXILIARY CONTROL CUBICLE

In No 2 compartment LHS front and contains start control equipment for single and three phase AC machines also their overload relays and line volt relay.

2.16 HK BRAKE RADIATOR & FAN

Each HK brake unit has its own cooling group adjacent to it.

Associated with the cooling group is a 0.6 kw 3 ph, circulating pump motor and a 4 kw 3 ph radiator fan motor with 20 A CB BCBL-4 and contactors. BPCL-4 and BFCL-4 located in the Aux. Control Cubicle.

2.17 HK BRAKE

See separate note APT 6.

2.18 AIR COMPRESSOR (DC)

This provides the air supply for operation of the pantograph and the EP contactors of the MA sets.

It is supplied off the battery

The subsequent main air supply is got from the 3 phase main compressor in the van trailer.

2.19 COOLING FANS (3 OFF)

These are located in the centre compartment RHS.

The centre machine is a 3.4 kw single phase motor and is used to ventilate the interior of the power car.

The two outer groups each consist of two single phase motor RCC1 & 2, RCC3 & 4 and their output is used to cooled the main oil filled radiator.

Their circuit breakers are in the Aux Control Cubicle.

2.20 COOLING RADIATOR GROUP (1 OFF)

This is located on the underframe in the centre of the vehicle and consists of four sections

Oil	for	cooling	the	main	transformer
"	"	"	"	"	choke
"	"	"	"	"	thyristors
"	"	"	"	"	vehicle tilt pack

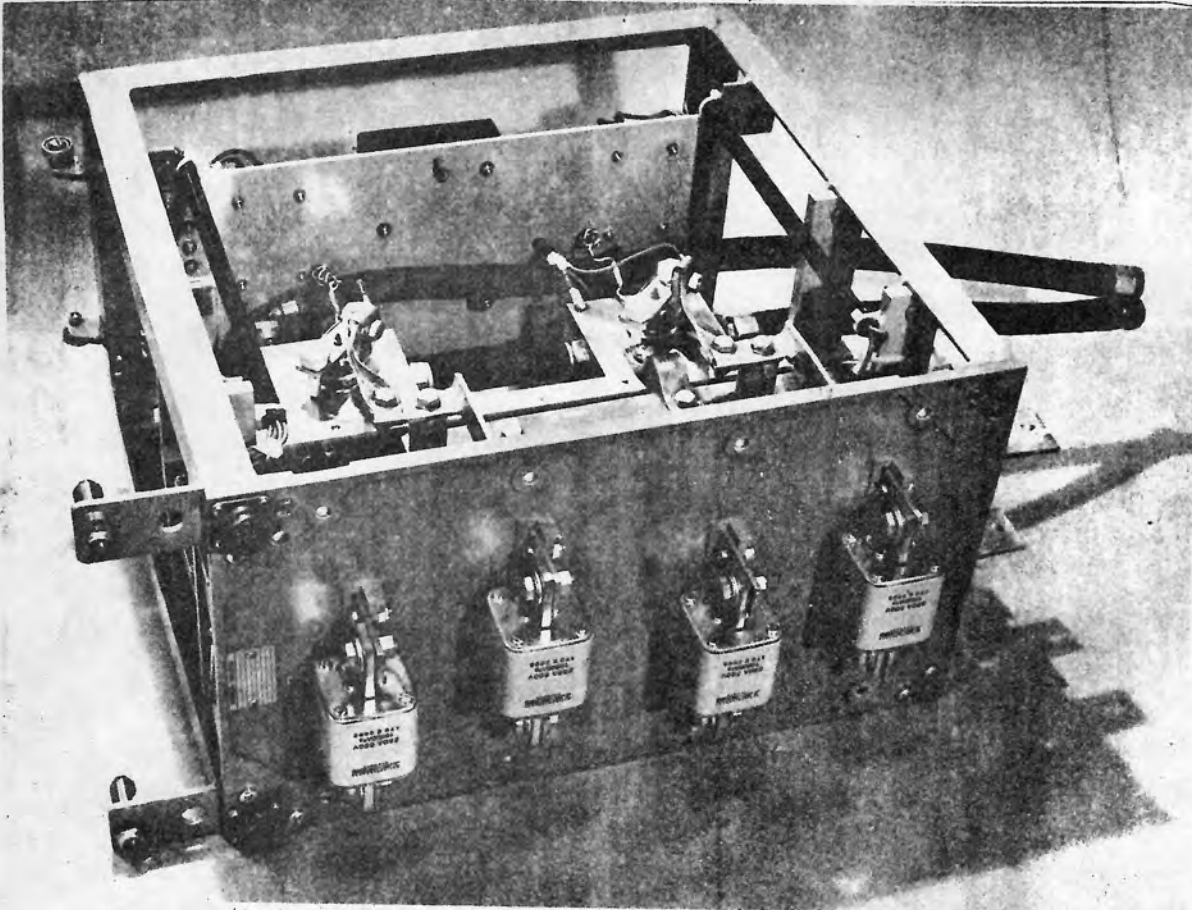
2.21 THYRISTOR CONVERTERS (2 OFF)

These are located in the centre compartment on either side of the gangway and they convert the AC voltage supplies into controllable DC supplies for:-

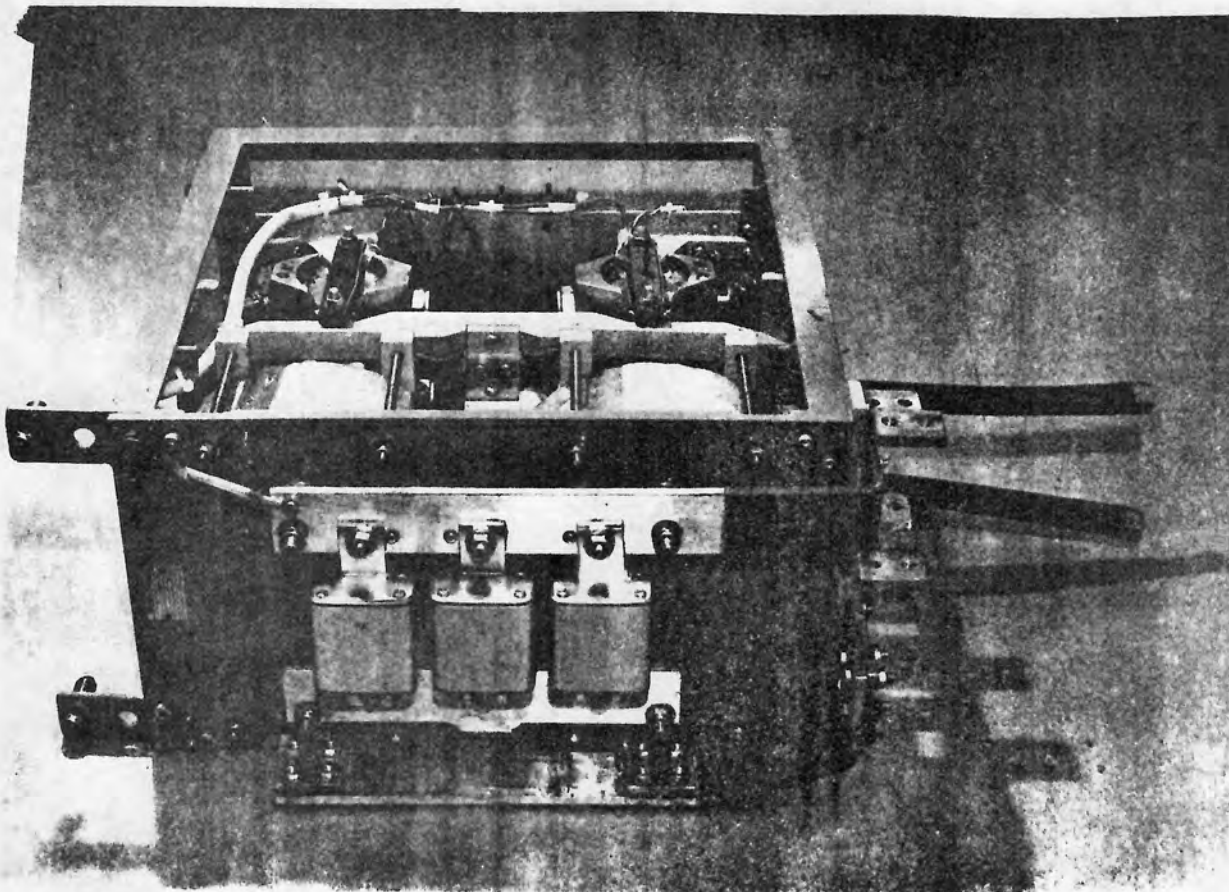
Thy Bridge	1A and 1B	are for	Motor 1	armature
"	" 2A " 2B	" "	" 2	"
"	" 3A " 3B	" "	" 3	"
"	" 4A " 4B	" "	" 4	"
"	" 5	is for	Motor Alternator	set 1
"	" 6	" "	"	" 2
"	" 7	is for	fields 1 & 2	
"	" 8	" "	" 3 & 4	

They are oil cooled.

Their effectiveness is monitored by current balance transformers or CT's.



THYRISTOR TRAY (MOTOR FIELD)



FRONT VIEW
MOTOR ARM
THYRISTOR

2.22 THYRISTOR OIL TANK & PUMP

This is located on the underframe directly under the two converter banks. The oil circulating pump is driven by a 240 V 7.75 kw single phase motor.

The system is self draining for ease of replacement parts.

2.23 BATTERY

This is a 72 cell Ni fe type battery and provides the 110 V D.C. control voltage. It is located in the centre compartment RHS. The BIS is located in the traction control cubicle access is by a carriage key. Emergency isolation outside (either side) by switches F.I.L.1 and 2. These will open VCB.

2.24 BATTERY CHARGER

This a solid state unit and is supplied from the single phase output on the excitation/auxiliary transformer and is located adjacent to the battery.

The ammeter indicates total output also has blue lamp.

2.25 TILT CONTROL PACK

This is located in centre compartment LHS opposite to cooling fans.

2.26 FAULT INDICATION PANEL

This is located in the centre compartment LHS opposite the small auxiliary compressor.

The top half of each indicator is a memory record of a cleared fault while the bottom half indicates the fault is still on.

It can be reset by maintenance staff after examination and there is a test and reset switch.

2.27 FIRE BOTTLE (2 off)

These are located in No 3 compartment LHS rearmost partition. They contain BCF and can be operated by detector or manually.

First there is an alarm then a delay then the bottles are fired.

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2.28

AUXILIARY MACHINES

DC MACHINES

1. Auxiliary compressor (for pantograph)

AC 3 ph MACHINES

1. 11 kw Oil pump for tilt system constant pressure
1. 5.5 kw " " " " " " flow
4. 0.6 kw circulating pump for HK brake
4. 4.0 kw Radiator Fan for HK brake

AC SINGLE PH MACHINES

1. 7.75 kw Thyristor oil cooling pump
1. 4.75 kw Choke " " "
1. 4.75 kw Transformer " " "
8. 3.4 kw Traction motor air cooling fans
(4 groups of two motors)
1. 3.4 kw Car Ventilating Fan
4. 3.4 kw Radiator Cooling Fan
(2 outer groups of two motors)

3. OPERATION (Fig 2)

The following notes refer to the simplified drawing of the electrical system on page 4.

3.1 Preparation

Close the battery isolating switch (BIS) on the power car(s) and on the driving trailer car.

On power cars this will provide a supply for the auxiliary air compressor which will run till 100 psi is established for the operation of pantograph. Two control supplies will be available from all battery sets via blocking diode as follows:-

Train wire 66 battery for traction control
 " " 67 " " auxiliary "

3.2 Pantograph - Vacuum Circuit Breaker

Unlock the master controller, using the standard master key and select the "Auxiliary" position.

Depress and hold down the "pan up" button this will energise the pan up relay (which will energise the pan up air valve) and reset the protective relays (VBR OLPR OVR and ARR) the pantograph will be released and under the action of springs be raised to touch the overhead line.

Release the pan up button this will de-energise ARR which will allow the Vacuum Circuit Breaker VCB to now close.

3.3 Auxiliaries

3.3.1 Single Phase

The primary of the main transformer is now energised and thus provides an 800 v ac supply for operation of the MA set and for operation of the Exc/Aux transformer from which we obtain the 240 v single phase supply for the following auxiliaries on the power car.

COMPONENT	SETTING		ACTION
	Alarm	Trip	
Thyristor Oil Pump TYOP	55°C	60°C	} Alarm - Traction off/ Aux left
Choke " " LOP	95°C	105°C	
Transformer " " TOP	95°C	105°C	
Traction Motor Blower	4 x 2 sets		Traction Fault Light Still work till oil temp rise reflected by detector
Car Vent Fan	1		
Rad. Cooling Fan	2 x 2 "		

3.3.2 Three Phase Supply

The motor alternator sets can now be started (by depressing the MA start button) to establish the 415 v three phase ac supply to both rakes of trailer cars.

Air conditioning and train lighting can now be switched on.

3.4 Driving

3.4.1 Tilt & HK Pumps

Selection of Forward or Reverse will energise a train wire 13 which will energise "Controls On" relay which will run the small tilt pump (the large pump is brought in by a speed relay when above 60 mph) and the HK brake re circulation pump on each vehicle of the train set. The brake coolant fan will run whenever cooling is required.

3.4.2 Direction

Selection of Forward or Reverse will energise train wires which will energise the forward or reverse relay FR/RR.

The forward and reverse relays are interlocked with the state of each reverser i.e. if any reverser is in 'forward' position, the reverse relay cannot be energised. The forward and reverse relays are also self latching for either of the following conditions

- a) a speed level greater than 10 kph, which is obtained from the brake wheel slip detection equipment.
- b) traction motor field current greater than zero, obtained from the ASEA electronics cubicle.

3.4.3 Power Demand Lever

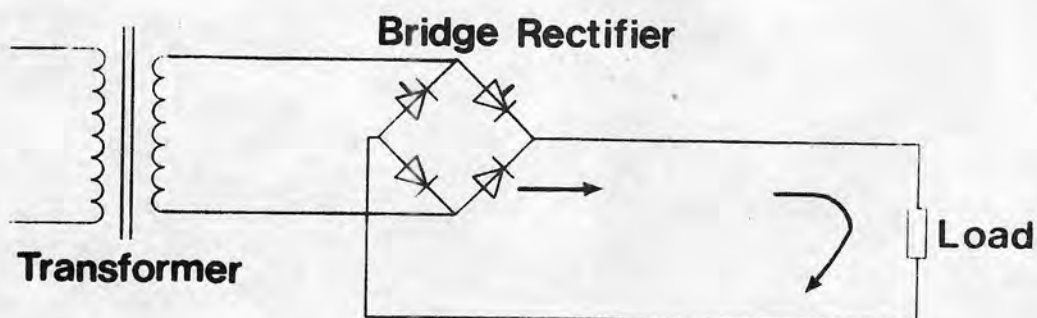
This is energised via the 'forward' or 'reverse' position of the master controller. The power lever will have nine positions, 'off', 7 equal power notches and 'boost' power notch.

3.4.3.1 Normal

The power demand controller contacts, energise train lines in sequence, which control de-coding relays in the ASEA electronics cubicle. The traction demand signal can be blocked, through the traction demand interlock relay which is situated in the driving cab, and this will only allow traction current in the motors if:-

- a) emergency brake loop is secure
- b) brake demand is not above notch two
- c) power demand lever is initially set at zero notch, or is returned to zero notch, after any of (a) or (b) interlocks have blocked traction demand signal.

THYRISTOR RECTIFIER



3.4.3.2 Boost

The 'boost' notch is provided to give a short duration burst of extra power, to assist starting from rest, under arduous conditions e.g. combined reversed curves and inclined track. If the train will not start with notch seven power demand, notch eight (boost) should be selected and as soon as the train begins to move, the controller should be returned to notch seven.

A timing relay will automatically modify the demand back to notch seven from notch eight, (if an attempt is made to maintain notch eight, this reversion is in order to protect the thyristor equipment from overheating.

Two timing relays are employed to achieve this. One limits the duration of 'boost' power demand to 3 seconds and the other ensures that a 20 seconds cooling period is allowed between successive boost power demand applications.

3.5 Thyristor Control

3.5.1 General

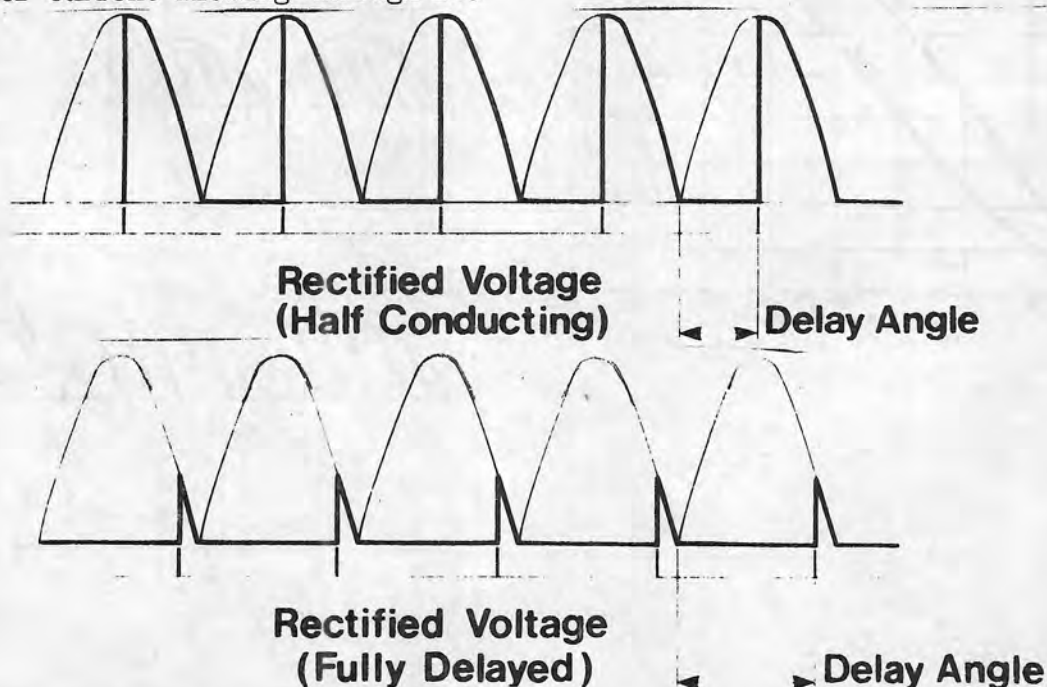
The thyristor is a four element semi conductor device which can be switched on or off very rapidly and can handle very high voltages and currents.

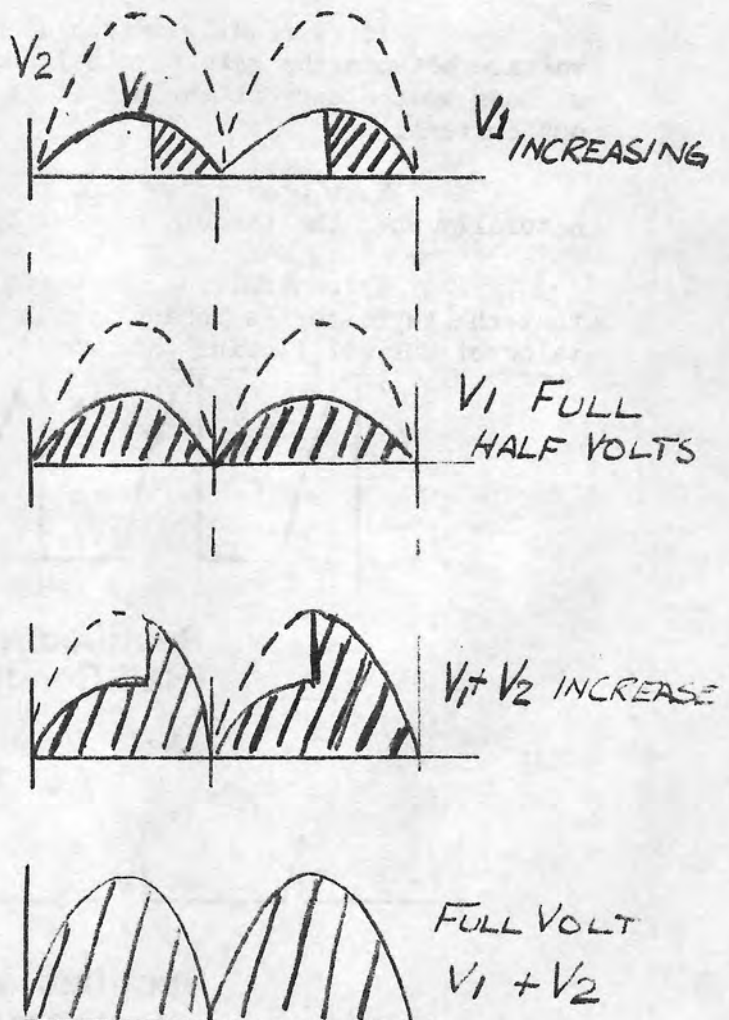
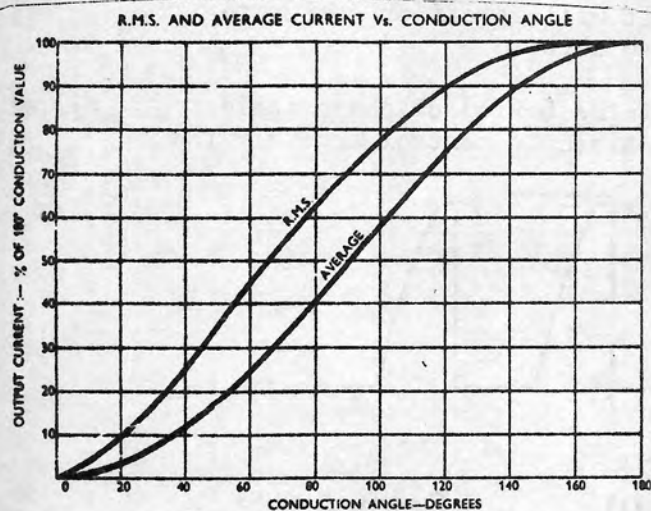
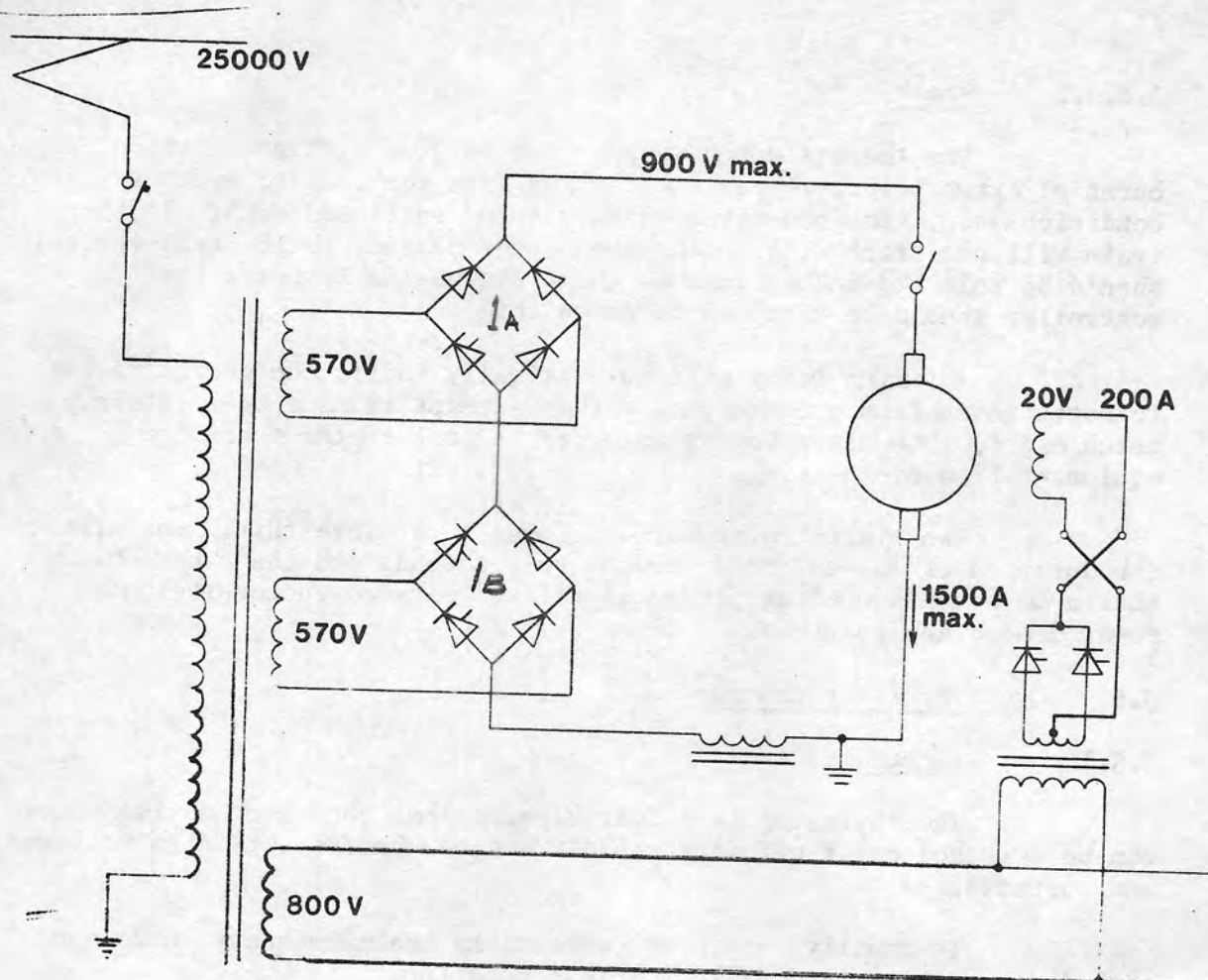
It usually has three connections the main heavy anode and cathode connections and a light gate connection.

It is readily switched on by applying a control or pulse voltage between the gate terminal and cathode while it will remain "ON" so long as the current through it is greater than its own minimum "hold on" current.

When used in an A.C. circuit it will go off or commutate naturally when the through current falls to zero.

By controlling the duration of the period or phase angle that the thyristor is conducting it is possible to control smoothly the value of current flowing through it.





3.5.2 Advantages of Thyristor Control

- 3.5.2.1 Solid state device no moving parts requires less maintenance than conventional control equipment.
- 3.5.2.2 Higher Mean T.E. for given adhesion.
- 3.5.2.3 Better control should motor slip.
- 3.5.2.4 Simpler design of transformer, fewer tapping, less weight.

3.5.3 Disadvantages

- 3.5.3.1 Poor power factor (AC System)
- 3.5.3.2 Interference problem (Adjacent equipment).

3.5.4 Operation of Power and Control Circuits

The power circuit comprises four separately fed traction motor armatures and four separately fed individually controlled field windings. The latter are all fed from an auxiliary winding in the main transformer and each via a thyristor rectifier bridge and reversing contacts.

The armature circuit of each motor is supplied from two series connected half-thyristor half rectifier bridges each of which is connected to a separate secondary winding in the main transformer e.g. 1A and 1B for motor 1 etc.

Two motor armature-bridge circuits share a common secondary winding

Each armature circuit comprises a contactor, overload, smoothing reactor. Also included is a current measuring device for producing the necessary signal for control purposes.

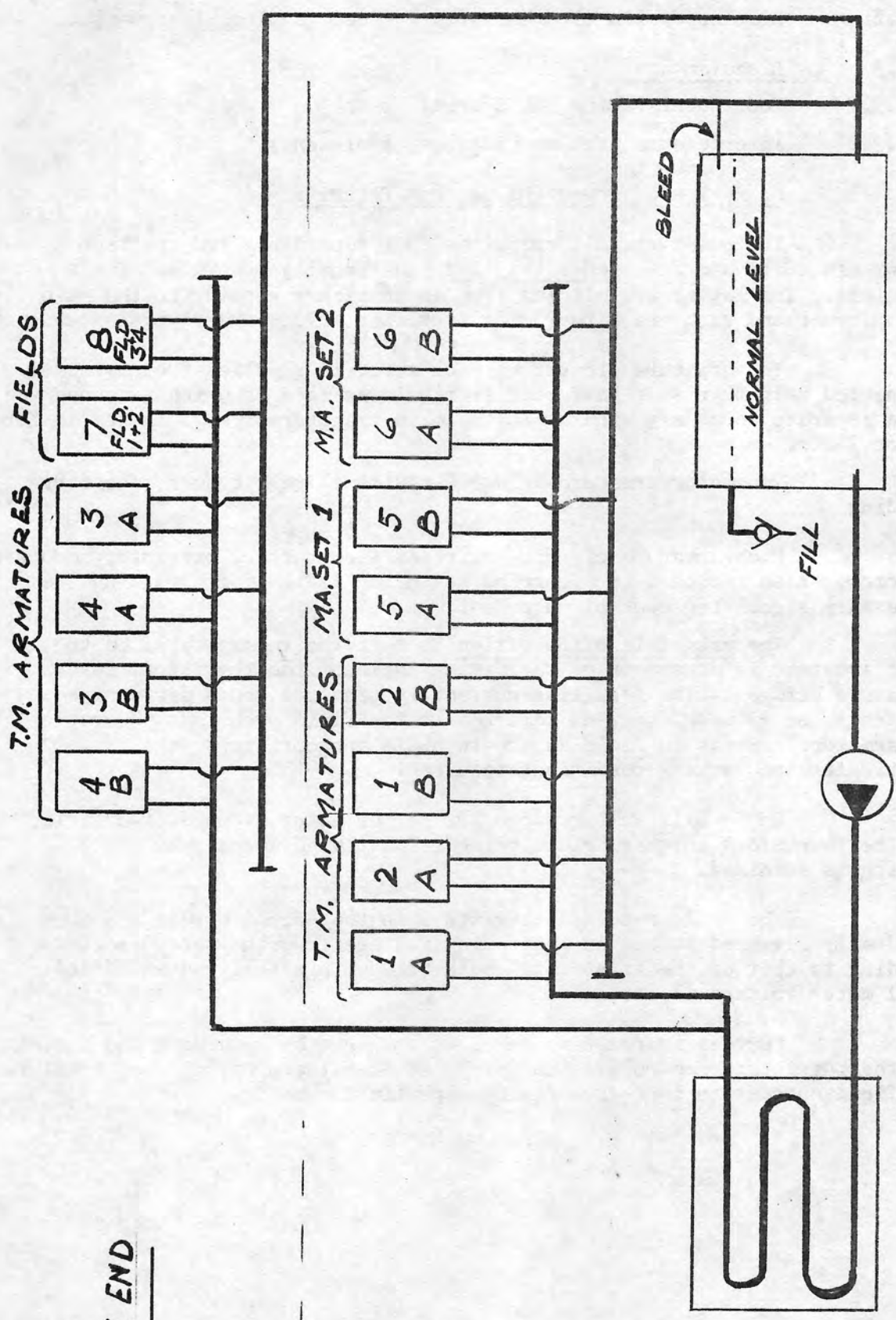
The principle of operation is that the voltage applied to each armature is dependent on the firing angle of the thyristors in the armature bridges. The resulting current is measured and a derivative controls the value of current admitted to the field such that the ratio of armature current to field ampere-turns is appropriate to the particular and varying conditions required.

Up to half voltage, one bridge per motor is used, the firing of the thyristors in that bridge being gradually advanced until free firing is attained.

The fully retarded thyristors in the second bridge are then gradually advanced to add an increasing voltage from the second secondary winding to that of the first until both bridges are fully advanced and full motor voltage is attained.

Further increase in speed is obtained by retarding the firing of the thyristors controlling the field so that the proportion of armature to field current is increased giving weak field running.

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CORRIDOR

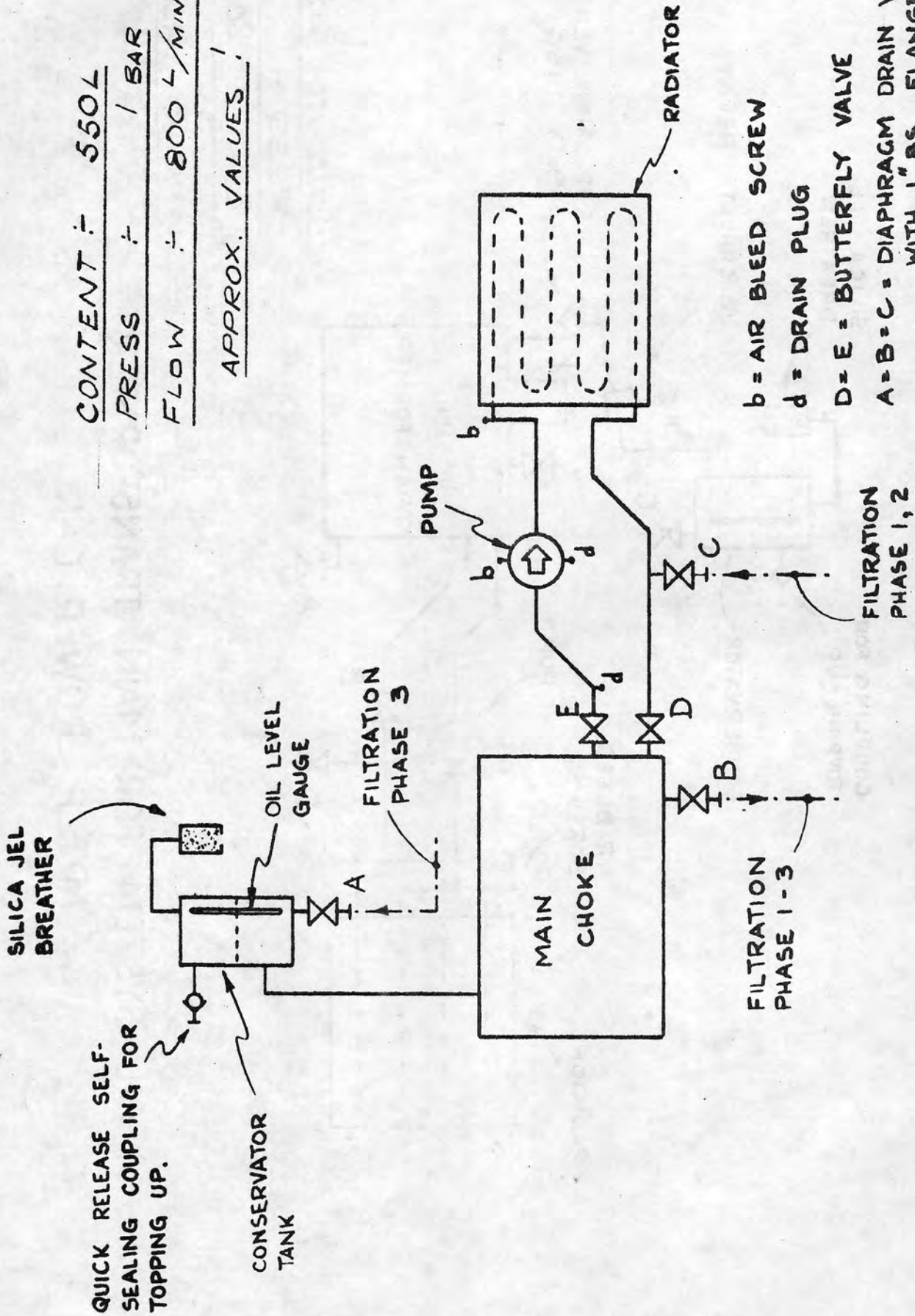


CONTENT :- 410 L
PRESS. :- 3 BAR
FLOW :- 460 L/MIN
APPROXIMATE
VALUES !!

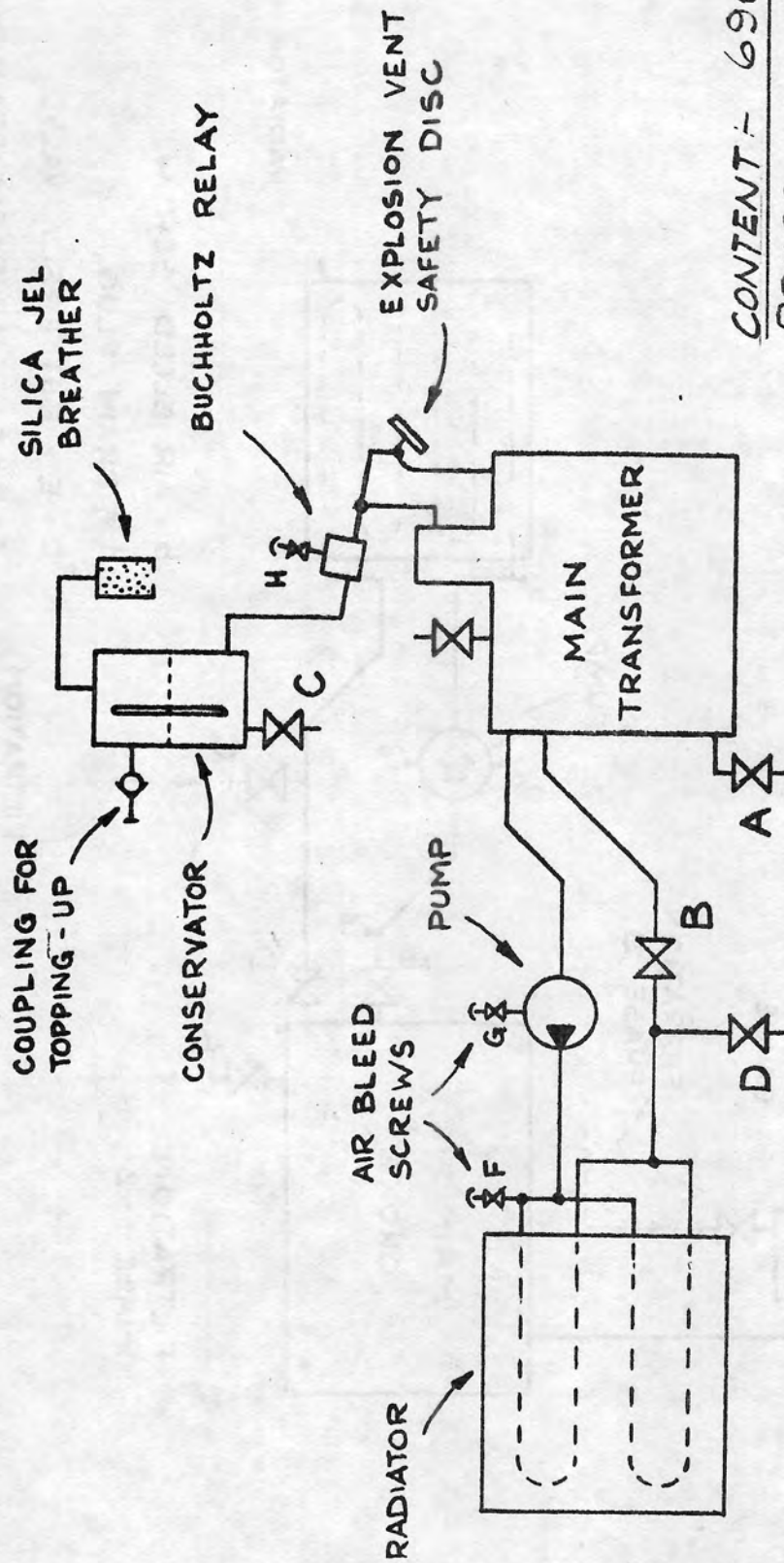
THYRISTOR OIL COOLING SYSTEM APT.

No 1 END
←

CONTENT ÷ 550 L
 PRESS ÷ 1 BAR
 FLOW ÷ 800 L/MIN
 APPROX. VALUES !



OIL COOLANT CIRCUIT FOR MAIN CHOKES. APT-P POWER CAR



CONTENT :- 690 L
PRESS :- 1 BAR
FLOW :- 800 L/MIN
APPROX. VALUES !

OIL SYSTEM FOR MAIN TRANSFORMER APT-P POWER CAR