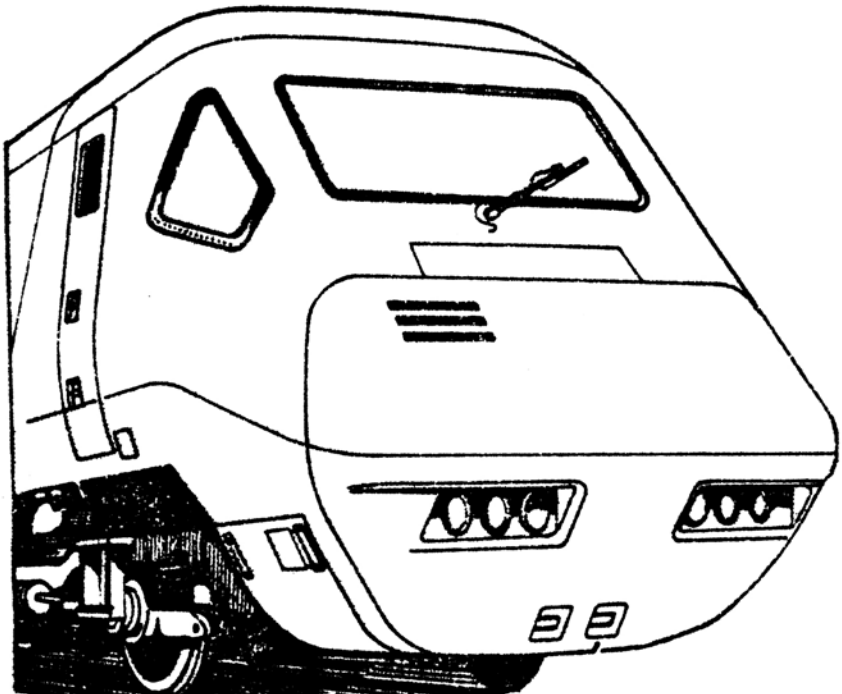
British Rail : Scottish Region

CM&EE Training Centres

APT



Course Notes

5. Tilt

TILT

Introduction.

The main objective in any modern railway system is to reduce journey times as much as possible whilst improving, or at least maintaining, passenger comfort. British Rail had reached the best possible journey times with conventional rolling stock and motive power. Further improvement to maintain a competitive edge in the face of increasing use of the private car and airlines was necessary.

Three options were open;

(a) Use conventional rolling stock and straighten the existing track on the main lines.

(b) Build new high speed Inter-City lines.

(c) Use existing track and in some way maintain passenger comfort for the increase in speed necessary around curves.

The first two options were not viable due to the enormous costs involved and the amount of new land acquisition required whilst (c) could be achieved by tilting the body of the vehicle at varying angles dependent upon the speed and severity of the curve. The existing transition curves between straight and constant radius track are relatively short for high speed operation, resulting in a demand for a tilt response of up to 5° per second. Such rates cannot be achieved by a passive (gravity operated) system as used on the Italian Railways in the 1950's so each vehicle has to be provided with its own self contained electro-hydraulic servo-system which responds to accelerometers measuring the lateral accelerations experienced by passengers. It is essential that higher curving speeds do not cause excessive overturning moments. The design of APT-P is such that the maximum transfer of load from inner to outer wheels at 9° cant deficiency is 33% leaving an adequate margin for side winds and other dynamic forces. In addition, APT-P has a low centre of mass which is kept over the centre of the track by the tilt system on straight track. The predicted overturning cant deficiency for APT-P is 25°. This was tested on a sharp curve near Dover by running a scrapped coach with suitably modified mass and suspension at successively higher speeds until it overturned - at a cant deficiency of 24.3°. The tilt system uses a tilting bolster as shown in Fig. 1 and this tends to be self righting *if* weight distribution is even. Additional measures have now been taken to cope with the righting of the vehicles in the event of tilt failure and these are described later in this note. The tilt components, now fitted to the train, are collectively known as the Mk3 or Precedence Tilt Control System.

LAST

Principle of the Mk3 or Precedence Tilt System.

All APT-P vehicles, including Power Cars are now fitted with the Mk3 system. It is completely automatic and has been tuned to meet the high performance requirements for fast and smooth operation. Each vehicle contains its own hydraulic pack and control system designed to tilt the vehicle to the angle demanded by the tilt accelerometer which is mounted on the leading bogie of the vehicle preceding the one to be tilted. Obviously there are interlocks to change over the accelerometers when the train reverses direction.

This new tilt control ensures that the vehicle is already starting to tilt as it enters a curve giving the passenger a smoother ride and less curving sensation.

1

On curves, the outer rail of the track is usually laid higher than the inside one. This produces a slope across the track known as its cant, and measured as an angle from the level. If the train goes around the curve at the correct speed, the passengers feel no sideways (lateral) force. If the train goes around the same curve at a slower speed, the passengers will experience a force towards the inside of the curve, and the vehicle is said to have cant excess (also measured as an angle). If the train goes around the same curve at a faster speed, passengers will experience a force towards the outside of the curve, and the vehicle is said to have cant deficiency. On APT, the tilt system adjusts the angle to which the vehicles are tilted to suit the speed at which the train is travelling. This means, whatever the speed of the train, the passengers do not experience any cant deficiency or excess.

1325
4
1300
125
13
125
250
325

FEED BACK

Basic Principle of Operation. (See Fig 2)

When the APT negotiates a curve it experiences a lateral (sideways) force.* This is detected by the tilt sensor mounted on the bogie frame and is converted to an electrical signal which is proportional to the amount of tilt required to counteract the lateral* force. This electrical signal is fed to the electronic control box in the Tilt Pack. The Pack then supplies oil, which is metered through two servo valves to the tilt jacks at either end of the vehicle to tilt the bolster and hence the body of the vehicle. The angle between the body and bogie is monitored by a ~~Linear Variable Differential Transducer~~. → SENSOR This converts the angle to an electrical signal which is fed back to the electronic box. When this signal matches the original tilt demand signal the servo valves cease to supply the tilt jacks and the system remains static until the next change in lateral force is detected by the tilt sensor on the bogie.

In order to accomplish this, a system of extremely fine electrical and mechanical tolerances is required which will now be covered in detail.

QUOTE IN SUMMARY

The Tilt Pack.

The Tilt Pack is to be found halfway along "B" side of Power Cars and in the underbelly, towards No. 1 end, of trailer vehicles on "A" side.

The Power Car and Trailer Cars Tilt Packs are of different physical dimensions and are NOT interchangeable. Both Packs contain identical major components except the Power Car Pack has some additional controls which are described later.

The following items are contained within the Tilt Pack Module. A detailed explanation of the hydraulic operation of the Pack follows this section. Each item is given a number which refers to the hydraulic circuit diagram, Fig. 12. Some of these items are illustrated in Figs. 4 and 5.

1. Constant Pressure (Large) Pump.

   Lucas Variable Delivery Axial Piston Pump driven at 2900 rpm through a Fenaflex coupling by a GEC 415v 3ph 50HZ 11Kw motor. Its output is controlled by a Constant Pressure Servo Valve which ensures that the constant pressure is maintained regardless of oil demand. This pump operates above 60Km/H.

2. Constant Flow (Small) Pump.

   Keelavite Fixed Delivery Internal Gear Pump driven at 2820 rpm via a flexible coupling by a GEC 415v 3ph 50HZ 3kW motor. It runs continuously to circulate a proportion of hydraulic fluid through a 1 micron filter and cooler and can also supplement the Constant Pressure pump.

3. Oil Reservoir.

   Fabricated of aluminium sheet and holds 20 gallons of Nuto HP32 oil.

5. Unloading Valve.

   Designed by Brown & Sharp and controls the pressure in the high pressure line, only while the oil is being pressurised by the Constant Flow pump. Set to open at 1800 psi.

6. Low Pressure Micro Filter.

   Fairey type 123A-3TY-101. Disposable fibreglass element of nominal one micron rating. Designed for flows up to 13 gallons per minute at a maximum pressure of 5500 psi. Fitted with a visual and electrical element condition indicator and having a bypass arrangement if the filter becomes blocked.

7. High Pressure Relief Valve.

   This valve is designed by Integrated Hydraulics Limited and will open when pressure goes above 100 psi in order to protect the cooling circuit.

8. Electro-Hydraulic Servo Valve. (2)

   An industrial servo valve manufactured by Dowty. Pilot operated having a closed centre 4 way sliding spool valve in which the output flow to a constant load is proportional to input current. The description of this valve is as follows: (see Fig.11)

It consists of a polarised electrical torque motor and two stages of hydraulic power amplification. The motor armature extends into the air gaps of the magnetic flux circuit and is supported in this position by a flexure tube. This tube also acts as the seal between the electro-magnetic and hydraulic sections of the valve. Two motor coils surround the armature, one each side of the flexure tube. The flapper of the first stage hydraulic amplifier is rigidly attached to the mid point of the armature. The flapper extends through the flexure tube and passes between two nozzles, creating two variable orifices. The pressure controlled by the flapper and nozzle varying the orifice is fed to the end areas of the second stage spool valve. This is a conventional 4 way sliding spool and the output flow from the valve at a fixed pressure differential across its end is proportional to spool displacement from the central or null position. A cantilever feedback spring is fixed to the flapper and engages a slot at the centre of the spool. Displacement of the spool deflects the feedback spring which creates a torque on the armature/flapper assembly. The electrical input signal induces a magnetic flux in the armature and causes armature and flapper to deflect. This movement of the flapper increases the size of one orifice whilst decreasing the size of the other. This creates a pressure differential across the spool valve which slides across causing the feedback spring to apply a torque to the armature which closes the original torque created by the electrical signal. Spool movement continues until the feedback spring torque equals the input signal torque. The flapper is centralised between the nozzles.

9. Non-Return Valve.

Manufactured by Integrated Hydraulics Limited and prevents oil flowing from the high pressure side to the low pressure side of the hydraulic circuit.

10. High Pressure Micro Filter.

Fairey type 121A-3TY-110. Disposable paper element of nominal 10 micron rating. Designed for flows up to 13 gallons per minute at a maximum working pressure of 5500 psi. Fitted with a visual and electrical element condition indicator and having an arrangement for bypassing the oil around the filter element when blocked.

11. Hydro-Pneumatic Accumulator.

This is connected to the high pressure line and is designed to absorb transient high pressures and supply peak oil flow demand.

This vessel contains a rubber bag and this in turn contains nitrogen gas which is called a "pre-charge". The pre-charge is charged to a pressure of 1800 psi and the bag is kept pressure tight by a Schraeder type valve and a Seales cap. This arrangement has been known to keep the pressure sealed in for several years.

When the oil pressure in the hydraulic system is below the pre-charge pressure, the gas bag completely fills the accumulator and pushes the poppet valve into the closed position, the poppet valve is designed to prevent the gas bag from going down the fluid port and into the hydraulic pipework.

As the oil pressure rises above the pre-charge pressure, oil is forced into the accumulator and compresses the gas bag until the nitrogen pressure equalises the oil pressure. As the oil pressure drops the gas bag will expand thus forcing the oil out until either the pressures have equalised or the gas bag closes the poppet valve.

WARNING : THIS DEVICE CONTAINS POTENTIAL ENERGY WHICH IS STORED IN A COMPRESSIBLE GAS.

The hydraulic system has been designed to provide safe use of this energy, but all personnel likely to be involved in the operation of, or likely to come into contact with the system, should be aware of the following points:-

(a) Hydraulic systems containing accumulators can be constantly pressurised even when the pump is not running.

(b) Before any part of the associated hydraulic system is dismantled or any maintenance or dismantling is carried out on associated machinery, the hydraulic oil should be vented to the reservoir.

(c) Before any part of the accumulator gas system or circuit is dismantled the gas charge should be vented to atmosphere.

(d) Only inert gases such as nitrogen should be used to charge the accumulator.

12. High Pressure Relief Valve.

This valve is designed to open when the pressure in the high pressure line exceeds 4500 psi.

13. Dual Relief Valve.

Two dual relief valves are connected between each end of the vehicle to prevent excess torque being applied to the body, should opposite end bolsters tilt in the opposite direction due to tilt failure.

These units will also limit wheel load transfer when on twisted track, the valves are set to open at 800 psi.

15. Servo Bypass Valve.

These are manually operated ball valves and are fitted for the purpose of filling, flushing and cleaning the hydraulic system for which the valves are opened, but in normal service condition these valves MUST be kept closed.

The oil reservoir is fitted with an Eltron 240v 50HZ 0.75kW heater element and controlling thermostat set to keep the oil at 10°C.

A Rototherm thermometer gives an indication of the oil temperature with its probe immersed in the hydraulic fluid within the reservoir. A Sperry Vickers level gauge is fitted to the side and a breather cap is fitted to the top of the reservoir.

The pressure in the system may be checked by depressing the gauge isolating button and reading the pressure on the glycerine filled gauge. Should the pressure in the system drop below 1450 psi the switch will open and give a fault indication in the Guard's compartment and vehicle vestibules.

A cock is provided in order that samples of the hydraulic oil may be taken for testing purposes.

The Pack is hydraulically connected to the vehicle via 6 hoses. (7 on Power Cars). Quick Release Couplings are used. See Fig. 6.

Also within the Tilt Pack is the Tilt Electronic Control Unit which will be described later.

Power Car Tilt Pack. (See Fig. 13.)

The Tilt Pack on the Power Car is laid out in a different way and has an additional item. This is a thermostatically controlled, electrically operated valve which controls the passage of fluid to the cooling circuit. When the thermostat registers an oil temperature above 54°C it switches off the supply to the valve and allows oil to pass through the cooling circuit.

External Hydraulic Circuit.

The Tilt Pack is connected to an external hydraulic circuit in order to operate and control the tilting of the vehicle. The following items are contained in the external hydraulic circuit. Each item is given a number corresponding to the circuit diagram in Fig.14.

14. Dump Valve.(See Fig. 15)

These are located on the left hand side of the Tilt Pack bay on trailer vehicles, and on Power Cars are situated on the floor in front of the Tilt Pack. These valves have 3 positions:-

Dump Position

To relieve pressure in the hydraulic system when staff are carrying out work, or before work commences on certain parts of the vehicle i.e. bogie, cardan shaft etc.

Service Position

This is the normal running position and these valves MUST be returned to this position when the tilt isolation is removed.

Level Position

This position allows the oil pressure on each side of the tilt actuators to equalise thus allowing the vehicle to come to the vertical position. This position does NOT destroy the pressure in the system.

16. Oil Cooler.

The oil cooler is an air blast type with Clayton Dewandre spirally coiled wire fins. This cooler is capable of dissipating the entire heat output of the Tilt Pack.

18. Shuttle Valve(See Fig. 17.)

This valve allows oil pressure from the highest pressure jack line to flow to 19, but prevents oil from flowing from one jack line to the other.

19. Bolster Clamp Actuator. (See Fig. 18a)

This actuator removes the locking pin from the bolster clamp.

20. Cross Jack Relief Valves. (See Fig. 17)

These valves limit the pressure applied to the tilt actuators, and are set to open at 3500 psi.

21. Bogie Bypass Valves. (See Figs 17 and 18b)

These are manually operated ball valves and are fitted for the purpose of flushing and cleaning the vehicle pipework for which these valves are opened, but in normal service condition these valves MUST be kept closed.

22. Actuator Bleed Nipples.

These are fitted so that air can be bled from the bolster pipework.

23. Tilt Actuators. (See Fig. 16)

Each vehicle end has two actuators to move the bolster, arranged so that oil flows in each direction (to and from the servo valve) are equal.

The trailer car actuators have a stroke of 310mm while the Power Car actuators stroke is 320mm, these strokes giving the maximum $\pm 9^{o}$ tilt body angle. The Power Car actuator has a larger bore compared to the trailer car actuator in order to cope with the increased weight of the vehicle (12 tonne) compared to 4.8 tonne of the trailer vehicle.

STUDENT'S NOTES.

Before moving on to the operation of the hydraulic system it is necessary to study the two pumps in greater detail.

(1) Constant Pressure Pump (See Fig 7)
The Constant Pressure Pump is designed to automatically maintain a constant pressure in the hydraulic system regardless of oil demand. The motor driven piston block rotates carrying the pump pistons of which there are 7, equally spaced around the block. These pistons are fixed via the spherical couplings on to the swash plate. As the block rotates a pumping action is created, oil being drawn in at the inlet and forced out of the delivery pipe. Adjustment of the angle of the swash plate will vary the amount of oil delivered for a revolution of the cyclinder. The angle adopted by the plate will depend on the pressure created by the pump acting on the underside of the flow control piston, this pressure being that in the delivery line, hence providing a constant pressure of output dependent upon the servo orifice and the spring setting in the chamber above the flow control piston. When the stall valve opens to drain due to excessive delivery presssure, the pressure above the flow control piston will collapse, and allow the swash plate to turn to the"no delivery"condition, i.e. plate vertical with no displacement of the pistons whilst the piston block is rotating. A diagram of the Constant Pressure Servo Valve is shown in Fig 8 whilst an exploded view of this pump with component list is shown in Fig 9.

(2) Constant Flow Pump (See Fig 10, 10a)
This is a two stage gear pump and will normally be running all the time there is an electrical supply. It is very important for passenger comfort that the noise level is low especially when the train is standing at a station. This gear pump has three special design characteristics:
Internal gears - the pump shaft drives a keyed pinion, which itself drives an internal gear. This design allows for the shaft end to be placed in the centre of the housing. The pump needs only 1 shaft and therefore lends itself easily to double and multi-stage design and multiple pump arrangements. Like external gear pumps, the oil fills teeth gaps in the suction zone, and is displaced from the gaps in the pressure zone. The inherent advantage of the internal gear design is the fact the suction and pressure zones are much longer than for comparable external gears. (See Fig 10b).
Special Shape Gear Piece - for ease of manufacture involute shaped teeth flanks are usually specified for conventional gear pumps. This particular tooth form has an inherent disadvantage, because a relatively large volume of oil is trapped between the tooth gap of one gear and the tooth of the meshing gear. This trapped oil volume varies considerably with the angle of rotation and this generates pressure pulsations and noise. A specially shaped tooth profile has been developed, which for all practical purposes eliminates any trapped oil volume. In this way ripple free flow and smooth, low-noise, operation is achieved. (See Fig 10c)
Multi Stage Principle - a conventional gear pump uses only one pair of gears. The pressure rating is therefore limited. But internal gear pumps for higher pressures are of multi-stage design in which two or three pump elements are working in series, so that the oil is flowing from the outlet of one stage to the inlet of the next stage.

Each element or stage participates equally in producing the eventual outlet pressure. (See Fig 10d)

Operation of Hydraulic Circuit on Trailer Vehicles (See Figs 12 and 14)

Providing the electrical supplies are available then pump (2) will run. Oil is drawn at a constant rate of 2 gallons per minute from reservoir 3 and is pumped through non-return valve 9 to the high pressure line 4. When the pressure reaches 1800 psi unloading valve 5 opens to pass fluid through the secondary (1 micron) filter 6, non-return valve to coupling 2C.

From here the fluid is pumped through the radiator 16. If oil temperature is 54°C or above the cooling fan is cut in, below 48°C the fan cuts out. It is activated by a thermostat probe in the radiator. The oil returns to the reservoir via coupling 1C. If either or both couplings 1C and 2C are disconnected, or there is a blockage in the cooling circuit, relief valve 7 set at 100 psi will open and allow oil to bypass the radiator. When line 4 becomes pressurised from pump 2 fluid passes through the primary (10 micron) filter past the pressure switch and pressure gauge to the servo valve 8. In the feed to the servos is the accumulator 11. Providing the servo valves are energised they pass pressure into either lines 1L and 2R or 2L and 1R. Oil passes the dual relief valve 13 set at 800 psi, and is transferred to the body of the vehicle and hence to the bogie by hi-Flex hoses and Sterling Hydraulic quick relief couplings. Referring to Vehicle body/Bogie circuit Fig 14 the oil passes the connections to the Dump valves 14. These are fully explained in Fig 15. The oil will then travel to the appropriate Tilt actuators 23 at each end of the vehicle. Protecting the actuators are the Cross Jack relief valves 20 whilst Shuttle valve 18 allows whichever line is pressurised to feed the bolster clamp. The manually operated bogie bypass valve 21 is only used when flushing and cleaning bogie pipework. The valves 18, 20, and 21 are located on the bogie as shown in Fig 17. The oil is fed through this circuit until a servo valve, upon receiving a suitable electrical signal, either reduces, cuts off or reverses the flow. When speed rises to 40 mph a Speed Sensing Relay brings in the large pump which maintains between 3000 psi and 3200 psi in the high pressure line 4; this will seat valve 9 and the small pump will continue to circulate fluid around the cooling circuit. If there is an abnormal pressure drain on the large pump then provided it can overcome valve 9 the small pump will assist the large pump.

NOTE. When there is no tilt demand the servo valves pass equal pressures to either side of each actuator on the vehicle.

Bolster Clamp Modification

This is a recent modification and is a device for restraining bolster to bogie movements under vehicles which have lost tilt system pressure. There are three different types of Bolster Clamp and these are shown in Fig 19a, b and c. They are drawn with the Bolster Clamp locking the vehicle in its upright position with the tilt system pressure lost. When the tilt system is activated oil pressure will be present in the tilt actuator supply lines and a pressure feed selected from the highest pressure line by the shuttle valve (18), will operate the bolster clamp actuator making it extend (minimum pressure 400 psi). This will withdraw the pawl from the ratchet plate and tension the spring. As the coach tilts, the ratchet plate will rotate by virtue of its linkage.

Bolster Clamp Modification (Cont'd)
If the tilt system oil pressure is lost while the vehicle is tilted, the pawl will engage the ratchet plate under the action of the return spring and due to the ratchet action, the bolster clamp will allow the vehicle to move only to the upright position.
Should the pawl return to the ratchet whilst the vehicle is still operating on high pressure (large pump) the pawl is designed to fracture.

STANDARDS OF CLEANLINESS

The table shown in Fig 20 is that used for comparison of the required standard of cleanliness for certain hydraulic systems. Typical applications are also shown.
The APT tilt hydraulic system lies in category class 2H. This compares with new oil which is in class 6H and is therefore considered insufficiently clean for use without processing prior to application on APT.
It is therefore absolutely essential that the oil supplied to the tilt system is scrupulously clean.

New oil from the barrel is much too dirty for use on the system and must be circulated through a specially designed oil flushing trolley before delivery to the vehicle system.

This can be best appreciated if one considers that normal low pressure system use large area actuating mechanisms, tolerating relatively large clearances between moving parts which could accept and pass fairly large dirt particles. By comparison servo systems such as used on APT working on very high pressures on small areas have as a result very much smaller working clearances to reduce pressure/power losses and are therefore very intolerant of dirt if a high order of both reliability and long life is to be expected.

To this end it is imperative that all Maintenance Staff know what they are dealing with and the following data will be of interest.

Dirt comes in all sizes but the main concern is dirt between 1 and 100 microns. To put these sizes in perspective a grain of salt is about 100 microns and the smallest particle that can normally be seen by the naked eye is 40 microns.
If comparisons are made with dirt and typical clearances within components it can be seen that cleanliness is very important.

(a)	Servo valve spool to bush clearance	1.5 microns
(b)	Main pump piston/bore clearance	15-30 microns

To satisfy these cleanliness standards certain precautions must be taken. Perhaps the most important of these is to flush dirt out of the system before starting to run. Secondly oil must be pre-cleaned before use and finally clean system must not be disturbed without cleaning on re-assembly.
Atmospheric dirt in the working area tends to enter the system and so, wherever possible, work on the tilt system should only be undertaken in the Clean Room at the Depot.

STANDARDS OF CLEANLINESS (CONT'D)

A flushing trolley has been designed in order to simplify the above procedures. The trolley accepts oil on a drum and recirculates it internally until it is cleaned to class 2H. This oil can then be used to flush out the train hydraulic system until the returning oil reaches class 2H.
An additional feature is the ability to pressure test the hydraulic system to confirm correct assembly.
Oil cleanliness class ratings can be assessed by passing a fixed quantity of oil through a fine filter, of mean pore size about 1 micron, and looking at the contamination collected on the surface through a microscope. This is compared with a pair of go-no go slides to determine the dirt classification. If the sample is too dirty further flushing must take place.
The flushing trolley contains all the oil sampling equipment and microscope to enable these checks to take place.

STUDENT'S NOTES.

Tilt System Electrical Supplies and Control, Trailer Vehicles (See Fig. 21.)

Tilt Pack On/Off, Local Control

The Local tilt on/off push buttons are located on the contactor panel adjacent to the COS switches. Operation of the Tilt On button (AOP1) energises the Tilt On Slave Relay (AC1), this coil holds itself in via interlock (AC1/2). With AC1/1 closed, a 240V AC from CCB1 via the Tilt Isolating Switch (TIS) and Tow Enable Switch (TES driving trailers only) is fed to:-

(1) Tilt System Monitoring Transformer (TLT)
This supplies a 24V AC feed to the tilt electronic box.

(2) Small Pump Contactor (TPC2) via Tilt Fault Lamp Relay 2 (TFR2), Tilt Test Push Button Start (TPB1 normally closed), and Small Pump Overload (TOL2)

(3) Large Pump Contactor (TPC1) via Tilt Fault Lamp Relay 2 (TFR2), load shedding relay (LSR, open when 3 phase supply is coming from D/A set). Speed Sensing Relay (SSR2, closes when vehicle speed reaches 40 mph and opens when vehicle speed drops to 30 mph) and Large Pump Overload (TOL1).

(4) Tilt Oil Fan Contactor (TFC) via Tilt Fan Thermostat (TFT) Closes at 54°C opens at 48°C.

(5) TILT TEST STATION

Tilt Test Station

This is located in the Tilt pack bay of the vehicle, and is fitted to enable local control of the pumps on the tilt pack for test purposes.

Before this test station can be operated the Tilt On Slave Relay (AC1) must be energised. To run the large pump the Tilt Test Push Button Start (TPB1, Green Button) must be pushed. This energises TEST RELAY (TR) via Tilt Test Push Button Stop (TPB2). The TEST RELAY having been energised will hold itself in via interlock TR/1. Interlock TR/2 puts a feed direct on to LARGE PUMP CONTACTOR (TPC1) via TOL1.

To stop the large pump the TILT TEST PUSH BUTTON STOP (TPB2, Red Button) must be pushed, this breaks the feed to TEST RELAY (TR) which in turn opens contacts TR/1 and TR/2.

Tilt Packs On/Off, Train Control

The Train Tilt Control Push Buttons, are located on the Guards control panel. Before either the ON or OFF switches can be operated a BR1 key has to be inserted into the TILT KEY SWITCH (TKS), operation of this switch puts a feed from TW67 on to the TRAIN TILT START PUSH BUTTON (TAB1) and TRAIN TILT STOP PUSH BUTTON (TAB2).

Tilt Packs On/Off, Train Control (Cont'd)

Operation of the TRAIN TILT START PUSH BUTTON (TAB1) puts a feed on to TW 14, and this in turn picks up VEHICLE TILT ON RELAY (AC3) on each vehicle on the train. With AC3/1 contact closed this puts a feed from TW67 on to TILT ON SLAVE RELAY (AC1) which, when energised, will hold itself in via interlocks AC1/2.

Operation of the TRAIN TILT STOP PUSH BUTTON (TAB2) puts a feed on to TW 15, and this in turn picks up VEHICLE TILT OFF RELAY (AC2) on each vehicle on the train. With AC2/1 contact open this breaks the feed to TILT ON SLAVE RELAY (AC1) which in turn will drop out.

Tilt Failure Detection Systems

The Tilt Failure Detection System on each vehicle, is designed to identify faults in any one of three areas of the tilt system:-

(1) LOW OIL PRESSURE. The hydraulic system is designed to create low oil pressure in the majority of fault conditions that could occur in the system. This is detected by a pressure switch fitted on the tilt pack. The electrical contact on this switch is normally open, and closes at 1500 psi rising pressure, and opens at 1450 psi falling pressure.

(2) ELECTRONIC SUPPLY FAILURE AND L.V.D.T. FAILURE. The integrity of both L.V.D.T. circuits is monitored by an electronic circuit in the tilt control box, when this circuit has approved of the L.V.D.T. circuits it energises the L.V.D.T. failure detect relay (RL1) which is fed from the +25V rail. With contact RL1/1 closed, it puts a tilt system proving supply of -25V out to the TILT FAILURE DETECTION RELAY interlock RL/1 which is located in the TILT FAILURE DETECT UNIT, this relay is closed under normal tilt operating conditions. The tilt system proving supply is then split into two, and feeds the following:-

   (a) TILT FAULT LAMP RELAY 2 (TFR2). With the electronic supplies, L.V.D.T. and tilt failure detection systems proved this relay is energised and in turn closes its contact TFR2/1 and allows the 240V AC feed to go to the tilt pump contactors.

   (b) MAIN TILT PRESSURE SWITCH (TPS). When the tilt pack hydraulic pressure is above 1500 psi, TPS is closed and energises TILT FAULT LAMP RELAY 1 (TFR1). With TFR1 energised, contacts TFR1/1 and TFR1/2 open and remove the electrical supply to the tilt fault lamps.

Vehicle Tilt Failure Indication

Under conditions of tilt failure, TILT FAULT LAMP RELAY 1 (TFR1) will be de-energised and its contacts TFR1/1 and TFR1/2 will be closed. With TFR1/2 closed, a 110V DC supply will be put on to the TILT FAULT THIS VEHICLE LAMP (LP17) this lamp is located in number 2 end vestibule, and has a BLUE lens.

Vehicle Tilt Failure Indication (Cont'd)

With TFR1/1 closed, a 110V DC supply will be put on to train wire 16 via TILT ISOLATING SWITCH (TIS).

Train Tilt Failure Indication
The TILT FAULT THIS RAKE TRAIN WIRE (TW16) feeds TRAIN TILT FAULT RELAY (TTFR) located in the Guards Control panel, when this relay is energised, contact TTFR/1 closes and puts a 110V DC feed on to TILT FAULT THIS RAKE LAMP (PL12).

Contact TTFR/2 closes and puts a 110V DC feed on to TILT FAULT OTHER RAKE TRAIN WIRE(TW18) contact TTFR/3 opens and prevents TW18 from putting a feed on to ALARM OTHER RAKE LAMP (LP13), thus preventing a condition where both TILT FAULT THIS RAKE and ALARM OTHER RAKE LAMPS are illuminated at the same time.

Tilt System Electrical Supplies and Control, Power Cars (See Fig. 23)
Tilt Pack on/off, Local Control
There are two switches where local operation of the tilt pack can take place. Both of these switches are located above the MCB's on the auxiliary control cubicle.

Tilt Test Station.

This is located at the top of the Auxiliary Control Cubicle. Operation is identical to Trailer vehicles with the exception that TPC 1 is fed via TFR2/1 then TOL 1. In addition, AOP 1 and AOP 2 (Trailer vehicles) are re-identified as TOP 1 and TOP 2 respectively.

Normal local tilt ON/OFF control should be done via the two push buttons. Operation of the TILT ON button (TOP1 GREEN) energises the TILT ON SLAVE RELAY (AC1), this will hold itself in via interlock AC1/1. With AC1/2 closed a 240V AC feed from auxiliary control supply fuse (FS14) is fed, via the TILT ISOLATING SWITCH (TIS) to:-

(1) TILT SYSTEM MONITORING TRANSFORMER (TLT). This supplies a 24V AC feed to the tilt electronic box.

(2) SMALL PUMP CONTACTOR (TPC2) via TILT FAULT LAMP RELAY 2 (TFR2), TPB 1 and SMALL PUMP OVERLOAD (TOL2).

(3) LARGE PUMP CONTACTOR (TPC1) via TILT FAULT LAMP RELAY 2 (TFR2) SPEED SENSING RELAY (SSR2/1). LOAD SHEDDING RELAY (LSR/1) and LARGE PUMP OVERLOAD (TOL1)

(4) TILT COOLING SOLENOID (SOL1) via TILT FAULT LAMP RELAY 2 (TFR2), TILT THERMOSTAT (TT) opens at 54 °C , closes at 48°C.

Train Tilt Systems on/off Control
The train tilt control push buttons are located on the Guards control panel. Before either the ON or OFF switches can be operated, a BR1 key has to be inserted into the TILT KEYSWITCH (TKS), operation of this switch puts a feed from TW67 on to the TRAIN TILT START PUSH BUTTON (TAB1) and TRAIN TILT STOP PUSH BUTTON (TAB2).

Train Tilt System On/Off Control (Cont'd)

Operation of the TRAIN TILT START PUSH BUTTON (TAB1) puts a feed on to TW14 and this in turn picks up the VEHICLE TILT ON RELAY (AC3). With AC3/1 contact closed it energises TILT ON SLAVE RELAY (AC1) and will, in turn, remain energised via interlock AC1/1.

Operation of the TRAIN TILT STOP PUSH BUTTON (TAB2) puts a feed on to TW15, which picks up VEHICLE TILT OFF RELAY (AC2) on each vehicle on the train. With AC2/1 contacts open, this breaks the feed to TILT ON SLAVE RELAY (AC1) which, in turn will drop out.

Tilt Failure Detection System
The tilt failure detection system on each vehicle is designed to identify faults in any one of four critical areas of the tilt system:-

(1) **LOW OIL PRESSURE**

As for Trailer vehicles except that TFR 1 interlocks illuminate Tilt fault lamp on "Shunter's Station", and T.W. 18.

(2) **ELECTRONIC SUPPLY FAILURE AND L.V.D.T. FAILURE**

As for Trailer Vehicles.

(3) **TILT BAY FAN FAILURE**

Current to the TILT BAY FAN (TBF) is monitored by the TILT BAY FAN RELAY (TBFR). If the current supply to TBF should fall below 0.5A, contacts TBFR/1 and TBFR/2 will close, these contacts are in parallel with TILT FAULT LAMP RELAY 1 (TFR1/2 and TFR1/1) contacts respectively.

Vehicle Tilt Failure Indication
Under conditions of tilt failure (except failure of TBF), TILT FAULT LAMP RELAY 1 (TFR1) will be de-energised, and its contacts TFR1/1 and TFR1/2 will be closed. With TFR1/1 closed, a 110V DC supply will be put on to the TILT FAULT THIS VEHICLE LAMP, which is located in number 1 end of the vehicle above TILT ISOLATING SWITCH (TIS).

With TFR1/2 closed a 110V DC feed will be put on to TW18, which in turn will illuminate the TILT ALARM OTHER RAKE LAMP, in both Guards vans.

Slew Rate Limit. (SRL)

This is an electronic module which limits the response of the Tilt System when the small pump only is running. It is activated via the Tilt System Monitoring Transformer (TLT) on Power Cars, and the Large Pump Monitoring Transformer (TST) on Trailer Cars . The primaries of these transformers are fed at 240v single phase and the secondaries supply 24v to the SRL module, if both pumps are running. If the Large Pump stops TST primary is no longer supplied on Trailer Cars, and on Power Cars TPC1 interlock (N.O.) opens when TPC1 coil is de-energised, open circuiting the 24v feed to SRL module.

Diagrams of the "Litton" pin wiring are included with this Technical Training Note.

Tilt Control System.

We have discussed the Mark III or Precedence Tilt System in hydraulic and electrical terms. This section will deal with the items that control this system.

(1) Electrolevel (Tilt Sensor). See Fig. 26. (Fig. 3 gives location.)

This is mounted on the bogie frame (see Fig. 25) and consists of a curved glass phial containing a brine solution and an air bubble, similar to a spirit level. Three electrical probes inside the phial measure the variation in liquid resistance as the bubble moves under the bogie's lateral force. This variation is noted by supplying a 400 HZ signal from the Tilt Control Box on the red wire and an identical signal, but 180° out of phase, on the blue wire. The resultant signal is fed back to the Tilt Control Box.It should be noted that the phase of this resultant signal changes according to which way the lateral force is acting. The voltage between the red and blue wires should be approximately 3.6 volts AC. TO BE MEASURED ON A DIGITAL VOLT METER ONLY. When the vehicle is dead level, the voltage between the blue and the green, and the red and the green wires, will be the same, i.e., half the voltage across the red and blue wires. The signal from the Electrolevel is fed to the Tilt Control Box. This control box also receives a signal from:-

Displacement Transducer (L.V.D.T).

The Linear Variable Differential Transducer is fitted between the bolster and bogie at each end of every vehicle, and is energised from the vehicle's Tilt Control Box. The electrical output of the device is proportional to the direction and degree of tilt. This principle is illustrated in Fig. 27. Note that, as in the Electrolevel, the phase of the resultant signal is changed through 180° as the length of the transducer alters. The L.V.D.T.s on the vehicles are mounted such that a tilt in one direction will extend one L.V.D.T. and compress the other. This helps to stabilise the control system, and in the event of a failure the vehicle will tend to right itself.

The L.V.D.T. and Electrolevel are part of a Closed Loop Control System, one for each bogie. This system is shown in Fig. 28.

The signal is passed from the bogie sensor through a filter to eliminate any harmonics and interference. The resultant is an electrical signal that is proportional to the required tilt angle. This is fed to the summing point and hence to another filter, followed by an amplifier, which boosts the signal in order to supply a current to the Servo-valves. The oil flow is proportional to the current and goes to the bolster tilt jacks and tilting commences. The L.V.D.T.s are sensing the tilts and producing a signal which is fed back to the summing point. When this signal is equal to the one being produced by the bogie sensor, the system will be caused to stabilise until the demand for tilt is altered in any way.

Referring to Fig. 27, it is possible to test the L.V.D.T. The resistance measurements are as shown below:-

(a) Primary Winding Resistance (A-B) 260Ω - 320Ω.

(b) Secondary Winding Resistance (C-P) 280Ω - 340Ω.

(c) Secondary Winding Resistance (C-D) 560Ω - 680Ω.

(d) Short Circuit A to B on Primary and C to P and C to D on the Secondary. Using a 500V megger, check insulation resistance is greater than 50MΩ.

(e) Short ALL primary connections to ALL secondary connections. Using a 500V megger, check resistance between the windings and screen of flying lead is greater than 50MΩ.

Tilt Failure Detection Unit (T.F.D.U). See Fig. 29.

The most recent modification to the Tilt System is the fitting of the T.F.D.U. It is located on the right-hand bulk-head of the tilt pack underbelly bay on Trailer vehicles, and on the left-hand bulk-head of the brake equipment compartment for No.1 axle on B side of the power car.

The unit is connected to connector 2 of the Tilt Control Box on the tilt pack. There is an MCB fitted to this unit, which should be in the down position when running normally.

PLEASE NOTE:-

This is a delicate unit, handle with care. The surface of the mounting plate is machined flat and should be protected if the T.F.D.U. is removed.

Principle of Operation. See Fig. 30.

The T.F.D.U. contains an Electrolevel similar to those described previously. The signal it produces has an amplitude proportional to the cant deficiency (or excess) felt by the passengers in that vehicle. Under normal operation the signal should be within $\pm 3^{\circ}$ of zero at all times, even when going around curves.

If this signal exceeds any of the pre-set trip angles (4° for 110 seconds, 7° for 10 seconds or 12° for 0.5 seconds), then the latching mechanism (the MCB) trips and the Tilt System is switched off.

The signal is filtered in the T.F.D.U. to stop the MCB tripping due to momentary high signal levels caused by the train running over rough track. These filters act as a block to short pulses, but will allow a sustained signal to pass through.

Three different paths are used so that the T.F.D.U. responds more quickly to higher cant deficiencies. For example, a sustained input signal of 4° will cause the unit to trip in about 2 minutes, whereas a 12° signal will cause an almost instantaneous trip. One reason for the lengthy delay at the 4° level is that the Driving Trailer Vehicles of necessity experience some cant deficiency on transition curves, as they do not have a preceding tilt sensor.

When the Tilt System's AC supply is switched off, either by the T.F.D.U. or by some other means, the T.F.D.U. injects a zero tilt demand signal into the Tilt Control Box which has the effect of bringing the vehicle into an upright position. This will also happen if there is a fault in either DC supply rail, or a fault in one of the L.V.D.T.s.

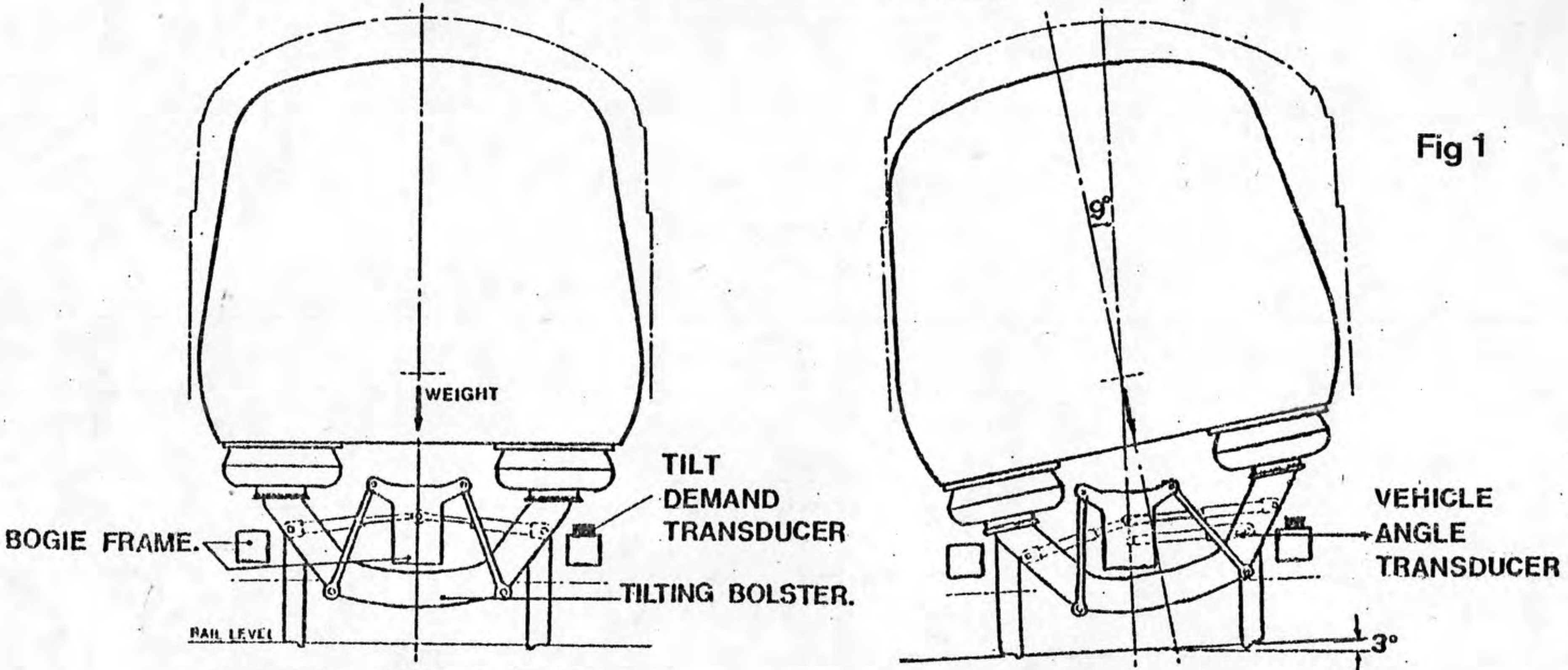
A complete schematic which combines the main items in all the various sections of this handout in a single diagram, is shown in Fig. 31. Using previous drawings and notes, the student will be expected to work out the operation of this circuit.

NOTE.
It is of vital importance that the Electrolevel is NOT subjected to resistance testing. The DC voltage used will cause an electrolytic action to take place in the brine solution rendering the device useless. A special meter will be provided for this task.

STUDENT'S NOTES.

STUDENT'S NOTES.

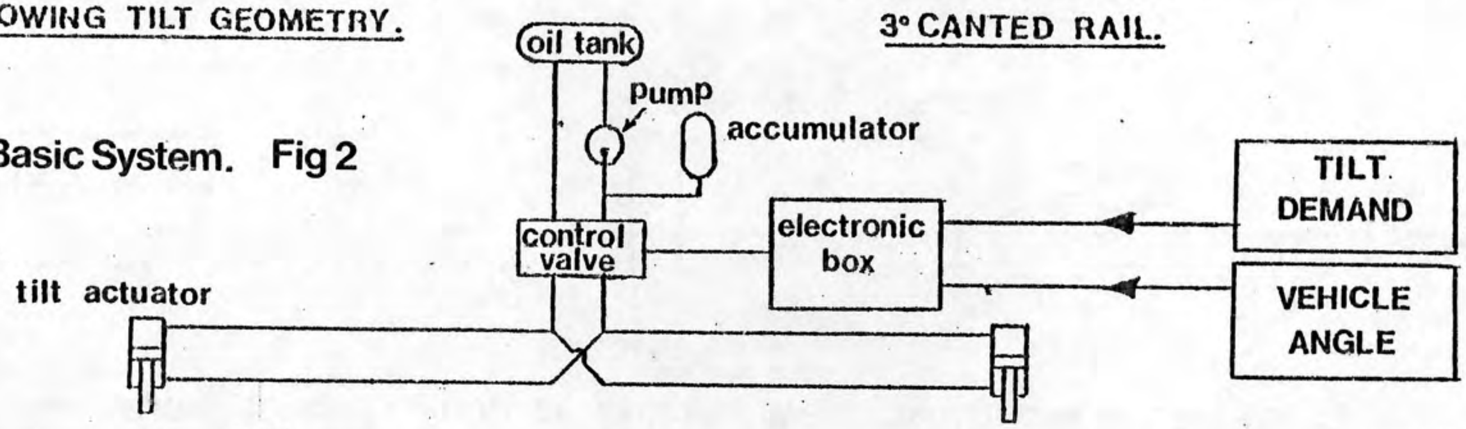
DIAGRAM OF TILT SUSPENSION.



SECTION THROUGH THE TRAIN
SHOWING TILT GEOMETRY.

CURVING AT 9°TILT ON A
3° CANTED RAIL.

Fig 1

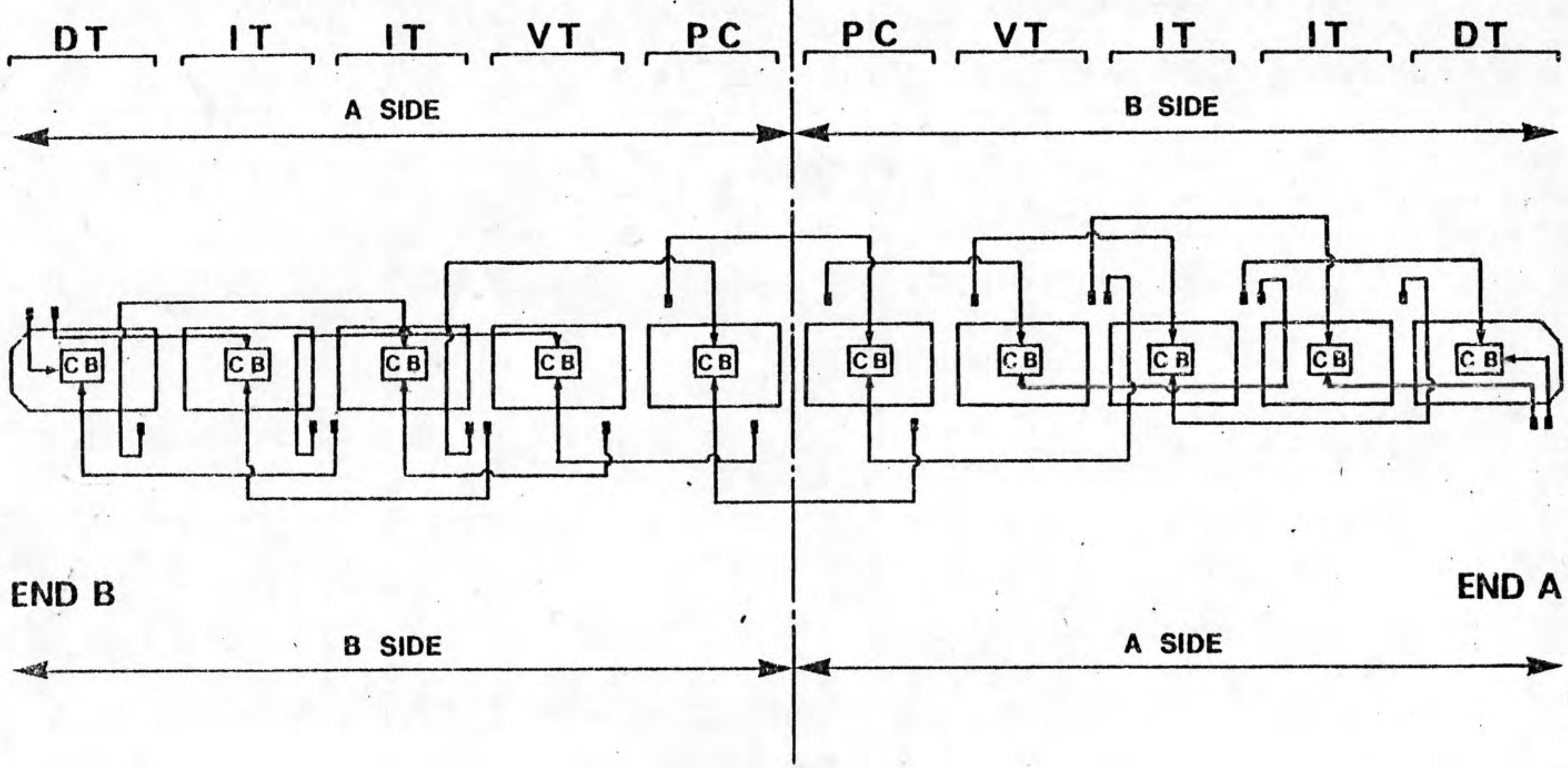


Tilt Control, Basic System. Fig 2

SCHEMATIC REPRESENTATION OF ELECTROLEVEL TRANSDUCER LOCATIONS

Mark 3 Tilt System

Fig 3



KEY

ELECTROLEVEL TRANSDUCER

CB TILT ELECTRONIC CONTROL BOX

It always has two transducer inputs – one from the forward going electrolevel & one from the reverse going electrolevel

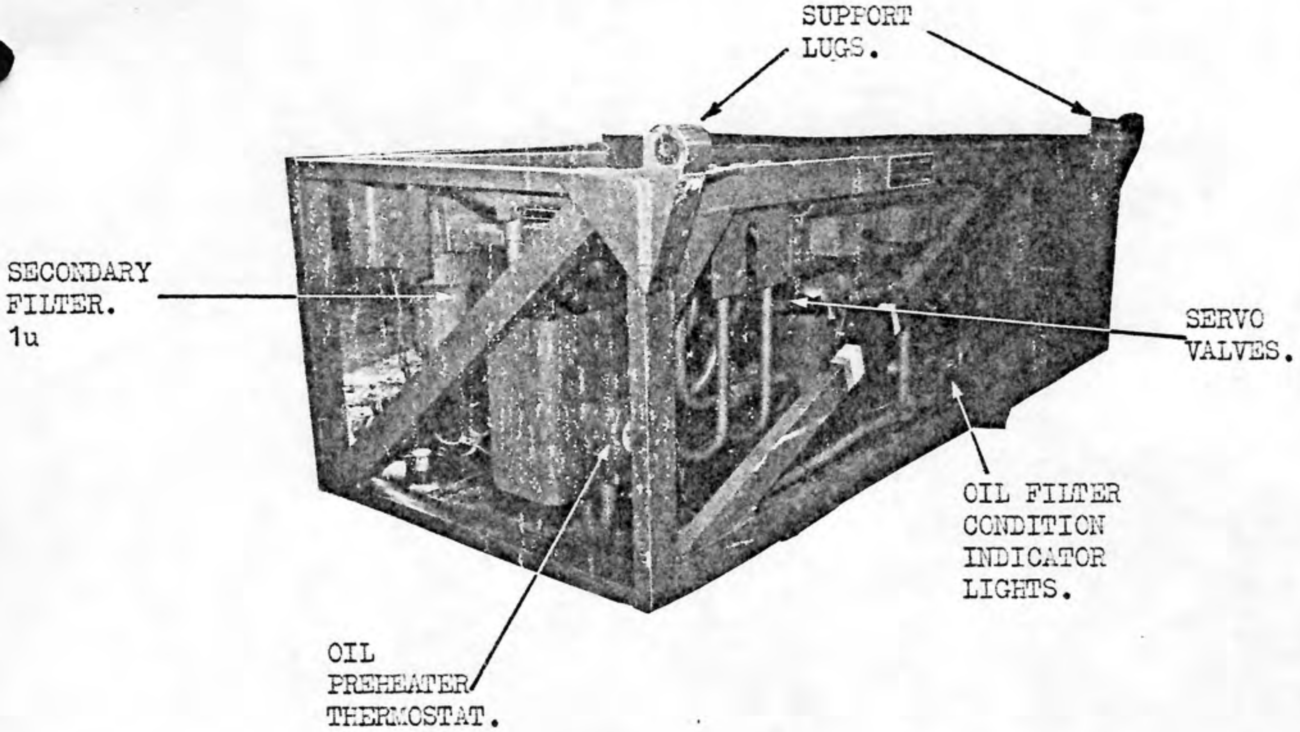
NOTE

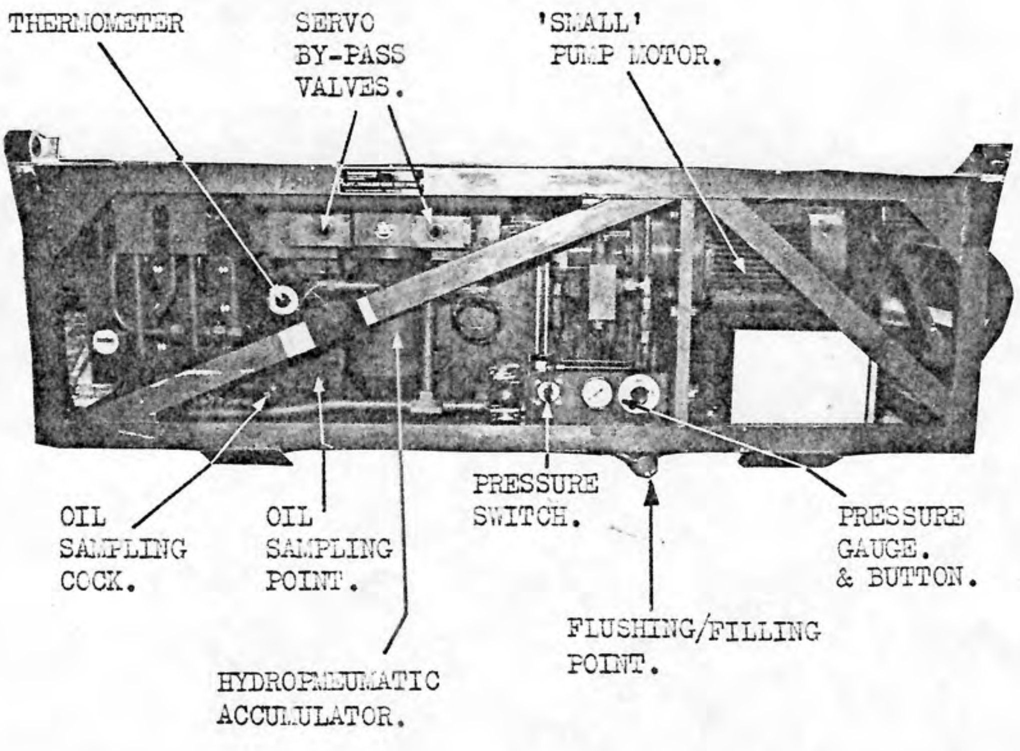
ALL TRAILER CAR TILT PACKS LOCATED SIDE A

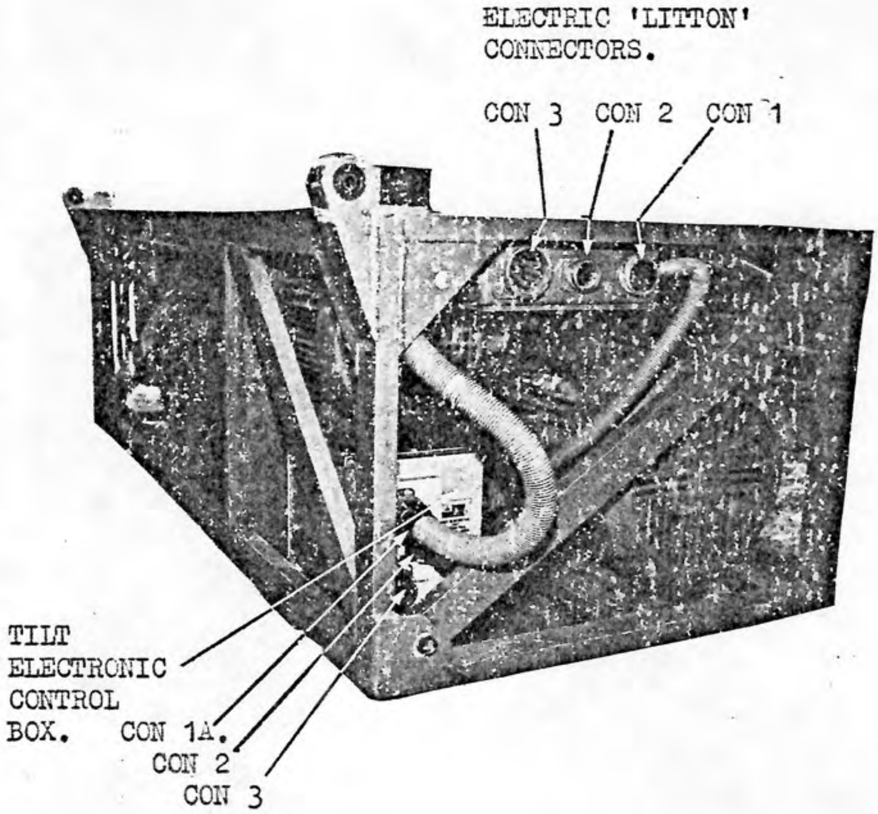
ALL POWER CAR TILT PACKS LOCATED SIDE B

Trailer Car Tilt Pack

Fig 4






ELECTRIC 'LITTON'
CONNECTORS.
CON 3
CON 2
CON 1
TILT
ELECTRONIC
CONTROL
BOX.
CON 1A.
CON 2
CON 3

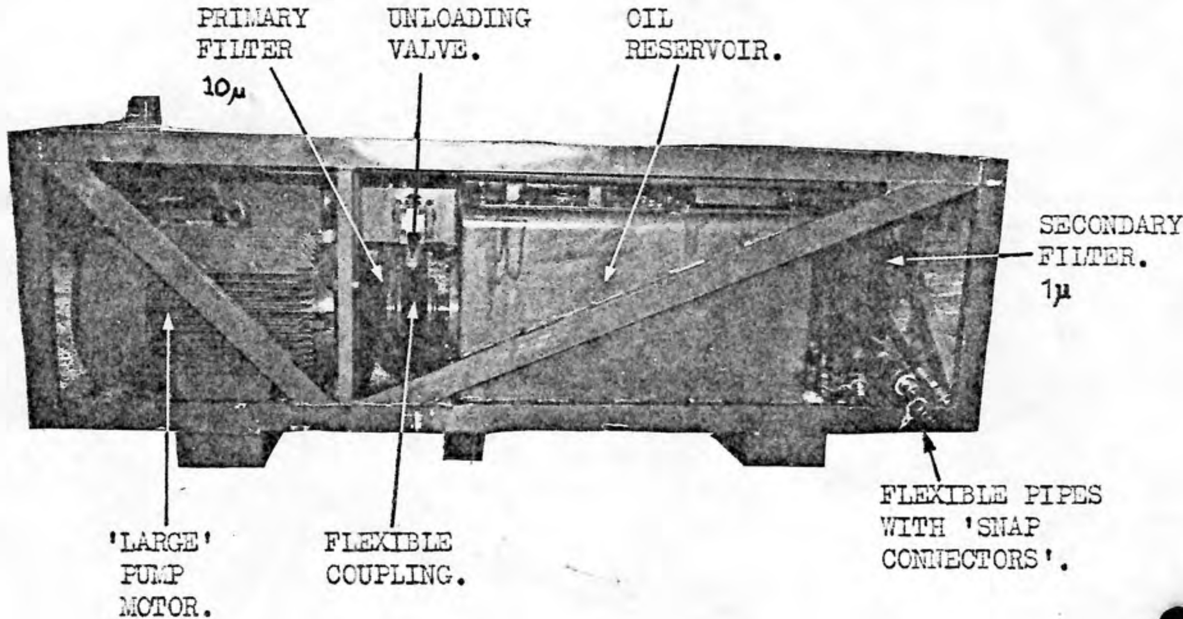
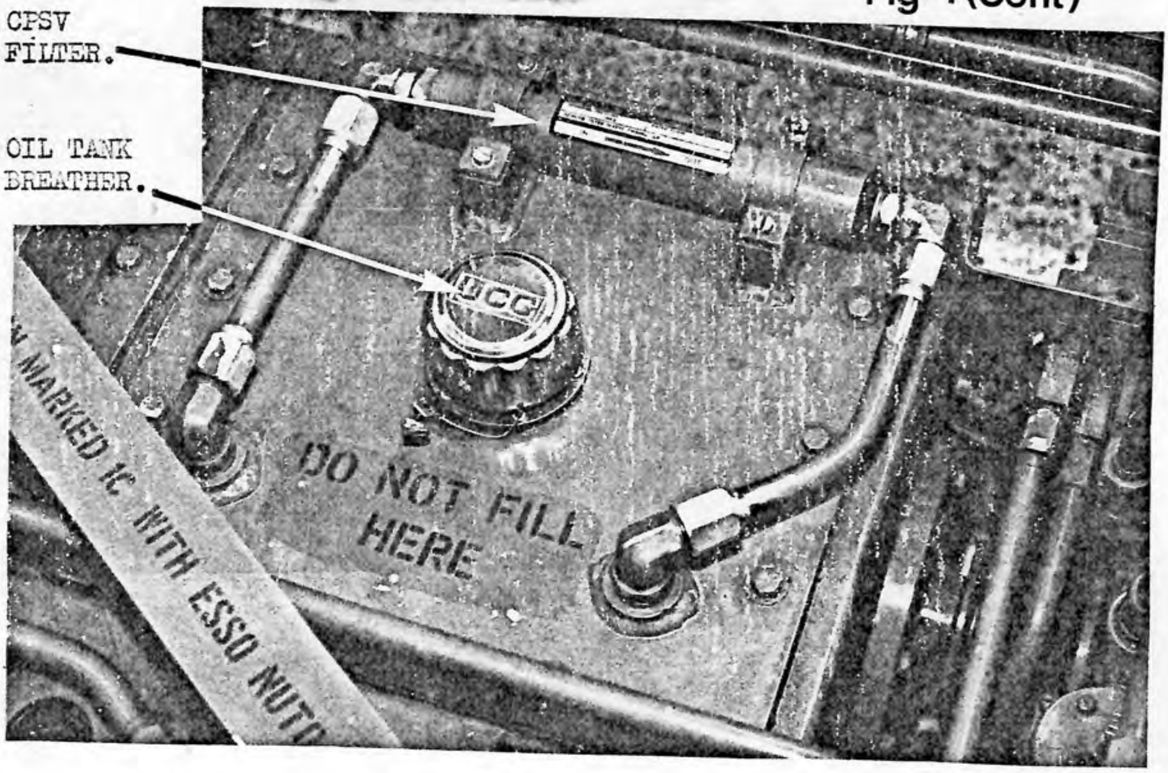

PRIMARY
FILTER
10µ
UNLOADING
VALVE.
OIL
RESERVOIR.
SECONDARY
FILTER.
1µ
'LARGE'
PUMP
MOTOR.
FLEXIBLE
COUPLING.
FLEXIBLE PIPES
WITH 'SNAP
CONNECTORS'.

Fig 4 (Cont)

Fig 4 (Cont)

CPSV
FILTER.

OIL TANK
BREATHER.

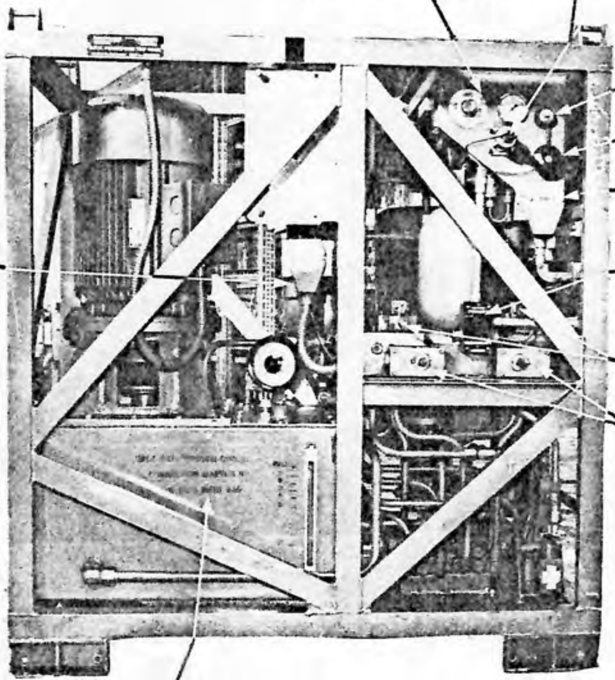


Power Car Tilt Pack Fig 5

PRESSURE
GAUGE
& PUSHBUTTON.

PRESSURE
SWITCH.

OIL PREHEATER
THERMOSTAT.



OIL SAMPLING POINT.

OIL SAMPLING COCK.

OIL COOLING THERMOSTAT.

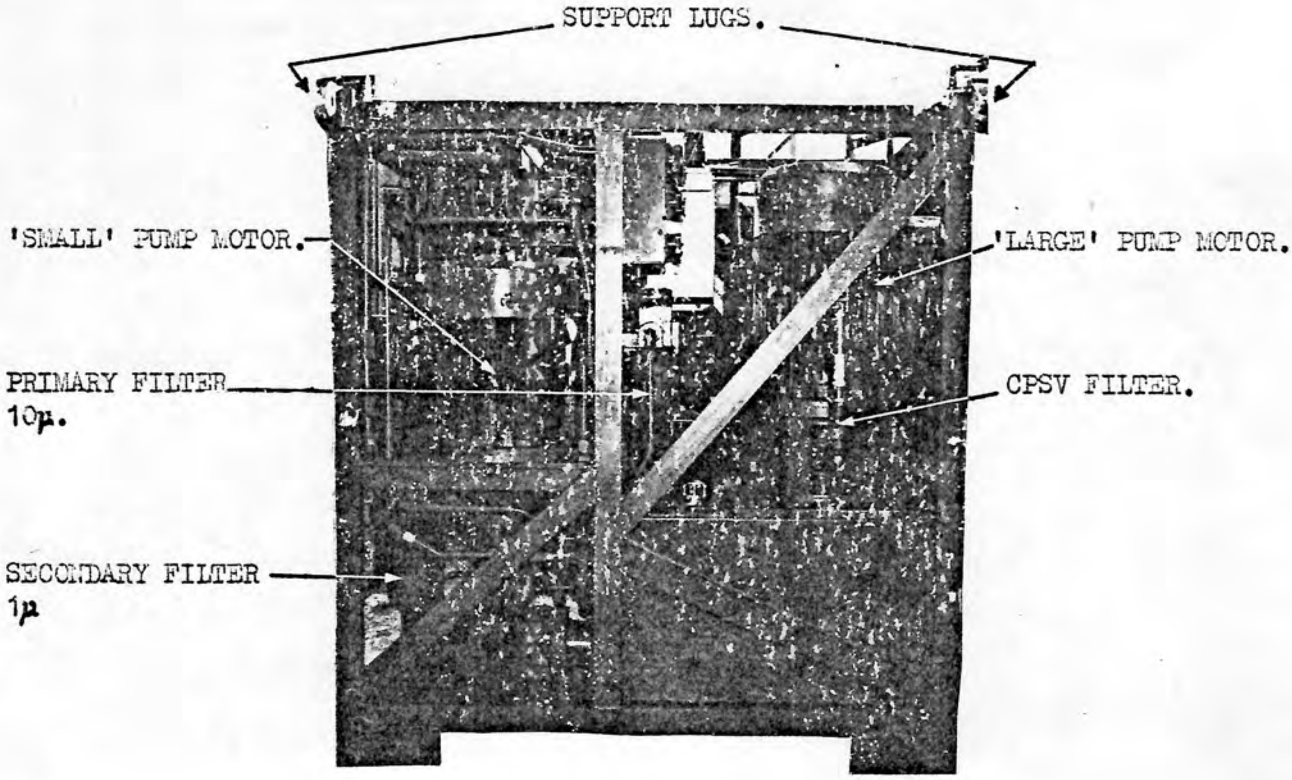
OIL FILTER CONDITION.

INDICATOR LIGHT.

SERVO VALVES.

SERVO BY-PASS
VALVES.

OIL
TANK.


SUPPORT LUGS.
'SMALL' PUMP MOTOR.
'LARGE' PUMP MOTOR.
PRIMARY FILTER 10μ.
CPSV FILTER.
SECONDARY FILTER 1μ

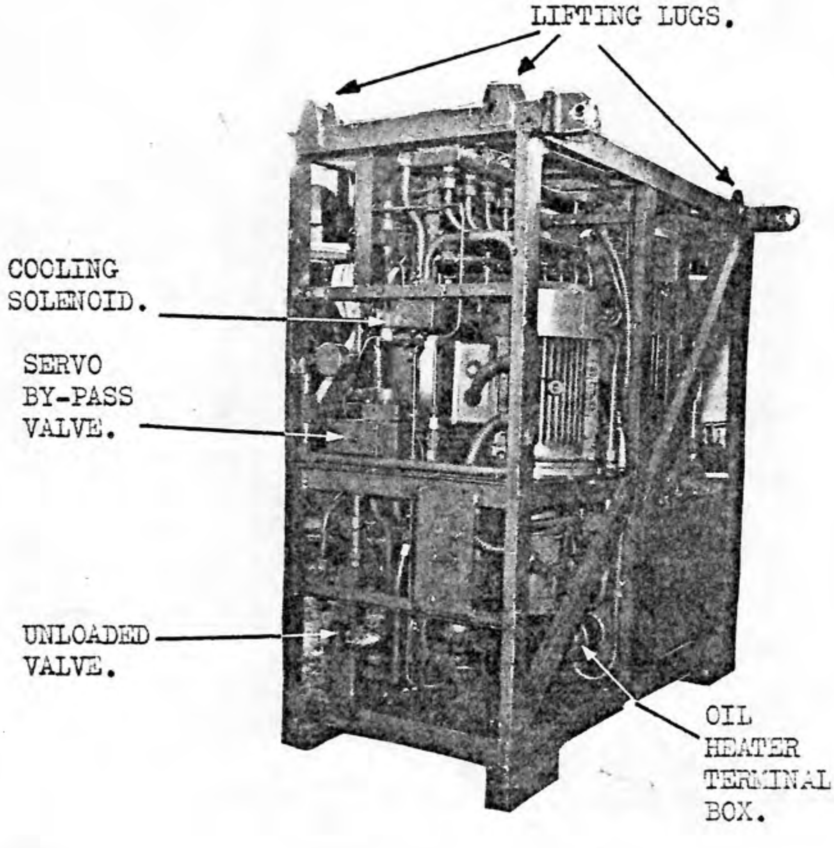

LIFTING LUGS.
COOLING SOLENOID.
SERVO BY-PASS VALVE.
UNLOADED VALVE.
OIL HEATER TERMINAL BOX.

Fig 5 (Cont)

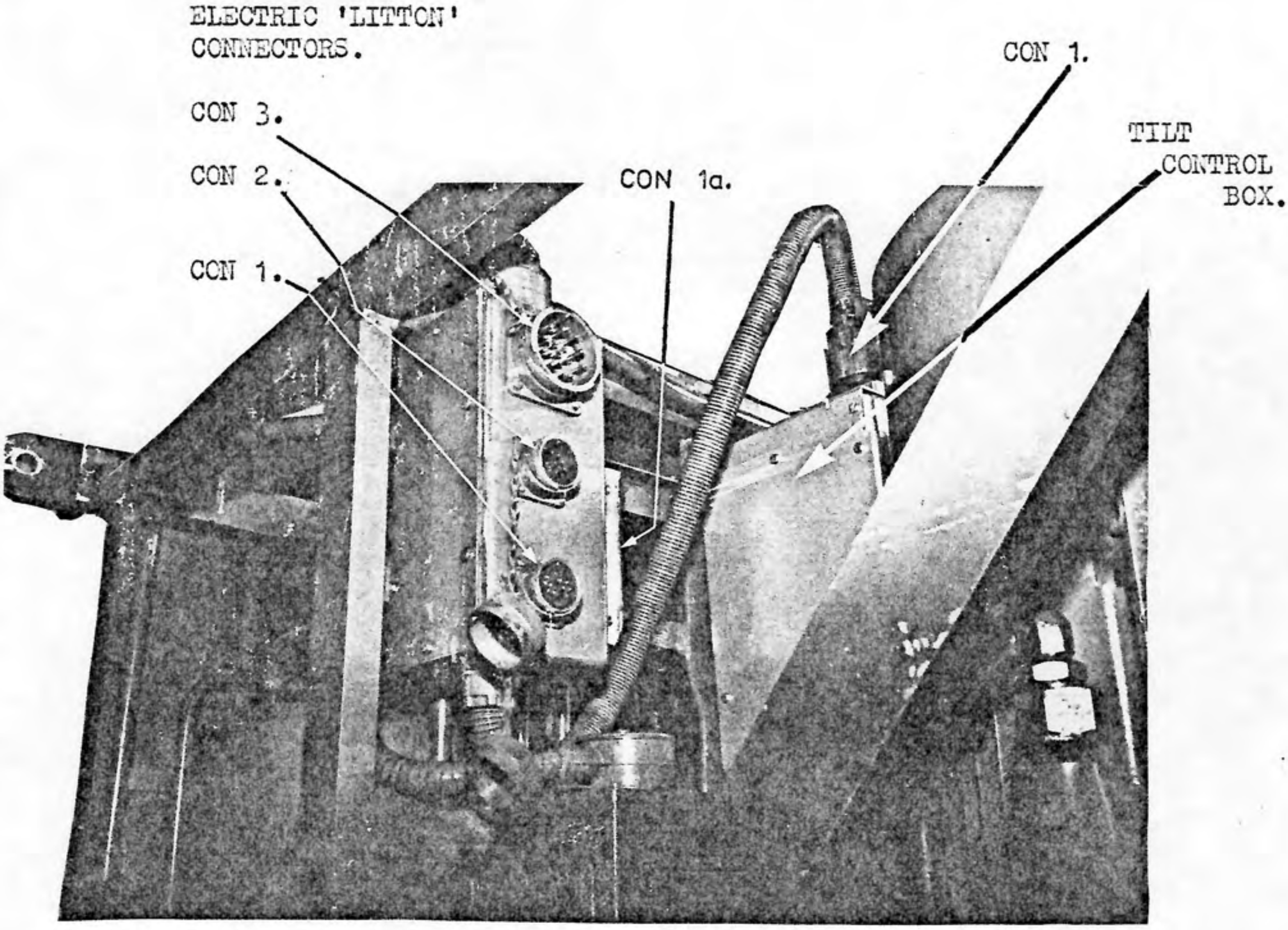

ELECTRIC 'LITTON' CONNECTORS.
CON 3.
CON 2.
CON 1.
CON 1a.
CON 1.
TILT CONTROL BOX.

Fig 5 (Cont)

QUICK RELEASE COUPLING.

OPERATION.

The sleeve is pulled to the left which releases the locking balls into the recess.
Upon parting of male and female connectors the spring loaded sealing valves will seal against their respective seats, thus forming two separate sealed couplings.

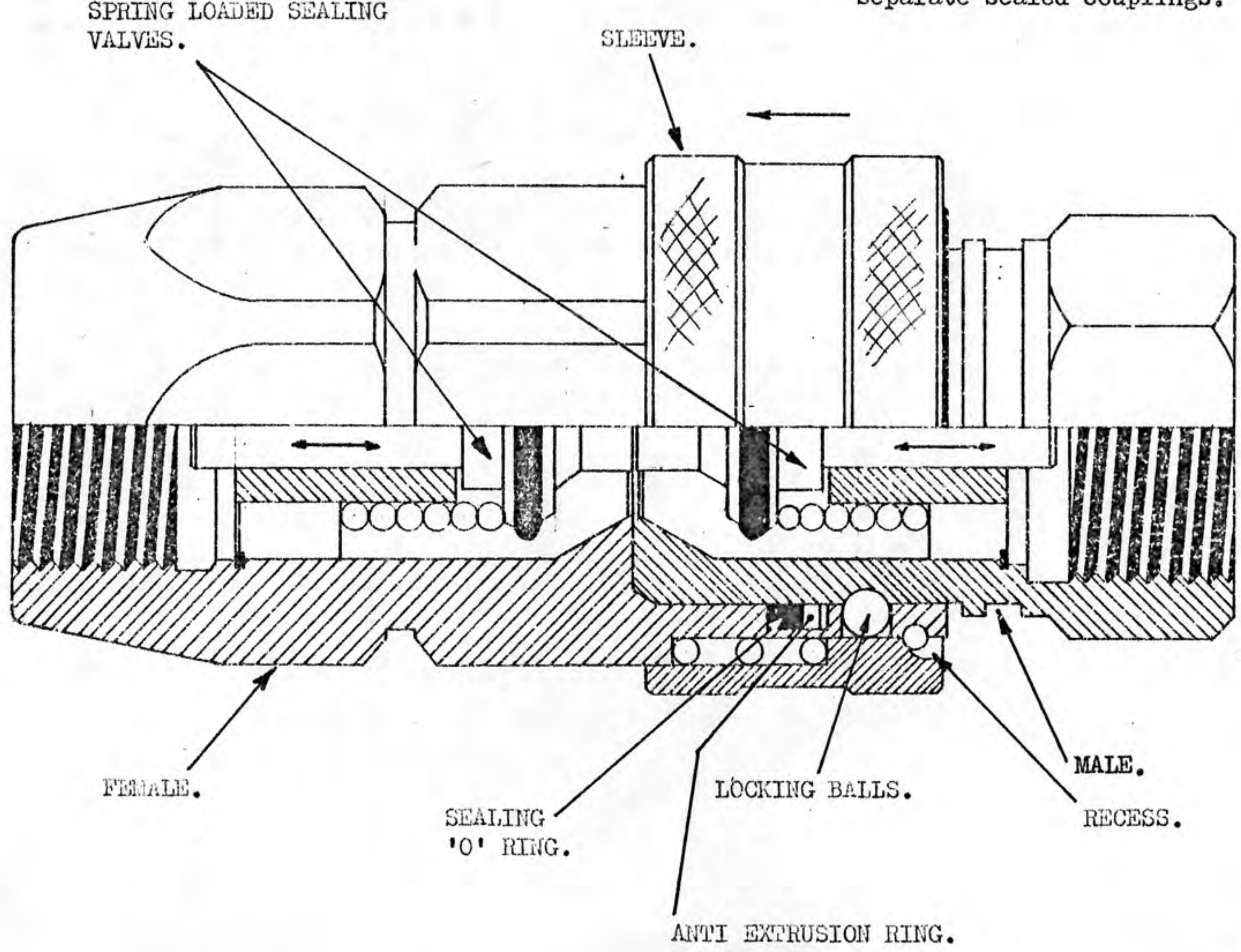
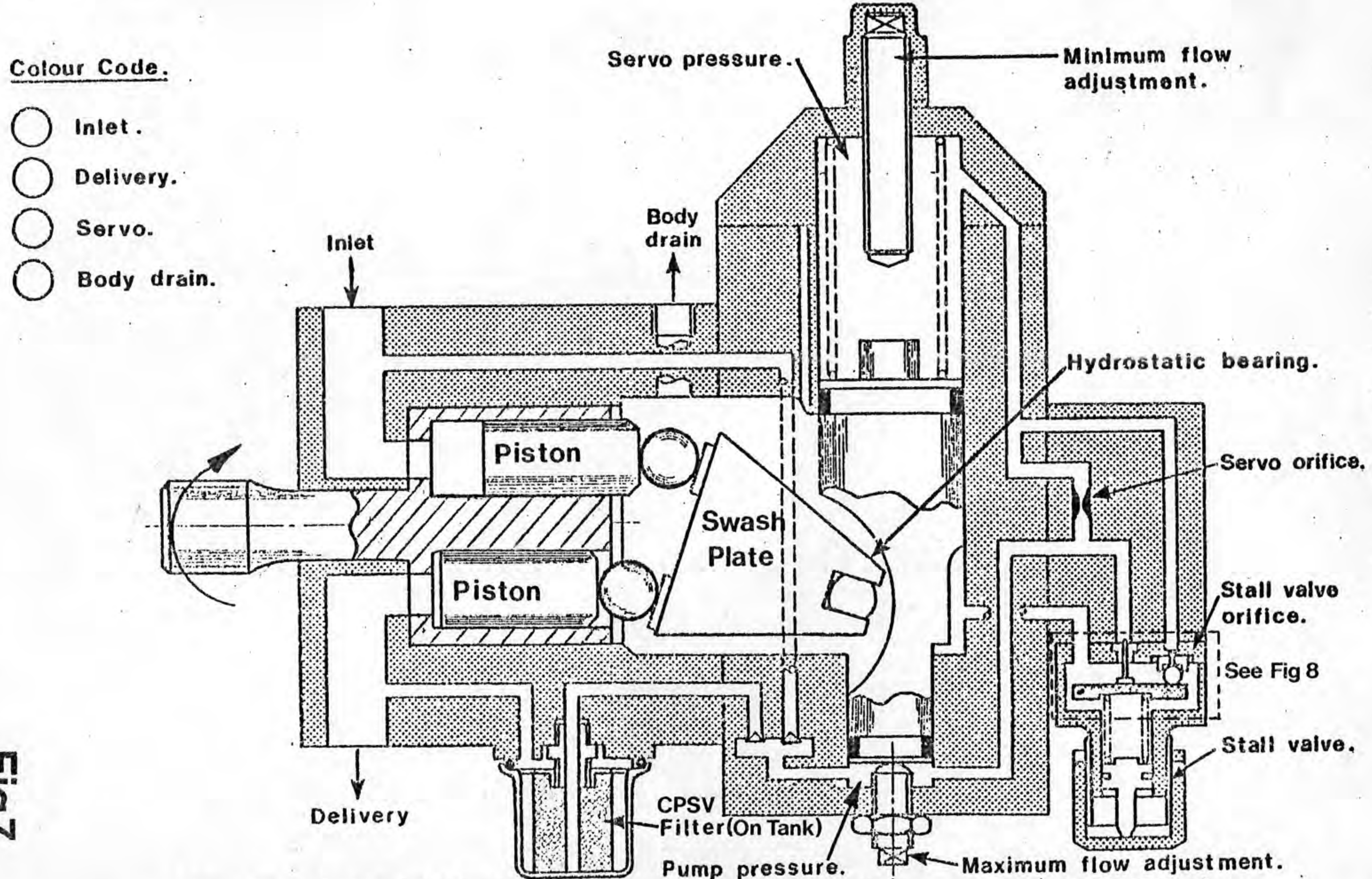
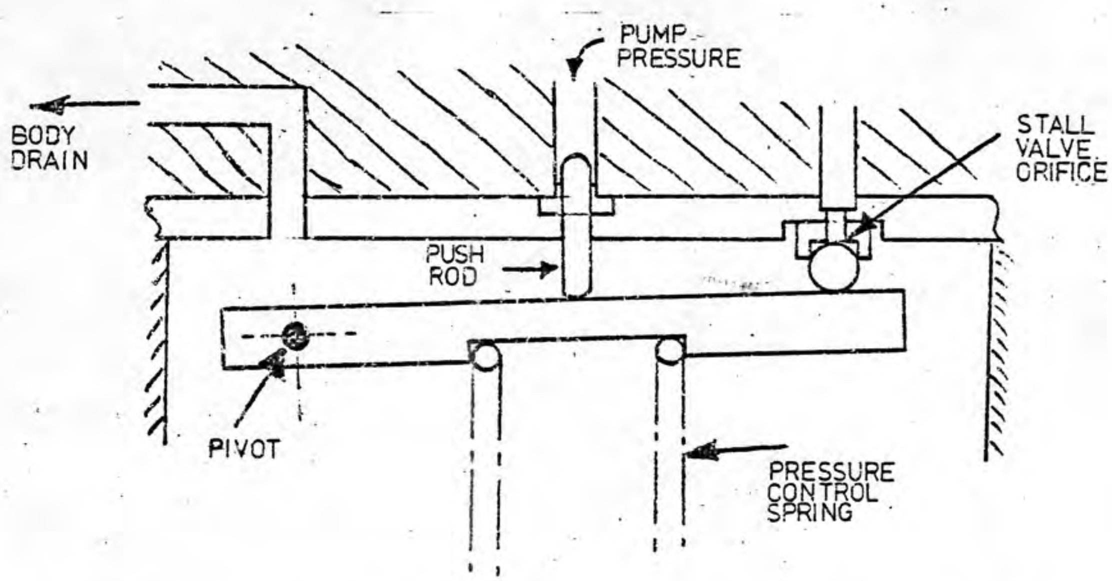


Fig 6

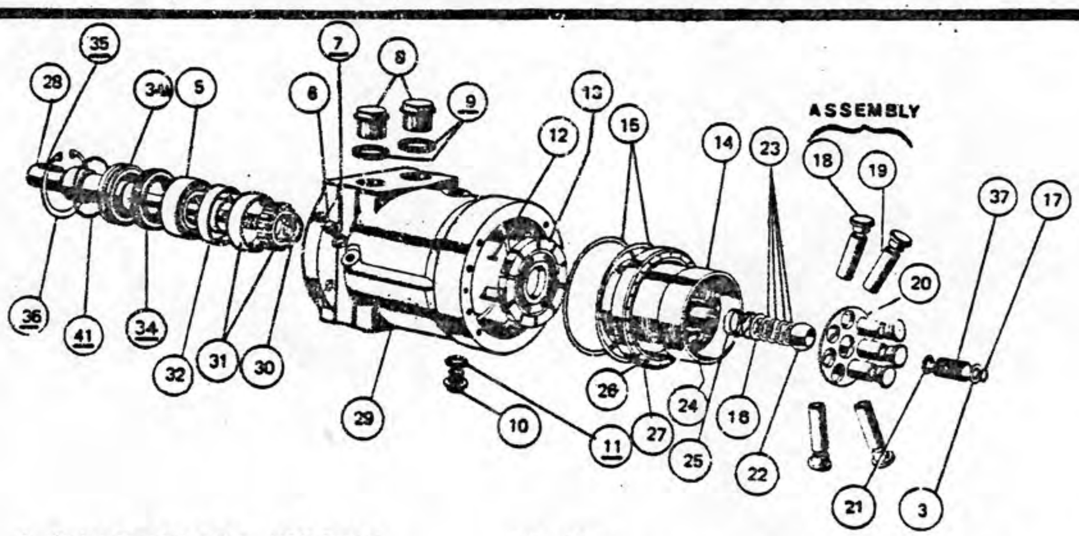


LUCAS CONSTANT PRESSURE PUMP WITH STALL VALVE (C.P.S.V.):

Fig7



CONSTANT PRESSURE SERVO VALVE (C.P.S.V.) **Fig 8**



1 Spring Retaining Pin NOT PM125
2 Sealing Ring NOT PM125
3 Washer (and shims 125 ONLY)
4 Backing Washer NOT PM125
5 Front Shaft Bearing
6 Plug (2)
7 Sealing Washer (2)
8 Plug (2) PM500 & PM125 only
9 Sealing Washer (2)
10 Plug
11 Sealing Washer
12 Locating Pin
13 Port Insert
14 Rotor Sub Assembly
15 Shims
16 Spring Seat NOT PM125
17 Circlip
18 Slipper } Assembly
19 Piston }
20 Auxiliary Complete
21 Thrust Washer
22 Thrust Ball
22a Spring Housing
23 Shims
24 Retaining Plate Screws PM125 & PM500 ONLY (7)
25 Thrust Ball Spring
26 Retaining Plate PM125 & PM500 ONLY
27 Rotor Bearing
28 Drive Shaft
29 Body
30 Circlip
31 Rear Shaft Bearing
32 Distance Pieces
33 Drive Coupling NOT PM125
34 Shaft Seal
34a Seal Housing
35 Key
36 Circlip
37 Spring
38 Shaft Retaining Bolt NOT PM125
39 Spacer PM1000 ONLY
40 Blanking Plate PM1000 & PM3000 ONLY (2)
41 Sealing Ring PM125 ONLY
42 Blanking Plate Bolts PM1000 & PM3000 ONLY (8)
43 Sealing Ring PM1000 & PM 3000 ONLY

EXPLODED VIEW OF C.P. PUMP

Fig 9

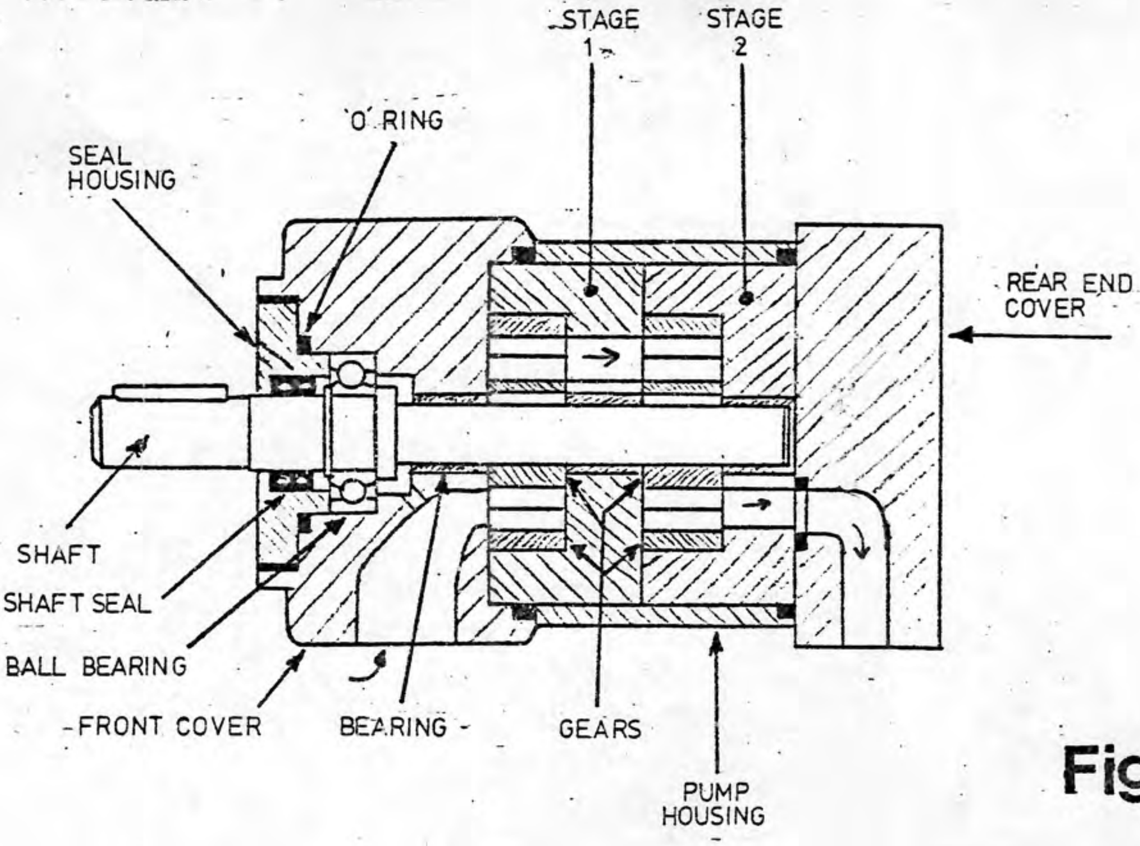
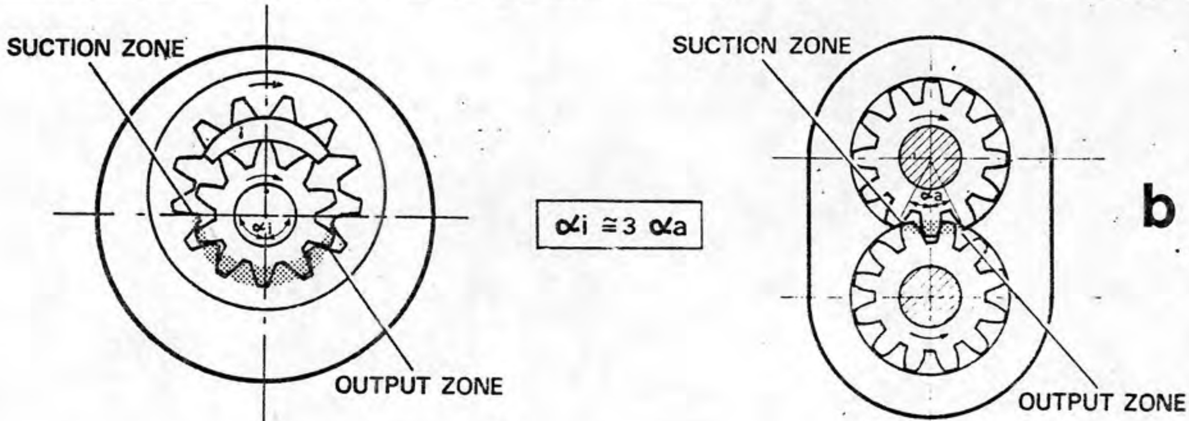
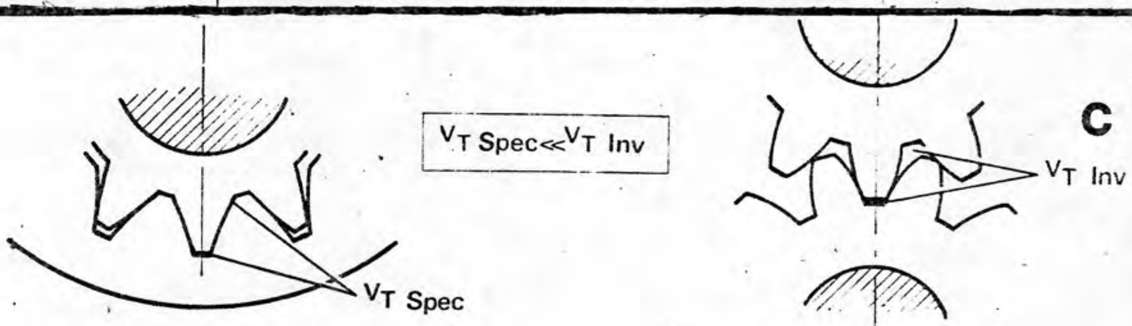

STAGE 1
STAGE 2
'O' RING
SEAL HOUSING
REAR END COVER
SHAFT
SHAFT SEAL
BALL BEARING
FRONT COVER
BEARING
GEARS
PUMP HOUSING

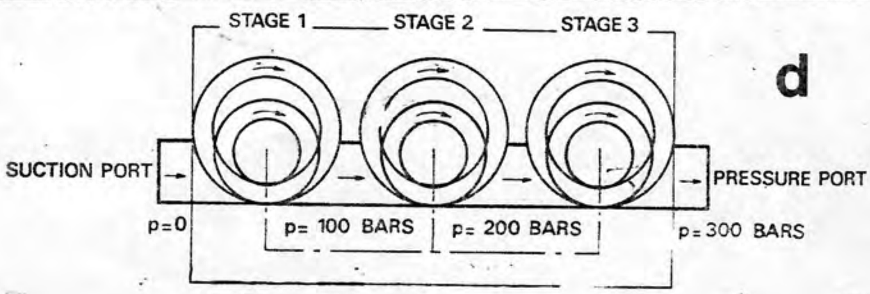
Fig 10 a


SUCTION ZONE
αi
$\alpha i \cong 3\ \alpha a$
SUCTION ZONE
αa
OUTPUT ZONE
OUTPUT ZONE

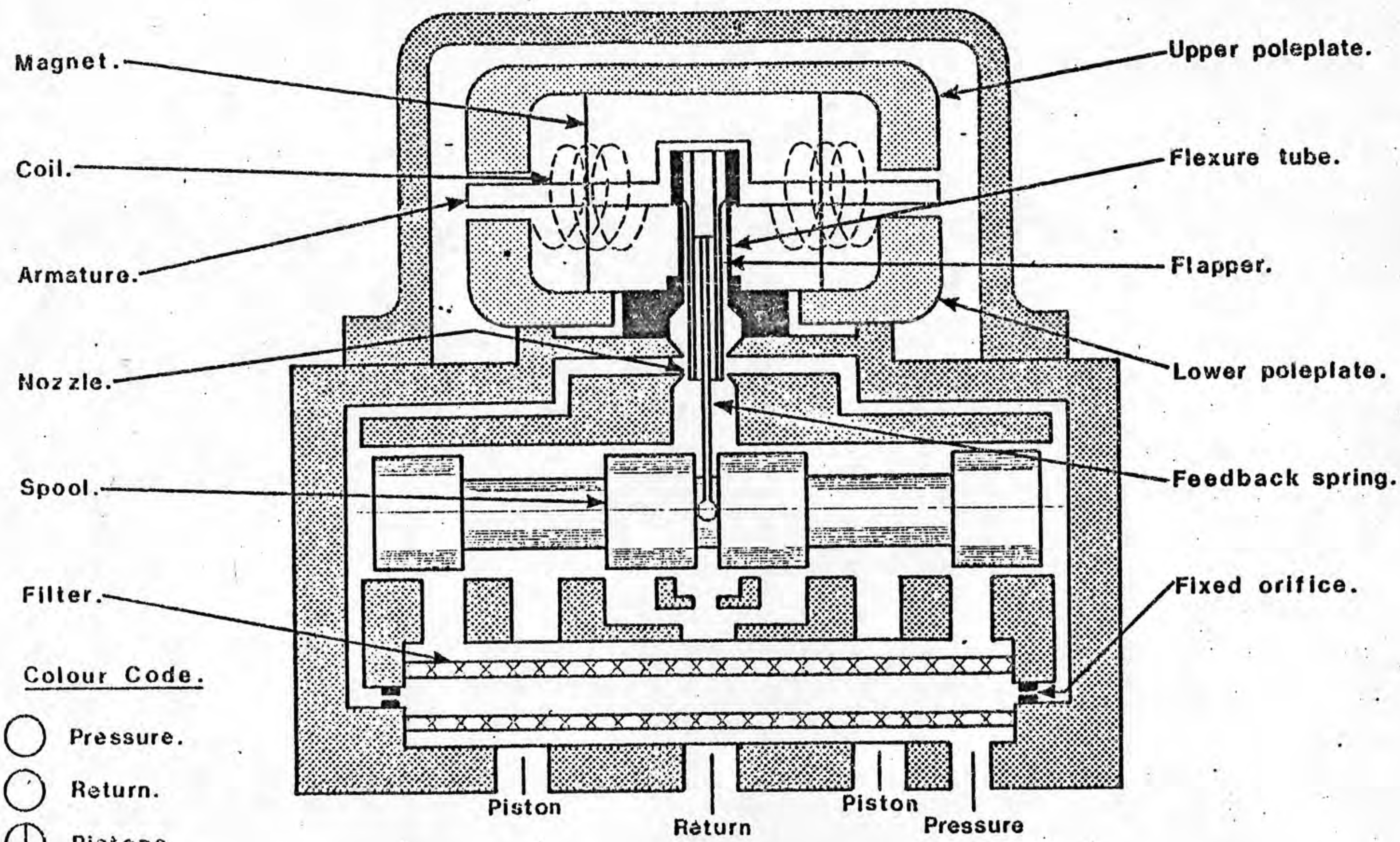
b


V_T Spec$\ll V_T$ Inv
V_T Spec
V_T Inv

c


STAGE 1
STAGE 2
STAGE 3
SUCTION PORT
PRESSURE PORT
p=0
p= 100 BARS
p= 200 BARS
p=300 BARS

d



Colour Code.

Pressure.
Return.
Pistons
Internal control pressure.

DOWTY SERIES 4551 SERVO VALVE.

Fig 11

APT TRAILER CAR TILT PACK HYDRAULIC CIRCUIT.

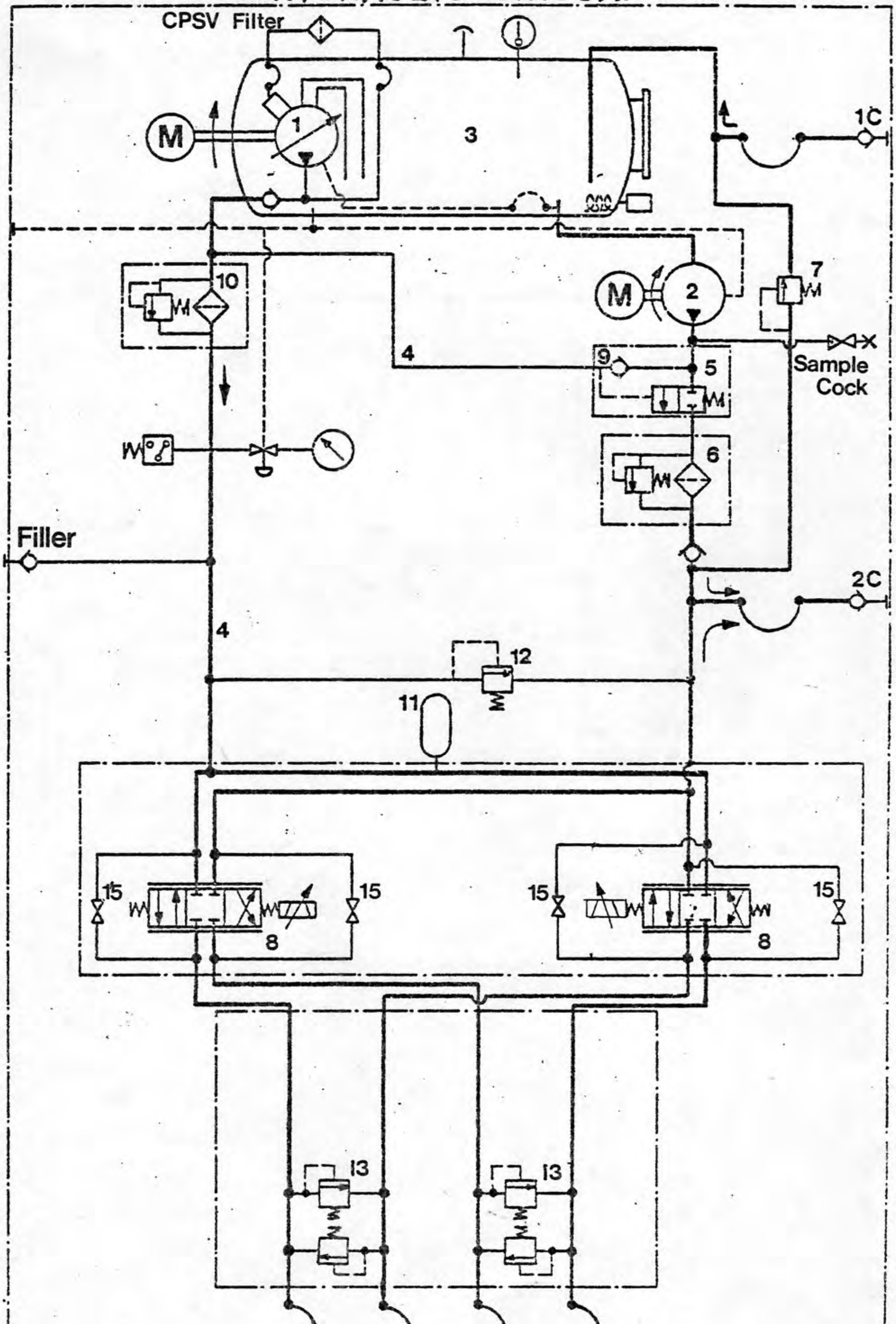


Fig 12

POWER CAR TILT PACK
COOLING CIRCUIT

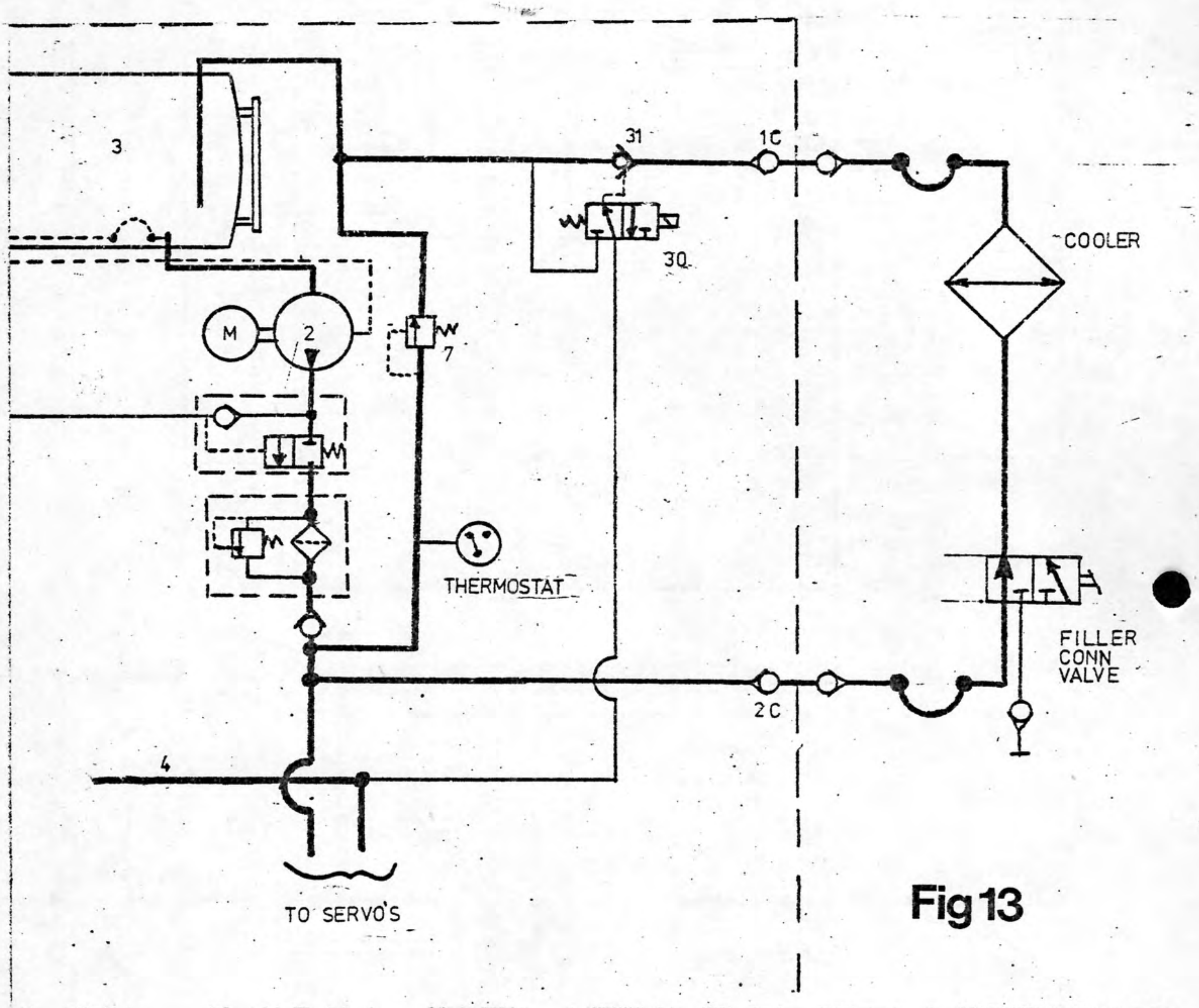
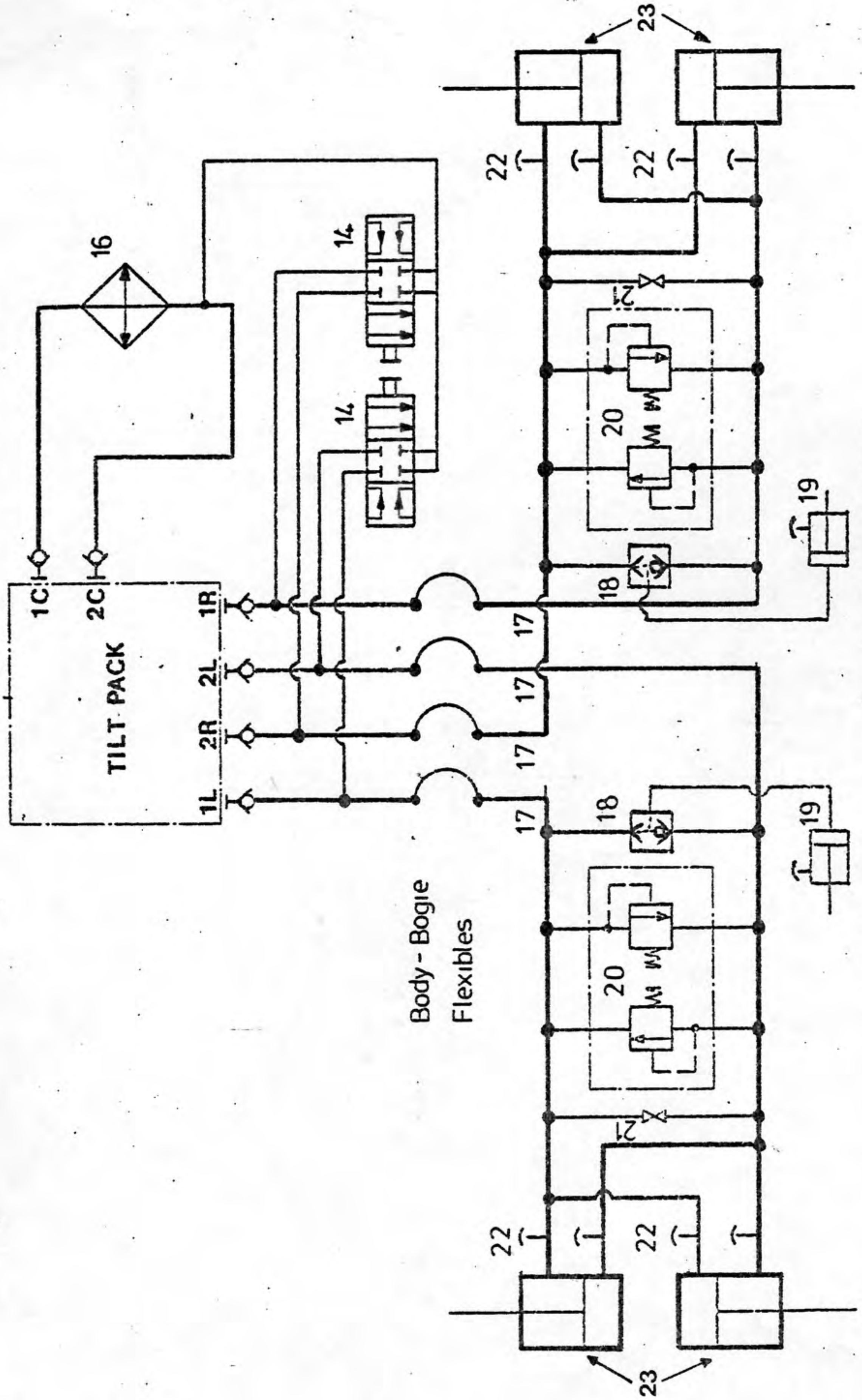


Fig 13



VEHICLE BODY / BOGIE CIRCUIT

Fig 14

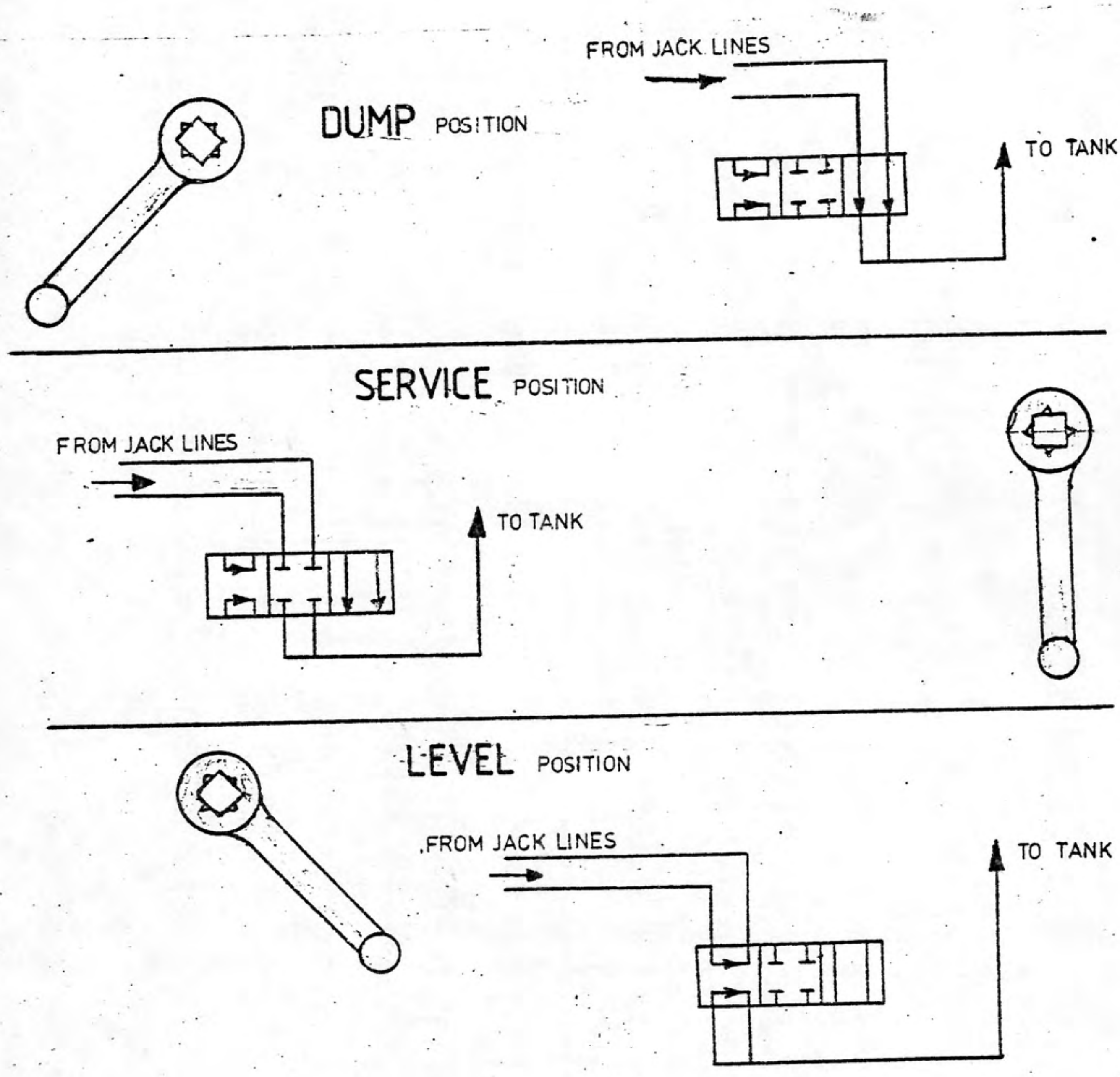
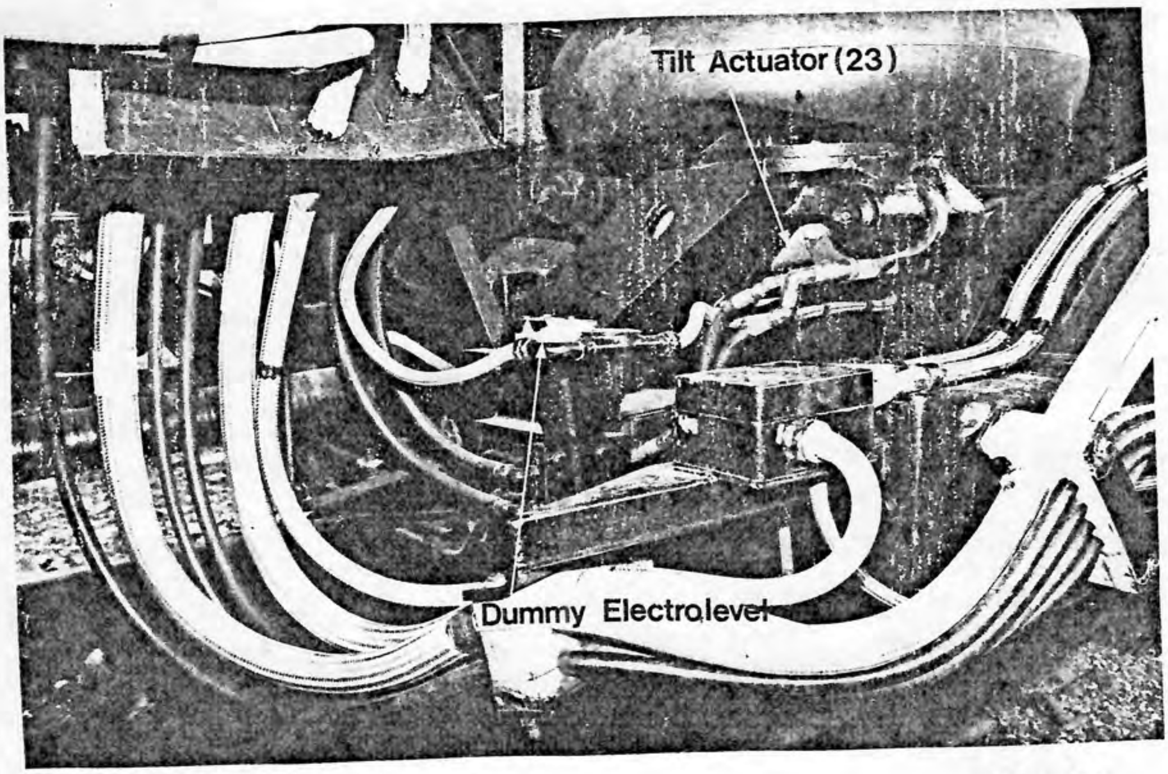
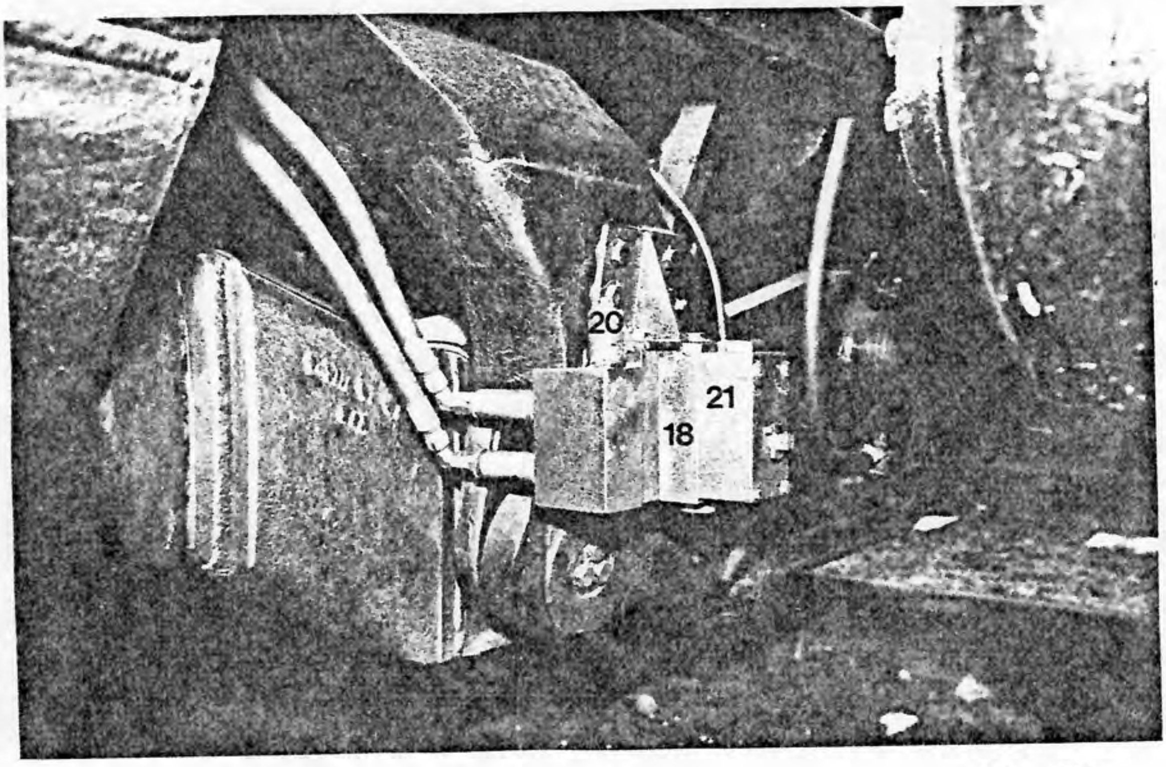

DUMP POSITION
FROM JACK LINES
TO TANK
SERVICE POSITION
FROM JACK LINES
TO TANK
LEVEL POSITION
FROM JACK LINES
TO TANK

Fig 15



Tilting Bolster

Fig 16



Location of Valves on Bogie

Fig 17

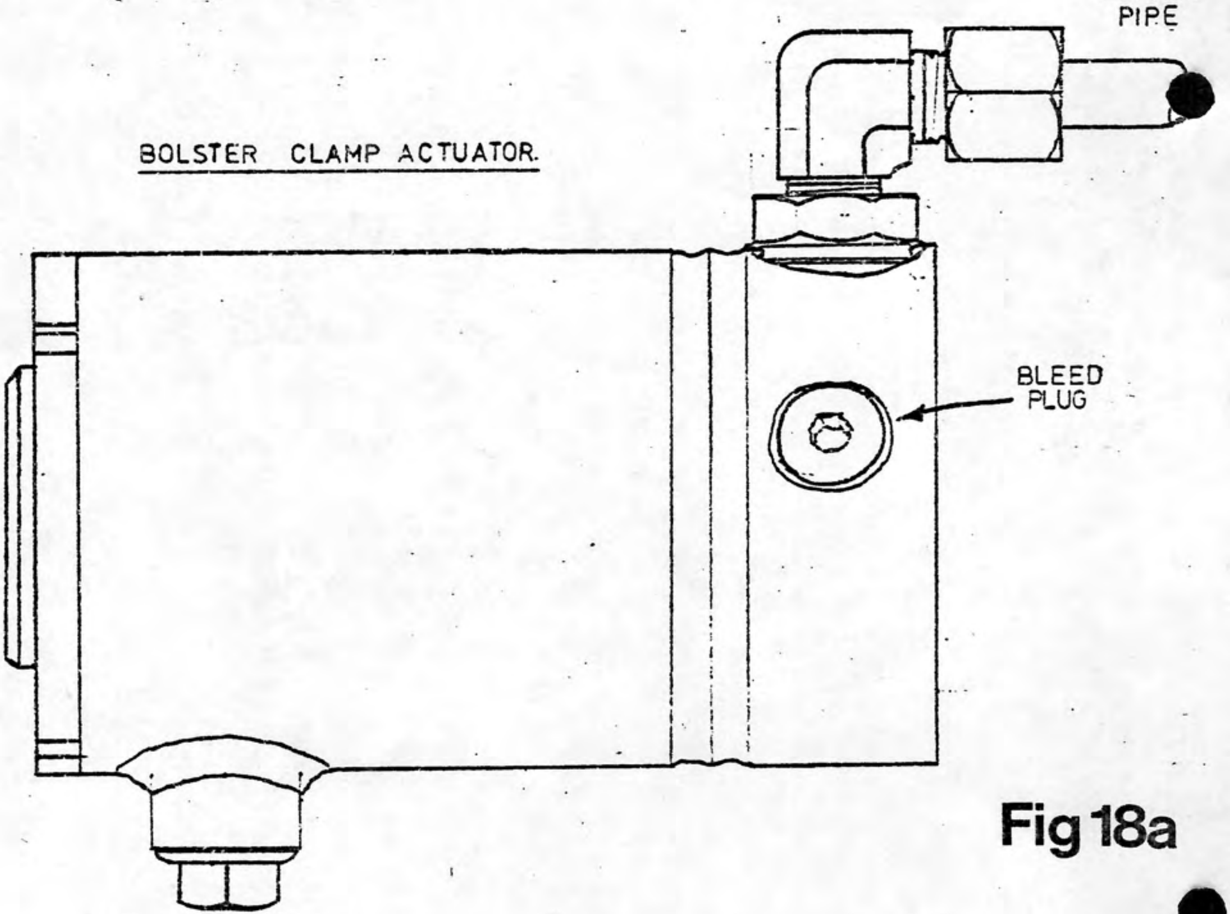
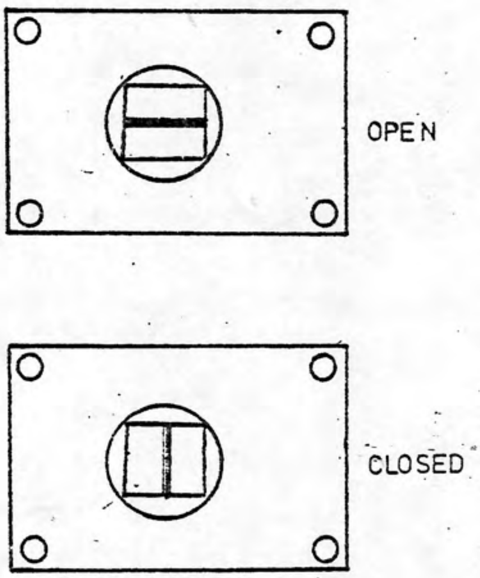
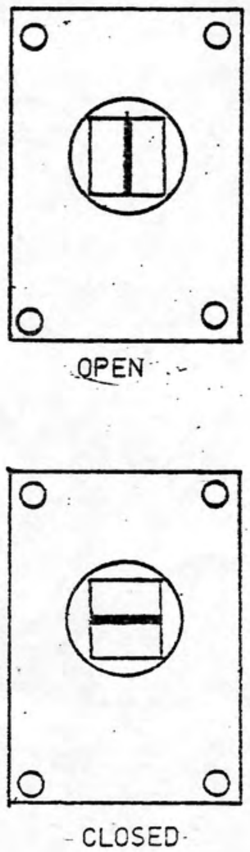


Fig 18a

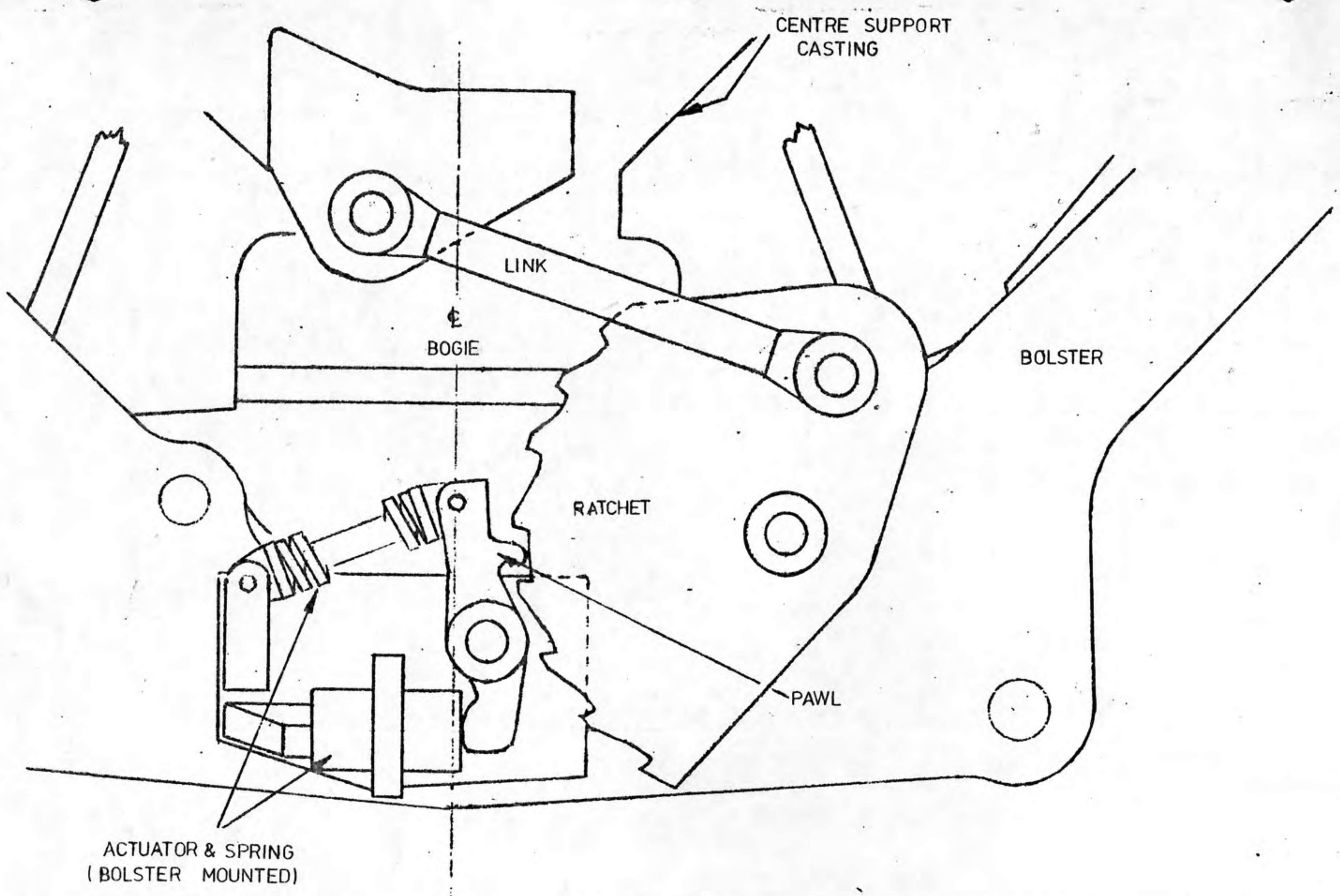


BOGIE FLUSHING VALVE
(POWER CARS)



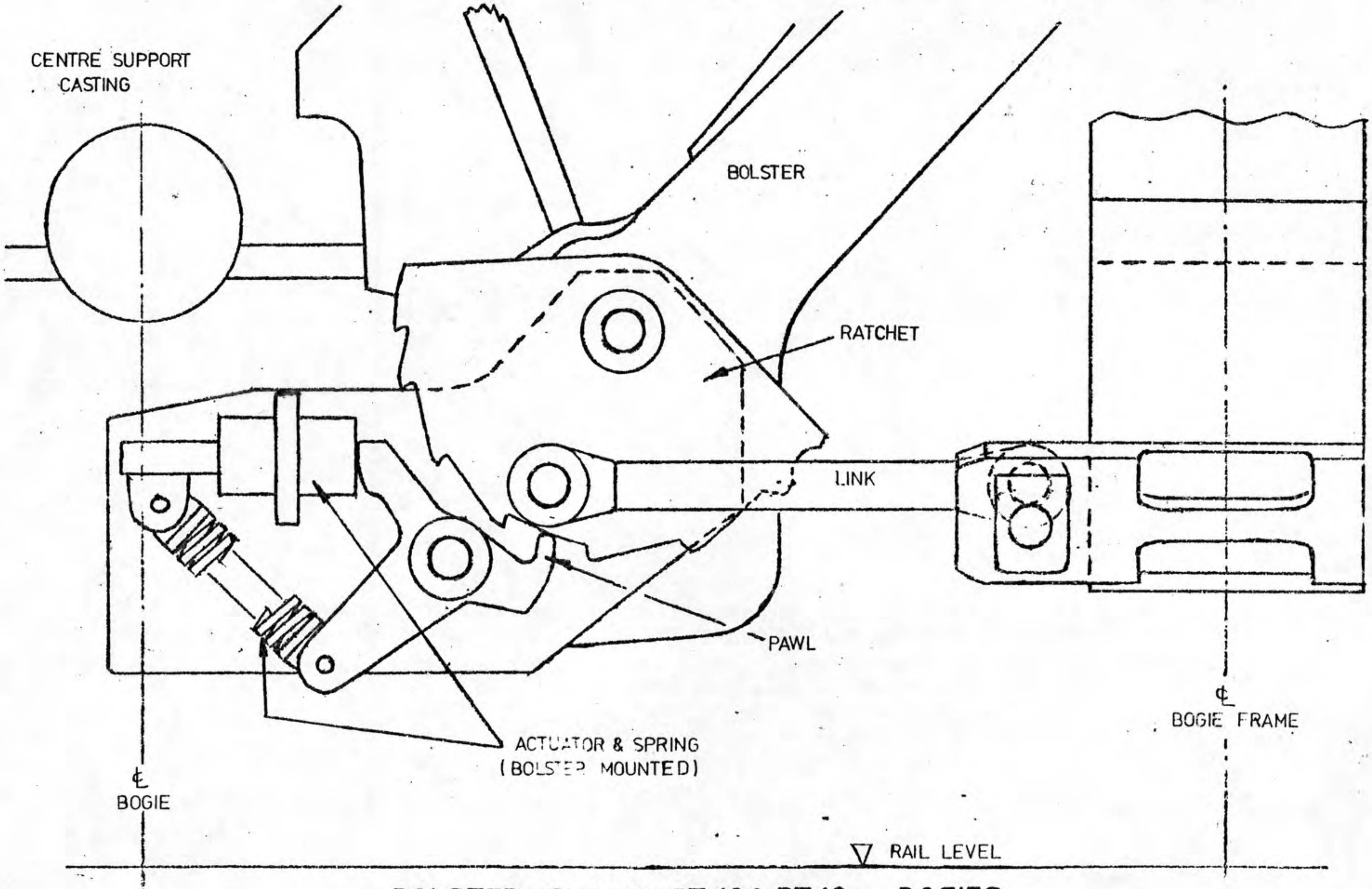
BOGIE FLUSHING VALVE
(TRAILER CARS)

Fig 18b



BOLSTER CLAMP - BT 11 & BT 11a BOGIES

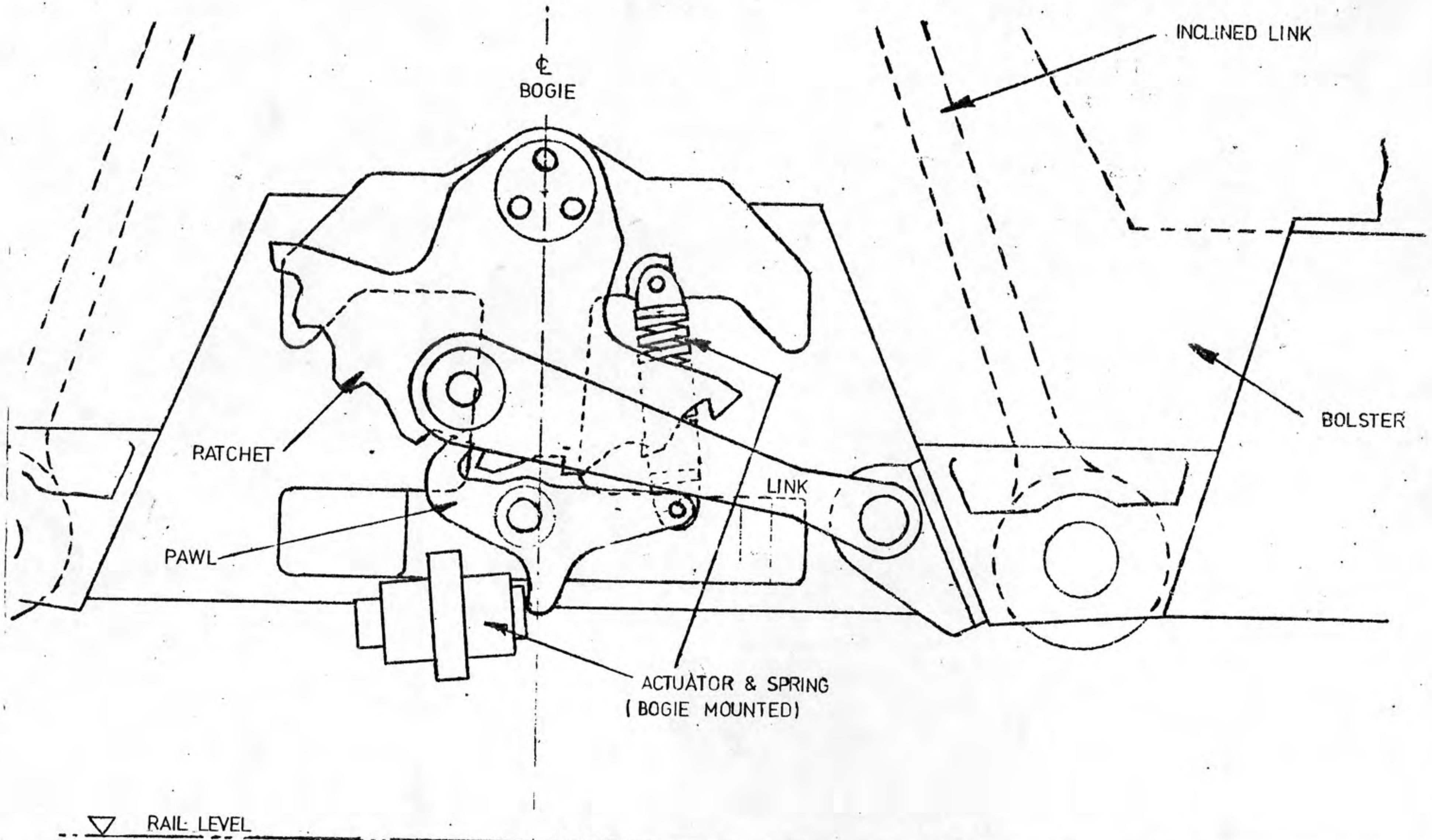
FIG 19a SCALE 1:5



BOLSTER CLAMP BT 12 & BT 12a BOGIES

CCH

FIG 19b SCALE 1:5



BOLSTER CLAMP BP 17 & BP 17a BOGIES

FIG 19c SCALE 1:5

CCH

Size Range µm	Particle Size and Count per 100 ml. Sample Volume								
	Class 1-H	Class 2-H	Class 3-H	Class 4-H	Class 5-H	Class 6-H	Class 7-H	Class 8-H	Class 9-H
+ 100	7	7	7	22	32	43	47	57	68
50 – 100	15	15	15	51	89	128	147	185	224
25 – 50	94	104	133	439	829	1220	1415	1805	2196
15 – 25	290	370	529	1744	3480	5220	6090	7830	9570
10 – 15	701	1810	3677	12137	29143	42181	50442	67240	84051
5 – 10	1617	22320	50050	165168	450864	714240	857088	1142784	1428480
1 – 5	30882	420000	860606	2840000	8568000	14280000	17136000	22848000	27720000
PARTICLE COUNT	33606	444626	915017	3019561	9052437	15043032	18051229	24067901	29244589

TYPICAL APPLICATIONS

CLASS 1 – H, CLASS 2 – H	Hypercritical systems – missile, satellite and critical control systems
CLASS 3 – H	Sub-miniature Servo-valves + certain aircraft hydraulic fluids as new.
CLASS 4 – H	Miniature Servo-valves
CLASS 5 – H, CLASS 6 – H	High pressure industrial and Hydrostatic transmission systems.
CLASS 7 – H, CLASS 8 – H, CLASS 9 – H	General uses such as store handling – hoists – winches cranes and industrial earthmoving equipment.

Fig 20

ANGLE PROJECTION

AK-AO-0978

TRAIN WIRE FUNCTION	
NUMBER	FUNCTION
14	TILT ON
15	TILT OFF
16	FAULT INDICATION
16	FAULT INDICATION
60	DIA. LOCKING & LOAD SHEDDING
67	AUXILIARY CONTROL POSITIVE

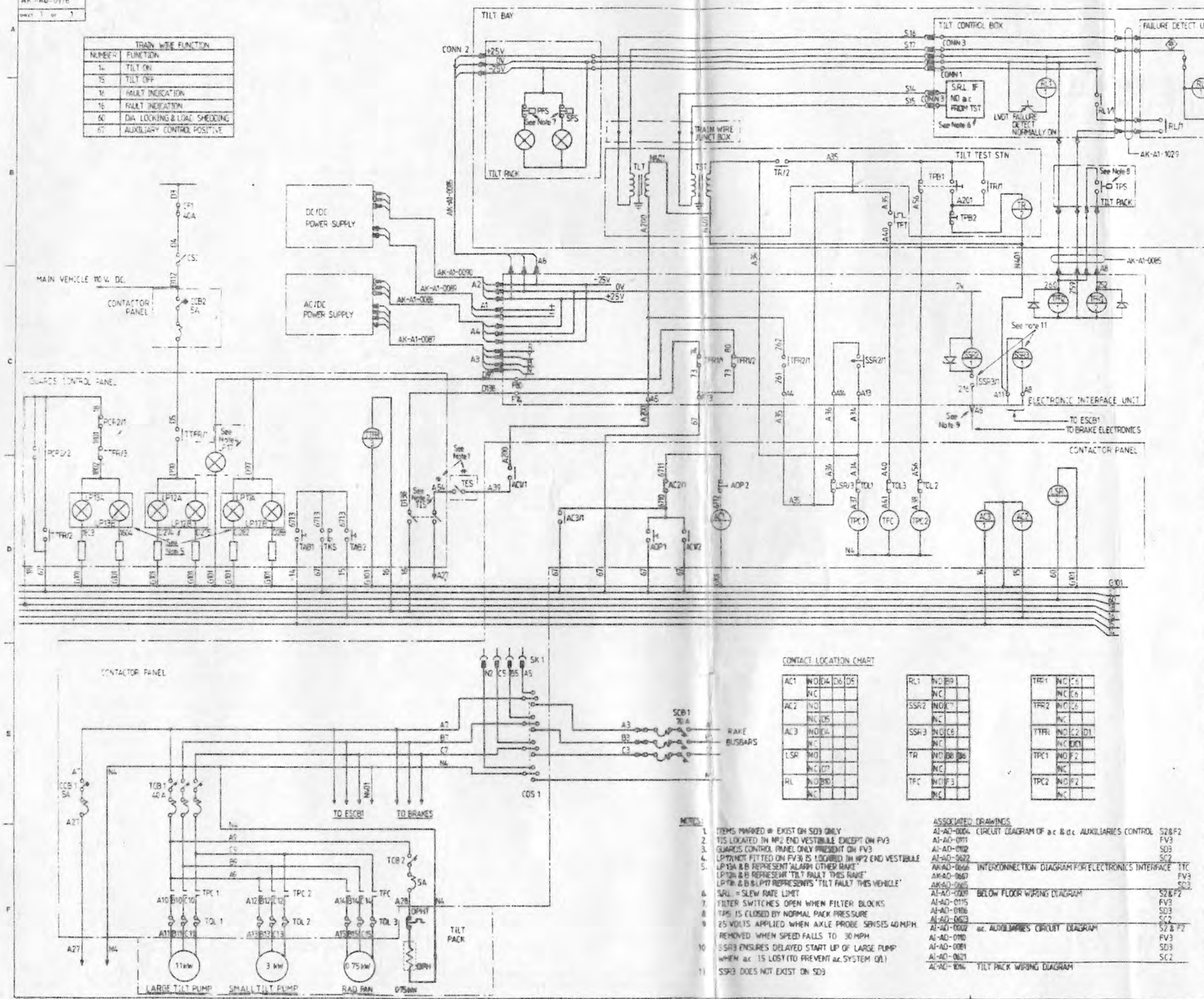


Fig 21

CONTACT LOCATION CHART

AC1	NO	D4	D6	D5
	NC			
AC2	NO			
	NC	D5		
AC3	NO	D4		
	NC			
LSR	NO			
	NC	D7		
RL	NO	B10		
	NC			

RL1	NO	B9	
	NC		
SSR2	NO	C7	
	NC		
SSR3	NO	C6	
	NC		
TR	NO	B8	B6
	NC		
TFC	NO	F3	
	NC		

TFR1	NC	C6	
	NC	C6	
TFR2	NO	C6	
	NC		
TTFR	NO	C2	D1
	NC	D1	
TPC1	NO	F2	
	NC		
TPC2	NO	F2	
	NC		

NOTES:

1. ITEMS MARKED ⊕ EXIST ON SD3 ONLY
2. TIS LOCATED IN Nº2 END VESTIBULE EXCEPT ON FV3
3. GUARDS CONTROL PANEL ONLY PRESENT ON FV3
4. LP17(NOT FITTED ON FV3) IS LOCATED IN Nº2 END VESTIBULE
5. LP13A & B REPRESENT 'ALARM OTHER RAKE'
   LP12A & B REPRESENT 'TILT FAULT THIS RAKE'
   LP17A & B & LP17 REPRESENTS 'TILT FAULT THIS VEHICLE'
6. SRL = SLEW RATE LIMIT
7. FILTER SWITCHES OPEN WHEN FILTER BLOCKS
8. TPS IS CLOSED BY NORMAL PACK PRESSURE
9. 25 VOLTS APPLIED WHEN AXLE PROBE SENSES 40 MPH. REMOVED WHEN SPEED FALLS TO 30 MPH
10. SSR3 ENSURES DELAYED START UP OF LARGE PUMP WHEN a.c. IS LOST (TO PREVENT a.c. SYSTEM O/L)
11. SSR3 DOES NOT EXIST ON SD3

ASSOCIATED DRAWINGS

AI-AO-0004	CIRCUIT DIAGRAM OF a.c. & d.c. AUXILIARIES CONTROL	S2&F2
AI-AO-0111		FV3
AI-AO-0102		SD3
AI-AO-0622		SC2
AK-AO-0666	INTERCONNECTION DIAGRAM FOR ELECTRONICS INTERFACE	TTC
AK-AO-0667		FV3
AK-AO-0665		SD3
AI-AO-0009	BELOW FLOOR WIRING DIAGRAM	S2&F2
AI-AO-0115		FV3
AI-AO-0106		SD3
AI-AO-0623		SC2
AI-AO-0002	a.c. AUXILIARIES CIRCUIT DIAGRAM	S2 & F2
AI-AO-0110		FV3
AI-AO-0081		SD3
AI-AO-0621		SC2
AC-AO-1016	TILT PACK WIRING DIAGRAM	

ISSUE	AMENDMENTS
B	TR/2 was connected between TOL1 and TST. AK-A1-0085 connections clarified at B9. SSR3 shown as timing relay Note 10 added
C	Harness AK-A1-0085 connection from Tilt Pack to Interface Unit amended at B8/9-C8/9. wire 259 was shown connected to 0V. wire 260 was shown connected to TPS. Freewheeling diode connected across TFR2. See note 4 at C2 was see note 3. SSR3 shown as timing relay in above amendment should read SSR2. Terminal F73 on Interface Unit was connected via contact AC1/3 to 671. Freewheeling diode mod no 41032 Note 11 added

REF	DESCRIPTION	LOCATION
TTFR	TRAIN TILT FAULT RELAY	GUARDS CONTROL PANEL
TST	LARGE PUMP MONITORING TRANSFORMER	TILT TEST STATION
TR	TEST RELAY	TILT TEST STATION
TPS	MAIN TILT PRESSURE SWITCH	TILT PACK
TPC2	SMALL PUMP CONTACTOR	CONTACTOR PANEL
TPC1	LARGE PUMP CONTACTOR	CONTACTOR PANEL
TPB2	TILT TEST PUSHBUTTON STOP	TILT TEST STATION
TPB1	TILT TEST PUSHBUTTON START	TILT TEST STATION
TOL3	FAN OVERLOAD	CONTACTOR PANEL
TOL2	SMALL PUMP OVERLOAD	CONTACTOR PANEL
TOL1	LARGE PUMP OVERLOAD	CONTACTOR PANEL
TLT	TILT SYSTEM MONITORING TRANSFORMER	TILT TEST STATION
TKS	TRAIN TILT KEYSWITCH	GUARDS CONTROL PANEL
TIS	TILT ISOLATOR SWITCH	GUARDS CONTROL PANEL or VESTIBULE No 2 END
TFT	TILT FAN THERMOSTAT	TILT FAN BAY
TFC	TILT FAN CONTACTOR	CONTACTOR PANEL
TFR2	TILT FAULT LAMP RELAY	ELECTRONIC INTERFACE UNIT
TFR1	TILT FAULT LAMP RELAY	ELECTRONIC INTERFACE UNIT
TES	TOW ENABLE SWITCH	DRIVERS CAB
TCB2	TILT OIL HEATER CIRCUIT BREAKER	CONTACTOR PANEL
TCB1	TILT CIRCUIT BREAKER	CONTACTOR PANEL
TAB2	TRAIN TILT STOP PUSHBUTTON	GUARDS CONTROL PANEL
TAB1	TRAIN TILT START PUSHBUTTON	GUARDS CONTROL PANEL
SSR3	SPEED SENSING RELAY	ELECTRONIC INTERFACE UNIT
SSR2	SPEED SENSING TIMER RELAY	ELECTRONIC INTERFACE UNIT
SK1	SHORE SUPPLY SOCKET No1	CONTACTOR PANEL
SFS	SECONDARY FILTER SWITCH	TILT PACK
SCB1	AC SUPPLY CIRCUIT BREAKER	VESTIBULE No 1 END
RL1	LVDT FAILURE DETECT	TILT CONTROL BOX
RL	FAILURE DETECTION RELAY	FAILURE DETECT UNIT
PCR2	PASS COMM RELAY	GUARDS CONTROL PANEL
PFS	PRIMARY FILTER SWITCH	TILT PACK
OPHT	OIL PRE-HEAT THERMOSTAT	TILT PACK
OPH	OIL PRE-HEAT	TILT PACK
LSR	LOAD SHEDDING RELAY	CONTACTOR PANEL
LP17A/B	TILT FAULT THIS VEHICLE	GUARDS CONTROL PANEL
LP17	TILT FAULT THIS VEHICLE	VESTIBULE No 2 END
LP13A/B	ALARM OTHER RAKE LAMP	GUARDS CONTROL PANEL
LP12A/B	TILT FAULT THIS RAKE LAMP	GUARDS CONTROL PANEL
ESCB1	AC/DC ELECTRONIC SUPPLIES CIRCUIT BREAKER	CONTACTOR PANEL
COS1	CHANGE OVER SWITCH	CONTACTOR PANEL
CS1	VEHICLE DC ISOLATOR	VESTIBULE No1 END
CF1	DC CONTROL FUSE BREAKER	VESTIBULE No1 END
CCB2	DC CONTROL CIRCUIT BREAKER	CONTACTOR PANEL
CCB1	AC CONTROL CIRCUIT BREAKER	CONTACTOR PANEL
AOP2	LOCAL TILT-OFF PUSHBUTTON	CONTACTOR PANEL
AOP1	LOCAL TILT-ON PUSHBUTTON	CONTACTOR PANEL
AC3	VEHICLE TILT-ON RELAY	CONTACTOR PANEL
AC2	VEHICLE TILT-OFF RELAY	CONTACTOR PANEL
AC1	TILT ON SLAVE RELAY	CONTACTOR PANEL

USED ON: ALL TRAILER CARS

CHIEF MECHANICAL & ELECTRICAL ENGINEER
BRITISH RAILWAYS BOARD. DERBY

CIRCUIT DIAGRAM OF APT-P TILT CONTROL & FAULT INDICATION SYSTEMS (TRAILER CARS)

AK-AO-0978

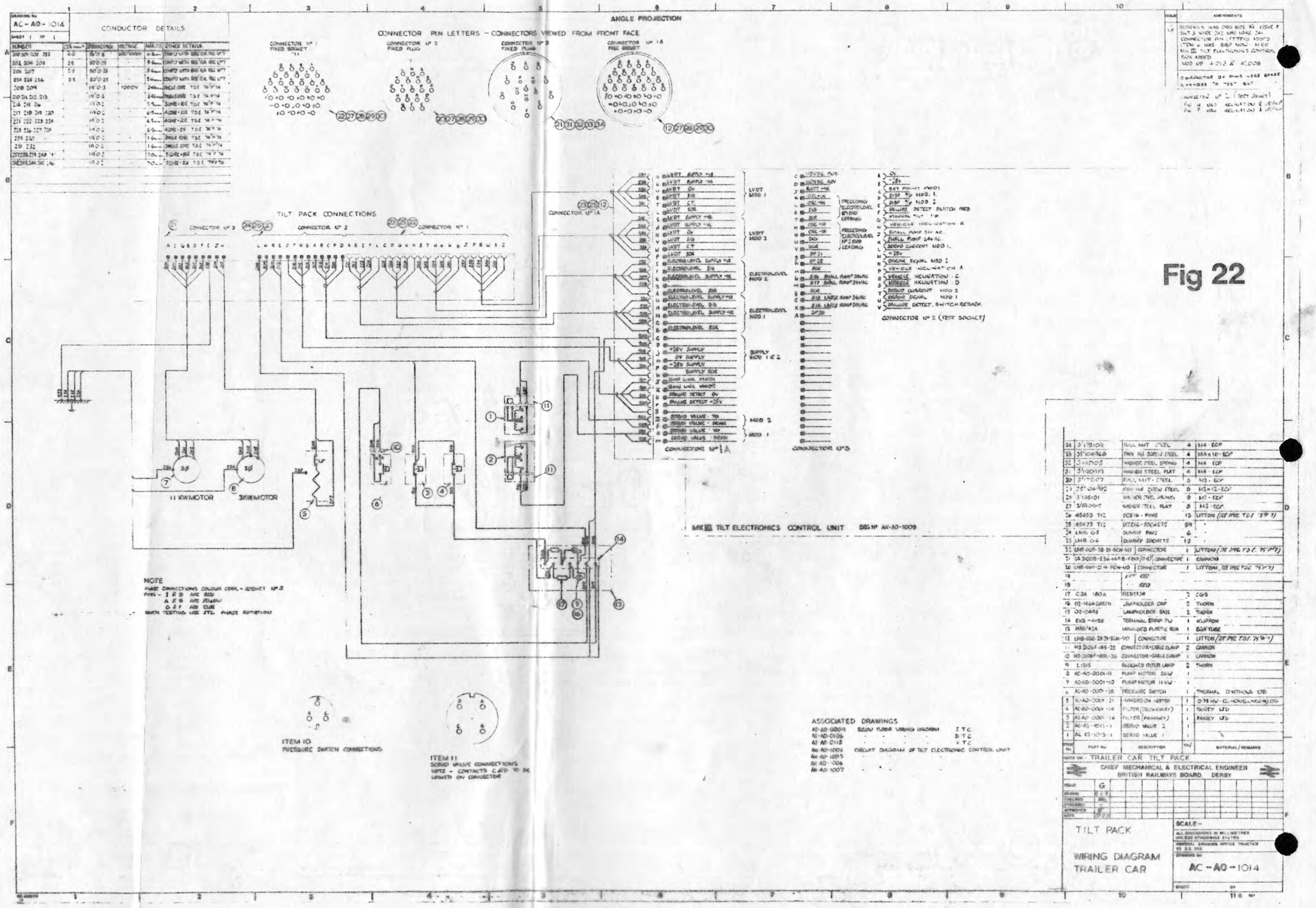
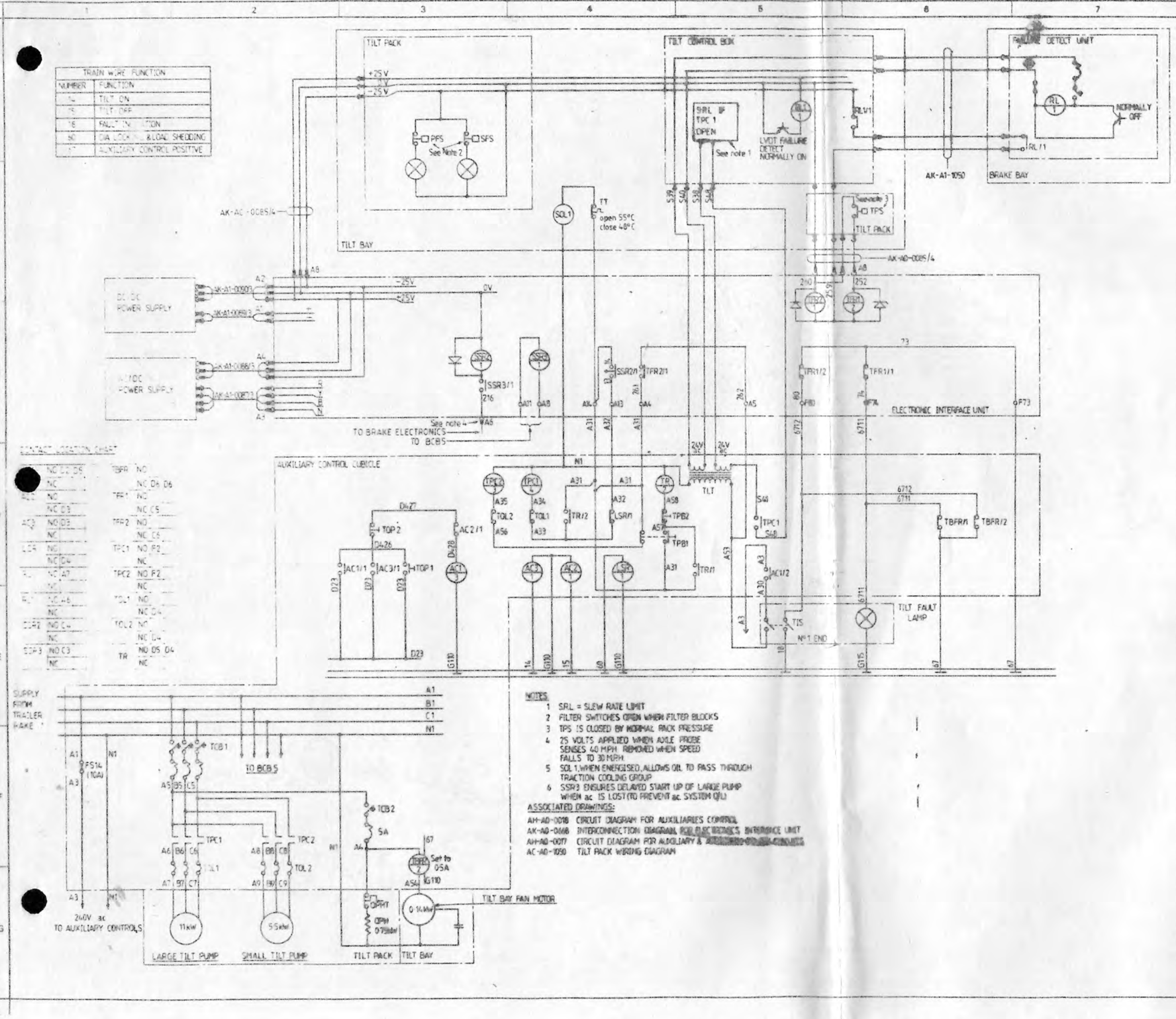

AC-A0-1014
CONDUCTOR DETAILS
ANGLE PROJECTION
CONNECTOR PIN LETTERS - CONNECTORS VIEWED FROM FRONT FACE
TILT PACK CONNECTIONS
CONNECTOR No 1A
CONNECTOR No 3
CONNECTOR No 2 (TEST SOCKET)
11 KW MOTOR
3KW MOTOR
MK III TILT ELECTRONICS CONTROL UNIT
NOTE
ITEM 10
PRESSURE SWITCH CONNECTIONS
ITEM 11
SERVO VALVE CONNECTIONS
ASSOCIATED DRAWINGS
TRAILER CAR TILT PACK
CHIEF MECHANICAL & ELECTRICAL ENGINEER
BRITISH RAILWAYS BOARD DERBY
TILT PACK
WIRING DIAGRAM
TRAILER CAR
SCALE:-
AC-A0-1014

Fig 22

Fig 23

TRAIN WIRE FUNCTION	
NUMBER	FUNCTION
14	TILT ON
15	TILT OFF
18	FAULT INDICATION
60	OIA LOCKOUT & LOAD SHEDDING
67	AUXILIARY CONTROL POSITIVE



NOTES

1. SRL = SLEW RATE LIMIT
2. FILTER SWITCHES OPEN WHEN FILTER BLOCKS
3. TPS IS CLOSED BY NORMAL PACK PRESSURE
4. 25 VOLTS APPLIED WHEN AXLE PROBE SENSES 40 MPH REMOVED WHEN SPEED FALLS TO 30 M.P.H.
5. SOL 1, WHEN ENERGISED, ALLOWS OIL TO PASS THROUGH TRACTION COOLING GROUP
6. SSR3 ENSURES DELAYED START UP OF LARGE PUMP WHEN ac IS LOST (TO PREVENT ac SYSTEM O/L)

ASSOCIATED DRAWINGS:

AH-A0-0018 CIRCUIT DIAGRAM FOR AUXILIARIES CONTROL
AK-A0-0668 INTERCONNECTION DIAGRAM FOR ELECTRONICS INTERFACE UNIT
AH-A0-0017 CIRCUIT DIAGRAM FOR AUXILIARY & [illegible]
AC-A0-1050 TILT PACK WIRING DIAGRAM

ISSUE	GRID REF	ALTERATION
A		Original
B	D5 B8/9 C8/9 A5	Terminal F73 on Interface Unit was connected via contact AC1/3 to 6710. Freewheeling diode connected across TFR2. Wire 260 was shown connected to TPS. Wire 259 was shown connected to 0V. Freewheeling diode mod no. 41033 SRL if TPC1 open was SRL if no ac from TLT — MFD
C	D6 D5 D4	Contacts TBFR/1 & 2 relocated in Auxiliary Control Cubicle Transformer TLT Relay TR & PB's TPB1 & 2 added Mod No 41035

REF	DESCRIPTION	LOCATION
TPB2	TILT TEST PUSHBUTTON STOP	AUXILIARY CONTROL CUBICLE
TPB1	TILT TEST PUSHBUTTON START	AUXILIARY CONTROL CUBICLE
TR	TILT TEST RELAY	AUXILIARY CONTROL CUBICLE
TT	TILT THERMOSTAT	TILT PACK
TS	TEST SWITCH	AUXILIARY CONTROL CUBICLE
TPS	TILT PRESSURE SWITCH	TILT PACK
TPC2	SMALL PUMP CONTACTOR	AUXILIARY CONTROL CUBICLE
TPC1	LARGE PUMP CONTACTOR	AUXILIARY CONTROL CUBICLE
TOP2	LOCAL TILT-OFF PUSHBUTTON	AUXILIARY CONTROL CUBICLE
TOP1	LOCAL TILT-ON PUSHBUTTON	AUXILIARY CONTROL CUBICLE
TOL2	SMALL PUMP OVERLOAD	AUXILIARY CONTROL CUBICLE
TOL1	LARGE PUMP OVERLOAD	AUXILIARY CONTROL CUBICLE
TLT	TILT SYSTEM MONITORING TRANSFORMER	AUXILIARY CONTROL CUBICLE
TIS	TILT ISOLATOR SWITCH	[illegible]
TFR2	TILT FAULT LAMP RELAY	ELECTRONIC INTERFACE UNIT
TFR1	TILT FAULT LAMP RELAY	ELECTRONIC INTERFACE UNIT
TCB2	TILT OIL HEATER CIRCUIT BREAKER	AUXILIARY CONTROL CUBICLE
TCB1	TILT CIRCUIT BREAKER	AUXILIARY CONTROL CUBICLE
TBFR	TILT BAY FAN RELAY	AUXILIARY CONTROL CUBICLE
SSR3	SPEED SENSING RELAY	ELECTRONIC INTERFACE UNIT
SSR2	SPEED SENSING TIMER RELAY	ELECTRONIC INTERFACE UNIT
SOL1	TILT COOLING SOLENOID	TILT PACK
SFS	SECONDARY FILTER SWITCH	TILT PACK
RL1	LVDT FAILURE DETECT	TILT CONTROL BOX
RL	FAILURE DETECT RELAY	FAILURE DETECTION UNIT
PFS	PRIMARY FILTER SWITCH	TILT PACK
OPHT	OIL-PRE HEAT THERMOSTAT	TILT PACK
OPH	OIL PRE-HEAT	TILT PACK
LSR	LOAD SHEDDING RELAY	AUXILIARY CONTROL CUBICLE
FS14	AUXILIARY CONTROL SUPPLY FUSE	AUXILIARY CONTROL CUBICLE
BCB5	BRAKE & TILT ELECTRONICS CIRCUIT BREAKER	AUXILIARY CONTROL CUBICLE
AC3	VEHICLE TILT-ON RELAY	AUXILIARY CONTROL CUBICLE
AC2	VEHICLE TILT-OFF RELAY	AUXILIARY CONTROL CUBICLE
AC1	TILT-ON SLAVE RELAY	AUXILIARY CONTROL CUBICLE

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ISSUE	DRAWN	CHECKED		
C	AGB	D3OP	23.3.81	
B	DJMP		4/-/80	
A	DJMP			

TITLE: CIRCUIT DIAGRAM OF APT-P TILT CONTROL & FAULT INDICATION SYSTEMS (POWER CARS)

DRAWING No: AK-A0-0978

SCALE

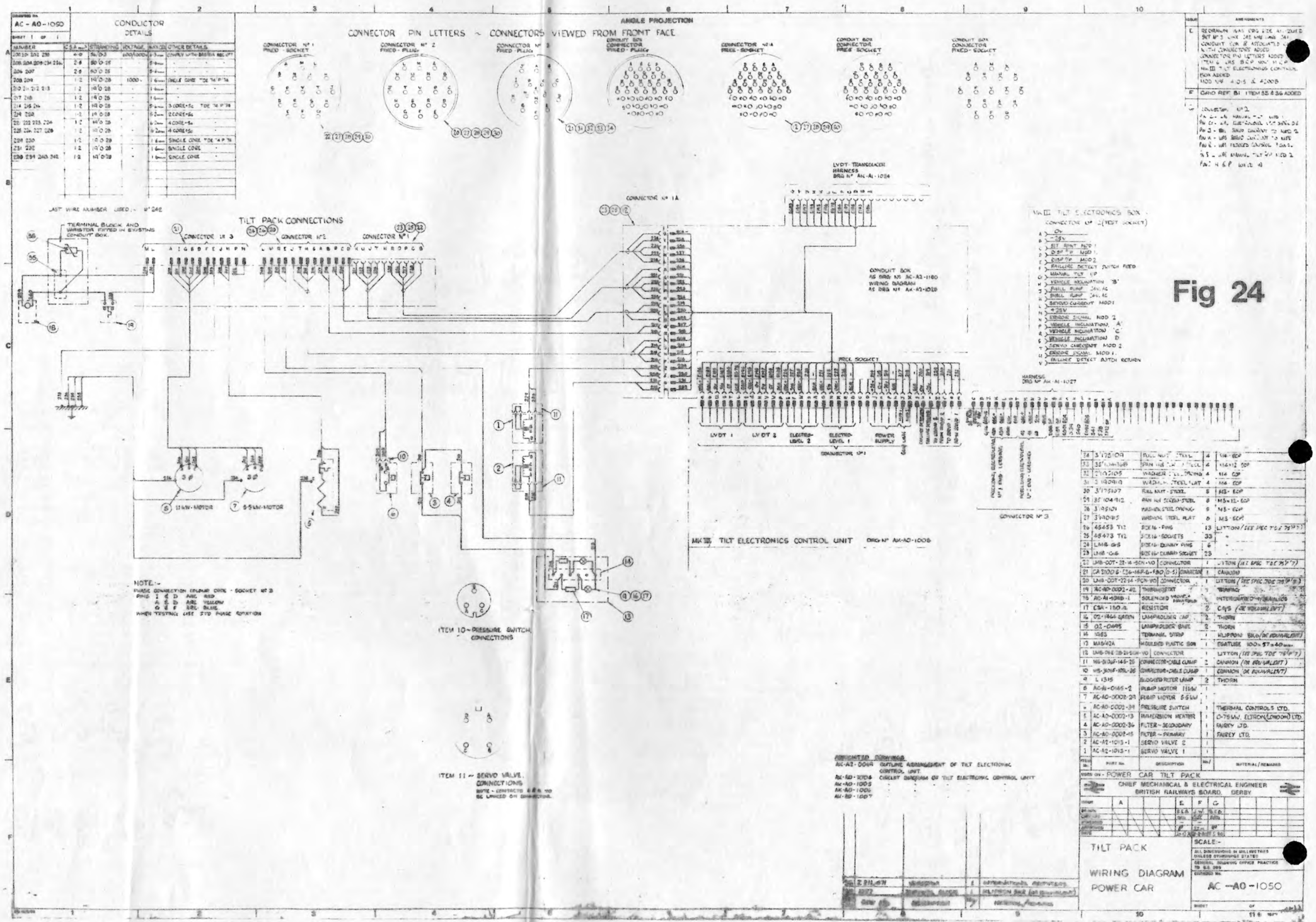
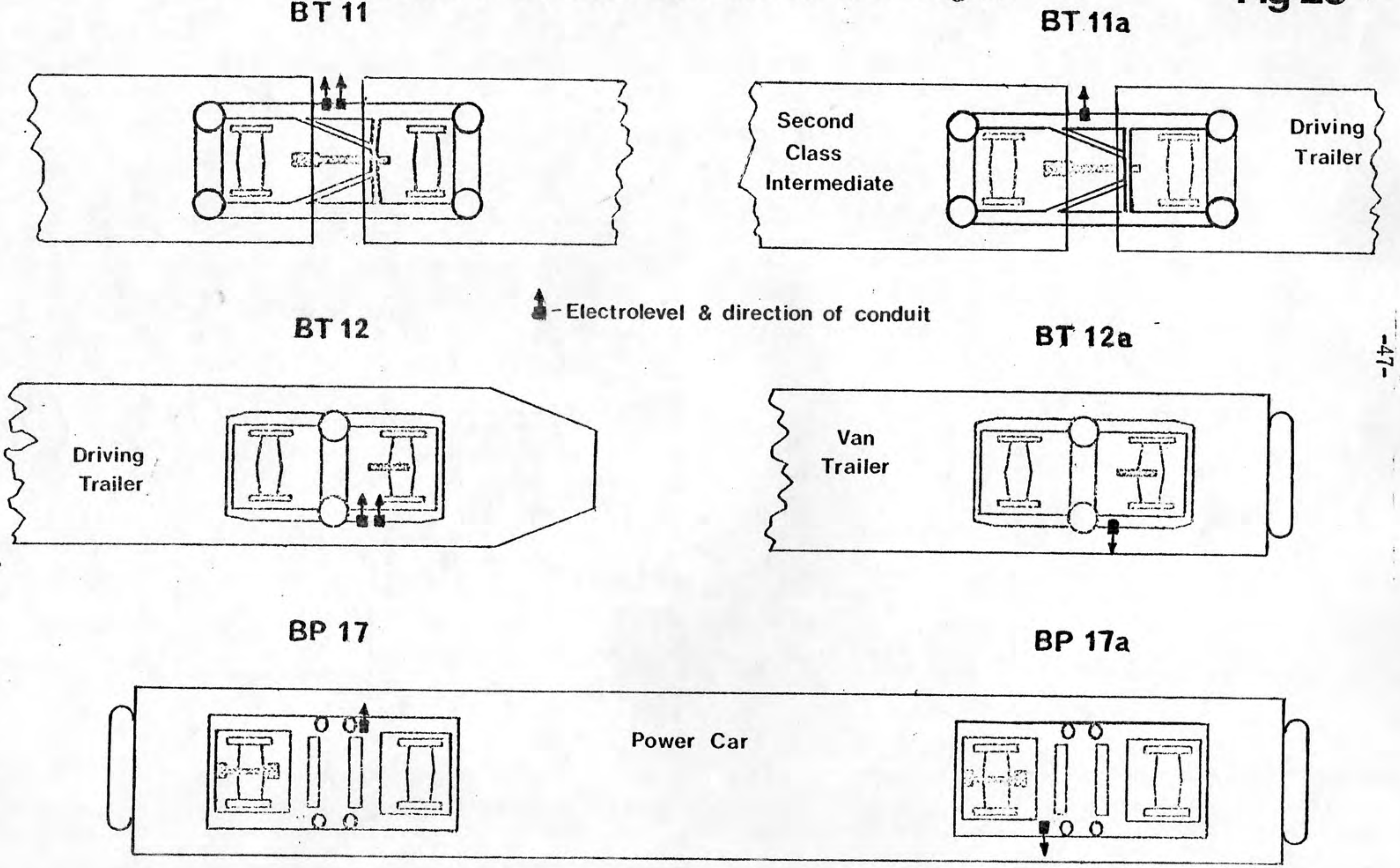

AC - AO - 1050
CONDUCTOR DETAILS
ANGLE PROJECTION
CONNECTOR PIN LETTERS ~ CONNECTORS VIEWED FROM FRONT FACE
TILT PACK CONNECTIONS
CONNECTOR Nº 3
CONNECTOR Nº 2
CONNECTOR Nº 1
CONNECTOR Nº 1A
LVDT TRANSDUCER HARNESS
MkIII TILT ELECTRONICS BOX
FREE SOCKET
LVDT 1
LVDT 2
POWER SUPPLY
MkIII TILT ELECTRONICS CONTROL UNIT
NOTE:-
ITEM 10 ~ PRESSURE SWITCH CONNECTIONS
ITEM 11 ~ SERVO VALVE CONNECTIONS
POWER CAR TILT PACK
CHIEF MECHANICAL & ELECTRICAL ENGINEER
BRITISH RAILWAYS BOARD, DERBY
TILT PACK
WIRING DIAGRAM
POWER CAR
SCALE-
AC -AO-1050

Fig 24

Positions Of Electrolevels On APT Bogies

Fig 25



ELECTROLEVEL SIGNALS

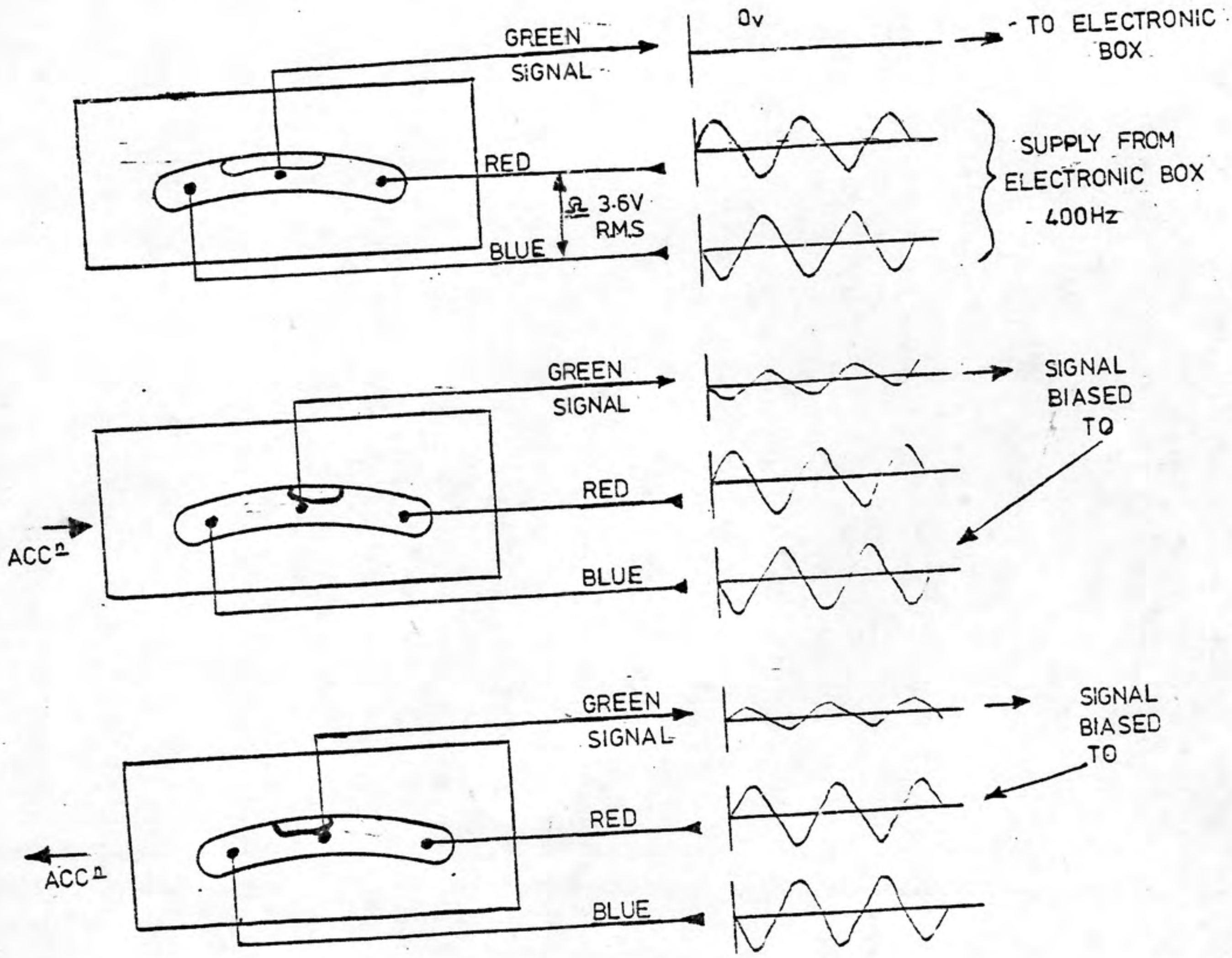


Fig 26

OPERATING PRINCIPLE OF L.V.D.T.

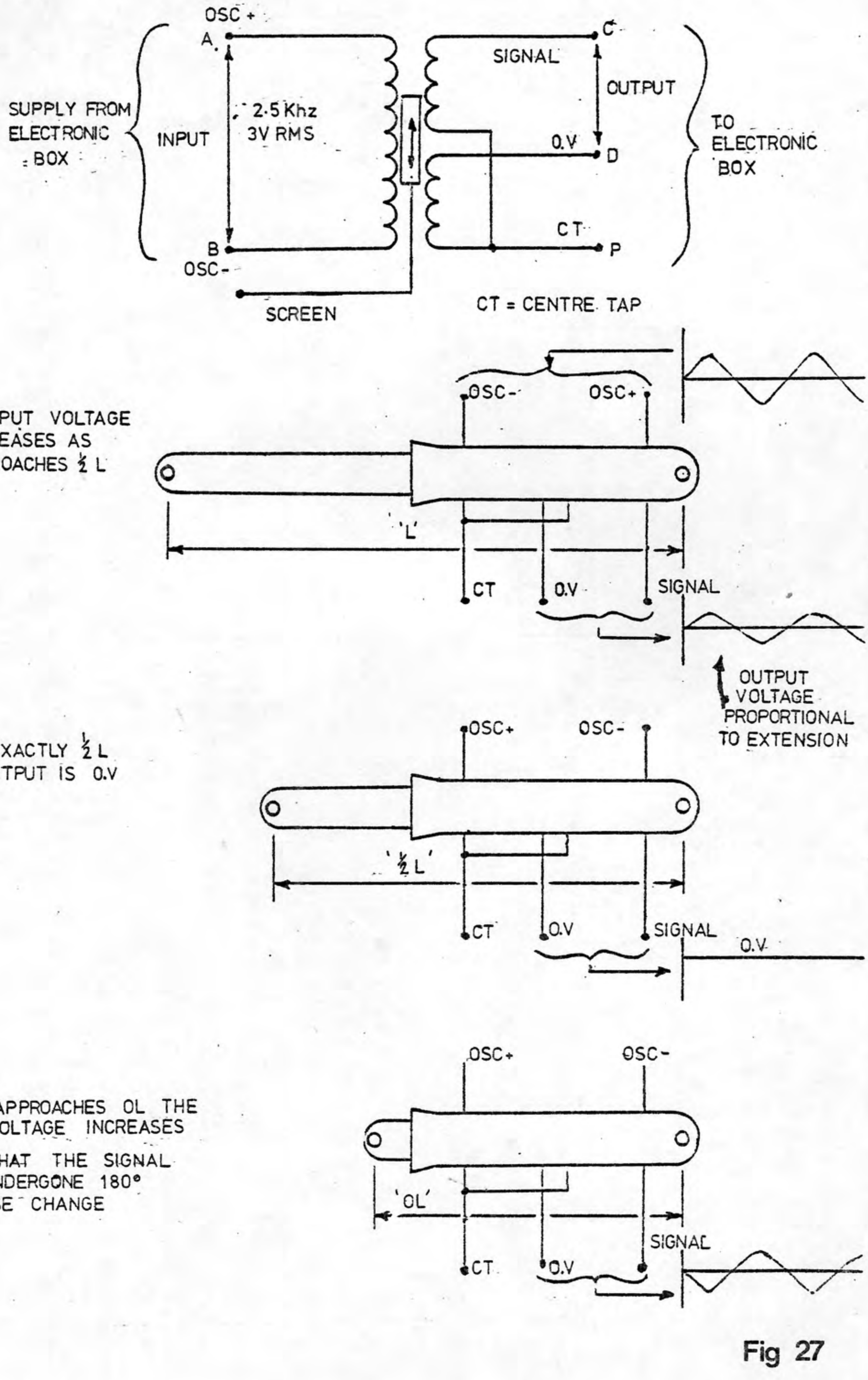


Fig 27

CLOSED LOOP CONTROL SYSTEM

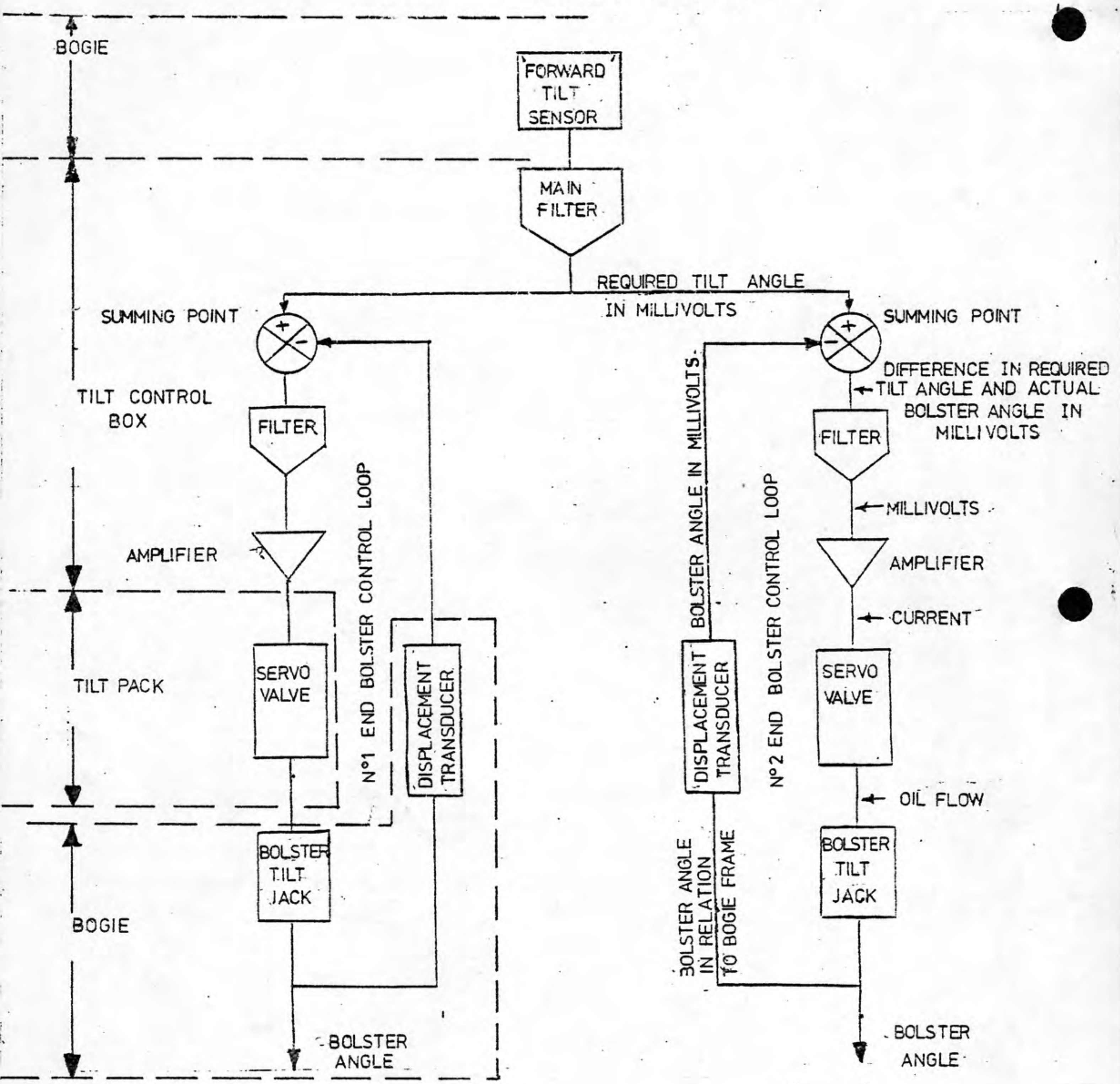


Fig 28

THE TILT FAILURE DETECTION UNIT (T.F.D.U.).

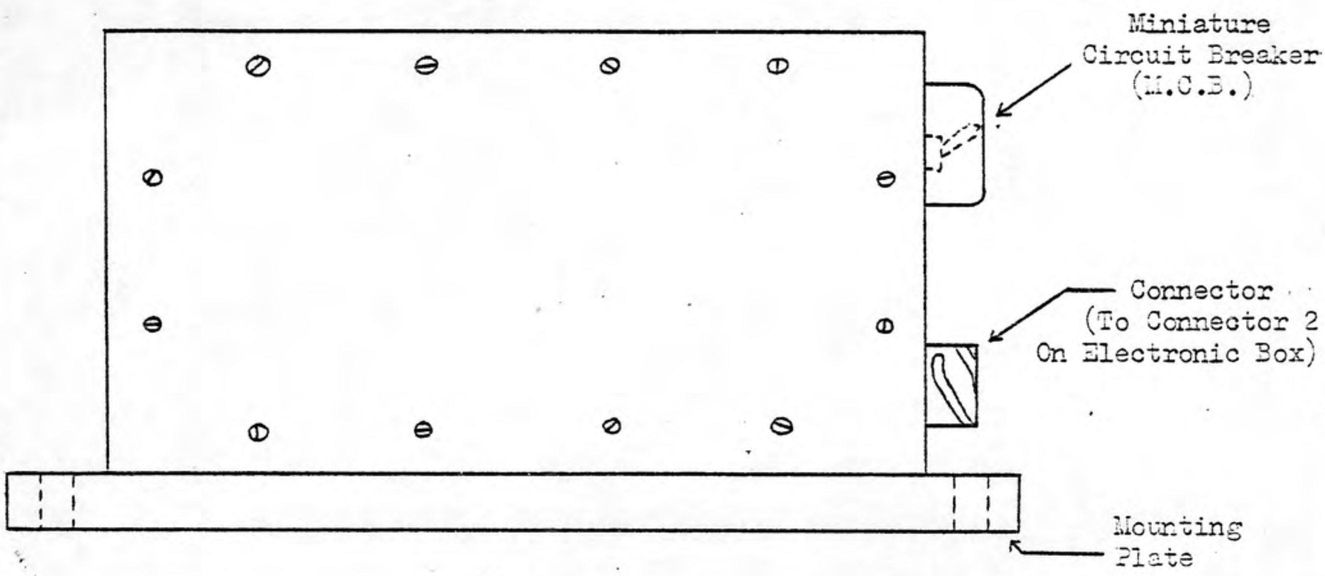


Fig 29

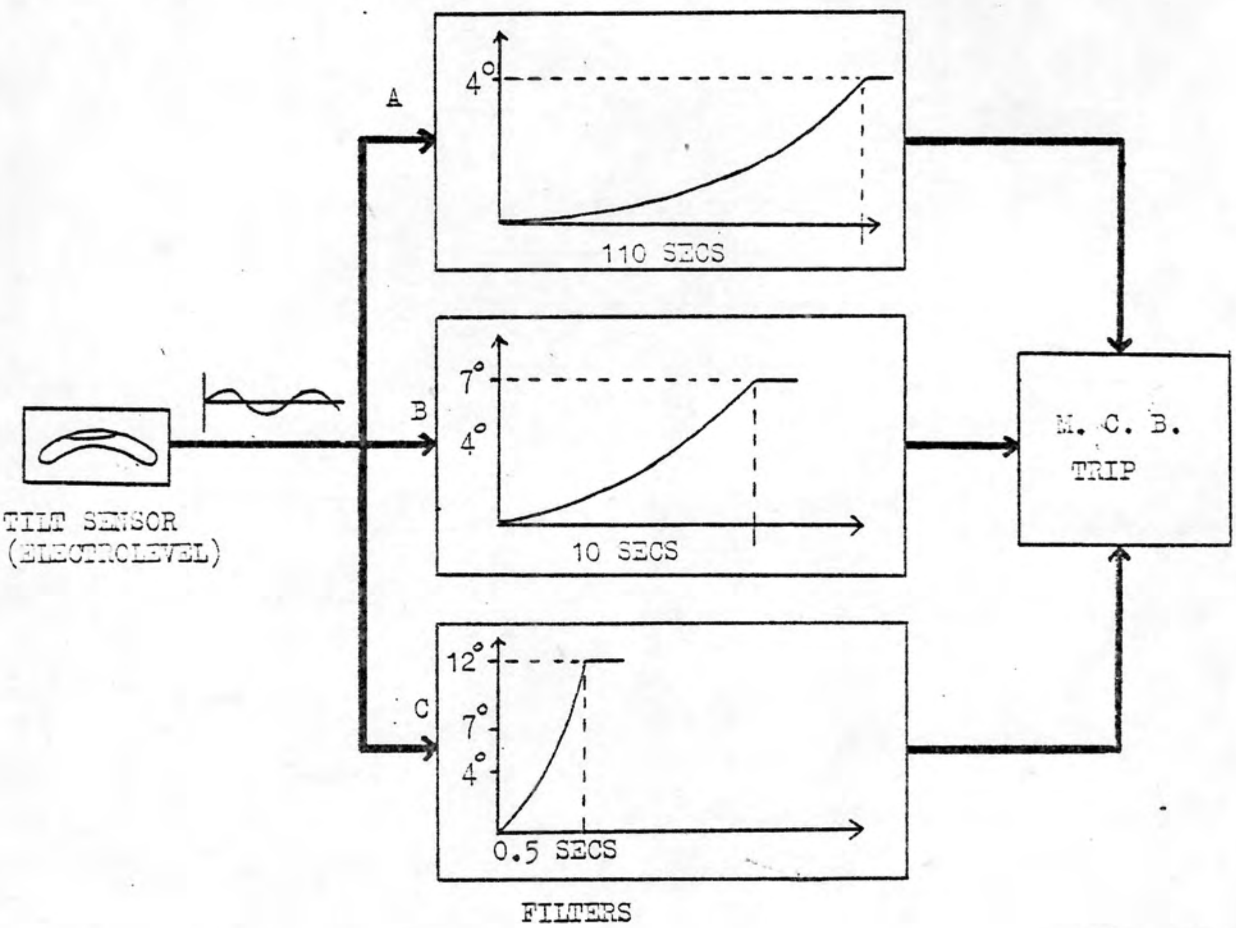


Fig 30

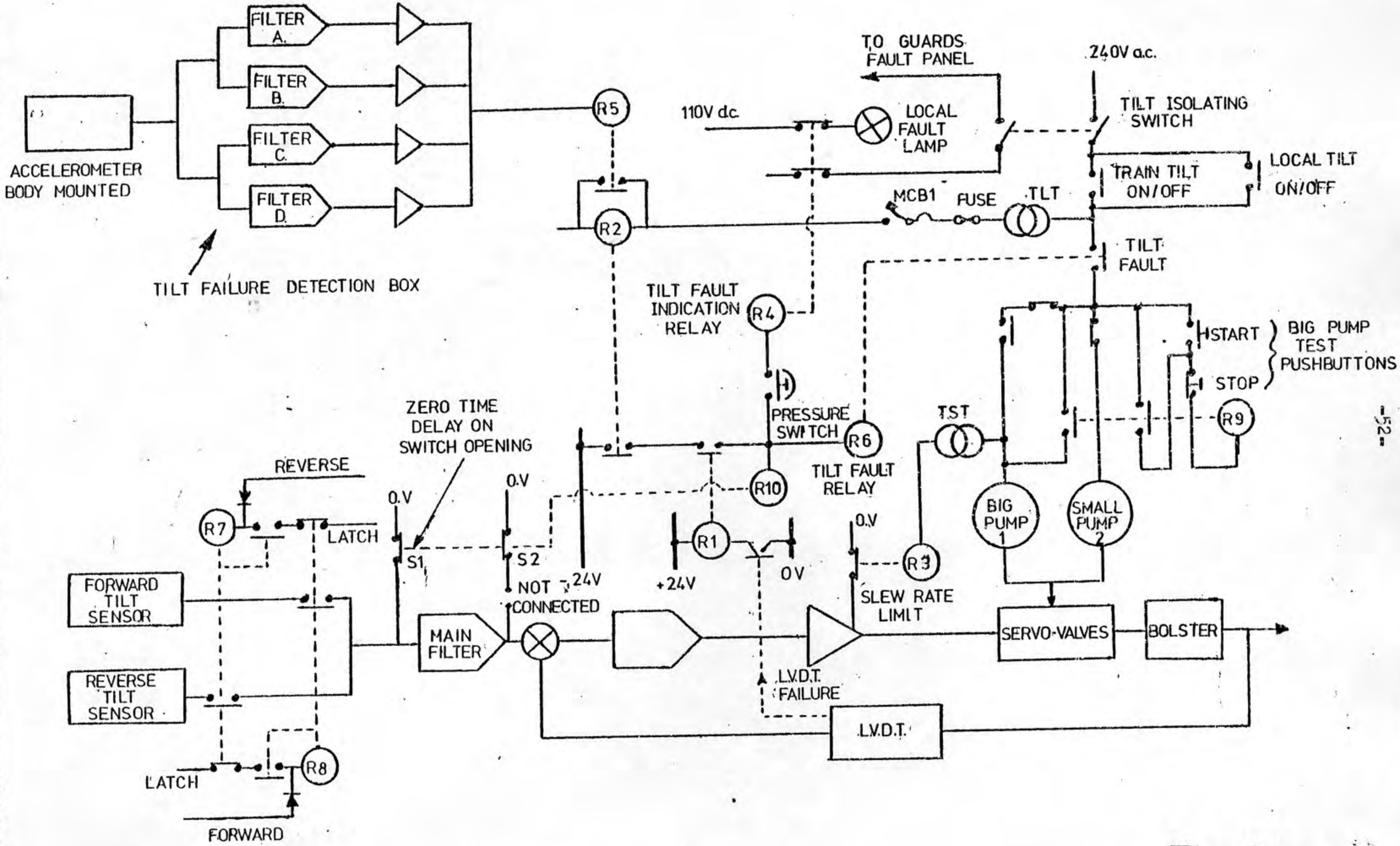


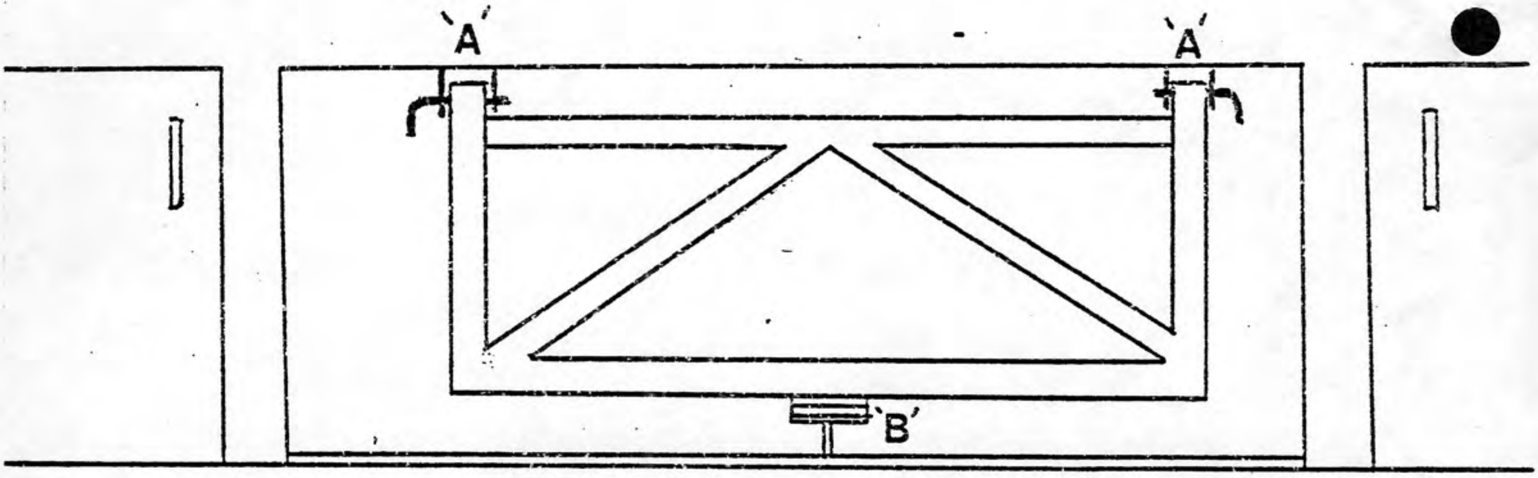
Fig 3I

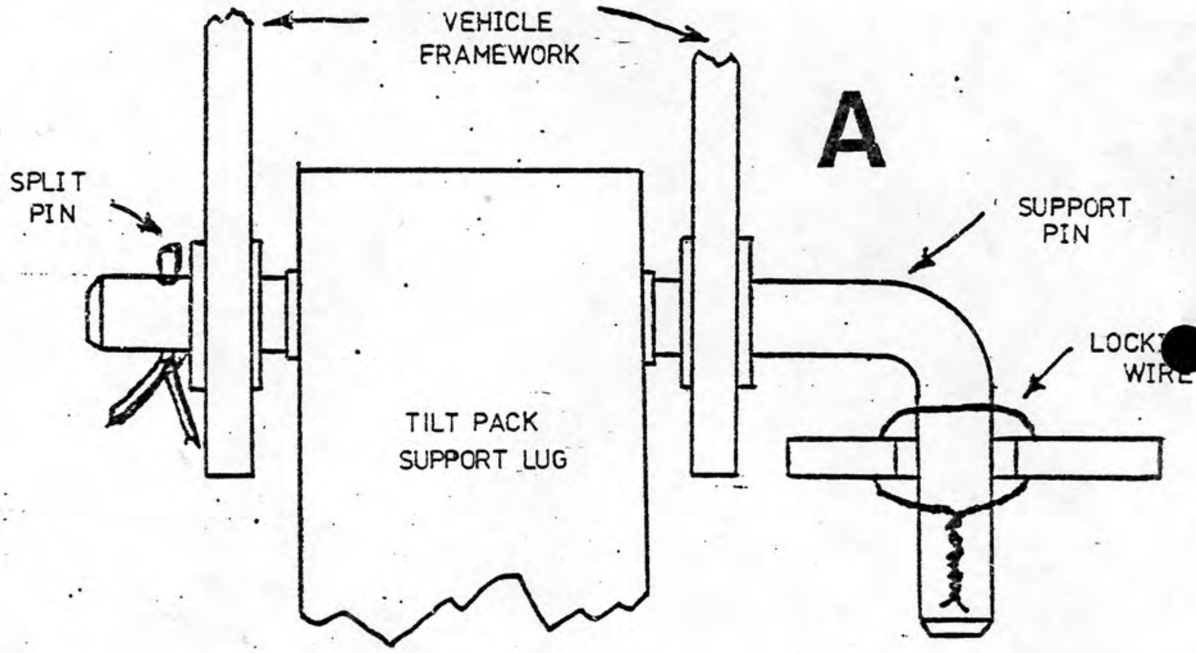
SCHEMATIC OF MK 3 TIL YSTEM CONTROL.

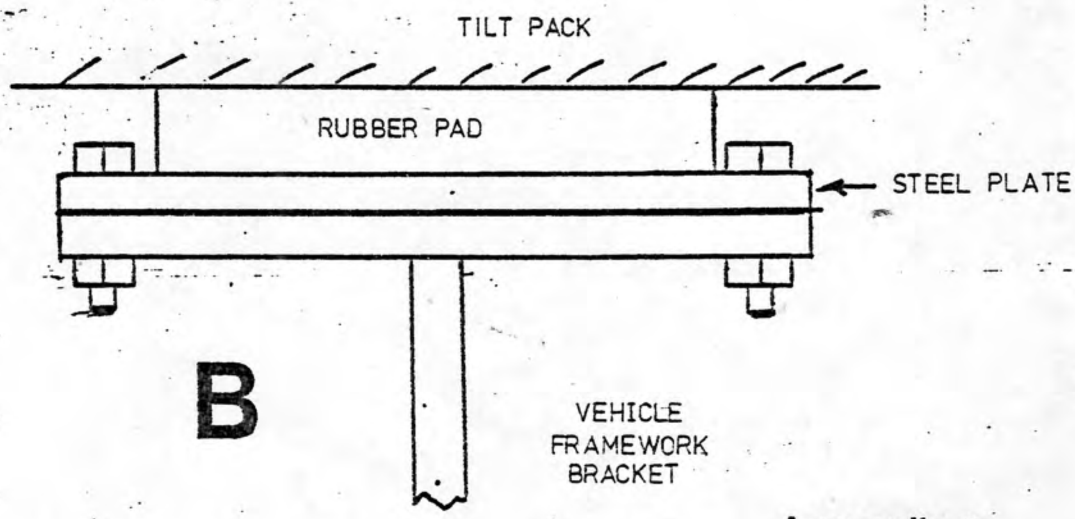
APPENDIX.

1. TRAILER CAR TILT PACK MOUNTINGS
2. POWER CAR TILT PACK MOUNTINGS.
3. CETOP SYMBOLS.
4. TILT SIGNAL ROUTE FROM LEADING TO TRAILING VEHICLE VIA REVERSER.
5.
6.
7.
8.
9.
10.

TRAILER CAR TILT PACK MOUNTINGS

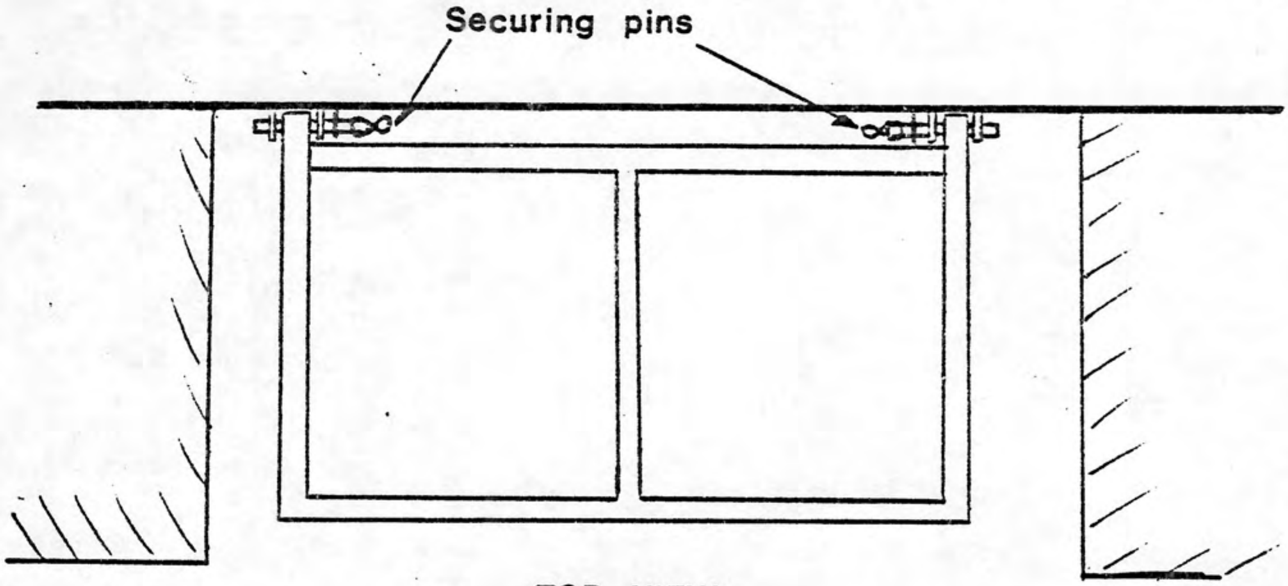




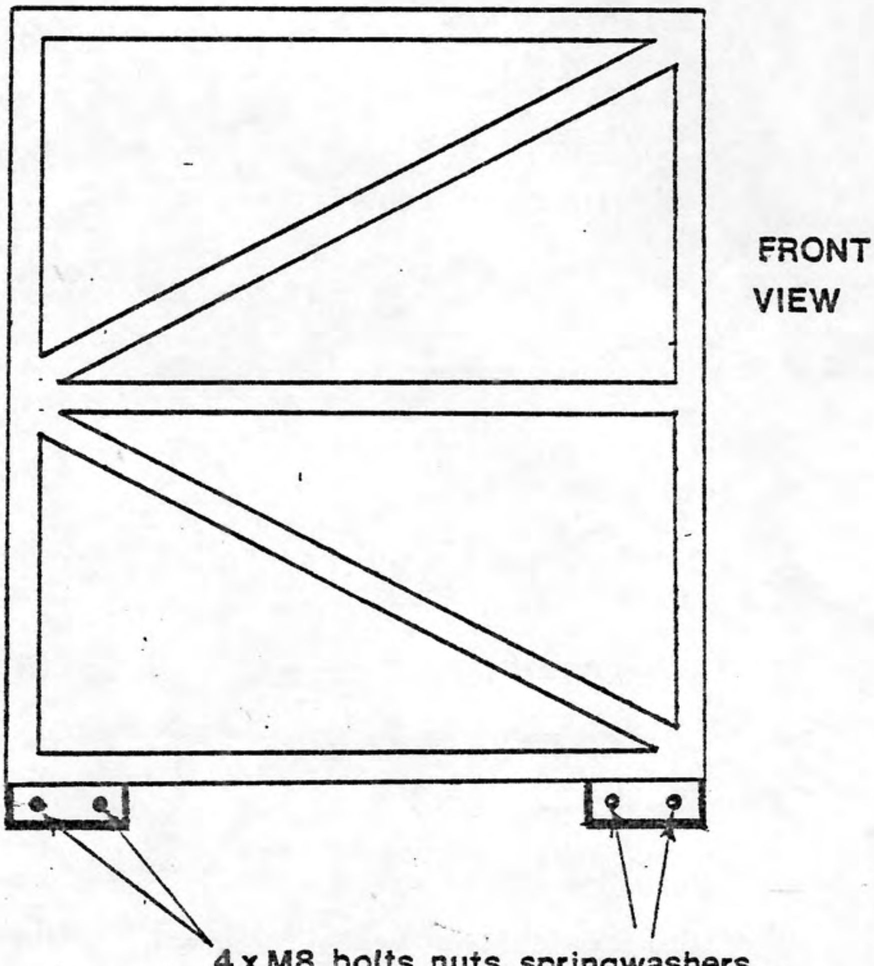


Appendix 1.

POWER CAR TILT PACK MOUNTINGS



TOP VIEW



Appendix 2.

SYMBOLS

(FUNCTIONAL SYMBOLS FOR HYDRAULIC & PNEUMATIC EQUIPMENT & ACCESSORIES).

- Working line (return and feed).
- Pilot control line.
- Drain line.
- Enclosure for several components assembled in one unit.
- Flexible hose.
- Indication of direction.
- Indication of rotation.
- Variable control.
- Direction of hydraulic flow.
- Exhaust to atmosphere.
- Shut-off valve.
- Plugged take-off point.
- Quick release coupling (with check valve).
- Quick release coupling (connected).
- Accumulator.
- Check valve.
- Air bleed.
- Flow line connection.
- Spring.
- Electric heater.

- Pressure gauge.
- Thermometer.
- M Electric motor.
- Hydraulic pump.
- Hydraulic pump (variable displacement)

Directional control valves.

- One path open.
- Two ports closed.
- Two paths open.
- etc Several fixed positions.
- Normally closed valve.
- Pressure switch.

Control methods.

- Push button.
- Spring.
- Solenoid (1 Winding).

- Filter.
- Radiator.
- Double acting cylinder (forward and return stroke effected by fluid pressure).