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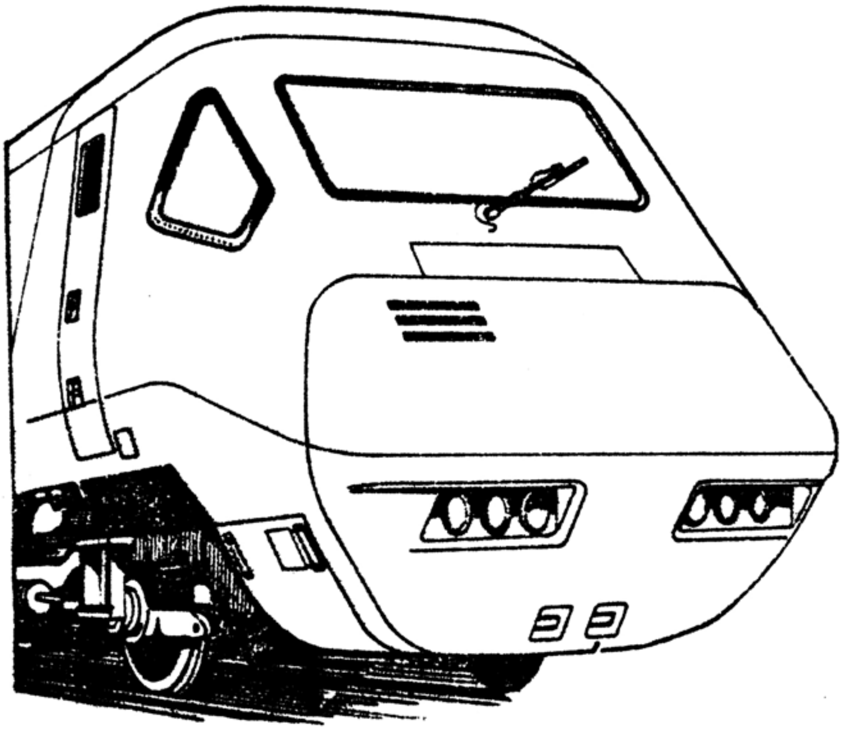

Course Notes

3. Brakes

APT BRAKING SYSTEMS

INTRODUCTION

To meet the requirements of braking a train such as APT within the existing signalling distances from speeds much in excess of normal train working it has been necessary to re-think the method of absorbing the kinetic energy possessed by the train at such speeds and to dissipate this energy as rapidly as possible.

The Hydro-kinetic brake is the only system of those available to the Brake Engineer which offers a combination of low unsprung mass (thereby meeting the needs of the Civil Engineer by keeping dynamic track forces to a minimum) and a high energy absorbtion/dissipation rate (as a braking medium) whilst demanding the minimum maintenance with maximum reliability. In addition the Hydro-kinetic brake offers a repeatedly consistent torque characteristic without brake fade. This consistent torque ensures accurate balancing of the braking effect through the train up to the limit of available adhesion.

GENERAL PRINCIPLE OF OPERATION

A Hydro-kinetic brake unit employs two pairs of rotors and stators, one rotor and one stator for each direction of vehicle travel. The working medium is water containing 25% ethylene glycol to prevent freezing. During the braking action this liquid passes rapidly between the rotor and stator and in doing so creates a retarding torque on the rotor. Fig. 1 indicates the path of the liquid around the brake. Toroidal circulation is shown in Fig. 2.

Liquid enters the stator blades at the centre of the toroid and passes into the rotor. As this liquid is accelerated to the speed of the rotor a retarding force is exerted, this force being dependant upon the mass flow and change in velocity that takes place. As the liquid arrives at the rotor's outer tip it is projected against the stator and flows inwards around the toroid towards the stators inner tip where it again passes to the rotor. Again the change in velocity which occurs creates a retarding force. The rotor pumps the liquid faster and faster on each circuit until the hydraulic friction and short losses are equal to the input power. At this balanced condition the forces from the rotor and stator cups sum together to give the braking torque.

The flow of fluid is controlled by the brake control unit (BCU) which ultimately responds to the signal produced by the Driver's Brake Controller. This signal passes to an encoding unit which "encodes" a suitable electronic signal to pass down the train lines. This signal is detected by the Brake Electronic Control Unit (BECU) which "decodes" it and passes an electrical signal to the Main Control Valve in the BCU.

The BCU then provides air pressure, corresponding to brake demand, to the water-glycol reservoir to force the fluid to the Brake Unit on the axle (Trailer Vehicles) or drive shaft (Power Cars).

BRAKING SYSTEM COMPONENTS.

The Hydro-kinetic brakes for trailing wheel sets are mounted between the wheels as shown in Fig. 3. The cast aluminium rotors (1) are rigidly connected to the outer casing (2) which in turn forms an integral part of the wheel set's axle, being bolted centrally between 2 conicle half axles (3). The stator (4), also of cast aluminium, is supported by a long tube (5) which takes the torque reaction back to the axle box via splines and also provides means of passing the water-glycol between the reservoir and brake.

Located on the end of the axle box is a shut-off valve (6) which allows or blocks the supply of water-glycol to the brake. Axle connections shown in Fig 5.

For the powered axles, advantageis taken of the mechanical transmission system to enable all Hydro-kinetic brake equipment to be body mounted. This brake's design, referring to Fig. 4 comprises a rotor (1) which is mounted on the "Free" end of the input shaft of the transfer gear box (2) with the stator (3) and the brake's outer casing carried by the gear casing itself (4).

The operating principle of this brake is the same as that of the trailer brake, but the whole arrangement is turned "inside out" with the rotors becoming enclosed by the stator casing.

DRIVER'S BRAKE CONTROLLER

The Driver's Brake Controller is graduated :-

Running - Initial - 2 - 3 - 4 - 5 - 6 - Full - Emergency. These positions correspond to a range of brake demand which are applied to the brake system. Movement to the handle operates micro-switches within the brake controller assembly to send appropriate electrical signals to the Brake Encoder.

ENCODER

The Encoder takes the electrical signal from the Driver's Brake Controller and produces two signals which are transmitted to all local brake systems throughout the train.

The first is the Pulse Width Modulated (P.W.M.) signal. The degree of modulation is controlled by the signal from the Driver's Brake Controller.

The second signal produced by the Encoder is the A.C. signal for the Emergency Brake Loop.

BRAKE ELECTRONIC CONTROL UNIT

This unit accepts signals from the PWM line, the load measurement transducer and the axle end probe (wheel slide detection),EBL and highest speed line and produces electrical signals to the Brake Control Unit.

BRAKE CONTROL UNIT

This is a Compair Maxam or Westinghouse unit containing the valve gear which takes air from the system's reservoir and electrical control signals from the Brake Electronic Control Unit to operate the hydro-kinetic and auxilliary friction brakes. This includes the blending of the hydro-kinetic brake and auxilliary friction brake at the lower speeds and also the wheel slide protection function.

The operation of this Unit is described in detail later in these notes.

AIR RESERVOIR

There is one air reservoir for each local brake system which supplies that system with air from the train pipe via a strainer, check valve and isolating drain cock.

WATER-GLYCOL RESERVOIR

There is one water-glycol reservoir for each local brake system which supplies the system when the hydro-kinetic brake is in operation. During brake operation the reservoir is pressurised with air at a pressure corresponding to the brake demand.

COOLING RADIATOR & FAN

Water-glycol is being constantly circulated through the radiator by the circulating pump. The fan is electrically driven and thermostatically controlled to provide a forced draft for cooling the water-glycol when it gets too hot for the radiator and pump to cope with alone.

BRAKE CIRCULATING PUMP

The Brake Circulating Pump is situated in the line between the water-glycol reservoir and the cooling radiator. It is running all the time a three phase supply is available and forward/reverse is selected on the master handle.

EJECTOR (SCAVENGE PUMP)

This is a convergent/divergent nozzle which has fluid passing through it all the time the Brake Circulating Pump is running. A pipe leading from the underside of the H-K Brake Unit is connected to the throat area of the nozzle. The fluid flow through the nozzle serves to draw fluid through the pipe from the Brake Unit to give a constant scavenging effect. See Fig. 6.

BRAKE METER (DECELEROMETER)

This is situated in front of the driver and measures the rate at which the train is slowing down when a brake application is made. The calibrations from 1-8 correspond to the graduations on the Brake Controller and enable the driver to see if the train is braking at the rate he has selected; any discrepancy will be due to either adverse rail conditions or brakes being isolated on the train.

The rate of deceleration is sensed by a longitudinally positioned transducer mounted behind the water filler on "A" side of the Driving Trailer. This transducer is identical to the one used in the Tilt system.

When replacing this transducer care should be taken that :-

(a) The 4 mounting feet face downwards.
(b) The electrical connection faces towards No. 2 end of the vehicle.

FRICTION BRAKE UNITS

INTENSIFIER (AIR/HYDRAULIC) See Fig 9.

This converts the air pressure from the BCU into an hydraulic pressure which is intensified by a ratio of 1:28 for Power Cars and BT 12a bogies and 1:41 for the Trailer Cars to operate the friction brake actuators. Some intensifiers are being fitted with indicators which will display a red aspect if the stroke becomes excessive.

ACTUATORS

There are two types of actuator fitted to the friction brake system These are:-

(1) Water Glycol operated actuators (Stirling Hydraulics) Fig 7.

(2) Oil operated parking brake actuators (Westinghouse) Fig.8

The water-glycol operated hydraulic friction brake actuator is basically a straightforward piston and cylinder arrangement where hydraulic pressure is applied to the piston which applies the blocks to the wheels. These actuators are fitted to all axles except the power car end of the van-trailers and the power cars themselves.

The oil operated parking brake actuator is somewhat more complicated device than the water-glycol version. This is mainly due to the parking facility. The actuator works in the normal manner when working in the service brake condition i.e. via the intensifier. In the parking brake condition it operates from the parking brake unit, via the shuttle valve and applies the friction brake. The application line then operates a mechanical clutch arrangement to lock the actuator on and the pressure is released. Both actuators are fitted with internal release springs and an adjustable control rod is connected in parallel with the actuator arm. This limits the travel of the actuator keeping within the intensifier stroke.

EMERGENCY BRAKE LOOP

APT-P does not have an air brake pipe : it has an electrical equivalent. The encoder unit in the driving cab produces an ac signal which passes down a train line to the end of the train and returns via each Brake Electronic Control Unit. Fig. 11 . If this signal is not detected at the local BECU it produces an emergency brake application. In general terms it operates in the same way as an air train pipe; Should the train break, both portions should stop.

TOWING MANIFOLD

The Driving Trailers of APT are provided with buffers, a drawhook/buckeye coupling assembly, an Auto Air Brake Pipe (AABP) and a Main Reservoir Pipe (MRP). This means that APT can be assisted in an emergency by an air-braked locomotive. See diagram D8 in Geography Course Notes.

However, to enable a brake application made on the locomotive (air controlled) to apply the brakes on APT (electrically controlled) it is necessary to convert the drop in AABP pressure to an electrical signal suitable to APT's braking system. This is done via the Towing Manifold situated beneath the front desk in the driving cab on "B" side.

The Towing Manifold has 3 functions :-

(a) To provide a comparable linear electrical braking effort on APT by monitoring the AABP pressure.

(b) To apply emergency brakes on the locomotive when an emergency application occurs on APT.

(c) To apply emergency application on APT when an emergency application occurs on the coupled assisting locomotive or train.

The system is activated by the "Tow Enable" switch on "A" side of the cab. This has three positions :-

(a) Normal

(b) APT coupled. used when assisting train is another APT.

(c) Air Brake coupled. Used when assisting traction unit is an air braked locomotive or train.

The Tilt system on the Driving Trailer is isolated by the movement of the "Tow Enable" switch. This is necessary to prevent the possibility of buffer-locking between the Driving Trailer and assisting unit.

Inside the Towing Manifold are 3 important components, a pressure transducer, a solenoid valve and a pressure switch.

The transducer is supplied from the Encoder and sends a signal back to the Encoder which is proportional to the AABP pressure within the Towing Manifold. This signal after being received by the Encoder modulates the PWM signal to give a brake application on APT proportional to the braking effort on the assisting unit.

The pressure switch operates when there is an emergency brake application on the assisting unit. As soon as the AABP drops below 1.38 Bar (20psi) the pressure switch open circuits the Emergency Brake Loop on APT causing an emergency brake application. When the AABP pressure builds up the switch will close as soon as pressure exceeds 1.38 Bar and APT's brakes will start to release.

An emergency brake application on APT (EBL broken) open circuits the solenoid valve and vents the AABP via the Towing Manifold to 2.77 Bar (40 psi). This causes an emergency brake application on the assisting unit.

The device can be isolated in the event of a fault by the "Towing Manifold Isolation cock situated beneath the Driver's desk behind the left side panel.

Parking Brake
In addition to the main braking systems APT is also provided with a parking brake operated via the friction brake actuators on the Power Car bogie and the BT12A bogie on the Van Trailer. The system can be controlled electrically from the Driver's cab or mechanically by using an externally fitted handle on each parking brake unit. The system is described in detail later in the notes.

The following pages in this training note deal in more detail with the major components of the braking system.

The Encoder
The encoder comprises four parts, each of which is duplicated, so that in the event of a failure the back-up system can be used. This changeover is effected by a switch on the front of the encoder box. The four parts comprise three printed circuit boards mounted in a racking system and one oscillator module mounted on a separate pile. The function of each module is described below and the modules are set out diagramatically in Fig.12

(a) Interface board/AC current detector.
This takes signals from either the Driver's handle or the towing manifold (in the case of APT being assisted). These signals are converted to a form suitable for encoding into PWM signals. The interface board also receives the a.c. current which has travelled through the train around the emergency brake loop.

The presence of current within the loop is sensed by the Encoder and if this current ceases to flow the Emergency Detection Relay is operated. This will cause the AABP to be exhausted if a loco is assisting APT and, if operating conventionally, traction control will be lost.

(b) Voltage Regulator board.
This accepts the supply from the local AC/DC or DC/DC packs and converts it into a stabalised $\pm$ 13 volt supply for powering the electronic boards. It also produces a -9 volt supply for the pressure transducer in the Towing Manifold.

(c) PWM Encoder board. (See Fig 13)

Produces the balanced $\pm$ 25 volt PWM signal in accordance with the Driver or Towing Manifold's brake demand.

(d) Emergency Loop board.
This is an oscillator producing a 275 HZ, 100 mA signal between 40 and 65 volts to energise the EBL.

If either the positive 25 volt PWM signal or the negative 25 volt PWM signal is lost then the remaining signal will also be lost and an Emergency brake application will occur.

The Brake Electronic Control Unit

Each HK brake has a local electronic unit which accepts signals from the Driver's demand (PWM) line, load measurement (transducer), axle end probe, Emergency Brake Loop, and Highest speed signal line and produces electrical signals for the Brake Control Unit.

The brake force required to stop the vehicle from a given speed in a given distance is dependent on its weight. A transducer is mounted in the air spring system and provides a voltage signal proportional to the vehicle weight, this is used to modify the brake torque as the resultant brake torque is proportional to:-

(a) Driver's demand.

(b) Vehicle weight.

A pulse transducer and toothed wheel assembly is mounted on the axle end. A pulse counting circuit inside the brake electronic control unit monitors the wheel speed.

If a brake demand is made by the Driver which exceeds the wheel/rail adhesion available the wheels will slide. To prevent the wheels from locking the wheel slide prevention system rapidly removes the brake force on the sliding axle; when the axle has recovered speed the brake is re-applied. If the adhesion level has not changed and the brake is re-applied at the same rate the wheel will slide again. The adaptive system fitted to APT "remembers" that the previous demand was too great and re-applies the brake at the lower level, bringing the demand back to the original value gradually. This process continues until the brake force demanded is within the wheel/rail adhesion limit.

The brake electronic control unit consists of 5 printed circuit modules as follows:-

(a) The Voltage Regulator Module

This module accepts the $\pm$ 25 volts local supply and converts it into a closely stabilised $\pm$ 13 volt supply suitable for powering the electronic devices within the brake electronic control unit.

(b) Brake Control Module

This module carries out the following functions:-

1. Decodes the PWM demand signal.

2. Accepts the load measurement signal and modifies the demand accordingly.

3. Accepts any back-off signal coming from the wheel slide system and modifies the demand further.

4. Provides - 9v supply to Pressure Transducer.

4. Produces a current signal for the Main Control Valve (3).

5. De-energises the brake inhibit solenoid when a demand is made.

6. Clamps the maximum brake demand to a reduced level in the event of a wheel slide system failure.

(c) Speed Signal Module.

1. Accepts the pulses from the axle end transducer and produces a voltage signal proportional to the wheel speed.

2. Makes the speed signal available to all the units on the vehicle.

3. Continually checks the continuity of the axle end probe and illuminates a light emitting diode on the box side upon failure.

4. Operates speed level switches to energise relays at pre-set speeds to (a) switch on the main tilt pump at speeds above 60KM/H (37 mph) (b) energise an interlock to prevent the traction reverser being operated at speeds above 10 KM/H (7 mph) and (c) cuts out WSP below 10 KM/H.

(d) WSP Module (Wheel Slide)

1. Continuously records the voltage (axle speed) from the speed signal module and compares it with the highest axle speed on the vehicle.

2. Measures the deceleration and compares it with the pre-set level.

3. Operates the WSP solenoid (23) should any axle speed drop significantly below the highest level or the wheel deceleration be excessive.

4. De-energises the WSP solenoid valve when the difference between the wheel speed voltage and the reference voltage is reduced to a pre-set value.

5. Provides a "back-off" signal (which decays to zero in a pre-determined time) to the brake control module on detection of wheel slide.

(Modifications will use the HK brake cut off line from BECU, recalibrated to 120 KPH, to be used for brake monitoring. Another modification will use the spare line, recalibrated to 95 KPH, to monitor gearbox performance.

6. Uses a timer which does not allow the WSP solenoid to be energised for longer than 10 seconds. The complete cycle of wheel slide-detection-prevention should not take longer than 10 seconds. If energised for a longer period (remembering that whilst WSP solenoid is energised there is no brake on the axle concerned) it is assumed that there has been a failure of the system and the brakes are re-applied regardless of the level of wheel/rail adhesion.

7. Sends a low level clamp signal to the brake control module in the event of a WSP module failure.

(e) Auxiliary Circuit Module

This module monitors the performance of the other modules and in the event of a fault:-

1. Operates the latching indicator (BITE) on the side of the unit. The visual indication is given by the disc changing from "BLACK" to "WHITE".

2. Energises the local Brake Not Demanded solenoid (22) to give a failsafe condition on the faulty axle. This is accomplished by comparing the incoming PWM signal to the EP current signal supplied to valve 3. If this is outside a predetermined tolerance valve 22 will be energised.
If there is an emergency application however the BECU will always attempt to provide a brake whatever the condition of the module.

The Brake Control Unit

Each HK brake has a Brake Control Unit which houses control solenoids and pneumatic devices. The Brake Control Unit accepts electrical inputs from the Brake Electronic Control Unit and produces pneumatic outputs to control the brake reservoir, and in the event of wheel slide, vent air line pressure.

The Westinghouse BCU is shown internally in Fig 15 and externally in Fig 17. Figs 16a/b/c will be completed in a class exercise, whilst Fig 18 shows the internal layout of the Maxam BCU.

Electrical Connections

The "main operator" magnet valve 21 is connected to a 25v supply from the AC/DC or DC/DC pack and becomes energised when BIS is closed.

The "brakes not demanded" magnet valve 22 is connected to the BECU and is normally energised whilst running with the brakes released and is de-energised when the brake is to be applied.

The "main control" valve 3 is connected to the BECU , and is normally de-energised whilst running with the brake released, and to which a variable current is fed when the brake is to be applied.

The "wheel slide" magnet valve 23 is connected to wheel slide control equipment and is energised whenever a condition of wheel sliding develops. It is de-energised at all other times.

Pneumatic Ports
Port M is connected to an air supply on the vehicle at a pressure of 10 bar. This supply is "protected" by a non-return valve.

Ports R, I, S, V1 and V2 are connected to the hydro kinetic brake and its associated fittings as shown in Fig.21.

Connections GR, GS & GI are pressure measuring points from lines R, S and I

The following paragraphs detail the operation of the valves in the Brake Control Unit for the various braking modes.

Running With The Brakes Released
Valve 21 is energised open as is valve 22. No control current is applied to the "main control" valve 3 which remains de-energised closed. Valve 23 is de-energised closed. Valve 21 passes air at a pressure controlled by "constant pressure" valve 5 to the control ports of the "emergency brake" valve 2 and "manual release" valve 14 and sets them to provide a path between the output port of valve 3 and the control port of "flow amplifier" valve 1. The control port of this valve is vented to atmosphere through valve 3 and valve 1 venting port R and the water/glycol reservoir shown in 13 to atmosphere.

Valve 22 passes air via "shuttle" valve 17 ("OR" Logic Unit) to the control port of "friction brake off" valve 7 and sets it to vent port I and the intensifier to atmosphere. It also passes air via another "shuttle" valve 17 to "brake shut off" valve 16 which vents port S and the fluid shut off valve (Figure 13) to atmosphere, and to the control port of the "vent sealing" valve 15 which shuts off "HK brake dump" valve 12 from atmosphere.

With the Brake Control Unit in this condition, the fluid shut off valve connected to port S is closed and the water/glycol reservoir connected to port R is not pressurised, no fluid can enter the toroids and the hydro kinetic brake is released. The friction brake is also released due to the venting of the intensifier which is connected to port I.

Brake Application Initiated By the Driver
Valve 21 remains energised open whilst valve 22 is de-energised closed. A control current (sometimes referred to as the EP current) is applied to valve 3 to a level selected by the Driver. Valve 23 remains de-energised until brought into action by the wheel slide control equipment.

On being de-energised valve 22 vents to atmosphere the control port on valve 16 which is then set to pass an air supply from valve 5 to port S and the fluid shut off valve. At the same time valve 3 passes air at a pressure proportional to the control current applied to it, through valves 2 and 14 to the control port of valve 1. In response to this control pressure valve 1 produces a similar pressure at port R and the water/glycol reservoir.

In this condition the reservoir is pressurised and the fluid shut off valve is opened to allow fluid to flow from the reservoir to the hydro kinetic brake toroids. Assuming that the brake application is made at high speed, the effective toroid then generates a braking torque, to a level proportional to the control air pressure from valve 3 which, in turn, is proportional to the control current applied to it via the BECU and the Driver's controls. Any subsequent variation of the control current by the Driver varies the pressure applied to the reservoir and, thereby, the braking torque, accordingly.

On being de-energised valve 22 also vents to atmosphere the control ports of valves 7 and 15. This sets "friction brake off" valve 7 to connect port I and the intensifier to "friction brake control" valve 10 via "limiting" valve 8 but, initially during a brake application at high speed, the intensifier remains connected to atmosphere through valve 10 exhaust port and the friction brake remains released. It also sets valve 15 to connect valve 12 to atmosphere and, as the valve 12 is set permanently to connect " valve 24 to valve 15, this means that the retaining valve outlet is opened to atmosphere.

If port V1 is connected to the vent pipe of the effective toroid, and V2 to the ineffective one, as soon as the hydro kinetic brake operates a pressure builds up in the core of the ineffective toroid and displaced air and fluid flow via port V2 to valve 24. This valve allows air to pass and exhaust through valves 12 and 15 but prevents the flow of fluid. When the air has been exhausted, a pressure is generated in the fluid at port V2 sufficient to pressurise the bottom pilot port of 24 which will remain as drawn. This lines up V1 with the pilot of valve 10.

As the train speed decreases, the effective toroid begins to fill up, and displaced air and water flow from its vent port via port V1 to the valve 24 which, once again allows the air to exhaust but stops the fluid. Subsequently, fluid pressure builds up at the port V1 and through valve 24 to the control port of valve 10 which then passes air at a proportional pressure to the intensifier via valve 7 and valve 8.

The fluid pressure generated at the core and vent port of the effective toroid reduces the pressure difference across the toroid and, thereby, the braking torque. Bearing in mind that the braking torque is proportional to the pressure difference across a non flooded toroid, it follows that the amount by which the torque is reduced is proportional to the pressure at the vent port. Also, as the vent port pressure is used to control the operation of the intensifier via a relay valve, the braking pressure applied by the intensifier to the friction brake is proportional to the torque reduction. Therefore, as the braking torque of the hydro kinetic brake fades as the train speed falls, the friction braking pressure is increased automatically to compensate and to maintain the total braking effort at the level demanded by the Driver. This brake characteristic is shown on the graph in Figure 15
Note the dip in the curves where friction brakes gradually take over from the hydro kinetic brake.

Brake Application Initiated by Disconnections of the Electrical Supply.

If there is a disconnection of the local electrical supply this will result in all solenoid operated valves in the BCU loosing their supply. Valve 21 is de energised closed, valve 22 is also de energised closed, valve 23 remains de energised, and no control current is applied to valve 3.

On being de-energised, valve 22 causes the fluid shut off valve to be opened and sets up the connections to the intensifier and valve in readiness for braking.

Valve 21 shuts off the air supply to the control ports of valves 14, 2 and 3 causing them to vent to atmosphere. When this occurs, the internal mechanism in valve 14 remains in its existing position but valve 2 is reset by an internal spring so that the control port of valve 1 is connected to "emergency set rate limiting" valve 4 instead of valve 3. The water/glycol reservoir connected to port R is then pressurised and the hydro kinetic and friction brakes are applied to a level proportional to the air pressure delivered by valve 4. This valve is normally set at a pressure

Action of the Wheel Slide Feature During a Brake Application Initiated By The Driver

If a condition of wheel sliding develops whilst the brake is applied by the Driver, valve 23 of the Brake Control Unit associated with the affected axle is energised open and connects an air supply from valve 5 to the control ports of valves 7 and 16. This vents port I and the intensifier to atmosphere via valve 7 and releases the friction brake. It also vents port S and the fluid shut off valve to atmosphere via valve 16 and stops the flow of fluid to the toroids.

The affected axle is thereby relieved of all braking force to allow it to regain speed. When this occurs, valve 23 is automatically de-energised to vent the control ports of valves 7 and 16, the return springs in these devices re set them into their original positions and the hydro kinetic and friction brakes are re-instated.

The passage to the control port of valve 12 is plugged and this valve is not affected by valve 23; it provides a permanent connection between the valve 19 and valve 15 with the connection to ports R shut off.

Compair Maxam BCU

The main difference between this BCU and the Westinghouse version is in the way the vent lines operate valve 10.

Air preceeding the water glycol is vented via valve 19. The fluid from the non effective toroid will pressurise the pilot port of one of the vent selector and friction brake control valves, 10.
When the effective toroid's vent line pressurises the pilot port of the other valve 10 air, proportional to the vent line pressure of the effective toroid, will pass to valve 7 in the same manner as described in the Westinghouse BCU paragraphs.

STUDENT'S NOTES.

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PARKING BRAKE

Introduction.

The parking brake units fitted to APT-P Power Cars and Van Trailers are fitted with an electro-hydraulic parking brake system in which brake blocks are applied to the wheels by hydraulic actuators under the control of electrical signals from a driving position. A parking brake unit is mounted on each side of these vehicles and is connected to the hydraulic actuators on the vehicle by two small bore hydraulic pipelines known as the application line and the release line.

The external view of the unit is shown in Fig. 19, whilst the internal connections are shown in Fig. 20.

The function of the parking brake unit is to exert hydraulic pressure in the application line or release line to apply or release the brake in response to electrical control signals carried by train wires, and to indicate whether the brake is applied or released.

The general arrangement of the parking brake unit is shown in Figure 16. It comprises two pipe brackets which are screwed together and on to which the various valves and other items are mounted to form a self-contained and compact unit. With the exception of two short pipes, all hydraulic connections between the component valves are made through passages in the pipe brackets. Tapped plugs complete with filters for connection to the application line and release line are provided in the horizontal pipe bracket and a manifold mounted on the vertical bracket contains connections for pipes to a fluid header tank,a filter is provided behind the header tank supply connection. All external electric wiring is connected into a single terminal box.

Application Of The Brake

The hydraulic parking brake is controlled from the Driver's cab by two push buttons (electrical), one button to apply, the other to release as required. Depression of the parking brake "apply" button will start the motor driven pump which draws fluid from the tank and delivers it via passage 1 to the selector valve. Fluid flows through the selector valve into passage 2 which communicates with the application relief valve, the unlocking valve, the indicator and the application line.

The application line is connected to the hydraulic brake actuators and, initially, fluid flow takes place at low pressure while the actuator pistons are pushed out to apply the brake blocks to the wheels. At this stage the slide in the indicator is moved to the right by pressure in passage 2 until the spring loaded plunger engages in the middle detent, in line with the stem of the unlocking piston, locking the slide in a central position. As the slide moves to this position the indicator in the indicator window changes from "OFF" to a blank, to show that the brake is now neither fully released or applied, and the contacts of one of the switches in the indicator are changed over and cause a corresponding change of indication in the Driver's cab. At the same time, the spool in the unlocking valve is moved to the right by pressure in passage 2 and closes the connection between passages 3 and 4.

When all actuator pistons have been fully extended, the rate of fluid flow is reduced, but the pressure in the application line and passage 2 is increased, as the pump continues to operate. The pressure necessary to ensure that the parking brake is fully applied is determined by the setting of the application relief valve, and when this pressure is reached in passage 2, the relief valve opens and allows fluid to spill into passage 3 which communicates with the indicator and locking piston and the check valve with by-pass choke. The choke restricts the return of this fluid to the tank and retains some pressure in passage 3. This pressure/

pressure acts on the unlocking piston which pushes the indicator plunger out of the middle detent and thereby permits the slide to be moved to the extreme right hand position by the pressure in passage 2. As the slide moves to this position the indicator in the indicator window changes from a blank to "ON", to show that the brake is now fully applied, and the contacts of the second switch in the indicator are changed over and cause a corresponding change of indication in the Driver's cab. Pressure continues to rise in passage 3 due to the restriction of the choke, until the spring loaded ball valve opens and provides a larger passage to the tank for the fluid spilling through the relief valve.

With the brake fully applied in this way, the parking brake "apply" button is released causing the pump motor to stop. The pressure in the system relaxes, the application relief valve closes, and the indicator slide remains in its right hand position with "ON" showing in the indicator window. The parking brake force remains locked on mechanically in the actuators. The spool of the unlocking valve is centralised by springs at each end and, as the indicator unlocking piston returns to its original position under the action of its return spring, the fluid it displaces returns to the tank via both the unlocking valve and the choke in the check valve with by-pass choke.

During the application sequence, the release relief valve remains closed as it is set to open at a higher pressure than the application relief valve. The release line remains connected through the selector valve to the tank so that fluid displaced by the hydraulic actuator pistons as they move to the application position may return without restriction.

Release of the Brake

Depression of the brake release button in the Driver's cab starts the motor driven pump and energises the selector valve solenoid which moves the spool to the right so that passage 1 is connected to passage 5, and passage 2 is connected to passage 4. The pump draws fluid from the tank and delivers it via passage 1 and through the selector valve into passage 5 which communicates with the release relief valve, the unlocking valve, the indicator and the release line. Fluid flows through the release line at low pressure at first, while the actuator pistons are retracted to release the brake. At the same time, the slide in the indicator is moved to the left until it locks in the central position, in which the "ON" indication is replaced by a blank, and an indicator switch is operated to cause a corresponding change of indication in the Driver's cab. The spool of the unlocking valve is moved to the left and closes the connection between passages 3 and 4. Fluid displaced by the actuator pistons as they retract returns through the application line to the tank via the selector valve.

When all actuator pistons have been fully retracted the pressure in the release line and passages 1 and 5 increases until it reaches the setting of the release relief valve. This valve opens and the resulting overspill into passage 3 operates the indicator and locking piston in the same way as during the application sequence, and allows the indicator slide to move to the extreme left hand position under the action of the pressure in passage 5. In this position the blank indication is replaced by "OFF", to show that the brake is fully released, and a second indicator switch is operated to cause a corresponding change of indication in the Driver's cab. Fluid entering passage 3 through the release relief valve returns to the tank via the check valve and the by-pass choke.

When the parking brake release button is released the pump motor is stopped and the selector valve solenoid is de-energised and allows the valve spool to return to the position shown in Figure 17. The pressure in the system relaxes, the release relief valve closes, the check valve with by-pass choke closes, and the indicator slide remains in its left hand position with "OFF" showing in the window. The spool of the unlocking valve is centralised by the action of the spring at each end and as the indicator unlocking piston returns to its original position under the action of its return spring, the fluid it displaces returns to the tank via both the unlocking valve and the choke in the check valve with by-pass choke. All the devices in the unit are then in the positions shown in Figure 17.

The action of the unlocking valve is therefore the same at the end of the application and release sequence. By providing an unrestricted passage for the flow of oil displaced by the indicator unlocking piston it ensures that the piston may be returned rapidly by its spring so that, even if the parking brake is switched very quickly from one condition to the other, it is not possible for the indicator slide to move from one extreme position to the other without locking first in the central position.

Manual Operation

If the motor driven pump is inoperative due to non availability of the electric power the parking brake may be applied and released on each of the parking braked vehicles individually by operating the hand pump. If the selector valve solenoid cannot be energised to obtain relief it is necessary to hold the selector valve lever depressed in the relief position whilst operating the hand pump.

A 'G' cramp arrangement will be provided to depress the manual release button on the activator.

Note that the selector valve in the guard's compartment/power car must be held over at the same time as the manual release plunger is operated.

Operation of the Brake System

Air is fed from the main train airline which in turn is supplied by a compressor. A "tee" off this line supplies the Brake Pack's air reservoir through an isolating cock and strainer check valve.

The Driver makes a brake demand by moving his brake handle. This action supplies a set of DC voltage signals into the Encoder where they modulate the pulse width of the signal being continuously produced by the Encoder Unit. This Pulse Width Modulated (PWM) signal is then sent down train lines 1 (positive) and 2 (negative) to each Brake Electronic Control Unit. Here the signal is received, decoded and matched with signals from the Load Measurement Transducer and Emergency Brake Loop. The resultant signal (which may be further modified by Brake "Back-Off" and/or "Wheel Slip Protection Failed" signals) is fed to the Brake Control Unit to operate the Main Control Valve (3). This passes control air, at a pressure proportional to the signal current, to the Water-Glycol Reservoir. Air, at 5.5 Bar, is also passed from the BCU to the Fluid Shut Off Valve on the axle to allow the pressurised Water-Glycol to enter the axle system.

There are two toroid chambers in each axle, one for each direction of travel. The fluid will initially fill the ineffective toroid, while partial filling of the effective toroid will take place. The filling of the ineffective toroid will cause the Selector (Flow Director) valve to move in favour of the effective toroid. At the same time Water-Glycol will pass up the vent pipe of the ineffective toroid closing the Water Retaining Valve (19) and move the Vent Selector Valve (11) in favour of the effective toroid. This action ensures that Water-Glycol flows to the correct toroid chamber in relation to the direction of vehicle travel.

The Water-Glycol within the effective toroid will be thrown by centrifugal force to the outside of the rotor with a corresponding increase in angular velocity, thus absorbing some of the rotational energy in the rotor. The design of the rotor chamber is such that the Water-Glycol will be directed back to the stator, the change of direction absorbing further energy.

The fluid passing to the stator has therefore a high kinetic energy, and on striking the stator establishes a turbulent flow and is converted to pressure energy and heat energy. The heat energy is dissipated through the radiator.

The pressure energy enables the assembly to act as a pump to return the Water-Glycol from the toroid tips to the reservoir against the controlling air pressure.

The effective braking effort will be proportional to the pressure difference across the toroid and this is maximised by venting the toroid core to atmosphere during braking.

The input of fluid to the toroid will be constant for any given control pressure and as speed drops, the ability of the assembly to pump fluid back to the reservoir also decreases and the toroid assembly will start to fill. When completely filled, the toroid assembly has a braking effect which is proportional to the square of rotational velocity and when brake speed has dropped to this point, where the toroid is full, (saturated) further reduction in speed results in a marked reduction in braking effort necessitating the introduction of friction braking.

Operation of the Brake System /cont'd

With the toroid filled, the Water-Glycol is forced down the Vent Line to valve 19 in the BCU. The ball in this valve will then "float" up and seal off the passage to atmosphere. The Water-Glycol then pressurises, via the Vent Selector Valve (11), the Friction Brake Control Valve (10) which will now allow main air to pass the Limit Valve (8) to Valve 7 and hence the Intensifyer which, according to its type, will intensify the pressure 28 times for the oil operated Parking Brake Actuator, and 41 times for the Water-Glycol operated Actuator on the Trailer Vehicles without Parking Brake. The slower the axle speed the greater becomes the pressure passed through the toroid as the ability of the toroid to oppose it decreases. This process continues until the pressure in the vent line is the same as the control air pressure in the Water-Glycol reservoir. It can be seen therefore that the effectiveness of the Friction Brake increases as that of the Hydro-Kinetic Brake decreases.

Meanwhile, the brake circulating pump has been passing Water-Glycol from the reservoir to the radiator and back to cool it. If the temperature of this circulating Water-Glycol rises above 55°C the electrically driven fan operates to blast air through the radiator and increase the cooling effect.

To release the brakes, the controlling air pressure within the Water-Glycol reservoir is vented to atmosphere. Simultaneously, the Fluid Shut Off Valve will close, stopping any further Water-Glycol entering the toroid. The Fluid present in the toroid will be returned to the Water-Glycol reservoir by the rotation and consequent pumping action of the toroid and operation of the Ejector.

The rotor seals are lubricated by a constant but strictly regulated flow of Water-Glycol which bypasses the Fluid Shut Off Valve via a small tube and enters the toroid. A Water-Glycol build up within the toroid assembly will not happen for the reasons previously stated, as the Ejector is operating whenever the brake circulating pump is running.

The Ejector is situated between the radiator delivery and the fluid return lines from the toroid on APT Power Cars and is positioned between the supply and radiator return line on all Trailer Vehicles.

BRAKES INVOLVEMENT IN EXAM SCHEDULES:

JOB NO.	DESCRIPTION	EXAM
301p	Brake System Functional Test	BCDE
302p	Brake System Test	DE
304p	Passenger Communication Switches Test	CDE
306p	Parking Brake Test	CDE
309p	Driver's Emergency Brake Test	ABCDE
316p	Friction Brake Blocks Visual Check	ABCDE
344p	Driver's Safety Device Check	ABCDE
381p	Friction Brake Actuators and Hoses Check	ABCDE
382p	Parking Brake Fluid Level Check	ABCDE
383p	HK Brake Fluid Level Check	ABCDE
388p	HK Brake Radiator Cleaning	E

The above jobs are detailed in the Examination Schedule, BR.12013 and 12014 where a full description will be found.

External Control of Brake System

So far we have not mentioned any electrical circuitry external to the brake system. It is important to realise that the BECU and the Encoder rely on the $\pm$ 25v supplied from the AC/DC pack, or in the event of a failure the DC/DC pack. These packs are on each vehicle so they supply from 2 to 4 sets of BECUs depending on vehicle type and the Encoder on the Driving Trailer vehicle. The AC/DC and DC/DC packs have an indicator fitted to show when they have failed. This indicator stays in the failed condition even though the pack is capable of self-reset. The other machines associated with the brake system are the Brake Circulating Pump motor and the Radiator Fan motor. They are both fed from a 415v 3 phase branch off the bus lines passing through a Brake Circuit Breaker (BCB) before the circuit splits to feed the Circulating Pump via the Brake Pump Contactor (BPC) and Brake Overload (BOL) the fan motor is fed via the Brake Fan Contactor (BFC) and Brake Overload. The contactors are fed from the 250v single phase circuit. In the feed to both contactors are the Brake Overload interlocks, and in the case of the Brake Fan Contactors a thermostat (immersed in Water Glycol in the radiator inlet pipe) which cuts in at 55°C and out at 48°C. All overloads can be manually reset. The above control circuitry is energised via a "Controls On" Relay (COR) which in turn is energised when the Driver has a supply on to the train and a key inserted with "Auxiliaries" position selected. When energised COR closes its interlock in the brake control circuitry. Upon closing a supply is fed to BFC coils via the thermostat and overload interlock and also to BPC coil via its overload interlock. The Brake Circulating Pump will now run and if the temperature of the water glycol is above 55°C the Radiator Fan Motor will also run. Note there is no thermal cut out on the system if the temperature of the water glycol exceeds its normal range. However, there is enormous capacity in the cooling circuit which is operational as soon as there is an AC supply available to BPC as seen above.

BASIC HK BRAKE LAYOUT

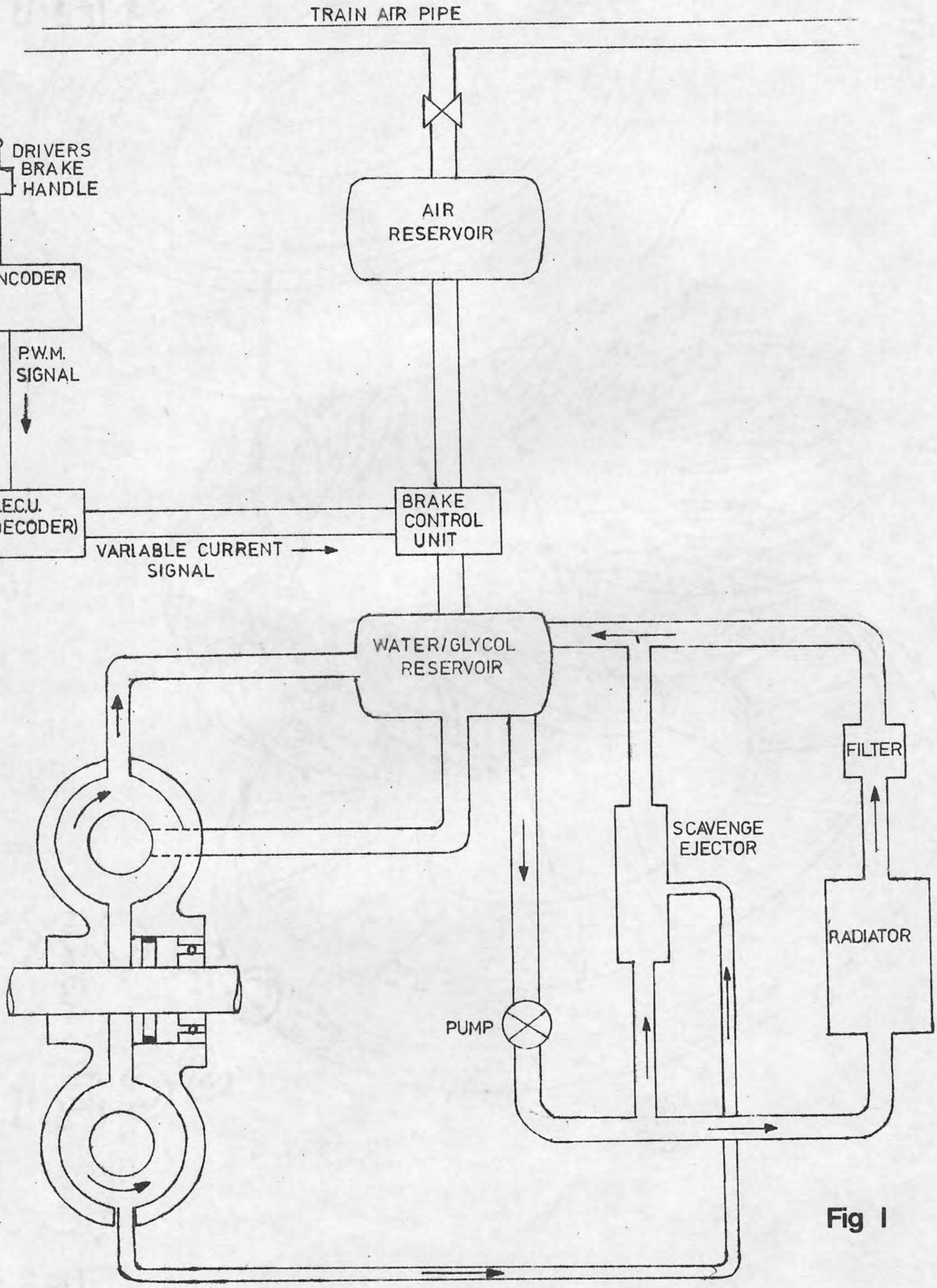


Fig I

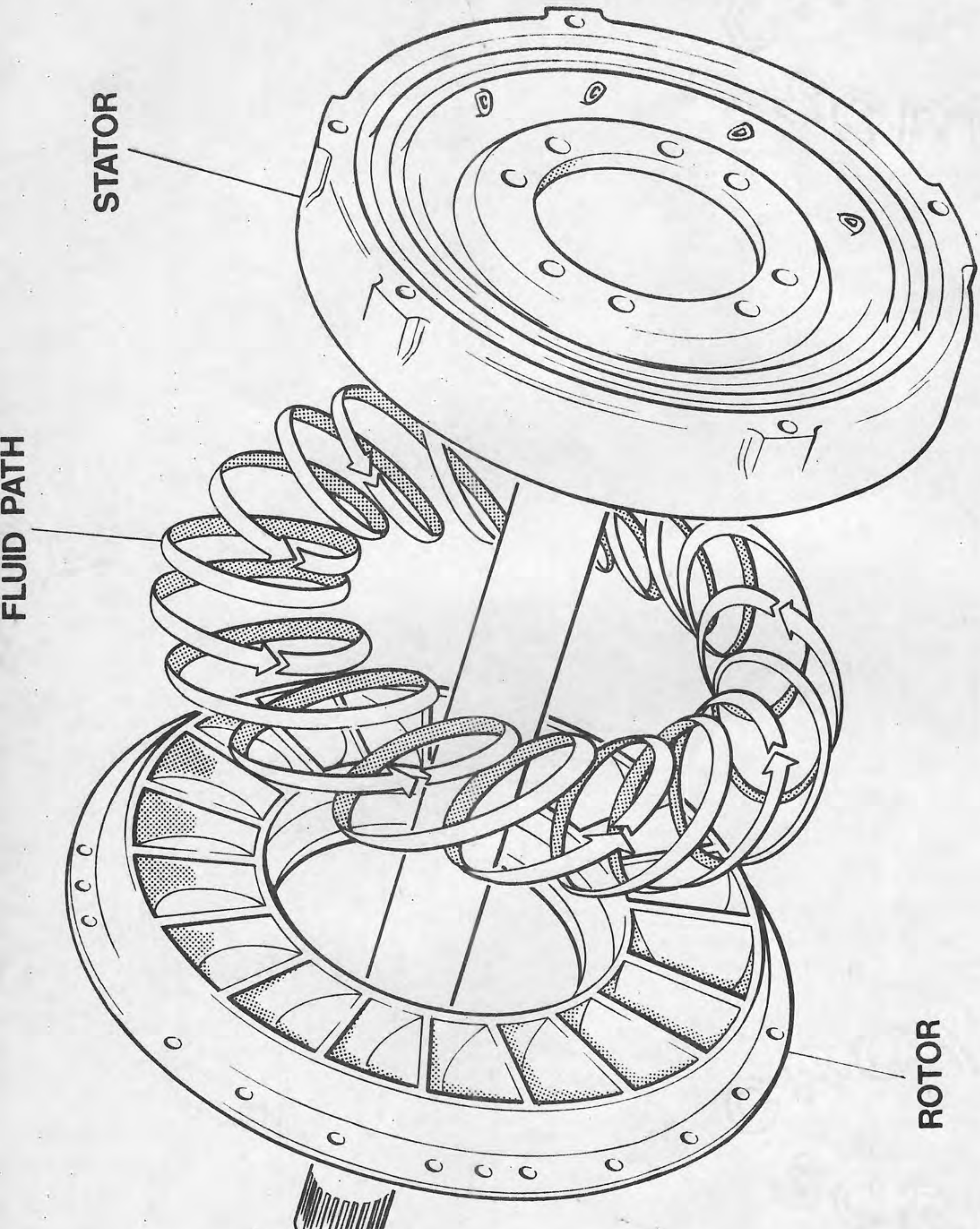


Fig. 2

APT TRAILER AXLE BRAKE

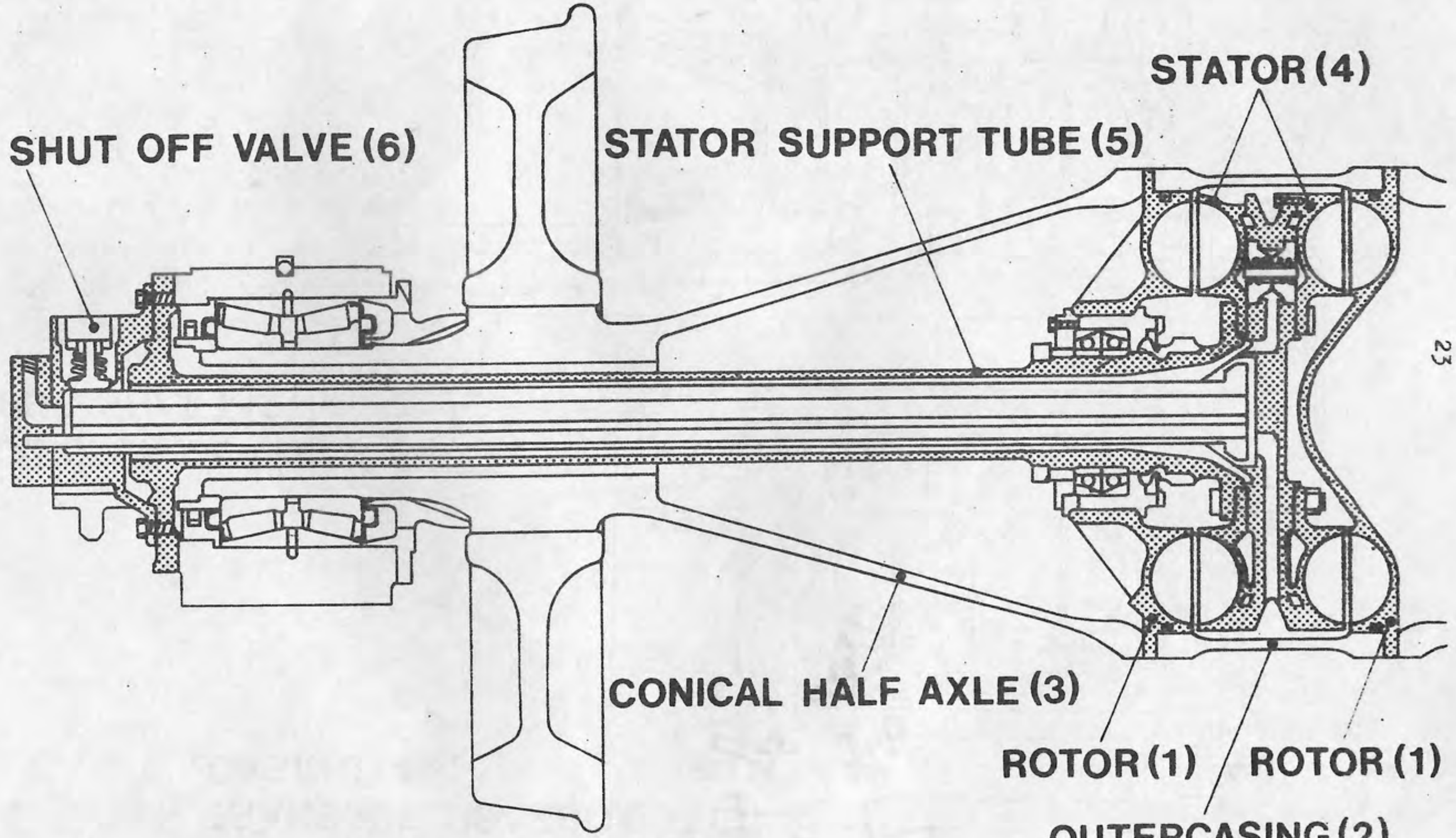


Fig. 3

APT TRANSMISSION BRAKE

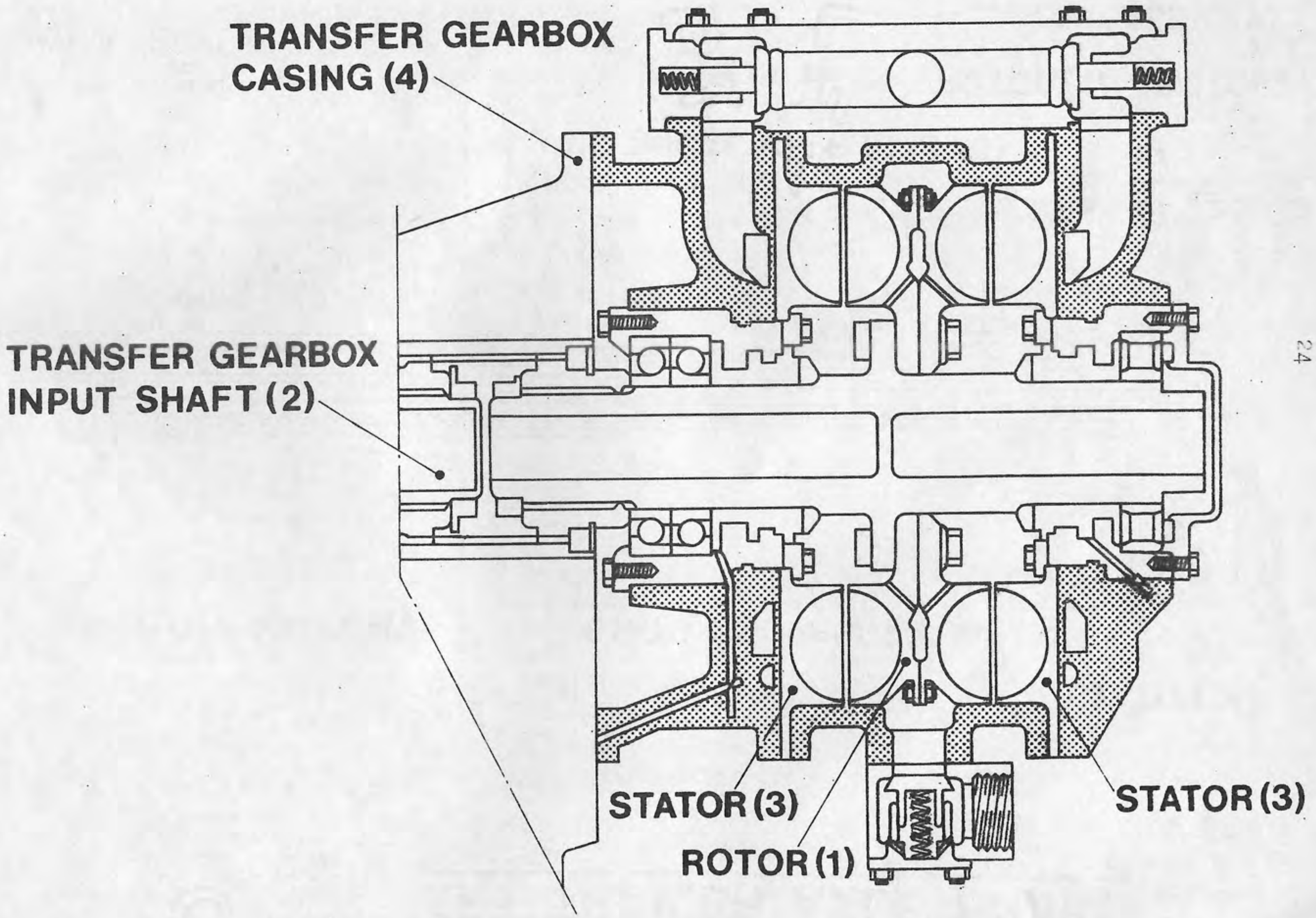


Fig.4

HK Brake Pipe Connections To Trailer Axles

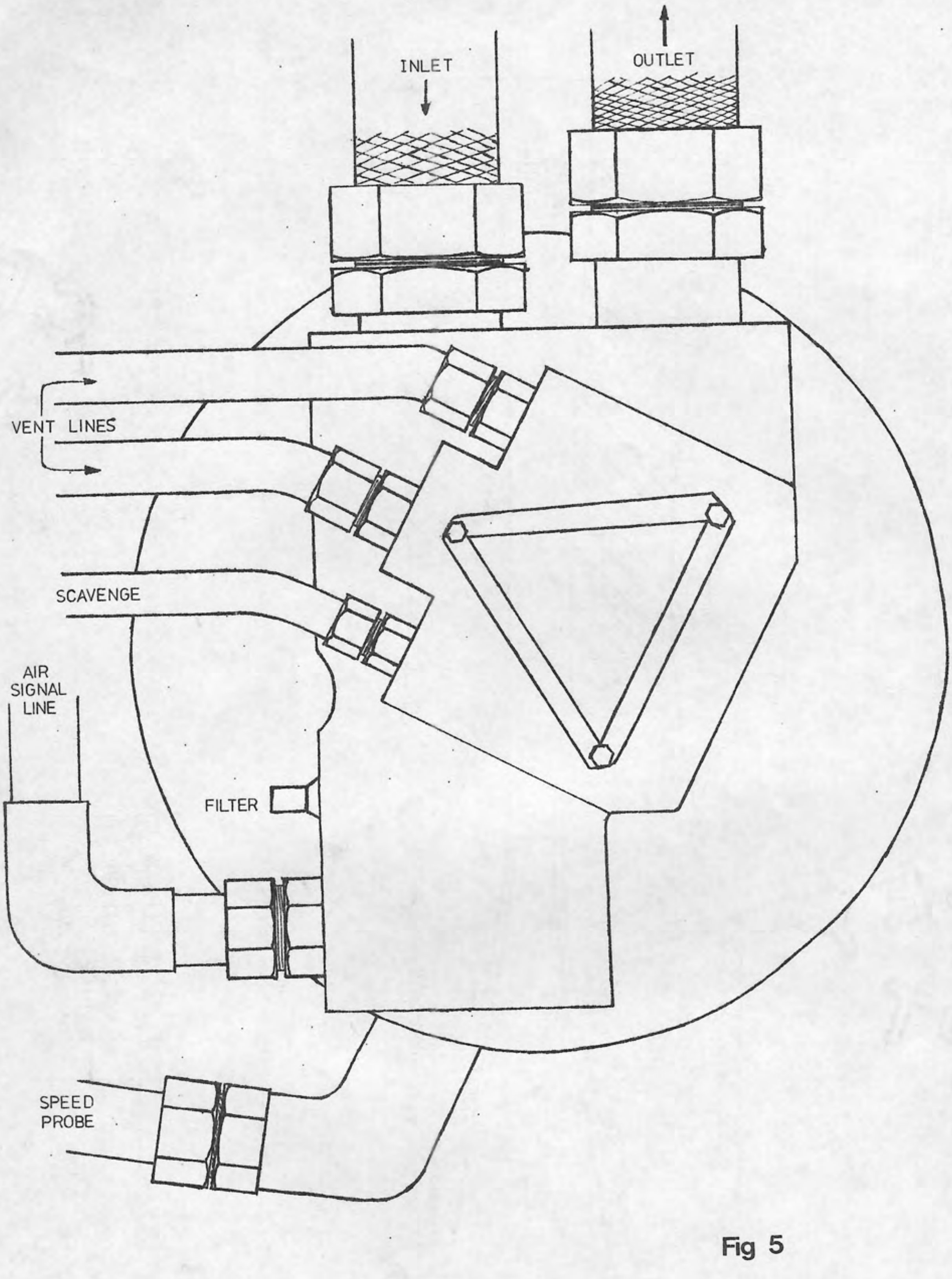


Fig 5

Brake Scavenge Ejector

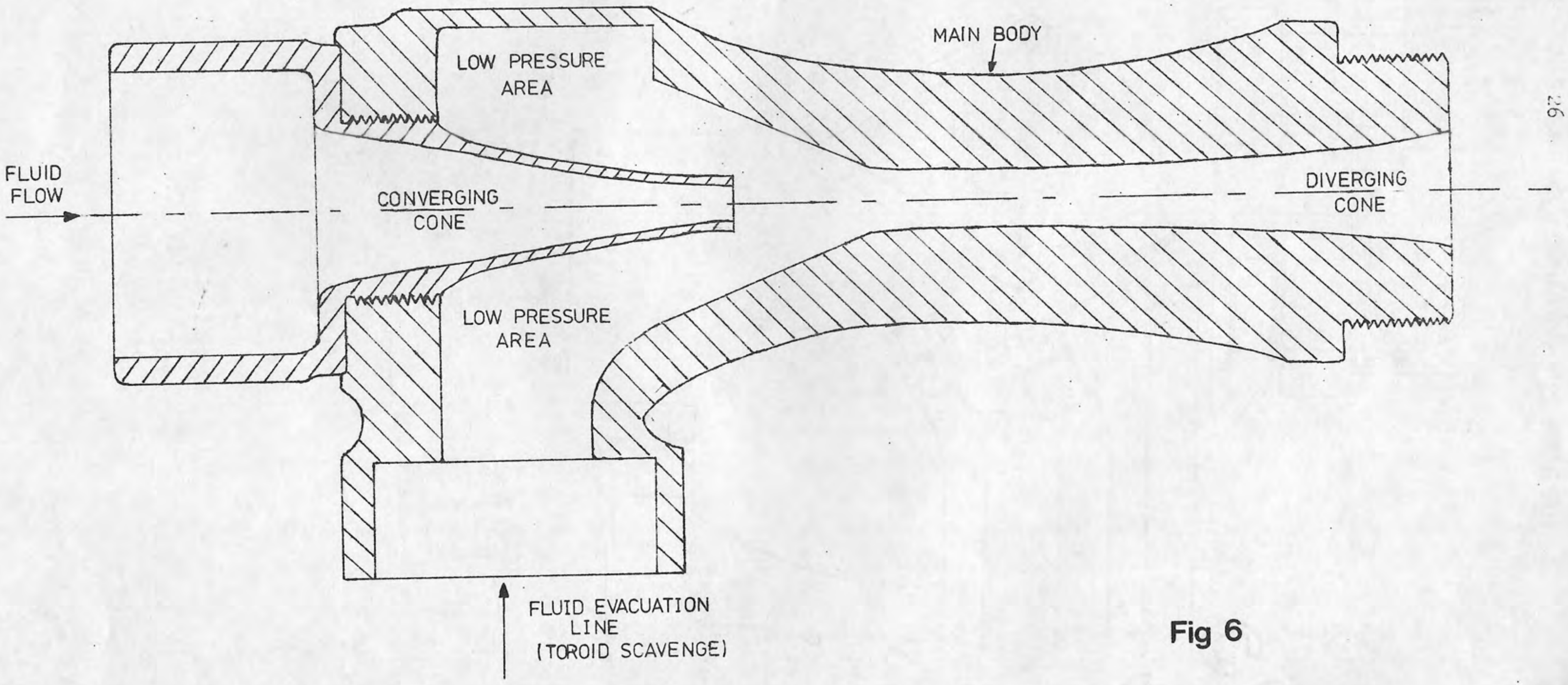
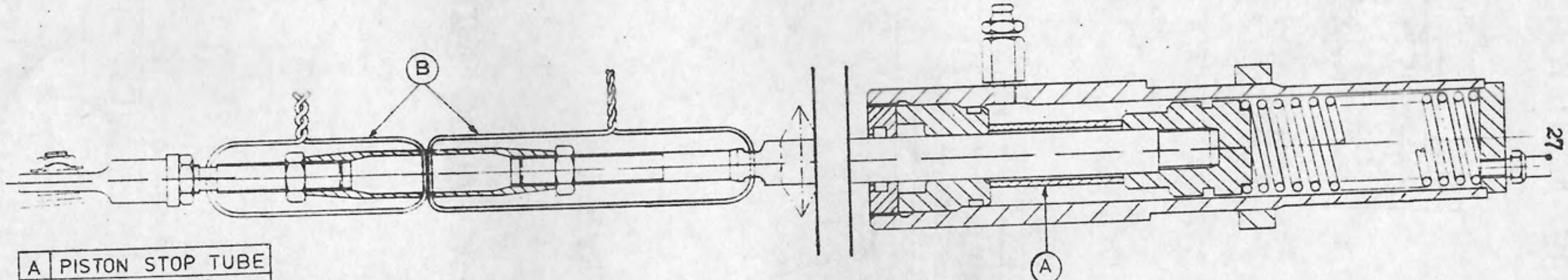


Fig 6

STERLING HYDRAULIC LTD BRAKE ACTUATOR



A	PISTON STOP TUBE
B	18 SWG WIRE

Note:-
A control rod similar to that fitted on Westinghouse units, is fitted in parallel with the actuator.

Fig 7

WESTINGHOUSE ACTUATOR

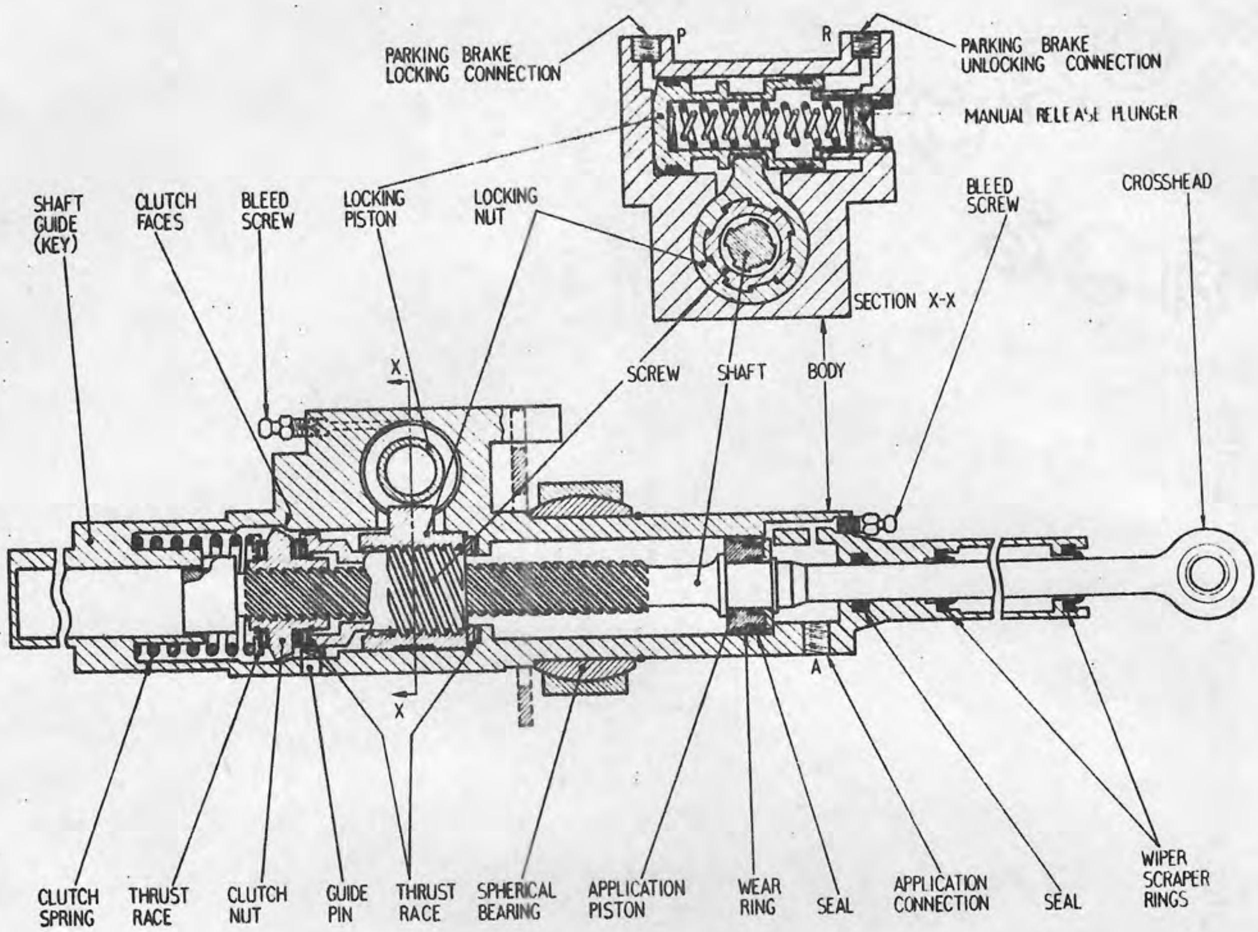


Fig. 8

WESTINGHOUSE AIR/HYDRAULIC INTENSIFIER

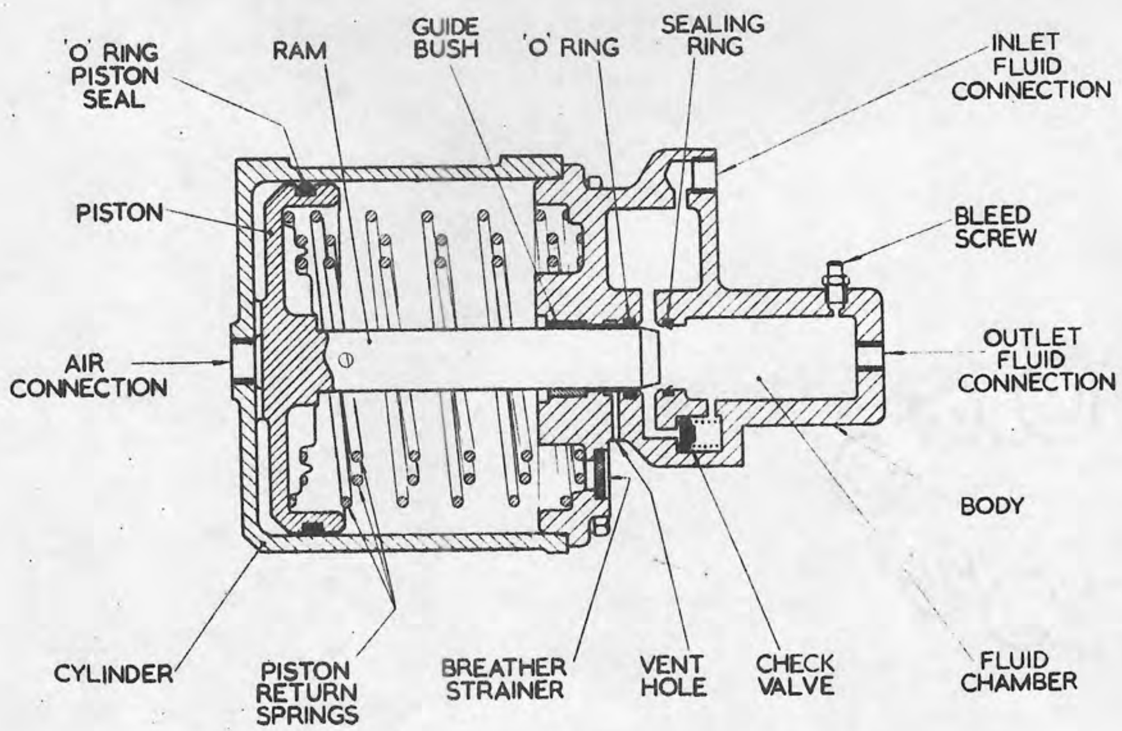


Fig 9

PARKING BRAKE

FRICTION ACTUATOR

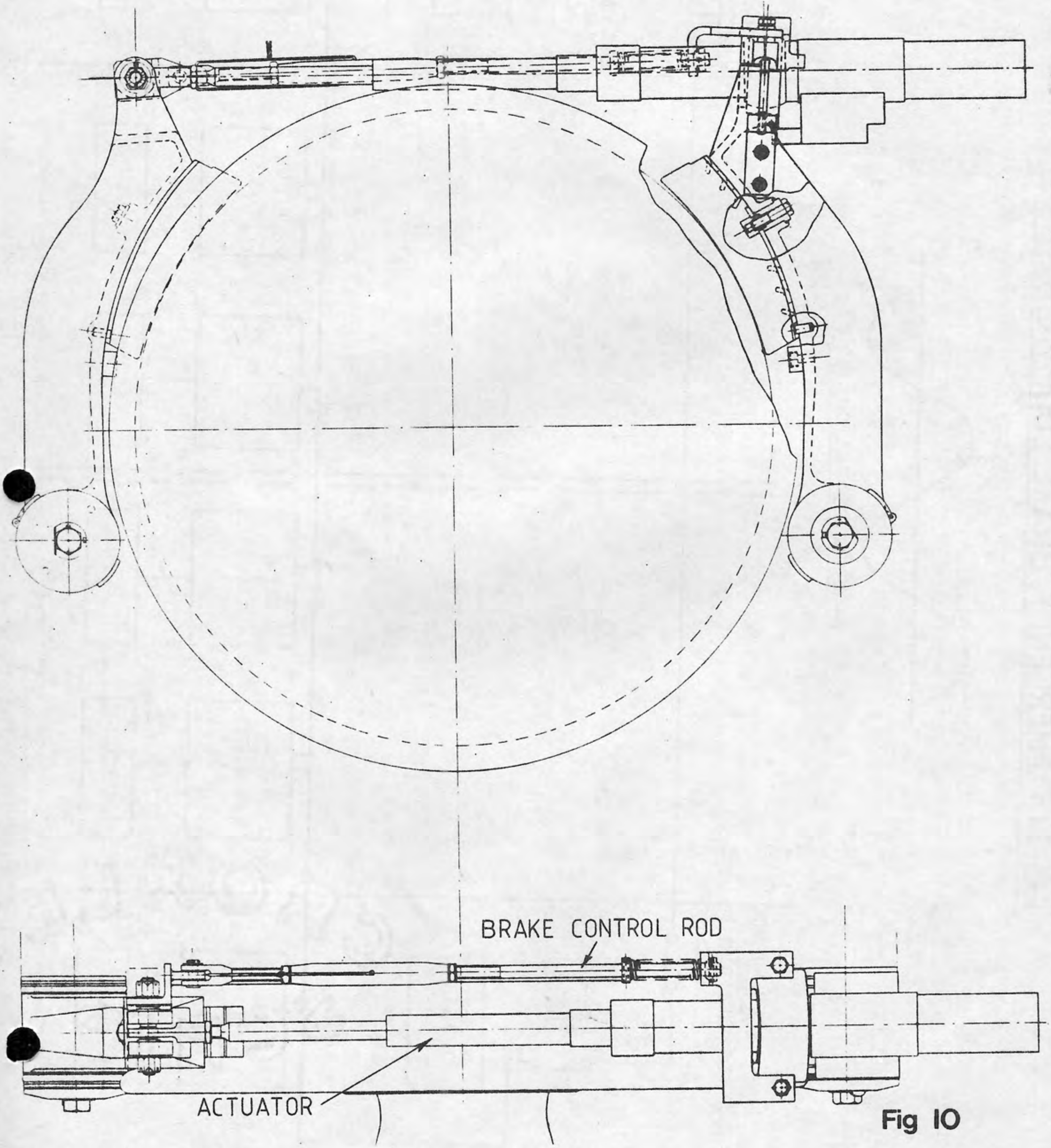


Fig 10

PART OF EMERGENCY BRAKE LOOP (E.B.L.)

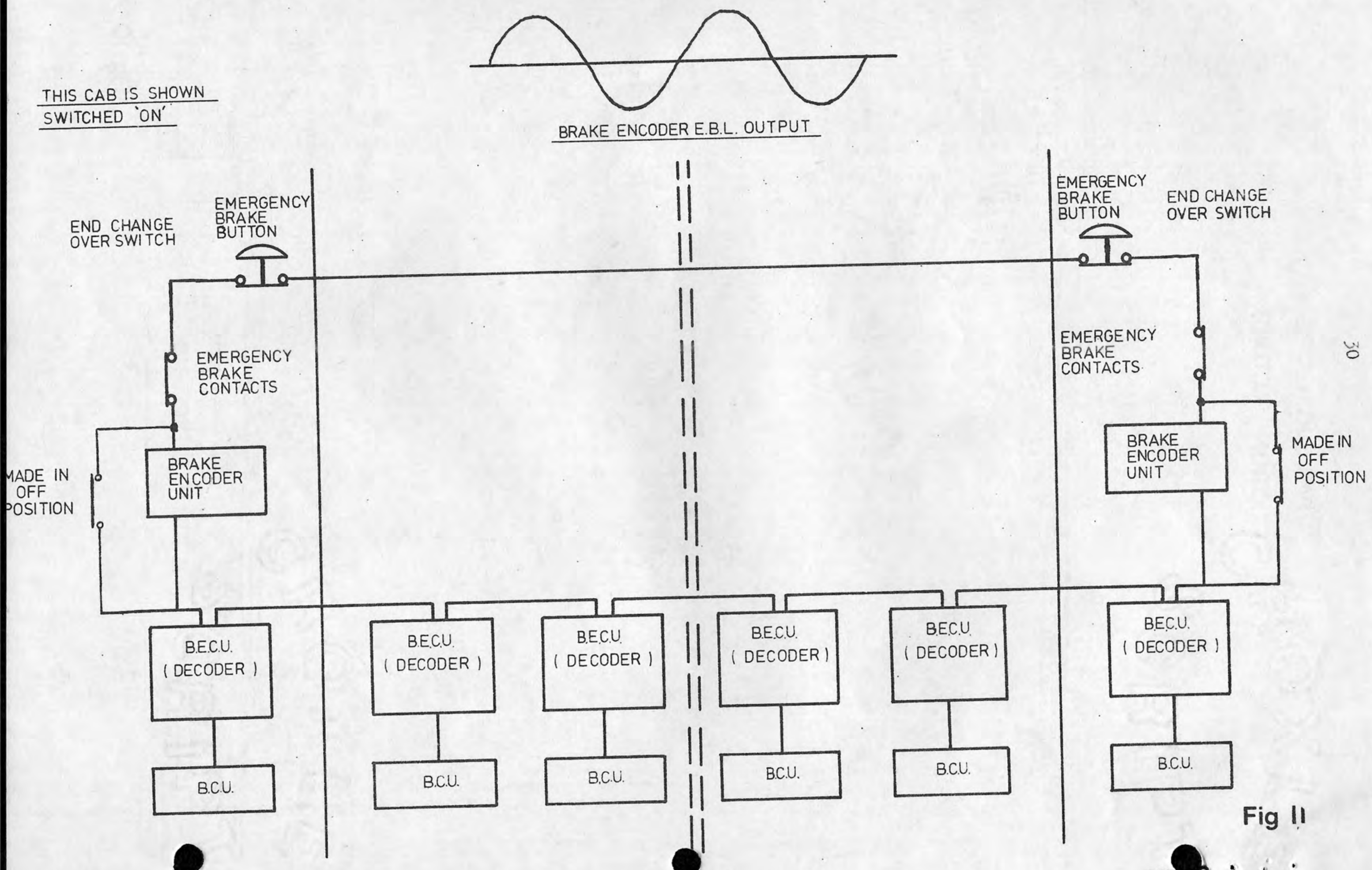
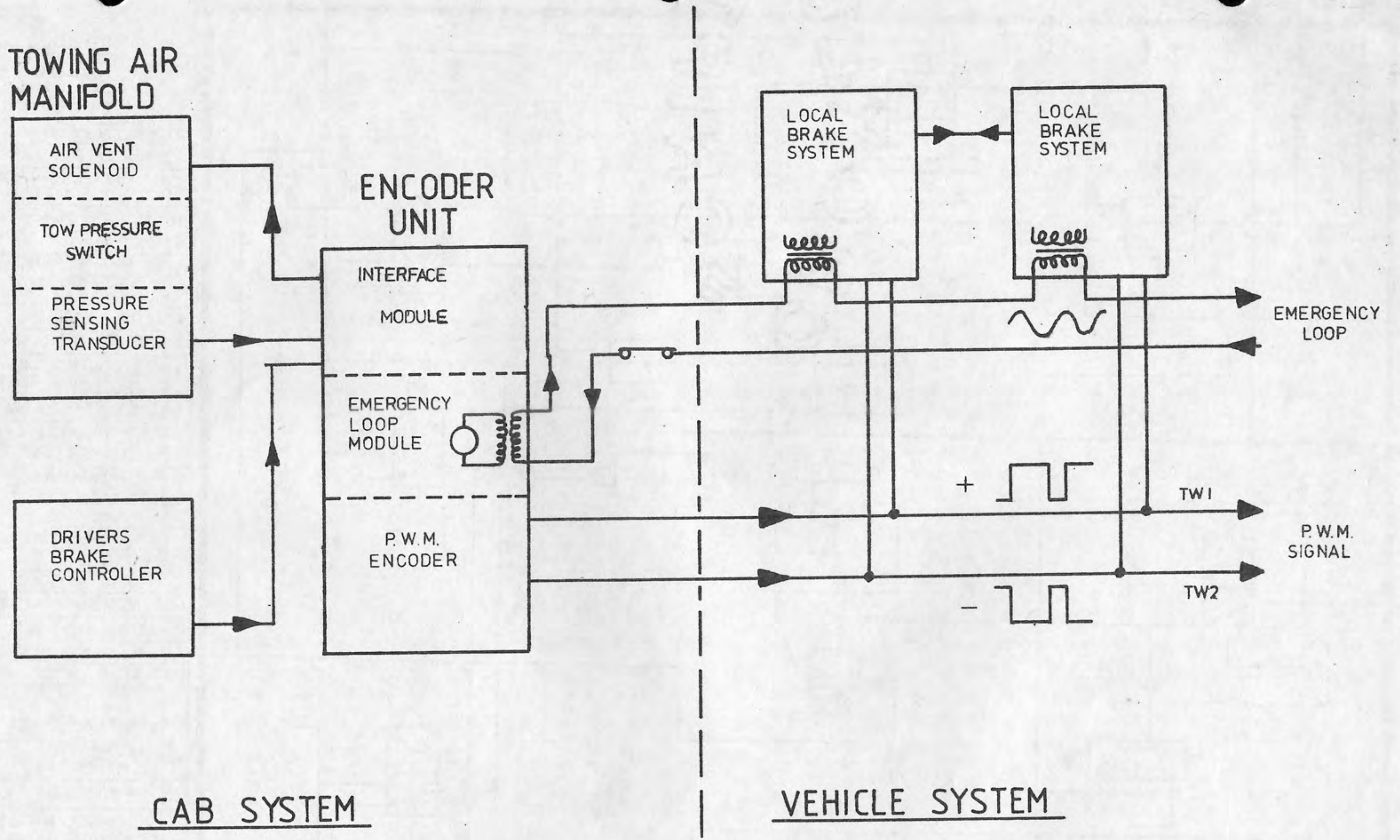


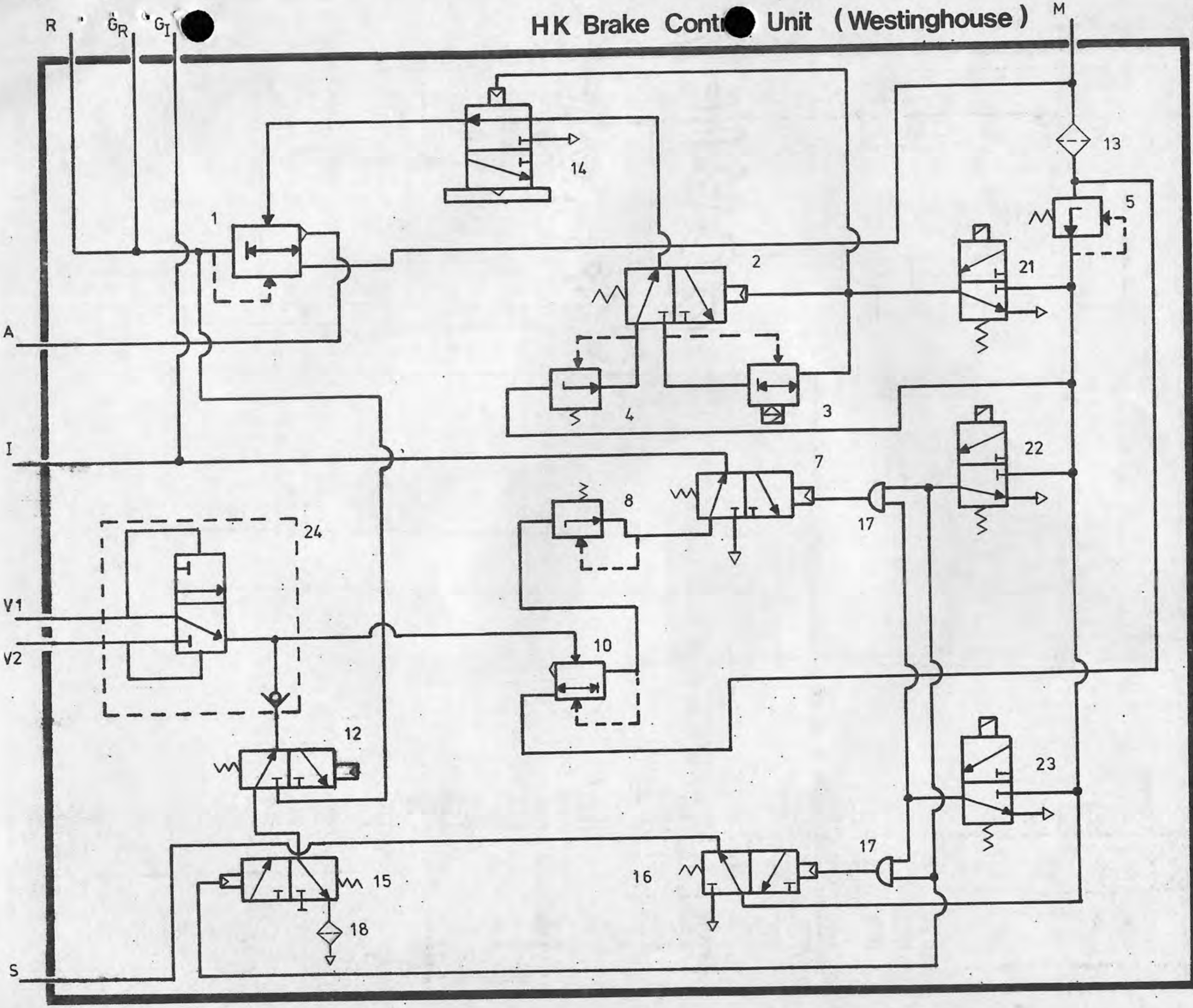
Fig II



ELECTRONIC BRAKE CONTROL

Fig 12

HK Brake Control Unit (Westinghouse)



ITEM	DESCRIPTION
M	MAIN AIR SUPPLY TO CONTROL UNIT
P	BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R	WATER/GLYCOL RES. AIR SUPPLY
A	CONTROL UNIT AIR EXHAUST
I	AIR/HYDRAULIC INTENSIFIER AIR SUPPLY
S	H.K. BRAKE CONTROL VALVE AIR SUPPLY
G_R G_I	PRESSURE MEASURING POINTS
V_1 V_2	H.K. BRAKE VENT CONNECTIONS
1	FLOW AMPLIFIER
2	EMERGENCY BRAKING
3	MAIN CONTROL VALVE
4	EMERGENCY SET RATE
5	CONSTANT PRESS VALVE
7	FRICTION BRAKE OFF
8	INTENSIFIER LIMITER
10	FRICTION BRAKE CONTROL
11	
12	H.K. BRAKE DUMP
13	FILTER
14	MANUAL RELEASE
15	VENT SEALING VALVE
16	BRAKE SHUT OFF
17	'OR' LOGIC UNIT
18	FILTER
19	
21	MAIN OPERATOR
22	BRAKES NOT DEMANDED
23	WHEELSLIDE
24	VENT SEL/WATER RETAINING VALVE

Fig 15

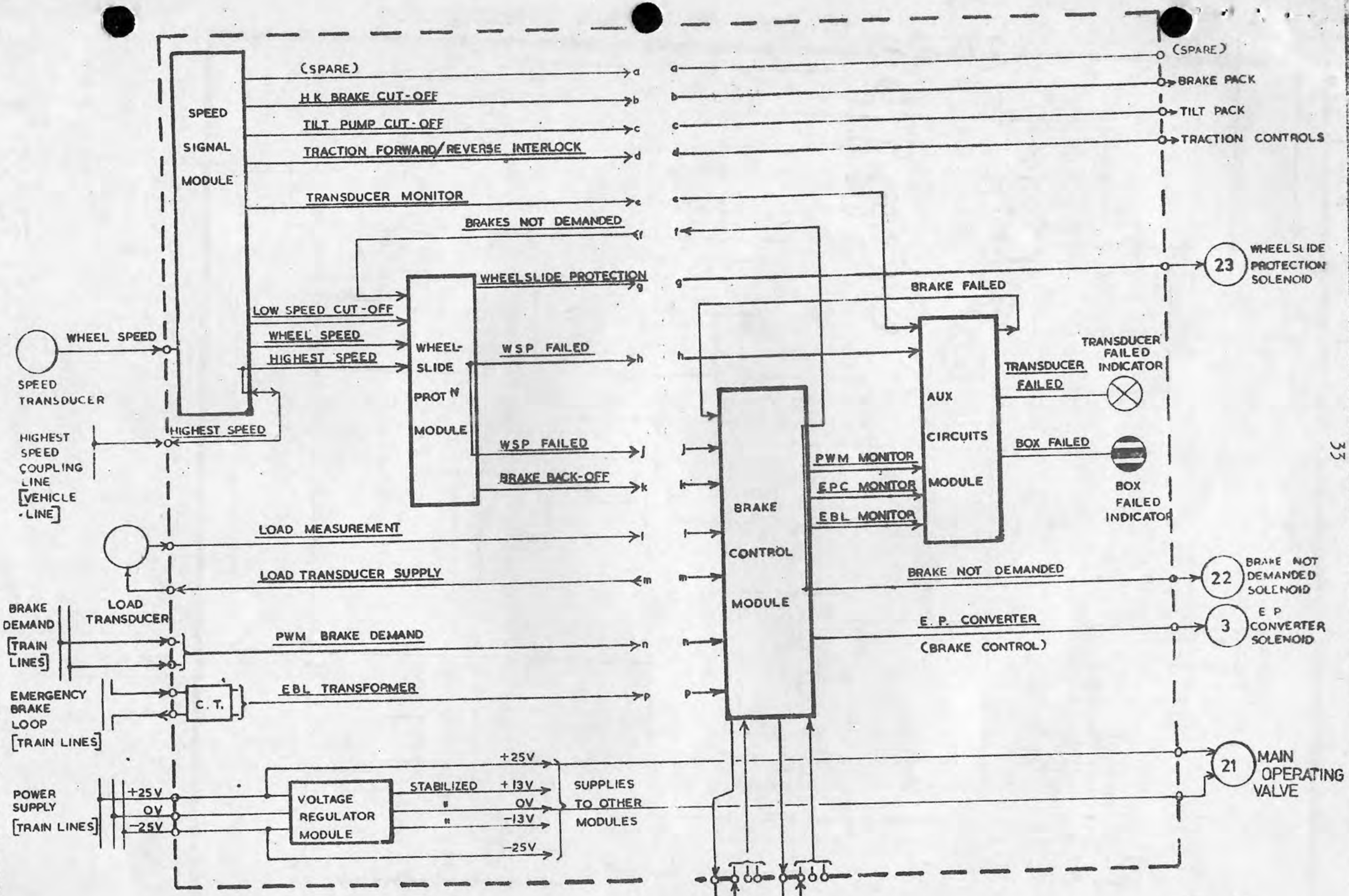
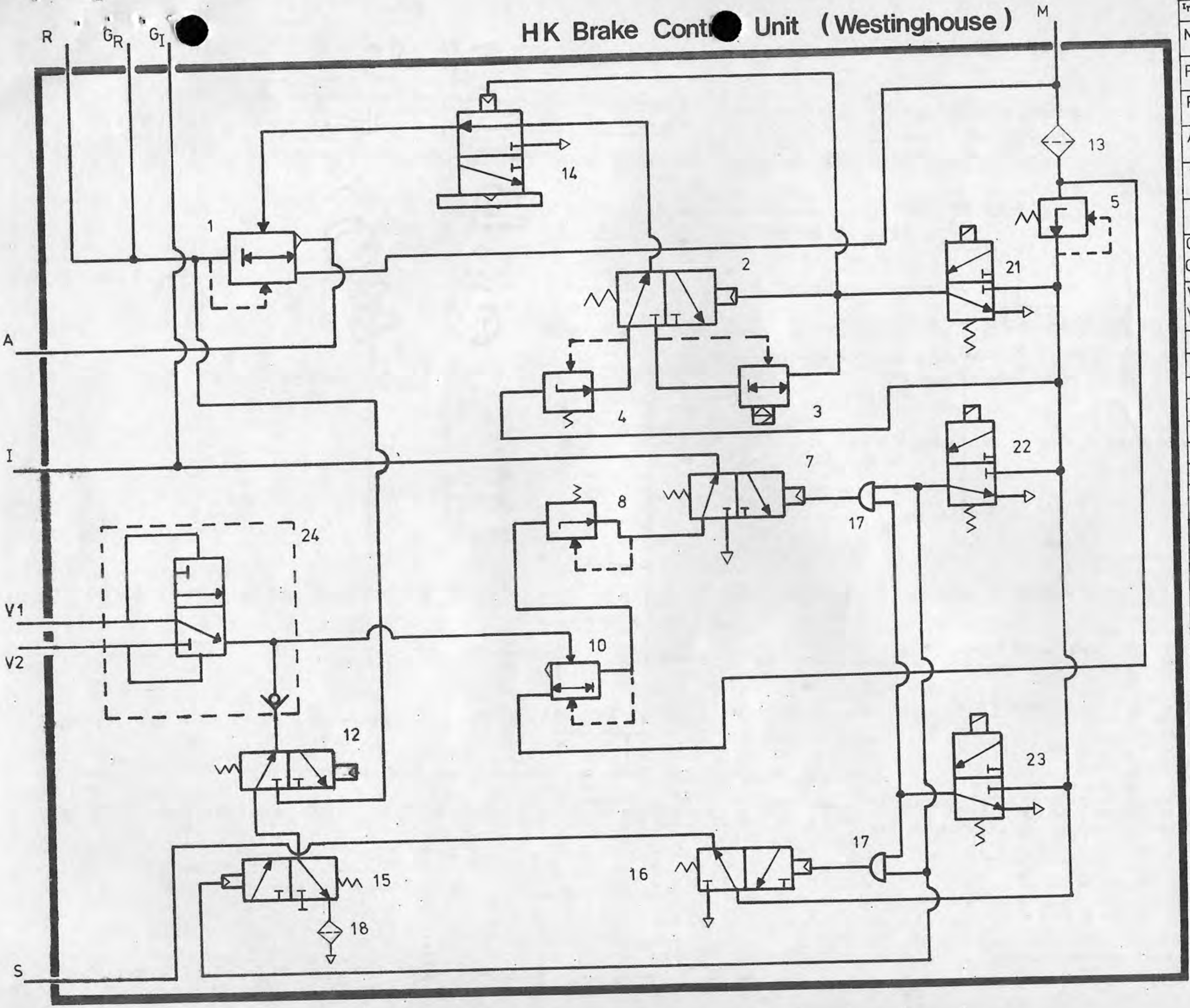


Fig 14

BLOCK DIAGRAM OF BRAKE ELECTRONICS CONTROL UNIT

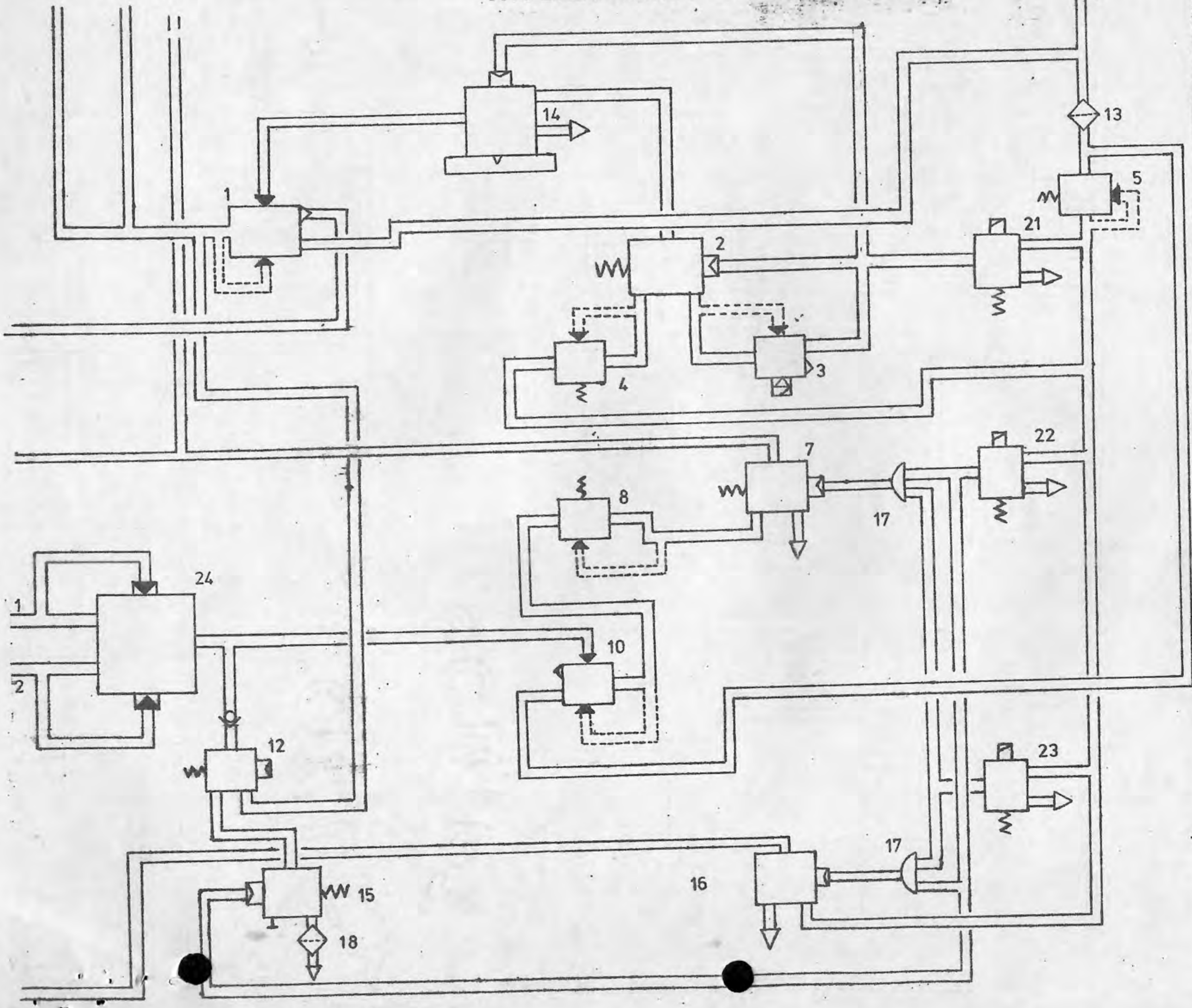
HK Brake Control Unit (Westinghouse)



ITEM	DESCRIPTON
M	MAIN [illegible] SUPPLY TO CONTROL UNIT
P	BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R	WATER/GLYCOL RES. AIR SUPPLY
A	CONTROL UNIT AIR EXHAUST
I	AIR/HYDRAULIC INTENSIFIER AIR SUPPLY
S	H.K. BRAKE CONTROL VALVE AIR SUPPLY
G_R G_I	PRESSURE MEASURING POINTS
V_1 V_2	H.K. BRAKE VENT CONNECTIONS
1	FLOW AMPLIFIER
2	EMERGENCY BRAKING
3	MAIN CONTROL VALVE
4	EMERGENCY SET RATE
5	CONSTANT PRESS VALVE
7	FRICTION BRAKE OFF
8	INTENSIFIER LIMITER
10	FRICTION BRAKE CONTROL
11	
12	H.K. BRAKE DUMP
13	FILTER
14	MANUAL RELEASE
15	VENT SEALING VALVE
16	BRAKE SHUT OFF
17	'OR' LOGIC UNIT
18	FILTER
19	
21	MAIN OPERATOR
22	BRAKES NOT DEMANDED
23	WHEELSLIDE
24	VENT SEL/WATER RETAINING VALVE

Fig 15

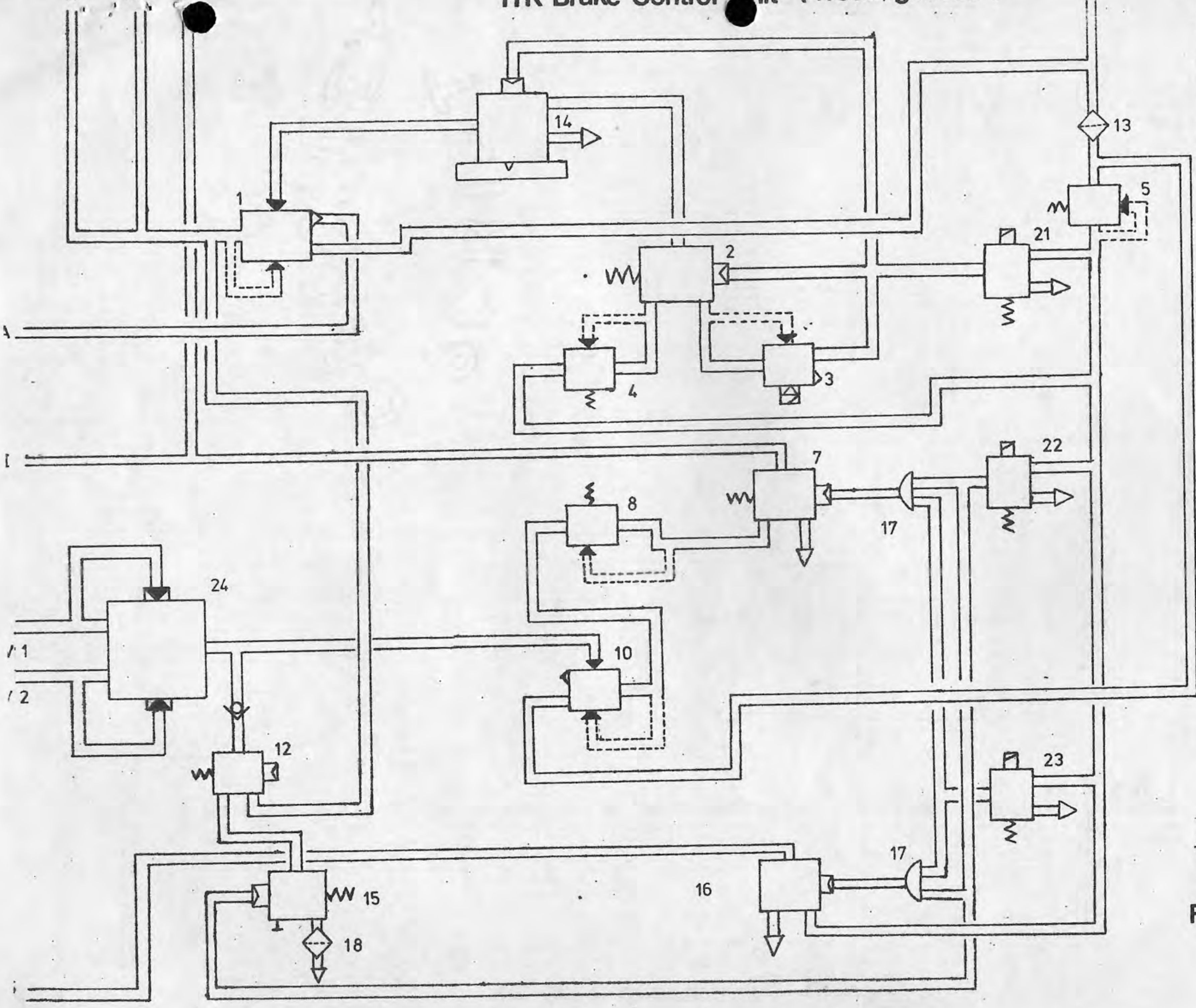
HK Brake Control Unit (Westinghouse')



M: MAIN AIR SUPPLY TO BRAKE CONTROL UNIT
P: BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R: WATER/GLYCOL RESERVOIR AIR SUPPLY
A: CONTROL UNIT AIR EXHAUST
I: AIR/HYDRAULIC INTENSIFIE AIR SUPPLY
S: H.K. BRAKE CONTROL VALVE AIR SUPPLY
GI&GR PRESSURE MEASURING POINTS
V1&V2 H.K. BRAKE VENT CONNECTIONS
1. FLOW AMPLIFIER
2. EMERGENCY BRAKING
3. MAIN CONTROL VALVE
4. EMERGENCY SET RATE
5. CONSTANT PRESSURE VALVE
7. FRICTION BRAKE OFF
8. INTENSIFIER LIMITER
10. FRICTION BRAKE CONTROL
11.
12. H.K. BRAKE DUMP
13. FILTER
14. MANUAL RELEASE
15. VENT SEALING VALVE
16. BRAKE SHUT-OFF
17. OR LOGIC UNIT
18. FILTER
19
21. MAIN OPERATOR
22. BRAKES NOT DEMANDED
23. WHEELSLIDE
24. VENT SEL/WATER RETAINING VALVE

Fig 16a

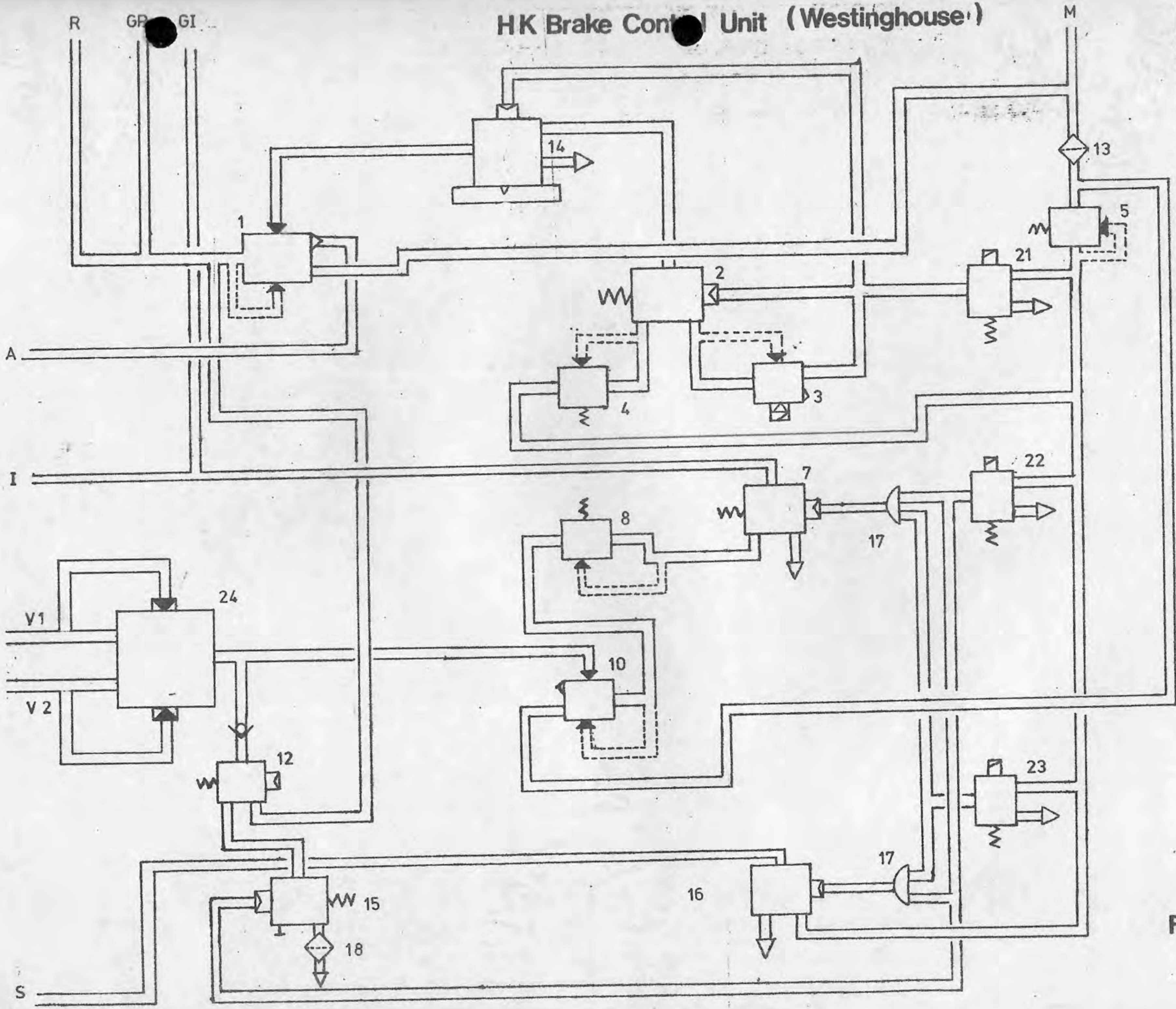
HK Brake Control Unit (Westinghouse)



M: MAIN AIR SUPPLY TO BRAKE CONTROL UNIT
P: BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R: WATER/GLYCOL RESERVOIR AIR SUPPLY
A: CONTROL UNIT AIR EXHAUST
I: AIR/HYDRAULIC INTENSIFIE AIR SUPPLY
S: H.K. BRAKE CONTROL VALVE AIR SUPPLY
GI & GR PRESSURE MEASURING POINTS
V1 & V2 H.K. BRAKE VENT CONNECTIONS
1. FLOW AMPLIFIER
2. EMERGENCY BRAKING
3. MAIN CONTROL VALVE
4. EMERGENCY SET RATE
5. CONSTANT PRESSURE VALVE
7. FRICTION BRAKE OFF
8. INTENSIFIER LIMITER
10. FRICTION BRAKE CONTROL
11.
12. H.K. BRAKE DUMP
13. FILTER
14. MANUAL RELEASE
15. VENT SEALING VALVE
16. BRAKE SHUT-OFF
17. OR LOGIC UNIT
18. FILTER
19.
21. MAIN OPERATOR
22. BRAKES NOT DEMANDED
23. WHEELSLIDE
24. VENT SEL/WATER RETAINING VALVE

Fig 16b

HK Brake Control Unit (Westinghouse)



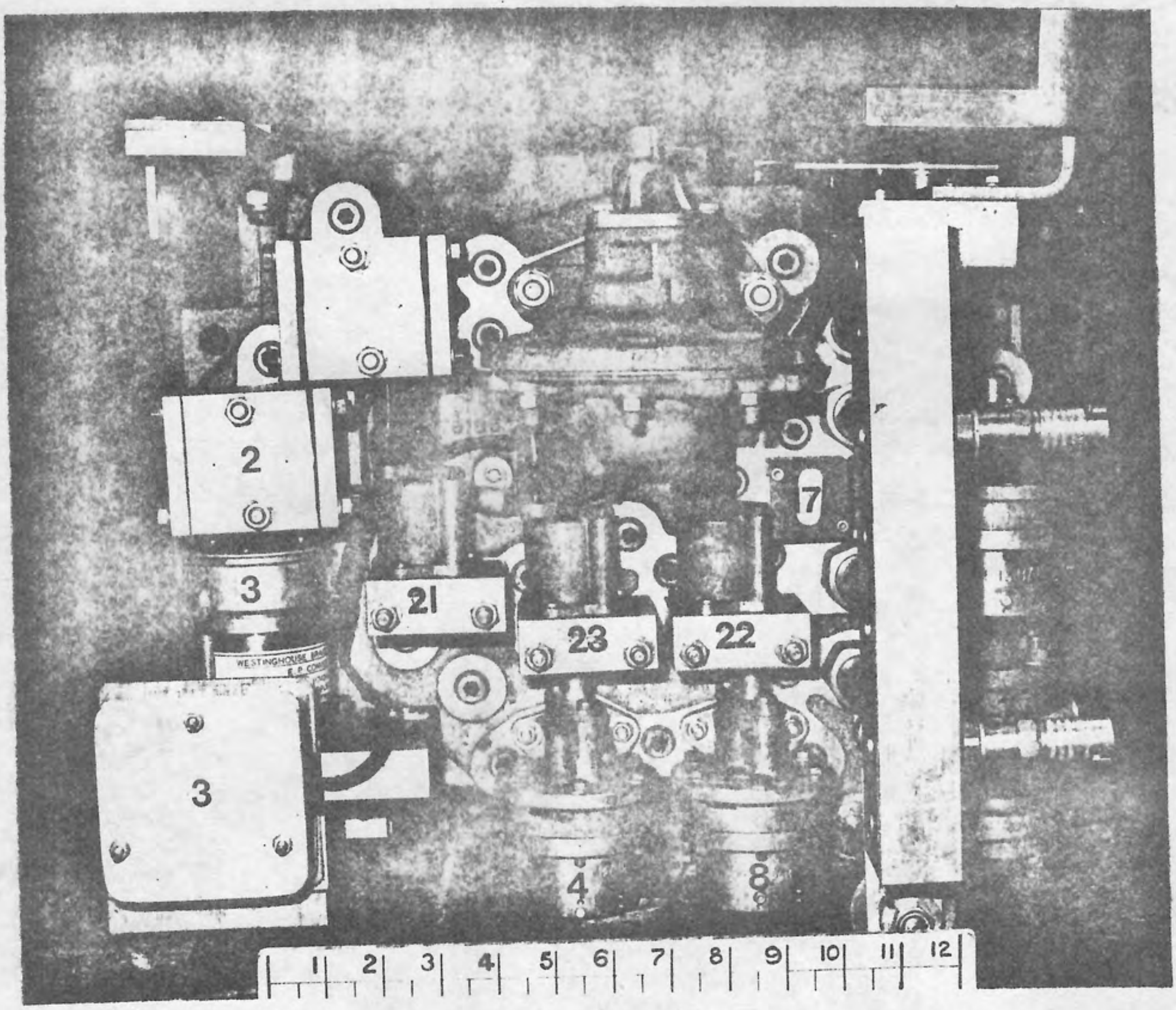
M: MAIN AIR SUPPLY TO BRAKE CONTROL UNIT
P: BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R: WATER/GLYCOL RESERVOI AIR SUPPLY
A: CONTROL UNIT AIR EXHAUST
I: AIR/HYDRAULIC INTENSIFI AIR SUPPLY
S: H.K. BRAKE CONTROL VALVE AIR SUPPLY
GI & GR PRESSURE MEASURING POINTS
V1 & V2 H.K. BRAKE VENT CONNECTIONS
1. FLOW AMPLIFIER
2. EMERGENCY BRAKING
3. MAIN CONTROL VALVE
4. EMERGENCY SET RATE
5. CONSTANT PRESSURE VALVE
7. FRICTION BRAKE OFF
8. INTENSIFIER LIMITER
10. FRICTION BRAKE CONTROL
11.
12. H.K. BRAKE DUMP
13. FILTER
14. MANUAL RELEASE
15. VENT SEALING VALVE
16. BRAKE SHUT-OFF
17. OR LOGIC UNIT
18. FILTER
19.
21. MAIN OPERATOR
22. BRAKES NOT DEMANDED
23. WHEELSLIDE
24. VENT SEL / WATER RETAINING VALVE

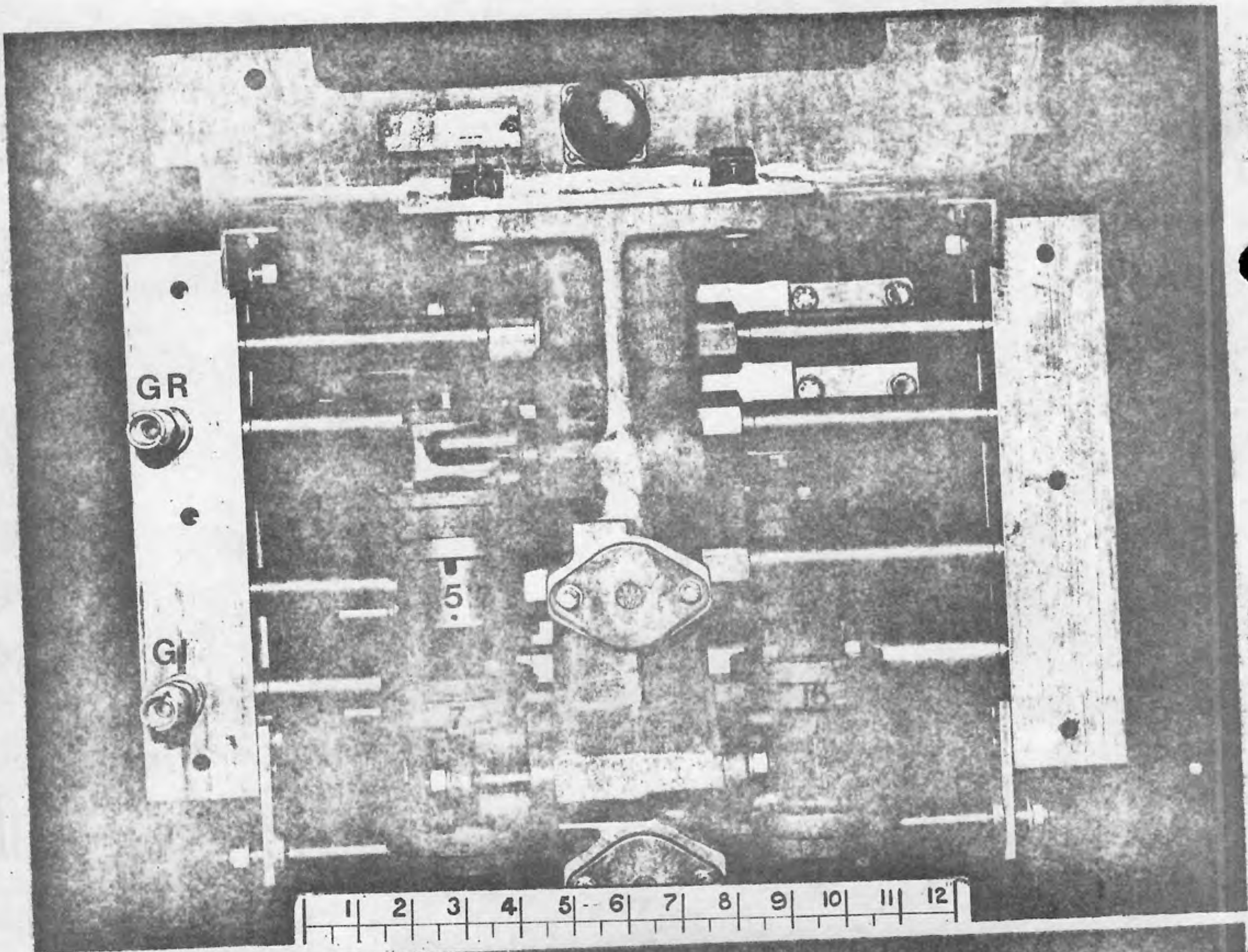
Fig 16c

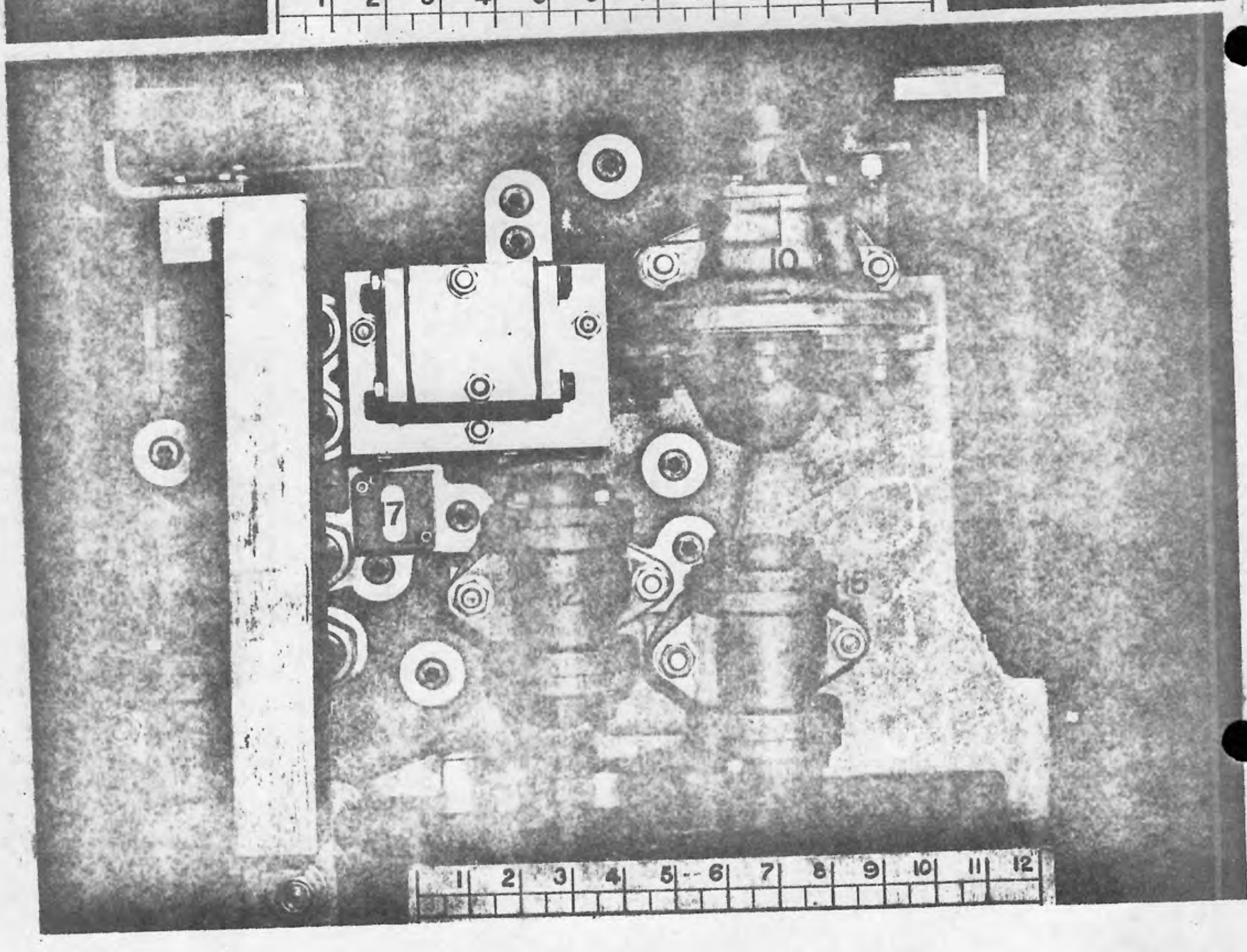
STUDENT'S NOTES.

Three views of
Westinghouse BCU

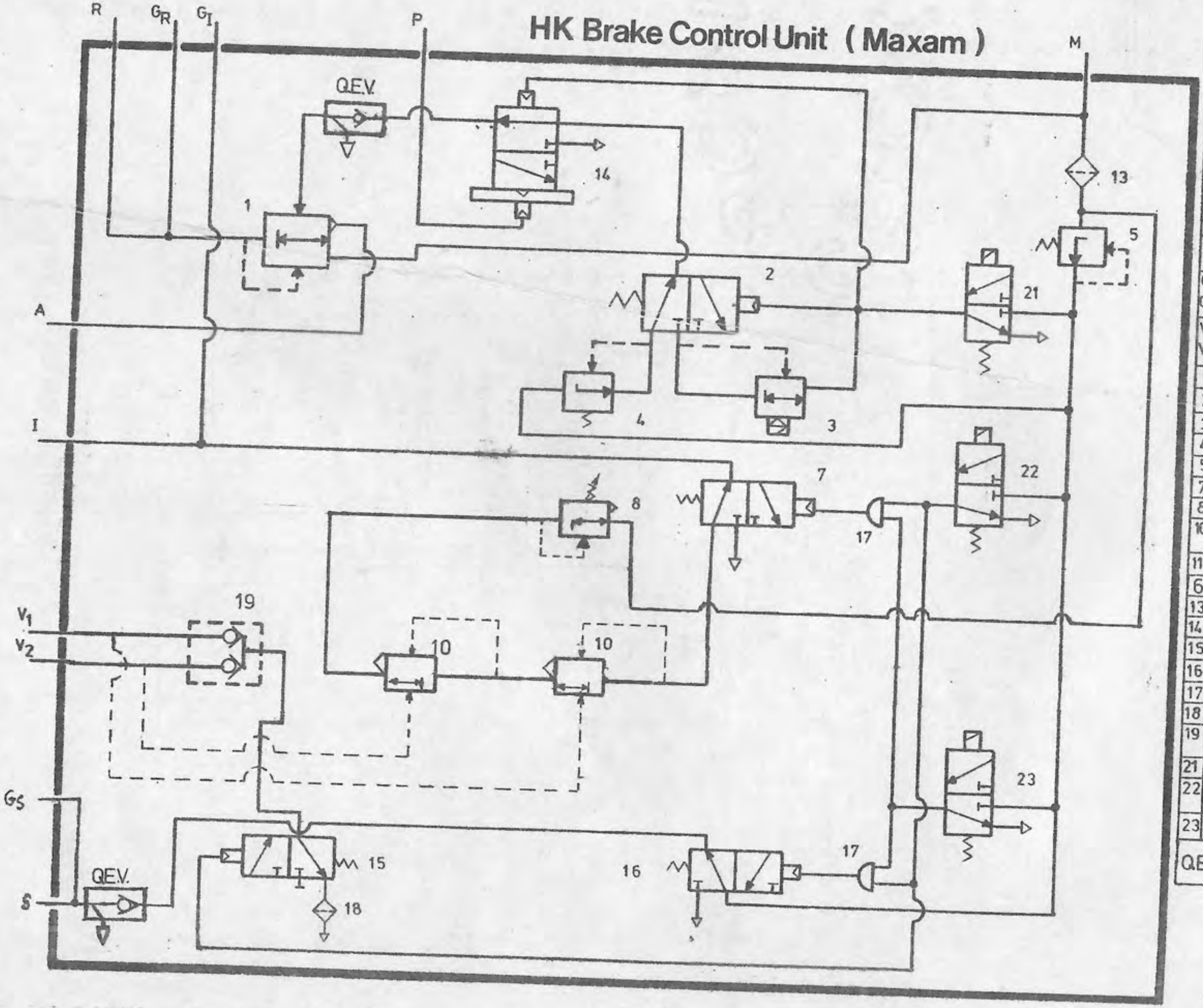
Fig 17




GR
G
5
1 2 3 4 5 6 7 8 9 10 11 12

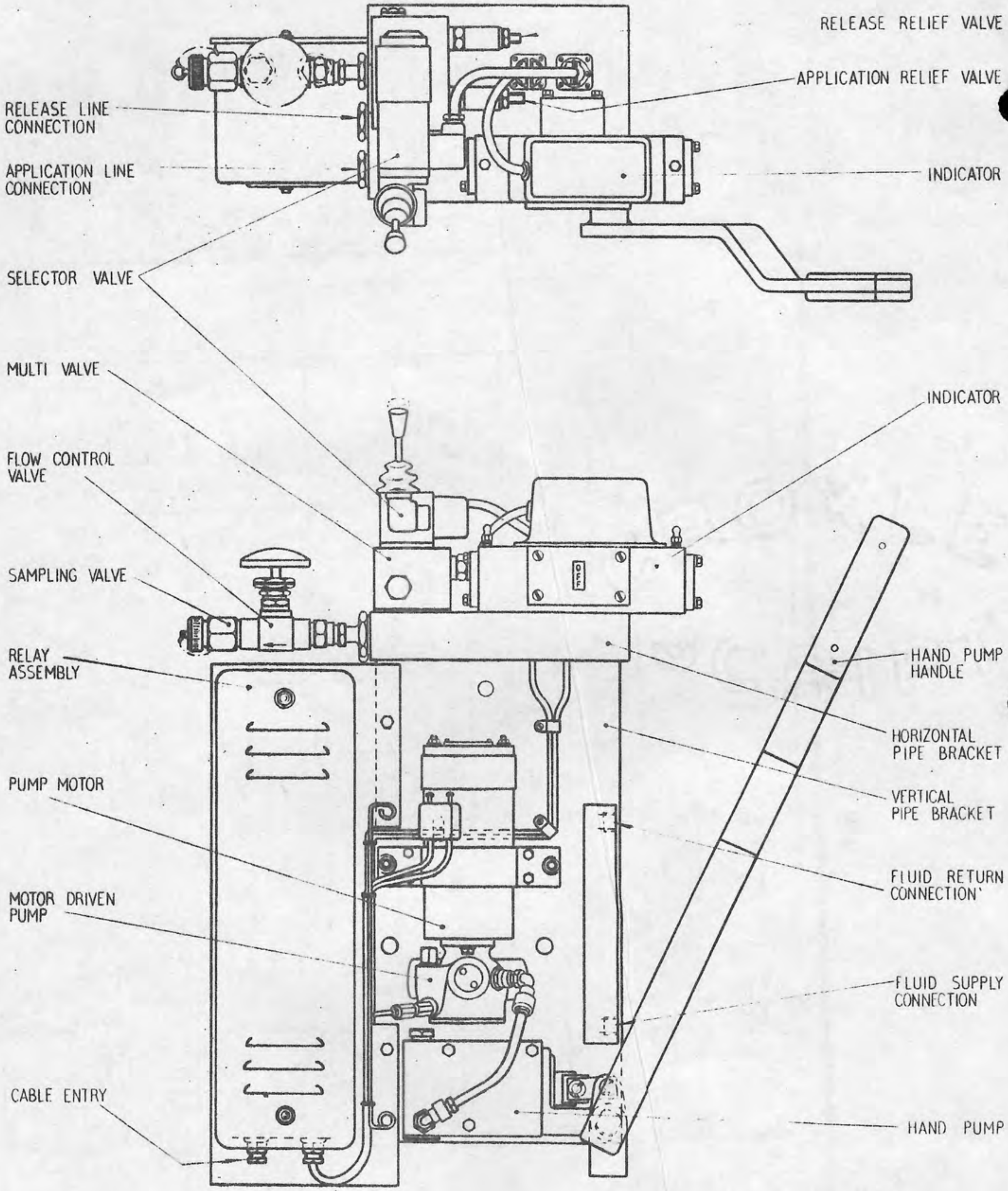

10
7
1 2 3 4 5 6 7 8 9 10 11 12

HK Brake Control Unit (Maxam)



REF	DESCRIPTON
M	MAIN AIR SUPPLY TO CONTROL UNIT
P	BRAKE RELEASE PUSH BUTTON (PILOT SIGNAL)
R	WATER/GLYCOL RES. AIR SUPPLY
A	CONTROL UNIT AIR EXHAUST
I	AIR/HYDRAULIC INTENSIFIER AIR SUPPLY
S	HK. BRAKE CONTROL VALVE AIR SUPPLY
G_R G_I	PRESSURE MEASURING POINTS
V_1 V_2	HK. BRAKE VENT CONNECTIONS
1	FLOW AMPLIFIER
2	EMERGENCY BRAKING
3	MAIN CONTROL VALVE
4	EMERGENCY SET RATE
5	CONSTANT PRESS VALVE
7	FRICTION BRAKE OFF
8	INTENSIFIER LIMITER
10	FRICTION BRAKE CONTROL
11	
6	VENT CHANGEOVER
13	FILTER
14	MANUAL RELEASE
15	VENT SEALING VALVE
16	BRAKE SHUT OFF
17	'OR' LOGIC UNIT
18	FILTER
19	WATER RETAINING VALVE
21	MAIN OPERATOR
22	BRAKES NOT DEMANDED
23	WHEELSLIDE
Q.E.V.	QUICK EXHAUST VALVE

Fig 18



PARKING BRAKE UNIT

Fig 19

PARKING BRAKE UNIT

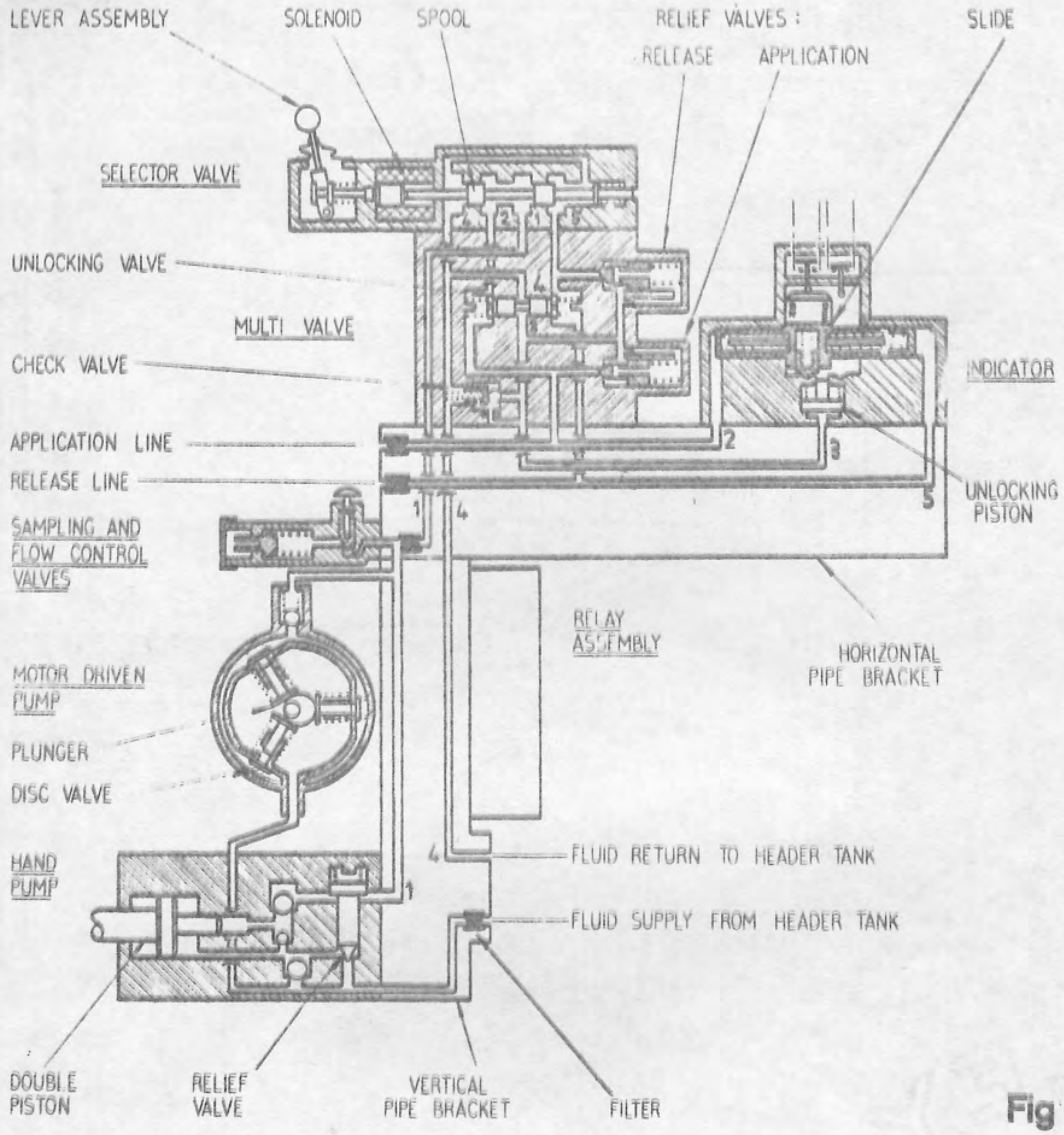


Fig 20

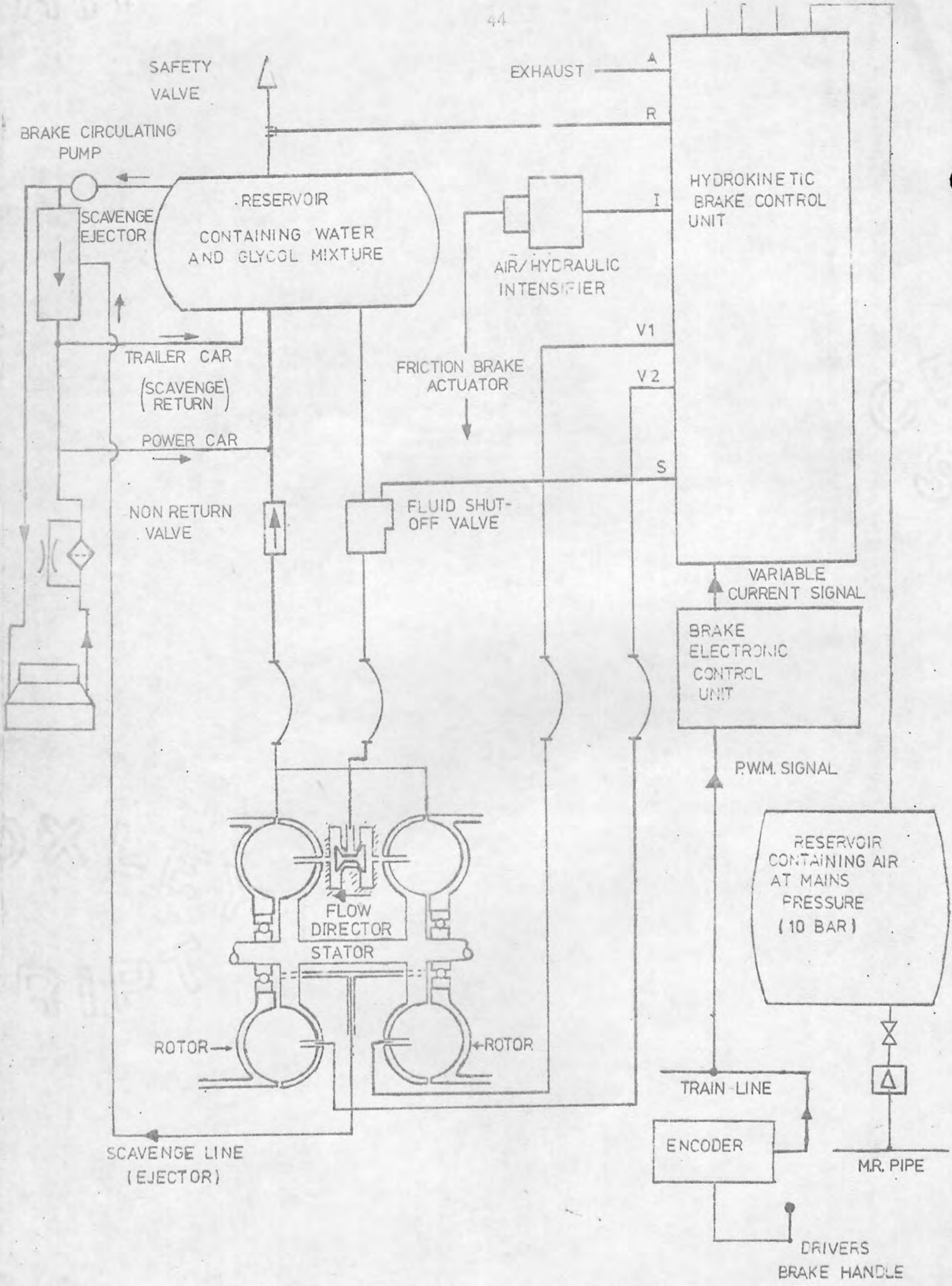
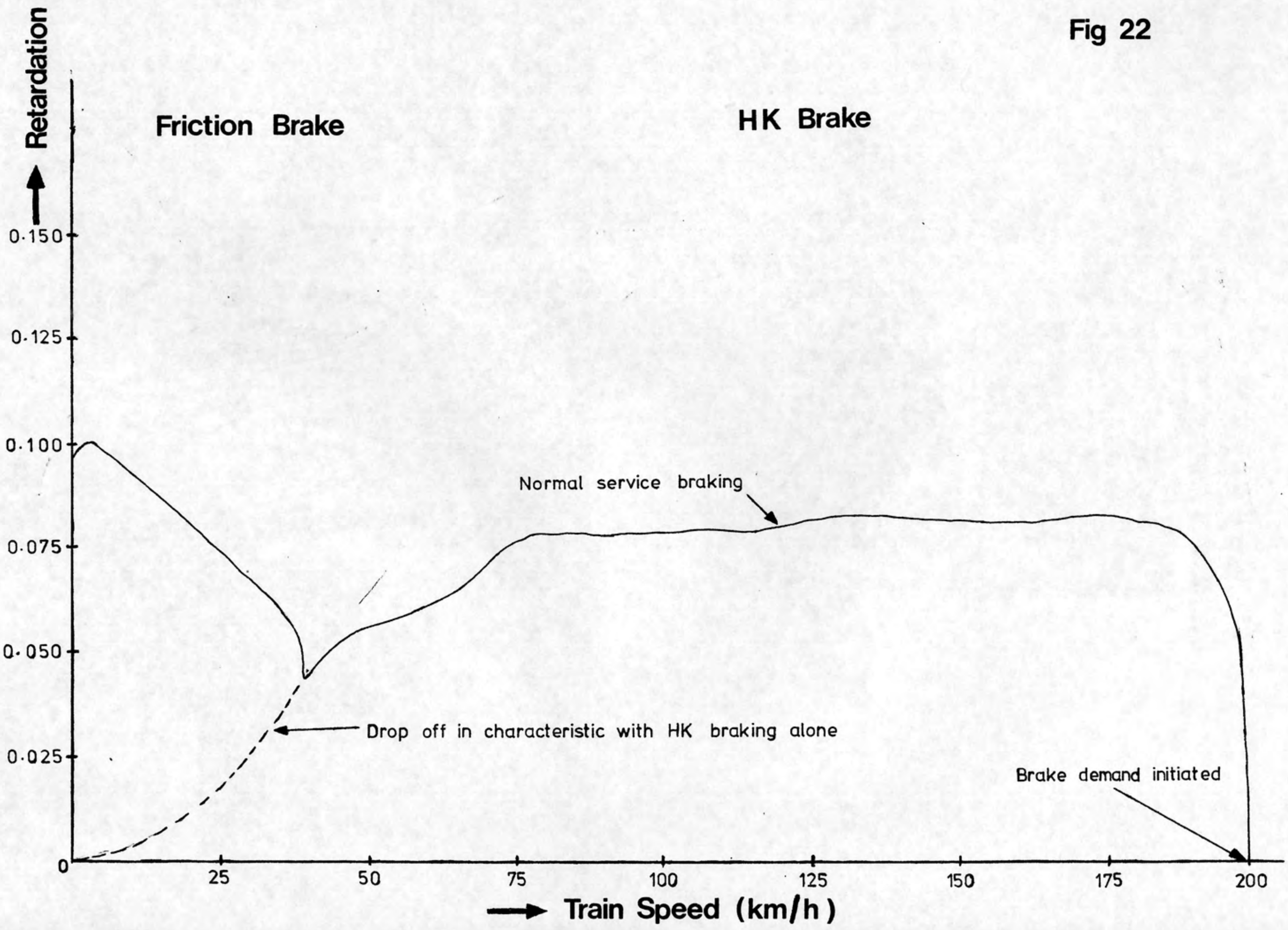


DIAGRAM OF THE HYDROKINETIC BRAKE

Fig 21

APT TRAILER BRAKE CHARACTERISTIC

Fig 22



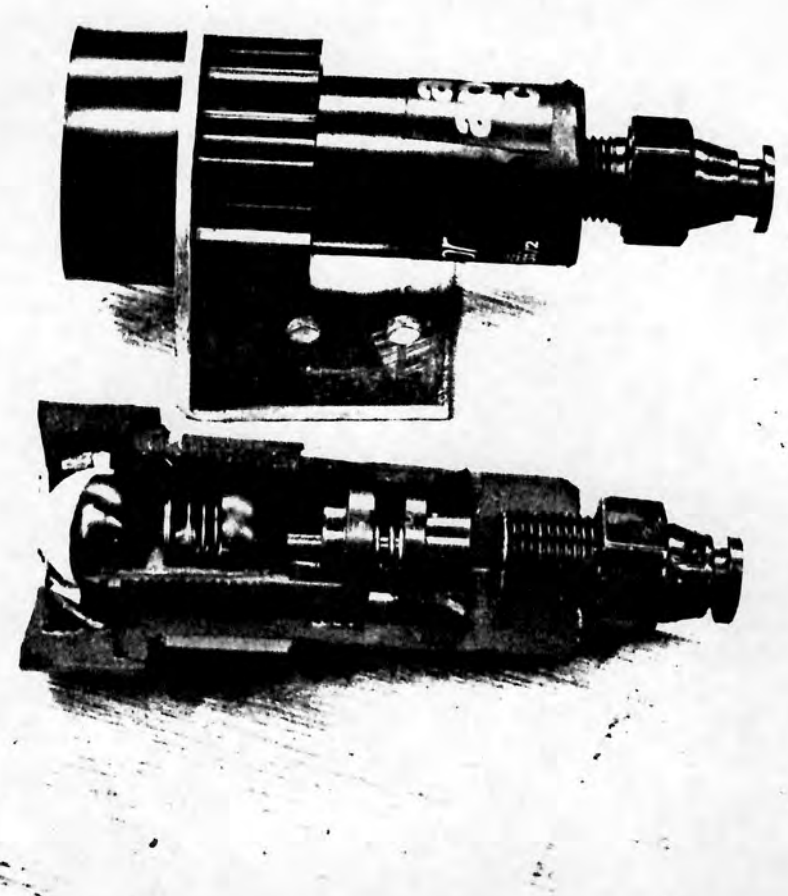


Fig 23

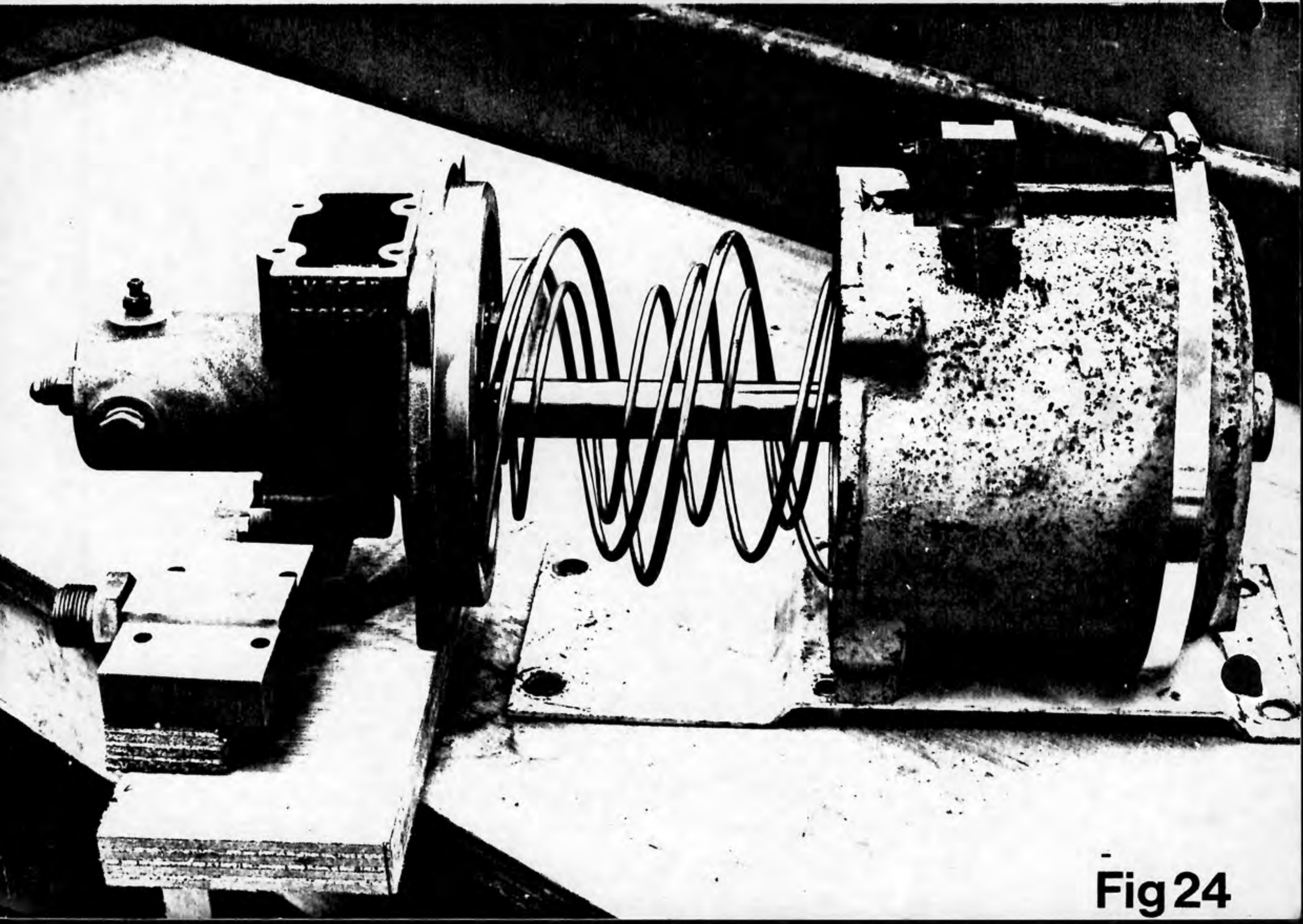


Fig 24

EYEBALL INDICATOR. FIG 23

A modification is being fitted to selected vehicles which incorporates an " Eyeball " type indicator. This indicator is connected to the main body of the Intensifier and is pressure operated.

If the Intensifier stroke becomes excessive, an indication of a potential brake fault, the port to the indicator will be uncovered allowing air pressure behind the piston to enter the device and cause the eyeball to give a red aspect.

When maintenance staff see this indication the filter should be removed and the piston stroke measured in the normal manner.

The indicator is located adjacent to its intensifier.

INTENSIFIER. FIG 24

This shows the Intensifier internal springs and the fitting for the attachment of the feed connection to the indicator on the top right side of the casing.

STUDENT'S NOTES.