POPPY
RECORDS

ARCHIVAL CYLINDER PLAYER

HANDBOOK

April 2011

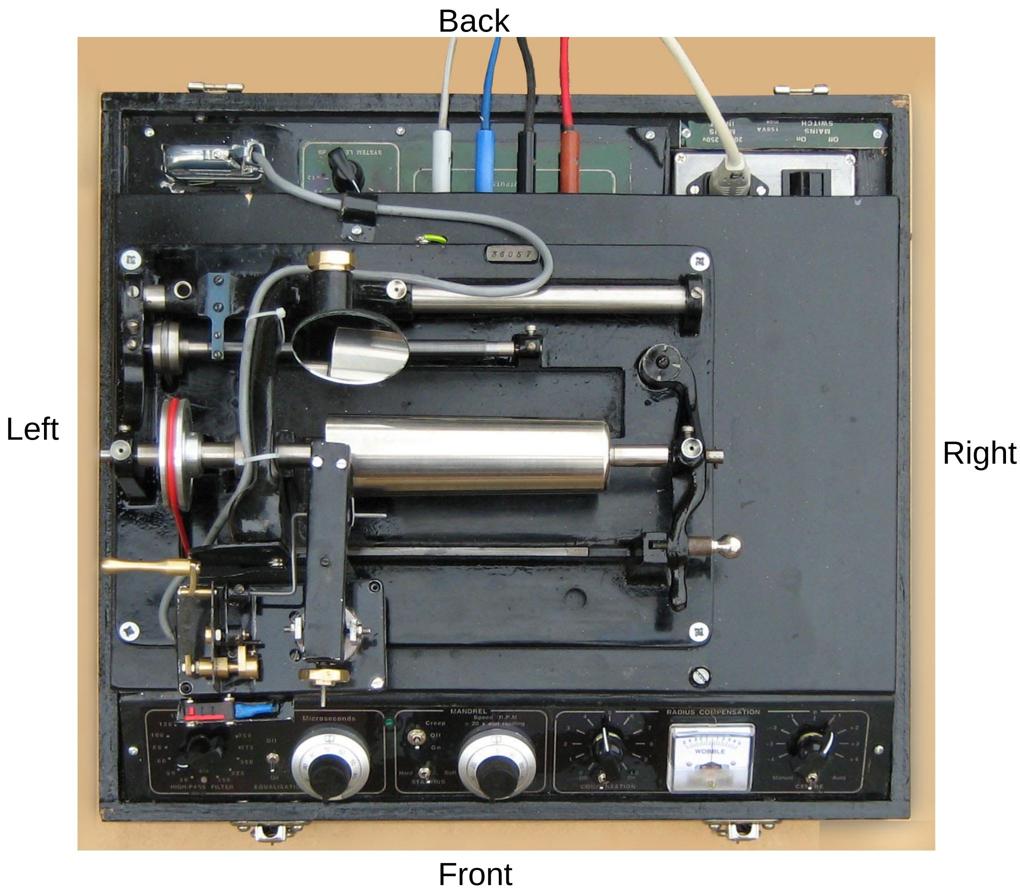

***Fig.*1 The Archival Cylinder Player**

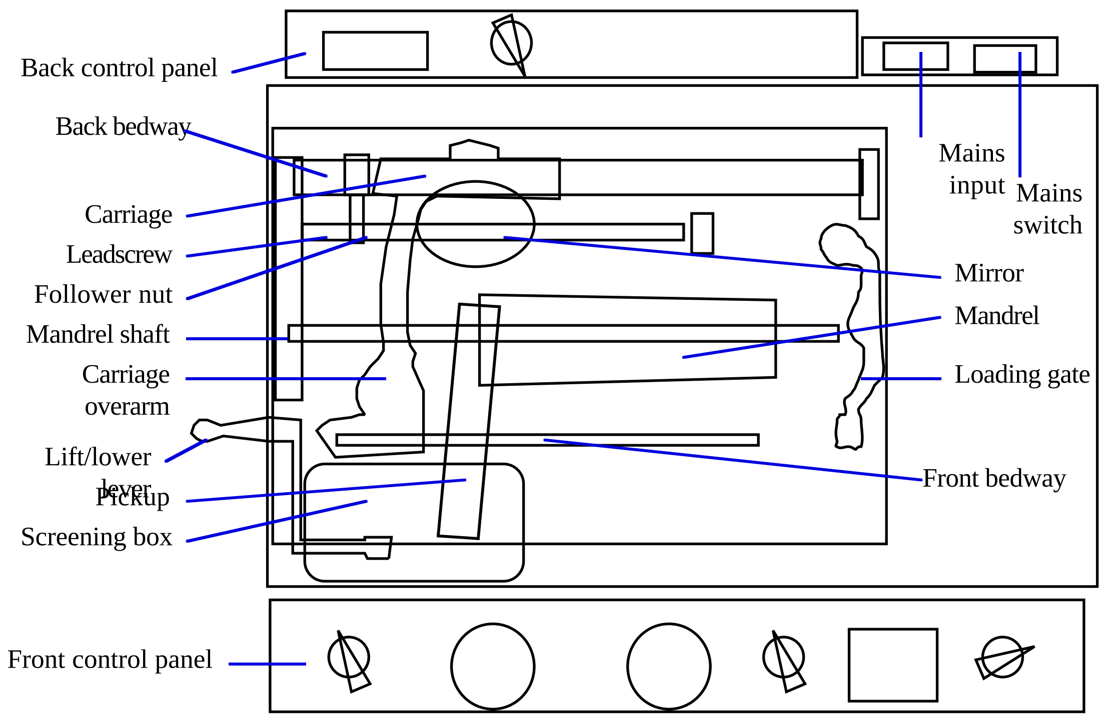

***Fig.*2 Identification of Parts**

POPPY RECORDS ARCHIVAL CYLINDER PLAYER

1.0 INTRODUCTION

This is an archival-quality player for cylinder recordings in the following ranges:

Diameter:	Up to 3″ (76mm)
Length:	Up to 7″ (178mm)
Speed:	10 - 200 revolutions per minute
Groove pitch:	25 - 250 turns per inch
Mandrel:	Standard Edison tapered (other types available upon request)

The player employs a special speed control mechanism which allows cylinders which have become eccentric or distorted to be played at constant surface speed by varying the rotational speed during each revolution.

A Shure 44 cartridge is employed, which allows a wide range of styli to be fitted in order to accommodate a variety of groove sizes and shapes. The playing weight is adjustable over a wide range to suit the material and condition of each cylinder.

The signals are amplified and processed internally to give outputs as follows:

Outputs:	Left channel Right channel Mono	Bandwidth 20 c/s to 20 Kc/s ± 1dB
	Equalised mono:	50 to 1050 microseconds (3.1 Kc/s to 50 c/s)
Signal level:		Nominal 0dBm into 600 ohms
Connectors:		P.O. / B.B.C. gauge ‘B’ jacks.

The unit can be configured to operate from 200 to 250v A.C or 100 to 125v A.C mains supplies at 50 or 60 c/s. Main supply is *via* an I.E.C Type C13 connector which must include an earthing connection.

The principal parts of the player are shown in Figs 1 & 2.

POPPY RECORDS ARCHIVAL CYLINDER PLAYER

CONTENTS

TECHNICAL DATA

2.1 Dimensions
(approximate)

Width	..	..	..	19″	483mm
Depth	..	..	..	18″	457mm
Height	..	..	..	12″	350mm
Weight	..	..	..	66lb	30Kg

2.2 Power Supply
This equipment requires a mains power supply of up to 150 VA at 50c/s or 60 c/s through an I.E.C.'C13' type of connector, which must include an earthing connection. The voltage for which the equipment has been set is shown on a plate adjacent to the mains input connector. If this need to be changed, the required voltage range can be selected internally by changing links on a tagstrip (see section 5.6 for details of how to do this).

2.3 Output Connections
The output signals are at nominal 0dBm level from a centre-tapped source of 600-ohms impedance. One leg of the signal may be earthed without affecting the other leg, but the source impedance will then appear to be 300 ohms. In balanced mode, signals up to +20dBm can be delivered without clipping (this is to allow damaged recordings to be reproduced faithfully without generating spurious intermodulation products). If non-professional equipment, operating to *de-facto* domestic standards, is to be fed from this equipment, it is recommended that 13dB attenuators should be included in the signal paths. The output signals are presented at British Post Office / B.B.C. Gauge 'B' jacks. Only use plugs which conform to this standard; incorrect plugs may damage the jacks. Adaptor leads are supplied in the tool kit for customers who require 'XLR' type connections; other types of adaptor can be supplied upon request.

2.4 Signals

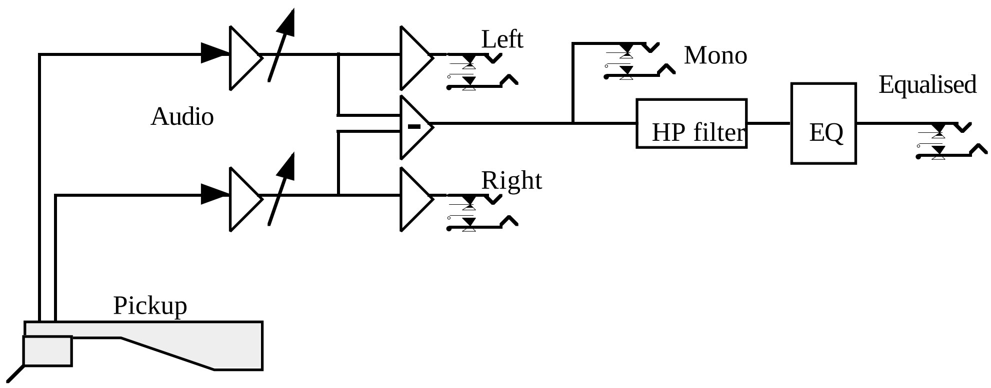

***Fig*.3 Audio Block Diagram**

Four independently-buffered signals are available:

1) Left channel
2) Right channel

These signals are taken from the cartridge pre-amplifier with a bandwidth from 20 c/s to 20 Kc/s ± 1dB. Because the majority of cylinders carry vertical modulation, the polarity of the signals is arranged so that summing the two channels will cancel any lateral signal and will enhance the vertical signal. In the event of the signal levels becoming unbalanced, for example after replacing the cartridge, the channel gains can be adjusted independently by means of two pre-set gain controls situated on the audio amplifier board.

3) Mono

This signal is derived by combining the left and right signals in equal proportions. Normally the polarity is set for vertical modulation, but it can be altered to lateral modulation by means of a switch situated on the audio amplifier board. If an apparently well-recorded cylinder plays with a faint amd distorted signal, suspect that the lateral/vertical switch has been left in the wrong position.

4) Equalised

This is the mono signal after equalisation and rumble filtering. See section 4.15 for a full description of the process.

For archival purposes the two channel signals, or the combined mono signal, would normally be recorded as the 'Archive' copy and the equalised signal would be recorded as the 'playback' copy.

2.5 Noise

Typical noise levels, measured at the 'filtered' output, are as follows:

Electrical noise

No equalisation	-60dBm
200uS E.Q.	-53dBm
50uS E.Q.	-45.5dBm

Mechanical noise, both motors running at normal speed.
(measured with the stylus resting on a light alloy spacer on the intermediate bearing of the mandrel shaft)

No equalisation	-45dBm

Slightly lower noise levels than these may be expected at the other outputs.

2.6 Transport Mechanism

The mechanical arrangements of the equipment are based on the top-works of a Columbia/Dictaphone cylinder shaving machine; an accurate and robust machine which was used professionally to prepare blank cylinders for recording purposes. The bedplate is a substantial iron casting and the mechanism is solidly made and smooth running.

The mandrel, which carries the cylinder, is belt-driven from a motor having a usable speed range from 10 to 200 revolutions per minute. The mandrel fits standard Edison cylinders with a taper of 3/8″ per foot (1:32). It is easily removable, complete with its shaft and pulley, and may be replaced by different-sized mandrels or other special arrangements for handling non-standard cylinders. The maximum length of cylinder which can be accommodated is 7″ (178mm) and the maximum diameter 3″ (76mm).

The leadscrew, which moves the carriage and pickup, is belt-driven independently of the mandrel by a second motor. The leadscrew motor is controlled by a servo tracking mechanism so as to maintain the pickup accurately at a right angle to the long axis of the cylinder. By this means, a wide range of cylinder groove pitches can be automatically accommodated. The maximum tracking speed is 9″ per minute.

The electrical waveforms which power the two stepper motors are generated by internal signal sources and are specially shaped to give a minimum of ‘cogging’ and vibration. Any remaining vibration is attenuated by resilient mountings between the motors and their weighted bedplates - which are further isolated from the machine structure by a second set of resilient mountings. Stepper motors exhibit a tendency to torsional oscillation at certain speeds; this is damped by a resilient torsional coupling to the drive wheel and drive belts made from high damping coefficient material.

The two drive belts are of different types and lengths. The longer of the two, which is coloured red, runs between the pulley on the front motor and the pulley on the mandrel shaft. The shorter, which is transparent, runs between the flywheel of the back motor and the pulley on the leadscrew.

2.7 Pickup

The pickup comprises a short arm carrying a Shure 44 stereo cartridge. A wide range of styli is available for this cartridge so that it may be used with many different groove sizes. The arm is a laminated structure of thin aluminium alloy and plywood, bonded with bituminous mastic, which effectively prevents any unwanted resonances. It is counterbalanced by a weight on a screw adjustment which can be used to set the tracking weight from 2.0 to 6.5 grams. The total inertial mass of the arm with its cartridge is exceptionally low (less than 15 grams referred to the stylus tip), which allows it to follow uneven cylinder surfaces whilst avoiding excessive stylus pressures.

2.8 Pickup Sensors

The pickup is mounted on a horizontal shaft in a fork by means of cup-and-cone bearings, which allows vertical movement of the cartridge. The fork is pivoted on a vertical shaft carried in miniature ball bearings which allows lateral movement.

Surrounding the vertical shaft is the primary coil of a goniometer, energised with a signal at approximately 45 Kc/s, the secondary coil of which is mounted inside the pickup shell on the horizontal shaft. Vertical movement of the pickup rotates the secondary coil, which picks up a 45 Kc/s signal with an amplitude and polarity that depend on the elevation angle of the pickup. The signal from the goniometer is used to generate a control signal which can be superimposed on the basic speed setting of the mandrel motor. Thus the mandrel speed can be made to vary inversely as the radius of the cylinder at the playback point, which allows eccentric or oval cylinders to be played at constant surface speed, thereby avoiding the 'wow' which usually results from such physical damage.

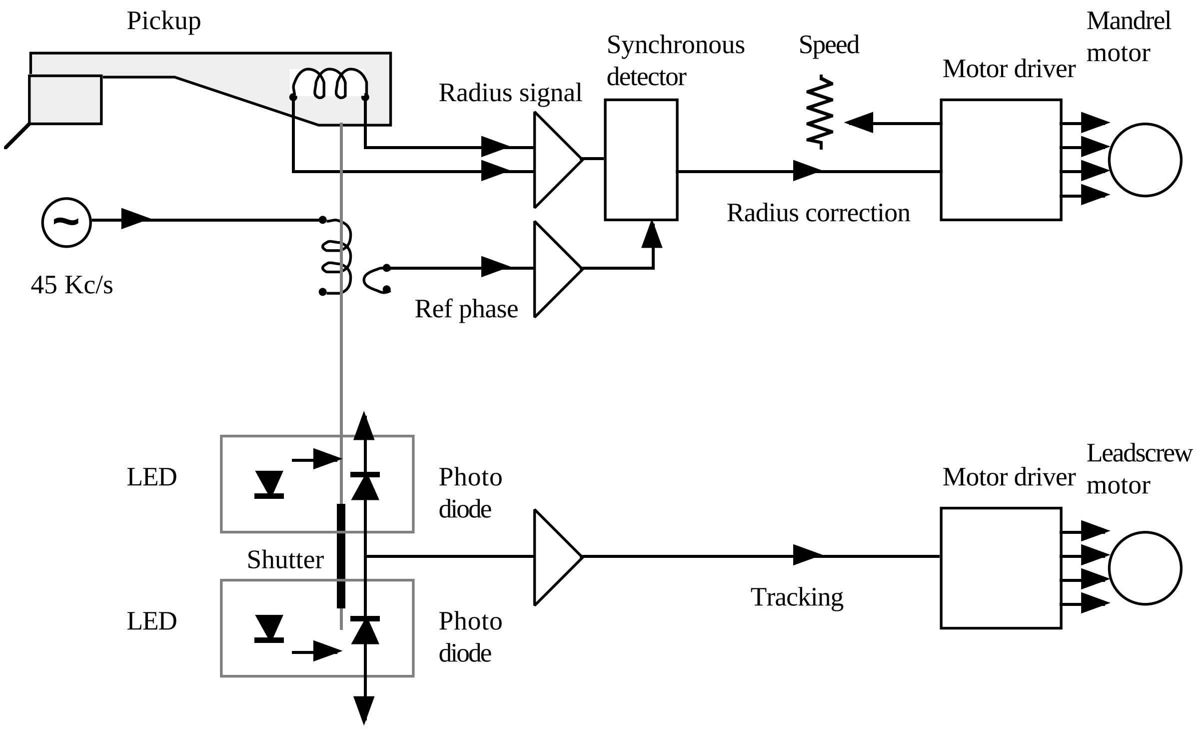

***Fig*.4 Goniometer Block Diagram**

Inside the metal screening box below the pickup is an optical mechanism with a shutter attached to the vertical shaft. When the pickup is at a right angle to the long axis of the cylinder, the shutter falls between two light beams in a position which half-obscures each of them. Lateral movement of the pickup causes the shutter to uncover one of the beams and to obscure the other. The beam intensities are sensed by two photo detectors and used to generate a control signal for the leadscrew motor which moves the entire pickup carriage assembly so as to accurately maintain the aforementioned right angle. This servo system is disabled by a microswitch, which is operated by the pickup lift/lower lever, so as to prevent runaway of the system when the stylus is not bearing upon the cylinder.

The metal screening box also contains the oscillator which powers the goniometer and two low-noise pre-amplifiers for the audio signals from the pickup.

For playing unusually large cylinders, the box can be mounted in higher positions.

CONTROL FACILITIES

3.1 Main on/off

The MAINS ON/OFF switch is located on the back control panel adjacent to the mains input connector.

3.2 System Level

The SYSTEM LEVEL control is located on the back control panel, it is used to set the overall system gain in steps of 4dB. For cylinders with average recorded levels it would be set to the ‘0’ position, but it can be adjusted over a range from -8 to +12 dB, so as to bring unusually quiet or loud recordings to a suitable level. All output signal levels are controlled simultaneously by this switch.

3.3 High-Pass Filter

Cylinder recording often require large amounts of bass boost to give a properly equalised response, this can exaggerate the already high level of rumble which some types of cylinder exhibit. To prevent overloading from rumble, the equipment is provided with a rumble filter in the form of an 8-pole Butterworth high-pass filter. The filter roll-off frequency is set by the front panel FILTER control and is marked in steps of frequency. The filter responds slowly to the control, so as to avoid sudden changes in the audio signal.

3.4 Equalisation

To correct for the bass loss of the recording equipment or to obtain a better power/bandwidth signal for subsequent processes, the equalisation stage applies a bass boost which rises at 6dB per octave below an adjustable turnover point. The turnover is expressed as a time constant measured in microseconds, which is calculated by multiplying the reading on the EQUALISATION dial by 100. The following conversion table may prove useful:

c/s	250	300	350	400	450	500	600	800	1000	1500
uSec	637	531	455	398	354	318	265	199	159	106

The range of settings is much wider than necessary for normal recordings in order to allow the correct time constant to be chosen when half-speed copying.
The bass boost cannot be continued indefinitely, so it is rolled off with a time constant of 6,800 microseconds (approximately 23 c/s turnover).

3.5 Speed

The mandrel speed is determined by the setting of the SPEED control. The dial reading of the control should be multiplied by 20 in order to give the speed in revolutions per minute. Thus, a dial reading of 8·00 will give a speed of 160 R.P.M. A three-position switch allows the mandrel to be started, stopped or revolved slowly. This latter facility is helpful for inspecting the cylinder or setting-up the radius compensation system without having to alter the setting of the main speed dial. When the mandrel motor is switched off, it is de-energised after a few seconds and the mandrel may then be rotated by hand if desired.

The START control determines the behaviour of the mandrel motor when it is switched on or off. ‘Soft’ starting, which makes the motor speed increase or decrease gradually, is preferable for delicate cylinders and general use. The ‘hard’ setting brings the motor up to the chosen speed in the shortest possible time, which can sometimes be useful for starting playback at some particular point on the cylinder. The speed transient which this generates has a duration of approximately 250 milliseconds.

3.6 Radius Compensation

A goniometer associated with the pickup is used to control the rotational speed of the cylinder so as to give a constant surface speed regardless of eccentricity or ovality. The goniometer signal is displayed on the WOBBLE meter, which can be adjusted to give an equal swing each side of the central point by means of the CENTRE control. This may be done with the cylinder playing at normal speed or, more conveniently, at a lower speed selected by the CREEP position on the mandrel speed control switch. The speed compensating signal is applied to the mandrel motor controller in the required proportion by adjustment of the COMPENSATION control. The compensation signal can be turned on and off for comparison purposes by means of a switch.

3.7 Accessories

A clamping system is located on the back of the pickup carriage to allow the attachment of accessories. Normally a magnifying mirror is supplied, so as to give a view of the stylus in contact with the surface of the cylinder. If required, the mirror can be removed and a 3/8″ diameter bar mounted in the clamp so as to permit the attachment of other standard laboratory devices, such as a magnifier or a microscope.

OPERATION

4.1 Location

The apparatus should be installed in a clean dry location with temperatures in the range 0°C to 30°C. Adequate space must be allowed at each side, so as to permit cooling air to flow freely through the ventilation grills.

Sound and other vibrations can be transmitted to the cylinder and pickup through resonant floors or furniture; a heavy solid base, mounted directly on the walls or the foundations, is preferred. Monitoring loudspeakers should be placed where their airborne sound does not impinge directly on the equipment and mounted so that their cabinet vibrations cannot be transmitted by contact with other structures.

A work surface should be arranged immediately adjacent to the equipment so that cylinders do not have to be individually carried long distances. It needs to be acoustically isolated from the equipment so that noises from writing-up the log book and manipulating the cylinders and their boxes are not transmitted to the recordings.

Good lighting is desirable but lamps which emit heat should not be positioned where they might warm wax cylinders.

4.2 Unpacking and Packing

To open the box, make sure it is standing the correct way up (the thinner section is the base). Lift up the levers on the two toggle latches, swing the latch bars clear and lift the lid gently. As the lid is swung back, the hinges will release and it can be removed altogether. The lid contains a kit of connecting leads and spare parts, so it should be stored in a safe and easily-accessible place.

Before replacing the lid, check that the carriage is locked and the pickup is resting on the lift/lower lever plate. It may be advisable to remove the stylus and pack it separately. The mirror mounting bar may need to be be rotated so that the mirror does not project above the highest part of the carriage over-arm. The spares compartment should be securely bolted shut and the bolt lever must lie flat. With the lid in an upright position, engage the two hinges, then swing the lid down to the closed position. If any resistance is met, stop immediately and check to see if anything is misplaced and trapped. Raise the levers of the toggle latches and swing the latch bars upwards onto the top part of each latch, then lower the levers and check that the latch bars have pulled down firmly into a position where they retain the lid securely closed.

4.3 Power

Ensure that the mains power and signal circuits are connected correctly and the supply voltage is within the range printed on the plate adjacent to the mains connector. Switch on at the mains switch, which is adjacent to the mains connector on the back panel. The green lamp on the front panel should light.

4.4 Unlocking & Locking the Carriage

If the pickup carriage is locked at the leftmost end of its travel, the locking bolt will need to be released by means of a slot-type screwdriver (supplied in the spares kit) as follows:

The end of the locking bolt is visible underneath the screening box on the carriage. Place a screwdriver in the slot on the end of the bolt and press firmly. The bolt will slide in, releasing the carriage. When the bolt reaches the end of its inwards travel, it can be locked in that position by turning it clockwise until the slot is at an angle of 45 degrees to the vertical.

To lock the carriage, return it to the leftmost position and press the the bolt inwards hard with a screwdriver. Turn it anticlockwise until the slot is vertical. The bolt will be released and will spring into the locked position (be prepared for the sudden release of the bolt spring during this operation).

4.5 Lubrication and Cleaning

At the start of each working day, apply one drop of lubricating oil to each of the six oiling points [see *Fig*.5]. In addition, smear a few drops along the leadscrew and along the front bedway. Only the correct grade of mineral oil, in the range SAE10 to SAE20 should be used (multigrade oils such as 10W40 are equally suitable). Vegetable oils or multi-component mineral oils will eventually gum-up the mechanism; in particular, oils such as “3 in 1” or “WD40” must <u>never</u> be used. Mop up any surplus oil from the bedplate.and ensure that both drive belts are clean and dry

From time to time clean old oil, which may have become contaminated with dirt and dust, from the leadscrew and bedways using a lint-free cloth; then re-lubricate them.

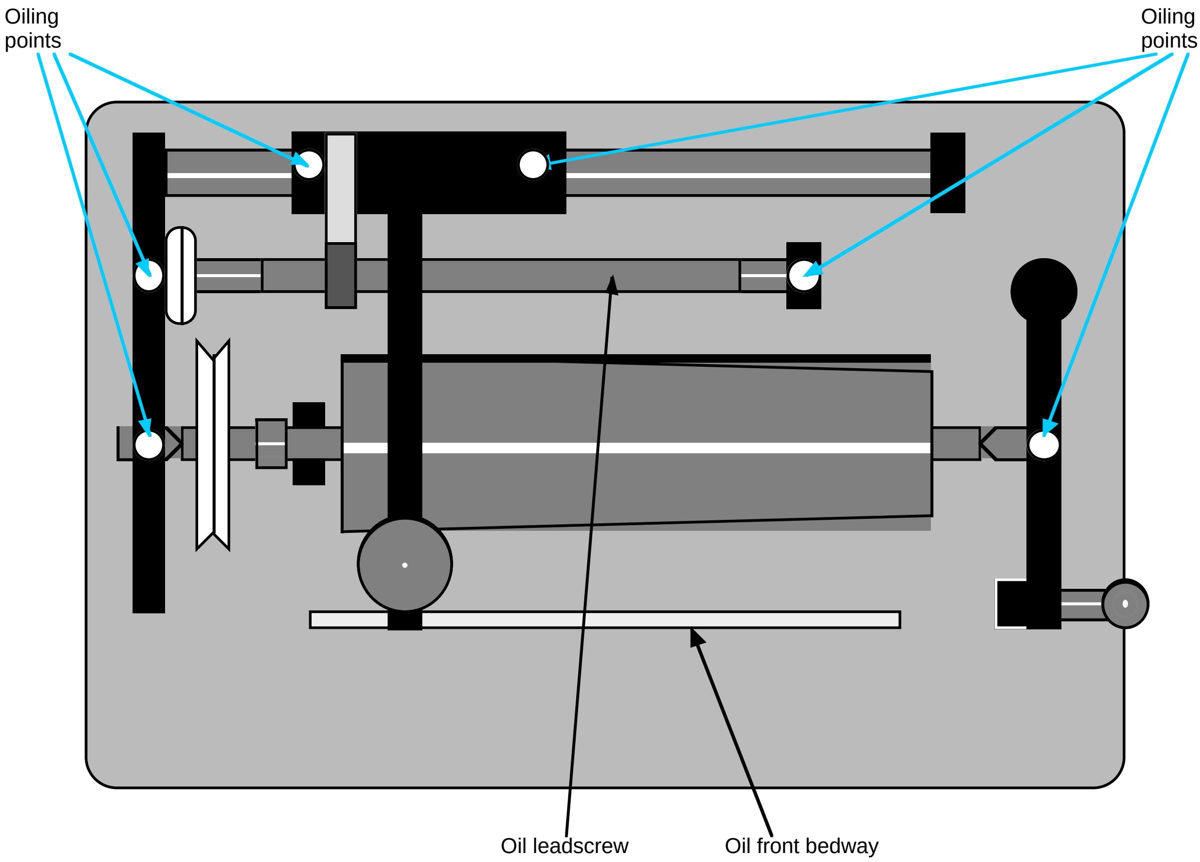

***Fig.*5 Oiling Points**

4.6 Moving the Carriage

The carriage can be moved left or right by lifting the pickup box sufficiently to free the follower nut from the leadscrew and gently sliding the whole assembly along the bedways. Never allow the follower nut to scrape along the thread of the leadscrew.

Alternatively, the pickup can be placed on its lifting arm in the raised position and a little to the right or left of its normal playing position. When the button on the lift/lower lever microswitch is pressed down, this will activate the leadscrew motor and drive the carriage gently in the required direction.

If the leadscrew motor runs but the carriage does not move, the follower nut may have run off the end of the threaded portion of the leadscrew. Lift the carriage and slide it to a position where the follower nut will engage the thread.

If the leadscrew motor runs, the carriage does not move and there is a clicking noise, this could be because the carriage has become jammed or the follower nut has been maladjusted, causing the follower nut to jump over the threads of the leadscrew. This condition must not be allowed to continue and should be investigated and corrected immediately.

4.7 Preparing the Pickup

The pickup needs to be fitted with the correct size of stylus to suit the cylinders being played. As a general guide: two-minute cylinders usually require a stylus of around 0.0354” (0.9mm) diameter and four-minute cylinders require a stylus of 0.0236” (0.6mm) diameter. Other sizes may be needed for less common groove profiles.

The stylus assembly is inserted, brass tube first and stylus downwards, into the diamond-shaped hole at the front bottom edge of the cartridge. To make this task easier, the pickup can be swung to a position parallel with the bedways by lifting it above the carriage arm, rotating it to the left and gently lowering it onto the top edge of the plate which supports the lift/lower mechanism. Extreme care must be taken when inserting the stylus assembly, as both the brass tube and the pole-pieces inside the cartridge hole can be easily damaged if force is applied whilst they are misaligned.

When the stylus assembly is in place, swing the pickup back to its normal position. Check that the lift/lower lever is in the lifted position (upwards and nearest the carriage mounting plate) before lowering the pickup onto the lifting arm.

Adjust the counterweight to give the required stylus pressure; turning it clockwise increases the pressure. To set the stylus pressure accurately, screw the counterweight fully clockwise, then unscrew it anticlockwise whilst counting the turns. Use the following table to determine the required number of anticlockwise turns or the spacing between the counterweight and the pickup:

Weight in gms	Turns	Spacing mm
1.5	42	22.0
2	38	20.0
2.5	34	18.0
3	30	16.0
3.5	25	13.5
4	21	11.5
4.5	17	9.5
5	13	7.5
5.5	9	5.5
6	5	3.4
6.5	0	1.0

If a greater playing weight than 6.5 gms appears necessary, special precautions will have to be taken to prevent the stylus cantilever from collapsing. The weight can then be increased by replacing the counterweight with a lighter one or, in extreme cases, by loading the pickup arm with additional weights (a coin bedded in Plasticene, Blu-Tak or putty can be used as a convenient weight which will not vibrate or fall off).

4.8 Handling Cylinders

Wax cylinders lose a little of their quality at each playing; do not play them unnecessarily because this will eventually cause the sound to deteriorate. They are very fragile and will almost certainly break if they are dropped or allowed to fall. Cylinders can also be broken if a heavy object falls on them or knocks against them, so place them where there is no risk of this happening.

Do not grasp the cylinder by the outside surface. To pick up a cylinder, gently expand two fingers of one hand inside the bore of the cylinder; support its end with your other hand until you are confident of not dropping it. Always stand cylinders on their ends, never on their sides; replace them in their boxes as soon as possible

Cylinder wax contracts when cooling, so do not place a warm cylinder onto a cold mandrel; it will contract onto the mandrel, seize and then split. Allow cylinders and mandrel to reach room temperature before using them. Do not handle cylinders excessively with warm hands and do not leave a cylinder tight on the mandrel when you have finished with it

If a cylinder becomes stuck on the mandrel, warm it gently by cupping it in the palms of your hands; it should expand and ease its grip. Push firmly against the end of the cylinder in several places with the backs of the fingernails of one hand whilst cupping the other hand to receive the cylinder when it suddenly releases its grip. If it does not immediately release, rotate it a few degrees, warm it again and keep trying.

Never attempt to release a stuck cylinder by striking it.

4.9 Loading and Unloading Cylinders

(Read the cylinder handling instructions before attempting this for the first time.)

Set the carriage to the leftmost end of its travel. Move the gate-locking lever downwards to release the loading gate. Swing the loading gate <u>fully</u> open (this is important to prevent the gate-end bearing cone from accidentally scratching the cylinder). The mandrel will settle onto the intermediate bearing saddle and will be retained there by a collar on the mandrel shaft.

The cylinder can be slid onto the mandrel from right to left, large diameter end first. When the cylinder is correctly seated on the mandrel, close the loading gate and raise the locking lever until it clicks into the horizontal position.

To unload the cylinder, release and <u>fully</u> open the loading gate, then slide the cylinder off the mandrel by gently pushing from the left-hand end.

4.10 Playing Cylinders

Load a cylinder as described above. Switch the COMPENSATION switch off and select a suitable rotational speed from the SPEED dial. Lift the carriage and slide it to a position where the stylus is close to the start of the groove on the left end cylinder. Lower the carriage and make any necessary fine adjustments to the pickup position so that it will commence playing at the start of the recording.

Switch on the mandrel motor and gently lower the stylus into the groove by swinging the lift/lower lever forwards and downwards. As the lever reaches its lowest position it will operate a microswitch, this will energise the leadscrew motor which will operate so as to align the carriage and pickup correctly. If the stylus does not enter the starting groove it can be gently guided by hand to the correct position, but take care not to damage the cylinder or stylus when doing this.

As the cylinder plays, the leadscrew should automatically rotate at the necessary speed to keep the pickup alignment correct. When the pickup reaches the end of the cylinder, it should be lifted by raising the lift/lower lever. The carriage should then be raised and returned to the leftmost end of its travel before unloading the cylinder.

4.11 Eccentricity

If the cylinder is oval or eccentric, this will show on the WOBBLE meter during playback and it may be obvious from the sound of the resulting ‘wow’ that some compensation is necessary. Switch the CENTRE control to ‘MANUAL’ and use the CENTRE knob to adjust the pointer on the WOBBLE meter so that it swings equally on each side of the centre mark (this may be easier to do with the mandrel running at CREEP speed). With the cylinder playing normally, switch on the COMPENSATION and adjust the COMPENSATION control until the ‘wow’ sounds as though it has reached a minimum (this would normally occur around the ‘5’ mark on the knob scale).

Some commercial moulded cylinders were tapered on the outside, in order to make them easier to remove from the moulds during manufacture. These can be identified by a gradual drift of the WOBBLE meter reading as the pickup progresses from one end of the cylinder to the other. To prevent this from resulting in a gradual change of speed when the compensation is in use, the CENTRE control may need continuous slight adjustment. Alternatively, the CENTRE control may be switched to ‘AUTO’, which allows it to automatically adjust to the changing cylinder radius (the meter will still drift, as it indicates the true situation). Switch the automatic control off before starting to play another cylinder, then switch it on again if it is needed. Automatic control may have an unpredictable effect on playback speed if the meter is significantly off-scale or if the wobble is asymmetric.

Eccentric cylinders may not be a good fit on the mandrel, so that one end of the cylinder may move around loosely during playback, or the whole cylinder may ‘walk’ along the mandrel. The solution is not to jam the cylinder onto the mandrel by force, which will risk splitting it, but to shim it with thicknesses of paper until it is held snugly. It does not matter if this process pushes the cylinder slightly off centre, because the compensation system can be used to automatically correct the resulting wow.

A few early commercial cylinders were recorded on machines having an unsteady governor, other cylinders may have surfaces which have become unevenly stretched by distortion during storage. The flutter which these defects impose on the recordings cannot be removed by this machine.

4.12 Large Diameter Cylinders

If the cylinder is of large diameter, it may be found that the WOBBLE meter cannot be brought on scale by the range of adjustment available on the CENTRE control. In this case, the screening box, which supports the pickup, will need to be raised so that the pickup is approximately horizontal when playing the larger cylinder.

Two thumbscrews underneath the screening box hold it onto the mounting plate of the carriage. The box is raised by undoing the thumbscrews and replacing them in one of the pairs of higher-positioned threaded holes which are provided in the mounting plate for that purpose.

4.13 Half Speed Playing

Some cylinders may be so badly damaged or warped that they cannot be played at normal speed because the pickup is thrown out of the groove. It is sometimes possible to achieve a satisfactory playback by playing these cylinders at a lower speed and subsequently speeding-up a recording of the performance to hear it at the original speed. Half-speed is usually found to be convenient, as many modern recording devices have the facility to exactly double their playback speed.

The SPEED control covers a sufficiently wide range to allow any normal cylinder to be played at half-speed. The calibration of the control also eases calculation because the resulting speed, after later correction, will be 10 times the dial setting.

In addition, the EQUALISATION control must also be adjusted. In this case, the resulting time constant after subsequent speed correction will be 50 x the dial reading (in microseconds).

4.14 Sound Level

For cylinders of average sound level, a setting of ‘0’ on the SYSTEM LEVEL switch will prove satisfactory and give output signals around the 0dBm level. The switch may be set to give up to +12dB gain for quieter cylinders or down to -8dB for very loud recordings or where the sound of a damaged cylinder needs to be accurately reproduced without overloading. If the equipment is being used for archival work, any changes in the settings should be noted in the recording logbook for future reference.

4.15 Sound Quality

For the ‘playback’ copy, the signal may be equalised by the EQUALISATION control. In the case of electrical recordings, the recording characteristics were usually well-documented and the setting of the required playback equalisation is a straightforward matter of objective fact.

With acoustically-recorded cylinders, the position is much more complex; a subjective judgement is often the only guide. The proper equalisation of acoustic recordings often requires much more elaborate facilities and specialist operation, which can best be provided by dedicated equipment further along the processing chain. Therefore the equalisation available in this equipment has been deliberately restricted in its effect to just a moderate degree of correction, which is accurately known and can be documented in the recording logbook.

In some cases the equalisation setting is a compromise between sound balance and the signal-to-noise ratio of the lower frequencies. In these cases it may be helpful to use the HIGH-PASS FILTER to cut out some of the rumble and other low frequency noise.

4.16 Changing the Mandrel

A special mandrel may be required in order to play badly-damaged or non-standard cylinders. The standard mandrel, shaft, drive pulley and collar must removed and replaced as a single unit and not dismantled.

To remove the mandrel unit, open the loading gate and slip the mandrel drive belt off the pulley. Lift the right hand end of the mandrel shaft until the collar can be lifted over the intermediate support bearing.

To replace the mandrel unit, raise the right hand end of the mandrel shaft and locate the left hand end over the drive end bearing cone. Gently return the shaft to a horizontal position, checking that the collar drops to the left of the intermediate bearing. Replace the drive belt and close the loading gate. The mandrel shaft bearings may need adjustment when one mandrel has been changed for another.

ADJUSTMENTS AND REPLACEMENTS

The equipment uses high quality components which should give a long and stable life without the need for adjustments. The following notes are given in case some of the settings have become disturbed, for instance by severe environmental conditions or replacement of damaged components - however, it must be emphasised that these adjustments must not be undertaken unnecessarily.
Before any interconnectors beween the circuit boards are disconnected, careful note should be made of their positions. A code of dots is drilled into each connector and shown in the board drawings, to assist in their correct re-assembly.

CAUTION: The motor circuits operate at 120v or higher, which can cause electric shock.

5.1 Mandrel Shaft Bearings

The mandrel shaft must run freely but with no looseness. If the equipment is exposed to sudden extreme temperature changes, the bearing settings may be temporarily upset, but they should return to normal as the bedplate casting and mandrel reach a stable temperature. Dirt in the loading gate seating can cause the bearings to suddenly become loose.

If, after checking the causes mentioned above, the mandrel shaft continues to show signs of looseness or binding, slacken one of the two bearing cone retaining screws and undo the adjacent adjusting screw by about one complete turn. Make sure the bearings are well oiled, then slip the drive belt off the mandrel shaft pulley and spin the shaft gently by hand. Rotate the adjustment screw clockwise until the mandrel shaft just ceases to have any end float but still rotates freely. Tighten the locking screw (gently, as it is tapped into an iron casting) and check that the setting of the bearing cone has not been disturbed.

5.2 Leadscrew Bearings

Tip up the carriage so that the follower nut does not bear on the leadscrew. Slip the leadscrew drive belt off its pulley and hold it to one side when checking the leadscrew for free rotation. Slacken both bearing cone retaining screws and gently press the bearing cones towards each other. If possible, have an assistant tighten the retaining screws (gently, as they are tapped into an iron casting), then check that the leadscrew rotates without binding or looseness; it should not be quite as free-running as the mandrel shaft.

5.3 Leadscrew Follower Nut

With the carriage over-arm resting on the front bedway, slacken both screws on the leaf spring which supports the follower nut. Gently but firmly press the nut down onto the leadscrew; avoid putting pressure on the leaf spring. Turn each of the two screws clockwise until it just touches the leaf spring, then turn each screw a further quarter of a turn clockwise. Lift and lower the carriage over-arm and check that the follower begins to make contact with the leadscrew when the arm is about 0.25" above the front bedway. The leaf spring should flex very slightly as the arm is brought fully down onto the bedway.

5.4 Cleaning the Jacks

From time to time the Gauge 'B' jacks and their plugs may need cleaning. The plugs should be cleaned with a hard nylon scouring pad of the domestic type, taking care that all three connecting surfaces are scoured. The jacks are cleaned by inserting a clean plug and rotating it rapidly a few times. Do not use sandpaper, Carborundum, emery cloth, liquid, paste or any other type of abrasive cleaner.

5.5 Internal Access

Before raising the player deck in order to gain access to the motors and the majority of the electronic circuit boards, disconnect the mains supply. It is also a wise precaution to lock the carriage at the left hand end of its travel by means of the spring-loaded bolt. This will prevent it from suddenly falling backwards when the deck is raised.

Undo the two countersunk screws at the front edge of the deck; these screws are long, but only need to be undone a short way in order to release them. Ensure that the loading gate is shut and locked, then grasp the player mechanism by the loading gate and the left hand mandrel bearing pillar and lift with both hands. The deck pivots about a hinge along its back edge; it is heavy and should not be raised so rapidly as to throw the apparatus or the operator off balance.

With the deck in an upright position, lift the brass stay rod which is stowed along the back edge of the front control panel bearer and swing it upwards towards the centre of the underside of the deck where a corresponding stay anchor pillar will be found. Slip the large hole in the end of the stay rod over the anchor pillar, then allow the deck to pivot slightly under its own weight so that the anchor locks into the slot in the stay.

When closing the deck, remember that it is heavy and liable to damage the equipment or the operator if it falls. Pivot the deck gently on its hinge until the stay rod can be disengaged from the anchor pillar. Return the stay rod to its stowage clip behind the front control panel, then carefully lower the deck by grasping the loading gate and the left hand mandrel bearing pillar, so as to keep the hands away from being trapped underneath the edge of the deck as it closes. The two countersunk screws, which are at at the front edge of the deck, can then be engaged with their threaded bosses in the front control panel bearer and screwed down.

5.6 Mains Voltage

Either 200 - 250v or 100 - 125v supplies can be accommodated by altering the position of links inside the power supply unit.

A plate adjacent to the mains power connector shows the voltage for which the equipment has been set up. To alter the settings it is necessary to open the power supply unit as follows:
Ensure the power lead is disconnected, then unscrew the two deck-retaining screws and lift the deck; lock it by means of the stay. Unscrew and remove the three screws which retain the fan mounting plate and gently pull the plate aside. Unplug the fan power connector and remove the fan with its plate. Unscrew the six screws which retain the top cover of the power supply unit. Lift the cover slightly so that the lip around its periphery disengages from the rest of the box, then slide it towards the front of the box until it can be lifted clear, still attached to its leads. The mains voltage links and tagstrip will then be accessible.

For 240 volts
link 2-3, 6-7

For 120 volts
link 1-2, 3-4, 5-6, 7-8

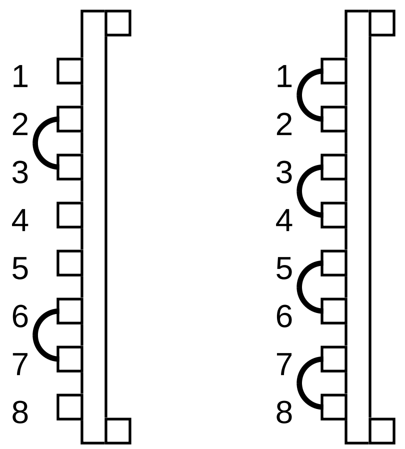

***Fig*.6 Mains Voltage Selection**

When re-soldering the links, take care not to melt the insulation on adjacent wiring.
When replacing the cover, ensure that no wires are trapped before screwing it down. Plug the fan back into its power supply, replace the fan mounting plate. After screwing everything back into position, keep hands clear and reconnect the mains power, switch on and check that the fan rotates freely before lowering the deck. Unscrew the voltage legend plate, turn it over to display the correct voltage setting and screw it back into place.

5.7 Motor Damping Rings

A pair of ‘O’ rings transmits the drive from the motor shaft to the drive wheel. These can become worn in time and will require replacement if the drive begins to slip. Replacement Viton ‘O’ rings to British Standard 110 are provided in the spares kit.

Slip the drive belt off the drive wheel. Using a 2mm A.F. Allen key, undo the grub screw on the locking collar (furthest from the motor) about 1 turn. Keep the Allen key engaged in the grub screw and use it as a lever to rotate the collar anticlockwise and unscrew it from the motor shaft. Pull off the drive wheel to remove the two ‘O’ rings.

In the case of the mandrel motor, clean all the old lubrication from the brass spindle and the bore of the drive wheel. Relubricate with clean mineral oil in the viscosity range SAE 10 to SAE 30. Place a new Viton ‘O’ ring on the motor shaft, followed by the drive wheel, spigot facing away from the motor, and a second new ‘O’ ring. Replace the locking collar, countersunk side towards the motor, and screw it clockwise by hand until it just begins to pinch the ‘O’ rings. Using the Allen key as a lever, tighten it a further half turn clockwise whilst hloding the drive wheel stationary. Gently tighten the grub screw to lock the collar.
Reinstate the drive belt.

In the case of the leadscrew motor, clean the components but do not lubricate them. Place a new Viton ‘O’ ring on the motor shaft, followed by the drive wheel, stepped side towards the motor, and a second new ‘O’ ring. Replace the locking collar, countersunk side towards the motor, and screw it clockwise by hand until it just begins to pinch the ‘O’ rings. Using the Allen key as a lever, tighten it a further half turn clockwise whilst holding the drive wheel stationary. Gently tighten the grub screw to lock the collar.
Rotate the drive wheel by hand; if it wobbles badly, loosen the collar, re-seat the ‘O’ rings to correct the fault and re-tighten the collar. Reinstate the drive belt.

5.8 Drive Belts

To change a drive belt, the driven shaft will have to be removed from its bearings. The mandrel shaft is removed as described in section 4.16. The leadscrew shaft is removed by undoing both bearing cone retaining screws one turn, then sliding the cones away from the shaft to release it (do not lose the cones).
Spare belts will be found in the spares kit, the red belt drives the mandrel and the transparent belt drives the leadscrew.

When fitting a new mandrel belt, it may be helpful to remove the air deflector plate from the belt aperture. This plate prevents warm air from the motor drive amplifiers from heating the mandrel shaft and must not be discarded. When the plate is replaced, take care to position it so that it does not rub on the belt.

Reinstate the mandrel as described in section 4.16. When replacing the leadscrew, make sure that the slot in each bearing cone is facing upwards and that the two cones are fitted approximately the same distance into their respective mounting pillars, then adjust the bearing settings as described in section 5.2.

5.9 Motor Current

Incorrect motor current may be indicated by one of the motors becoming noisy with no mechanical cause. If a motor suddenly becomes extremely noisy with rumbling or grumbling sounds, suspect a fault in the drive circuit, but if the noise is of a 'singing' nature, the motor drive current may be at fault. (*Note:* The motor speed will need re-adjustment if the mandrel motor current setting is altered.)

With the motor running, measure the voltage across each of its collector load resistors to check whether one of the phases differs significantly from the other three. If this is the case, suspect that a driver transistor or load resistor is at fault. If the phase voltages are all similar, unsolder the white wire of the relevant motor from the motor tagboard. Reconnect the wire through a D.C. ammeter to read the average current of the motor. Adjust the relevant 'Ref' voltage control, R305 or R405, to give 300 mA when the motor is running at a moderate speed. Solder the white wire back onto the correct tag.

5.10 Mandrel Motor Speed

If an accurate 50 c/s or 60c/s mains supply is available: the 40-spot stroboscope supplied in the spares kit should be fitted temporarily to the gate end of the mandrel drive shaft or may be left permanently in position at the drive end of the mandrel shaft. View the stroboscope by the light of a tungsten bulb, choke-ballasted flourescent tube or special strobe light running from A.C. mains of accurately known frequency. Adjust the SPEED dial to 7·50 for 50 c/s mains or to 9·00 for 60 c/s mains (corresponding to 150 or 180 RPM respectively) and set the mandrel running. If the stroboscope image shows a tendency to revolve, make small adjustments to the the motor speed pre-set control, R251, until the image is stationary. The dial indications should now be accurate over the entire range of the SPEED control.

If an accurate mains supply is not available, the speed may be calibrated with the aid of an accurate watch or clock with a hand which steps at one-second intervals. Adjust the speed dial to 9·00 and set the mandrel running. Gently trail the back of a fingernail against the mandrel shaft collar so that a click is felt as one of the collar grub screws passes under the nail at each revolution. Check that every third click synchronises with the one-second movement of the timepiece hand. Continue to observe this for at least a minute, to check that the events stay in synchronism over the whole period. If any discrepancy is found, adjust R251 as described above.

5.11 Cartridge Sensitivity Adjustment

Setting the level accurately requires a test cylinder recorded at the required standard level; if a test cylinder is not available, choose a cylinder recorded at average volume. Set the SYSTEM LEVEL control to 0dB. To gain access to the R508 and 509, which adjust the level, raise the playing deck and undo the two screws at the extreme ends of the front panel bearer. Lift the front panel and carefully swing it to the left side (sufficient extra cable has been provided to allow this to be done easily). Replace the two screws and screw them downwards until the flats of their heads are about 1mm above the top of the ventilation grills. Carefully lower the deck onto the screws and load the test cylinder. Adjust R509 and R508 until the left and right outputs give a signal of 0dBm (a reading of ‘4’ on a BBC peak programme meter). If a test cylinder is not available, adjust the level from the average cylinder for an average reading which peaks occasionally to 8dBm. (a reading of ‘6’ on a BBC peak programme meter). Switch the vertical/lateral switch to ‘lateral’ and adjust both gain controls slightly in opposite directions until the lowest signal is obtained. Switch back to ‘vertical’.

Remove the cylinder and raise the deck. Unscrew the two front panel screws, replace the front panel and screw it back in place. Lower the deck.

5.12 High-pass Filter

Realignment of the high-pass filter on the audio board should only be undertaken if there is a clear indication that it is necessary. It requires specialist equipment as follows:

a) An audio signal generator of 600 output capable of giving a hum-free 1 Kc/s sinewave of stable amplitude at about 1v R.M.S. and having a fine amplitude control. If the signal generator is only equipped with a step attenuator, the output can be varied between steps by loading the output terminals with a 10k variable resistor.

b) A high input impedance A.C. voltmeter which can read the amplitude of a 1v R.M.S. sinewave to an accuracy of one millivolt.

Set the front panel BASS CUT switch to ‘0’ and carefully remove Ic507 from its socket. Connect the signal generator between the earthing point and Tp501. Connect the voltmeter to the earthing point and Tp501.

> Stage 1) Adjust the signal generator output to read 1·000v on the meter. Transfer the meter to Tp502 and adjust R555 until the meter reads 1·036v.
>
> Stage 2) Reduce the signal generator output until the meter reads 1·000v at Tp502. Transfer the meter to Tp503 and adjust R561 until the meter reads 1·337v.

Stage 3) Connect the signal generator and the meter to Tp504. Adjust the signal generator output until the meter reads 1·000v. Transfer the meter to Tp505 and adjust R570 until the meter reads 1·889v.

Stage 4) Reduce the signal generator output until the meter reads 1·000v at Tp505. Transfer the meter to Tp506 and adjust R577 until the meter reads 2·610v.

Set overall gain) Inject a 1·000v signal into Pin 1 of the empty socket of Ic507. Transfer the meter to Tp507 and adjust R582 until the meter reads 1·000v.

Switch off the power and replace Ic507 in its socket, taking care that it is the facing the correct way and no pins are bent.

CIRCUIT DESCRIPTION

6.1 Pickup Circuits (Prefix 100)

The pickup contains a Shure moving iron stereophonic cartridge type 44, (L104, L105) connected in the conventional way for lateral recordings. The inversion of one channel which is necessary for vertical recordings is performed later. The pickup also contains the secondary winding of a goniometer, L102, which is used to measure the vertical displacement of the pickup arm.

Unbalanced stereophonic audio signals from the cartridge, a two-wire balanced signal from the goniometer secondary coil and an earthing connection are brought down through the hollow pickup shaft as extra-flexible conductors encased in a silicone rubber sleeve. These connections are fragile and must be treated with care.

The cartridge coils are loaded by R102 and R103 and the audio signals are amplified by Ic107 and Ic108 with a voltage gain of approximately 34.

The goniometer is powered from a signal generated by an oscillator, Ic101. From Ic101, a squarewave at approximately 45 Kc/s is buffered by Ic102 - 106 and used to drive a series-resonant circuit formed by L101 and C108. L101 forms the primary winding of the goinometer of which L102 is the secondary and L103 the tertiary winding. The signal picked up by the moving coil L102 will vary in amplitude and polarity, depending on the physical relationship between L102 and L101, hence it can be used as an indicator of the angle (measured about a horizontal axis) between the pickup and the fixed base on which L101 is mounted. The tertiary winding, L103, picks up a small signal which is used as a phase reference to determine the polarity of the signals from L102.

Rotation of the pickup about a vertical axis is detected by an optical system which comprises a metal shutter attached to the pickup shaft and arranged to partially block two light beams. The light beams are generated by two infra-red LEDs, D101 and D102, and detected by two photo-diodes, D103 and D104. The photo-diodes are arranged so that when the shutter is in the mid position, corresponding to the pickup arm being at right angles to the long axis of the cylinder mandrel, they are both half-covered by the shutter and their currents are in balance. There is therefore no net current at their mid point. If the pickup swings away from the central position, one photo-diode is progressively covered and the other is progressively uncovered, causing an imbalance in their currents which flows to a later detector stage as the ‘slew’ signal.

The microswitch which is operated in the ‘fully down’ position of the pickup lift/lower lever changes the polarity of the lift/lower signal by connecting one end of R112 to the -ve line. R113, in combination with a capacitor at the far end of the flexible pickup cable, dampens switching transients in the cable which might otherwise be picked up by the audio circuits.

The power supply to the various pickup circuits is decoupled by C106 and C107 in conjunction with R110 and R111, which act as burn-out resistors to protect the main power supply in the event of a fault. The supply to Ic101 to 106 is reduced to 12 volts and stabilised by Ic109.

6.2 Speed Control (Prefix 200)

a) GONIOMETER SIGNAL AMPLIFIER AND DETECTOR
Balanced 45Kc/s signals from the goniometer secondary, L102, are amplified by Ic201 to 204, connected in ‘instrumentation amplifier’ configuration to give a voltage gain of 21 per stage. The gain-bandwidth product is sufficiently low to allow ordinary audio operational amplifiers to be used for this function. The phase reference signal from the goniometer tertiary, L103, is similarly amplified by Ic207 to 210. Although this signal is unbalanced, a balanced amplifier configuration is used to ensure similar phase errors in both the signal and the reference amplifier chains. The reference signal is limited in amplitude by D201 and D202, so that the signal into Ic223 does not exceed a value which would cause the CMOS switching circuit to latch up.

The balanced goniometer signals are combined by Ic205 and 206 to give two unbalanced signals of opposite polarity, which are reduced in voltage by the dividers R217 and 218, R219 and 220, to prevent latch-up of Ic223. The reference signals are similarly combined by Ic211 and used to control the switching action of Ic223.

The switching action of Ic223 synchronously demodulates three signals simultaneously: Swa gives a voltage level proportional to the goniometer signal, Swb and Swc give positive and negative voltage levels proportional to the goiniometer reference voltage. All three signals are passed through filters, R339 and C101, R240 and C102, R241 and C103 to remove any residual 45 Kc/s component, then buffered by Ic 212 to 214.

Because cylinders are not standardised in diameter, the goniometer signal will usually contain a significant D.C. offset which needs to be cancelled in order to give a speed correction signal which swings equally each side of zero. This cancellation is achieved in Ic215 by combining the goniometer signal from Ic212 with a cancellation signal from the front panel RADIUS ZERO control. The cancellation signal can be either positive or negative, but is proportional to the amplitude of the phase reference signal - which is, in turn, proportional to the amplitude of the goniometer primary signal. Thus variations in amplitude of the goniometer primary signal caused, for instance, by movement of nearby metallic objects, do not affect the accuracy of the offset cancellation.

b) SPEED CONTROLLER

The speed compensation signal from Ic215 is used to operate the front panel meter, which is a centre-zero instrument calibrated in arbitrary units of WOBBLE. Full scale on the meter corresponds to a wow in pitch of over 10% peak-to-peak and this represents the practical limit of the correction capabilities of the system. The meter is protected against overload by D203 and D294.

The required amplitude of compensation signal is selected by the COMPENSATION control, R246. When playing a tapered cylinder, there will be a slow drift in the D.C. level of the compensation signal causing an unwanted drift in mandrel speed. By using a long time-constant A.C coupling, the slow change in the correction signal will be removed.

The basic speed signal is derived from a pre-set potentiometer, R251. It is fed from the same stabilised supply as the motor driver circuits, so any slight drift in the supply will be cancelled by later circuitry and will not cause a change in the calibration of the speed settings. The basic speed signal and the speed correction signal are buffered by Ic216 and 217, they are combined by Ic218 to give a speed signal which can be selected by the front panel SPEED control.

A three-position switch on the front panel is used to start and stop the mandrel motor, or to set it to ‘creep’ slowly for examination of the cylinder surface or to help in setting up the compensation system. The pull-down resistors, R258 and 259 give negative voltages on the two control lines when the mandrel motor switch is switched off. The selected line becomes positive when connected to the +7.5v supply via the mandrel motor switch and R257. The resistors R260 and 261, with the capacitors C204 and 205, form long time-constants which slow the voltage changes on the control lines so as to give a soft starting facility. This effect can be disabled when required by Sw204, which only acts upon the main speed control line.

The oscillator Ic226 generates a 2 Kc/s triangular wave which is applied to the non-inverting inputs of Ic221 and 222. These op-amps are used as comparators between the triangle waveform and the voltages on control lines. The output of the op-amps are variable on-off ratio square waves, which are buffered by Ic224 and 225 and used to control Swa and Swb respectively. In Ic223, Swa progressively switches in the speed control signal whereas Swb progressively switches in a fixed low voltage derived from the divider R268 and 269 which gives a suitable creep speed. The residual chopping signal is removed from the speed signal by the time constant R270 and C209.

The leadscrew disable signal from the lift/lower lever microswitch is damped by C207 and used to control Swc of Ic223.

The off-balance current signal from the pickup slew detecting photo-diodes develops a voltage across R265 which is buffered by Ic219 and used to control the leadscrew motor. It is disabled by the action of Ic223 Swc to prevent the carriage from running away when the pickup is lifted.

6.3 Mandrel Motor & Leadscrew Motor (Prefix 300 - 400)

The leadscrew motor circuit will be considered first, with any differences between that and the mandrel motor circuit being noted later.

The drive waveform which gives the lowest noise and vibration for this particular type of motor has been determined by a series of experiments. The optimum appears to be a truncated triangular waveform with a maximum amplitude of 200mA per phase. Four phases of this waveform, in quadrature phase relationship, need to be generated at a speed which gives the desired rate of motor rotation.

a) LEADSCREW MOTOR WAVEFORM GENERATOR
The slew signal from Ic223 Swc is damped by R401, R402 and C410. This large time constant not only serves to stabilise the control loop, but also keeps the maximum rate of speed change within the capabilities of the leadscrew motor, which is coupled to a high inertia flywheel. To allow a faster response time when the control signal is a long way out of range, D412 and 413 by-pass R402 if the error signal exceeds 0.6 volts; R403 gives a small degree of extra damping to the system.

The motor speed signal is buffered by Ic402 and inverted by Ic403, so that both the normal and inverted control signals are available on the switches Swb and Swc of Ic415. These voltages are used to control the rate of rise and fall of the ramp waveforms generated by Ic409 and Ic411, which act as integrators in conjunction with the time constants of R422 and C404, R432 and C405 respectively.

Matching positive and negative reference voltages are generated by Ic403 and 404. The ramp waveform from Ic409 and Ic411 are compared with the reference voltages by comparators Ic 407 and 408, Ic 410 and 412.

Consider a situation where Swc is connected to a negative speed signal. The output voltage of Ic409 will ramp upwards until it reaches the +ve reference voltage. At this point the output of Ic407 will swing positive and inject sufficient current through D404 to prevent any further voltage rise on Ic409 output. The divider action of R419 and 420 means that the output voltage of Ic407 must be a good deal higher than that necessary to overcome the 0.6 volt drop of D404.

The output of the lower comparator, Ic408, will be positive at this stage and a combination of the two positive voltages on

R418 and R426 will raise the voltage across R417 sufficiently to exceed the triggering threshold of the Schmidt trigger Ic405. The output of Ic405 will become negative, thereby connecting Swb to the -ve control voltage. This will cause the output of Ic411 to ramp positive until it is clamped by the action of Ic410.

When the clamp Ic410 operates, it will change the state of the Schmidt trigger Ic406, which will cause Swc to select a positive speed control voltage. This will cause the output of Ic409 to ramp downwards. As the ramp falls below the positive reference threshold, the output of Ic407 would swing negative, but this alone is not sufficient to cause Ic405 to change state. When the output of Ic409 is clamped by the action of Ic 408, the further voltage change from Ic408 is sufficient to cause the input voltage to Ic405 to exceed its negative operating threshold, whereupon the output of Ic405 changes state and causes the output of Ic411 to begin ramping downwards.

When the output of Ic411 is clamped by Ic412, the state of Swc changes and the cycle begins again. Thus two phases of truncated triangle waveforms are generated at a speed which depends upon the speed control voltage.

The purpose of C402 and C403 is to make the inputs of the Schmidt triggers less liable to false triggering from glitches picked up by capacitance from adjacent wiring. R422 and R432 ensure stability of the integrator circuit when the clamps are operating.

When the speed input signal is zero, there is a danger that the motor could be stopped with one of the output transistors on a high dissipation part of its characteristic for a long time. In order to prevent the overheating which this might cause, the triangle waveform generators are disabled when the speed control signal remains below 50 millivolts for more than a few seconds.

The control signal voltages are sensed by D402 and 403 and applied to the input of Ic 415. The current through R411, D401 and R412 develops a voltage across D401 which counteracts the threshold voltages of D402 or 403. The current through R413 provides the necessary 50 millivolts standoff. The divider R415 and 415 protects Ic415 against latch-up and the timing circuit R416 and C407 delays the switch-off; D412 ensure a prompt re-start.

When the voltage across C407 rises sufficiently, the inhibit action of Swa and Swb is triggered. This disconnects the speed control voltage from the integrators and R421 and 431 allow the timing capacitors C404 and 405 to discharge, thereby reducing the motor current to zero.

b) LEADSCREW MOTOR DRIVER

The two triangle waveforms are applied to Ic 413 and 414, which generate inverted versions to give the four phases which are required. These waveforms are buffered by Tr401 to 404, which appear to be PNP emitter followers but are not used as such. The base-emitter offset voltage of these driver transistors is used to counteract the offset voltage of the output transistors, Tr 405 to 408, thereby removing any ‘Class B’ discontinuity from the motor currents. The resistors R438, 441, 440, 443 will only pass the required maximum base current to the output transistors to allow them to operate normally, as there is no current amplification emitter follower action from the driver transistors in the positive signal direction. This means that the voltage waveforms across the emitter resistors of the output stage (R447, 449, 451, 453) will only be an accurate replica of the waveforms on the emitters of the driver transistors if the motor currents are within the normal range. If distortion is noted in the emitter resistor waveforms, this is a powerful diagnostic tool for locating the source of a fault.

The output transistors will accurately control the current through the motor windings as long as there is sufficient supply voltage to overcome the inductive component of the winding impedance. For full speed operation, a supply in excess of 120 volts is required and this would cause considerable power dissipation in the output transistors. To help to reduce the dissipation in the transistors, resistors R446, 448, 450, 452 have been placed in series with the motor windings. Diodes D408 to 411 prevent the collector voltage of the output transistors from swinging negative, which limits the positive excursion of the opposite transistor of the pair to a safe value.

c) DIFFERENCES IN THE MANDREL MOTOR CIRCUIT

The mandrel motor drives a system with much less inertia than the leadscrew motor and it needs to generate rapid speed variations to correct for eccentric cylinders, therefore the input signal damping components are not required.

The input voltage sensor for the mandrel motor does not include a diode equivalent to D402. This is to ensure that the mandrel can never rotate backwards and damage the stylus. The provision for including the missing diode has been retained in case it is needed for some future variant. The switchoff timing circuit has been omitted.

The circuit diagram of the mandrel motor driver includes Ic316 and Ic317 which provide the +ve and -ve 7.5v lines for both drivers.

6.4 Audio Amplifiers (Prefix 500 - 600)

a) INPUT STAGES

Signals from Ic107 and 108 are processed by the amplifier board; only one channel will be described, as the action of the other channel is identical.

The network R501, R502, C501, C502, in conjunction with Ic501 and R504 forms a Wein Bridge rejector notch centred on 45 Kc/s. This is to reject any residual goniometer signal which may have found its way into the audio circuits. The Wein notch is not very sharp and has a small unwanted attenuating effect on signals at the top end of the audio range, so the deficiency is made up by the following stage. Ic502 is configured as a Sallen & Key low pass filter with a 3dB point around 23.6 Kc/s. By under-damping it, a slight rise in response is produced at the top end of the audio band which counteracts the droop caused by the Wein notch. The combined rejection of 45 Kc/s signals by these two stages is in excess of 60dB.

To allow for the possible use of different types of cartridge or to accurately balance the two channels, a cartridge sensitivity control, R509, allows the channel gains to be set individually. The signal is then amplified by Ic503 with a gain which is determined by the setting of the SYSTEM LEVEL back panel control. The capacitor C505 is included to prevent instability being caused by the long wiring to the back panel control.

At Ic507 the two channel signals are combined to give a monophonic signal. Because cylinders are usually cut with vertical modulation, the mono signal is obtained by subtraction of the two channels. A very few cylinders, mostly of the dictating machine type, were recorded with lateral modulation; Sw501 is included to allow the signals to be summed in this special case, but it is located on the amplifier board so as to prevent mis-operation in normal use.

b) HIGH-PASS FILTER

The signal is reduced in level by R529 to avoid overloading the filter stages which operate from + and - 7.5v rails. As each filter stage incorporates a certain amount of gain, the input signal level is made adjustable so that the overall gain of the filter and equalisation stage will return the signal to its normal level.

The high pass Butterworth filter consists of four cascaded stages with identical time constants but different stage gains, which must be accurately set if the correct response curve is to be generated. Taking the first stage around Ic519 as an example: the time constants are produced by C518 with R550 and by C519 with R551. The stage gain is set by R555 in conjunction with R554 and R556. The time constants are accurately tracked by changing the apparent values of R550 and 551 by means of fast-acting switches with variable on/off ratio. To prevent loss of the bias current return path when the switches are completely open, R553 and 552 have been included. The circuits around Ic520, 522 and 523 are similar.

Because of the increasing signal amplitude through the filter stages, there is a need for some attenuation to prevent overloading (whilst still maintaining a good signal to noise ratio at the input stages). This is achieved by R563 and 564, followed by a buffer, Ic521, so as to present the correct impedance to the following stage.

The apparent value of the time constant resistors is determined by the on/off ratio of the switches, which are controlled by a servo loop so as to track a master control on the front panel. The master control, R533, forms part of a Wheatstone Bridge with the switched R534 being its counterpart in the opposite limb. The off-balance voltage of the bridge is amplified by the 'instrumentation amplifier' triple formed by Ic509, 510 and 511. After damping by R544 and C513, it is buffered by Ic512 and any residual noise removed by R545 with C517. It is then further buffered by Tr502 and used to control a constant current source, Tr503, which serves to discharge C516. At high currents, the emitter resistor is shunted by a Zener diode, D503, operated on the 'knee' of its characteristic. This is done to allow fine control at low currents but to prevent the emitter voltage from rising above the lower triggering voltage of Ic515 at high currrents. The non-linearity of the transfer characteristic does not matter because the current source is within a feedback-controlled loop.

An oscillator, generating a square wave at about 100 Kc/s, is formed by R548, C514 and Ic513. The square wave is differentiated by C515 and R549 to give very short pulses, which are sharpened by Ic514 and applied to D501 to charge C516. As already mentioned, the discharge rate of C516 is controlled by Tr503 in response to the off-balance signal from the bridge. Thus the bridge signal lengthens or shortens the width of the pulse, which is reconstituted by Ic515 and fed to the switch control inputs by Ic516 to 518.

When the master resistor is altered, the switch pulse width changes until the bridge is back in balance - thus all the slave resistors in the filter, which are switched with the same pulse width, simultaneously track the value of the master resistor.

A low-pass filter, based around Ic524, follows the main filter stages in order to remove any residual 100 Kc/s switching components from the signal. It is set to cut off around 22 Kc/s and the damping factor can be adjusted over a limited range so as to counteract any slight losses which may have occurred elsewhere in the circuit at high audio frequencies.

c) EQUALISATION

An equalisation stage of this type would normally be used to counteract the deliberate controlled bass loss which is introduced during electrical recording to prevent groove inter-cutting. Although electrical cylinder recordings are rarely encountered, this facility can still be helpful as a first stage in compensating the characteristics of acoustic recordings.

The signal is passed through two paths, one of which incorporates an integrator giving a 6db/octave bass boost. When the two signals are recombined, an accurate compensation results. The direct signal is fed to the combining amplifier, Ic527, through R590; the value of R591 being chosen to make up gain lost in the filter. As well as passing directly to Ic527, the signal is inverted by Ic525 and fed to the integrator Ic526. Capacitor C529 is specially selected for accuracy and, together with R586 and 587 determines the time constant of the integrator and, therefore, the point at which its output predominates over the direct signal.

Careful choice of component values allows the effective turnover time constant to be read directly in microseconds off the dial attached to R586. If this dial is removed and replaced for any reason, care must be taken to ensure that it adjusted on its shaft to read 0·50 when R586 is fully anticlockwise.

Any residual D.C. which might upset the action of the integrator is removed by C528 and the bottom limit of integration is set by the combination of R588 and C529, which rolls-off the bass boost below 25 c/s.

d) OUTPUT STAGES

Four output stages are used to feed the signals to standard British Post Office / B.B.C. Gauge ‘B’ jacks. The output stage circuitry is mounted on a board attached to the jackfield. The circuits are identical so only the ‘direct left’ signal stage will be described.

The input signal is buffered by Ic606 and fed to the output jack through R614 and C604. Any residual D.C. is removed from the output signal by C604 with R618. The same signal is also fed to Ic608, which runs in tandem with Ic606 driving C604 through R616 which is effectively in parallel with R616. Thus the output impedance appearing at the jack is equivalent to R614 and 616 in parallel i.e. 300 . The parallel arrangement being necessary because each individual amplifier is limited to driving no less than a 600 load at full voltage swing. The signal is inverted by Ic605, which, in parallel with Ic607, drives current through C603 in a similar manner.

Thus the output signal appears to come from two 300 sources in series, i.e. 600 , and can deliver +20dBm into a 600-ohm load. Either signal pole can be short-circuited to earth without causing damage to components or distortion to the remaining signal, so unbalanced systems can be driven without modification (the signal source resistance will then appear to be 300).

The signal connections to the ‘direct right’ output jack are transposed, so that paralleling the direct left and right signals gives a mono signal which corresponds to vertical modulation.

e) POWER SUPPLIES
The +15v supply is decoupled by R594 and C531; the -15v supply is decoupled by R595 and C532. In addition, the two resistors are designed to burn out and protect the main power supply in the event of a fault in the audio circuitry.

Two further supplies of + and - 7.5volts are require to operate the logic and switching Ics, These are derived from the 15-volt rails, but any noise signal between them will cause the on/off ratio of the high-pass filter switches to vary, which will modulate the input leakage current of the filter amplifiers and impose noise on the signal. To prevent this, the -7.5v rail is derived in the usual way by Ic538 with reference to the 0v rail, but the +7.5v rail is supplied by Ic537 with reference to the -7.5v rail, so that any noise on the negative rail appears in common mode between the two power rails.

In addition, the supply to Ic513 to 515 need to be particularly quiet, so they are derived from Tr501, a low-noise transistor which emitter follows a heavily decoupled stabilised voltage derived from the +7.5v rail.

6.5 Power Supply (Prefix 700)

Main power is connected to two mains transformers through a fuse and double-pole switch. The transformer primary connections are brought out to a tagstrip which allows them to be connected in series or in parallel to cover the voltage ranges of 200 - 250v and 100 - 125v respectively.

a) L.T. SUPPLIES
The transformer comprising L701 to 704 is centre tapped to earth and supplies 15v - 0 - 15v to a full wave rectifier bridge, D 701 to 704 to give unregulated + and - supplies in the region of 18v. The voltages are smoothed by C701 and 702 and regulated to 15v by Ic701 and 702. Stability is ensured by C703 to 706. This supply is also used to run the 24v fan motor through a voltage dropping resistor, R706.

b) H.T. SUPPLIES
The transformer comprising L705 to 708 has the two 55-volt secondary windings connected in series to give a supply of 110v A.C. This is rectified by a full wave bridge rectifier, D705 to 708 and smoothed by C707 to give an unregulated supply of about 150v D.C. which is used to supply both motors. R705 ensures prompt discharge of C707 when the supply is switched off, so as to minimise any risk of electrical shock.

Burnout resistors, R701 to 703 are fitted to protect the transformers in the event of sustained overload. If they are found to have burned out, they must be replaced by similar types for continued safety. The fault which caused the problem must be traced and cleared before switching on again.

6d

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