FORD

Service Manual

FORD
NEW HOLLAND

Ultra-Command™ Powershift Transmission 8630, 8730, 8830

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Reprinted

PART 5
TRANSMISSION SYSTEMS

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PART 5

TRANSMISSION SYSTEMS

(POST MARCH 1990)

Chapter 5

ULTRA–COMMAND™ POWERSHIFT TRANSMISSION FORD 8630, 8730 and 8830

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A. TRANSMISSION – DESCRIPTION AND OPERATION

The ULTRA–COMMAND™ Powershift Transmission is an 18 forward speed and 9 reverse speed hydro–mechanical transmission with electronic management. The term "powershift" refers to the feature of the transmission that allows gear changing, or shifting, to be performed without interruption of the power delivery to the wheels.

Eighteen forward speeds are achieved by using a constant mesh system of high quality carburized straight cut gears. Power flow selection is made possible by multi–plate wet clutches engaged hydraulically using an electronic control system. Figure 1 shows a cut–away view of the mechanical aspect of the transmission.

Transmission Housing

With reference to Figure 1, the housing is cast in three major parts, a front housing, a centre section and a rear housing. Access to the internal components is only possible by separating the rear housing from the centre section, and then removing the centre section from the front housing. The transmission must be completely removed from the tractor for all disassembly procedures involving the internal components.

The front housing contains the primary speed components that provide the first 9 speeds in their initial stages. In addition, it provides support on its forward face for the front bearings of these components. The centre section provides support for the rear bearings of these components and has attached to it the main hydraulic control valve housing. This centre section also acts as the oil circuit distributor. All circuits are drilled and routed to the various components through this item. Additionally, the forward bearings of the components in the rear housing are supported by this centre section. The rear

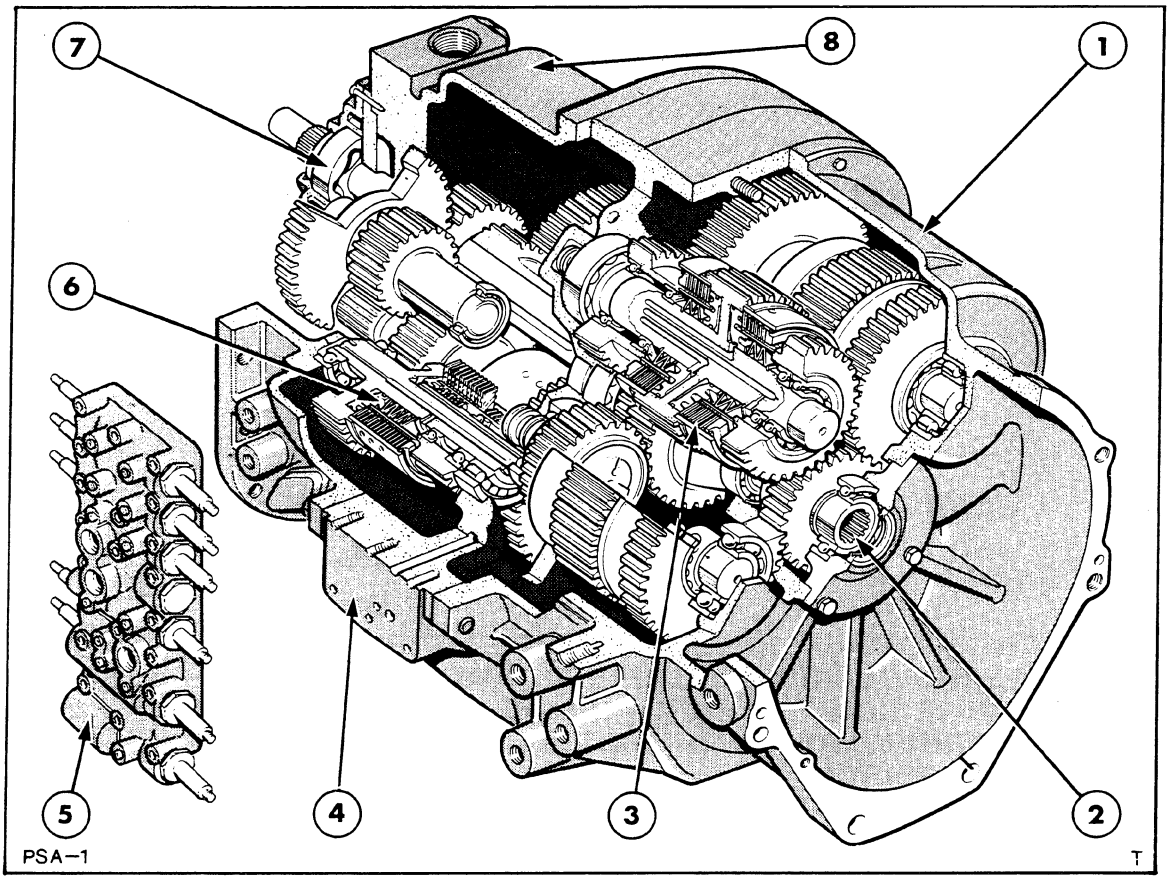

Figure 1
Mechanical Components of the powershift Transmission

1. Front Housing
2. Main Input and Drive Gear
3.. Sectioned Speed Clutch Assembly (one of three paired clutches)
4. Centre Section
5. Hydraulic Control Valve
6. Sectioned Directional Clutch (one of three single clutches)
7. Hydraulic Pump
8. Rear Housing

housing contains the components providing speeds 10 to 18 and reverse speeds. This housing also provides support for the rear bearings of these components.

The transmission housings together with the rear axle centre housing form a common oil reservoir.

Clutches

Nine multi–plate clutches are used in conjunction with twenty two gears. The clutches can be divided into two groups. The first group, consists of six clutches positioned in the transmission front housing; the second group of 3 clutches are positioned in the transmission rear housing.

The first group of clutches are termed "speed" clutches and control the selection of the first nine ratios. The clutches provide the early stages of engine speed reduction. The second group of clutches are termed "directional" clutches and working with the speed clutches, provide a further two stages of engine speed reduction to the required final output level and additionally provide reverse direction.

Illustrated in Figure 2 is a sectional view of a speed clutch assembly. In fact, two speed clutches are shown sharing a common centre shaft. This illustration is representative of all six speed clutches in that they are all paired and share common shafts. The only differences in these three pairs of speed clutches are the centre shaft of one of them and the number of gear teeth and hub shape of the related gears.

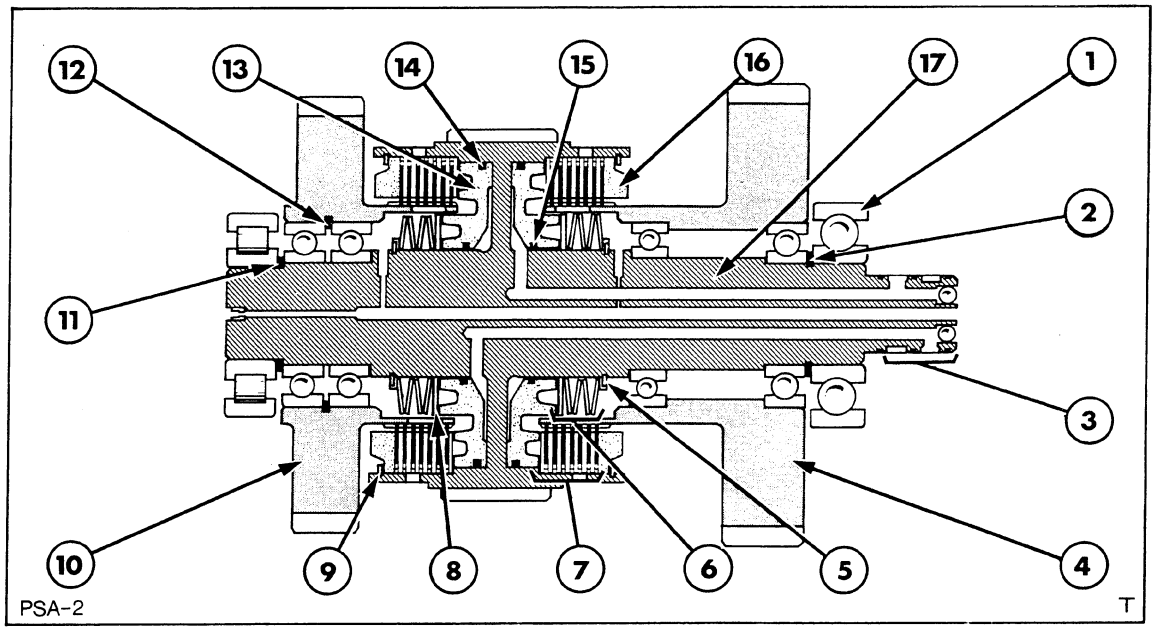

Figure 2
Speed Clutch Assembly – Sectional View

1. Shaft Support Bearing
2. Snap Ring
3. Sealing Rings
4. End Gear
5. Snap Ring and Retainer
6. Belleville Washers
7. Clutch Plates
8. Piston Protective Washer
9. Snap Ring
10. End Gear
11. Washer
12. Snap Ring
13. Piston
14. Piston Seal
15. Piston Seal
16. Retainer Plate
17. Shaft

The main shaft has a central gear that is precision welded to it. This weldment also provides the housings for the two multi–plate clutches. At each end of the main shaft are two free running gears, both supported by two ball bearings. The complete assembly is carried by a roller bearing at one end and a ball bearing at the other.

All of the six speed clutches are identical. Six internally splined, composition friction plates are carried on the hub of the end gears, and six polished steel plates are externally splined and carried by the central housing. The clutches are hydraulically applied and spring released. The spring medium is provided by four belleville washers in each clutch. As the clutches are hydraulically applied there is automatic compensation for normal wear, eliminating any need for adjustment.

When the clutches are applied, the respective end gear is locked to the shaft, and power can be transmitted from the end gear to the centre gear, or vice versa. When both clutches are actuated power can be transmitted from end gear to end gear.

The speed clutch assemblies each receive three separate oil supplies. A supply for each of the two clutch actuation circuits and one common supply for lubrication and cooling of the two clutch assemblies, the bearings of the two main gears, and the two support shaft bearings.

The three oil supplies are controlled by an electronically managed hydraulic control valve mounted externally on the right hand side of the centre section of the three piece main casing. Details of the hydraulic control valve and the electronic management system are covered in Sections C and D respectively. Internal drillings in the housing centre section route the oil supplies to the ends of the three pairs of speed clutches. Bronze impregnated teflon sealing rings are positioned in annular grooves on the shaft ends. Oil for clutch actuation is fed between these sealed grooves from the drillings in the centre section. The centre section carries serviceable steel sleeves should wear occur in this oil transfer area. The third oil supply for lubrication and cooling enters the end of the

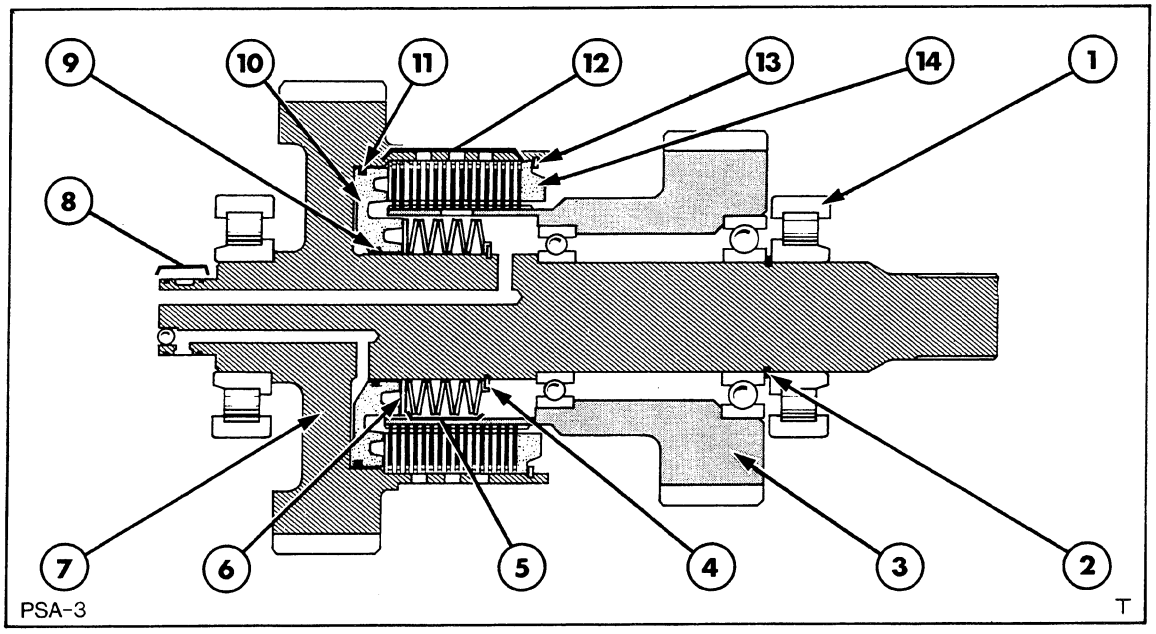

Figure 3
Directional Clutch Assembly – Sectional View

1. Shaft Support Bearing
2. Snap Ring
3. End Gear
4. Snap Ring and Retainer
5. Belleville Washers
6. Piston Protective Washer
7. Shaft and Gear
8. Sealing Rings
9. Piston Seal
10. Piston
11. Piston Seal
12. Clutch Plates
13. Snap Ring
14. Retainer Plate

shaft from a similar drilling in the centre section.

Oil is transferred along the centre of the shaft through axial drillings and meets cross drillings connecting with the clutch piston chambers.

Oil entering the piston chamber at 'A' acts on the surface area of the piston, which is sealed to the central housing and the shaft by sealing rings, and moves the piston against the force of the four belleville washers. The polished steel plates that are externally splined to the central housing, are then compressed against the composite friction plates which are internally splined to the end gears. Power can be transmitted between the central gear to the end gear, or vice–versa, depending on which speed is selected. Note that for some speeds both clutches within a speed clutch assembly may be engaged transferring power from one end gear to the other end gear. When the electronically managed control valve signals release of a clutch, the belleville springs return the piston to its original position, sending the exhausted oil back to the control valve and releasing the friction between the two sets of plates. The rate and amount of pressure supplied to and released from the clutch is controlled by the electronic management system and provides smooth, progressive, and timely clutch engagements

Lubrication and cooling oil, entering the shaft at its end face, is allowed to exit the shaft at various lateral drillings, all carefully positioned to ensure all components are thoroughly lubricated and cooled.

The directional clutches F1 and F2 for forward speeds and R for reverse speeds are much heavier in construction compared with the speed clutches and are typified in section in Figure 3. These directional clutches are operating at slower revolutions and consequently are carrying higher torque loads. All three directional clutches are similar to each other but differ to the speed clutches in that there is only one clutch system in each directional clutch assembly.

The directional clutch assemblies each have a gear precision welded to the centre shaft and a second free running gear which can be connected to the shaft and its gear by the

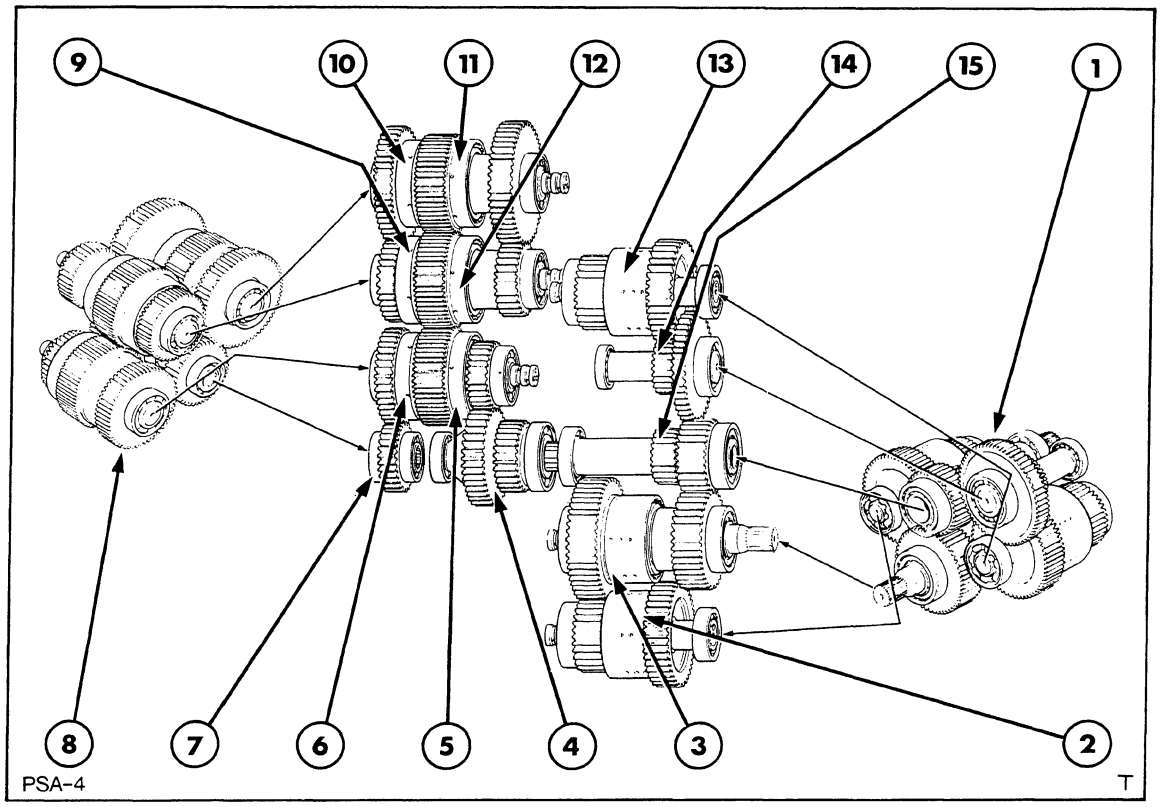

Figure 4
Clutch and Gear Assemblies in Front and Rear Housings – Identified in Diagrammatic Format

1. Directional Clutches and Gears in Rear Housing.
2. Reverse Directional Clutch
3. Directional Clutch F2
4. Two Gear Cluster in Front Housing
5. Speed Clutch Letter A
6. Speed Clutch No. 2
7. Input Gear
8. Speed Clutch and Gears in Front Housing
9. Speed Clutch No. 3
10. Speed Clutch No. 1
11. Speed Clutch Letter C
12. Speed Clutch Letter B
13. Directional Clutch F1
14. Two Gear Cluster in Rear Housing
15. Transfer Gear and Shaft

clutch. The second gear is supported by two ball bearings mounted on the common shaft. Each directional clutch is similar, only the number of teeth on the respective gears and the hub design differing.

Like the speed clutches, the directional clutches receive oil supplies from the electronically managed control valve, but they only receive two supplies, one supply for the actual clutch operation and the second for lubrication and cooling. Application of the clutch and oil routing in principle is identical to the speed clutches, oil being channelled from the control valve through the transmission housing centre section to the ends of the directional clutch assemblies. Each directional clutch, because of its heavier duty, features fourteen composition internally splined friction plates and fourteen polished steel externally splined plates. The plates, pistons, snap rings, and seals are all common between both speed clutches and directional clutches, although the number of plates is increased to fourteen, and the number of belleville spring washers increased to eight.

The centre shaft of directional clutch F2 is utilised as the main output shaft for all 18 forward and 9 reverse speeds. However, the clutch is only engaged for the forward speeds 10 – 18.

Thirty–nine ball and roller bearings are used in the transmission but are covered by only sixteen different part numbers.

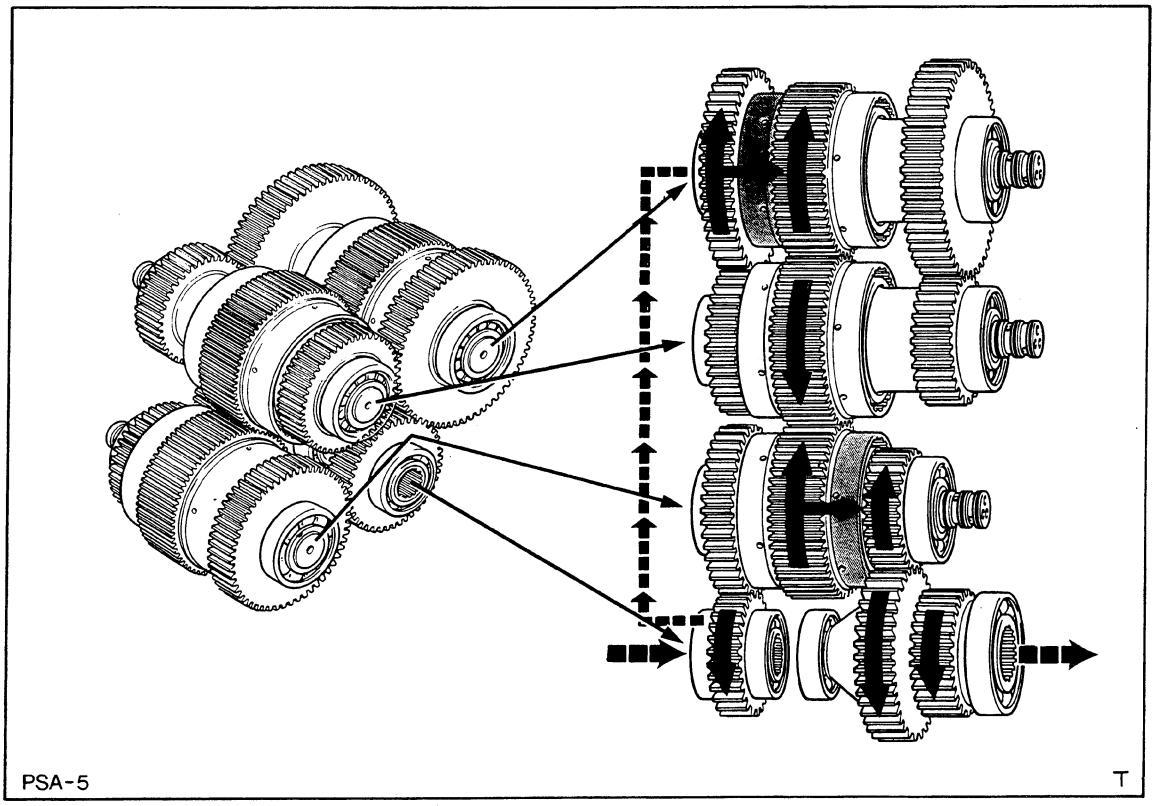

Figure 5
Power Flow in Front Housing for 1st. Speed – Speed Clutches 1 and A Applied

Power Flows

The following power flows are described in three stages commensurate with the actual sequence within the transmission. Figure 4 shows the complete transmission gear and clutch system in diagrammatic format. When compared with Figure 1, it can be seen that the diagrammatic format has unfolded the various meshing components. The highlighted connecting indicators, featured in Figure 4, denote that these gears are in mesh. Figures 5–13 illustrate the power flows for speeds 1–9 involving the speed clutches positioned in the front housing. Although these speed clutches create the first 9 speeds, they are not at final output level until they have been transferred through the rear housing components. It is important to note that for explanation reasons the six speed clutches must be identified and as such are shown in Figures 4–13. identification 1, 2 and 3, and A, B and C being given. Note that 1 is paired with C, 2 is paired with A, and 3 is paired with B.

Forward Speeds 1–9 (initial stage)

1st Speed– Clutch 1 and Clutch A applied Figure 5

Engine output enters the transmission front housing via the connecting shaft which is cushioned damped at the engine flywheel, and splined to the input gear. This gear rotates whenever the engine is running. Clutch 2/A assembly end gear meshing with the input gear is running freely and has no effect. Clutch 1 end gear, which is in mesh with the input gear, is locked to the speed clutch shaft because clutch 1 is applied. Power is transmitted to the shaft of this speed clutch assembly and transferred via the central gear to the central gear of the speed clutch 3/B. Neither clutch 3 or B is applied but the central gear of this speed clutch is meshing with the central gear of speed clutch 2/A. Clutch A is applied and locking the end gear to the shaft. Power is thus transferred to

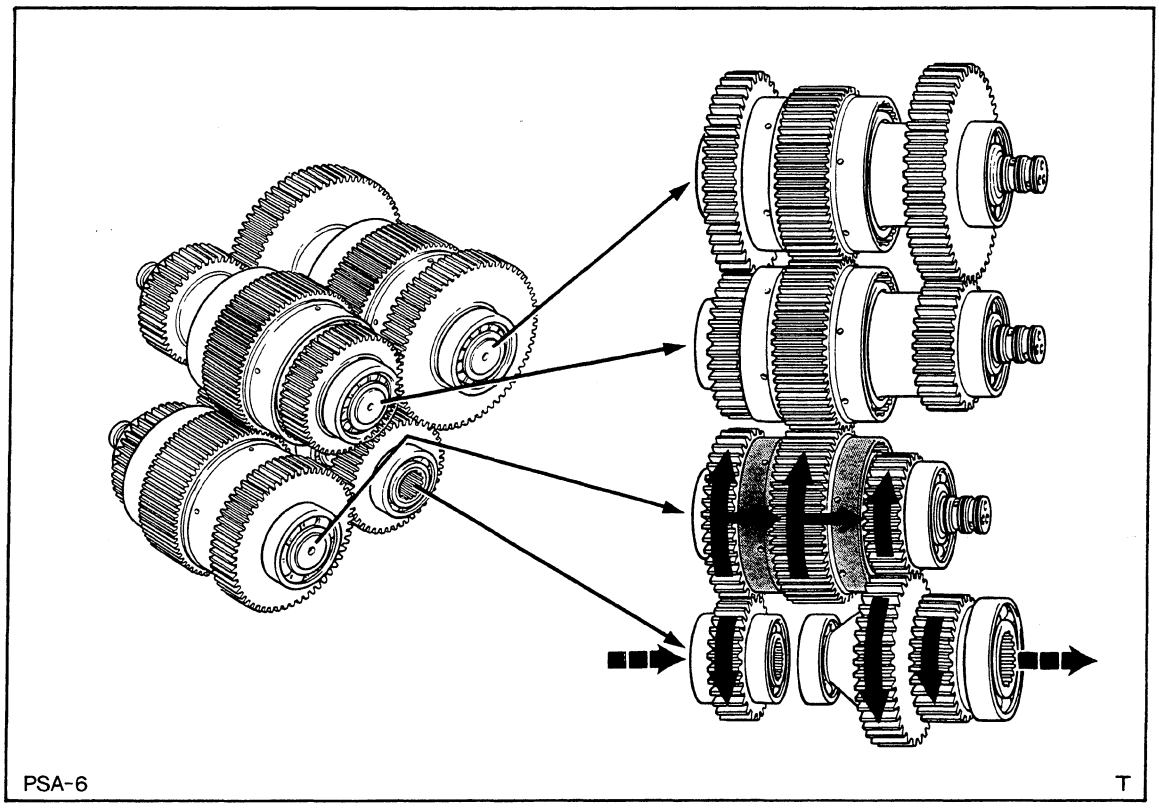

Figure 6
Power Flow in Front Housing for 2nd. Speed – Speed Clutches 2 and A Applied

the front gear of the two gears on the front housing output shaft, which transfers the power flow to the rear housing components.

Gear ratio is:– 65/42 x 71/71 x 71/71 x 56/40 = 2.167

2nd– Speed Clutch 2 and Clutch A applied Figure 6

Power flows from the input gear to speed clutch assembly 2/A. Clutch 2 and clutch A are applied, and consequently power flows from one end gear to the other, and drives the front gear of the output to the rear housing.

Gear ratio is:– 55/42 x 56/40 = 1.833

3rd Speed– Clutch 3 and Clutch A applied Figure 7

Power flows from the input gear to the end gear of speed clutch assembly 1/C. The end gear is in mesh with the end gear of speed clutch assembly 3/B. Clutch 3 is applied and locks the end gear to the central gear, which in turn drives the central gear of speed clutch assembly 2/A. Clutch A is applied which locks the end gear to the central gear and power is transferred to the front gear on the output to the rear housing.

Gear ratio is:– 65/42 x 47/65 x 71/71 x 56/40 = 1.567

4th Speed – Clutch 1 and Clutch B applied Figure 8

Power flows from the input gear to the end gear of speed clutch assembly 1/C. As clutch 1 is applied power is transferred to the central gear. Speed clutch assembly 1/C central gear is in mesh with the central gear of speed clutch assembly 3/B. Clutch B is applied and power is transferred to the end gear. This end gear is in mesh with the end gear of speed clutch assembly 1/C, which in turn meshes with the rear gear on the output shaft to the rear housing.

Gear ratio is:– 65/42 x 71/71 x 70/43 x 38/70 = 1.368

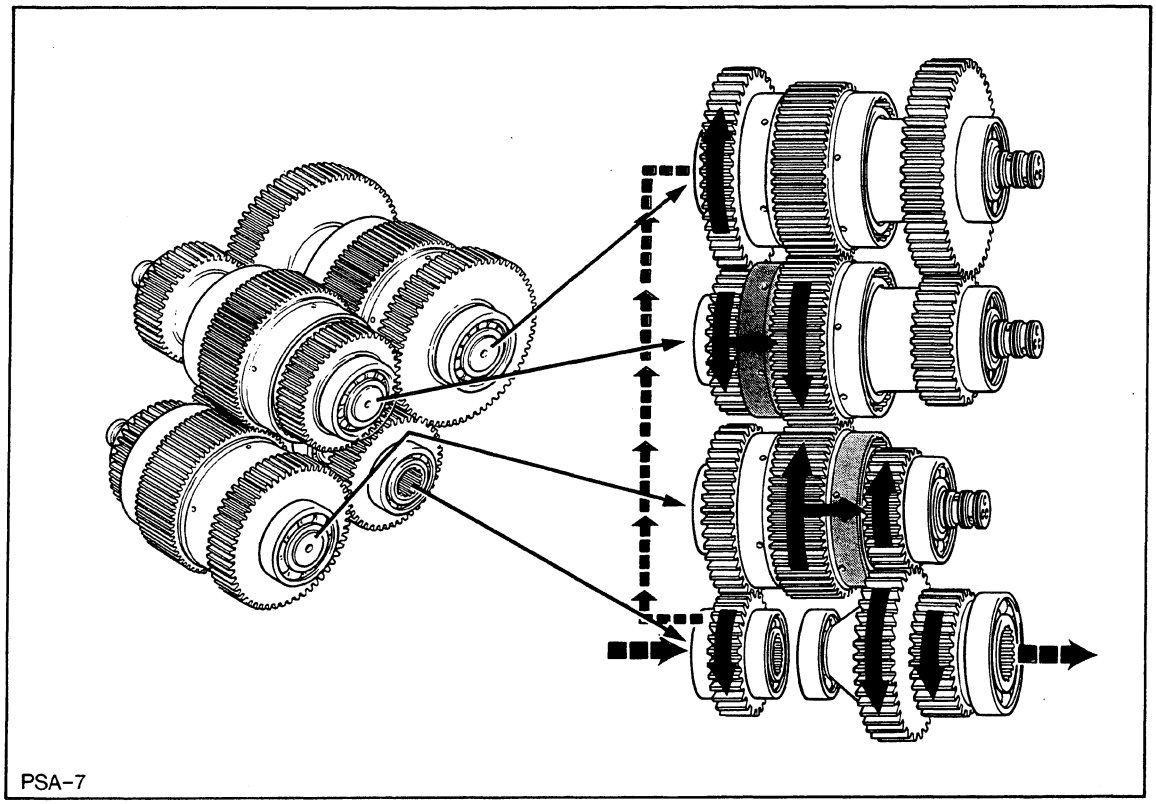

Figure 7
Power Flow in Front Housing for 3rd. Speed – Speed Clutches 3 and A Applied

5th Speed – Clutch 2 and Clutch B applied Figure 9

Power flows from the input gear to the end gear of speed clutch assembly 2/A. Clutch 2 is applied and power is transmitted via the central gear to the central gear of speed clutch assembly 3/B. Clutch B is applied and power flows from the end gear to the end gear of speed clutch assembly 1/C. This end gear is in mesh with the rear gear on the output shaft to the rear housing.

Gear ratio is:– 55/42 x 71/71 x 70/43 x 38/70 = 1.157

6th Speed – Clutch 3 and Clutch B applied Figure 10

Power flows from the input gear to the end gear of speed clutch assembly 1/C which is in mesh with the end gear of speed clutch assembly 3/B. Both clutch 3 and clutch B are applied and power flows from the opposite end gear to the end gear of speed clutch assembly 1/C. This gear in turn meshes with the rear gear on the output shaft to the rear housing.

Gear ratio is:– 65/42 x 47/65 x 70/43 x 38/70 = 0.989

7th Speed – Clutch 1 and Clutch C applied Figure 11

Power flows from the input gear to the end gear of speed clutch 1/C. As both clutches of this assembly are applied, power is directly transferred to the opposite end gear which is in mesh with the rear gear on the output shaft to the rear housing.

Gear ratio is 65/42 x 38/70 = 0.840

8th Speed – Clutch 2 and Clutch C applied Figure 12

Power flows from the input gear to the end gear of speed clutch assembly 2/A. As clutch 2 is applied the power flow is transferred to the

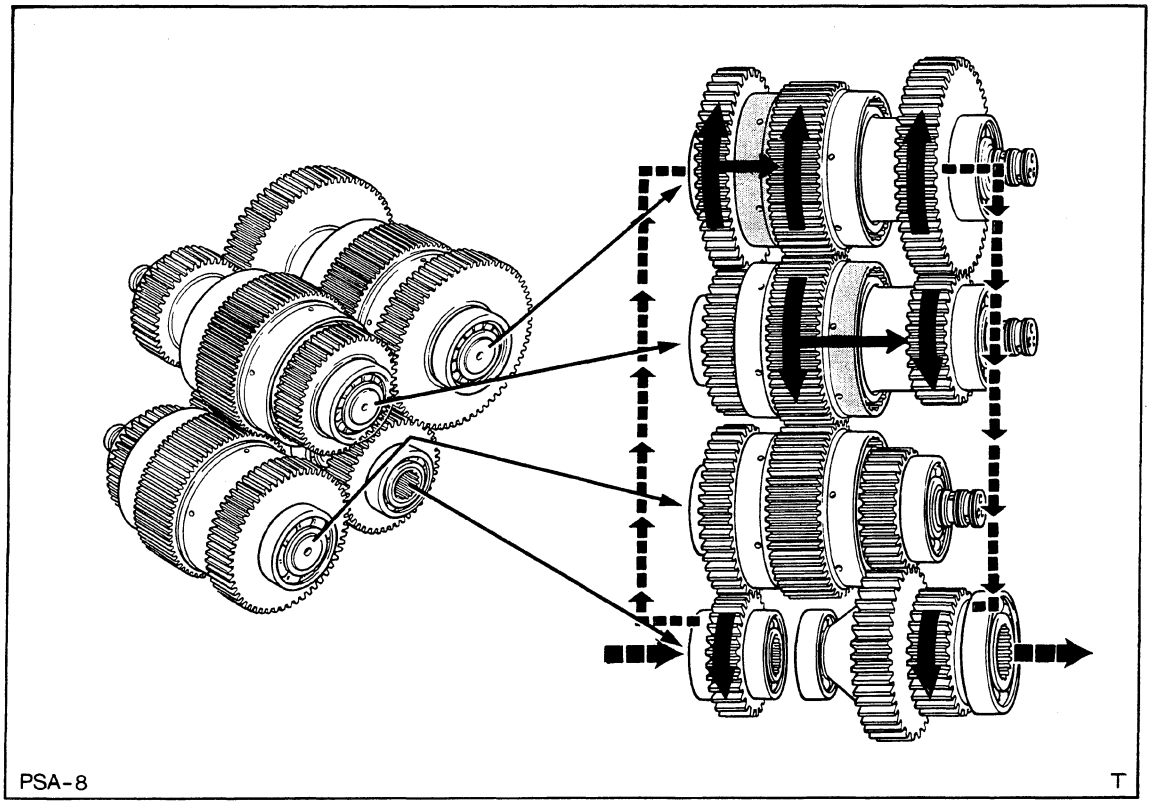

Figure 8
Power Flow in Front Housing for 4th. Speed – Clutches 1 and B Applied

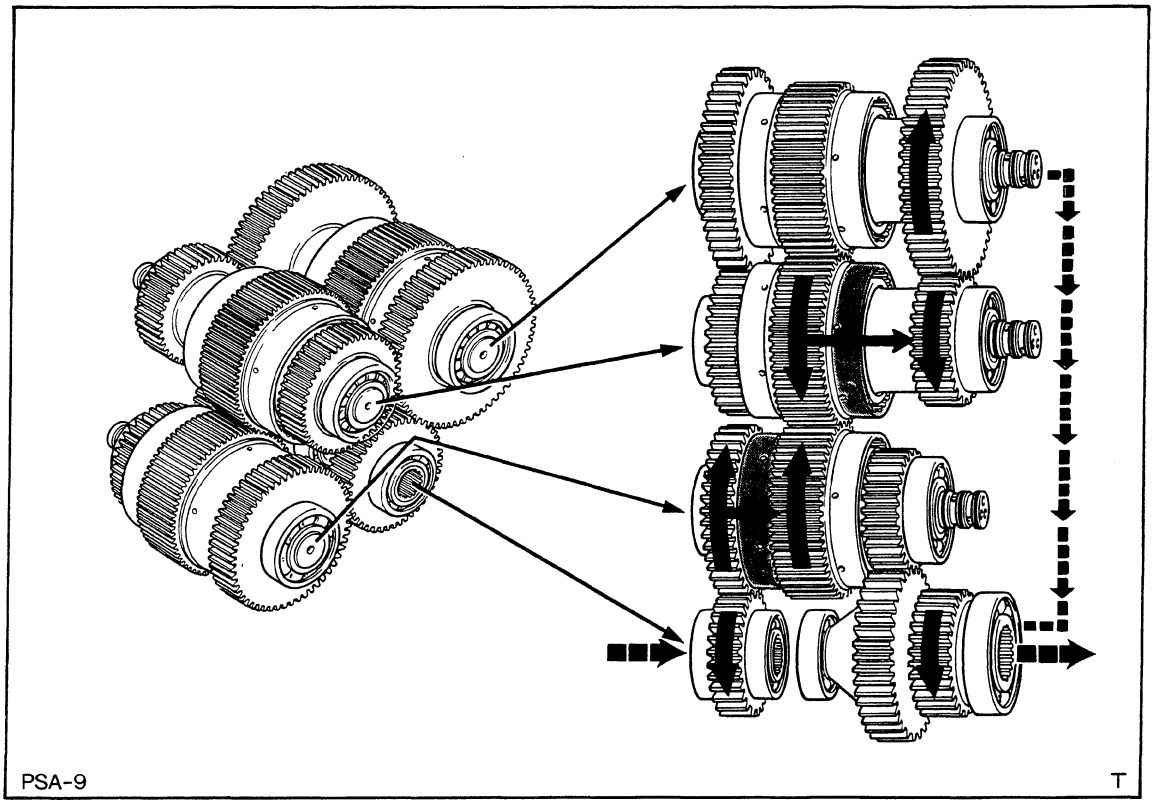

Figure 9
Power Flow in Front Housing for 5th. Speed – Speed Clutches 2 and B Applied

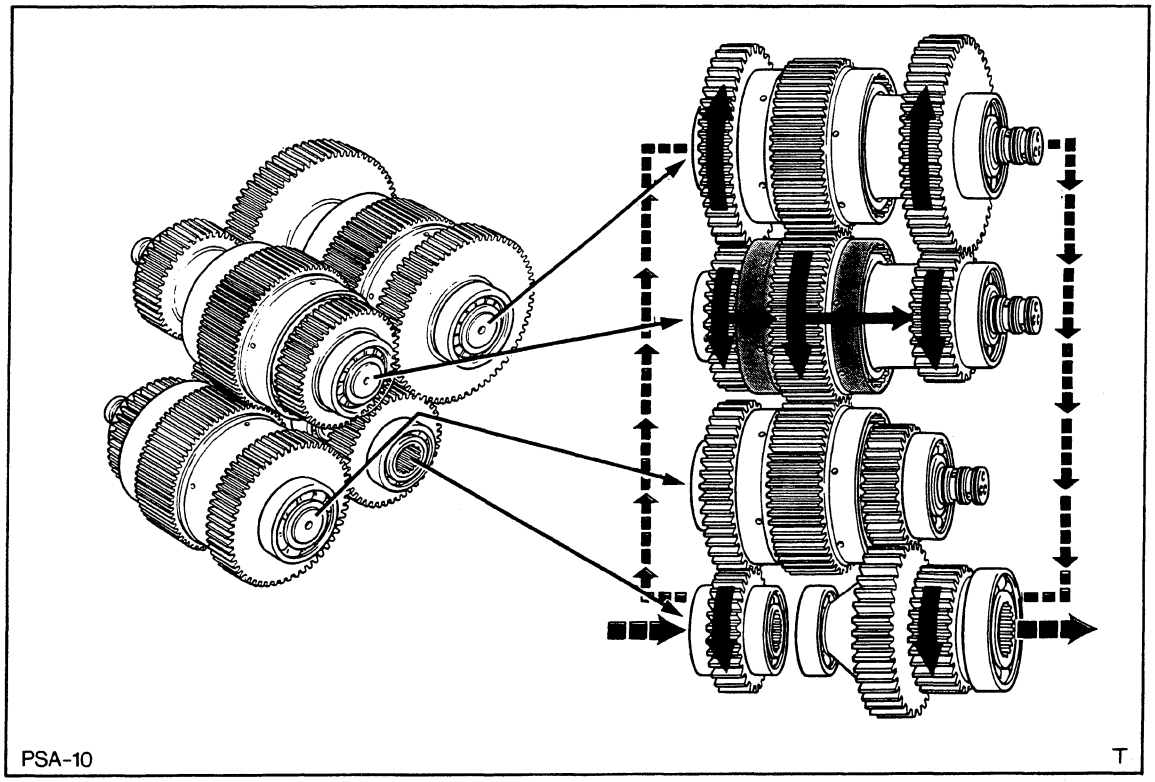

Figure 10
Power Flow in Front Housing for 6th. Speed – Speed Clutches 3 and B Applied

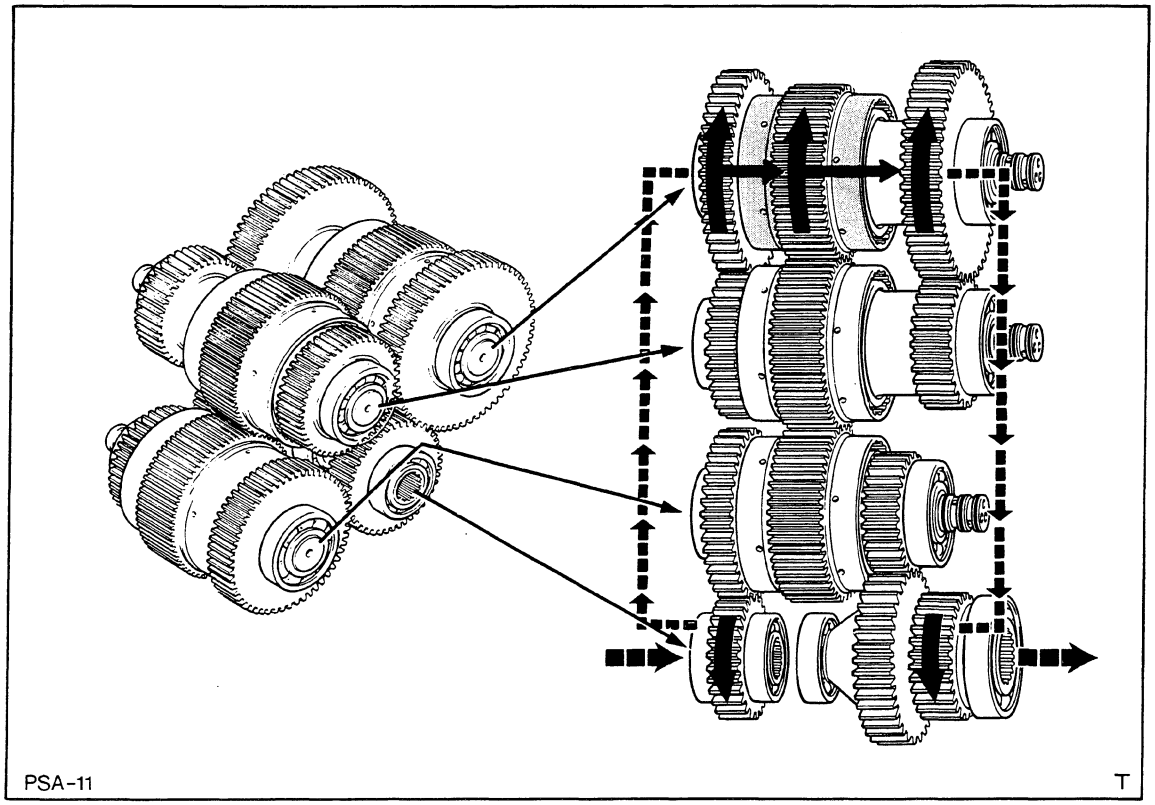

Figure 11
Power Flow in Front Housing for 7th. Speed – Speed Clutches 1 and C Applied

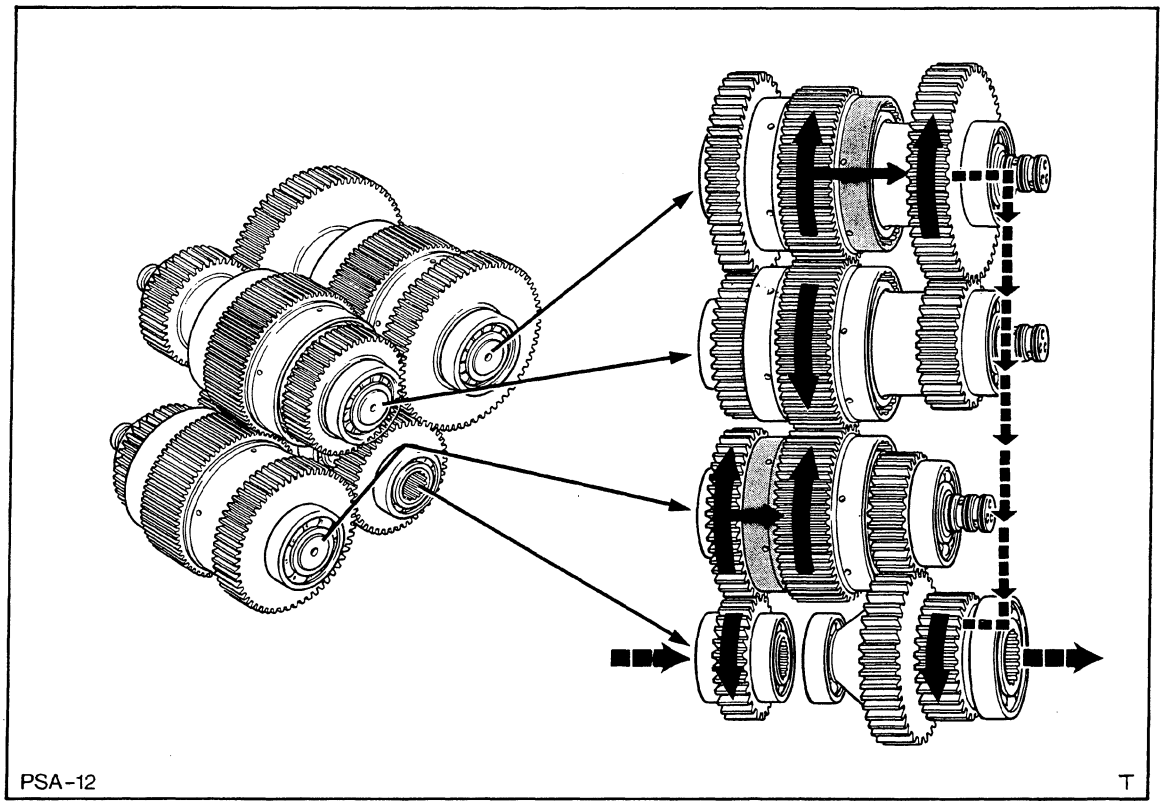

Figure 12
Power Flow in Front Housing for 8th. Speed – Speed Clutches 2 and C Applied

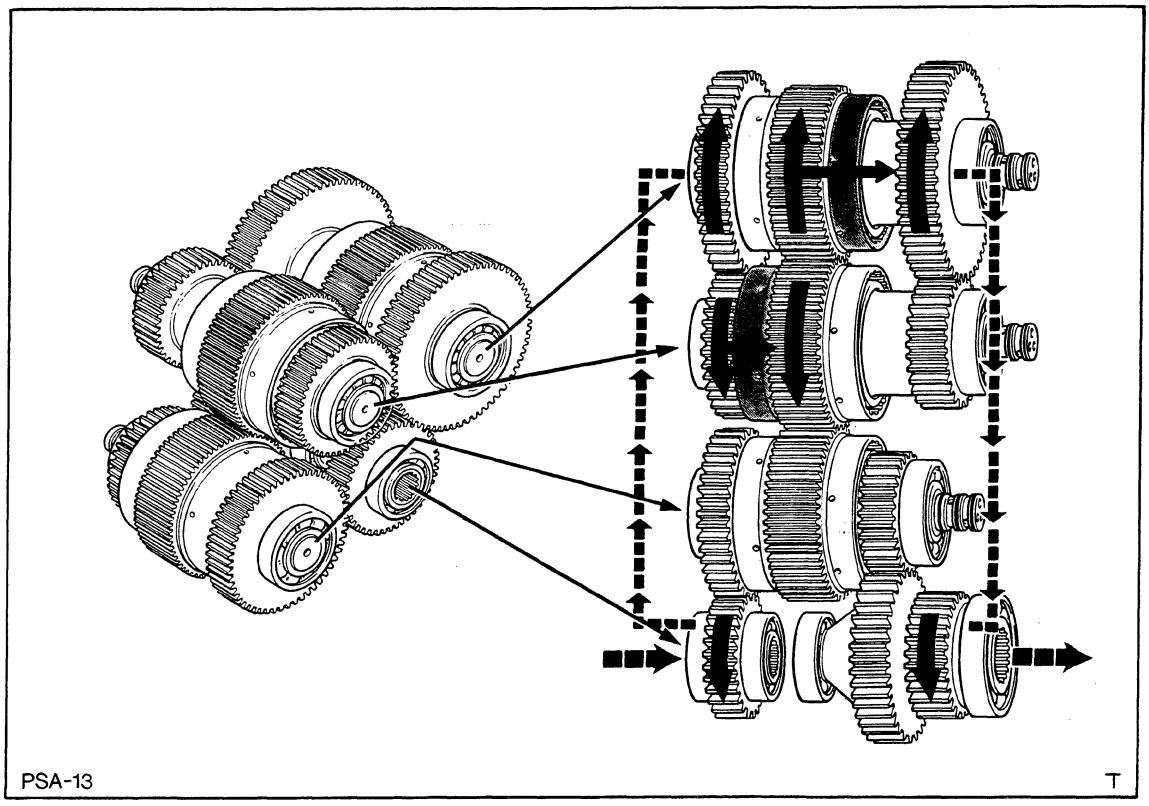

Figure 13
Power Flow in Front Housing for 9th. Speed – Speed Clutches 3 and C Applied

central gear of speed clutch 3/B and on to the central gear of speed clutch 1/C. Clutch C is applied and power is transferred to the end gear.This end gear is in mesh with the rear gear on the output shaft to the rear housing.

Gear ratio is:– 55/42 x 71/71 x 71/71 x 38/70 = 0.711

9th Speed – Clutch 3 and Clutch C applied Figure 13

Power flows from the input gear to the end gear of speed clutch assembly 1/C and transferred to the end gear of speed clutch assembly 3/B. Clutch 3 is applied and consequently power is transferred from the central gear to the central gear of speed clutch 1/C. Clutch C is applied, thereby transferring power to the end gear. This end gear is in mesh with the rear gear on the output shaft to the rear housing.

Gear ratio is 65/42 x 47/65 x 71/71 x 38/70 = 0.607

Forward Speeds 1–9 (second stage) Figure 14

The forward clutches positioned in the rear housing provide the final stages of gearing. These components modify the incoming input from the speed clutches in the front housing. The following power flow describes and completes the speeds 1–9 using the directional clutch F1.

Each of the first nine speeds follow the same power flow path through the rear housing. Power is transferred to the rear housing, along the centre two gear cluster shaft to the rear gear. This gear is in mesh with the larger gear of a second two gear cluster. The smaller gear of this cluster is in mesh with the driven gear of directional clutch F1. This clutch is applied, locking the front gear to the shaft. In mesh with this gear is the driven gear of directional clutch F2, which also acts as the main output shaft. Directional clutch F2 is not applied for speeds 1–9. Nor is directional clutch

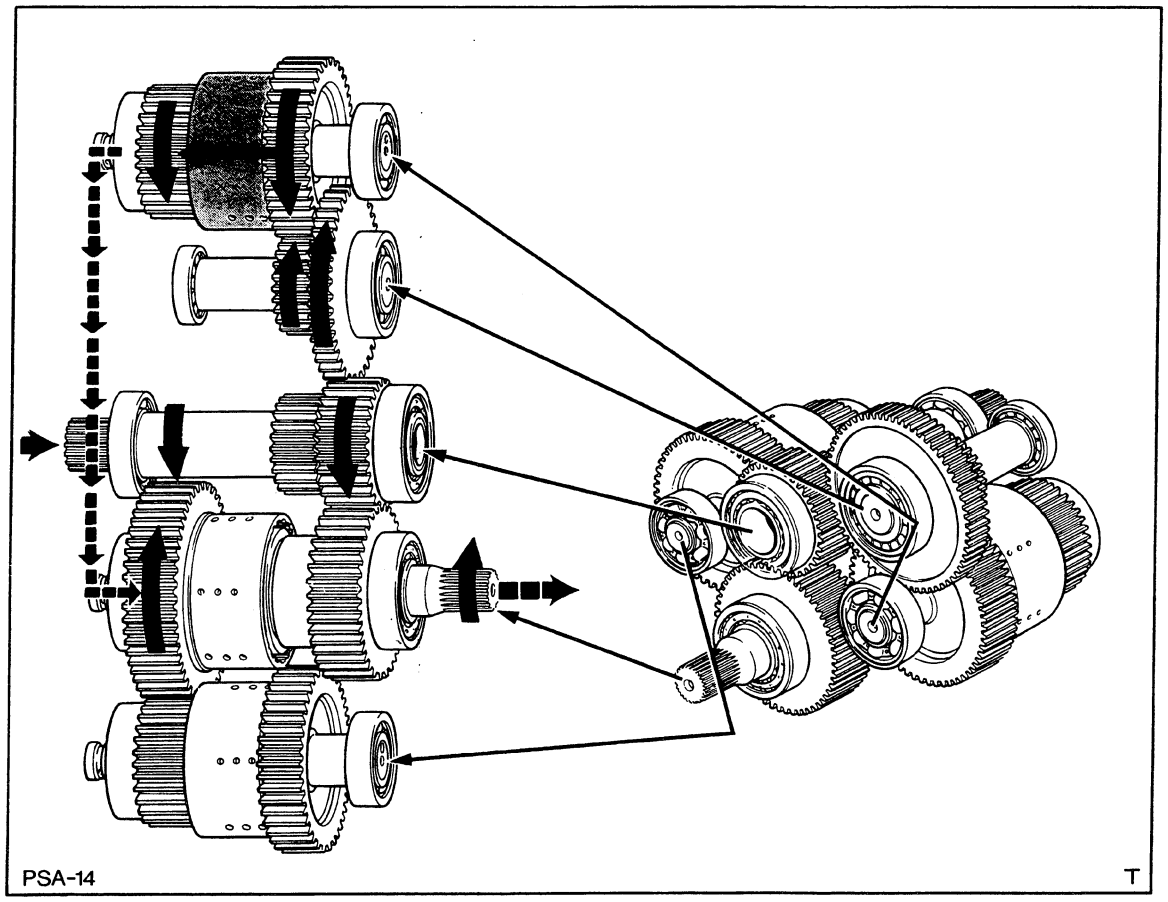

Figure 14
Power Flow in Rear Housing for 1st. – 9th. Speeds – Directional Clutch F1 Applied

R applied for reverse speeds, but is in mesh with the driven gear of directional clutch F2. Directional clutches F2 and R have no effect for these first nine speeds. The following gear ratio is added to complete the overall ratio for each of these first nine speeds.

64/40 x 60/29 x 72/41 = 5.813

Forward Speeds 10–18 Figure 15

Directional clutch F2 is now applied, but directional clutches F1 and R are released. Each of the incoming 1–9 speed power flows are directed from the rear gear of the centre two gear cluster to the rear gear of the directional clutch F2. The clutch is applied locking the gear to the shaft which is also the main out put shaft. The following gear ratio, is added to the original 1–9 speeds generated in the front housing by the speed clutches, to complete the forward speeds 10–18.
56/40 = 1.4

Reverse Speeds Figure 16

Nine reverse speeds are provided, again using the nine initial speeds generated in the front housing by the speed clutches. The reverse speeds are designed to correspond to forward speeds 4–12 and by ratio are within 2% of the corresponding forward speeds. Accordingly reverse speeds are designated R4–R12.

Power is transferred to the rear housing, along the centre, two gear, cluster shaft. The forward smaller gear of this shaft is in mesh with the driven gear of directional clutch R. The clutch is applied, locking the end gear to the shaft and driven gear. Power flows from this end gear to the driven gear of the output shaft.

The following gear ratio is added to the nine speeds generated by the speed clutches and

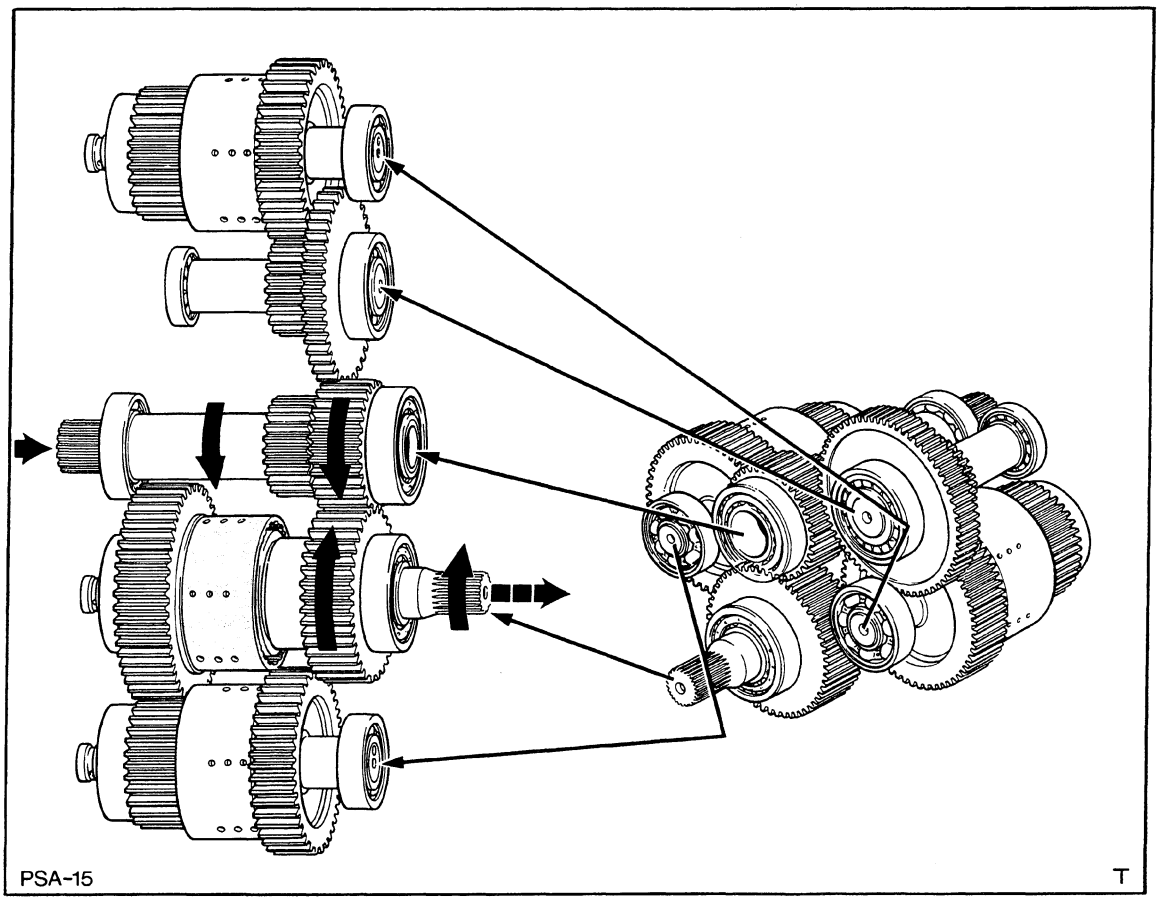

Figure 15
Power Flow in Rear Housing for 10th. – 18th. Speeds – Directional Clutch F2 Applied

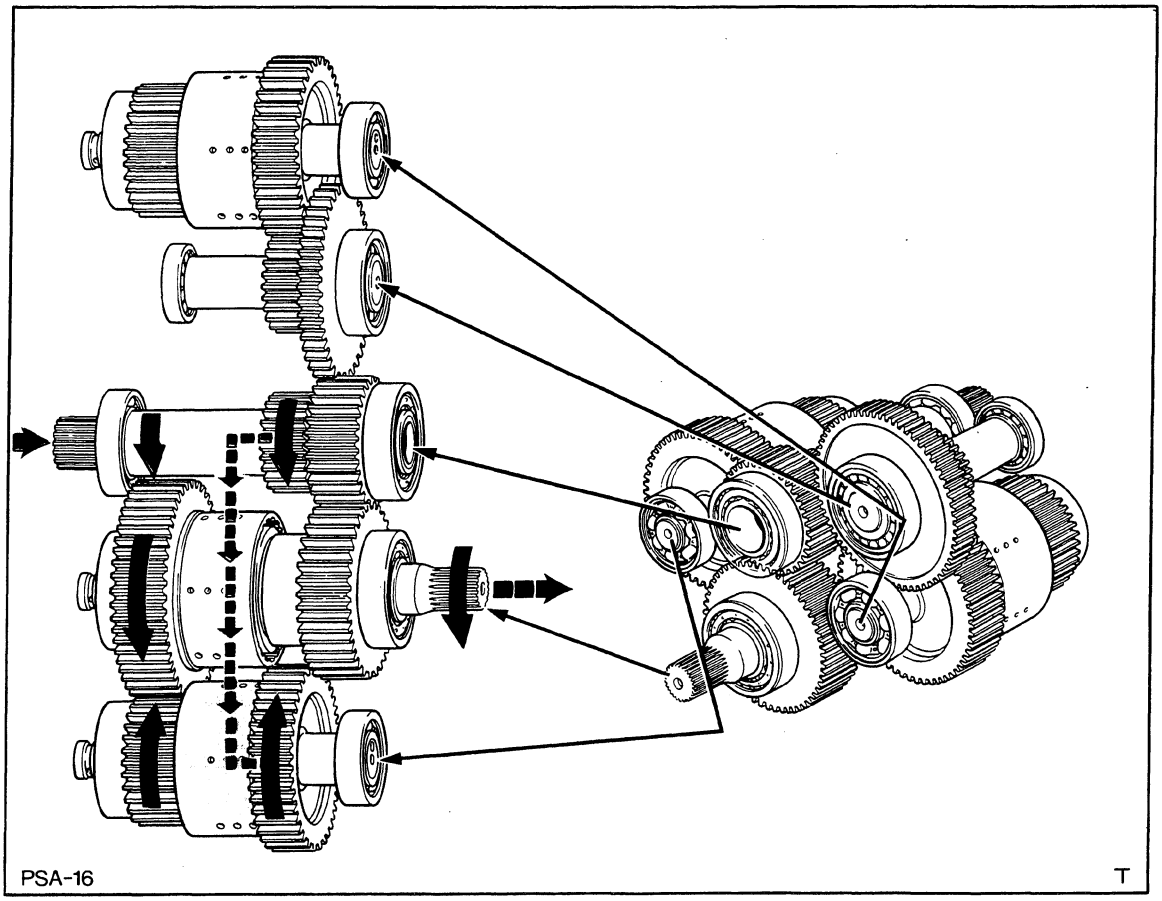

Figure 16
Power Flow in Rear Housing for Reverse Speeds 4th. – 12th. – Directional Clutch REV Applied

completes the overall ratios, but in the reverse mode.
60/29 x 72/41 = 3.633

Power Take Off Figure 17

The power take off (P.T.O.) facility comprises a central shaft running the full length of the transmission. The shaft is splined into the continuously running input gear, situated in the front housing. The shaft is supported at the front by the input gear and at the rear by a single ball bearing. The shaft also drives the hydraulic pump as described in the following paragraph. The splined output end of the shaft engages with the P.T.O. clutch pack components situated in the rear transmission (or axle) centre housing.

Pump

The hydraulic pump is a gerotor type, driven by the continuously running P.T.O. shaft that passes centrally through the transmission. The pump draws its oil from the common front and rear transmission housing reservoir, having a pick up point in the four wheel drive transfer gear assembly housing, or, in the case of two wheel drive tractors, the parking brake component housing. The pump passes all oil through an external spin–on type filter which is equipped with an electrically indicated restriction by–pass system. The oil flow is then directed to the main hydraulic control valve and to the external cooler. Full details of the function of the cooler are covered in Section C.

Cooler

An external heat exchanger or cooler is positioned in front of the engine radiator. The cooler receives a portion of the transmission hydraulic oil flow, cooling this portion of the oil before it is supplied to the speed and direc-

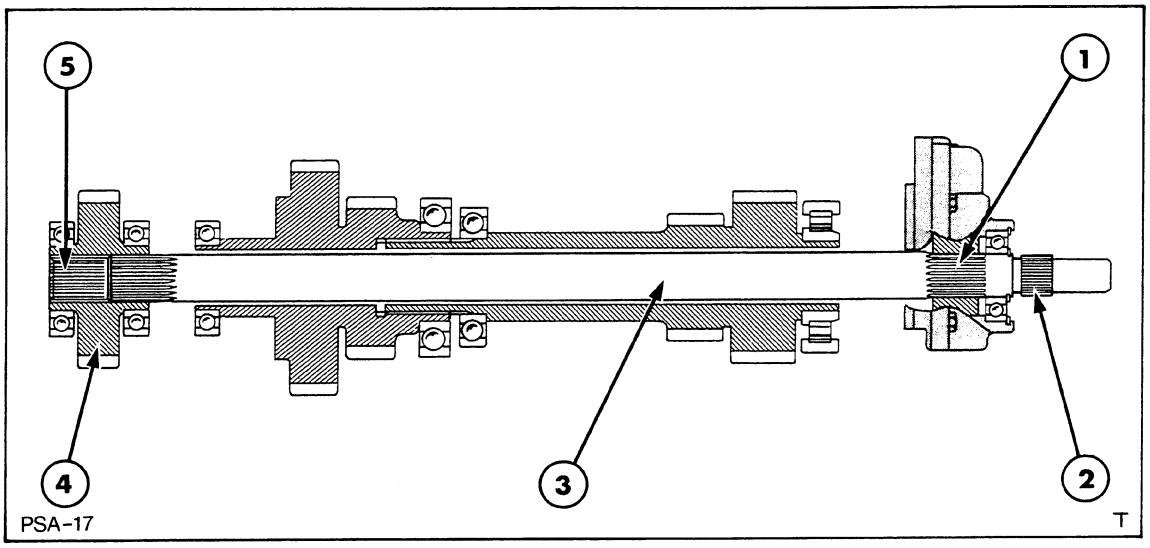

Figure 17
Power Flow to P.T.O. Shaft through Front and Rear Housings

1. Spline Driving Pump Rotor
2. Spline to Engage PTO Clutch Pack
3. PTO Shaft
4. Main Input Gear with PTO Shaft Splined to Inner Bore
5. Engine Drive Splined to Input Gear

tional clutch assemblies for lubrication and cooling purposes.

Speed Control, Inching Pedal and Electronic Management System

A single lever control is ergonomically positioned to the right side of the operator, in front of the tractor hydraulic and P.T.O. control console. This single lever controls selection of all speeds for both forward and reverse, and is complimented with a visual display unit (VDU) to indicate the selected speed, and the directional mode. The display can also be used to indicate diagnostic repair codes in the unlikely event of a fault occurring.

The lever is electrically coupled to the transmission hydraulic control valve via an electronic management system. A foot pedal is positioned in the area normally occupied by the clutch pedal on a conventional transmission. This pedal is correctly described as an inching pedal, and serves to interrupt the power output through the directional clutches. As its description suggests, the pedal functions to assist precise traction control when for example hitching implements or precisely positioning the tractor in confined spaces. Use of the inching pedal is unnecessary when making normal speed changes, or even directional changes.

Full details of the control lever, inching pedal, and management system are given in Sections B and D respectively. Section C gives full operational description of the hydraulic control valve.

B. OPERATING CONTROLS – DESCRIPTION AND OPERATION

The operating controls consist of a single Speed Control Lever and an Inching Pedal coupled electronically to the transmission hydraulic control valve via an electronic management system employing, a micro processor. Full details of the electronic management system are given in Section D.

The Speed Control Lever allows all 18 forward speeds and all 9 reverse speeds to be selected without the use of conventional levers and range selection levers. The lever moves through a three legged gate activating miniature reed switches, requiring extremely low effort.

The complete assembly is dust proofed and housed in its own ergonomically designed console, Figure 1. Alongside the lever is a liquid crystal display (LCD) which indicates which speed is selected. This LCD also provides diagnostic information to assist Servicing, should in the unlikely event, a fault develop in the system. The display can also be used to programme shuttle shifts where automatic programming of the control can be made to allow a reverse speed to be selected which can be up to either 3 speeds higher or 3 speeds lower than the originally selected forward speed.

Inadvertent lever movements, from neutral to forward or reverse, are prevented by the use of a neutral interlock consisting of a spring loaded collar that must be lifted before the lever can be moved.

The inching pedal replaces the conventional clutch pedal but maintains the same function when positioning the tractor in confined spaces or attaching implements. Its use is unnecessary when making speed selections.

The pedal actuates two electrical components, a long life potentiometer or variable resistor, and an open or shut switch. Both these components are detailed in Section D. There is no mechanical connection between the pedal and the transmission

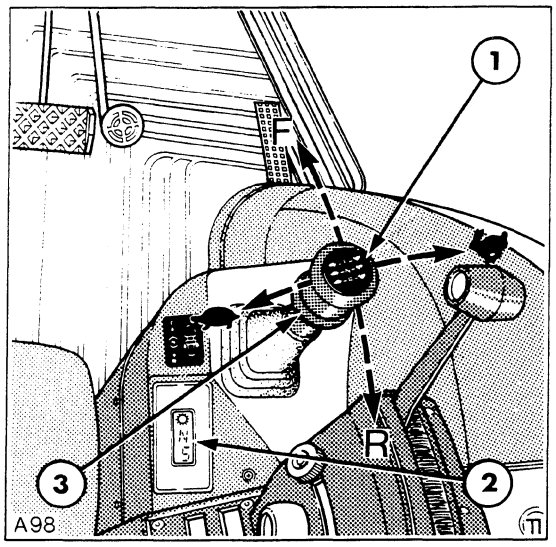

Figure 1
Speed Control Lever

1. Speed Control Lever
2. Liquid Crystal Display
3. Neutral Lock Collar

Speed Control Lever Operation

The Speed Control Lever, Figure 1, is used to select forward or reverse travel and to change transmission speeds. Move the lever forward for forward travel and rearward for reverse travel.

NOTE: *A neutral lock device is fitted. The Speed Control Lever may only be moved to the forward or reverse positions if the neutral lock collar under the control lever is raised. Neutral may be selected without the need to lift the neutral lock collar.*

The Speed Control Lever is also used to make instantaneous upward or downward speed changes. Nudge the lever to the right for upward changes and to the left for downward changes. In this context, 'nudge' means move the lever and then release.

Several consecutive speed changes may be made, either by nudging the lever several times, or by holding the lever to the left or right and allowing the transmission to run through the speeds automatically.

Digital Display

The main function of the LCD is to inform which speed is selected and whether the transmission is in forward (F), neutral (N) or reverse (R).

A secondary function of the digital display is that in the unlikely event of a fault occurring in the system, it will show a diagnostic repair code such as U2, A11, C5, etc. Should this happen, the operator can contact his dealer, quoting the diagnostic code displayed.

Inching Pedal

The inching pedal is installed in place of the clutch pedal found on tractors with conventional transmissions. The inching pedal operates like a clutch, for safe accurate positioning of the tractor when hitching up to implements or operating in confined spaces, etc.

The inching pedal may also be used to automatically select a speed ratio to match load, engine speed, and road conditions.

To stop the tractor in an emergency, depress the inching pedal and apply the foot brakes together.

The inching pedal is not required for normal speed changes.

Starting the Engine and Moving Forward

There are two methods:

1. Start the engine with the main control lever in neutral (the digital display will show 'N7'). Nudge or hold the control lever to the right and allow the transmission to select any speed between 7th. and 12th. as shown in the display. (12th. speed is the highest available speed for moving from a standstill). Alternatively, nudge or hold the control lever to the left and allow the display to change sequentially from 7th. down to 1st.

Increase engine speed, as required, by means of the throttle. Lift the neutral lock collar and move the control lever forward for smooth forward motion. To increase tractor speed, open the throttle further and/or continue to nudge or hold the control lever to the right to select a higher speed. To decrease speed, close the throttle and/or nudge or hold the control lever to the left to select a lower speed.

2. Alternatively, with the engine running, lift the neutral lock collar and move the control lever forwards (the digital display will show 'F7' and the tractor will start to move forward). Increase engine speed and/or nudge or hold the lever to the right and allow the transmission to run through the speeds until the desired operating speed is achieved.

To further increase tractor speed, open the throttle more and/or continue to nudge or hold the control lever to the right to select a higher speed. To decrease speed, close the throttle and/or nudge or hold the control lever to the left to select a lower speed.

WARNING: *Never move the Speed Control Lever to neutral when travelling at high speeds. This could allow the transmission to speed match and it may not be possible to reselect the original ratio, particularly if traveling down a steep gradient. In any event, actions such as coasting should never be practiced for safety reasons.*

IMPORTANT: *A tractor fitted with the powershift transmission should not be towed other than to remove it from the field or onto a transporter. Do not attempt to tow start the tractor.*

Starting the Engine and Moving in Reverse

As with forward travel there are two methods:

1. Start the engine with the Speed Control Lever in neutral (the digital display will show 'N7', provided the transmission has not been pre–programmed – see Programming Reverse Speeds later in this description). Nudge or hold the control lever to the right and allow the transmission to select any speed between 5th. and 12th. as shown in the display. Nudge the lever to the left to select 6th, 5th or 4th.

NOTE: *There are nine reverse speeds, the lowest shown as "R4" on the digital display, the highest being shown as "R12". They are numbered "R4" to "R12" as the ground speeds correspond to the forward speeds "F4" to "F12".*

With a speed selected, lift the neutral lock collar and move the Speed Control Lever rearward for smooth reverse travel. To increase speed, open the throttle further and/or continue to nudge or hold the Speed Control Lever to the right to select a higher speed. To decrease speed, close the throttle and/or nudge or hold the Speed Control Lever to the left to select a lower speed.

2. Alternatively, with the engine running, lift the neutral lock collar and move the Speed Control Lever rearward for smooth rearward travel. The digital display will show 'R7', provided the transmission has not been pre–programmed (see Programming Reverse Speeds later in this description). Nudge or hold the lever to the right and allow the transmission to run through the speeds until the desired operating speed is achieved.

To further increase tractor speed, open the throttle more and/or continue to nudge or hold the Speed Control Lever to the right to select a higher speed. To decrease speed, close the throttle and/or nudge or hold the lever to the left to select a lower speed.

Shuttle Operations

To change from forward to reverse travel, simply lift the neutral lock collar and move the Speed Control Lever fully rearward. This may be done at any engine speed and with any speed selected.

WARNING: *Speeds 1 to 3 and 13 to 18 inclusive, are not available in reverse. If travelling forward in, for example, 2nd. speed, the lowest reverse speed (4th.) will be automatically selected when the control lever is moved to the reverse position. The operator should be aware of this feature as there will be a corresponding* ***increase*** *in tractor speed. Conversely, if travelling forward in, for example, 17th. speed, the highest reverse speed (12th.) will be automatically selected when the control lever is moved to the reverse position with a corresponding* ***reduction*** *in tractor speed.*

Programming Reverse Speeds

When changing from forward to reverse speed, the transmission will normally select the same speed in reverse as was selected for forward travel (when operating in speeds between 4th. and 12th.). For special shuttle shift applications, the Ford Powershift offers the advantage of automatically changing the reverse speed by up to three speeds higher or lower.

The transmission may be programmed to provide an alternative reverse speed as follows:

- Stop the engine and turn the keystart switch off.

- Move the control lever to the reverse speed position then hold the lever to the right.

- While holding the lever to the right, turn on the key–start switch (but do not start the engine). The digital display should show '0' unless the transmission has been previously programmed to select a higher a lower reverse speed.

- Return the control lever to neutral.

- Nudge the lever to the right one, two or three times, as required. The display will show '1', '2' or '3'. This indicates that when reverse is selected the speed will be one, two or three speeds higher than the forward speed.

- Conversely, if the lever is nudged to the left one, two or three times, the display will show '–1', '–2' or '–3'. This indicates that when reverse is selected the speed will be one, two or three speeds lower than the forward speed. If the lever is nudged to the left a fourth time, 'L' will be displayed. This means that whichever forward speed is engaged, when the lever is moved rearward the lowest reverse

speed (4th.) will always be selected regardless of forward speed.

NOTE: *Remember that only reverse speeds between 4th. and 12th. are available.*

- Turn the keystart switch off. The transmission is now programmed to provide a reverse speed different to the forward speed. Return the lever to neutral and start the engine to commence shuttle shift operations.

To cancel the programme, proceed as follows:

- Pull the stop control to stop the engine.
- Turn the keystart switch off.
- Engage reverse speed and hold the lever to the right.
- While holding the lever to the right, turn on the keystart switch (but do not start the engine).
- Return the lever to neutral. The programme is now cancelled.

Speed Matching

When travelling on the road in any speed between 12th. and 18th., the transmission will automatically select a speed to match the engine speed to road speed if the inching pedal is depressed and the throttle setting adjusted.

Momentarily depress the inching pedal then decrease engine speed with the foot throttle. Release the inching pedal then increase engine speed. The transmission will automatically select a higher ratio (provided 18th. speed is not already selected) to match the lower engine speed and so maintain approximately the same road speed.

Note: *It is recommended that the hand throttle is set to maintain a minimum engine speed of 1000 rev/min and the foot throttle is used when higher engine speeds are required.*

Conversely, decrease engine speed, then depress the inching pedal, simultaneously increasing engine speed by pressing the foot throttle further down, then release the inching pedal. The transmission will automatically select a lower speed (provided 12th. speed is not already selected) to match the higher engine speed.

Transmission Oil Filter Restriction Warning Light

To the right of the Speed Control Lever is a red warning light. Should the transmission oil filter become blocked, the warning light will illuminate.

NOTE: *When the keystart switch is first turned on in temperatures below 50°F (10°C), the light may stay on continually for up to five minutes (or more, dependent upon the amount of contaminant in the filter and the temperature of the oil. The light may continue to flash momentarily for an additional period of time until the transmission oil warms up.*

IMPORTANT: *If the light stays on continually for 30 minutes, the transmission oil filter requires servicing.*

C. HYDRAULIC CONTROL VALVE – DESCRIPTION AND OPERATION

The hydraulic control valve assembly is mounted externally on the right hand side of the transmission housing centre section. The valve functions to perform the actual application and release of the speed clutches and the directional clutches. A regulating valve within the main control valve assembly, set at 240 – 260 lbf/in ^{2} (16.2–17.9 bar), maintains a constant oil pressure for the tractor low pressure circuit which controls the power brake valve, the P.T.O. clutch and four wheel drive engagement clutch. This regulating valve replaces the regulating and brake priority valve used on tractors fitted with the standard 8x2 or 16x4 Dual Power transmission.

The main control valve contains twelve separate hydraulic valves, the regulating valve, and eleven valves which are actuated by electronically energised coils. Of these eleven electronically actuated valves, nine control the application of the six speed and three directional clutches, while the two remaining valves control modulating circuits – one for the F1 (forward 1) directional clutch and the other for the F2 (forward 2) and REV (reverse) directional clutches.

The energisation of these valves and modulator circuits is controlled by the electronic management system, which in turn is signalled by the in–cab control lever and the foot operated inching pedal.

The hydraulic circuits are shown in schematic format in Figure 1; hydraulic oil is supplied to the control valve by the transmission charge pump, via the external filter. The main regulator valve acts to maintain a pressurised oil supply to each of the nine clutch circuits, and to the modulator valves, plus in addition, a supply for the tractor low pressure circuit. The oil flow from the hydraulic pump continues past the regulator valve, to the lubrication and cooling circuit, passing a lubrication and cooling circuit relief valve, the external heat exchanger, or cooler, mounted in front of the engine radiator, and an internal by–pass port cast into the main control valve housing. The external cooler handles only a proportion of the total lubrication and cooling oil flow. All excess flow is passed through the internal by–pass port directly to the transmission lubrication and cooling circuit.

Figure 2, shows in diagrammatic form, the operation of the main regulator valve. Pump oil, present in gallery "A", which is also linked to the clutch circuits at gallery "B", cannot escape until the regulator spool has moved to the right. Oil enters the hollow spool through an opening and via a removable orifice plate, incorporated for cushioning purposes, acts on the left hand side of the spool. This oil pressure moves it to the right, against the opposing force of the two springs. As the spool moves, pump oil, surplus to that required for operating the speed clutches, directional clutches and modulating valves, moves on to the lubrication and cooling circuits via gallery "C".

Each of the nine clutch circuit valves, shown diagrammatically in Figure 3, operates in an identical manner. However the directional clutch application circuits are modulated or proportionally controlled, allowing their application and release to be cushioned and feathered when required.

The nine clutch circuits operate on a simple open or shut basis. Oil from the now regulated pressure gallery "A", shown diagrammatically in Figure 3, is not allowed to pass to the clutch supply port "S" by the position of the clutch circuit valve spool (shown as an example as the left hand valve of Figure 3). With the coil energised, the core of the valve is magnetically drawn into the surrounding tube allowing the clutch circuit to open to the regulated oil supply, shown as an example on the right hand side of Figure 3. The simple coil spring, positioned in the hollowed end of the valve core acts as a shock absorber when the valve is energised, and a return device when the electrical signal is removed to close the valve. Any oil leaking past the valve from the regulated pressure supply will exhaust to the peripheral gallery "R", connected to sump. When the valve closes, oil within the clutch pack can return to sump from gallery "S" to "R", as shown on the left hand side of Figure 3.

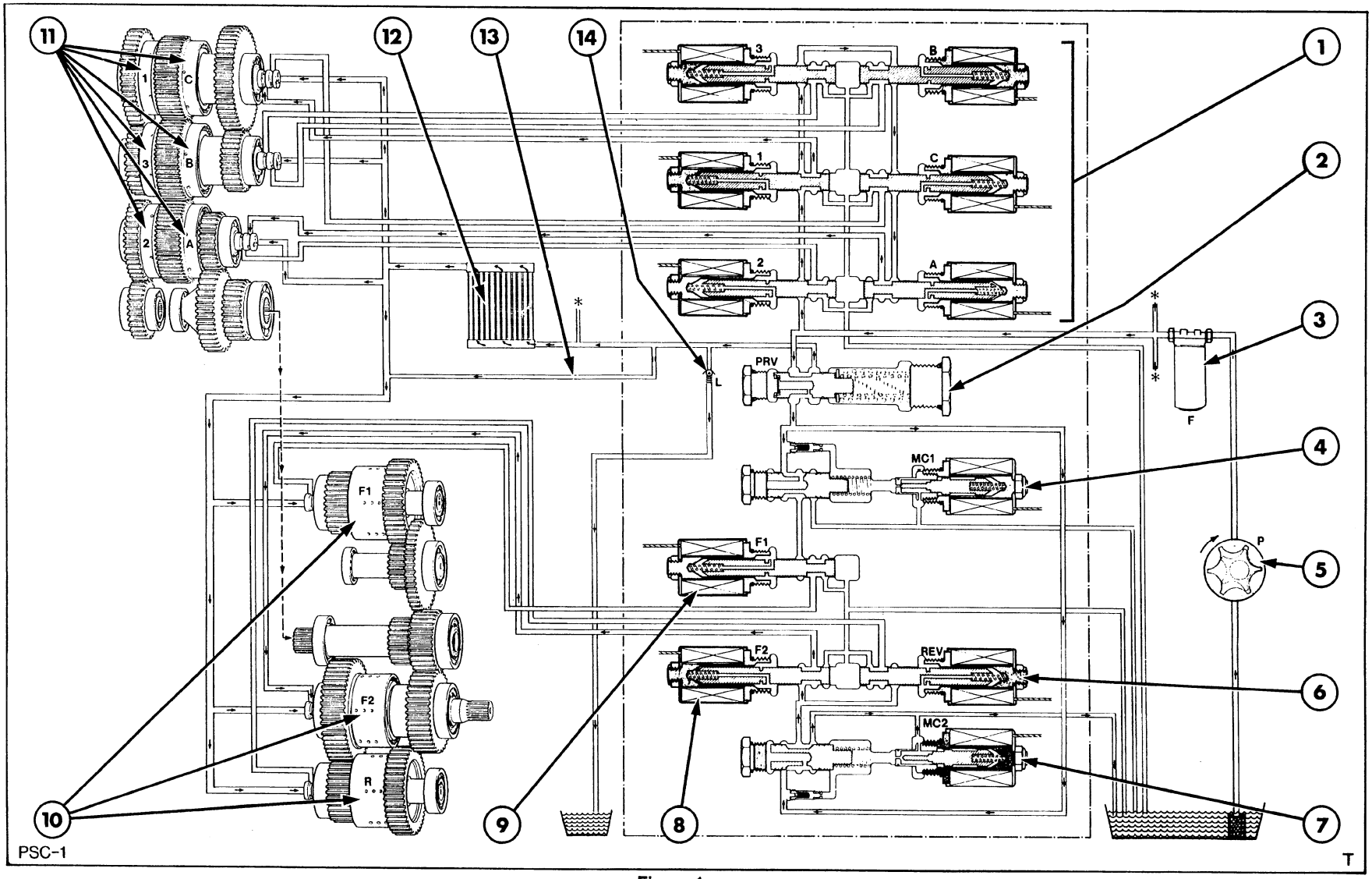

Figure 1
Main Hydraulic Control Valve Circuits – Schematic View

1. Speed Clutch Circuit Valves x 6
2. Regulating Valve
3. Filter
4. Modulator Valve for F1 Clutch
5. Pump
6. Reverse Clutch Circuit Valve
7. Modulator Valve for F2 and REV
8. F2 Clutch Circuit Valve
9. F1 Clutch Circuit Valve
10. Directional Clutches
11. Speed Clutches
12. Oil Cooler
13. Internal By–pass
14. Lubrication and Cooling Relief Valve

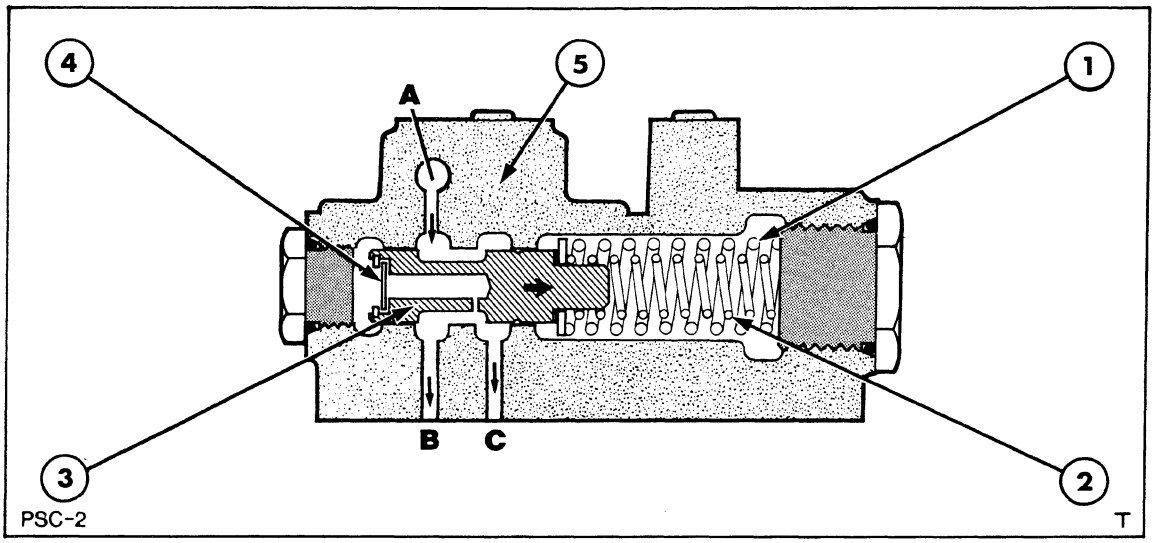

Figure 2
Regulator Valve Operation – Diagrammatic View

1. Outer Spring
2. Inner Spring
3. Valve Spool
4. Orifice Plate
5. Control Valve Housing

The modulator valve, controlled by the electronic management system, proportionally varies the pressure being sent to the directional clutches, the variation being determined by the degree of movement of the valve controlled by the strength of the electrical signal from the electronic management system.

Figure 4 shows, in diagrammatic format, a modulator or proportional valve. Oil from the regulated oil pressure gallery "A" passes around the waisted section of the modulating spool to gallery "D" which, in turn, is connected to the directional clutch circuit valves. As the solenoid coil, in this situation , is not energised, oil passing into the centre of

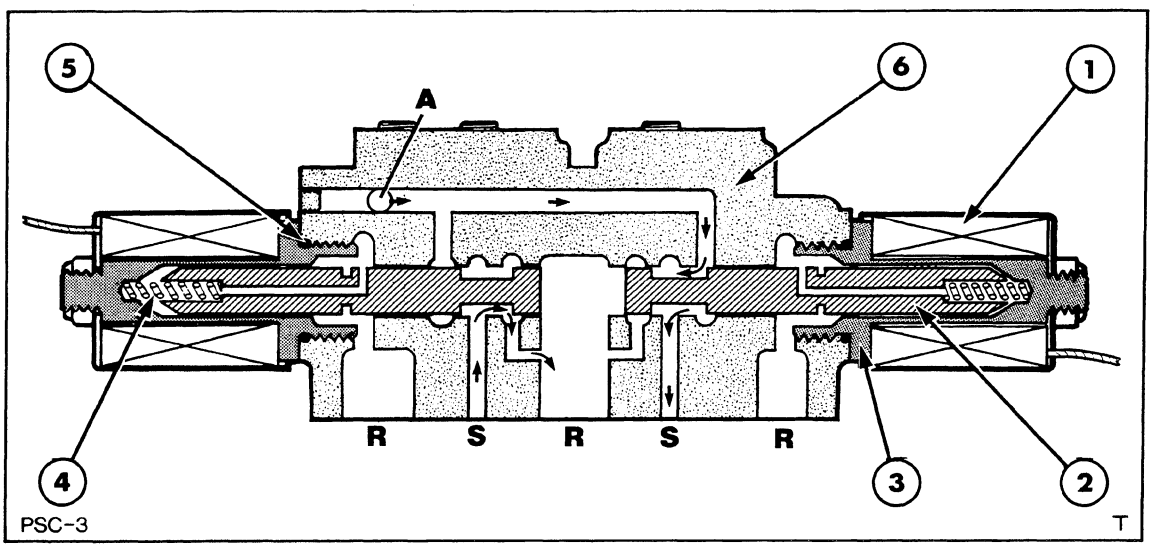

Figure 3
Clutch Circuit Valve Operation – Diagrammatic View

1. Solenoid Coil
2. Valve Spool
3. Solenoid Body
4. Return/Cushioning Spring
5. "O" Ring Seal
6. Main Control Valve Housing

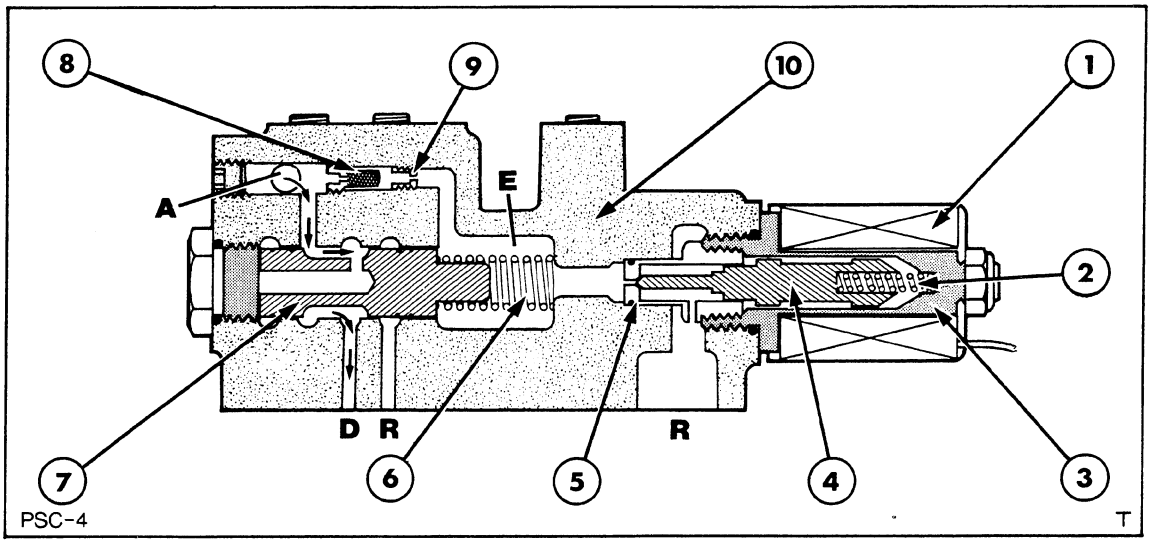

Figure 4
Modulator Valve Operation – Diagrammatic View

1. Solenoid Coil
2. Return/Cushioning Spring
3. Solenoid Housing
4. Pilot Valve Spool
5. Pilot Valve Seat
6. Spring
7. Modulating Spool
8. Filter Screen
9. Removable Orifice
10. Control Valve Housing

the spool and acting on the inner right hand end of the spool cannot overcome the same oil pressure which is present in chamber "E" and assisted by the force of the spring.

In Figure 5, the solenoid coil has been energised and the pilot valve spool drawn off its seat. This allows oil to flow from chamber "E" over the pilot seat to sump at "R". The degree of flow is controlled by the removable orifice and the amount the pilot valve is drawn off its seat. The degree of pilot valve movement is dictated by the strength of the current supplied to the coil.

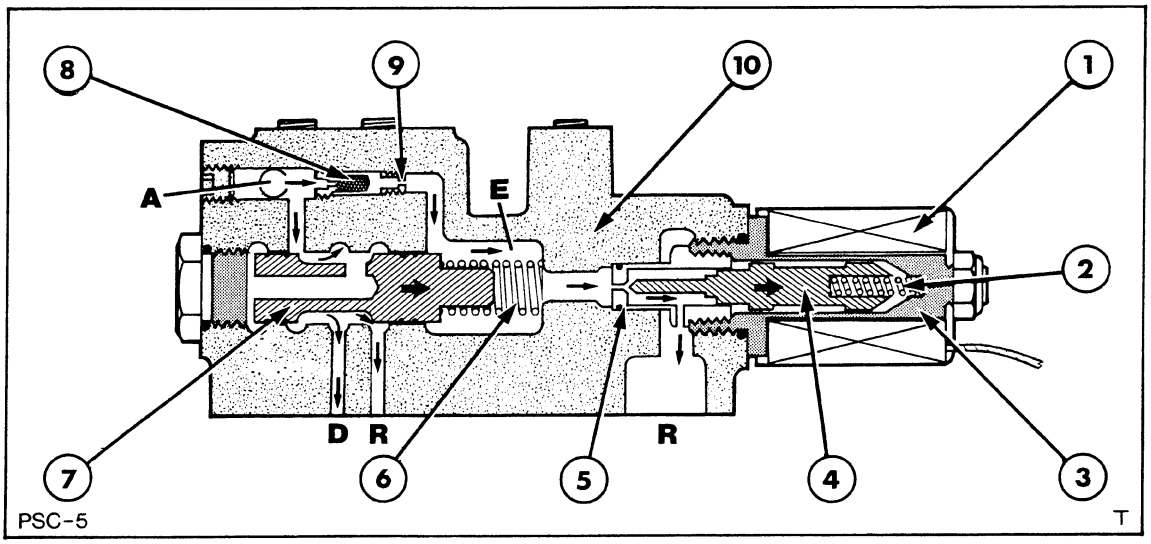

Figure 5
Modulator Valve Operation – Diagrammatic View

1. Solenoid Coil
2. Return/Cushioning Spring
3. Solenoid Housing
4. Pilot Valve Spool
5. Pilot Valve Seat
6. Spring
7. Modulating Spool
8. Filter Screen
9. Removable Orifice
10. Control Valve Housing

As the oil flows across the pilot valve seat, the pressure in chamber "E" reduces, dependant on the rate of flow, and unbalances the modulating spool causing it to move to the right. This allows pressure at gallery "D" to be regulated by the throttling action of the spool as it opens the gallery "R" to sump.

Depending on the strength or degree of electrical current supplied to the proportional valve solenoid and the timing of the opening of the clutch circuit valve, speed of application and release of the directional clutches will be controlled. All signals to the solenoids are precisely controlled by the electronic management system. Full details of this management system are contained in Section D

D. ELECTRONIC MANAGEMENT SYSTEM – DESCRIPTION AND OPERATION

The transmission control system consists of three major components. A transmission control module or TCM, a speed selector and a display module. Complimenting these components are wiring harnesses, solenoid controlled valves, relays and sensors.

The transmission control module is in fact a micro processor which during manufacture is programmed with complex instructions to control the management of the transmission. Within these pre–programmed instructions is a fail safe mode which instantly allows the transmission to go to neutral in the unlikely event that a mal–function should occur. The TCM can be calibrated by the serviceman to tune it to a particular transmission to take into account the pressure required by the wet clutches to reach the point where they just start to transmit power and to perform selective shuttle shifts as described in Section B. The TCM, in addition, has a built in programme to provide a self diagnostic display giving guidance to the serviceman, in the form of alpha numerics, of any conditions either external or internal to the TCM effecting its function. These diagnostic codes may either automatically put the transmission in neutral or allow it to continue to operate depending on the diagnosed condition. No mechanical adjustment of the TCM is possible and on no account should the module be disassembled.

Figure 1 illustrates in diagrammatic format the Transmission Control System.

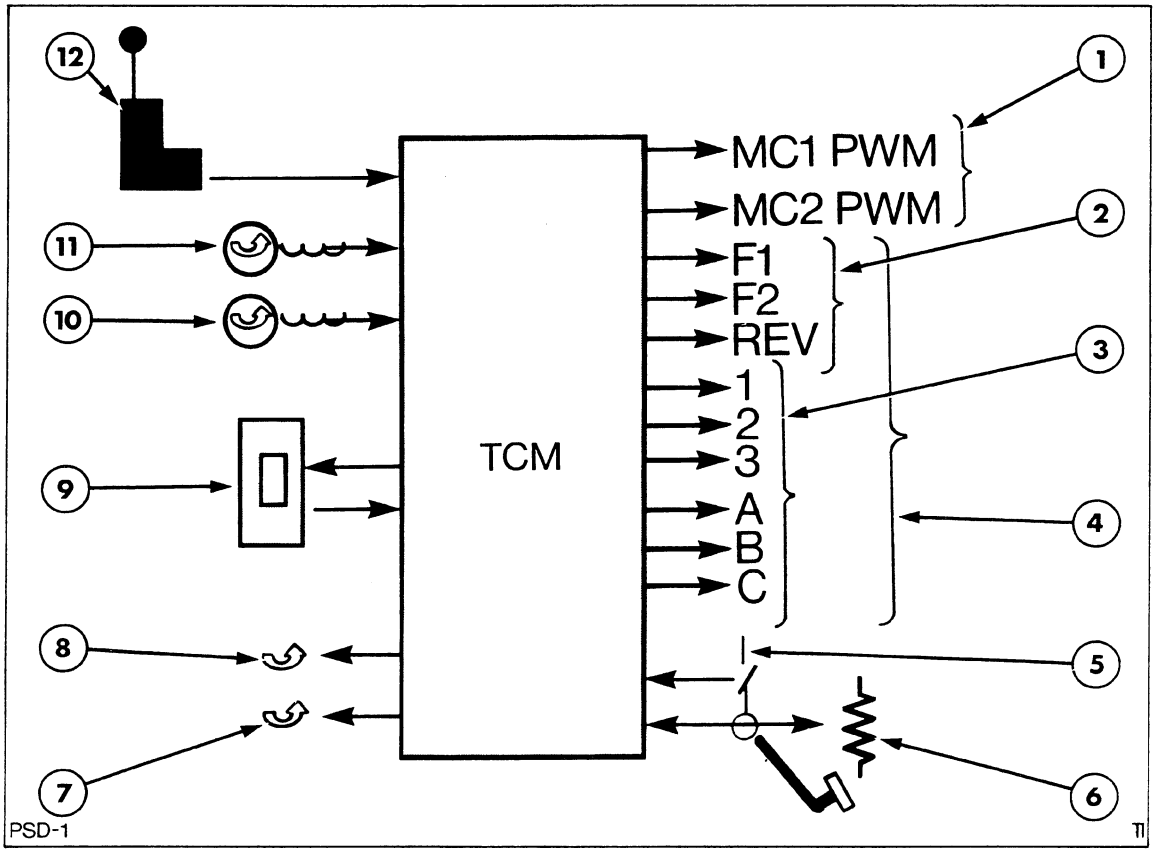

Figure 1

Transmission Control System – Diagrammatic Format

1. Modulating Valve Solenoids
2. Directional Solenoids
3. Speed Clutch Solenoids
4. Direct Acting Solenoids
5. Inching Pedal Sense Switch
6. Inching Pedal Sensor Potentiometer
7. Axle Speed Output
8. Engine Speed Output (not used)
9. Visual Display Module
10. Axle Speed Sensor
11. Engine Speed Sensor
12. Speed Control Lever Assy

Figure 2 illustrates in diagrammatic format the nine direct acting clutch circuit valve solenoids that signal the application of pressure to the speed and directional clutches. The three directional clutches F1, F2, and REV have their direct acting clutch circuit valves controlled by two modulating valves signaled by two further solenoids at MC1 and MC2

The clutches are wet oil filled that engage when hydraulic pressure is applied to the clutch cavity, see Section A. Once the appropriate valve is energized (Solenoid signalling causes clutch circuit direct acting valves to apply clutch pressure), hydraulic oil fills the clutch cavity and after a very short "fill time" interval, the clutch plates engage and transmit torque. The numbered and lettered speed clutches 1, 2, 3, and A, B, C, do not tolerate extended periods of slippage and are either fully engaged or not engaged.

Figure 3 illustrates in chart form which direct acting clutch circuit valve solenoids are energised for a given speed selection. One clutch only in each of the numbered and lettered speed clutch groups, and one directional clutch must be applied.

Since clutches F1, F2, and REV are used for inching, speed changes that require controlled slippage and directional changes, these clutches are far more tolerant of slippage and consequently their construction reflects this. To control the period and timing of this slippage, the pressure must be controlled at these clutches. Clutch circuit valves F1, F2 and REV are direct acting and thus do not control pressure. These three valves are hydraulically controlled by two modulating valves, MC1 and MC2, as described in Section C. The modulating valve solenoids are pulse width modulated. "Pulse Width Modulation" (PWM) is a term used to describe the control function of the electrical output from the TCM. The PWM solenoid allows regulation of the hydraulic valve pressure to the appropriate clutch, to be inversely proportional to the average DC electrical current in the solenoid coil. That is, the lower the solenoid current, the higher the pressure applied to the clutch.

Figure 4 shows a very simplified view of the operation of this valve and is also described in Section C from an hydraulic standpoint. When the solenoid is not electrically energised, a needle valve is spring loaded in the

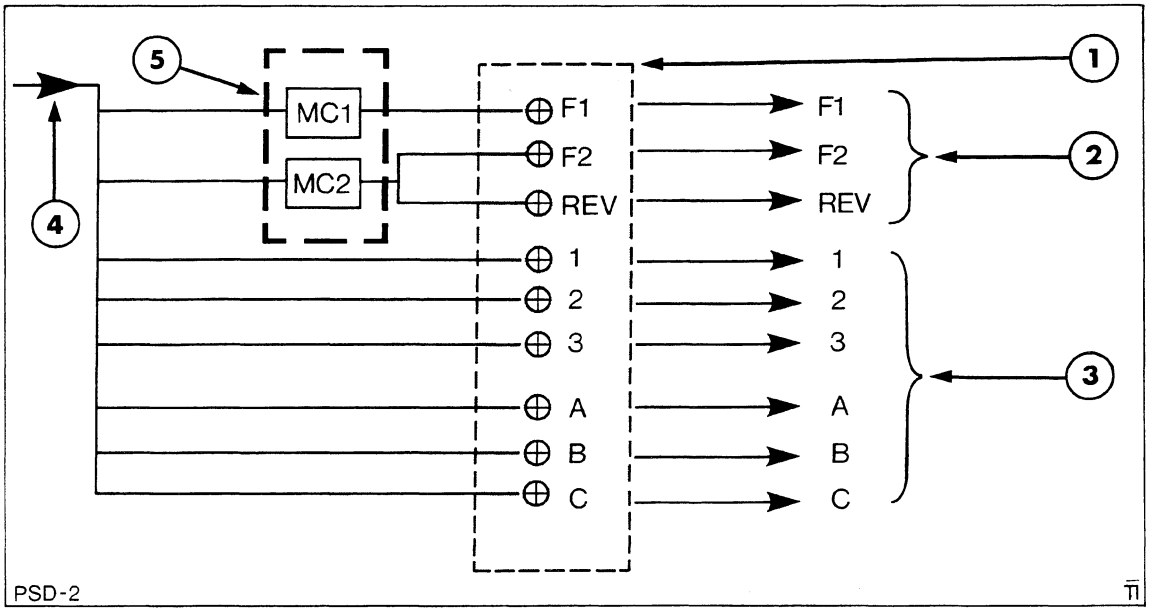

Figure 2
Direct Acting Solenoids – Diagrammatic View

1. Direct Acting Clutch Circuit Valves and Solenoids
2. Directional Clutches
3. Speed Clutches Numbered and Lettered
4. Regulated Input Oil Pressure
5. Proportional Valves and Solenoids