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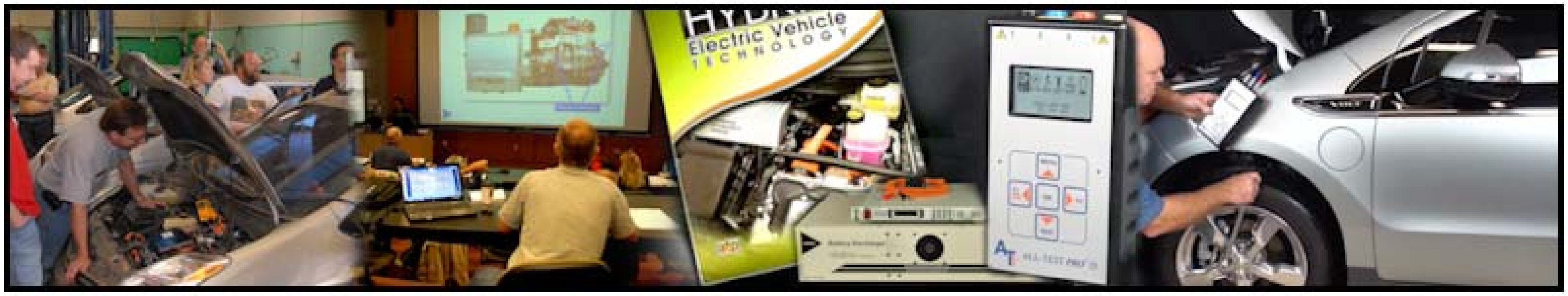

HEV Systems Technical eNewsletter

Introduction to GM 2-Mode Hybrid System

Part 2 of the 3-Part Series

As a quick overview, Part 1 of this topic series (ref: Oct 2011 Newsletter) we covered the following aspects of the GM 2-Mode Hybrid System:

- Engine Cranking
- Components
- EVT Mode 1 Low
- EVT Mode 2 High
- Engine Auto-Stop and Start
- Fixed Gear Operation
- Regenerative Braking

Download a copy of Part 1 of this series in the October 2011 eNewsletter here.

In Part 2 of this series we will concentrate on the 2ML70 Transmission Specifications, Drive Motor and Design, as well as the clutch assemblies.

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A low state of charge (SOC) auxiliary battery can be the cause of a no crank condition because all vehicle controllers and high voltage contactors (relays) are powered by the 12 volt system.

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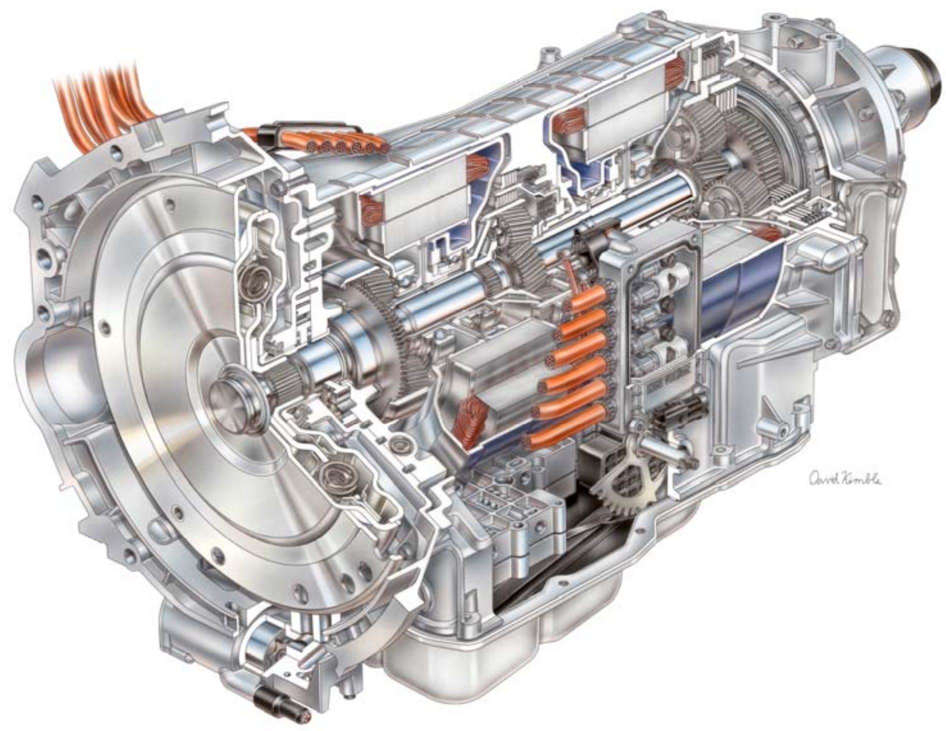

GM 2-Mode 2ML70 Hybrid Transmission

2-Mode Hybrid 2ML70 Transmission Specifications

-Maximum Gross Vehicle Weight: 1745 – 2360 kg (3847 – 5203 lbs)

- 2ML70 Transmission Weight w/Torque Dampener: 167 kg (368 lbs)

- Hybrid EVT:

  - 4 Forward gears, 2 EVT Modes
  - 2 – 60kW (80hp) Internal Motors
  - Mounting: Longitudinal

- Sustained Engine rpm Input: 6,500

- Maximum Engine Input Torque: 583 N·m (430 lb·ft)

- Gear Ratios:

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- 1^{st} – 3.692 Electric or ICE
- 2^{ND} - 1.705
- 3^{RD} - 1.00
- 4^{TH} - 0.738
- Reverse – 3.692 Electric Only
- EVT Mode 1 – Infinity to 1.700
- EVT Mode 2 – 1.700 to <0.738

-Transmission Fluid Type: Dexron VI

- Transmission Fluid Capacity (Approximate)

- Dry Transmission (Empty): 12.30 L (13 qt)
- Bottom Pan Removal: 10.88L (11.5 qt)
- Drain Plug Only: 9.93L (10.5 qt)

2ML70 Transmission Overview

Drive motor assemblies each provide 65kW (80hp) peak power. Both are actively cooled by transmission fluid and are encased in steel housings to facilitate the manufacturing of the transmission assembly. Three high voltage AC cables, connected to each of the two drive motors, connect the drive motors to the drive motor generator control module (DGMCM) and Traction Power Inverter Module (TPIM).

The drive (w/generator) motor assembly – 1st position is used to start the engine, and also reacts to torque from the drive (w/generator) motor assembly – 2nd position. The drive (w/generator) motor assembly – 2nd position propels the vehicle when operating in full-electric mode with the engine OFF or in Reverse. Drive motor speeds are controlled and monitored by position sensors (resolver sensor) internal to the motor housings.

The drive motor generator resolver position sensor is monitored by a motor control module (MCM). The drive motor generators are connected to the traction power inverter with the 3-phase cable assembly. The drive motor-generator (i.e., electric machines) can be viewed in Figure 1, and a picture of the drive motor-generator 2^{nd} position can be seen in Figure 2. Drive-motor 1^{st} position is identical to the 2^{nd} position electric machine.

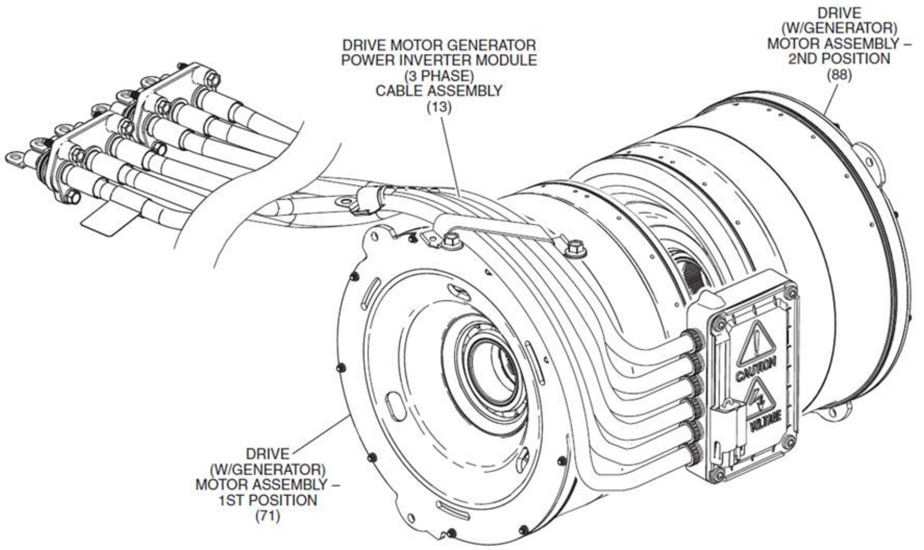


Figure 1. Drive Motor-Generator and 3-Phase Cable Assemblies

Figure 2. Drive Motor-Generator 2nd Position

The 2-Mode hybrid permanent magnet electric machines contain a stator assembly; rotor assembly, resolver sensor, and cover/end plate (see Figure 3). The 2-Mode hybrid stator assembly is a unique design for an electric machine. In lieu of using a wound coils this electric machine uses a single rectangular wire for each phase. Therefore, the 2-Mode has two wires for each stator slot (see Figure 4). The rectangular wire permits a much higher stator slot fill (higher copper density) that results in a stronger magnetic field flux. Traditional round wire slot fill is much lower because there is space between the individual wires results in area not containing copper. Therefore, since there is less copper in the stator slot the magnetic field will be lower resulting in lower hp and torque output.

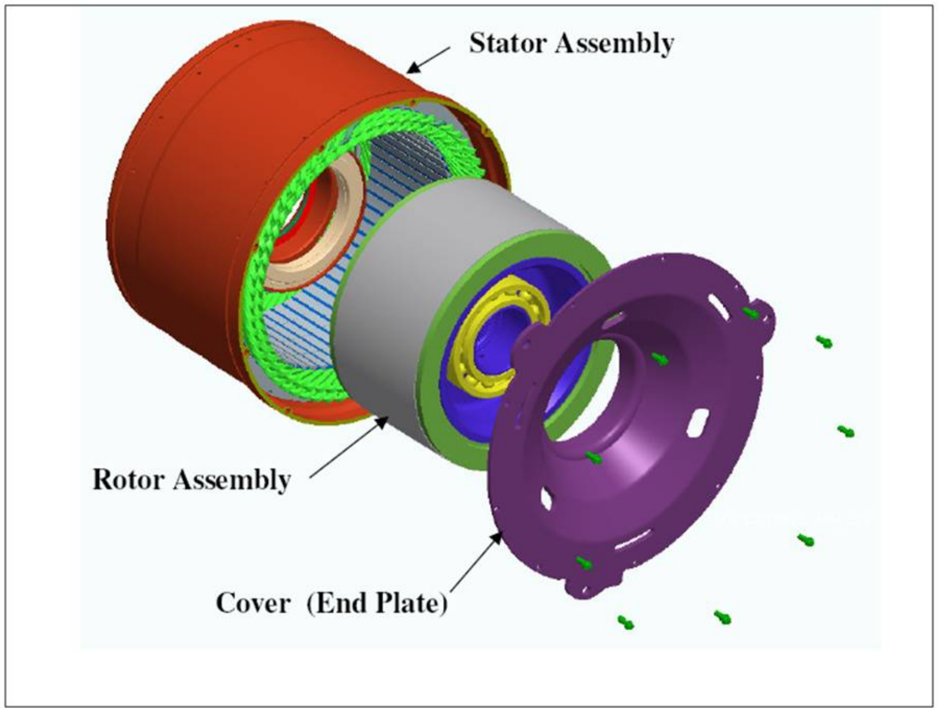


Figure 3. 2-Mode Electric Machine Component View

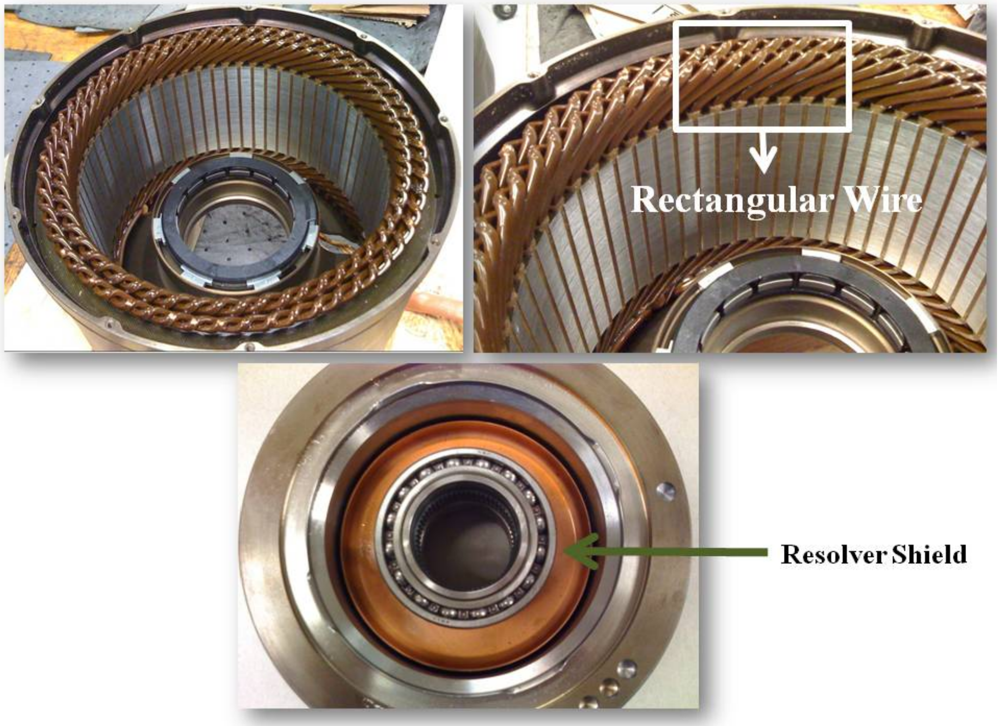


Figure 4. 2-Mode Electric Machine Stator

Another unique feature of the 2-Mode electric machine is the copper shield for the resolver sensor (refer to Figure 4). Due to resolver being in close proximity to the rotor magnetic field, it is shielded by a copper (Faraday) shield to mitigate the rotor magnetic field interfering with the resolver magnetic field. If an external magnetic field influences the resolver sensor operation, this would result in the motor controller receiving erroneous data. If the motor controller receives erroneous data this would ultimately result in the controller terminating the operation of the electric machine (motor-generator).

As a point of review, the MCM monitors the angular position, speed and direction of the drive motor generator based upon the signals of the resolver type position sensor. The resolver position sensor contains a drive coil, two driven coils and a metallic rotor with elliptical lobes. The metallic rotor is mechanically attached to the shaft of the drive (w/generator) motor assembly. With the ignition ON, the MCM transmits a 5 volt AC, 10 kHz excitation signal to the drive coil. The drive coil excitation signal creates a magnetic field surrounding the two driven coils and the irregularly shaped metallic rotor. The MCM then monitors the varied amplitudes from the two driven coil circuits to determine the electric machine rotor position and rpm. The position of the irregularly shaped metallic rotor causes the magnetically-induced return signals of the driven coils to vary the shape and size of their respective output AC sine wave signatures. Comparison of the! two driven coil signals permits the MCM to determine the exact angle, speed and direction of the drive (generator) motor assembly.

The 2-Mode rotor is also another unique design that uses two rows of horizontal interior mounted magnets in a "V" shaped configuration (see Figure 5). The interior mounted magnets reduce the back-EMF (i.e., voltage that is produced by the magnets) that reduce torque-ripple (cogging effect) resulting in an unsmooth driveline.

The rotor has a total of 10 magnet groups and therefore, is considered to be a 10-pole rotor. Another advantage in using a double-row magnet construction is dispersing the strong magnetic field over a wider area. The upper row concentrates a magnetic field in a small area while the bottom row of magnets provides a strong magnetic field that is wider than the upper row. The two fields will combine resulting in a strong field in a wide area and smoother electric machine functionality.

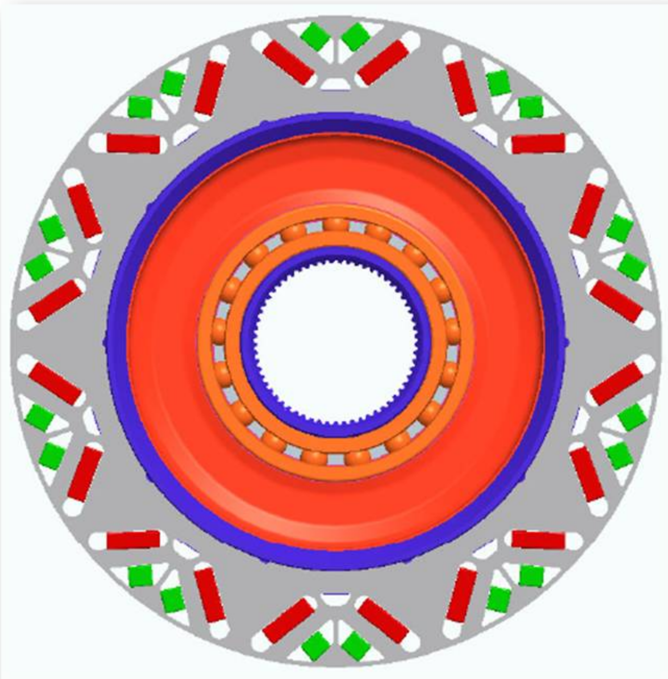


Figure 5. 2-Mode Electric Machine Rotor Magnet Design

Both drive motor-generator 1st and 2nd position are easily mounted in the transmission case. Each of the electric machines has a mounting plate with three machined flanges that will mount into 3 recessed areas of the case. This will prevent the electric machines from rotating in the transmission case when either of them is transmitting torque to the driveline. The electric machines are mounted so that the bottom of each machine is facing the other (see Figure 6 as reference).

Motor "A" - Trans Front **Motor "B" - Trans Rear**

Figure 6. Electric Machine Mounting In Transmission Case

Drive Motor – First Position (Motor "A")

The drive (w/generator) motor assembly – 1st position (Motor A) is located in the front of the transmission case assembly, between the sun gear carrier assembly – 1st position and the sun gear carrier assembly – 2nd position, and is splined to the sun gear shaft assembly – 1st position (see Figures 7 and 8). The drive (w/generator) motor assembly – 1st position provides power input used to Auto Start the internal combustion engine (ICE), and provides propulsion assistance electrical power generation at highway speeds in EVT Mode High.

Figure 7. Location of Motor A

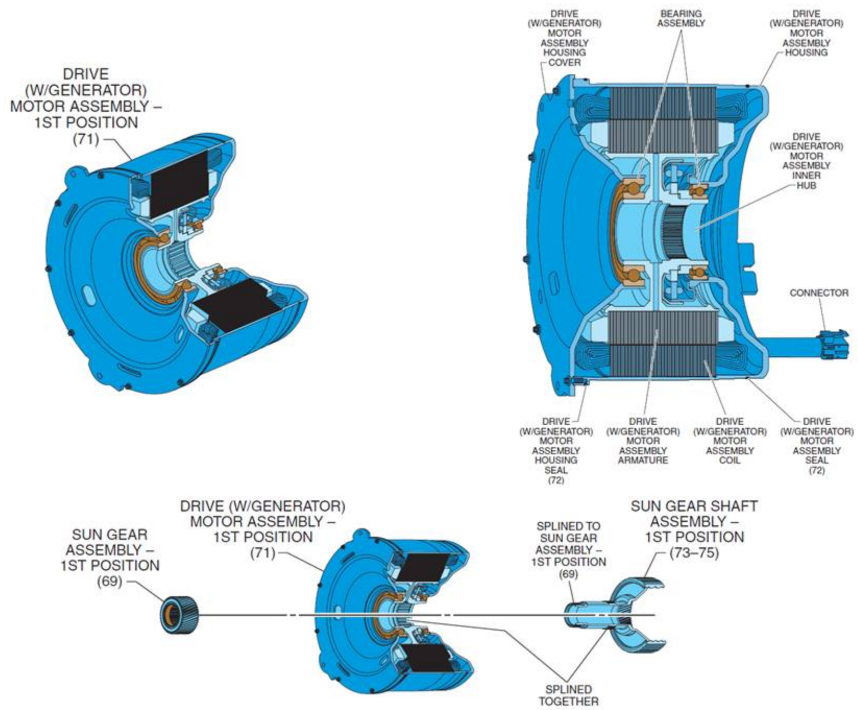


Figure 8. Motor "A" Construction

Engine Starting

The drive (w/generator) motor assembly – 1st position is also used as the starter for the ICE. The 300 V drive motor can rotate the ICE to operating speed (800 RPM) within just a few hundred milliseconds, resulting in near instant engine starting.

Regenerative Braking

When the vehicle is coasting or braking at lower speeds (>35mph) the Hybrid Processor Control Module (HPCM) may operate the drive (w/generator) motor assembly – 1st position in an electrical generation mode. Operating as an electrical generator, the drive (w/generator) motor assembly – 1st position exerts a driveline load that helps to slow the vehicle. The electrical energy that the drive (w/generator) motor assembly – 1st position creates is transferred by the drive motor generator TPIM to the drive motor generator battery assembly (high voltage battery). Constant communication between the HPCM and the electronic brake control module (EBCM) controls the blending of regenerative braking force with hydraulic braking force. At speeds <35mph the HPCM will use the drive (w/generator) motor assembly -2nd position to generate electrical power.

1-3 Clutch Assembly

The 1–3 clutch assembly (see Figure 9) is located in the 1–3 clutch housing assembly, which is splined to the sun gear shaft assembly – 3rd position. The external teeth on the 1–3 clutch plates are splined to the housing assembly, while the internal teeth on the 1–3 clutch plate assemblies are splined to the internal gear – 2nd

position. The 1–3 clutch is applied only when the transmission is in First or Third gear.

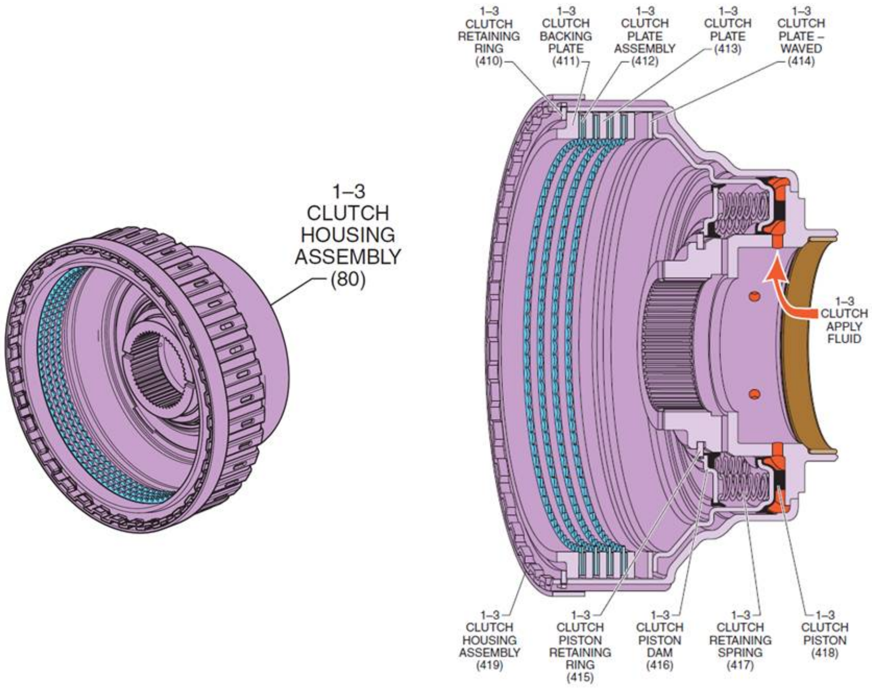


Figure 9. 1-3 Clutch Assembly

1–3 Clutch Apply

To apply the 1–3 clutch, 1–3 clutch apply fluid is transmitted through the center support assembly and into the

inner hub of the 1–3 clutch housing assembly. Feed holes in the inner hub allow 1–3 clutch apply fluid to enter the housing behind the 1–3 clutch piston. 1–3 clutch fluid pressure moves the piston and compresses the 1–3 clutch retaining spring. As fluid pressure increases, the piston compresses the 1–3 clutch plates until they are held against the 1–3 clutch backing plate. Also included in the assembly is a 1–3 clutch waved plate that helps cushion the application of the 1–3 clutch. When fully applied, the 1–3 clutch waved plate, the 1–3 clutch plates and the clutch plate assemblies are locked together, thereby holding the 1–3 clutch housing assembly and the sun gear shaft assembly – 3rd position together. This forces the sun gear shaft assembly – 3rd position, which is splined to the 1–3 clutch housing assembly, to rotate at the same speed as the internal! gear – 2nd position.

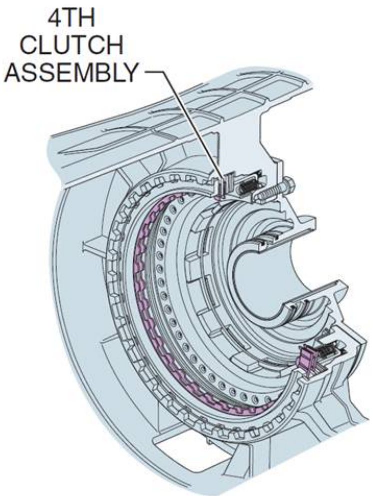
1–3 Clutch Release

To release the 1–3 clutch, 1–3 clutch apply fluid exhausts through the 1–3 clutch apply fluid circuit, allowing

pressure at the 1–3 clutch piston to decrease. Spring force from the 1–3 clutch retaining spring moves the 1–3 clutch piston away from the clutch pack. This disengages the 1–3 clutch waved plate, the 1–3 clutch plates, and the 1–3 clutch plate assemblies from the 1–3 clutch backing plate and disconnects the 1–3 clutch housing assembly (from the internal gear – 2nd position.

4th Clutch Assembly

The 4th clutch assembly (see Figure 10) is located in the case assembly. The external teeth on the 4th clutch plates are splined to the case assembly, while the internal teeth on the 4th clutch plate assemblies are splined to the 1-3 clutch housing assembly. The 4th clutch is applied only when the transmission is in Fourth gear.



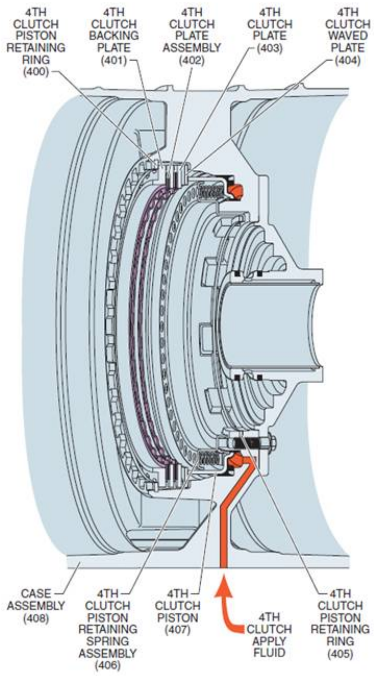


Figure 10. 4th Clutch Assembly

4TH Clutch Apply

To apply the 4th clutch, clutch apply fluid is fed through the control valve upper body assembly into the case assembly. A fluid feed hole in the case assembly allows fluid to enter behind the 4th clutch piston. 4th clutch apply fluid pressure moves the piston and compresses the 4th clutch piston retaining spring assembly. As fluid pressure increases, the piston compresses the 4th clutch plates together until they are held against the 4th clutch backing plate. Also included in the assembly is a 4th clutch waved plate that helps cushion the application of the 4th clutch. When fully applied, the 4th clutch waved plate, the 4th clutch plates, and the 4th clutch plate assemblies are locked together, thereby holding the 1–3 clutch housing assembly stationary to the case assembly.

4TH Clutch Release

To release the 4th clutch, 4th clutch apply fluid exhausts through the case assembly and into the control valve upper body assembly, allowing pressure at the 4th clutch piston to decrease. In the absence of fluid pressure, spring force from the 4th clutch piston retaining spring assembly moves the 4th clutch piston away from the clutch pack. This disengages the 4th clutch waved plate, the 4th clutch plates, and the 4th clutch plate assemblies from the 4th clutch backing plate, thereby allowing the 1–3 clutch housing assembly to rotate freely.

December Newsletter: The 2-Mode Transmission Part 3 to complete this Series

*Until next time remember - knowledge is **POWER***

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