



SPICER®

Off-Highway Products

Service Manual

Transmission
T12000 3, 4, & 6-speed Intermediate Drop
VDT12000
VDT 17°

TSM-0022
April 2011



T12000, VDT & 17°

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MOT12000T20

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NOTICE

All information mentioned in the and Service manual T12000 Powershift Transmission 3, 4 & 6 Speed Intermediate Drop is valid, unless otherwise specified in this 17° Drop Box and VDT.

FOREWORD

This manual has been prepared to provide the customer and the maintenance personnel with information and instructions on the maintenance and repair of the SPICER OFF-HIGHWAY PRODUCTS product.

Extreme care has been exercised in the design, selection of materials, and manufacturing of these units.

The slight outlay in personal attention and cost required to provide regular and proper lubrication, inspection at stated intervals, and such adjustments as may be indicated will be reimbursed many times in low cost operation and trouble free service.

In order to become familiar with the various parts of the product, its principle of operation, troubleshooting and adjustments, it is urged that the mechanic studies the instructions in this manual carefully and uses it as a reference when performing maintenance and repair operations.

Whenever repair or replacement of component parts is required, only SPICER OFF-HIGHWAY PRODUCTS approved parts as listed in the applicable parts manual should be used. Use of "will-fit" or non-approved parts may endanger proper operation and performance of the equipment. SPICER OFF-HIGHWAY PRODUCTS does not warrant repair or replacement parts, nor failures resulting from the use of parts which are not supplied by or approved by SPICER OFF-HIGHWAY PRODUCTS.

TOWING OR PUSHING

Before towing the vehicle, be sure to lift the rear wheels off the ground or disconnect the driveline to avoid damage to the transmission during towing.



If the transmission has 4 wheel drive, disconnect both front and rear drivelines. Because of the design of the hydraulic system, the engine cannot be started by pushing or towing.

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SAFETY PRECAUTIONS

To reduce the chance of personal injury and/or property damage, the following instruction must be carefully observed. Proper service and repair are important to the safety of the service technician and the safe, reliable operation of the machine. If replacement parts are required the part must be replaced by a spare part which has the same part number or with an equivalent part. Do not use a spare part of lesser quality.

The service procedures recommended in this manual are effective methods for performing service and repair. Some of these procedures require the use of tools specifically designed for the purpose.

Accordingly, anyone who intends to use a spare part, service procedure or tool, which is not recommended by SPICER OFF-HIGHWAY PRODUCTS, must first determine that neither his safety nor the safe operation of the machine will be jeopardized by the spare part, service procedure or tool selected.



NOTE: IT IS IMPORTANT TO NOTE THAT THIS MANUAL CONTAINS VARIOUS 'CAUTIONS' AND 'NOTICES' THAT MUST BE CAREFULLY OBSERVED IN ORDER TO REDUCE THE RISK OF PERSONAL INJURY DURING SERVICE OR REPAIR, OR THE POSSIBILITY THAT IMPROPER SERVICE OR REPAIR MAY DAMAGE THE UNIT OR RENDER IT UNSAFE. IT IS ALSO IMPORTANT TO UNDERSTAND THAT THESE 'CAUTIONS' AND 'NOTICES' ARE NOT EXHAUSTIVE, BECAUSE IT IS IMPOSSIBLE TO WARN ABOUT ALL THE POSSIBLE HAZARDOUS CONSEQUENCES THAT MIGHT RESULT FROM FAILURE TO FOLLOW THESE INSTRUCTIONS.

CLEANING AND INSPECTION

CLEANING

Clean all parts thoroughly using solvent type cleaning fluid. It is recommended that parts be immersed in cleaning fluid and moved up and down slowly until all old lubricant and foreign material is dissolved and parts are thoroughly cleaned.



CARE SHOULD BE EXERCISED TO AVOID SKIN RASHES, FIRE HAZARDS, AND INHALATION OF VAPOURS WHEN USING SOLVENT TYPE CLEANERS.

BEARINGS

Remove bearings from cleaning fluid and strike flat against a block of wood to dislodge solidified particles of lubricant. Immerse again in cleaning fluid to flush out particles. Repeat above operation until bearings are thoroughly clean. Dry bearings using moisture-free compressed air. Be careful to direct air stream across bearing to avoid spinning. Do not spin bearings when drying. Bearings may be rotated slowly by hand to facilitate drying process.

HOUSINGS

Clean interior and exterior of housings, bearing caps, etc..., thoroughly. Cast parts may be cleaned in hot solution tanks with mild alkali solutions providing these parts do not have ground or polished surfaces. Parts should remain in solution long enough to be thoroughly cleaned and heated. This will aid the evaporation of the cleaning solution and rinse water. Parts cleaned in solution tanks must be thoroughly rinsed with clean water to remove all traces of alkali. Cast parts may also be cleaned with steam cleaner.



CARE SHOULD BE EXERCISED TO AVOID INHALATION OF VAPOURS AND SKIN RASHES WHEN USING ALKALI CLEANERS.

All parts cleaned must be thoroughly dried immediately by using moisture-free compressed air or soft, lintless absorbent wiping rags free of abrasive materials such as metal fillings, contaminated oil, or lapping compound.

INSPECTION

The importance of careful and thorough inspection of all parts cannot be overstressed. Replacement of all parts showing indication of wear or stress will eliminate costly and avoidable failures at a later date.

BEARINGS

Carefully inspect all rollers: cages and cups for wear, chipping, or nicks to determine fitness of bearings for further use. Do not replace a bearing cone or cup individually without replacing the mating cup or cone at the same time. After inspection, dip bearings in Automatic Transmission Fluid and wrap in clean lintless cloth or paper to protect them until installed.

OIL SEALS, GASKETS, ETC.

Replacement of spring load oil seals, "O"-rings, metal sealing rings, gaskets, and snap rings is more economical when unit is disassembled than premature overhaul to replace these parts at a future time. Further loss of lubricant through a worn seal may result in failure of other more expensive parts of the assembly. Sealing members should be handled carefully, particularly when being installed. Cutting, scratching, or curling under of lip of seal seriously impairs its efficiency. When assembling new metal type sealing rings, these should be lubricated with coat of chassis grease to stabilize rings in their grooves for ease of assembly of mating members. Lubricate all "O"-rings and seals with recommended type Automatic Transmission Fluid before assembly.

GEARS AND SHAFTS

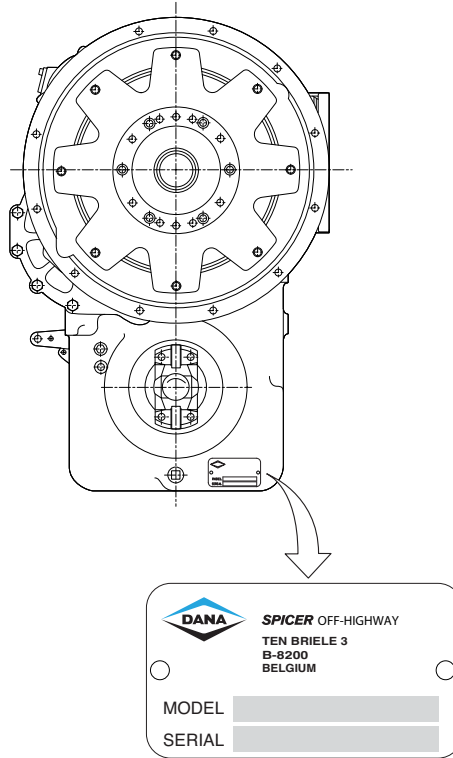
If magna-flux process is available, use process to check parts. Examine teeth on all gears carefully for wear, pitting, chipping, nicks, cracks, or scores. If gear teeth show spots where case hardening is worn through or cracked, replace with new gear. Small nicks may be removed with suitable hone. Inspect shafts and quills to make certain they are not sprung, bent, or splines twisted, and that shafts are true.

HOUSINGS, COVERS, ETC.

Inspect housings, covers and bearing caps to ensure that they are thoroughly clean and that mating surfaces, bearing bores, etc..., are free from nicks or burrs. Check all parts carefully for evidence of cracks or conditions which would cause subsequent oil leaks or failures.

TECHNICAL SPECIFICATION

T12000 - 3,4,6 speed



IDENTIFICATION OF THE UNIT

- 1 Model and type of the unit.
- 2 Serial number.

WEIGHT, DIMENSIONS, OIL CAPACITY

Weight (dry): ±174.6 kg (385 lb.)

DIMENSIONS	T-MODEL	MT-MODEL
Maximum length:	623.1 mm (24.53")	623.1 mm (24.53")
Maximum width:	477.0 mm (18.78")	477.0 mm (18.78")
Maximum height:	701.1 mm (27.60")	701.1 mm (27.60")

OIL CAPACITY

±12.9 l (3.4 US Gallon) without cooler and hydraulic lines.

Consult operator's manual on applicable machine for system capacity.

PRESSURE AND TEMPERATURE SPECIFICATIONS

- Normal operating temperature 70 - 120 °C (158 - 248 F) measured at temperature check port converter out (port 71 - **).
- Maximum allowed transmission temperature 120 °C (248 F).
- Transmission regulator pressure (*) - (neutral) - port 31 (**).
 - At 600 RPM min. 12.76 bar (185 PSI) minimum.
 - At 2000 RPM: 19.31 bar (280 PSI) maximum.
- Pump flow (*)
 - At 2000 RPM in neutral: 53 l/min. minimum (14 GPM).
- Clutch pressures (*)
 - 1st clutch: port 41 (**).
 - 2nd clutch: port 42 (**).
 - 3rd clutch: port 43 (**).
 - Forward High clutch: port 44 (**).
 - Forward clutch: port 45 (**).
 - Reverse clutch: port 46 (**).
- At 1800 RPM :
 - 16.5 - 19.3 bar (240 - 280 PSI) clutch activated.
 - 0 - 0.2 bar (0 - 3 PSI) clutch released.
- Filter bypass valve set at 2.1 - 3.5 bar (*) (30 - 50 PSI).
- Lube pressure (*) (port 33) 2.9 - 4.0 bar (42 - 58 PSI) at 49 l/min. (13 GPM) pump flow (±1850 RPM).
- Safety valve: cracking pressure (*) 8.27 - 10.20 bar (120 - 148 PSI), measured at port 32 with convertor out shut off.
- Transmission out pressure (*) (port 32) 2.9-6.41 bar (42-93 PSI) at 49 l/min, (13 GPM) pump flow (±1850 RPM), and max. 8.27 bar (120 PSI) at no load governed speed.

(*)All pressures and flows to be measured with oil temperature of 82-93 °C (180-200 F)

(**)Refer to section 7 "Troubleshooting" for check port identification.

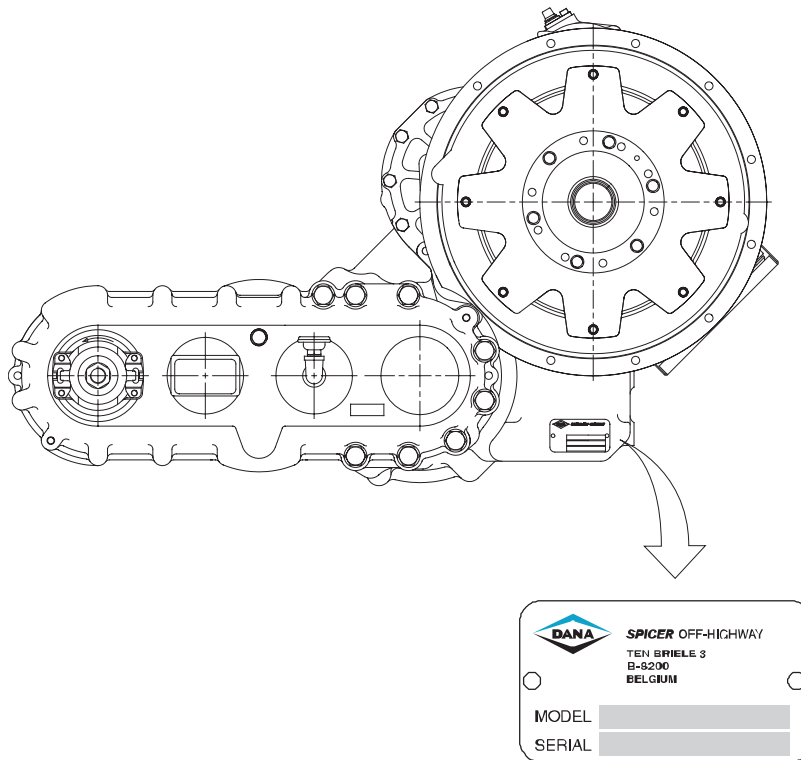
ELECTRICAL SPECIFICATIONS

- Solenoid (forward, reverse, 1st, 2nd and splitter).
- Coil resistance:
 - 12V: 9.79 Ω \pm 0.5 Ω .
 - 24V: 39.3 Ω \pm 2 Ω .
- Speed sensor:
 - Type: magneto resistive sensor.
 - Sensing distance: 0 - 1.8 mm (0" - 0.07").
 - Sensor signal: generates a square current with a fixed amplitude changing between 7 and 14 mA.

HYDRAULIC COOLER AND FILTER LINE SPECIFICATIONS

- Minimum 19 mm (.75") internal diameter for lines and fittings.
- Suitable for operation from ambient to 120 °C (248 F) continuous operating temperature.
- Must withstand 20 bar (290 PSI) continuous pressure and with 40 bar (580 PSI) intermittent surges.
- Conform SAE J1019 and SAE J517, 100RI.

VDT12000



IDENTIFICATION OF THE UNIT

- 1 Model and type of the unit.
- 2 Serial number.

WEIGHT, DIMENSIONS, OIL CAPACITY

TRANSMISSION WITH A 3 SHAFT DROP BOX

Weight (dry): ± 255 kg [562 Lbs.]

DIMENSIONS	VDT3 SHAFT DROP BOX
Max. lenght:	529.3 mm [20.84"]
Max. Width:	872.0 mm [34.33"]
Max. Heigth	619.2 mm [24.38"]

OIL CAPACITY

Transmission: ± 13.5 l [3.6 US gallon]

(without cooler and hydraulic lines. Consult Operator's Manual on applicable machine for system capacity.)

Drop Box: ± 0.75 l [0.2 US gallon]

TRANSMISSION WITH A 4 SHAFT DROP BOX

Weight (dry): ± 255 kg [562 Lbs.]

TRANSMISSION WITH A 4 SHAFT DROP BOX

Weight (dry): ± 272 kg [600 Lbs.]

DIMENSIONS	4 SHAFTS DROP BOX
Max. length:	529.3 mm [20.84"]
Max. Width:	1007.2 mm [39.66"]
Max. Height	619.2 mm [24.38"]

OIL CAPACITY

Transmission: ± 13.5 l [3.6 US gallon]

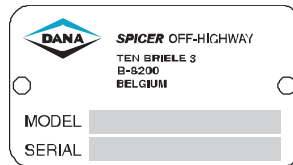
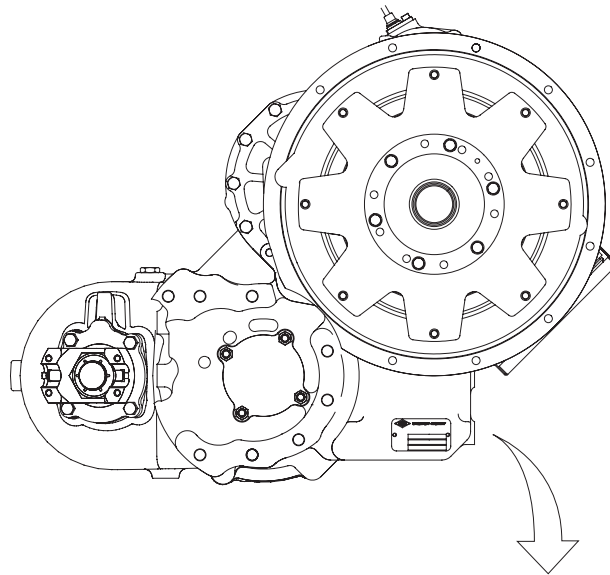
(without cooler and hydraulic lines. Consult Operator

Drop Box: ± 1.0 l [0.26 US gallon]



NOTE: THE OIL OF THE DROP BOX IS COMPLETELY SEPARATED FROM THE OIL OF THE TRANSMISSION.

VDT 17 DEGREES



IDENTIFICATION OF THE UNIT

- 1 Model and type of the unit.
- 2 Serial number.

WEIGHT, DIMENSIONS, OIL CAPACITY

Weight (dry): ± 249 kg 9 Lbs.

DIMENSIONS	17 DEGREES VERSION
Max. lenght:	730.7 mm .77"
Max. Width:	803.4 mm .63"
Max. Heigth:	619.9 mm .40"

OIL CAPACITY

- Transmission: ± 13.5 l 6 US gallon (without cooler and hydraulic lines. Consult Operator's Manual on applicable machine for system capacity.)
- 17° Drop Box: ± 0.25 l [0.07 US gallon]



NOTE: THE OIL OF THE DROP BOX IS COMPLETELY SEPARATED FROM THE OIL OF THE TRANSMISSION.

TIGHTENING TORQUES

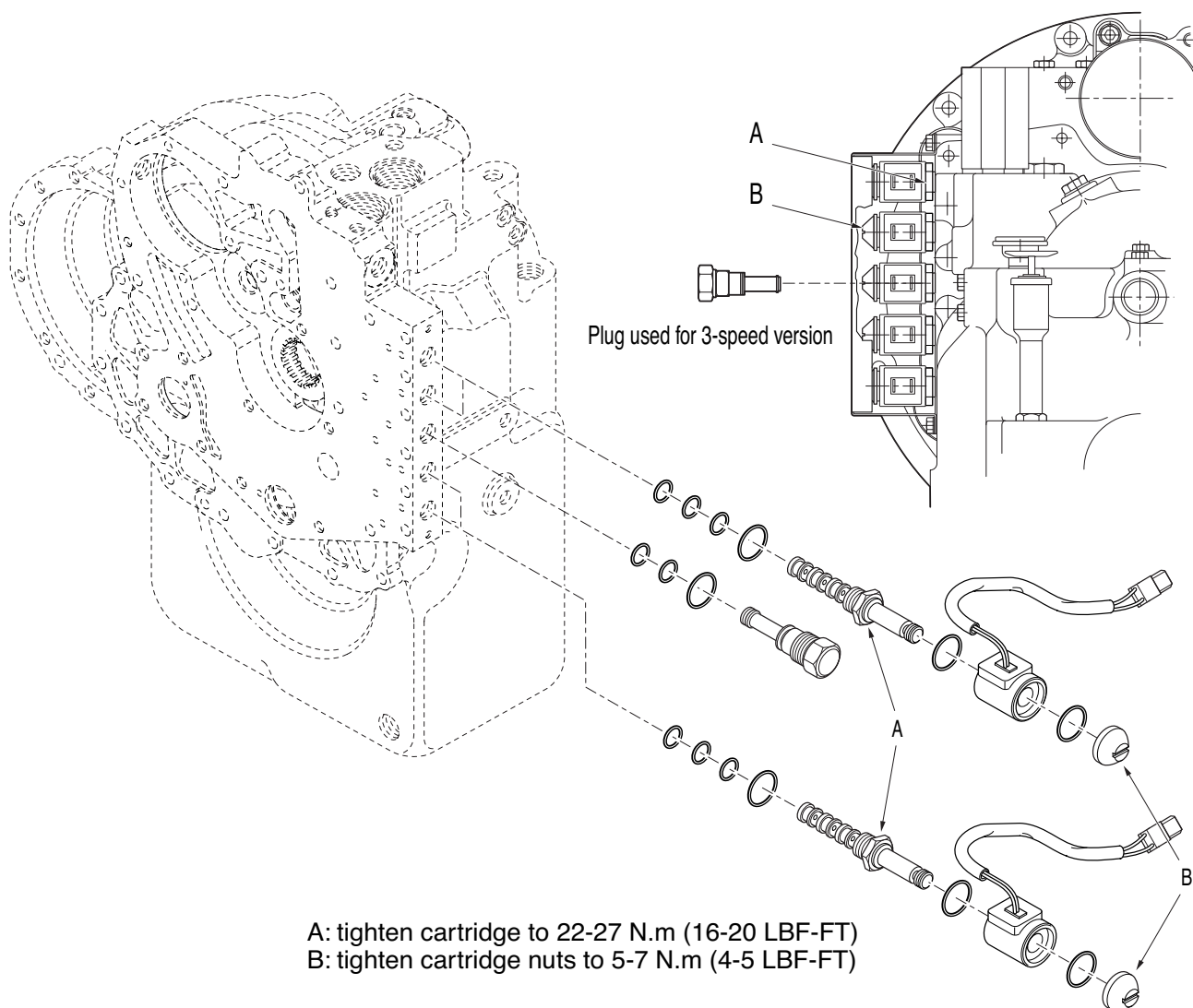
COARSE PITCH

SIZE OF BOLT	TORQUE WRENCH					
	8.8	8.8 + Loctite 270	10.9	10.9 + Loctite 270	12.9	12.9 + Loctite 270
M6 x 1	9,5 – 10,5	10,5 – 11,5	14,3 – 15,7	15,2 – 16,8	16,2 – 17,8	18,1 – 20
M8 x 1,25	23,8 – 26,2	25,6 – 28,4	34,2 – 37,8	36,7 – 40,5	39 – 43	43,7 – 48,3
M10 x 1,5	48 – 53	52 – 58	68 – 75	73 – 81	80 – 88	88 – 97
M12 x 1,75	82 – 91	90 – 100	116 – 128	126 – 139	139 – 153	152 – 168
M14 x 2	129 – 143	143 – 158	182 – 202	200 – 221	221 – 244	238 – 263
M16 x 2	200 – 221	219 – 242	283 – 312	309 – 341	337 – 373	371 – 410
M18 x 2,5	276 – 305	299 – 331	390 – 431	428 – 473	466 – 515	509 – 562
M20 x 2,5	390 – 431	428 – 473	553 – 611	603 – 667	660 – 730	722 – 798
M22 x 2,5	523 – 578	575 – 635	746 – 824	817 – 903	893 – 987	974 – 1076
M24 x 3	675 – 746	732 – 809	950 – 1050	1040 – 1150	1140 – 1260	1240 – 1370
M27 x 3	998 – 1103	1088 – 1202	1411 – 1559	1539 – 1701	1710 – 1890	1838 – 2032
M30 x 3,5	1378 – 1523	1473 – 1628	1914 – 2115	2085 – 2305	2280 – 2520	2494 – 2757

FINE PITCH

SIZE OF BOLT	TORQUE WRENCH					
	8.8	8.8 + Loctite 270	10.9	10.9 + Loctite 270	12.9	12.9 + Loctite 270
M8 x 1	25,7 – 28,3	27,5 – 30,5	36,2 – 39,8	40 – 44	42,8 – 47,2	47,5 – 52,5
M10 x 1,25	49,4 – 54,6	55,2 – 61	71,5 – 78,5	78 – 86	86 – 94	93 – 103
M12 x 1,25	90 – 100	98 – 109	128 – 142	139 – 154	152 – 168	166 – 184
M12 x 1,5	86 – 95	94 – 104	120 – 132	133 – 147	143 – 158	159 – 175
M14 x 1,5	143 – 158	157 – 173	200 – 222	219 – 242	238 – 263	261 – 289
M16 x 1,5	214 – 236	233 – 257	302 – 334	333 – 368	361 – 399	394 – 436
M18 x 1,5	312 – 345	342 – 378	442 – 489	485 – 536	527 – 583	580 – 641
M20 x 1,5	437 – 483	475 – 525	613 – 677	674 – 745	736 – 814	808 – 893
M22 x 1,5	581 – 642	637 – 704	822 – 908	903 – 998	998 – 1103	1078 – 1191
M24 x 2	741 – 819	808 – 893	1045 – 1155	1140 – 1260	1235 – 1365	1363 – 1507
M27 x 2	1083 – 1197	1178 – 1302	1520 – 1680	1672 – 1848	1834 – 2027	2000 – 2210
M30 x 2	1511 – 1670	1648 – 1822	2138 – 2363	2332 – 2577	2565 – 2835	2788 – 3082

COIL AND CARTIDGE TORQUE



MAINTENANCE

OIL SPECIFICATIONS

RECOMMENDED LUBRICANTS

CUSTOMER	OIL TYPE
CATERPILLAR	TO-4.
JOHN DEERE	J20 C. D.
MILITARY	MIL-PRF-2104G.
ALLISON	C-4.
DEXRON	II Equivalent - See note below.



DEXRON* II EQUIVALENT IS ACCEPTABLE; HOWEVER IT IS NOT COMPATIBLE WITH TORQUE CONVERTERS OR TRANSMISSIONS EQUIPPED WITH GRAPHITIC FRICTION MATERIAL CLUTCH PLATES.



DEXRON* III, ENGINE OIL OR GL-5 OILS ARE NOT RECOMMENDED.

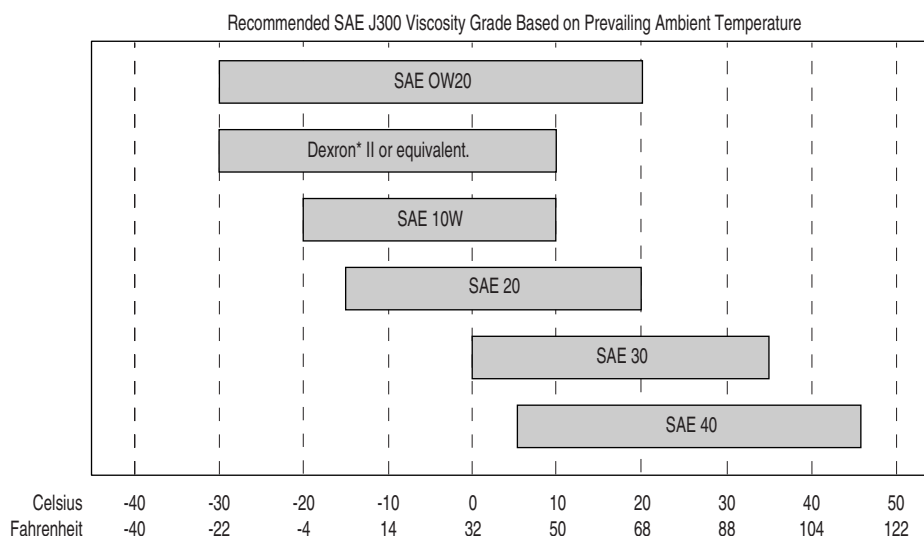
PREFERRED OIL VISCOSITY

It is recommended that the highest viscosity monograde lubricant available be used for the anticipated ambient temperature. Typically this will be a CAT TO-4 qualified lubricant. When large swings in ambient temperature are probable, J20 C, D multigrades are recommended. Multigrade lubricants should be applied at the lower viscosity rating for the prevailing ambient temperature, i.e. a 10W20 should be used where a 10W monograde is used. If a C-4 multigrade is used in stead of J20 lubricant it is recommended that the viscosity span no more than 10 points, i.e. 10W20.



SYNTHETIC LUBRICANTS ARE APPROVED IF QUALIFIED BY ONE OF THE ABOVE SPECIFICATIONS. OIL VISCOSITY GUIDELINES APPLY, BUT SYNTHETIC MULTIGRADES MAY SPAN MORE THAN 10 POINTS.

FOR FIRE RESISTANT FLUID RECOMMENDATIONS PLEASE CONTACT SPICER OFF-HIGHWAY PRODUCTS.





VALID FOR: VDT12000 & T12000

NORMAL OIL CHANGE INTERVAL

Drain and refill system every 1000 hours for average environmental and duty cycle conditions. Severe or sustained high operating temperature or very dusty atmospheric conditions will result in accelerated deterioration or contamination. Judgement must be used to determine the required change intervals for extreme conditions.

EXTENDED OIL CHANGE INTERVAL

Extended oil service life may result when using synthetic fluids. Appropriate change intervals should be determined for each transmission by measuring oil oxidation and wear metals, over time, to determine a baseline. Wear metal analysis can provide useful information but a transmission should not be removed from service based solely on this analysis.

VALID FOR: T12000

SUMP PREHEATERS

Preheat the transmission fluid to the minimum temperature for the oil viscosity used before engine start up.

FILTERS

Service oil filters element every 1000 hours under normal environmental and duty cycle conditions.

*Dexron is a registered trademark of GENERAL MOTORS CORPORATION.

T12000 - 3, 4, 6 speed

MAINTENANCE INTERVALS

DAILY

Check oil level daily with engine running at idle (600 RPM) and oil at 82 - 93 °C (180-200 F).

Maintain oil level at full mark.

NORMAL DRAIN PERIOD

Normal drain period and oil filter element change are for average environment and duty cycle condition.

Severe or sustained high operating temperature or very dusty atmospheric conditions will cause accelerated deterioration and contamination.

For extreme conditions judgement must be used to determine the required change intervals.

EVERY 1000 HOURS

Change oil filter element.

Drain and refill system as follows (Drain with oil at 65 - 93 °C (150 - 200 F)):

- 1 Drain transmission.
- 2 Remove and discard filter. Install new filter.
- 3 Refill transmission to FULL mark.
- 4 Run engine at 500 - 600 RPM to prime convertor and lines.
- 5 Recheck level with engine running at 500 - 600 RPM and add oil to bring level to FULL mark. When oil temperature is hot 82.2 - 93.3 °C (180- 200 F) make final oil level check and adjust if necessary to bring oil level to FULL mark.



NOTE: IT IS RECOMMENDED THAT OIL FILTER BE CHANGED AFTER 100 HOURS OF OPERATION ON NEW, REBUILT OR REPAIRED UNIT.


SERVICING MACHINE AFTER COMPONENTS OVERHAUL

The transmission, torque converter, and its allied hydraulic system are important links in the driveline between the engine and the wheels. The proper operation of either unit depends greatly on the condition and operation of the other. Therefore, whenever repair or overhaul of one unit is performed, the balance of the system must be considered before the job can be considered complete.

After the overhauled or repaired transmission has been installed in the machine, the oil cooler, and connecting hydraulic system must be thoroughly cleaned. This can be accomplished in several manners and a degree of judgment must be exercised as to the method employed.

The following are considered the minimum steps to be taken:

- 1 Drain entire system thoroughly.
- 2 Disconnect and clean all hydraulic lines. Where feasible hydraulic lines should be removed from machine for cleaning.
- 3 Replace oil filter element.
- 4 The oil cooler must be thoroughly cleaned. The cooler should be "back flushed" with oil and compressed air until all foreign material has been removed. Flushing in direction of normal oil flow will not adequately clean the cooler. If necessary, cooler assembly should be removed from machine for cleaning, using oil, compressed air, and steam cleaner for that purpose.
- 5 Reassemble all components and use only type oil (See chapter 4.1.1 "Recommended lubricants"). Fill the transmission through filler opening until fluid comes up to FULL mark on transmission dipstick.

 **NOTE:** IF THE DIPSTICK IS NOT ACCESSIBLE OIL LEVEL CHECK PLUGS ARE PROVIDED.

- Remove check plug, fill until oil runs from oil hole. Relift filler and level plug.
 - Run engine two minutes at 500 - 600 RPM to prime torque convertor and hydraulic lines.
 - Recheck level of fluid in transmission with engine running at idle (500 - 600 RPM).
 - Add quantity necessary to bring fluid level to FULL mark on dipstick or runs from oil level check plug hole.
 - Install oil level plug of dipstick.
 - Recheck with hot oil 82.2 - 93.3 °C (180 - 200 F).
 - Adjust oil level to FULL mark on dipstick or runs freely from oil level plug.
- 6 Recheck all drain plugs, lines, connections, etc...., for leaks and tighten where necessary.

VDT12000

MAINTENANCE INTERVALS FOR THE 3 & 4 SHAFT DROP BOX

DAILY

Check oil level daily.

Maintain oil level at full mark. (Middle of oil level glass)

NORMAL DRAIN PERIOD

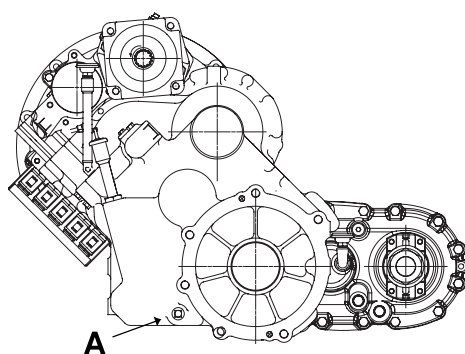
Normal drain period is every 1000 hours for average environment and duty cycle condition. Severe or sustained high operating temperature or very dusty atmospheric conditions will cause accelerated deterioration and contamination. For extreme conditions judgement must be used to determine the required change intervals.

MAINTENANCE INTERVALS FOR THE TRANSMISSION.

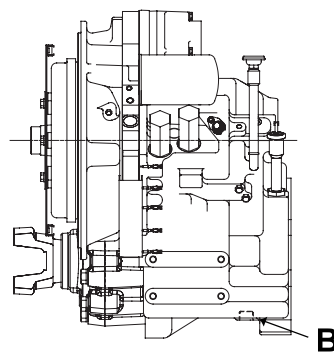


TO DRAIN THE TRANSMISSION, BOTH DRAIN PLUGS (A & B) NEED TO BE REMOVED

- 3 shaft drop box

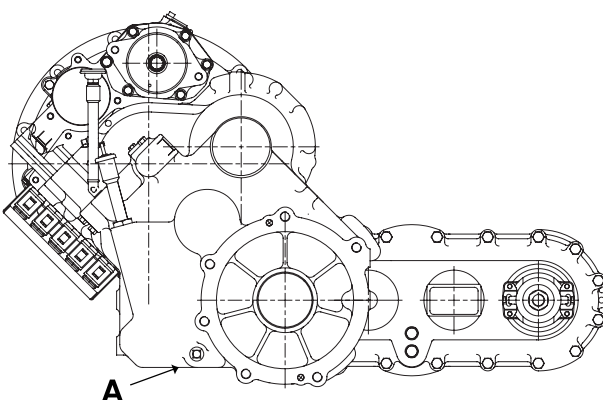


REAR VIEW

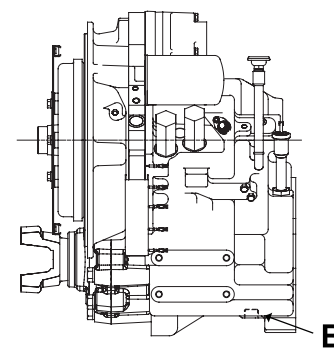


LEFT VIEW

- 4 shaft drop box



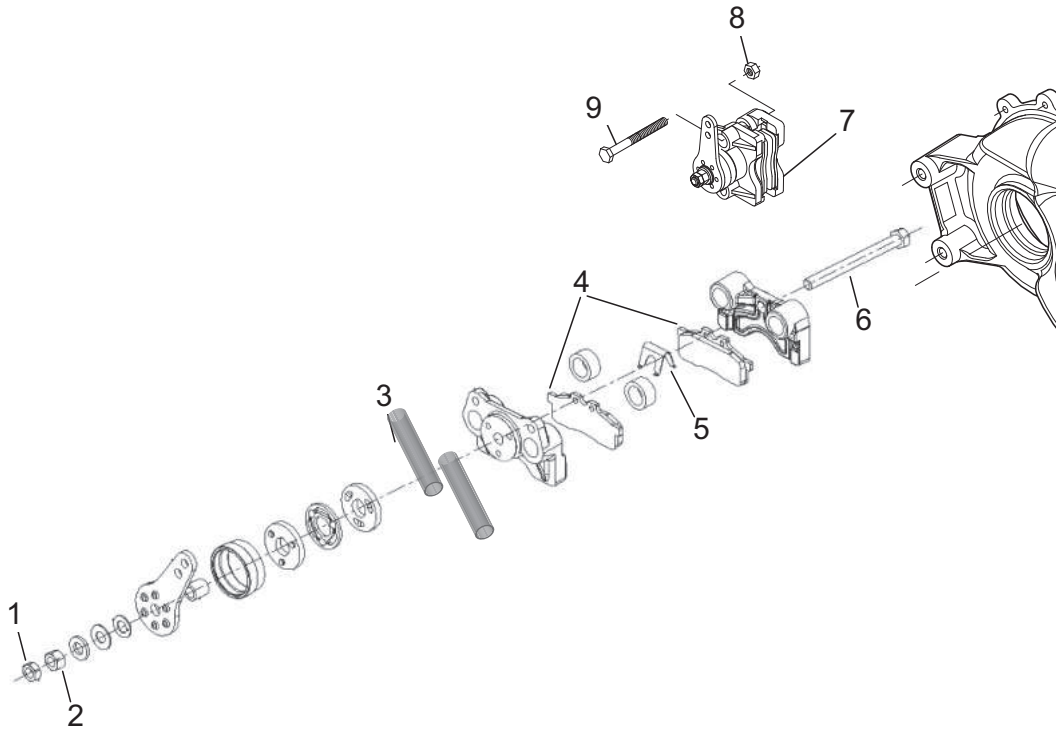
REAR VIEW



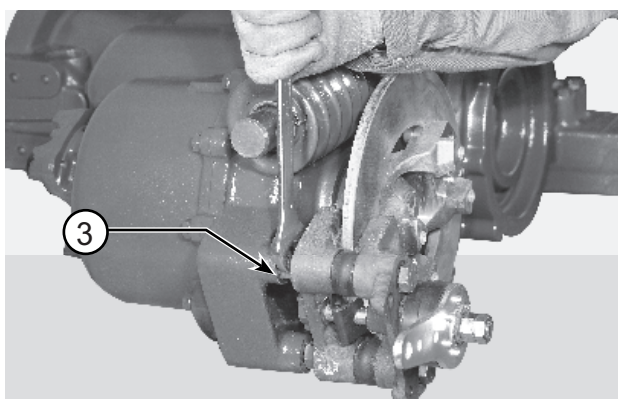
LEFT VIEW

INSTRUCTIONS FOR LINING REPLACEMENT AND ADJUSTMENT OF PARKING BRAKE ASSEMBLY

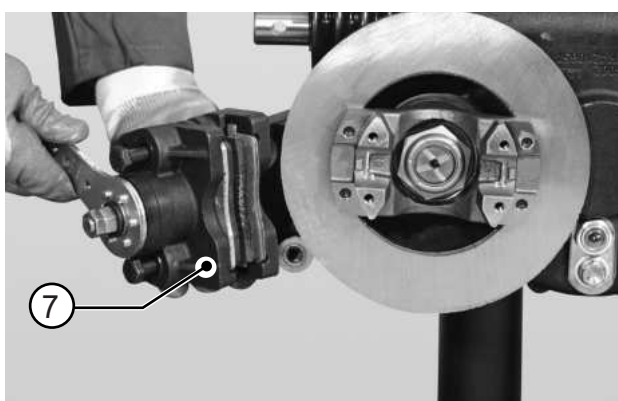
ASSEMBLY DIAGRAM



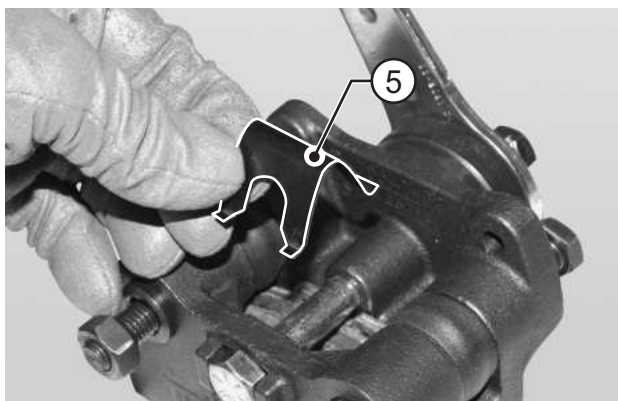
DISASSEMBLY

**1**

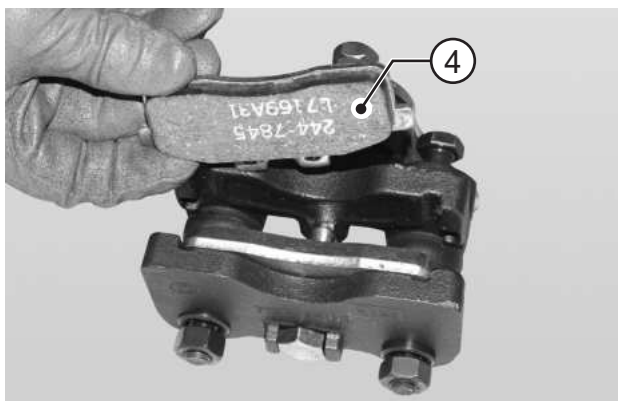
Undo the lock nuts (9) securing the runner pins (10). Remove the runner pins (10), holding the lock nuts (9) in position.

**2**

Remove the brake calliper (8).

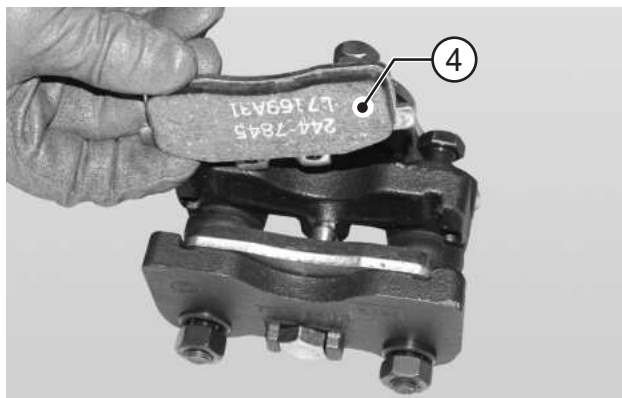
**3**

With a plier press and remove the spring flat.

**4**

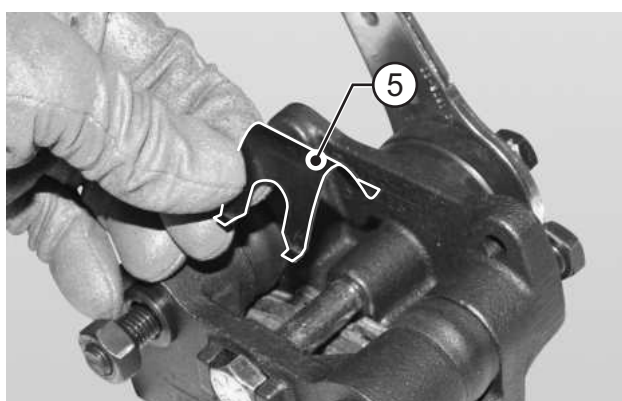
Remove the pads (4).

ASSEMBLY



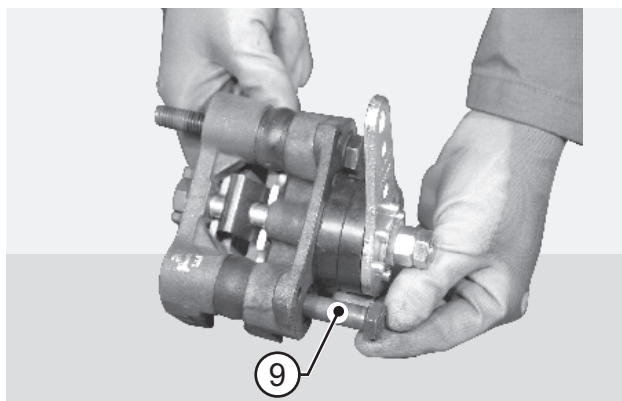
5

Install the brake pads (4).



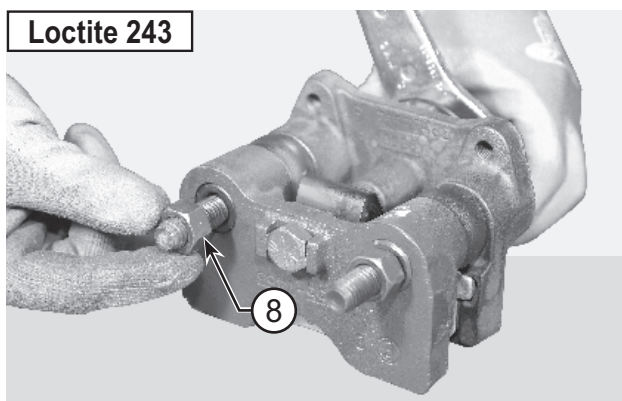
6

Install the spring flat (5) and fit it in the pads holes.



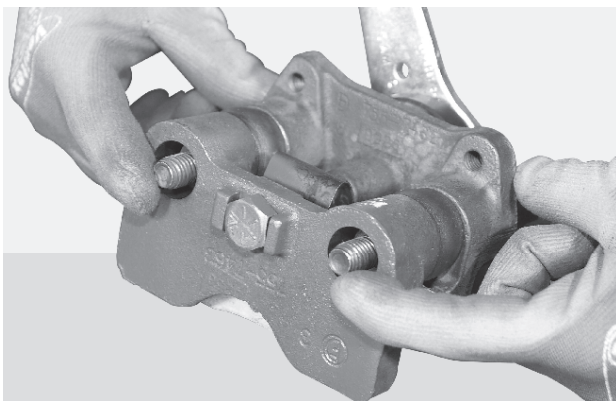
7

Insert the fixing screws (9) through the sleeves (3) in the brake caliper (7).



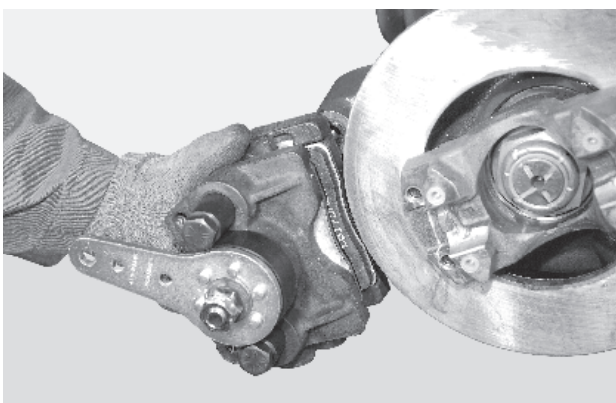
8

- ① Screw the lock nuts (8) on the fixing screws (9) and leave a gap of 2 mm between the lock nuts (8) and the sleeves (3).
- ② Spread the threaded portion of the screws (9) with LOC-TITE 243.



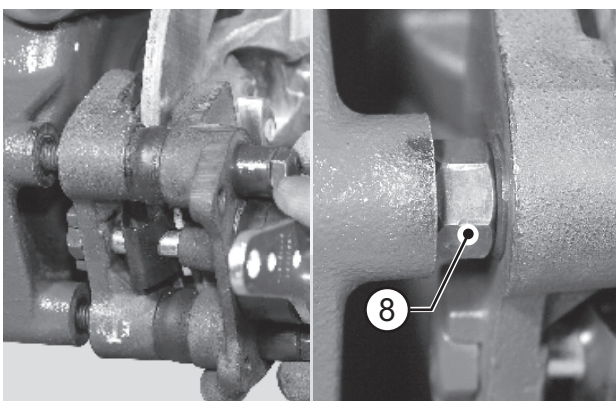
9

Move towards the external part of the brake caliper (7) the screws (9) complete with sleeves (3) and lock nuts (8) to facilitate the brake caliper (7) installation.



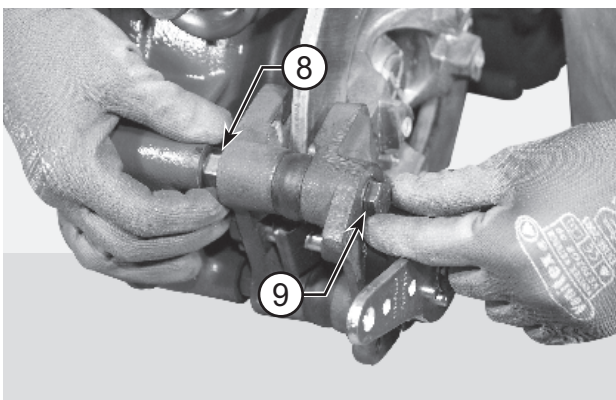
10

Insert the brake caliper (7) in the braking disc and install it in its seat, fasten the fixing screws (9).



11

Remove the backlash between screws (9) and sleeves (3) working on the lock nuts (8). Send the screws (9) to end stroke, complete with sleeves (3) and lock nuts (8).

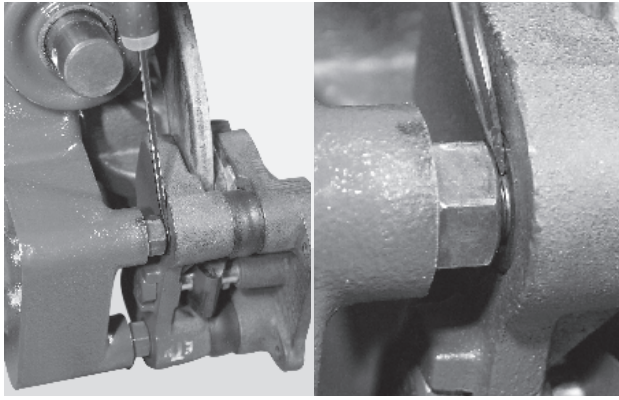


12

BRAKE CALIPER BACKLASH REGULATION

Repeat the operation on both screws.

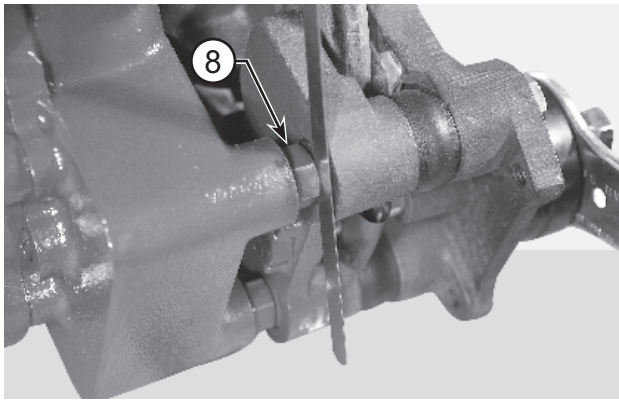
Holding the lock lock nut in position, unloose the screw of about 1 turn.



13

Repeat the operation on both screws.

Using a screwdriver adjust the sleeve (3) as shown in picture.

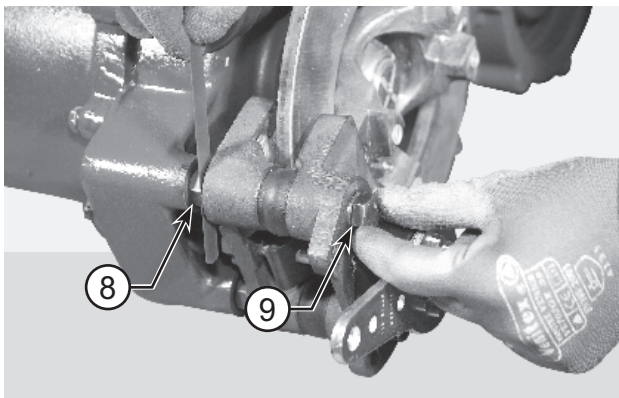


14

Repeat the operation on both screws.

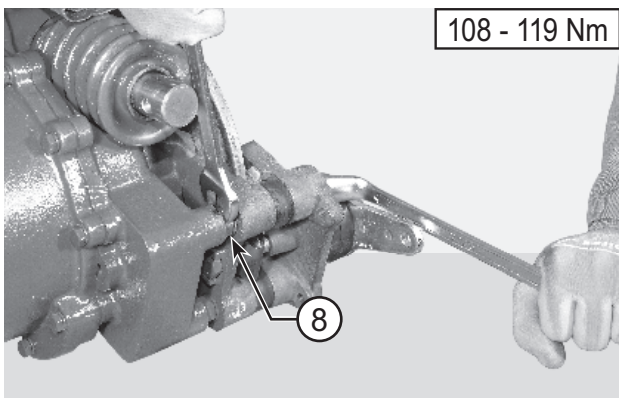
Insert a 0,7 mm shim between the sleeve (3) and the lock nut (8) to check the brake caliper (7) backlash.

NOTE: Check that the lock nut (8) is at end of stroke.



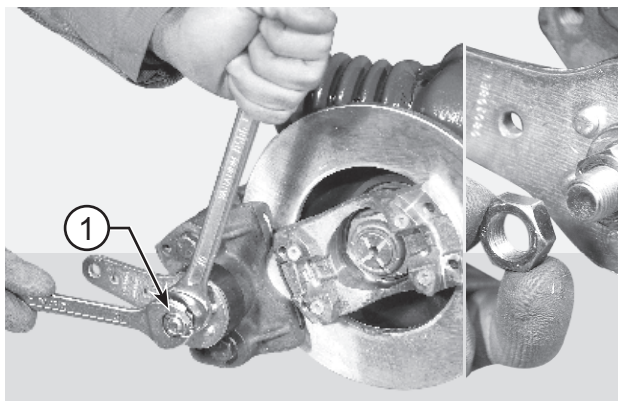
15

Repeat the operation on both screws. Keeping the shim in position, insert the screw (9) to regulate the backlash between sleeve (3) and lock nut (8).



16

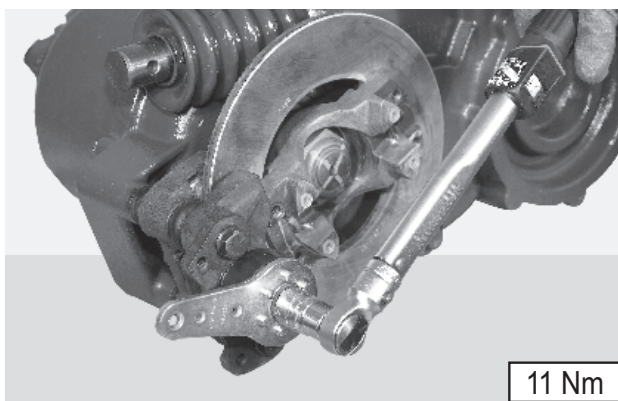
Repeat the operation on both screws. Keeping the screws (9) in position, torque the lock nuts (8) to a tightening torque of 108 - 119 Nm.



17

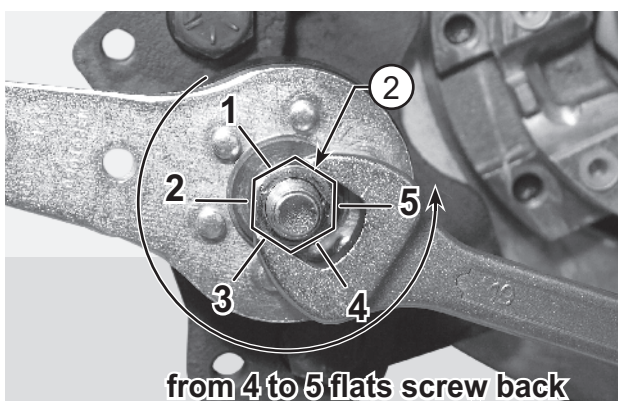
BRAKE PADS BACKLASH ADJUSTMENT

Loosen and remove the brake pads (4) outer adjustment nut (1).



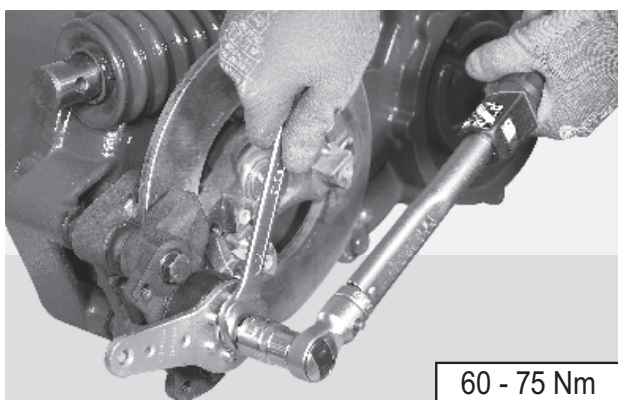
18

Tighten the inner adjustment nut (2) until firm contact is made with the disc by the pads (4). Using a dynamometric wrench tighten the nut to a tightening torque of 11 Nm.



19

Loosen the inner adjustment nut (2) by 4-5 surfaces. Check the correct working of the brake caliper (7).



20

Screw the outer nut (1) on the adjustment bolt (6). Keeping the inner nut (2) in position, torque the outer nut (1) to a tightening torque of 60 - 75 Nm.

TROUBLESHOOTING GUIDE

T12000 - 3, 4, 6 speed

The following information is presented as an aid to isolating and determining the specific problem area in a transmission that is not functioning correctly.

When troubleshooting a "transmission" problem, it should be kept in mind that the transmission is only the central unit of a group of related powertrain components. Proper operation of the transmission depends on the condition and correct functioning of the other components of the group. Therefore, to properly diagnose a suspected problem in the transmission, it is necessary to consider the transmission fluid, charging pump, torque converter, transmission assembly, oil cooler, filter, connecting lines, and controls, including the engine, as a complete system.

By analysing the principles of operation together with the information in this section, it should be possible to identify and correct any malfunction which may occur in the system.

T12000 TRANSMISSION

T12000 (power shift with torque converter transmission) troubles fall into three general categories:

- 1 Mechanical problems.
- 2 Hydraulic problems.
- 3 Electrical problems.

In addition to the mechanical and electrical components, all of which must be in the proper condition and functioning correctly, the correct functioning of the hydraulic circuit is most important. Transmission fluid is the "life blood" of the transmission. It must be supplied in an adequate quantity and delivered to the system at the correct pressures to ensure converter operation, to engage and hold the clutches from slipping, and to cool and lubricate the working components.

TROUBLESHOOTING PROCEDURES

STALL TEST

A stall test to identifies transmission, converter, or engine problems.

Use following procedure:

- 1 Put the vehicle against a solid barrier, such as a wall, and/or apply the parking brake and block the wheels.
- 2 Put the directional control lever in FORWARD (or REVERSE, as applicable).
- 3 Select the highest speed. With the engine running, slowly increase engine speed to approximately one-half throttle and hold until transmission (converter outlet) oil temperature reaches the operating range.



DO NOT OPERATE THE CONVERTER AT STALL CONDITION LONGER THAN 30 SECONDS AT ONE TIME, SHIFT TO NEUTRAL FOR 15 SECONDS AND REPEAT THE PROCEDURE UNTIL DESIRED TEMPERATURE IS REACHED.

EXCESSIVE TEMPERATURE 120 °C (250 F) MAXIMUM WILL CAUSE DAMAGE TO TRANSMISSION CLUTCHES, FLUID, CONVERTER, AND SEALS.

TRANSMISSION PRESSURE CHECKS

Transmission problems can be isolated by the use of pressure tests. When the stall test indicates slipping clutches, then measure clutch pack pressure to determine if the slippage is due to low pressure or clutch plate friction material failure.

In addition, converter charging pressure and transmission lubrication pressure can also be measured.

MECHANICAL AND ELECTIRCAL CHECKS

Prior to checking any part of the system for hydraulic function (pressure testing), the following mechanical and electrical checks should be made:

- Check the parking brake and inching pedal for correct adjustment.
- Be sure all lever linkage is properly connected and adjusted in each segment and at all connecting points.
- The controls are actuated electrically. Check the wiring and electrical components.
- Be sure that all components of the cooling system are in good condition and operating correctly. The radiator must be clean to maintain the proper cooling and operating temperatures for the engine and transmission. Air clean the radiator, if necessary.
- The engine must be operating correctly. Be sure that it is correctly tuned and adjusted to the correct idle and maximum no-load governed speed specifications.

HYDRAULIC CHECKS

Also, before checking the transmission clutches, torque converter, charging pump, and hydraulic circuit for pressure and rate of oil flow, it is important to make the following transmission fluid check:

Check oil level in the transmission. The transmission fluid must be at the correct (full level). All clutches and the converter and its fluid circuit lines must be fully charged (filled) at all times.



THE TRANSMISSION FLUID MUST BE AT OPERATING TEMPERATURE OF 82 - 93 °C (180 - 200 F) TO OBTAIN CORRECT FLUID LEVEL AND PRESSURE READINGS.

DO NOT ATTEMPT TO MAKE THESE CHECKS WITH COLD OIL.

To raise the oil temperature to this specification it is necessary to either operate (work) the vehicle or run the engine with converter at "stall" (Refer to 7.2.1 "Stall test").



BE CAREFUL THAT THE VEHICLE DOES NOT MOVE UNEXPECTEDLY WHEN OPERATING THE ENGINE AND CONVERTER AT STALL RPM.

TROUBLESHOOTING GUIDE

Refer to the following troubleshooting guide for the diagnosis of typical transmission troubles.

LOW CLUTCH PRESSURE

CAUSE	REMEDY
Low oil level.	Fill to proper level.
Clutch pressure regulating valve stuck open.	Clean valve spool and housing.
Faulty charging pump.	Replace pump.
Broken or worn clutch shaft or piston sealing rings.	Replace sealing rings.
Clutch piston bleed valve stuck open.	Clean bleed valves thoroughly.

LOW CHARGING PUMP OUTPUT

CAUSE	REMEDY
Low oil level.	Fill to proper level.
Suction screen plugged.	Clean suction pump.
Defective charging pump.	Replace pump.

OVERHEATING

CAUSE	REMEDY
Worn oil sealing rings.	Remove, disassemble, and rebuild converter assembly.
Worn charging pump.	Replace charging pump.
Low oil level.	Fill to proper level.
Dirty oil cooler.	Clean cooler.
Restriction in cooler lines.	Change cooler lines.

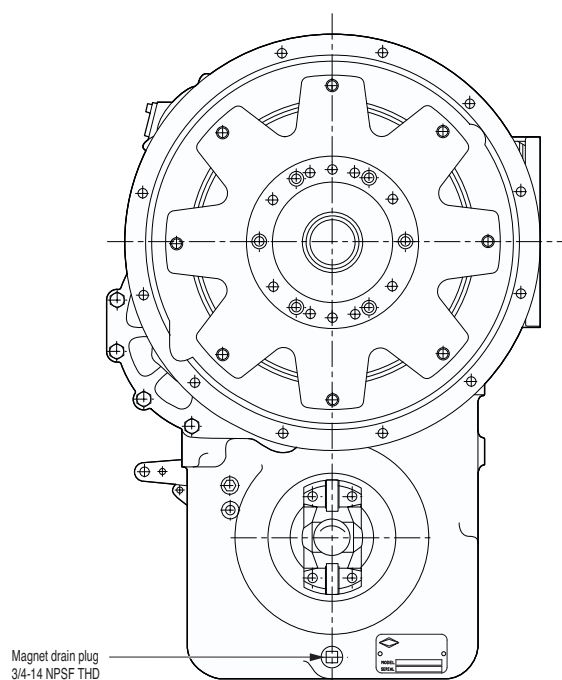
NOISY CONVERTER

CAUSE	REMEDY
Worn charging pump.	Replace charging pump.
Worn or damaged bearings.	A complete disassembly will be necessary to determine which bearing is faulty.

LACK OF POWER

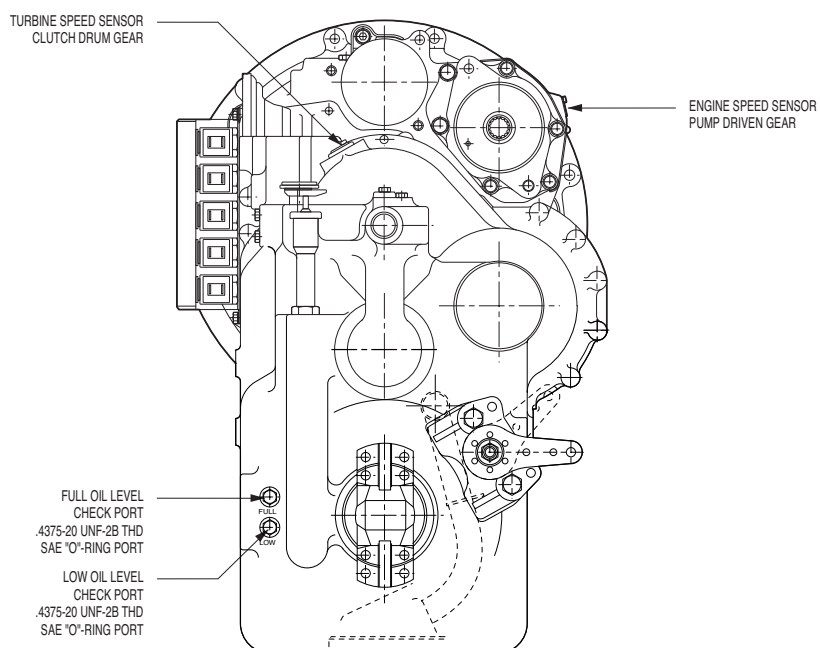
CAUSE	REMEDY
Low engine RPM at converter stall.	Tune engine check governor.
See "Overheating" and make same checks.	Make corrections as explained in "Overheating".

CHECK POINTS



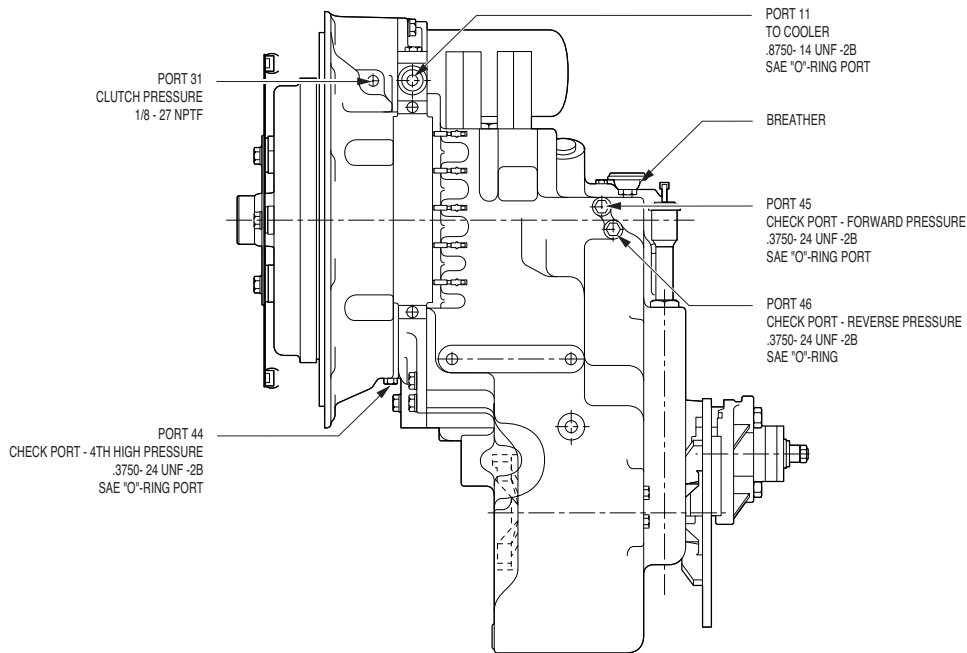
FRONT VIEW

Fig. 1 Front view



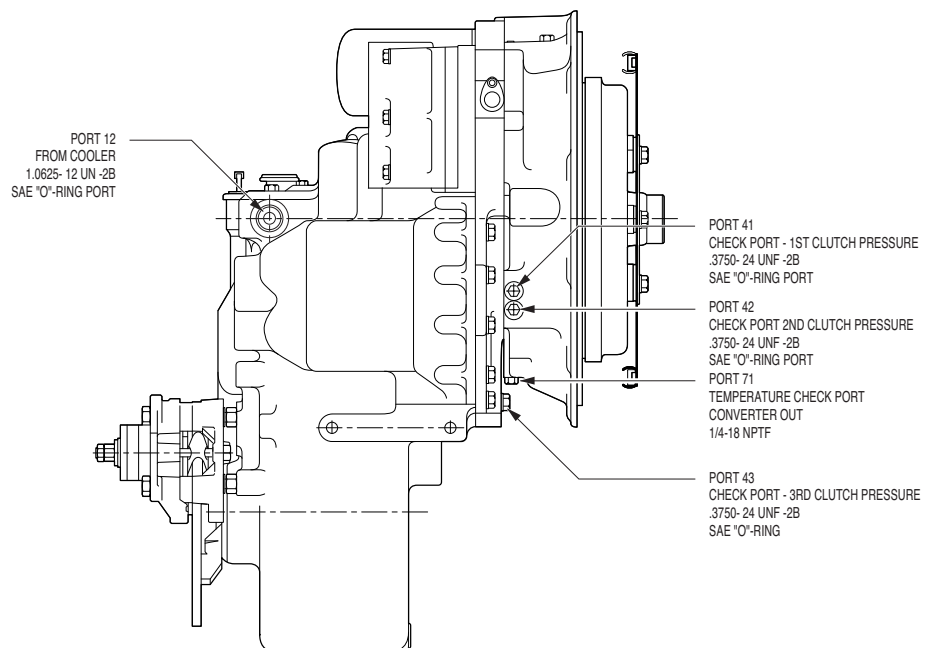
REAR VIEW

Fig. 2 Rear view



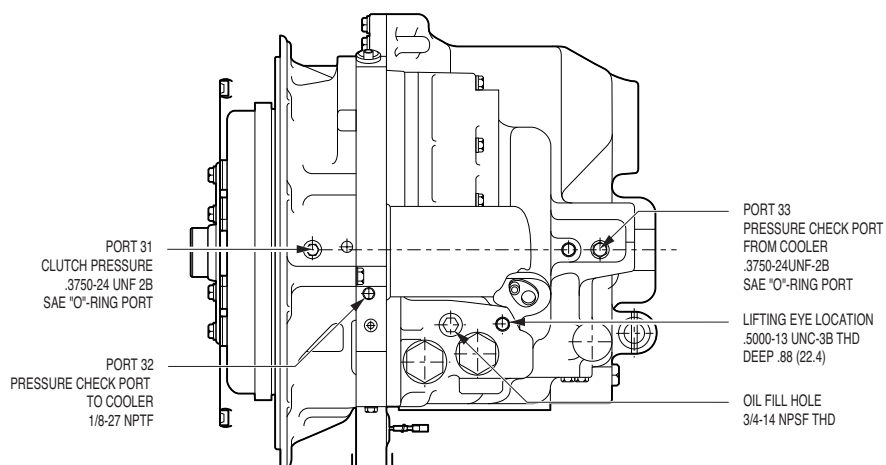
LEFT SIDE VIEW

Fig. 3 Left side view



RIGHT SIDE VIEW

Fig. 4 Right side view



TOP VIEW

Fig. 5 *Top view*

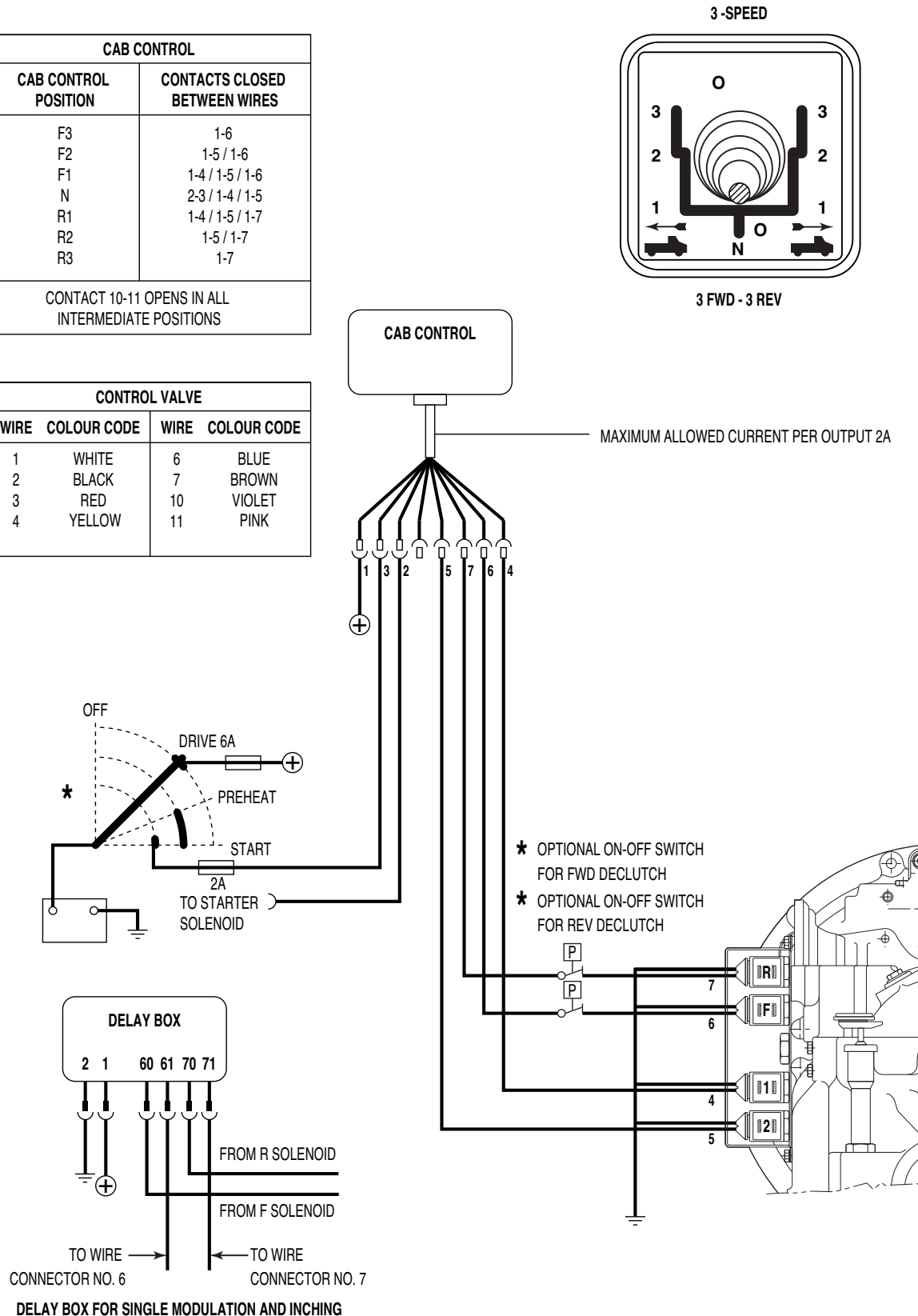
ELECTRICAL WIRING

3-SPEED TRANSMISSION

SPICER OFF-HIGHWAY WILL NOT SUPPLY ITEMS INDICATED WITH *

CAB CONTROL	
CAB CONTROL POSITION	CONTACTS CLOSED BETWEEN WIRES
F3	1-6
F2	1-5 / 1-6
F1	1-4 / 1-5 / 1-6
N	2-3 / 1-4 / 1-5
R1	1-4 / 1-5 / 1-7
R2	1-5 / 1-7
R3	1-7
CONTACT 10-11 OPENS IN ALL INTERMEDIATE POSITIONS	

CONTROL VALVE			
WIRE	COLOUR CODE	WIRE	COLOUR CODE
1	WHITE	6	BLUE
2	BLACK	7	BROWN
3	RED	10	VIOLET
4	YELLOW	11	PINK

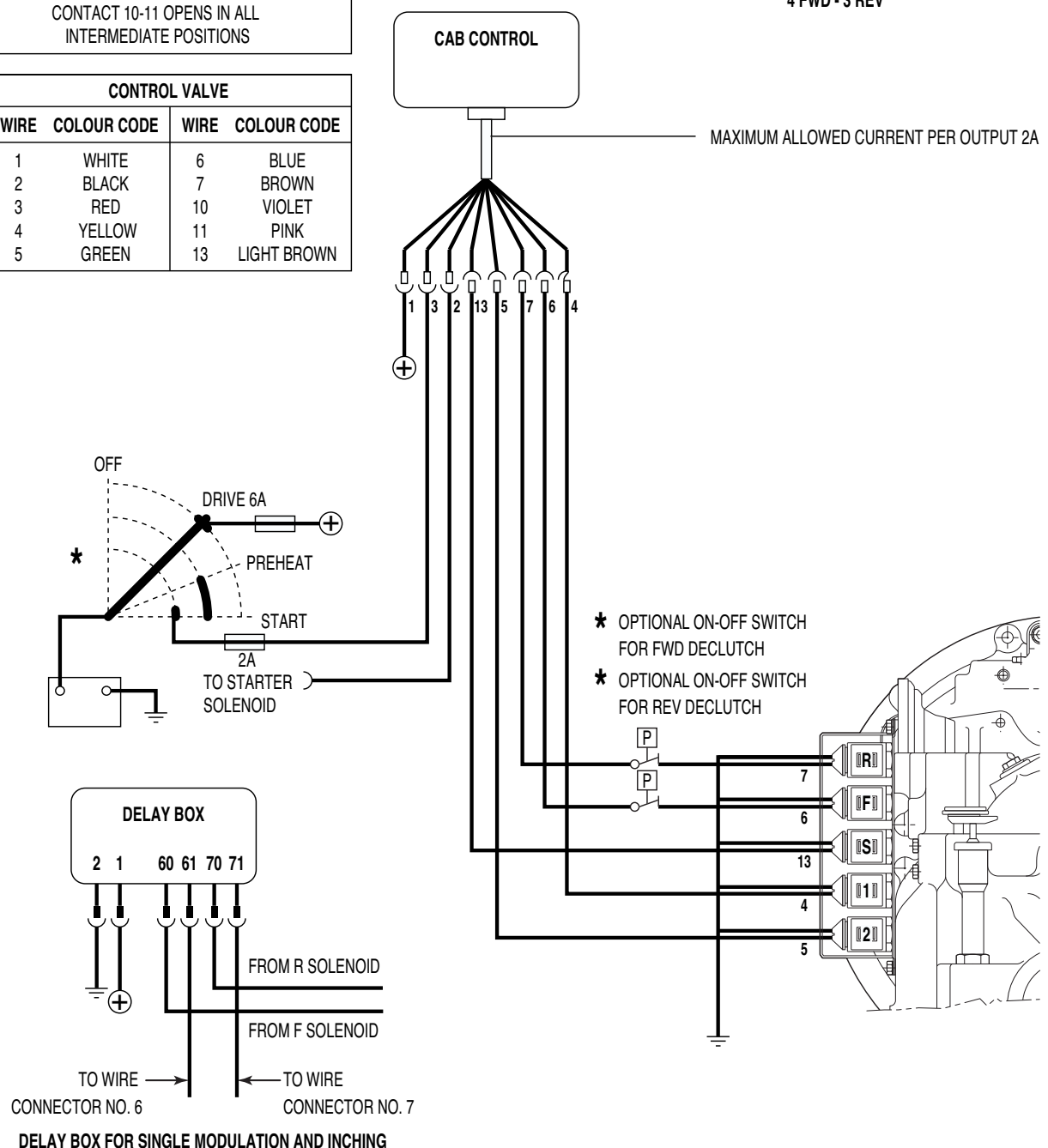
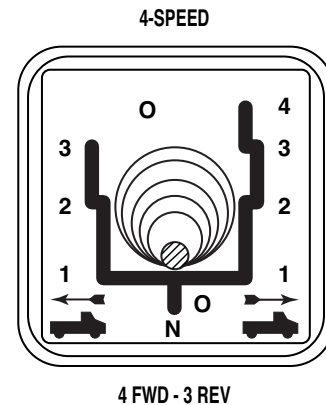


STANDARD 4-SPEED TRANSMISSION (1-3-5 ≈ 6 SPEED)

SPICER OFF-HIGHWAY WILL NOT SUPPLY ITEMS INDICATED WITH *

CAB CONTROL	
CAB CONTROL POSITION	CONTACTS CLOSED BETWEEN WIRES
F4	1-6 / 1-13
F3	1-6
F2	1-5 / 1-6
F1	1-4 / 1-5 / 1-6
N	2-3 / 1-4 / 1-5
R1	1-4 / 1-5 / 1-7
R2	1-5 / 1-7
R3	1-7
CONTACT 10-11 OPENS IN ALL INTERMEDIATE POSITIONS	

CONTROL VALVE			
WIRE	COLOUR CODE	WIRE	COLOUR CODE
1	WHITE	6	BLUE
2	BLACK	7	BROWN
3	RED	10	VIOLET
4	YELLOW	11	PINK
5	GREEN	13	LIGHT BROWN



ALTERNATIVE 4-SPEED TRANSMISSION (1-3-4-5 ≈ 6 SPEED)

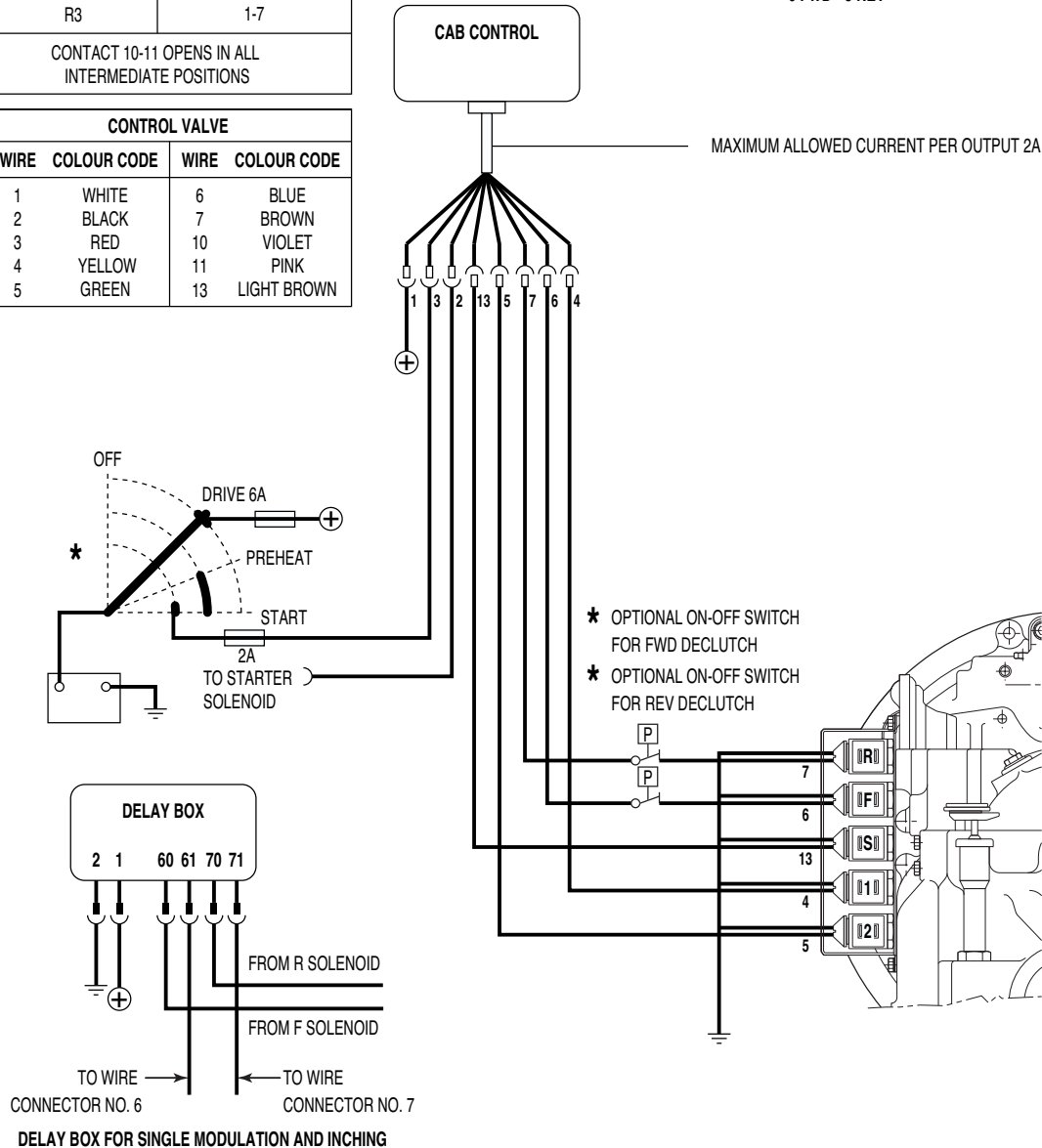
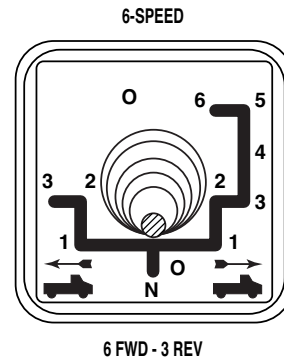
NOTE: ALTERNATIVE 4-SPEED TRANSMISSION IS ONLY AVAILABLE WITH EGS OR APC.
ELECTRIC SOLENOID CONTROL WIRING DIAGRAM FOR ALTERNATIVE 4-SPEED TRANSMISSION:
REFER TO WIRING DIAGRAM OF CORRESPONDING CONTROLLER.

6-SPEED TRANSMISSION

SPICER OFF-HIGHWAY WILL NOT SUPPLY ITEMS INDICATED WITH ★

CAB CONTROL	
CAB CONTROL POSITION	CONTACTS CLOSED BETWEEN WIRES
F6	1-6 / 1-13
F5	1-6
F4	1-6 / 1-5 / 1-13
F3	1-6 / 1-5
F2	1-6 / 1-5 / 1-4 / 1-13
F1	1-6 / 1-5 / 1-4
N	2-3 / 1-4 / 1-5
R1	1-7 / 10-5 / 1-4
R2	1-7 / 1-5
R3	1-7
CONTACT 10-11 OPENS IN ALL INTERMEDIATE POSITIONS	

CONTROL VALVE			
WIRE	COLOUR CODE	WIRE	COLOUR CODE
1	WHITE	6	BLUE
2	BLACK	7	BROWN
3	RED	10	VIOLET
4	YELLOW	11	PINK
5	GREEN	13	LIGHT BROWN

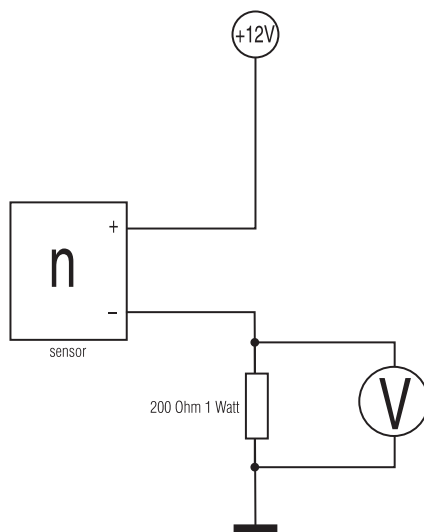


SPEED SENSOR - STATIC STANDALONE TEST

In order to be able to sense the currents, a series resistor of e.g. 200 Ohms must be used. This resistor is integrated in the controller, but when the sensor is to be tested, it must be connected externally.

The idea is to connect the sensor to an external power source and measure the DC voltage across the series resistor. The voltage reading should be either 1.2V-1.6V (for the 7mA \pm 1mA current level) or 2.6-3.0V (for the 14mA \pm 1mA current level)

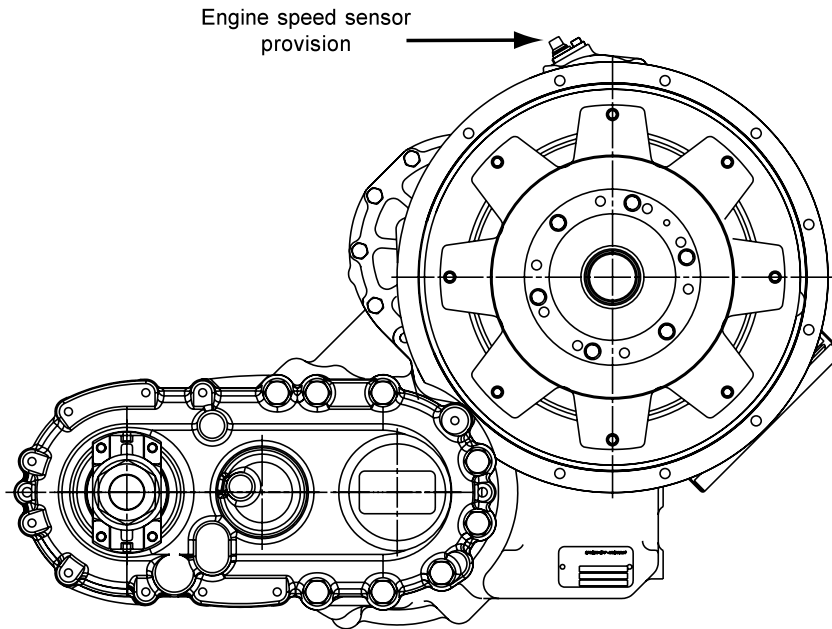
If the teeth can be moved slowly, distinct toggling between the two levels should be noticed.



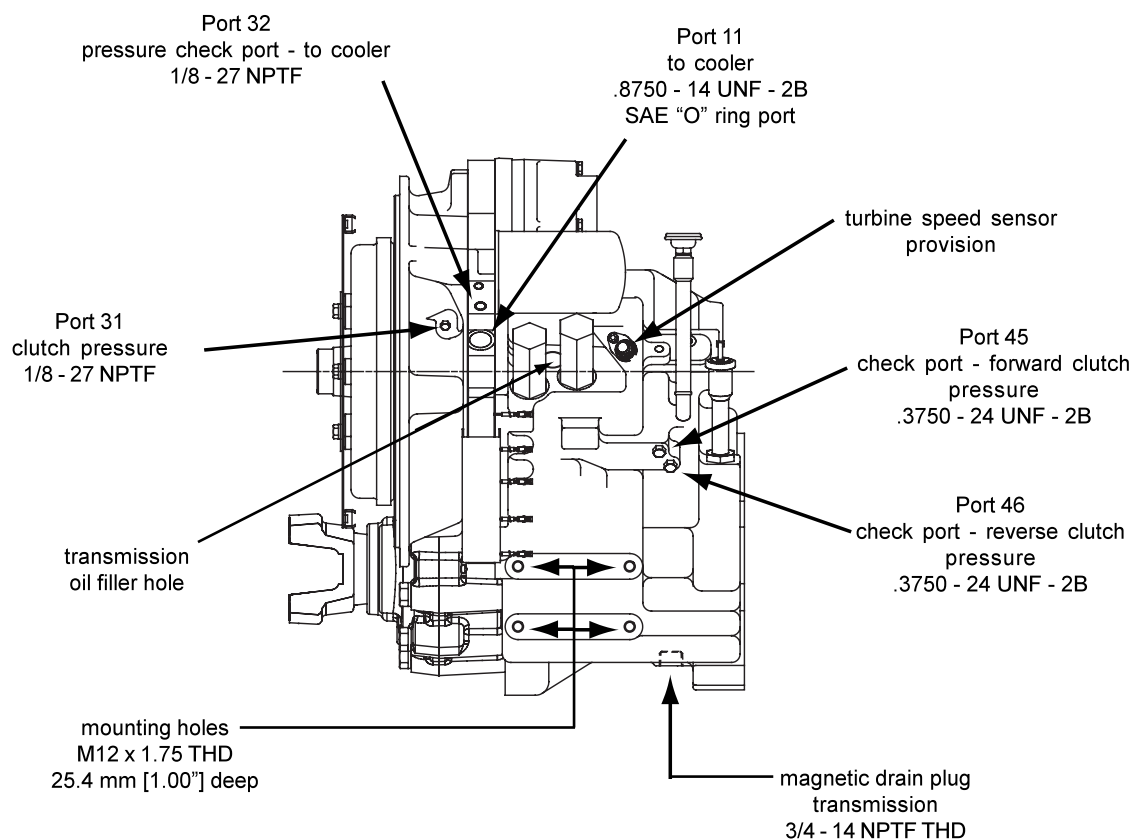
VDT 12000

CHECK POINTS

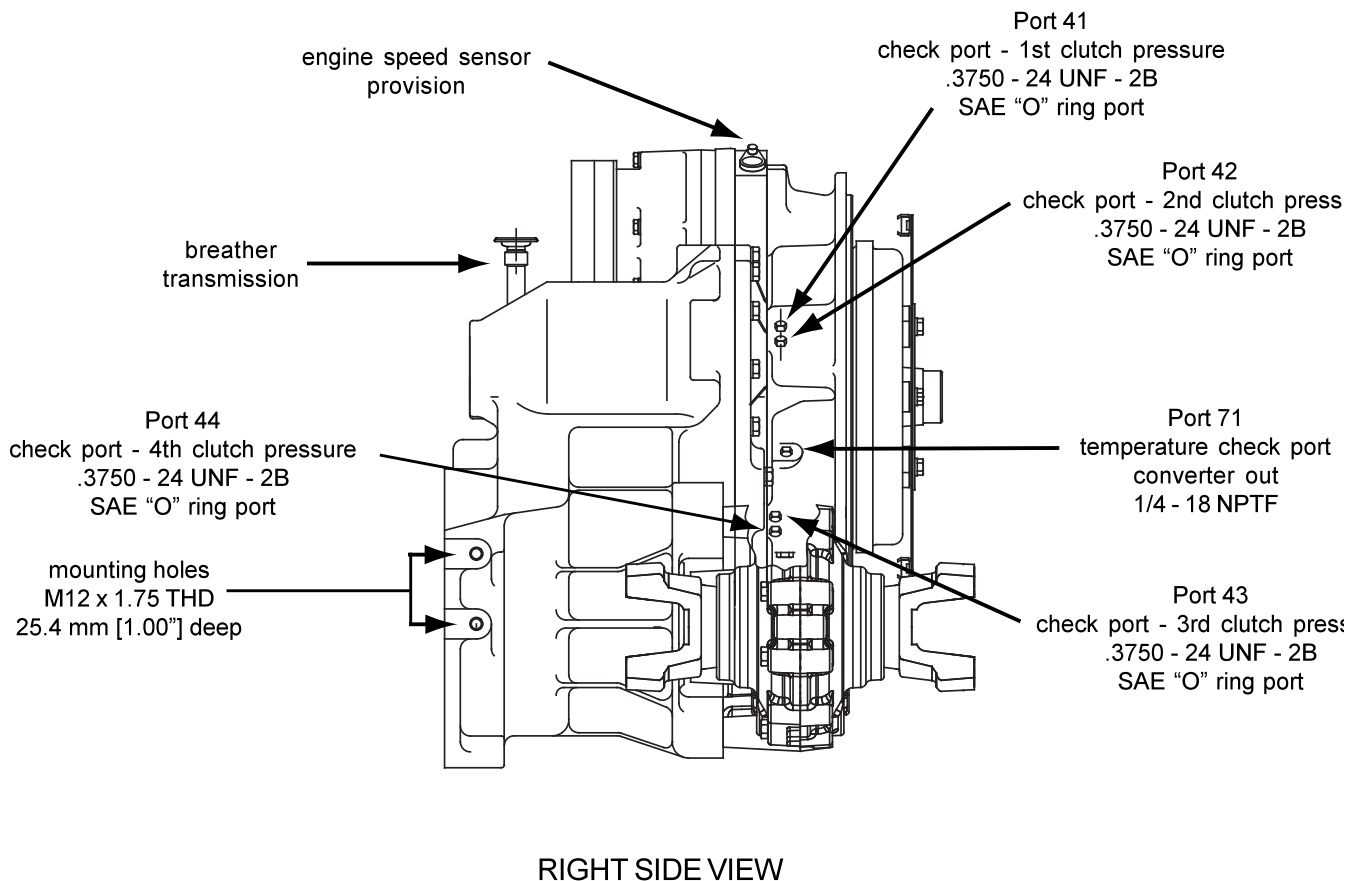
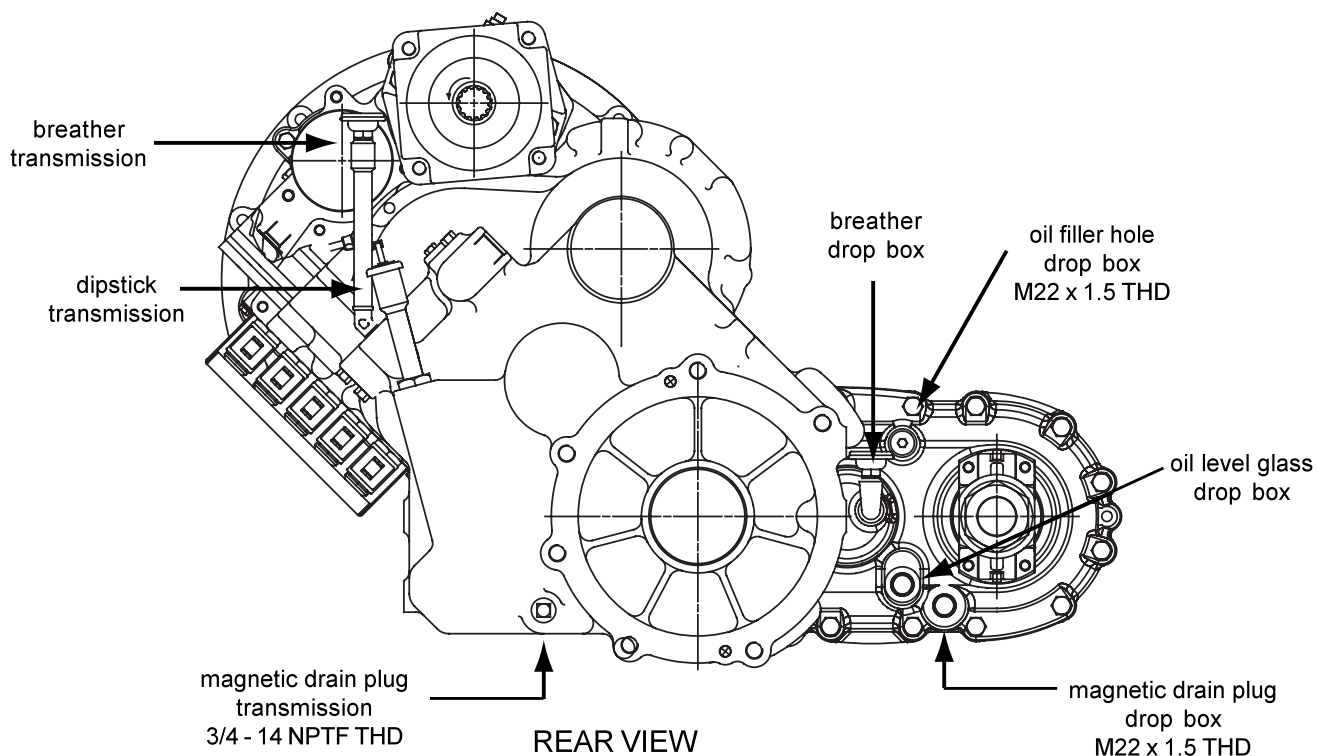
TRANSMISSION WITH A 3 SHAFT DROP BOX



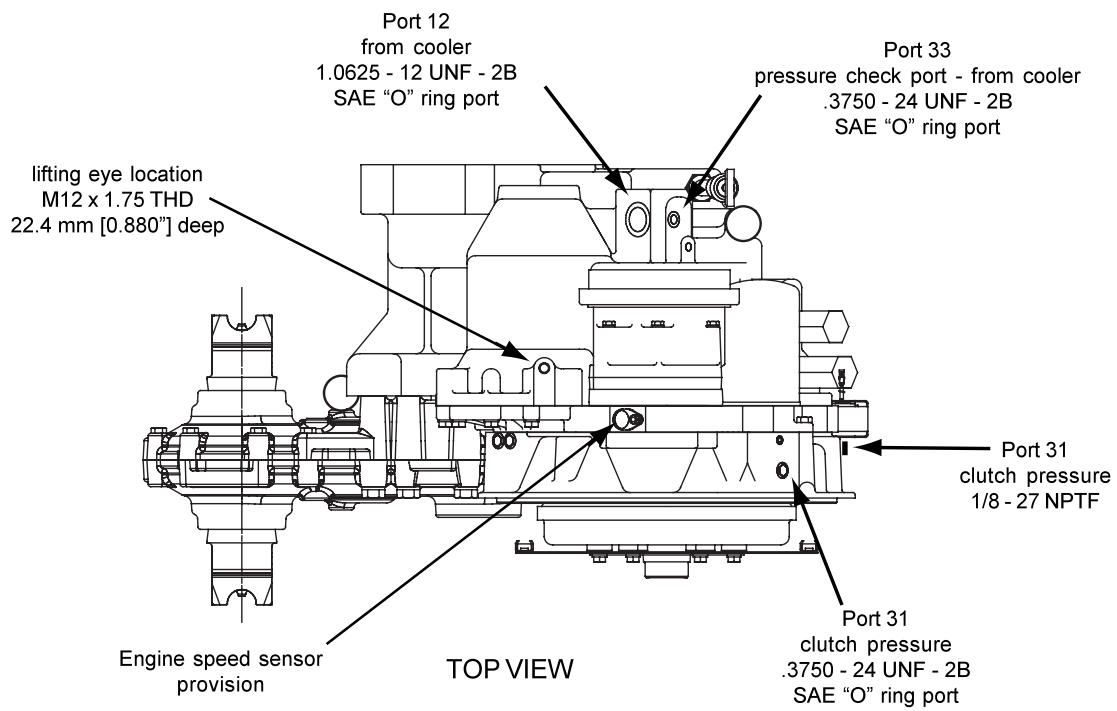
FRONT VIEW

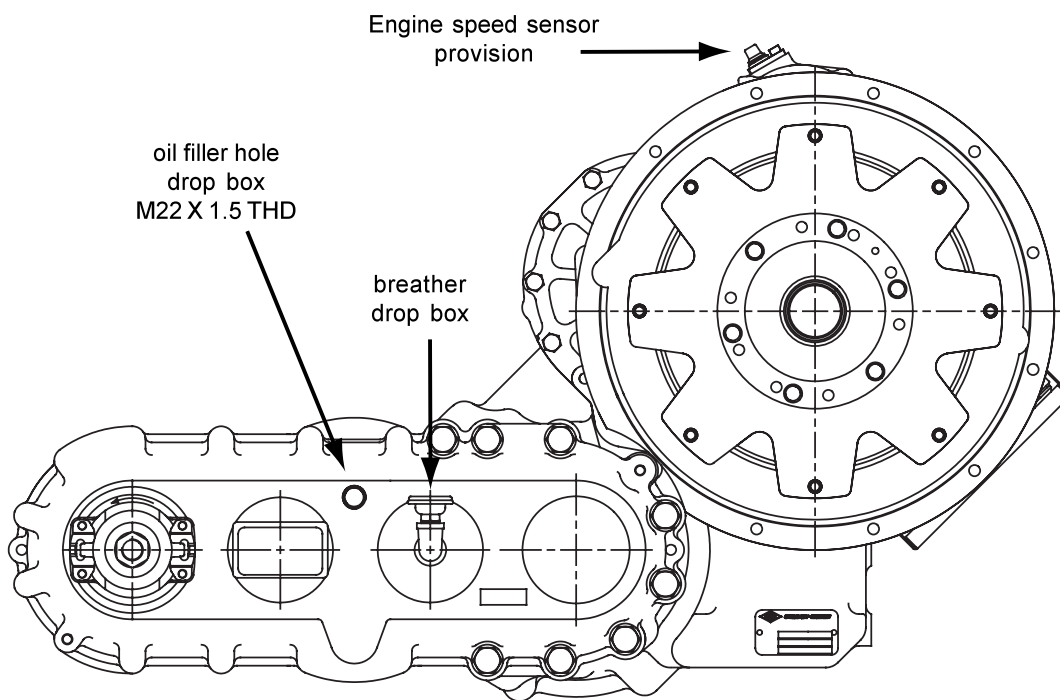
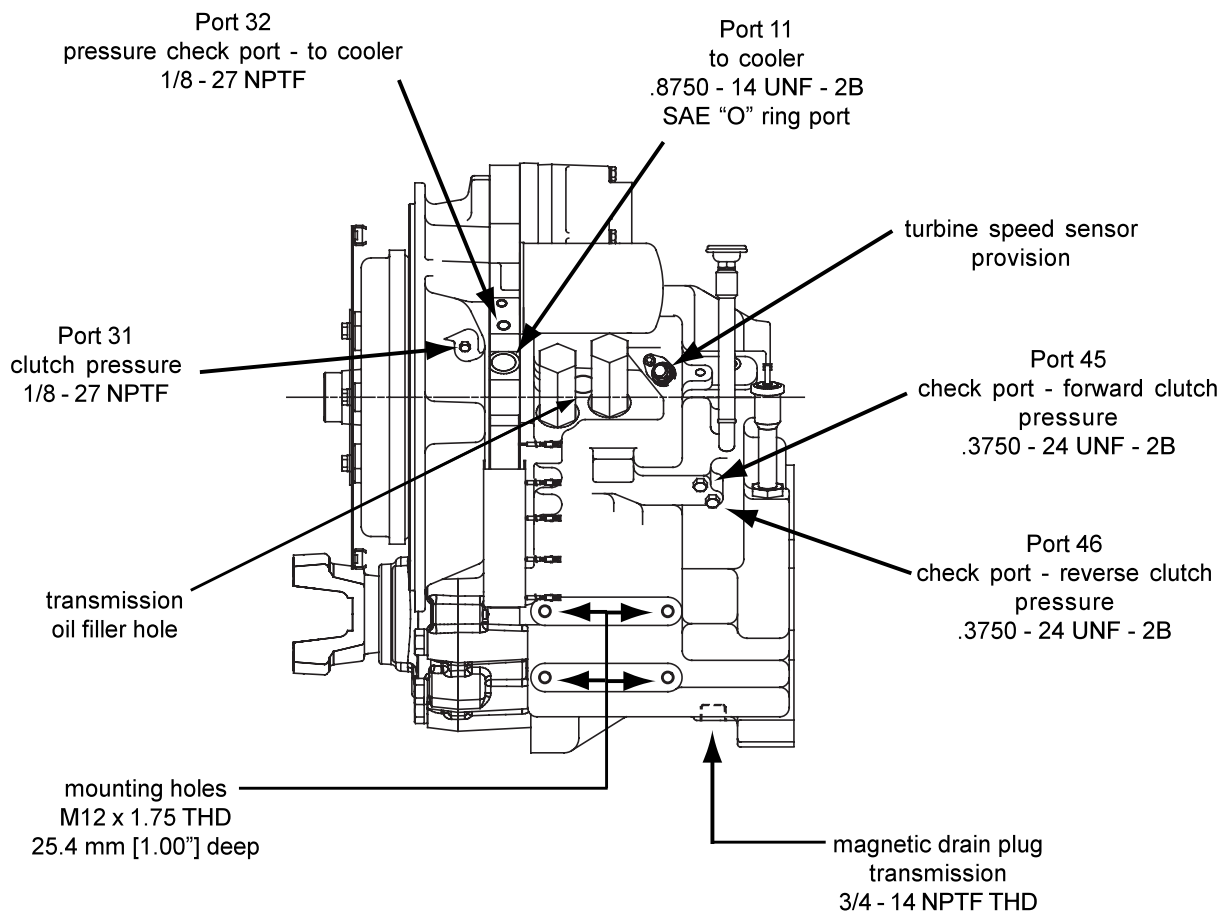


LEFT SIDE VIEW

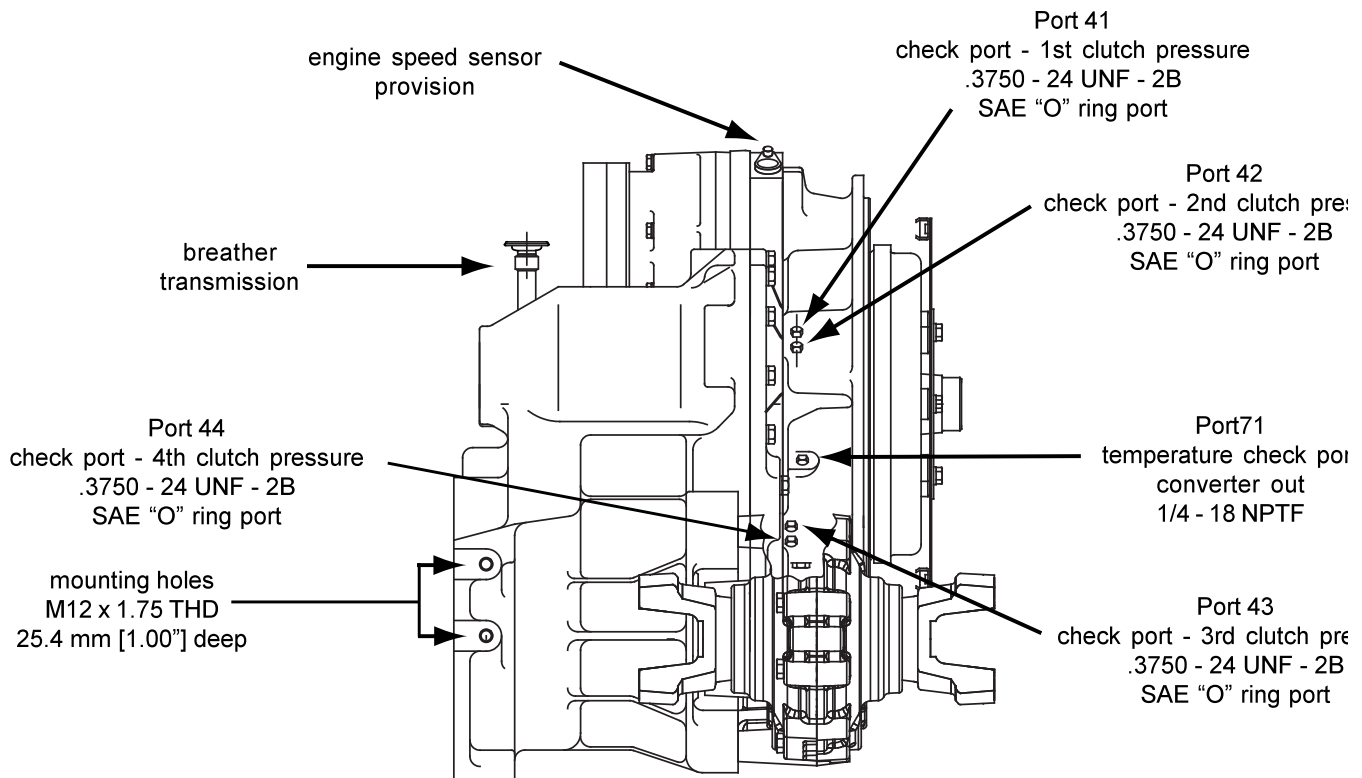
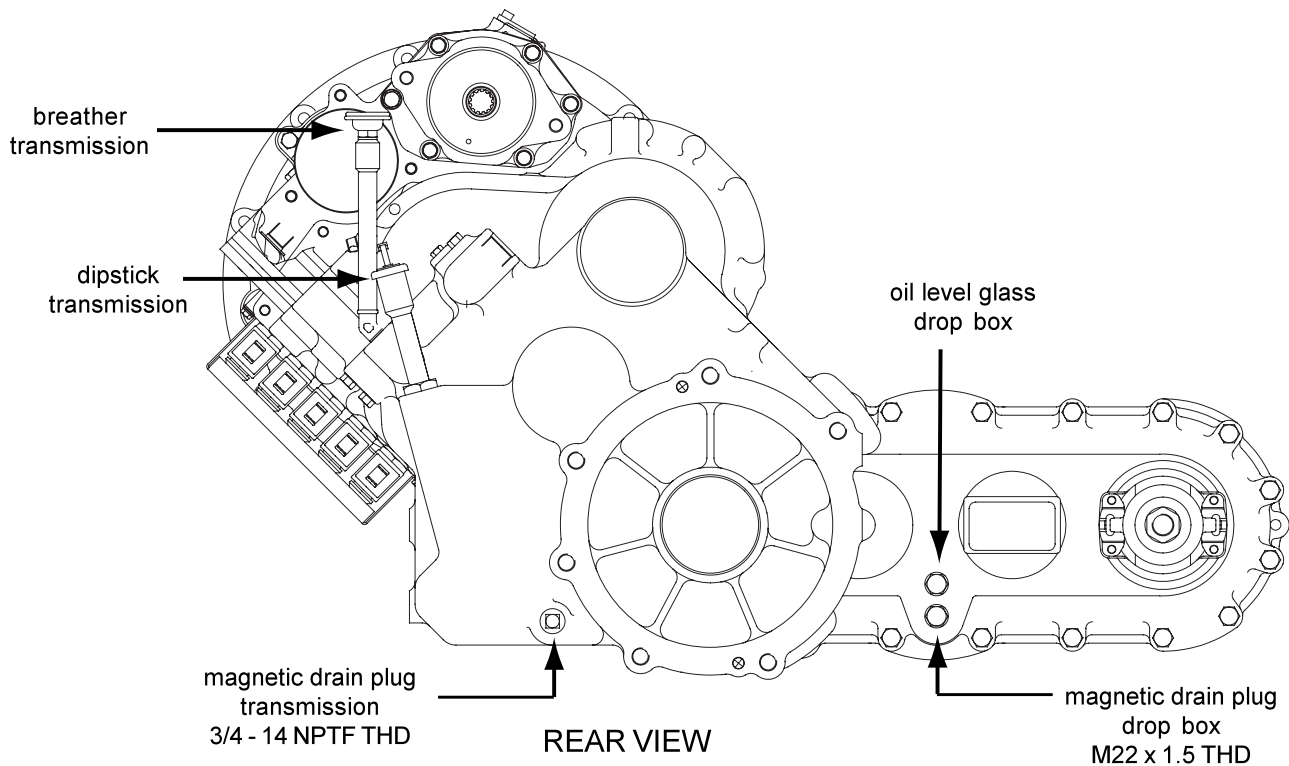
TRANSMISSION WITH A 3 SHAFT DROP BOX

TRANSMISSION WITH A 3 SHAFT DROP BOX

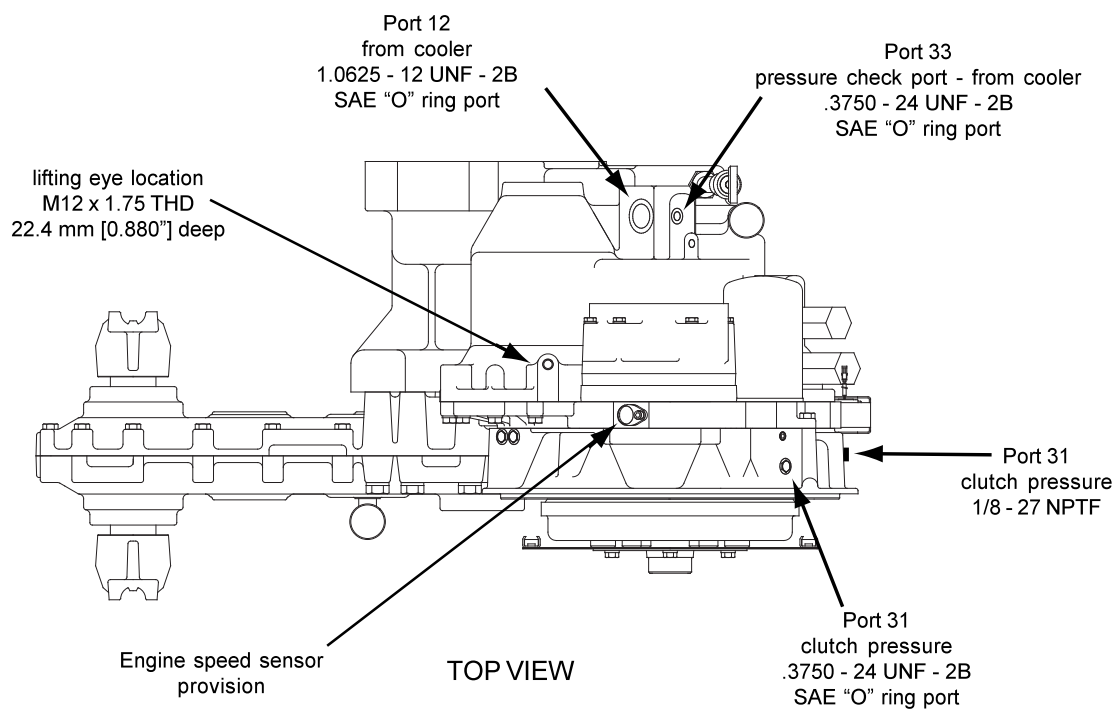


TRANSMISSION WITH A 4 SHAFT DROP BOX**FRONT VIEW****LEFT SIDE VIEW**

TRANSMISSION WITH A 4 SHAFT DROP BOX

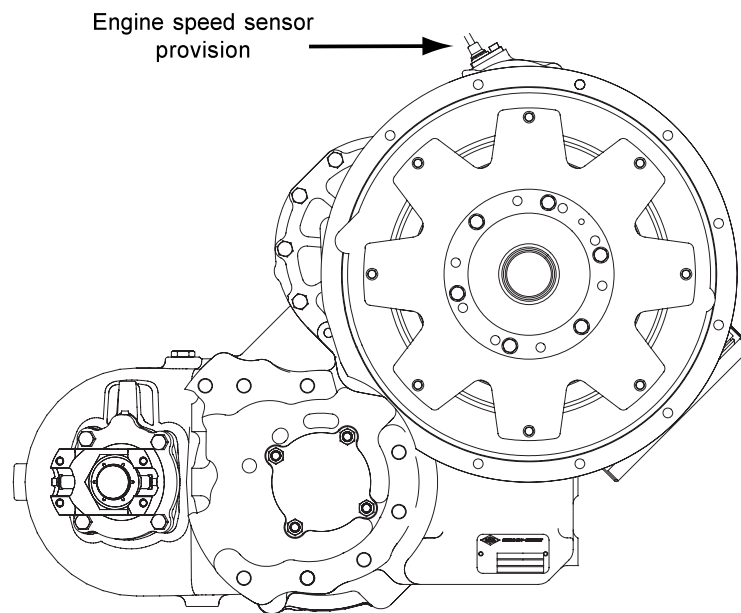


RIGHT SIDE VIEW

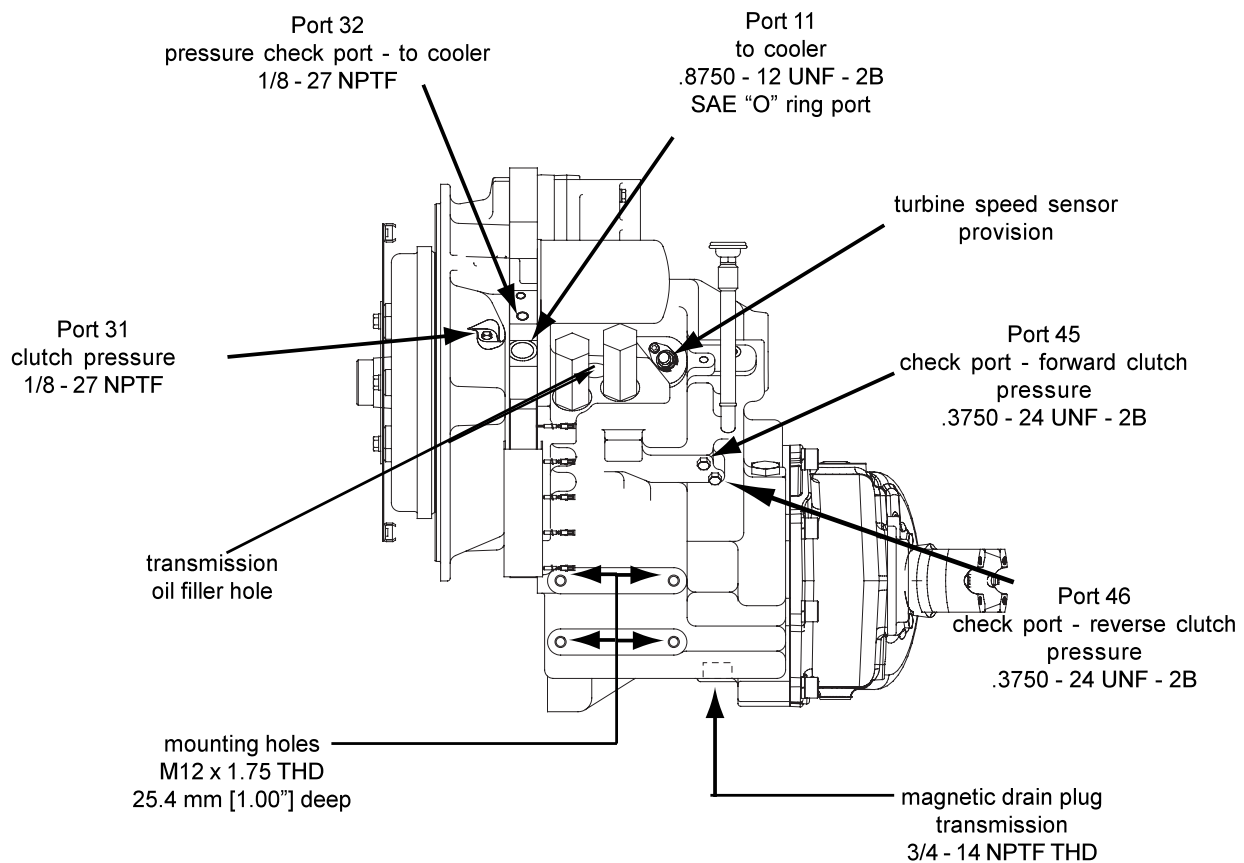
TRANSMISSION WITH A 4 SHAFT DROP BOX

VDT 17 DEGREES

CHECK POINTS



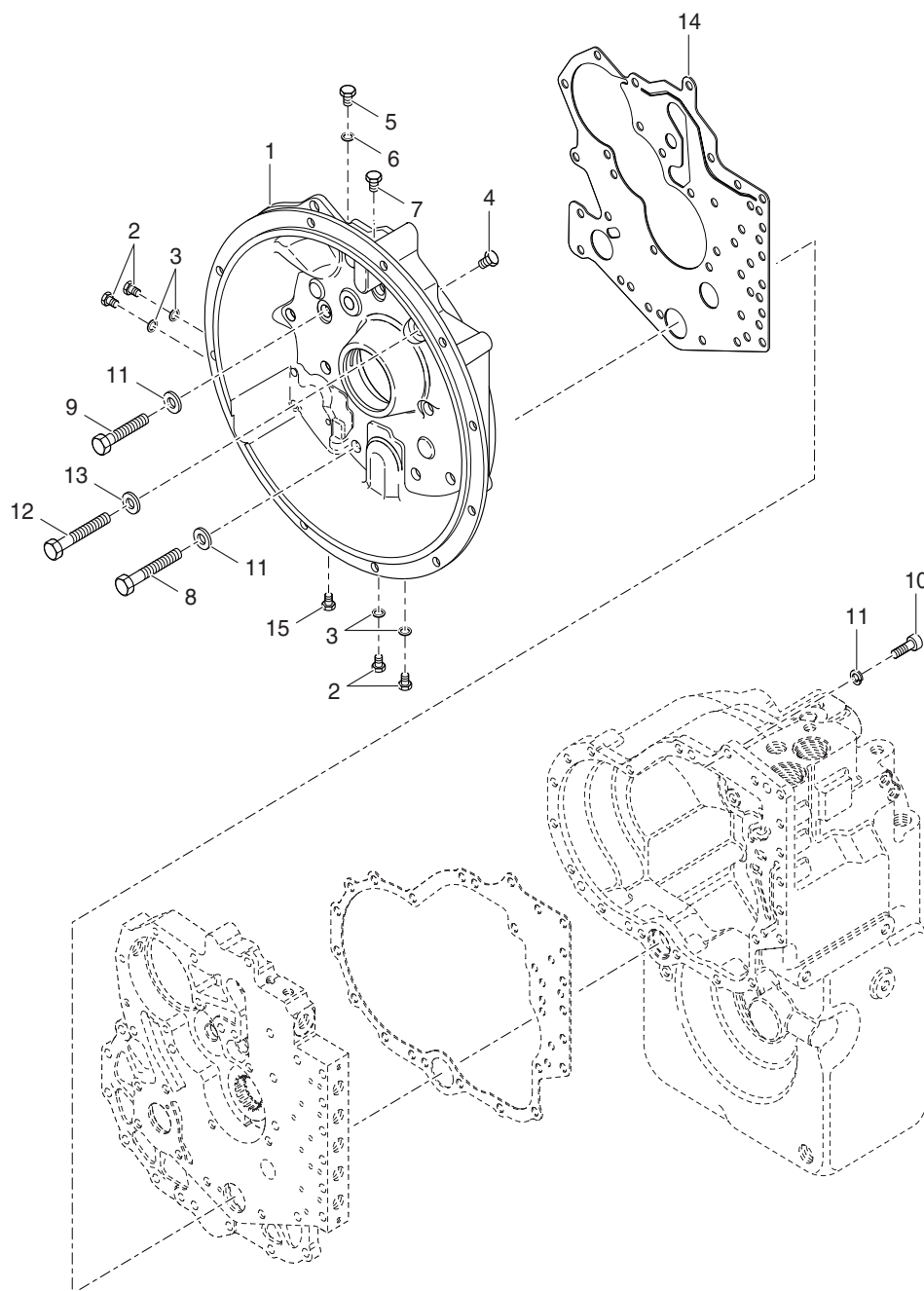
FRONT VIEW



SECTIONAL VIEWS AND PARTS IDENTIFICATION

T12000

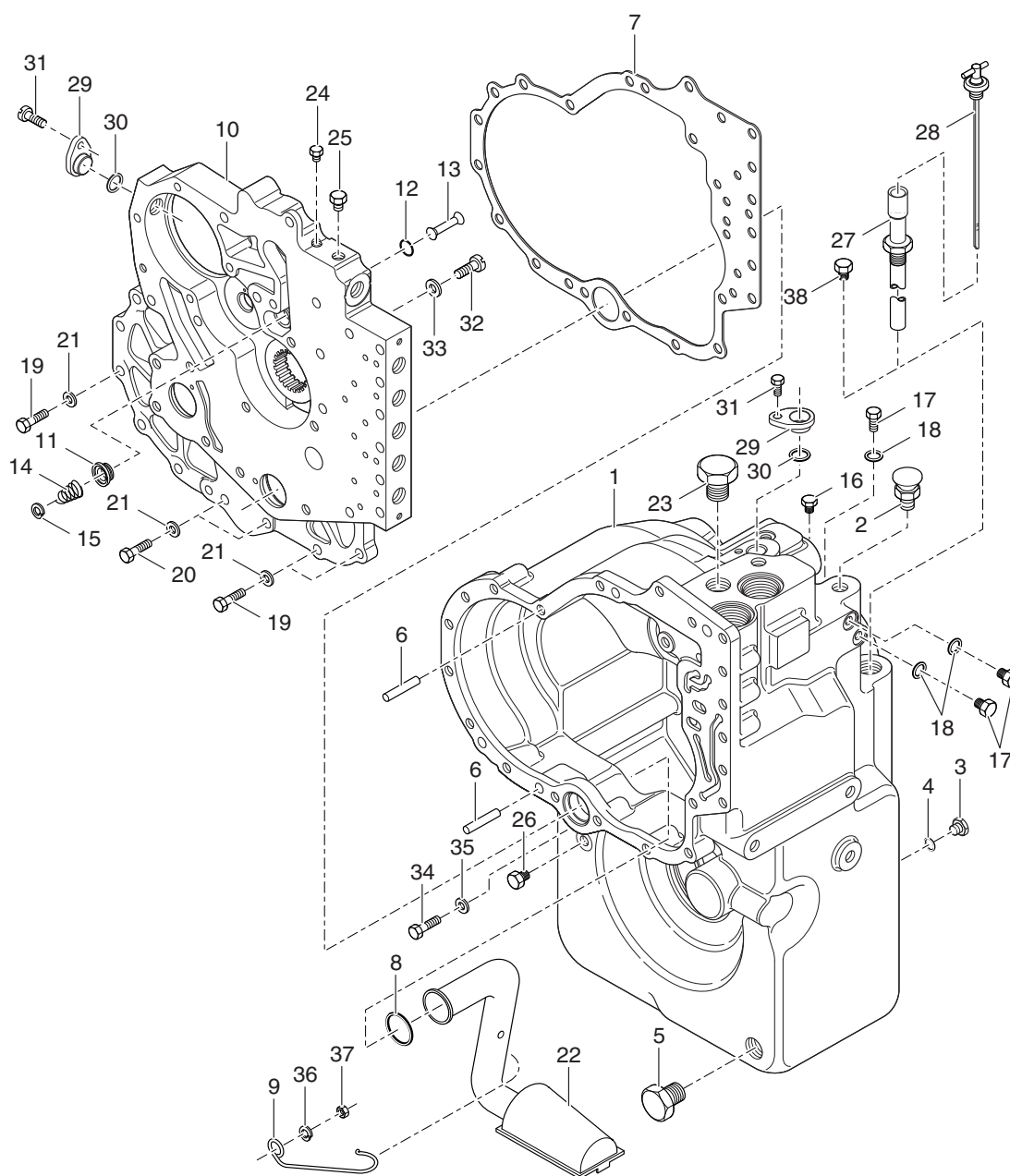
GROUP - CONVERTER HOUSING



ITEM	DESCRIPTION	QUANTITY
1	Housing - Converter	1
2	Plug	4
3	"O"-ring	4



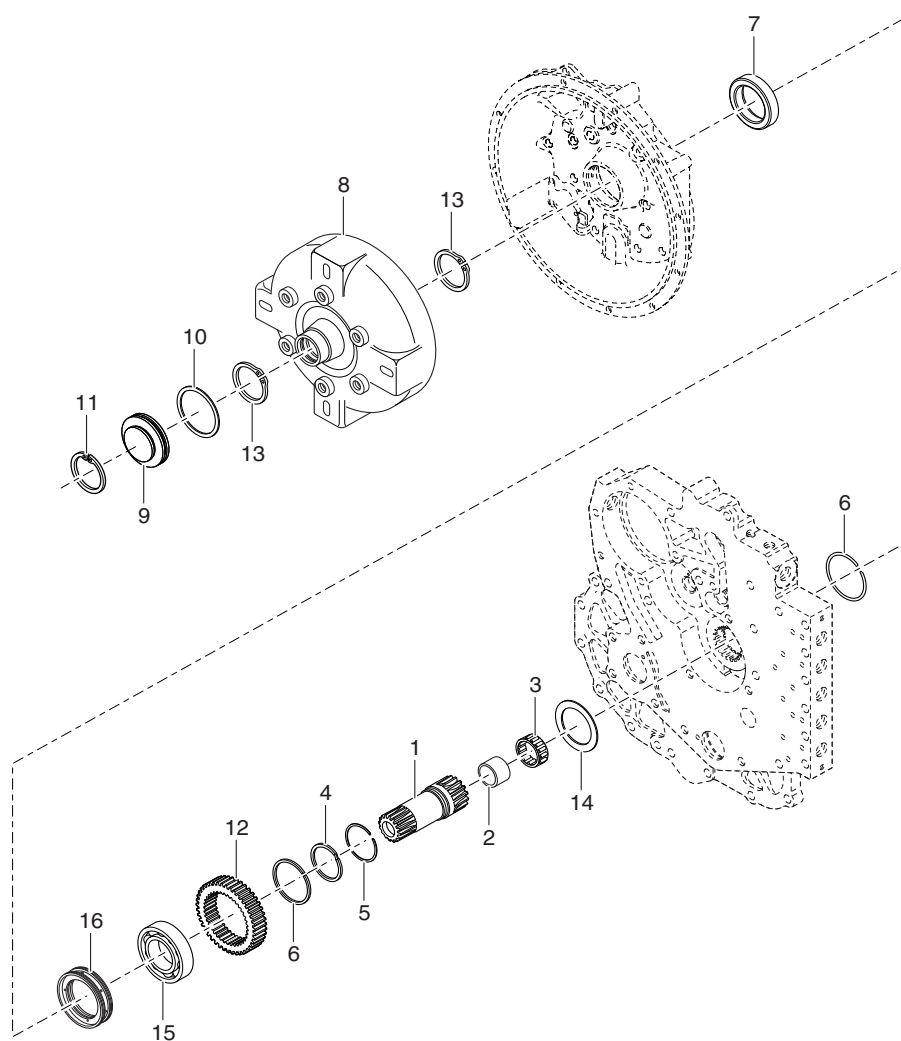
ITEM	DESCRIPTION	QUANTITY
4	Plug	1
5	Plug	1
6	"O"-ring	1
7	Plug	1
8	Screw - Converter housing to plate	6
9	Screw - Converter housing to plate	3
10	Screw - Converter housing to plate	1
11	Lockwasher - Converter housing to plate screw	10
12	Screw - Converter housing to transmission case	13
13	Lockwasher - Converter housing to transmission case screw	13
14	Gasket - Converter housing to plate	1
15	Plug	1

GROUP -TRANSMISSION CASE AND PLATE

ITEM	DESCRIPTION	QUANTITY
1	Case - Transmission	1
2	Breather - Air	1
3	Plug - Oil level	1
4	"O"-ring	1
5	Plug - Magnetic drain	1
6	Pin - Plate to transmission case dowel	2
7	Gasket - Plate to transmission case	1
8	Ring - Oil supply tube seal	1
9	Clip - Oil supply tube retainer	1
10	Spacer - Plate	1

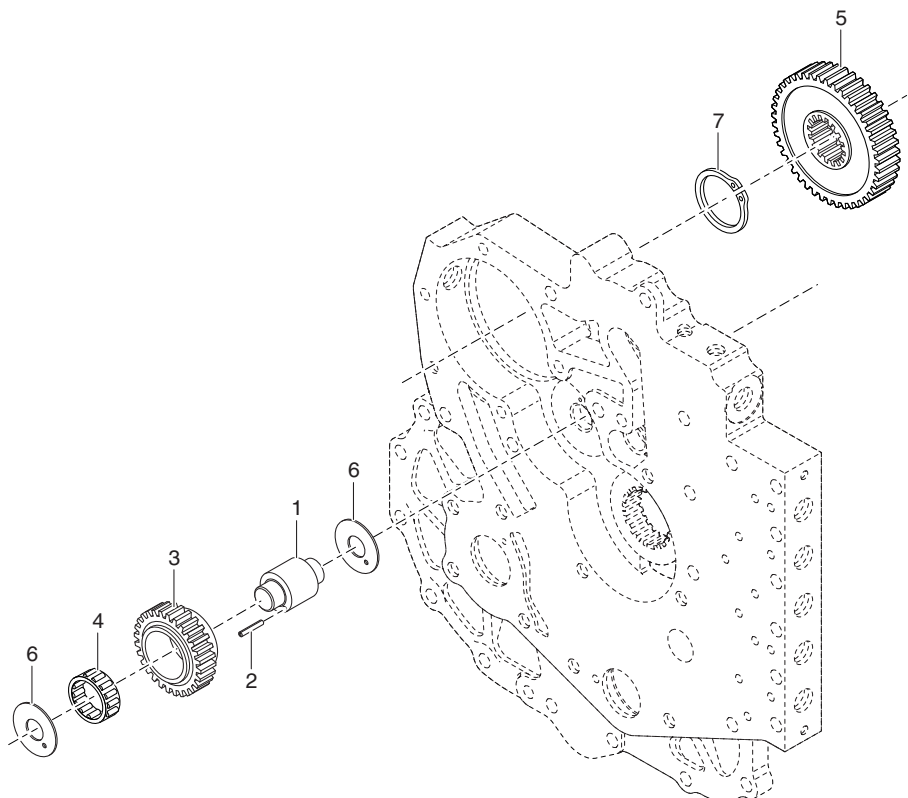


ITEM	DESCRIPTION	QUANTITY
11	Seat - Safety valve	1
12	Snap ring - Seat	1
13	Poppet - Converter safety valve	1
14	Spring - Converter safety valve	1
15	Washer - Poppet retaining	1
16	Plug	1
17	Plug	3
18	"O"-ring	3
19	Screw - Plate to transmission case	7
20	Screw - Plate to transmission case	2
21	Lockwasher - Plate to transmission case screw	9
22	Assembly - Tube & screen	1
23	Plug - Filler	1
24	Plug	1
25	Plug	1
26	Plug - Drain back port	1
27	Tube - Dipstick	1
28	Assembly - Dipstick	1
29	Plug - Speed sensor port	2
30	"O"-ring - Speed sensor	2
31	Screw - Speed sensor	2
32	Screw - Baffle hole	1
33	Washer - Baffle seal	1
34	Screw	1
35	Washer - Seal	1
36	Washer	1
37	Nut	1
38	Plug - Dipstick hole	1

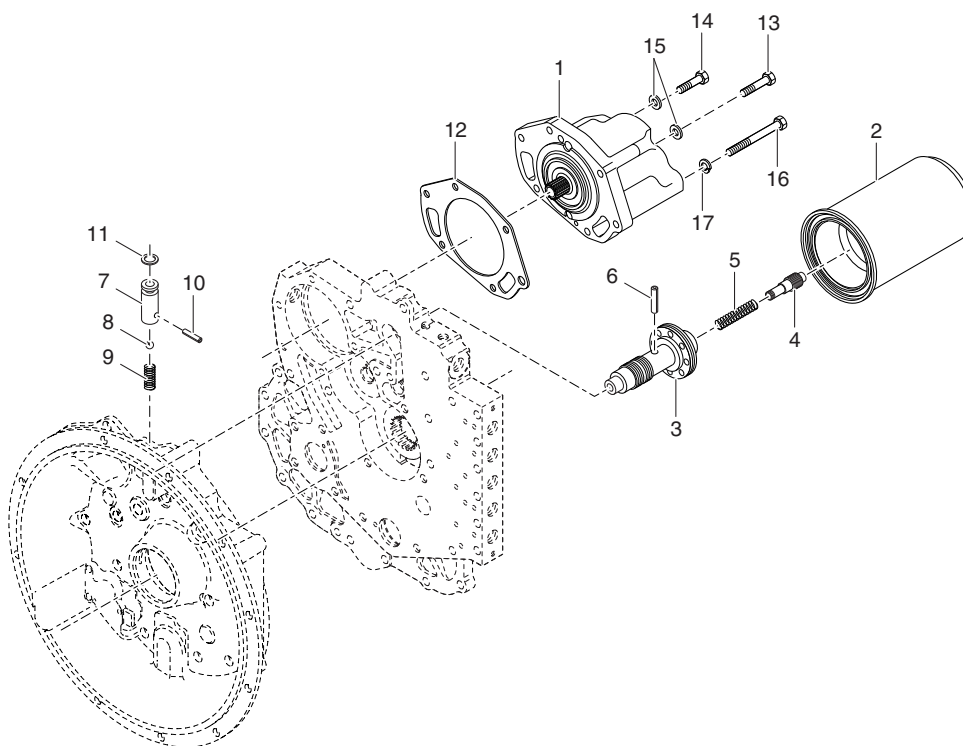
GROUP - TORQUE CONVERTER

ITEM	DESCRIPTION	QUANTITY
1	Stator support	1
2	Bushing	1
3	Bearing	1
4	Ring - Stator support piston	1
5	Expander - Stator support piston ring	1
6	Snap ring - Stator support	2
7	Seal - Converter housing oil	1
8	Assembly - Torque converter	1
9	Plug - Torque converter	1
10	"O"-ring - Torque converter plug	1
11	Snap ring - Torque converter plug	1
12	Gear - Impeller hub	1
13	Snap ring - Impeller hub	2
14	Washer - Impeller hub gear	1
15	Bearing - Torque converter	1
16	Ring - Oil distributor	1

GROUP - PUMP DRIVE

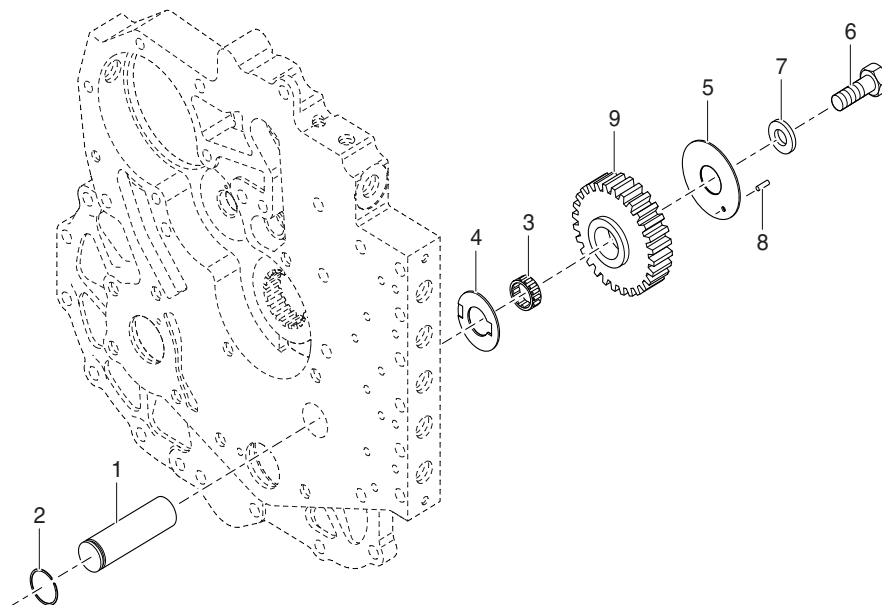


ITEM	DESCRIPTION	QUANTITY
1	Shaft - Pump drive idler & pilot	1
2	Pin - Roll	1
3	Gear - Pump drive idler	1
4	Bearing - Idler gear	1
5	Gear - Pump drive	1
6	Washer - Pump drive idler thrust	2
7	Snap ring - Pump drive gear retaining	1

GROUP - CHARGING PUMP

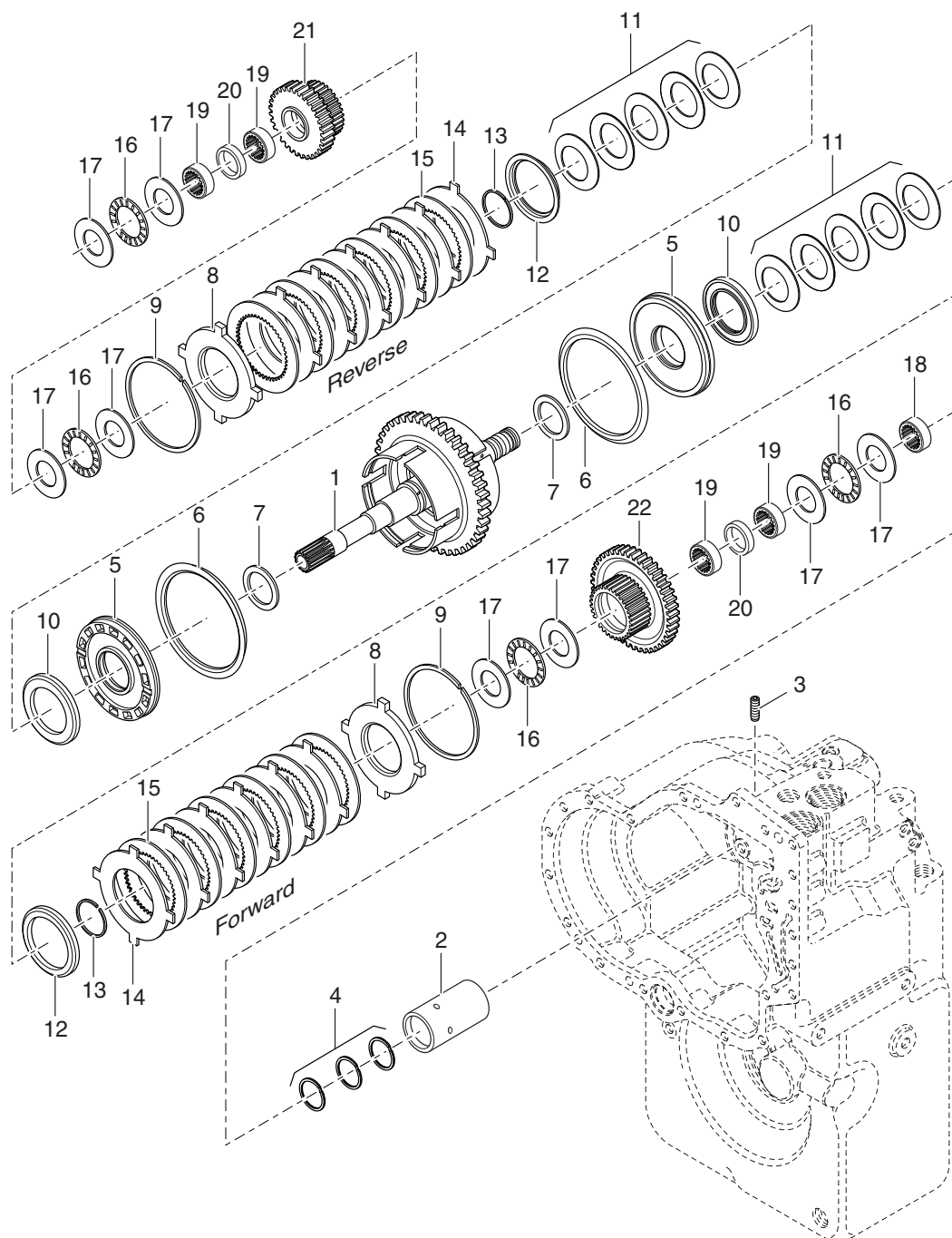
ITEM	DESCRIPTION	QUANTITY
1	Assembly - Charge pump	1
2	Assembly - Hydraulic spin filter	1
3	Sleeve - Regulator valve	1
4	Piston - Regulator valve	1
5	Spring - Regulator valve	1
6	Pin	1
7	Body - Check valve	1
8	Ball	1
9	Spring - Check valve	1
10	Pin - Check valve	1
11	"O"-ring	1
12	Gasket - Charging pump	1
13	Screw - Pump mounting	4
14	Screw - Pump mounting	1
15	Lockwasher - Pump mounting screw	5
16	Screw - Pump mounting	1
17	Lockwasher - Pump mounting screw	1

GROUP - REVERSE IDLER



ITEM	DESCRIPTION	QUANTITY
1	Shaft - Idler & pilot	1
2	Snap ring - Idler shaft	1
3	Bearing - Reverse idler gear	1
4	Washer - Thrust	1
5	Plate - End	1
6	Capscrew - Reverse idler end plate	1
7	Washer - End plate cap screw	1
8	Roll pin - End plate to shaft	1
9	Gear - Reverse idler	1

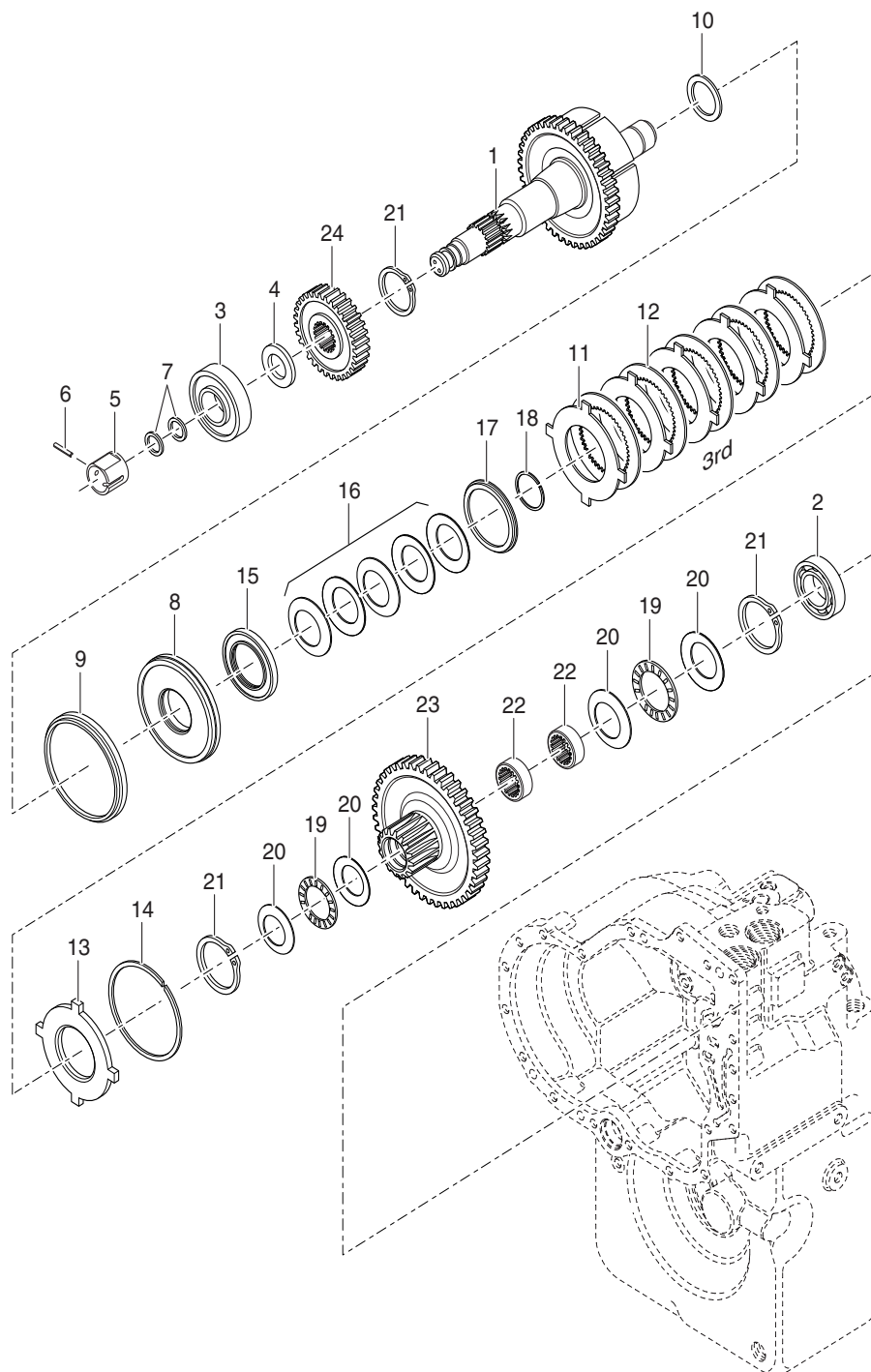
GROUP - FORWARD AND REVERSE SHAFT



ITEM	DESCRIPTION	QUANTITY
1	Assembly - Turbine shaft, drum & plug	1
2	Sleeve - Oil distributor	1
3	Screw - Retainer	1
4	Ring - Piston	3
5	Piston - Clutch	2
6	Seal - Clutch piston (Outer)	2



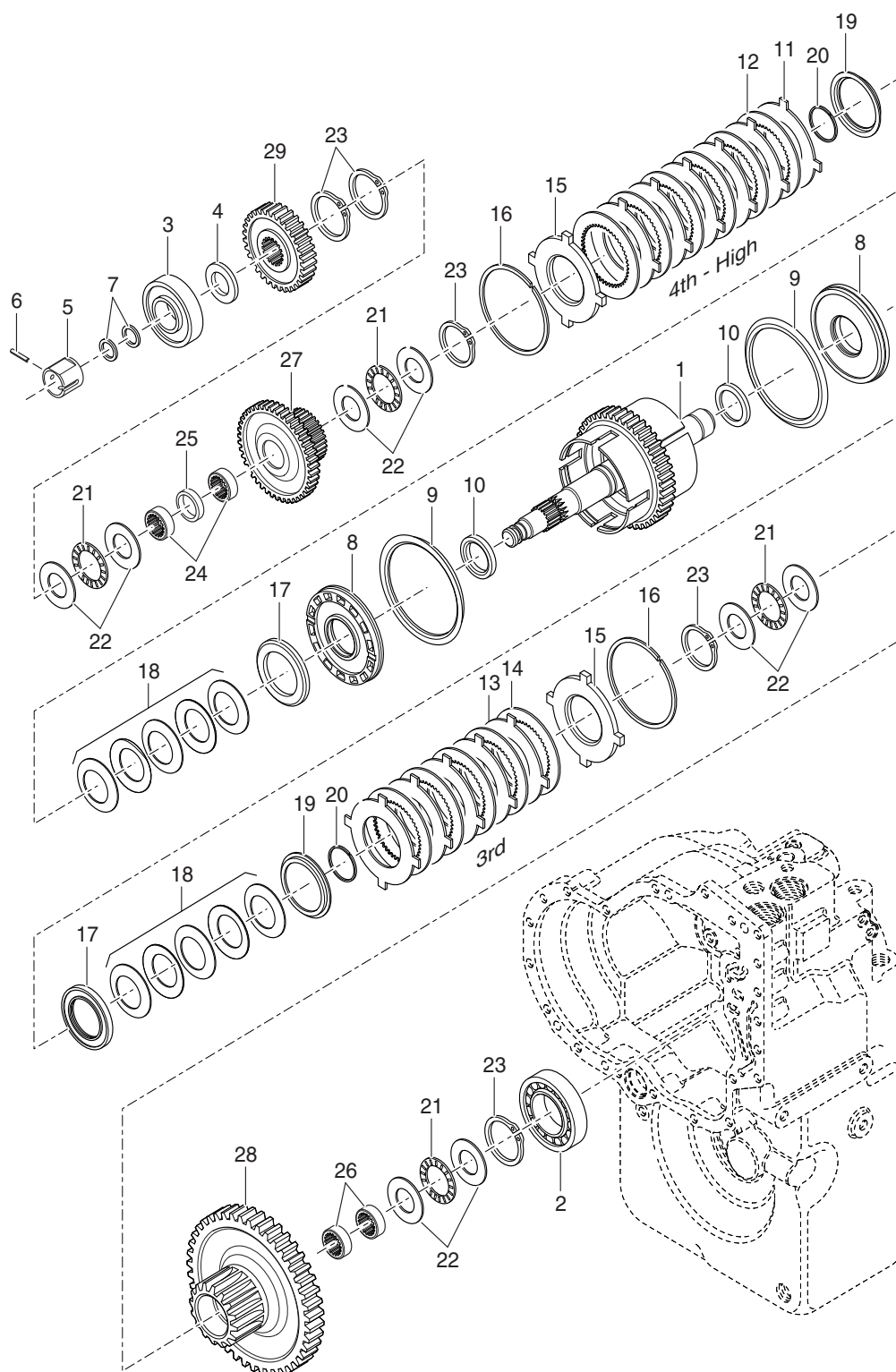
ITEM	DESCRIPTION	QUANTITY
7	Seal - Clutch piston (Inner)	2
8	Plate - End	2
9	Snap ring - End plate	2
10	Plate - Clutch piston wear	2
11	Assembly - Disc spring	2
12	Retainer - Snap ring	2
13	Snap ring - retainer	2
14	Disc - Outer (6 forward - 6 reverse)	12
15	Disc - Inner (6 forward - 6 reverse)	12
16	Bearing - Clutch gear thrust	4
17	Washer - Clutch gear thrust	8
18	Bearing - Turbine shaft rear	1
19	Bearing	4
20	Spacer	2
21	Gear - Reverse clutch	1
22	Gear - Forward clutch	1

GROUP - 3RD SHAFT (FOR 3-SPEED TRANSMISSION ONLY)

ITEM	DESCRIPTION	QUANTITY
1	Assembly - 3rd shaft, drum and plug	1
2	Bearing - Roller	1
3	Assembly - Bearing and seal	1
4	Washer - Bearing support	1
5	Sleeve - Oil distributor	1



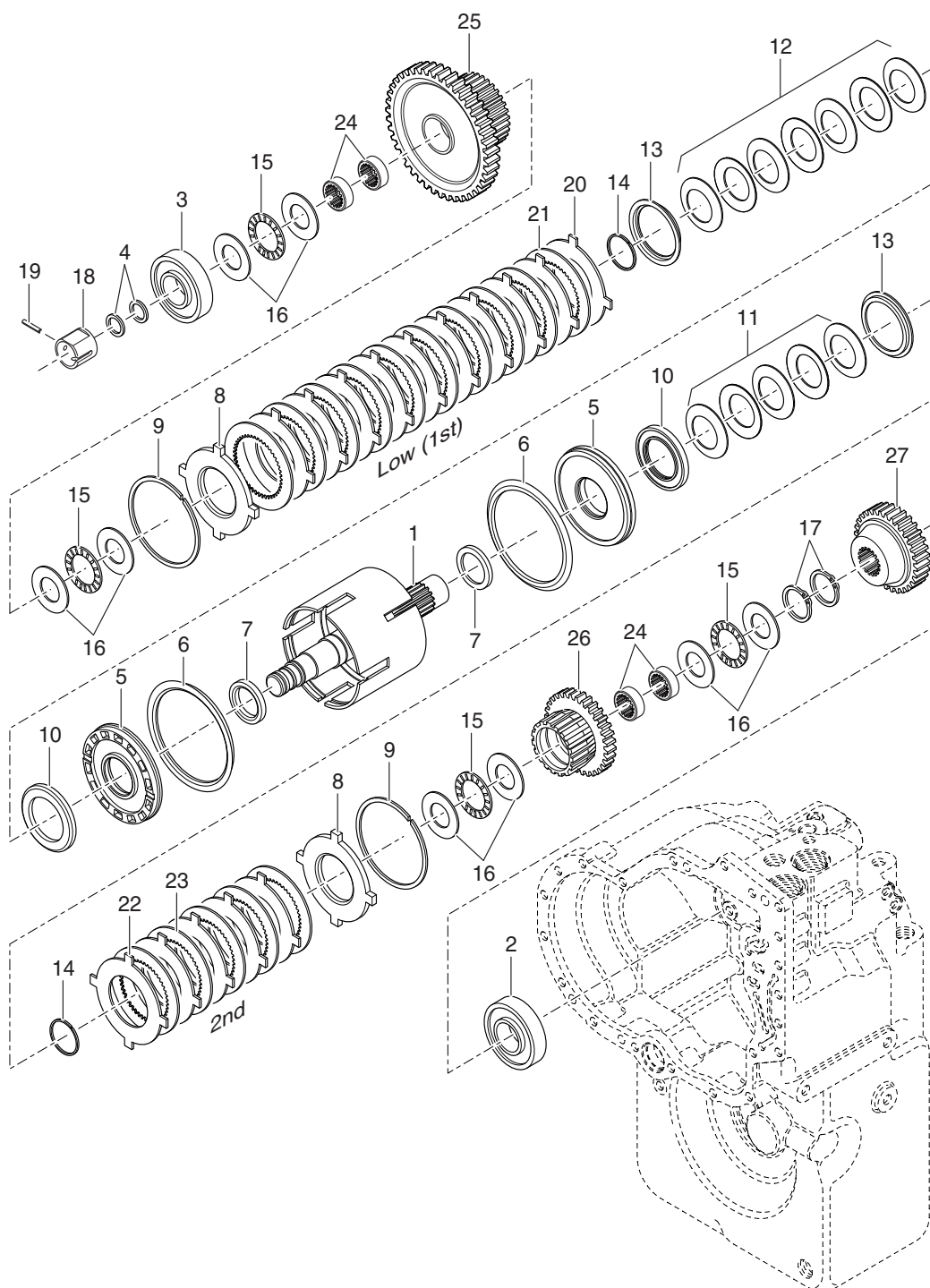
ITEM	DESCRIPTION	QUANTITY
6	Screw - Sleeve retaining	1
7	Ring - Piston	2
8	Clutch - Piston	1
9	Seal - Clutch piston (Outer)	1
10	Seal - Clutch piston (Inner)	1
11	Disc (Outer)	5
12	Disc (Inner)	5
13	Plate - End	1
14	Snap ring - end plate	1
15	Plate - Clutch piston wear	1
16	Assembly - disc spring	1
17	Retainer - Snap ring	1
18	Snap ring - Retainer	1
19	Bearing - Thrust needle roller	2
20	Washer - Clutch gear thrust	4
21	Snap ring - External	3
22	Bearing - 3rd clutch gear	2
23	Gear - 3rd clutch	1
24	Gear - First drive	1

GROUP - HIGH (4TH) AND 3RD SHAFT

ITEM	DESCRIPTION	QUANTITY
1	Assembly - High and 3rd shaft, drum and plug	1
2	Bearing - Roller	1
3	Assembly - Bearing and seal	1
4	Washer - Bearing support	1



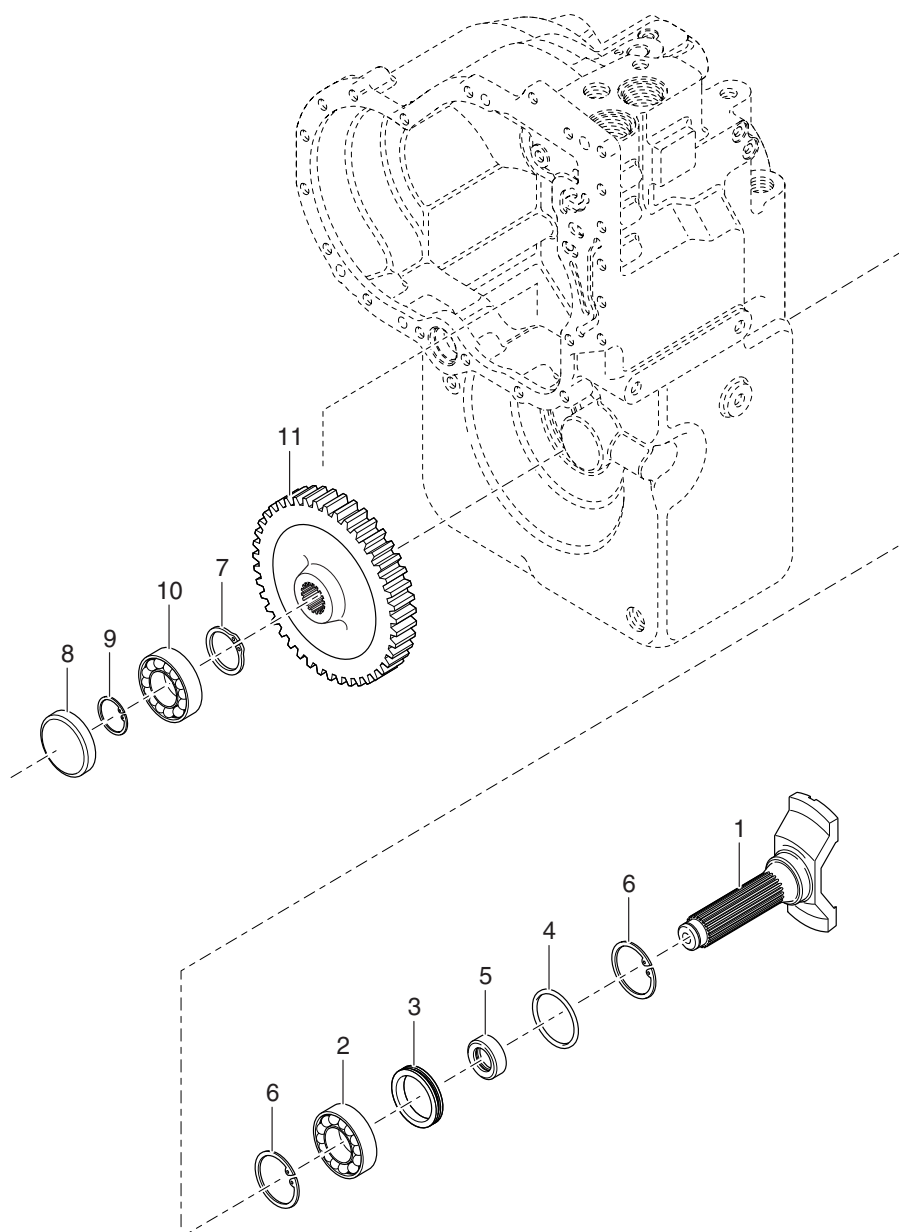
ITEM	DESCRIPTION	QUANTITY
5	Sleeve - Oil distributor	1
6	Screw - Sleeve retaining	1
7	Ring - Piston	2
8	Clutch - Piston	2
9	Seal - Clutch piston (Outer)	2
10	Seal - Clutch piston (Inner)	2
11	Disc (Outer) Hi	6
12	Disc (Inner) Hi	6
13	Disc (Outer) 3rd	5
14	Disc (Inner) 3rd	5
15	Plate - End	2
16	Snap ring - End plate	2
17	Plate - Clutch piston wear	2
18	Assembly - Disc spring	2
19	Retainer - Snap ring	2
20	Snap ring - Retainer	2
21	Bearing - thrust needle roller	4
22	Washer - Clutch gear thrust	8
23	Snap ring - Gear hub	5
24	Bearing - 4th clutch gear	2
25	Spacer	1
26	Bearing - 3rd clutch gear	2
27	Gear 4th clutch	1
28	Gear 3rd clutch	1
29	Gear - First drive	1

GROUP - 1ST AND 2ND SHAFT

ITEM	DESCRIPTION	QUANTITY
1	Assembly 1st and 2nd shaft, drum, plug and seat	1
2	Bearing - Roller	1
3	Assembly - Bearing and seal	1
4	Ring - Piston	2

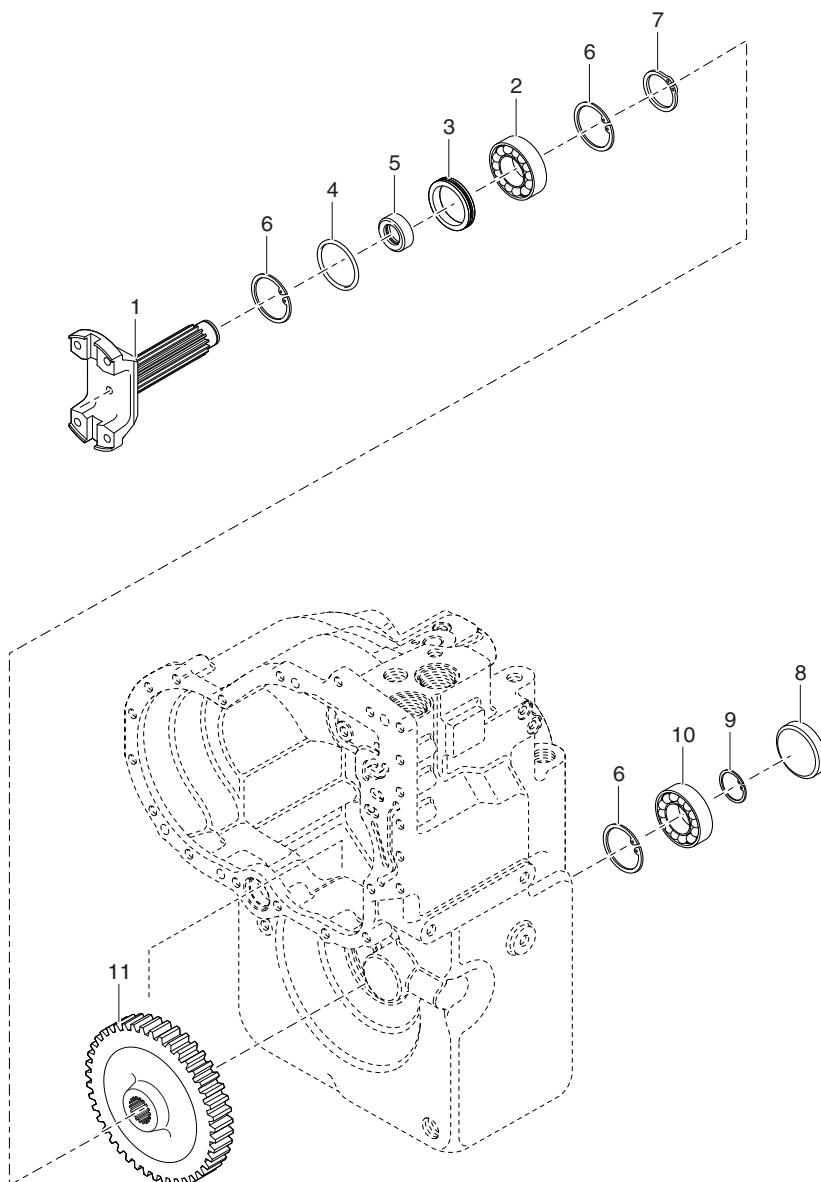


ITEM	DESCRIPTION	QUANTITY
5	Piston - Clutch	2
6	Seal - Clutch piston (Outer)	2
7	Seal - Clutch piston (Inner)	2
8	Plate - End	2
9	Snap ring - End plate	2
10	Plate - Clutch piston wear	2
11	Assembly - Disc spring	1
12	Assembly - Disc spring	1
13	Retainer - Snap ring	2
14	Snap ring - Retainer	2
15	Bearing - Clutch gear thrust	4
16	Washer - Clutch gear thrust	8
17	Snap ring - 2nd clutch gear hub	2
18	Sleeve - Oil distributor	1
19	Screw - Sleeve retaining	1
20	Disc (Outer) 1st	10
21	Disc (Inner) 1st	10
22	Disc (Outer) 2nd	5
23	Disc (Inner) 2nd	5
24	Bearing	4
25	Gear - 1st clutch	1
26	Gear - 2nd clutch	1
27	Gear - 3rd driven	1

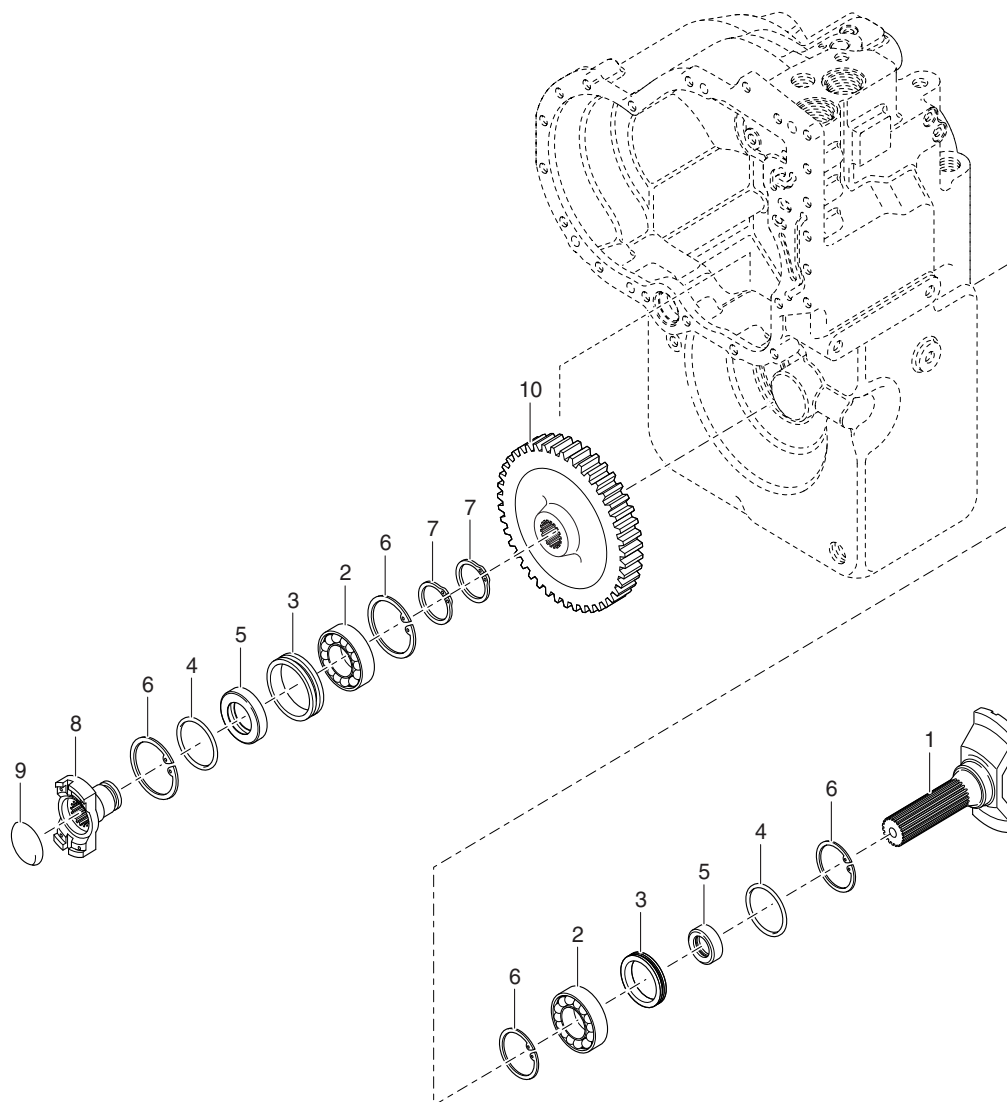
GROUP - OUTPUT SHAFT (REAR ONLY)

ITEM	DESCRIPTION	QUANTITY
1	Shaft - Output	1
2	Bearing - Output shaft	1
3	Sleeve - Oil seal	1
4	O ring - Oil seal sleeve	1
5	Seal - Output shaft oil	1
6	Snap ring - Output shaft bearing	2
7	Snap ring - Gear & bearing retaining	1
8	Plug - End	1
9	Snap ring - Bearing retainer	1
10	Bearing - Output shaft	1
11	Gear - Output shaft	1

GROUP - OUTPUT SHAFT (FRONT ONLY)

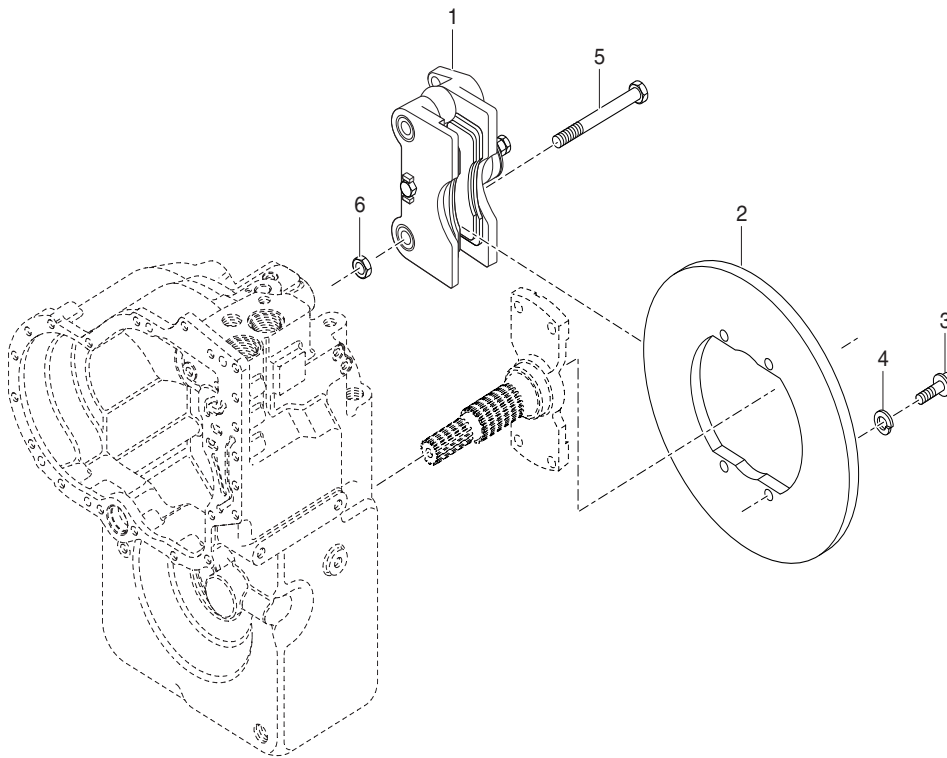


ITEM	DESCRIPTION	QUANTITY
1	Shaft - Output	1
2	Bearing - Output shaft	1
3	Sleeve - Oil seal	1
4	"O"ring - Oil seal sleeve	1
5	Seal - Output shaft bearing	1
6	Snap ring - Output shaft bearing	3
7	Snap ring - Gear & bearing retaining	1
8	Plug - End	1
9	Snap ring - Bearing retainer	1
10	Bearing - Output shaft	1
11	Gear - Output shaft	1

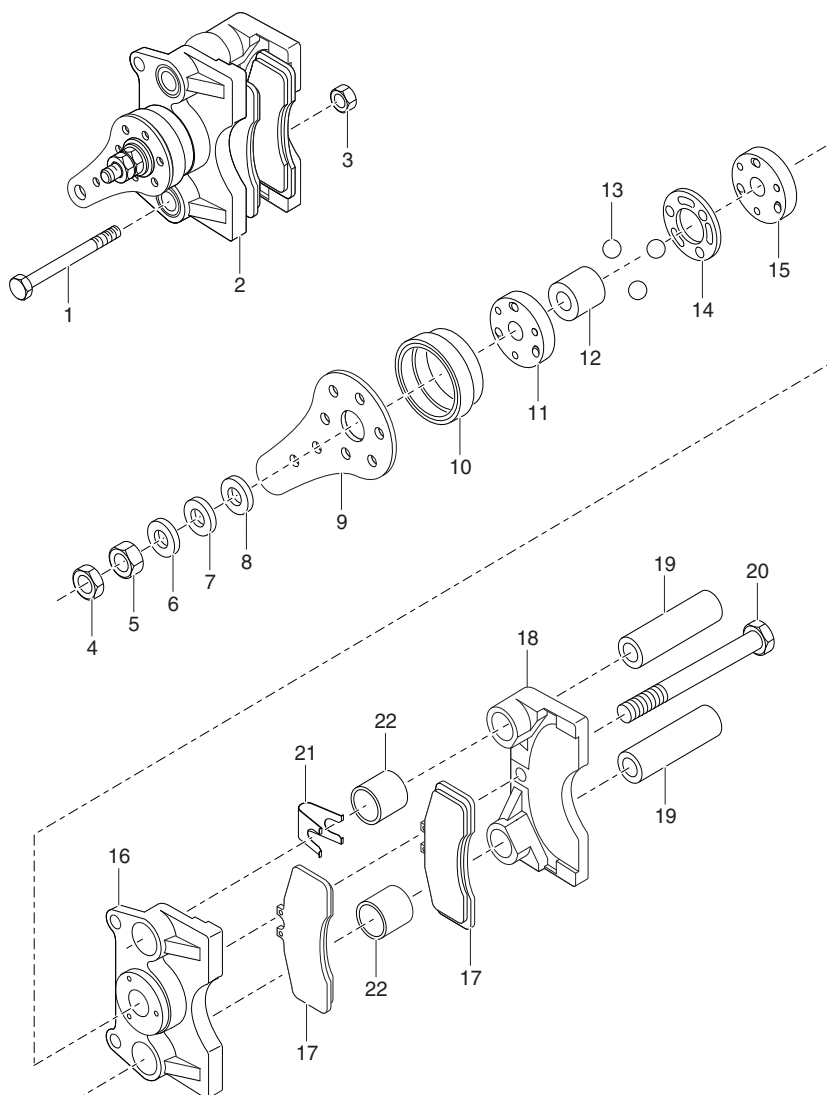
GROUP - OUTPUT SHAFT (FRONT & REAR)

ITEM	DESCRIPTION	QUANTITY
1	Shaft - Output	1
2	Bearing - Output shaft	2
3	Sleeve - Oil seal	2
4	"O"-ring - Oil seal sleeve	2
5	Seal - Output shaft oil	2
6	Snap ring - Output shaft bearing	4
7	Snap ring - Gear & bearing retaining	2
8	Flange - Output	1
9	Plug - Flange	1
10	Gear - Output shaft	1

GROUP - DISK BRAKE



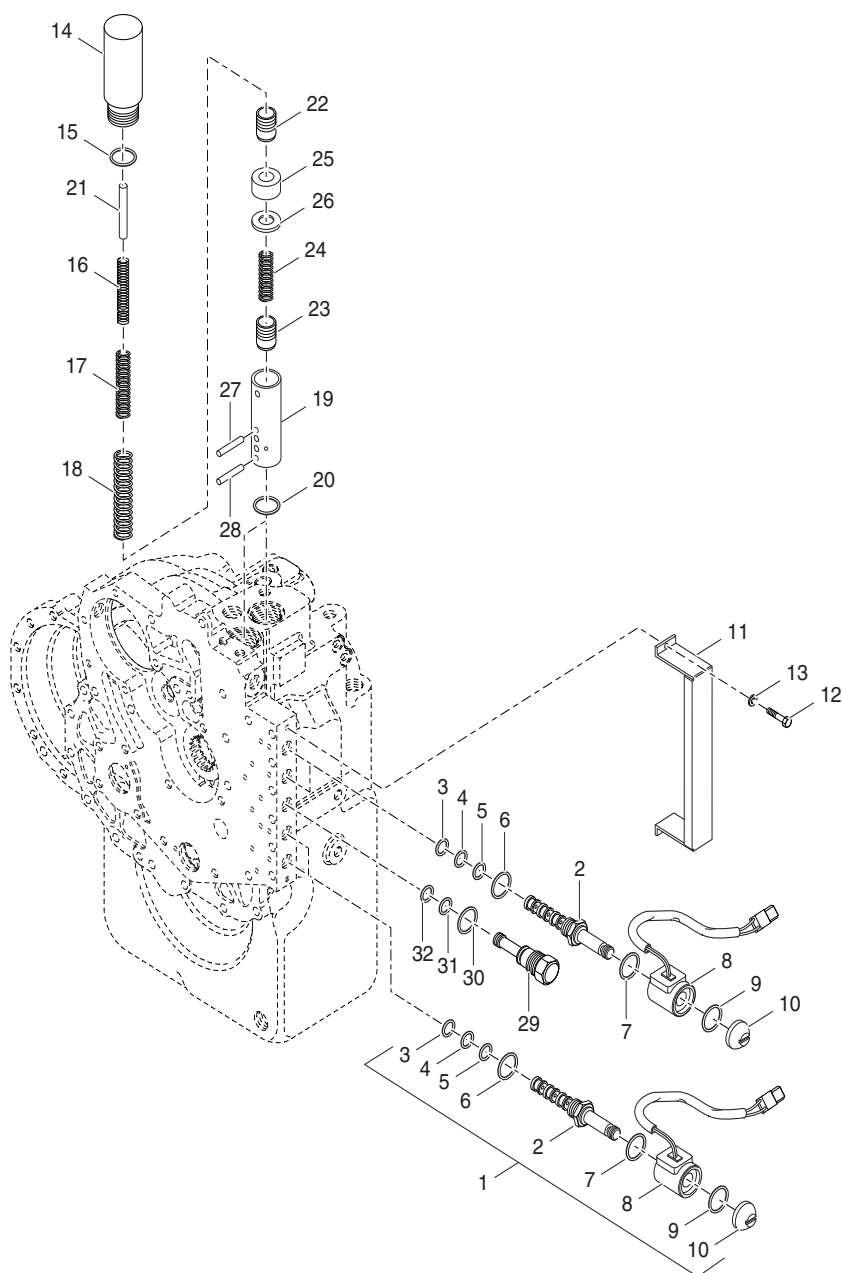
ITEM	DESCRIPTION	QUANTITY
1	Assembly - Caliper	1
2	Disc - Brake	1
3	Capscrew - Brake disc	4
4	Lockwasher	4
5	Capscrew - Caliper assembly mounting	2
6	Nut - Caliper assembly capscrew locking	2

GROUP - CALIPER ASSEMBLY

ITEM	DESCRIPTION	QUANTITY
1	Screw - Brake mounting	2
2	Assembly - Caliper	1
3	Nut - Brake mounting screw	2
4	Nut - Jam adjustment	1
5	Nut - Adjustment	1
6	Washer - Hardened	1
7	Washer - Stainless steel	1
8	Washer - Thrust	1
9	Lever	1
10	Boot	1
11	Cam	1
12	Id seal	1



ITEM	DESCRIPTION	QUANTITY
13	Ball bearing	3
14	Plastic retainer	1
15	Cam	1
16	Torque plate (Front)	1
17	Carrier and lining assembly	2
18	Torque plate (Rear)	1
19	Sleeve mounting	2
20	Bolt - Adjusting	1
21	Spring	1
22	Seal - Sleeve	2

GROUP - ELECTRIC CONTROL

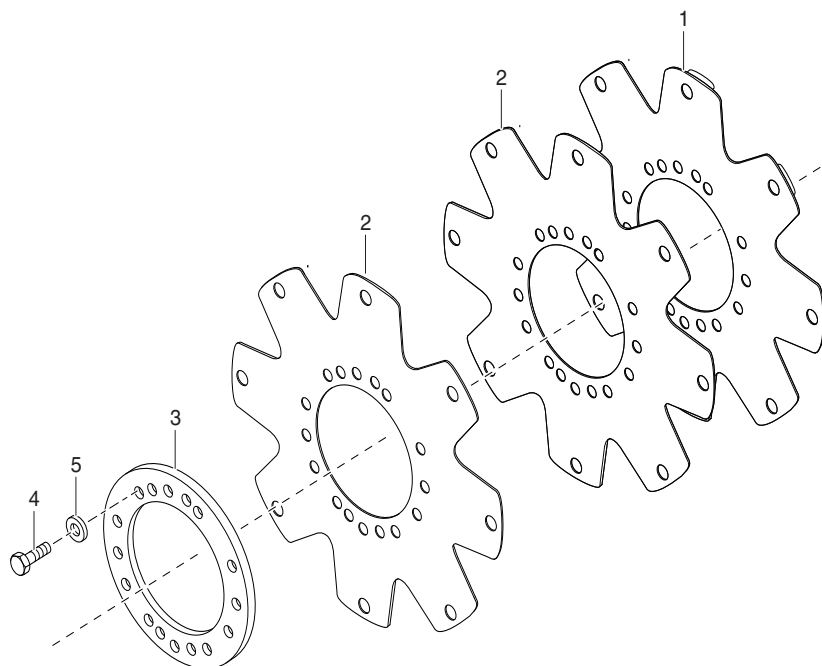
ITEM	DESCRIPTION	QUANTITY
1	Assembly - Solenoid cartridge	5*
2	Cartridge - Valve 4-way including items 3, 4, 5 and 6	5*
3	"O"-ring - Cartridge	5*
4	"O"-ring - Cartridge	5*
5	"O"-ring - Cartridge	5*
6	"O"-ring - Cartridge	5*
7	"O"-ring - Cartridge to coil	5*
8	Coil - Solenoid	5*



ITEM	DESCRIPTION	QUANTITY
9	"O"-ring - Coil to nut	5*
10	Nut - Valve cartridge retainer	5*
11	Cover - Protective	1
12	Screw - Protective cover	2
13	Lockwasher - Protective cover screw	2
14	Housing - Modulation valve	2
15	"O"-ring - Modulation housing	2
16	Spring (Inner)	2
17	Spring (Middle)	2
18	Spring (Outer)	2
19	Sleeve - Modulation valve	2
20	"O"-Ring - Sleeve	2
21	Pin - Stop	2
22	Spool - Accumulator	2
23	Spool - Regulator	2
24	Spring - Modulation valve	2
25	Retainer - Spring	2
26	Spacer - Spring	2
27	Pin (Upper)	2
28	Pin (Lower)	2
29	Plug - Solenoid bore plug, used at forward high and low	1**
30	"O"-ring - Plug	1**
31	"O"-ring - Plug	1**
32	"O"-ring - Plug	1**

* Quantity = 4, with 3-speed.

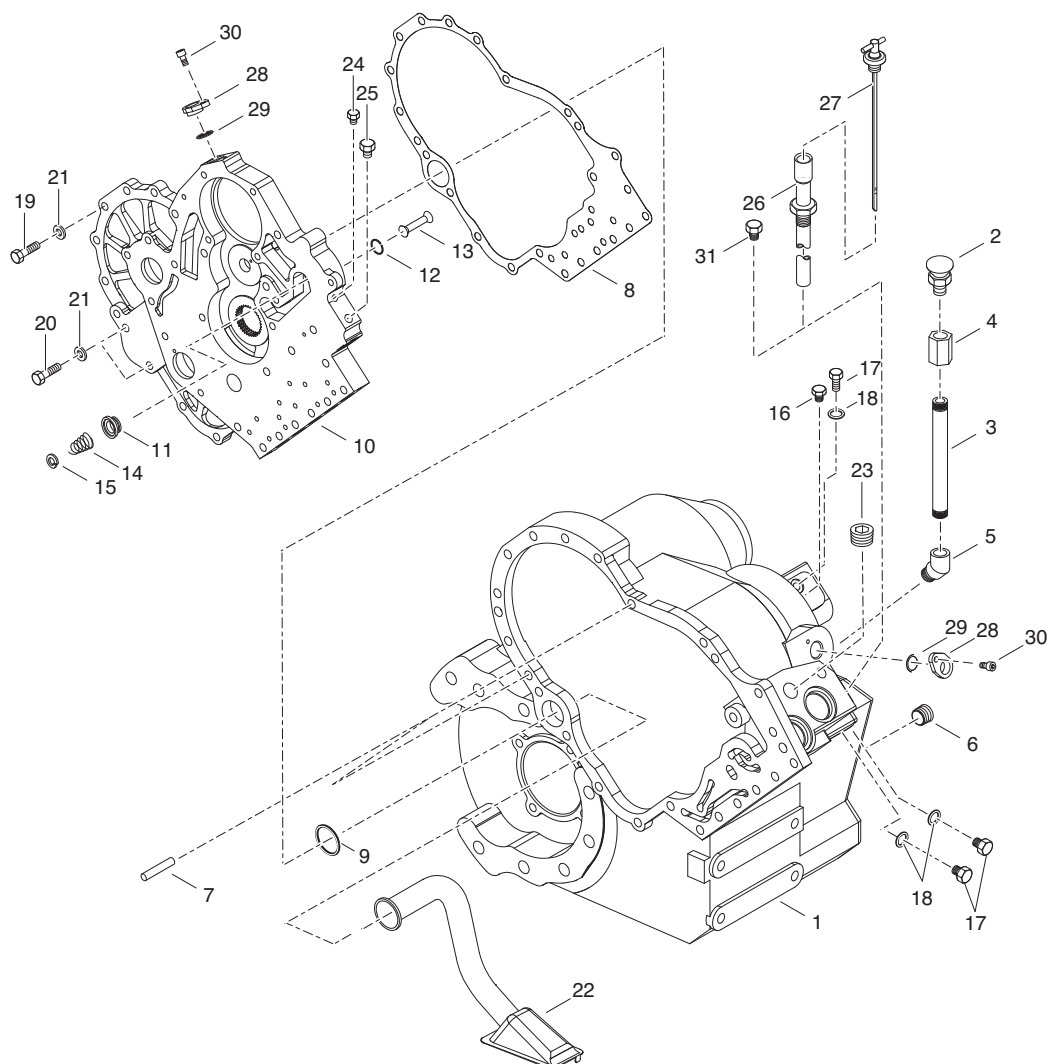
** Used with 3-speed only.

GROUP - DRIVE PLATE

ITEM	DESCRIPTION	QUANTITY
1	Assembly - Drive plate and (when used) weld nut	1
2	Plate - Drive	2
3	Ring - Drive plate backing	1
4	Screw - Drive plate mounting	6
5	Lockwasher - Drive plate mounting screw	6

VDT 12000

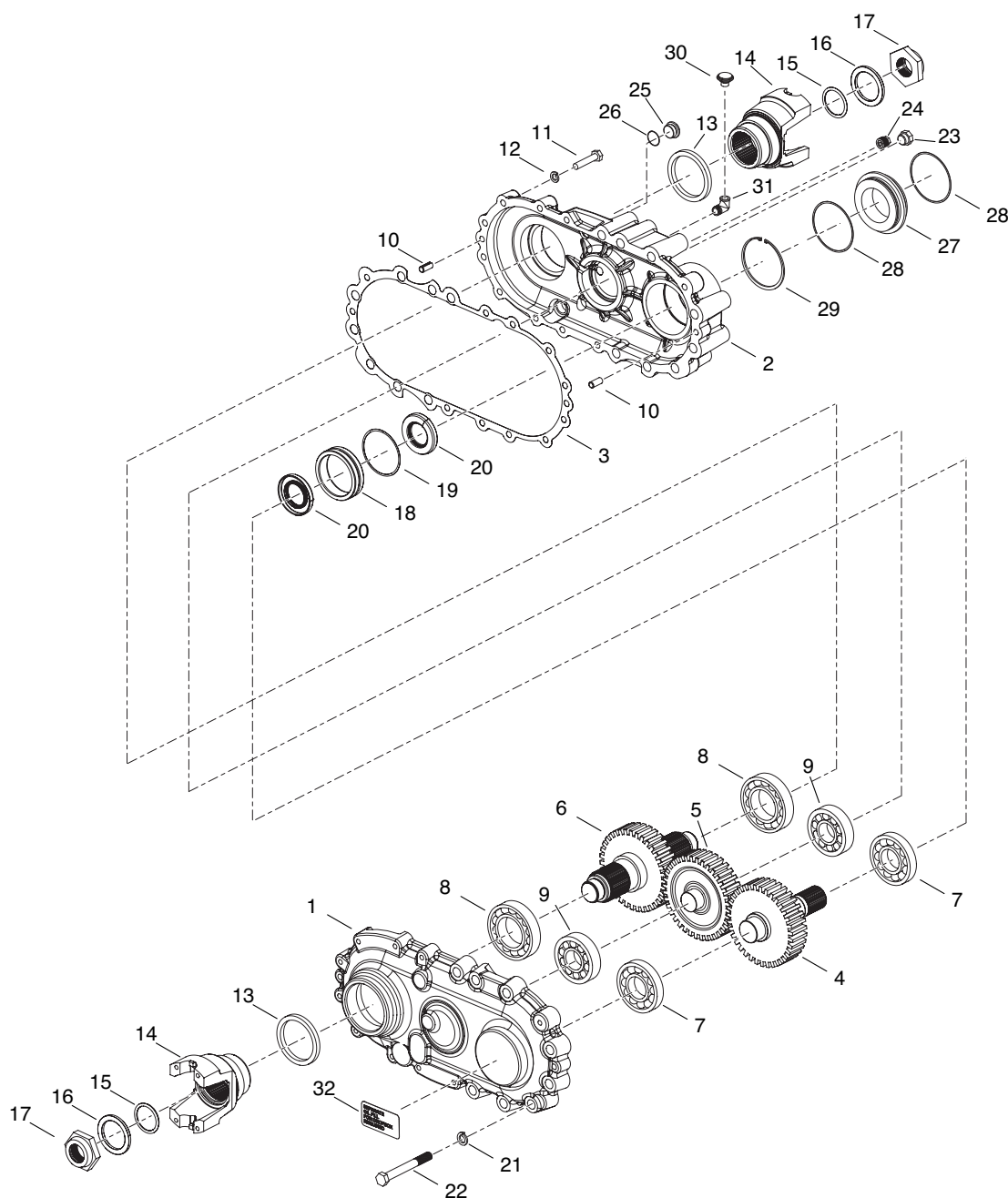
TRANSMISSION CASE & PLATE GROUP



ITEM	DESCRIPTION	QUANTITY
1	Case - Transmission	1
2	Breather - Air	1
3	Nipple Pipe	1
4	Coupling - Pipe	1
5	Fitting - Elbow	1
6	Plug - Magnetic drain	2
7	Pin - Plate to transmission case dowel	2
8	Gasket - Plate to transmission case	1
9	Ring - Oil supply tube seal	1
10	Plate - Spacer	1
11	Seat - Safety valve	1
12	Snapping - Seat	1
13	poppet - Converter safety valve	1

ITEM	DESCRIPTION	QUANTITY
14	Spring - Converter safety valve	1
15	Washer - Puppet retaining	1
16	Plug	1
17	Plug	3
18	"O" ring - Plug	3
19	Screw - Plate to transmission case	7
20	Screw - Plate to transmission case	2
21	Lockwasher - Plate to transmission	9
22	Assembly - Tube & screen	1
23	Plug - Filler	1
24	Plug	1
25	Plug	1
26	Assembly - Dipstick tube	1
27	Dipstick	1
28	Plug - Speed sensor port	2
29	"O" ring - Speed sensor port plug	2
30	Screw - Speed sensor port plug	2

3 SHAFT DROP BOX GROUP



ITEM	DESCRIPTION	QUANTITY
1	Cover - Drop box front	1
2	Cover - Drop box rear	1
3	Gasket - Rear to front cover	1
4	Shaft - Drop box input	1
5	Gear - Drop box idler	1
6	Shaft - Drop box output	1
7	Bearing - Drop box input shaft	2
8	Bearing - Drop box output shaft	2
9	Bearing - Drop box idler shaft	2

ITEM	DESCRIPTION	QUANTITY
10	Pin - Dowel	2
11	Screw - Rear cover to front cover	10
12	Lockwasher - Rear cover to front cover screw	10
13	Seal - Drop box output shaft oil	2
14	Flange - Output	2
15	"O" ring - Output flange	2
16	Washer - Output flange	2
17	Nut - Output flange	2
18 Sleeve - Oil seal	1	
19	"O" ring - Oil seal sleeve	1
20	Seal - Oil seal sleeve oil	2
21	Lockwasher - Drop box mounting screw	8
22	Screw - Drop box mounting	8
23	Glass - Oil level	1
24	Plug - Magnetic drain	1
25	Plug	1
26	"O" ring - Plug	1
27	Sleeve - Pilot	1
28	"O" ring - Sleeve	2
29	Ring - Retaining	1
30	Breather - Air	1
31	Fitting - Elbow 90 street	1
32	Sticker	1

4 SHAFT DROP BOX GROUP

ITEM	DESCRIPTION	QUANTITY
1	Cover - Drop box rear	1
2	Cover - Drop box front	1
3	Gasket - Rear to front cover	1
4	Shaft - Drop box input	1
5	Shaft - Drop box idler	1
6	Shaft - Drop box idler	1
7	Shaft - Drop box output	1
8	Bearing - Drop box input shaft	2
9	Bearing - Drop box output shaft	2
10	Bearing - Drop box idler shaft	4
11	Pin - Dowel	2
12	Screw - Rear cover to front cover	13
13	Lockwasher - Rear cover to front cover screw	13
14	Seal - Drop box output shaft	2
15	Flange - Output	2
16	"O" ring - Output flange	2

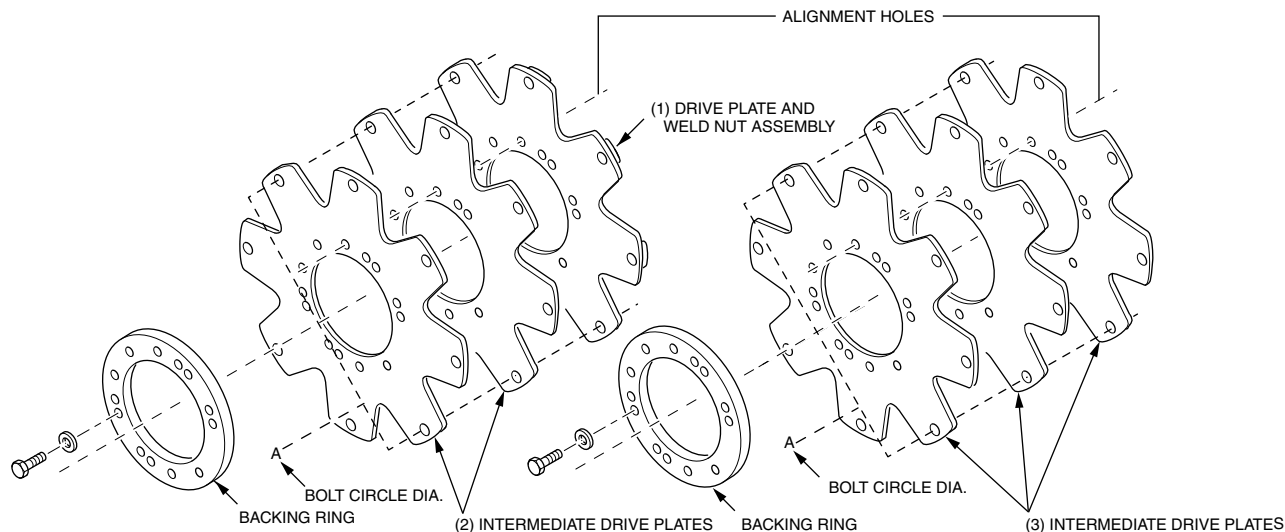


ITEM	DESCRIPTION	QUANTITY
17	Washer - Output flange	2
18	Nut - Output flange	2
19	Sleeve - Oil seal	1
20	"O" ring - Oil seal sleeve	1
21	Seal - Oil seal sleeve oil	1
22	Lockwasher - Drop box mounting screw	8
23	Screw - Drop box mounting	8
24	Plug - Magnetic drain	1
25	Glass - Oil level	1
26	Plug	1
27	Sleeve - Pilot	1
28	"O" ring - Sleeve	2
29	Ring - Retaining	1
30	Breather - Air	1
31	Fitting - Elbow 90 street	1
32	Sticker	1

T12000 INSTALLATION DETAILS

CONVERTER DRIVE COUPLING

Measure the “A” dimension (bolt circle diameter) and order drive plate kit listed below. Note three (3) kits have two (2) intermediate drive plates and one (1) drive plate and weld nut assembly. Three (3) kits with three intermediate drive plates.



“A” DIMENSION (BOLT CIRCLE DIAMETER)	“A” DIMENSION (BOLT CIRCLE DIAMETER)
11.380” (288.900 mm) diameter Kit No. 802501.	11.380” (288.900 mm) diameter Kit No. 802543.
13.125” (333.38 mm) diameter Kit No. 802424.	13.125” (333.38 mm) diameter Kit No. 802426.
13.500” (342.90 mm) diameter Kit No. 802425.	13.500” (342.90 mm) diameter Kit No. 802427.
Each kit will include the following parts:	Each kit will include the following parts:
2 Intermediate drive plates.	3 Intermediate drive plates.
1 Drive plate and weld nut assembly.	1 Backing ring.
1 Backing ring.	6 Mounting screws.
6 Mounting screws.	6 Lockwashers.
6 Lockwashers.	1 Instruction sheet.
1 Instruction sheet.	



NOTE: TO FACILITATE ASSEMBLY, ALIGN SMALL HOLES IN DRIVE PLATES - SEE ILLUSTRATION ABOVE - ALIGNMENT HOLES.

Position drive plate and weld nut assembly on torque converter assembly with weld nuts toward converter. Align intermediate drive plates and backing plate with holes in torque converter assembly.



NOTE: TWO DIMPLES 180° APART IN BACKING RING MUST BE OUT TOWARD ENGINE FLYWHEEL (HOLLOW SIDE FACING TORQUE CONVERTER ASSEMBLY). INSTALL CAP SCREWS AND LOCKWASHERS. TIGHTEN CAP SCREWS TORQUE 35 - 39 N.M. (26 - 29 LB. FT.).

TRANSMISSION TO ENGINE INSTALLATION PROCEDURE

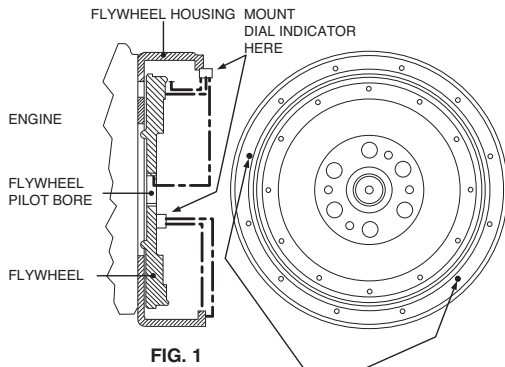


FIG. 1

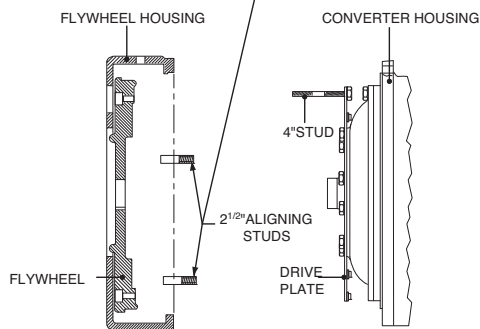


FIG. 2

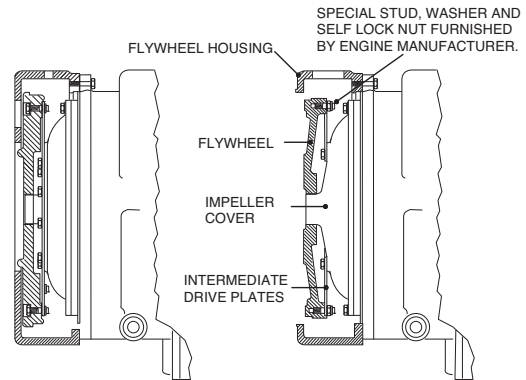


FIG. 3

FIG. 4

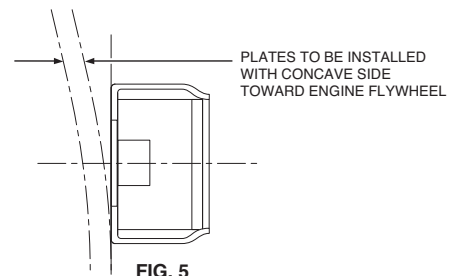
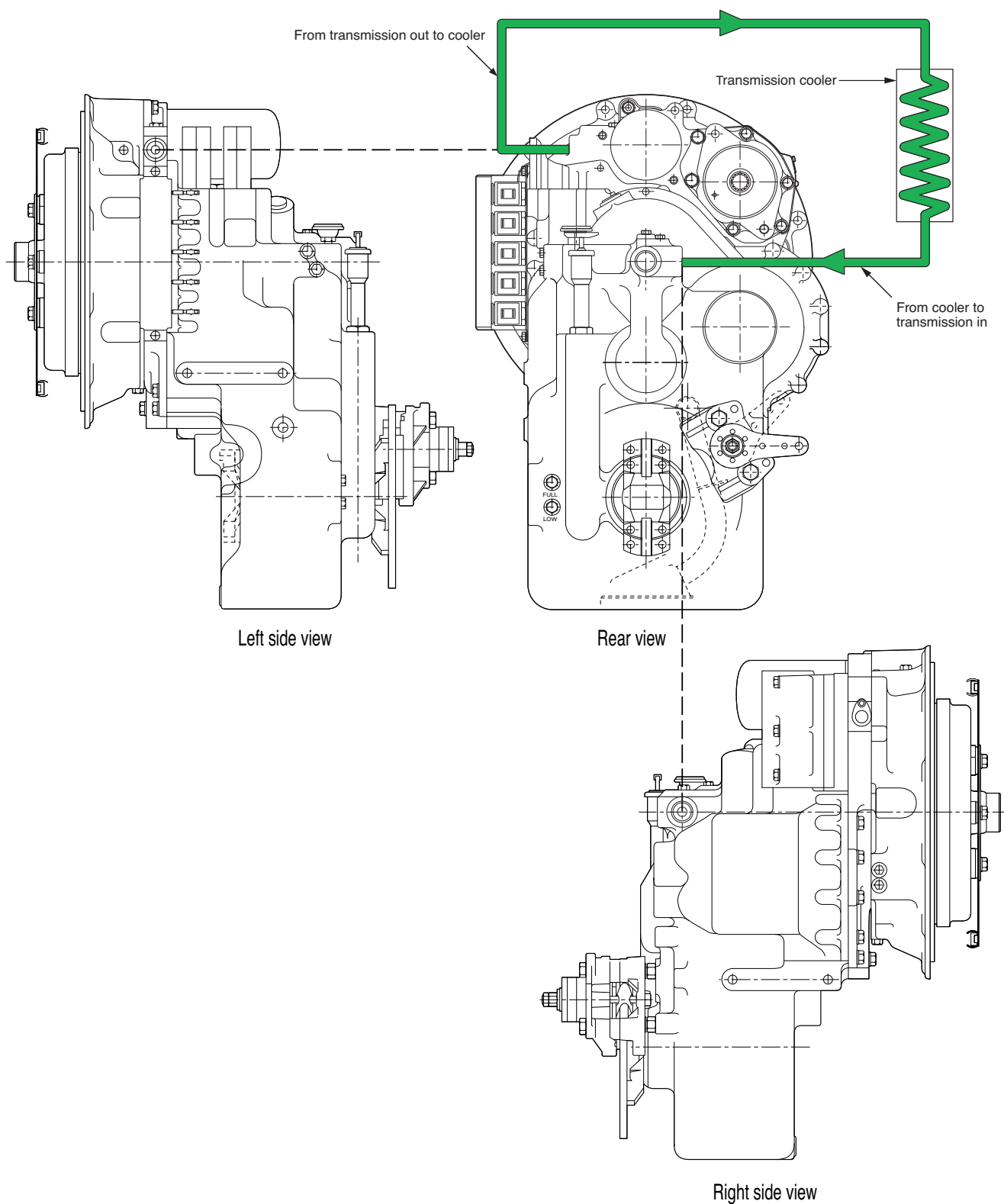


FIG. 5

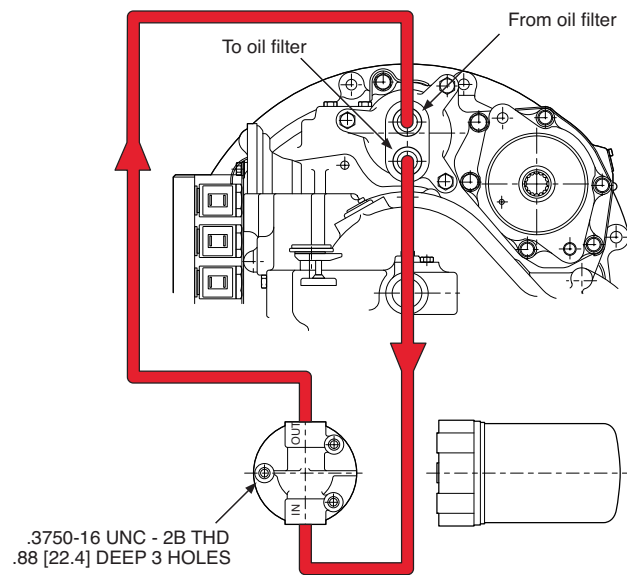
- 1 Remove all burrs from flywheel mounting face and nose pilot bore. Clean drive plate surface with solvent.
- 2 Check engine flywheel & housing for conformance to standard SAE No. 3 per SAE J927 and J1033 tolerance specifications for pilot bore size, pilot bore runout and mounting face flatness. Measure and record engine crankshaft end play (Fig. 1).
- 3 Install two 63,50 mm (2.50") long transmission to flywheel housing guide studs in the engine flywheel housing as shown. Rotate the engine flywheel to align a drive plate mounting screw hole with the flywheel housing access hole (Fig. 2).
- 4 *Install a 101,60 mm (4.00") long drive plate locating stud .3750-24 fine thread in a drive plate nut. Align the locating stud in the drive plate with the flywheel drive plate mounting screw hole positioned in step No. 3.
- 5 Rotate the transmission torque converter to align the locating stud in the drive plate with the flywheel drive plate mounting screw hole positioned in step No. 3. Locate transmission on flywheel housing. Aligning drive plate to flywheel and transmission to flywheel housing guide studs. Install transmission to flywheel housing screws. Tighten screws to specified torque. Remove transmission to engine guide studs. Install remaining screws and tighten to specified torque.
- 6 *Remove drive plate locating stud.
- 7 Install drive plate attaching screw and washer. Snug screw but do not tighten. Some engine flywheel housings have a hole located on the flywheel housing circumference in line with the drive plate screw access hole. A screwdriver or pry bar used to hold the drive plate against the flywheel will facilitate installation of the drive plate screws. Rotate the engine flywheel and install the remaining seven (7) flywheel to drive plate attaching screws. Snug screws but do not tighten. After all eight (8) screws are installed. Torque each one 35 to 39 N.m. (26-29ft.lbs.). This will require tightening each screw and rotating the engine flywheel until the full amount of eight (8) screws have been tightened to specified torque.
- 8 Measure engine crankshaft end play after transmission has been completely installed on engine flywheel. This value must be within 0,025 mm (0.001") of the end play recorded in step No. 2.

*Does not apply to units having 3 intermediate drive plates. See Fig.4.

EXTERNAL PLUMBING



OPTIONAL REMOTE FILTER



Optional remote filter

COOLER & FILTER LINES SPECIFICATIONS

- Minimum 19 mm (.75 inch) internal diameter for lines and fittings.
- Suitable for operation from ambient to 120 °C (248 F) continuous operating temperature.
- Must withstand 20 bar (290 psi) continuous pressure and with 40 bar (580 psi) intermittent surges.
- Conform SAE J1019 and SAE J517,100RI.

SPEED SENSOR INSTALLATION

On the sensor body there is a small plastic triangular position sign. Make sure the position sign on the sensor points as shown below in the direction of the movement of the gear teeth (Teeth rotation as shown).

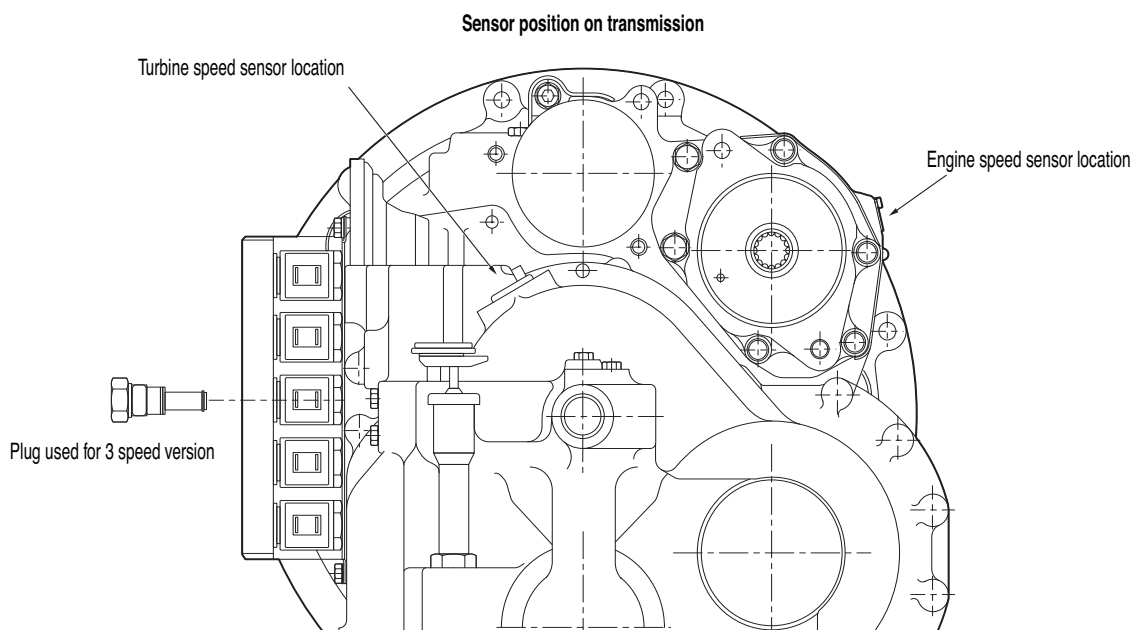
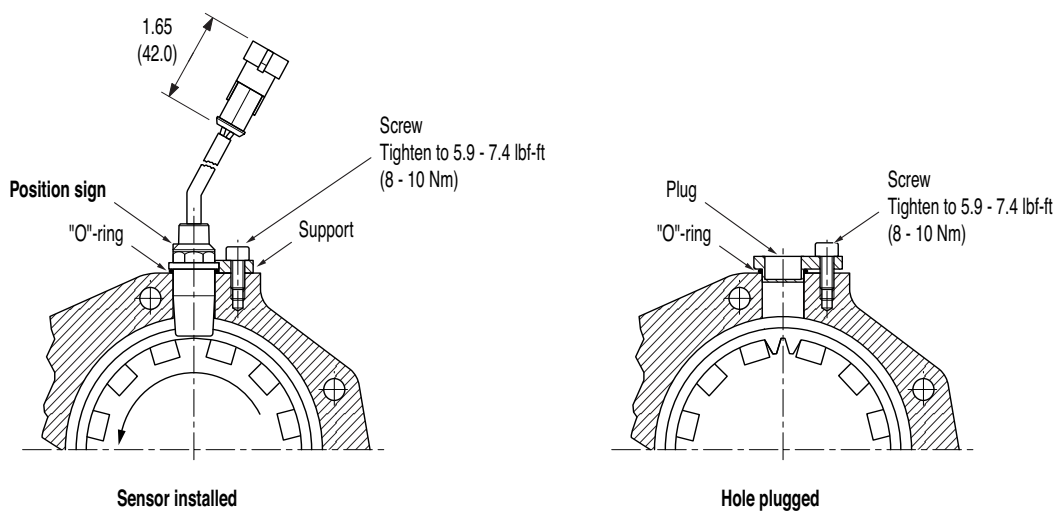
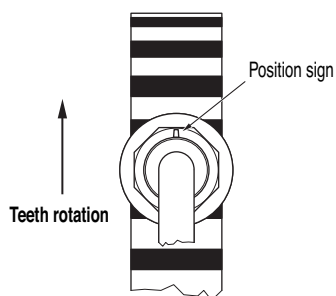
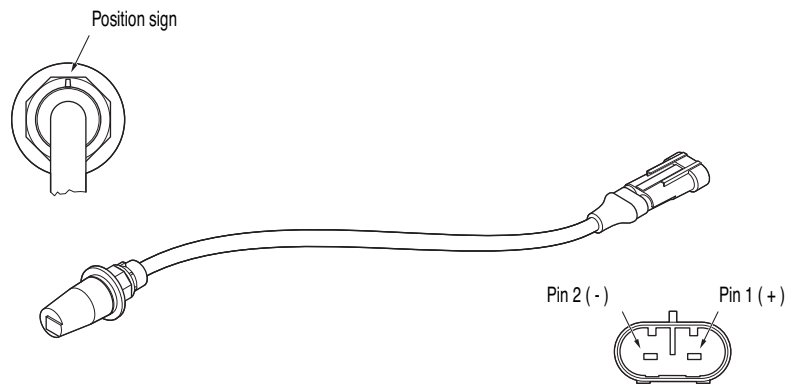


Fig. 6 Sensor installation





The magneto resistive sensor generates a square wave current with a fixed amplitude changing between 7 mA and 14 mA.

The sensor has an integrated AMP superseal 2 pin connector.

The two pins are numbered 1 and 2.

Following table shows the relation between wire colour, pin number and connection.






COLOUR	PIN NUMBER	FUNCTION	CONNECTION
BROWN	1	Current input	Hot wire
BLUE	2	current output	Ground wire

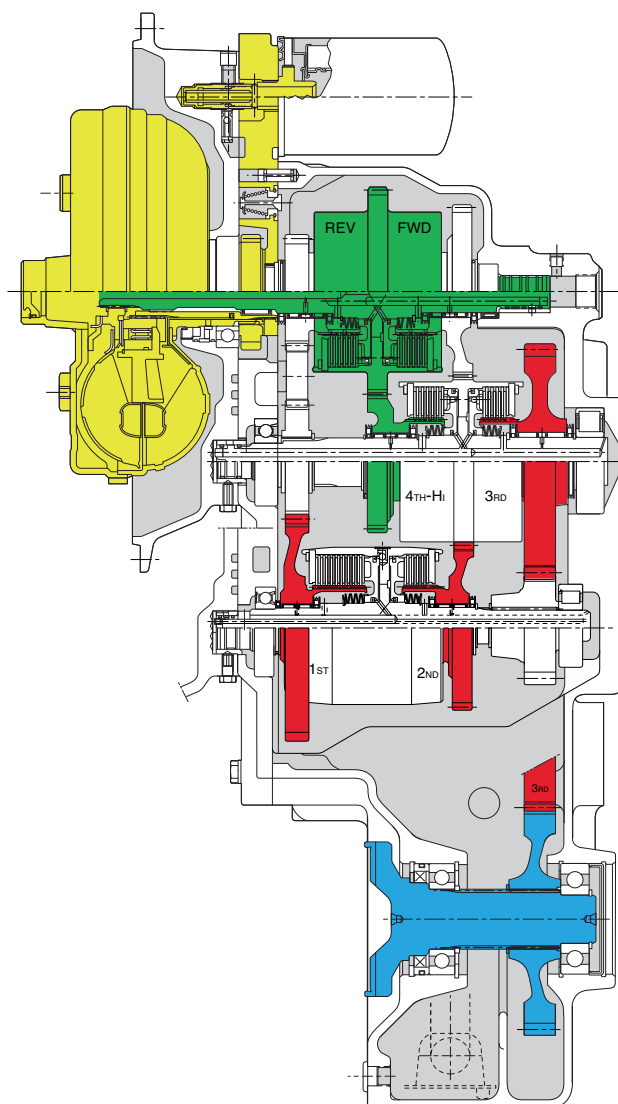
NOTE: THE SENSOR WIRES HAVE A POLARITY.
Be sure to correctly observe sensor polarities, as wrong connections will deactivate the sensor!

OPERATION OF THE T12000 TRANSMISSION

THE TRANSMISSION ASSEMBLY

Basically the transmission is composed of five main assemblies:

1.  The converter, pump drive section and pressure regulating valve.
2.  The input shaft and directional clutches.
3.  The range clutches.
4.  The output section.
5.  The transmission solenoids.



THE CONVERTER, PUMP DRIVE SECTION AND PRESSURE REGULATING VALVE

Engine power is transmitted from the engine flywheel to the impeller through the impeller cover.

This element is the pump portion of the hydraulic torque converter and is the primary component which starts the oil flowing to the other components which results in torque multiplication. This element can be compared to a centrifugal pump, that picks up fluid at its centre and discharges it at the outer diameter.

The torque converter turbine is mounted opposite the impeller and is connected to the turbine shaft of the torque converter. This element receives fluid at its outer diameter and discharges it at its centre.

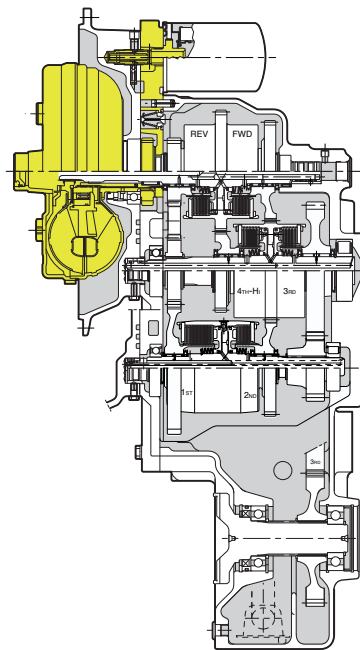
The reaction member of the torque converter is located between and at the centre of the inner diameters of the impeller and turbine elements. Its function is to take the fluid which is exhausting from the inner portion of the turbine and change its direction to allow correct entry for recirculation into the impeller element. This recirculation will make the converter to multiply torque.

The torque multiplication is function of the blading (impeller, turbine and reaction member) and the converter output speed (turbine speed). The converter will multiply engine torque to its designed maximum multiplication ratio when the turbine shaft is at zero RPM (stall).

Therefore we can say that as the turbine shaft is decreasing in speed, the torque multiplication is increasing. The hydraulic pump is connected with the pump drive gear. This pump drive gear is driven by the impeller hub gear. Since the impeller hub gear is connected with the impeller cover, the pump speed is in direct relation with the engine speed.



NOTE: THE PRESSURE REGULATOR VALVE IS MOUNTED BEHIND THE FILTER, IN THE FILTER ADAPTER HOUSING.



 THE CONVERTER, PUMP DRIVE SECTION AND PRESSURE REGULATING VALVE

THE INPUT SHAFT AND DIRECTIONAL CLUTCHES

The turbine shaft driven from the turbine transmits power to the forward, 4th-High or reverse clutch. These clutches consist of a drum with internal splines and a bore to receive a hydraulic actuated piston. The piston is oil tight by the use of sealing rings. The steel discs with external splines, and friction discs with internal splines, are alternated until the required total is achieved.

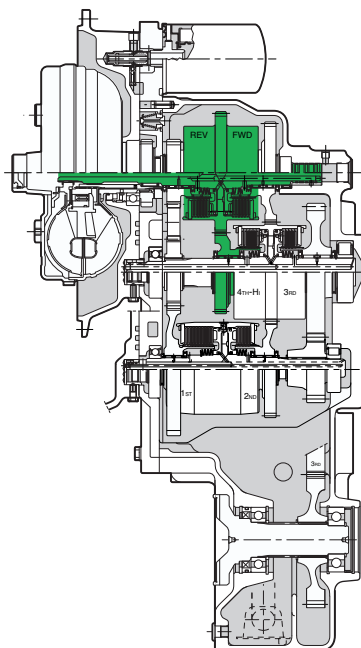
A back-up plate is then inserted and secured with a retainer ring. A hub with outer diameter splines is inserted into the splines of discs with teeth on the inner diameter. The discs and hub are free to increase in speed or rotate in the opposite direction as long as no pressure is present in that specific clutch. To engage the clutch, the solenoid will direct oil under pressure through tubes and passages to the selected clutch shafts. Oil sealing rings are located on the clutch shafts. These rings direct the oil through a drilled passage in the shaft to the desired clutch.

Pressure of the oil forces the piston and discs against the back-up plate. The discs with splines on the outer diameter clamping against discs with teeth on the inner diameter enables the drum and hub to be locked together and allows them to drive as one unit. When the clutch is released, a return spring will push the piston back and oil will drain back via the solenoid, the bleed valve or holes in the clutch piston into the transmission sump.

These bleed valves will only allow quick escape of oil when the pressure to the piston is released. The T12000 transmission, 3-speed version, has one reverse clutch and one forward clutch. This in combination with the 3 range clutches results in the transmission having 3 forward and 3 reverse speeds.

The T12000 transmission, 4- and 6-speed versions, have one reverse clutch and two forward clutches (forward and 4th-High). This in combination with the 3 range clutches results in the transmission having 4 forward (for the 4-speed) or 6 forward (for the 6-speed) and 3 reverse speeds.

The engagement of the directional clutches (forward and reverse) are modulated. This means that clutch pressure is built up gradually. This will enable the unit to make forward, reverse shifts while the vehicle is still moving and will allow smooth engagement of drive. The modulation is done hydraulically.



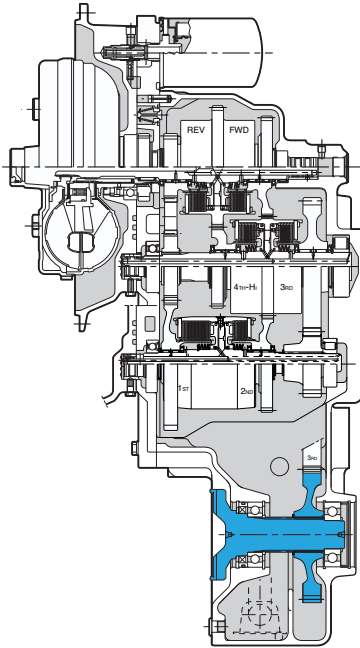
 THE INPUT SHAFT AND DIRECTIONAL CLUTCHES


THE RANGE CLUTCHES

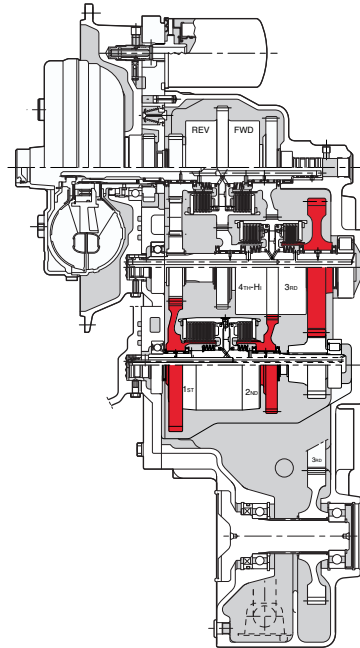
Once a directional clutch is engaged power is transmitted to the range clutches (1st, 2nd or 3rd).
Operation and actuation of the range clutches is similar to the directional clutches.
The engagement of the range clutches is not modulated.

THE OUTPUT SECTION

With a range clutch engaged, power is finally transmitted to the output shaft. Output rotation is same as the engine rotation when the forward clutch is engaged. A front axle disconnect is optional and is located on the output shaft.
The drive to the front axle can be disconnected or connected by manual shifting.



 THE OUTPUT SECTION

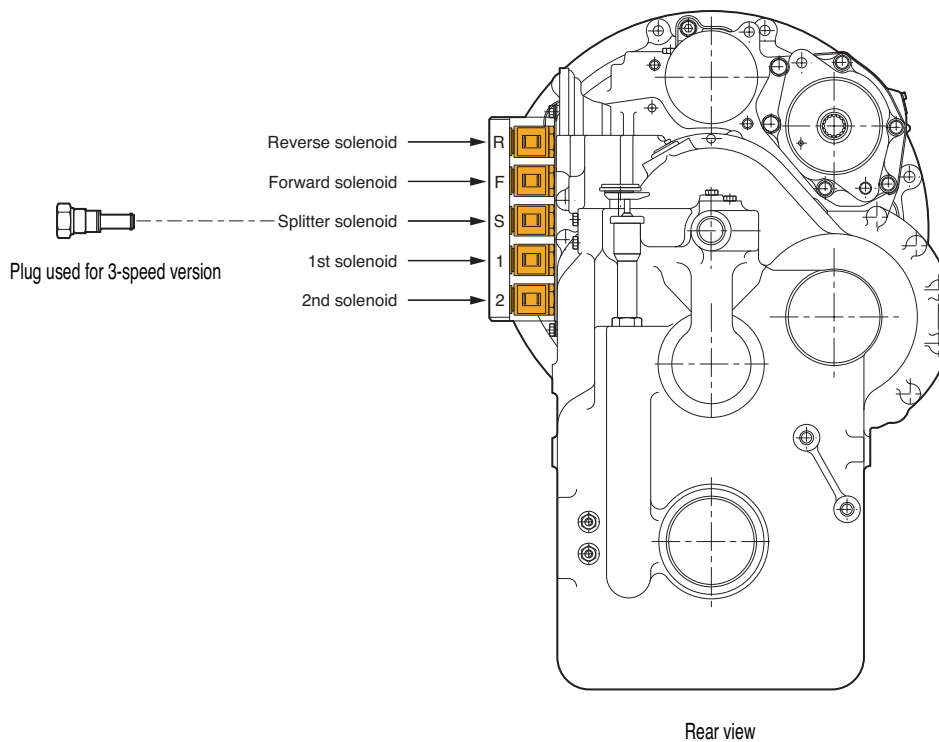


 THE RANGE CLUTCHES

Fig. 7

THE TRANSMISSION CONTROLS (REFER TO HYDRAULIC DIAGRAM)

The transmission is controlled by the direction and range solenoids. The solenoids are mounted on the left side of the transmission case. When the selected direction and range solenoids are energised, oil under pressure will flow through tubes and passages to the selected clutch shafts. Oil sealing rings are located on the clutch shafts. These rings direct oil under pressure through a drilled passage way in the shaft to the desired clutch.



 THE TRANSMISSION CONTROLS

ELECTRIC SOLENOID CONTROLS

3-SPEED TRANSMISSION

TRANSMISSION GEAR	ACTIVATED SOLENOIDS	ACTIVATED CLUTCHES
Forward 3	Forward	Forward, 3rd
Forward 2	Forward, 2nd	Forward, 2nd
Forward 1	Forward, 1st, 2nd	Forward, 1st
Neutral 3	-	3rd
Neutral 2	2nd	2nd
Neutral 1	1st, 2nd	1st
Reverse 3	Reverse	Reverse, 3rd
Reverse 2	Reverse, 2nd	Reverse, 2nd
Reverse 1	Reverse, 1st, 2nd	Reverse, 1st



FOR THE 3-SPEED TRANSMISSION, THE SPLITTER SOLENOID DOES NOT EXSIST.

3-SPEED TRANSMISSION

STANDARD 4-SPEED TRANSMISSION (1, 3, 5, 6 ≈ 6-SPEED)

TRANSMISSION GEAR	ACTIVATED SOLENOIDS	ACTIVATED CLUTCHES
Forward 4	Forward, Splitter	4th-High, 3rd
Forward 3	Forward	Forward, 3rd
Forward 2	Forward, 2nd	Forward, 2nd
Forward 1	Forward, 1st, 2nd	Forward, 1st
Neutral 3	-	3rd
Neutral 2	2nd	2nd
Neutral 1	1st, 2nd	1st
Reverse 3	Reverse	Reverse, 3rd
Reverse 2	Reverse, 2nd	Reverse, 2nd
Reverse 1	Reverse, 1st, 2nd	Reverse, 1st

ALTERNATIVE 4-SPEED TRANSMISSION, MODEL T12496 ONLY (1, 3, 4, 5 ≈ 6-SPEED)

TRANSMISSION GEAR	ACTIVATED SOLENOIDS	ACTIVATED CUTCHES
Forward 4	Forward	Forward, 3rd
Forward 3	Forward, Splitter, 2nd	4th-High, 3rd
Forward 2	Forward, 2nd	Forward, 2nd
Forward 1	Forward, 1st, 2nd	Forward, 1st
Neutral 3	-	3rd
Neutral 2	2nd	2nd
Neutral 1	1st, 2nd	1st
Reverse 3	Reverse	Reverse, 3rd
Reverse 2	Reverse, 2nd	Reverse, 2nd

TRANSMISSION GEAR	ACTIVATED SOLENOIDS	ACTIVATED CUTCHES
Reverse 1	Reverse, 1st, 2nd	Reverse, 1st

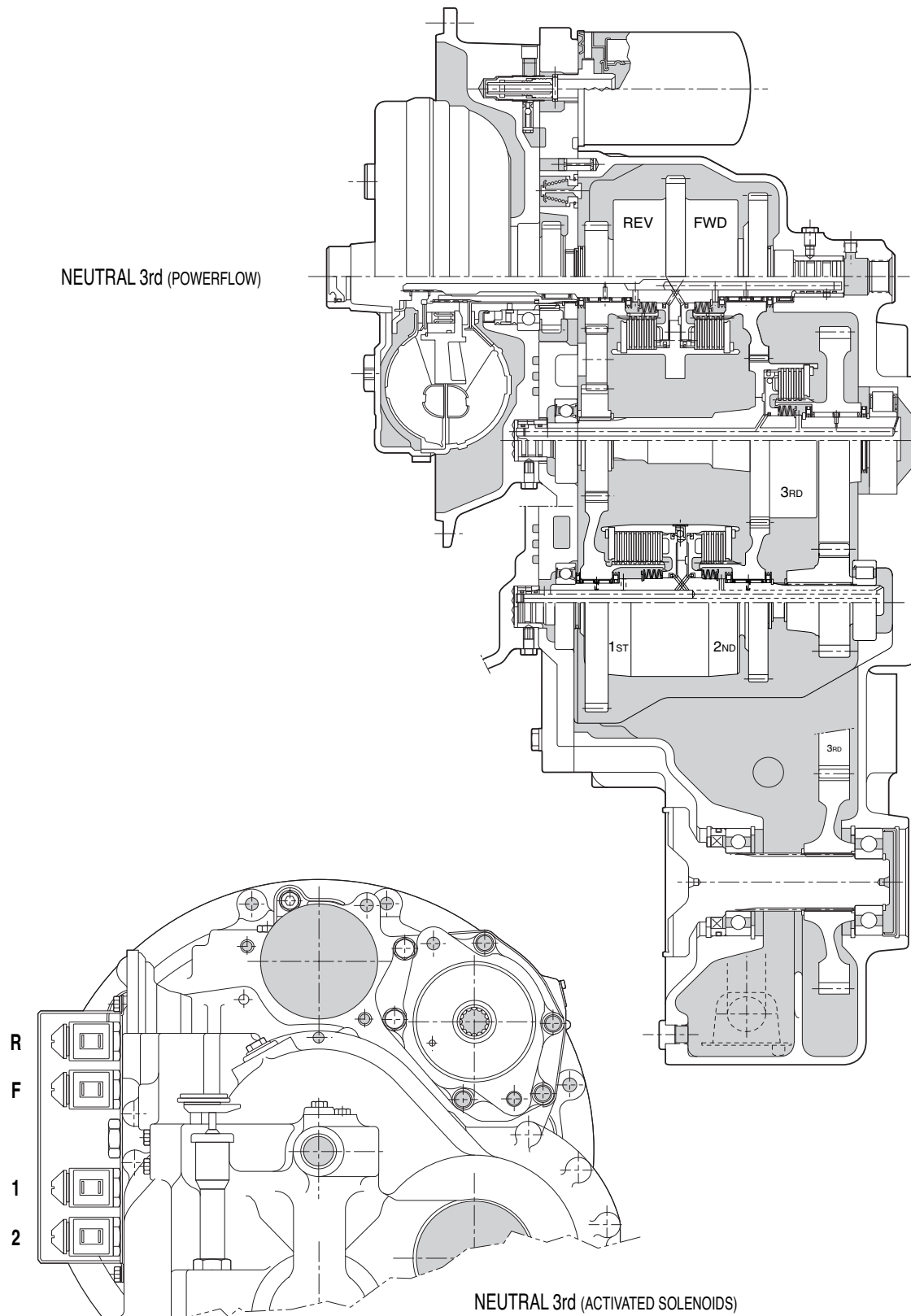
6-SPEED TRANSMISSION

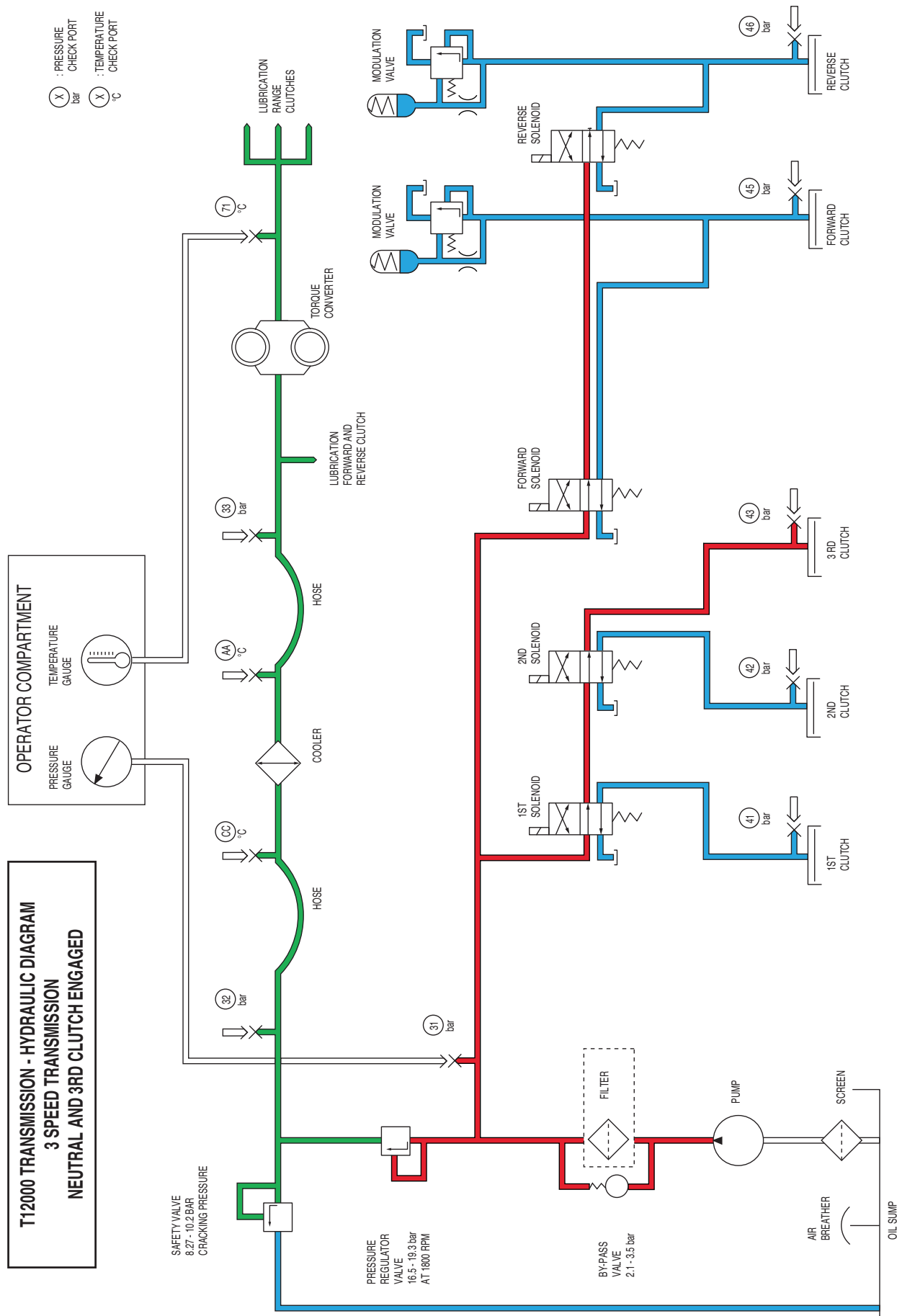
TRANSMISSION GEAR	ACTIVATED SOLENOIDS	ACTIVATED CUTCHES
Forward 6	Forward, Splitter	4th-High, 3rd
Forward 5	Forward	Forward, 3rd
Forward 4	Forward, Splitter, 2nd	4th-High, 2nd
Forward 3	Forward, 2nd	Forward, 2nd
Forward 2	Forward, Splitter, 1st, 2nd	4th-High, 1st
Forward 1	Forward, 1st, 2nd	Forward, 1st
Neutral 3	-	3rd
Neutral 2	2nd	2nd
Neutral 1	1st, 2nd	1st
Reverse 3	Reverse	Reverse, 3rd
Reverse 2	Reverse, 2nd	Reverse, 2nd
Reverse 1	Reverse, 1st, 2nd	Reverse, 1st

POWERFLOWS, ACTIVATED SOLENOIDS AND HYDRAULIC CIRCUIT

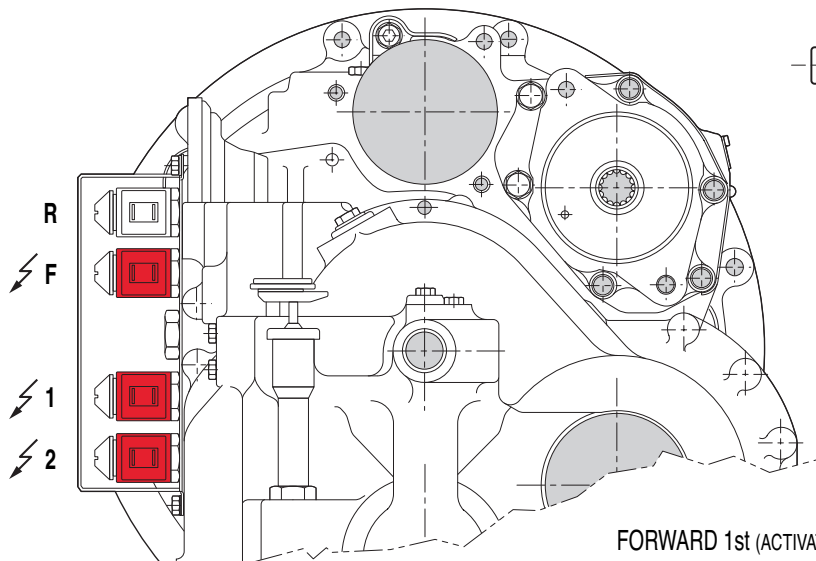
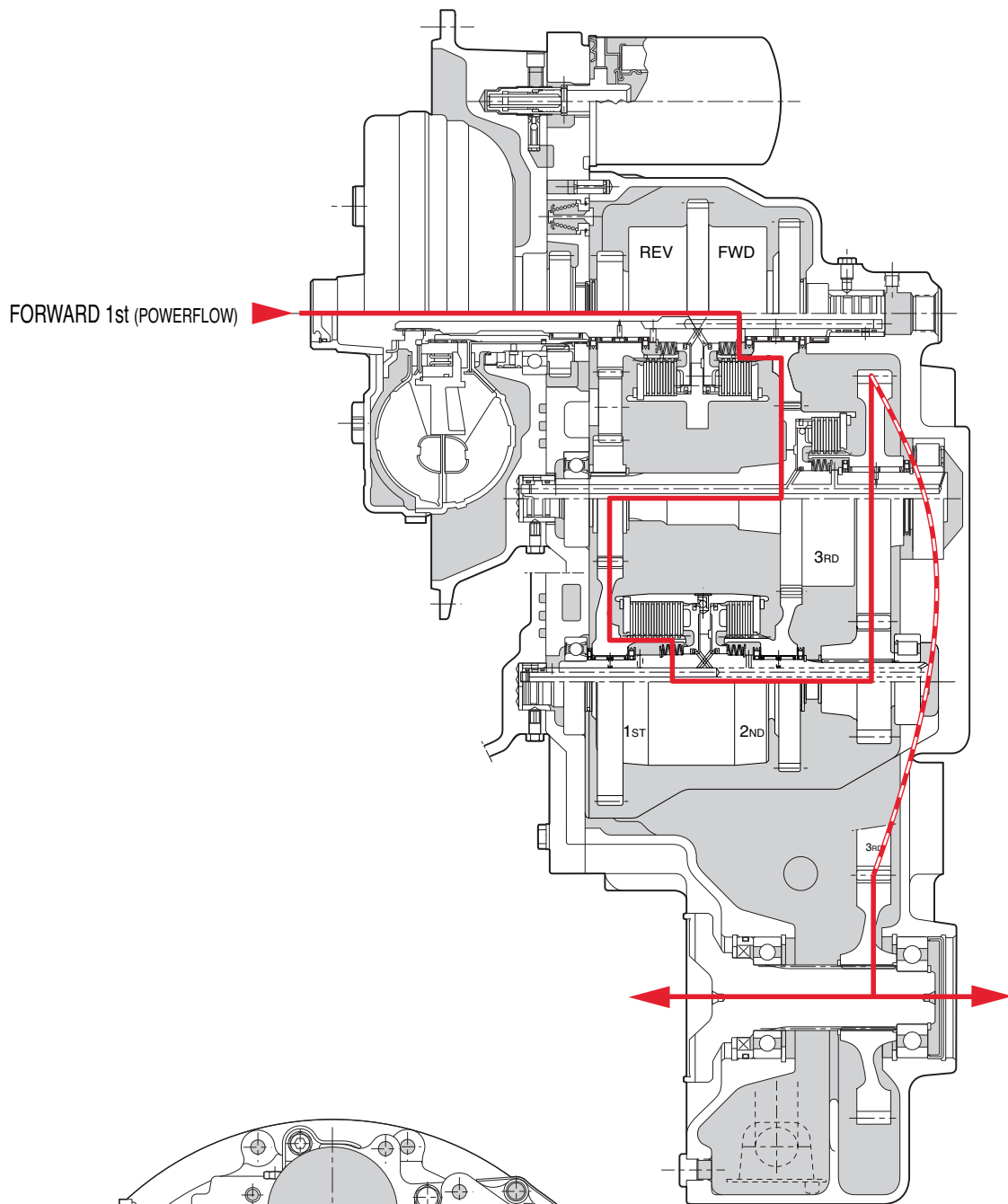
3-SPEED TRANSMISSION

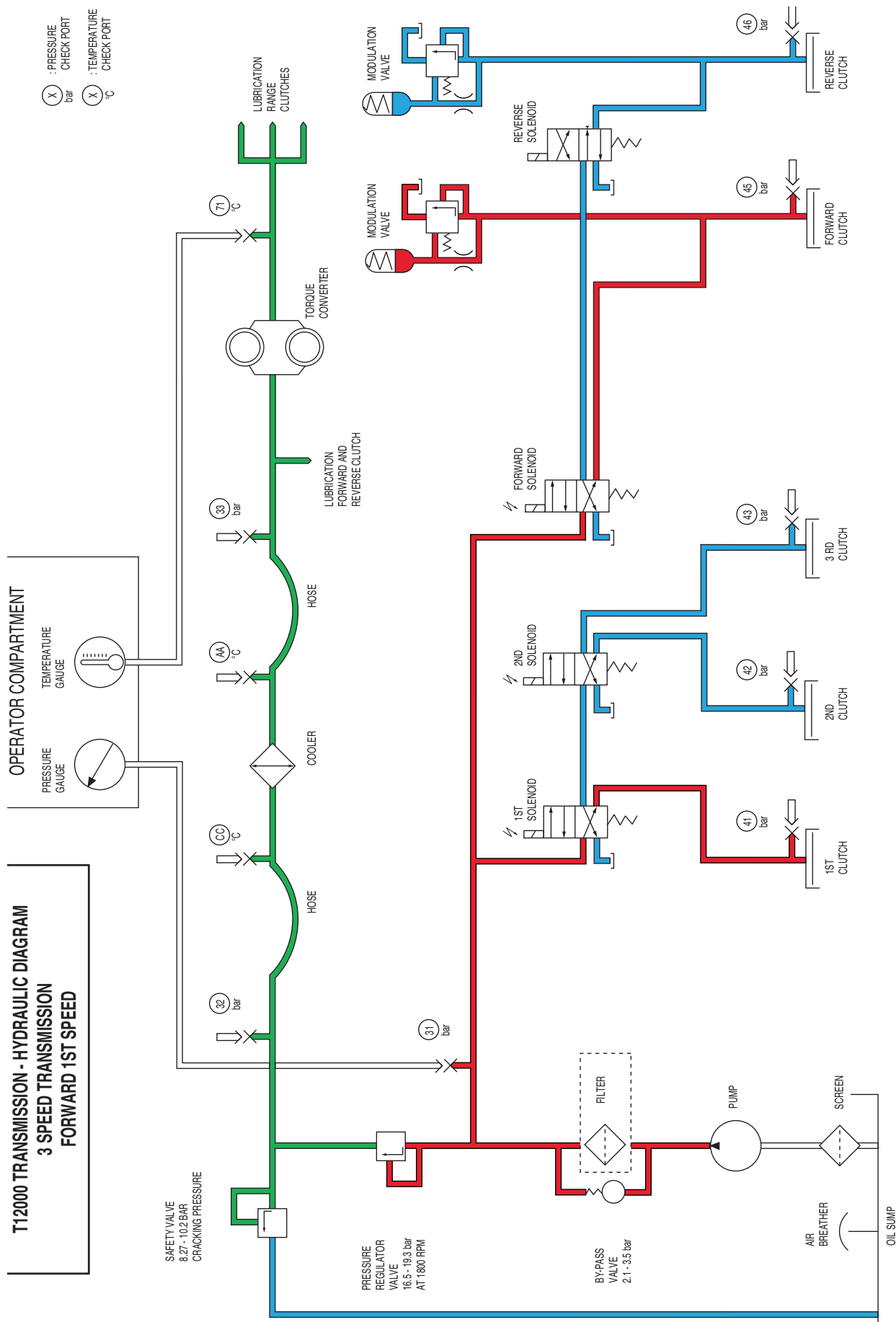
NEUTRAL AND 3RD CLUTCH ENGAGED



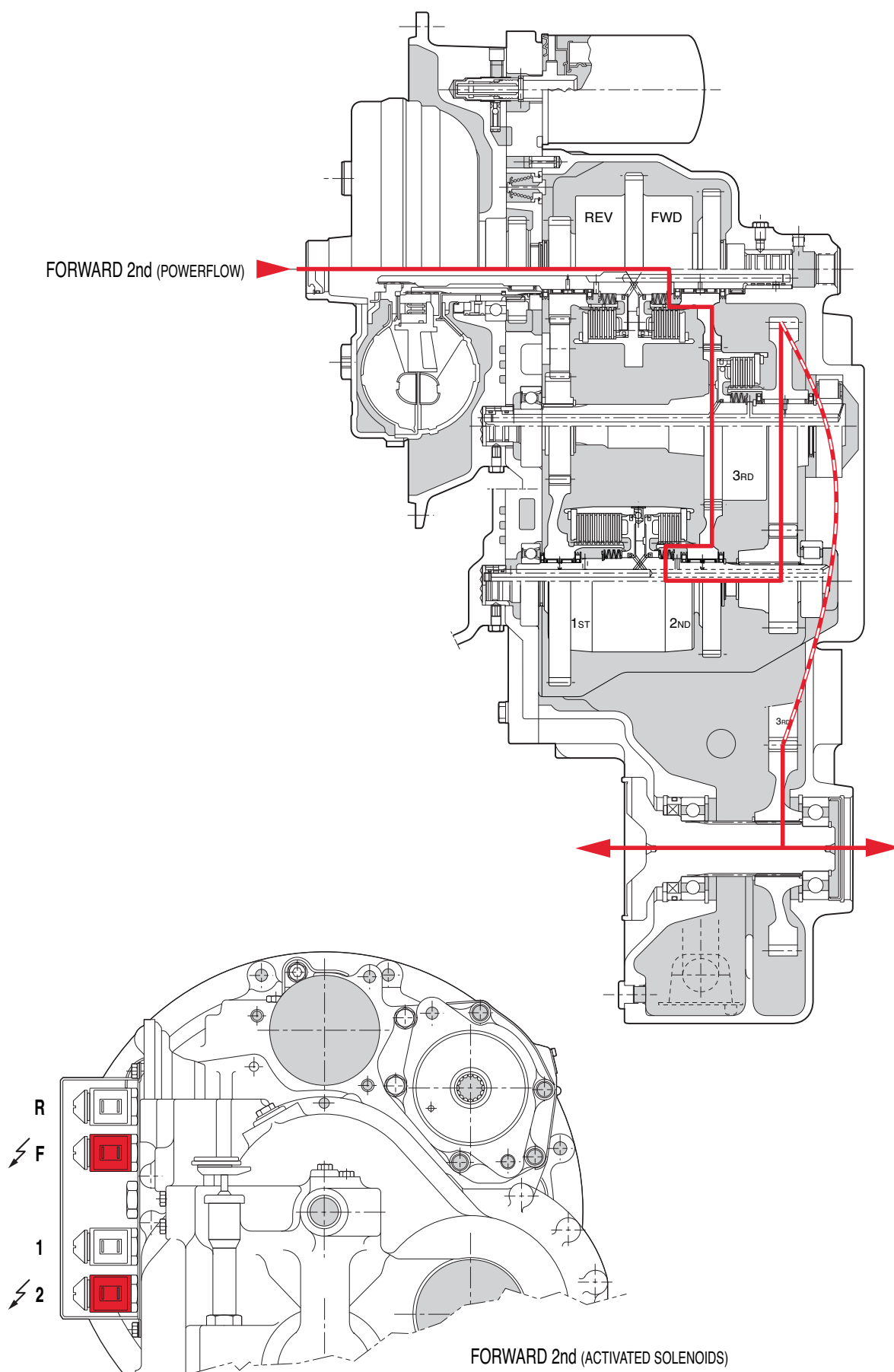


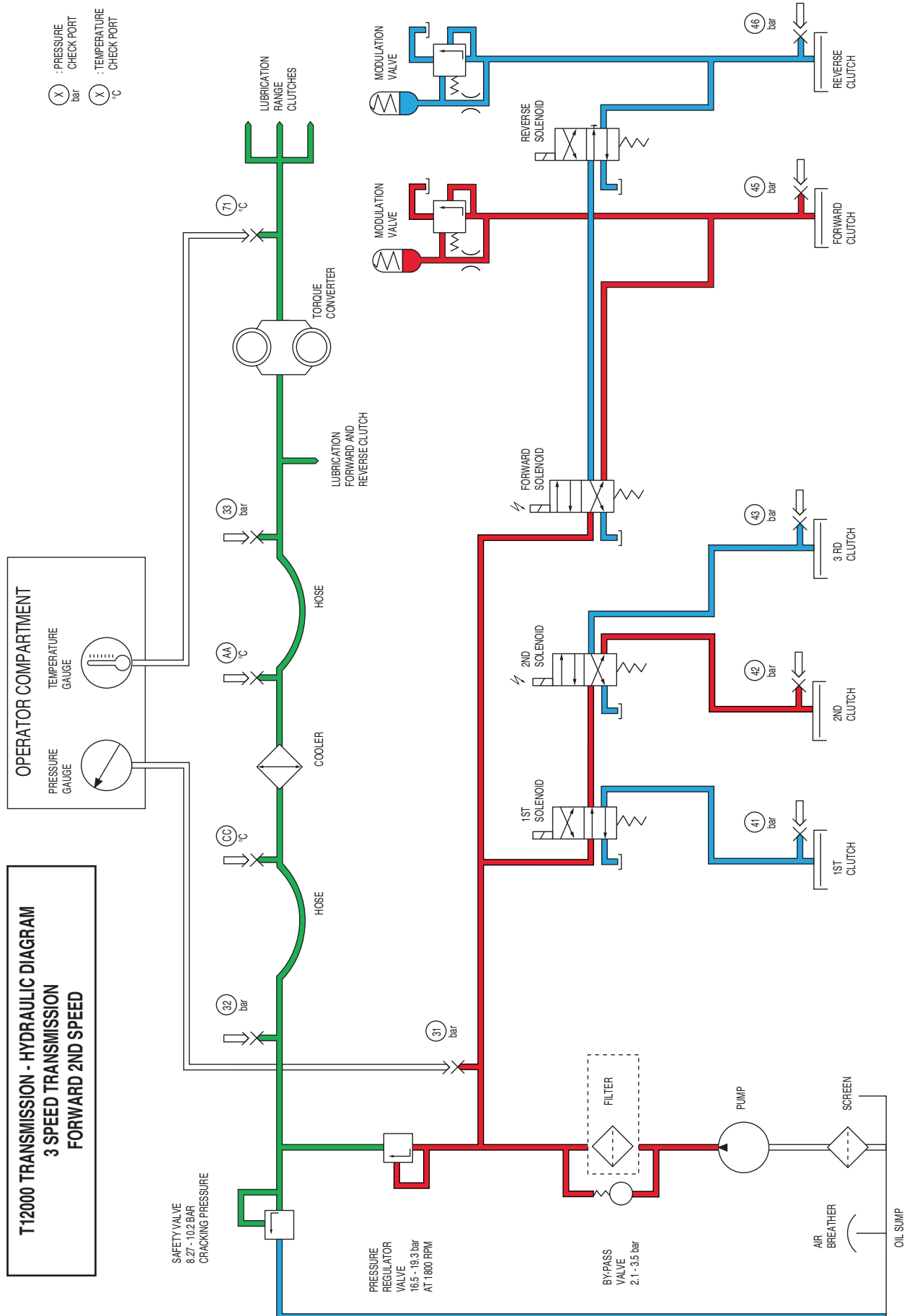
FORWARD 1ST SPEED



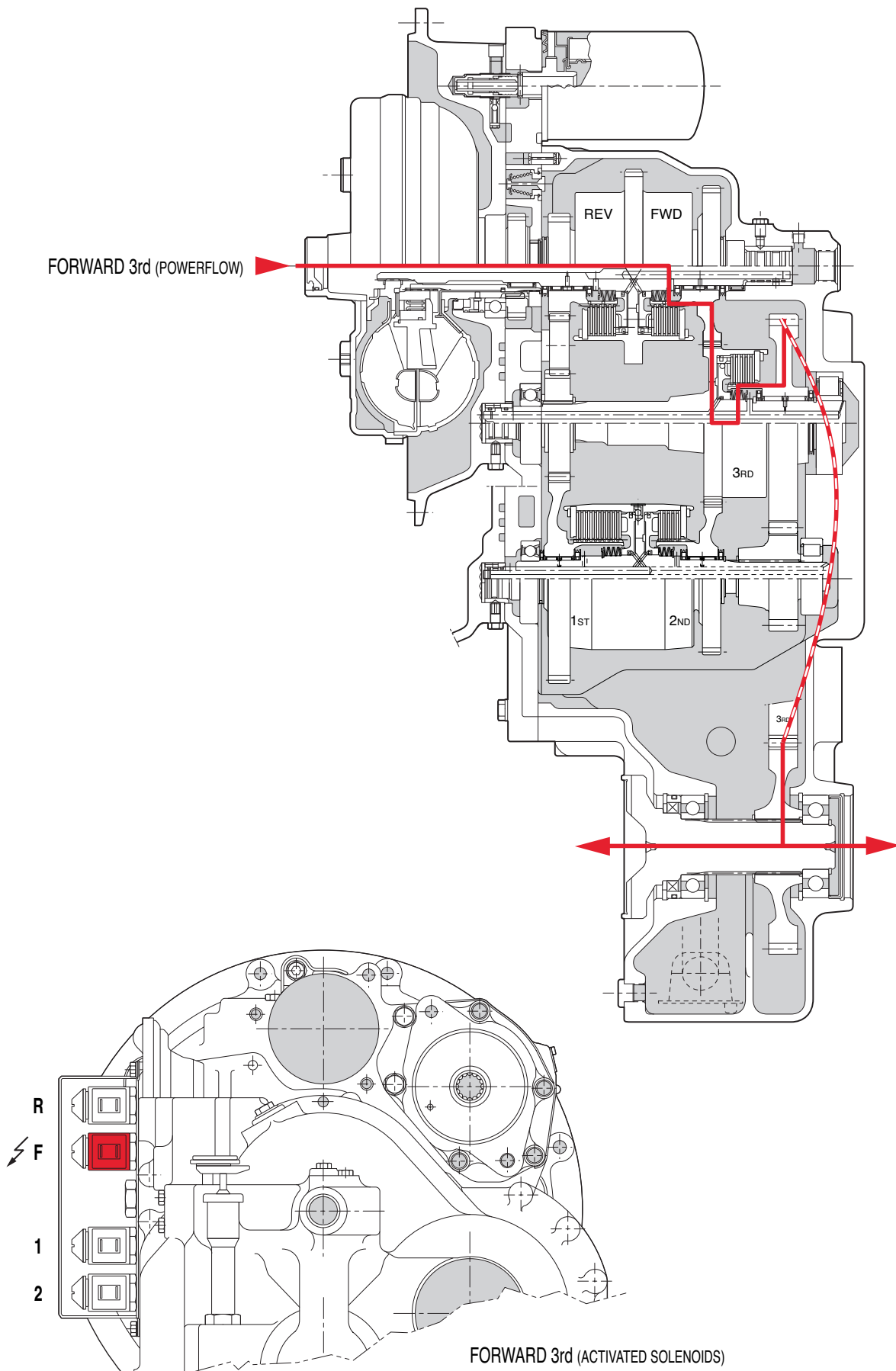


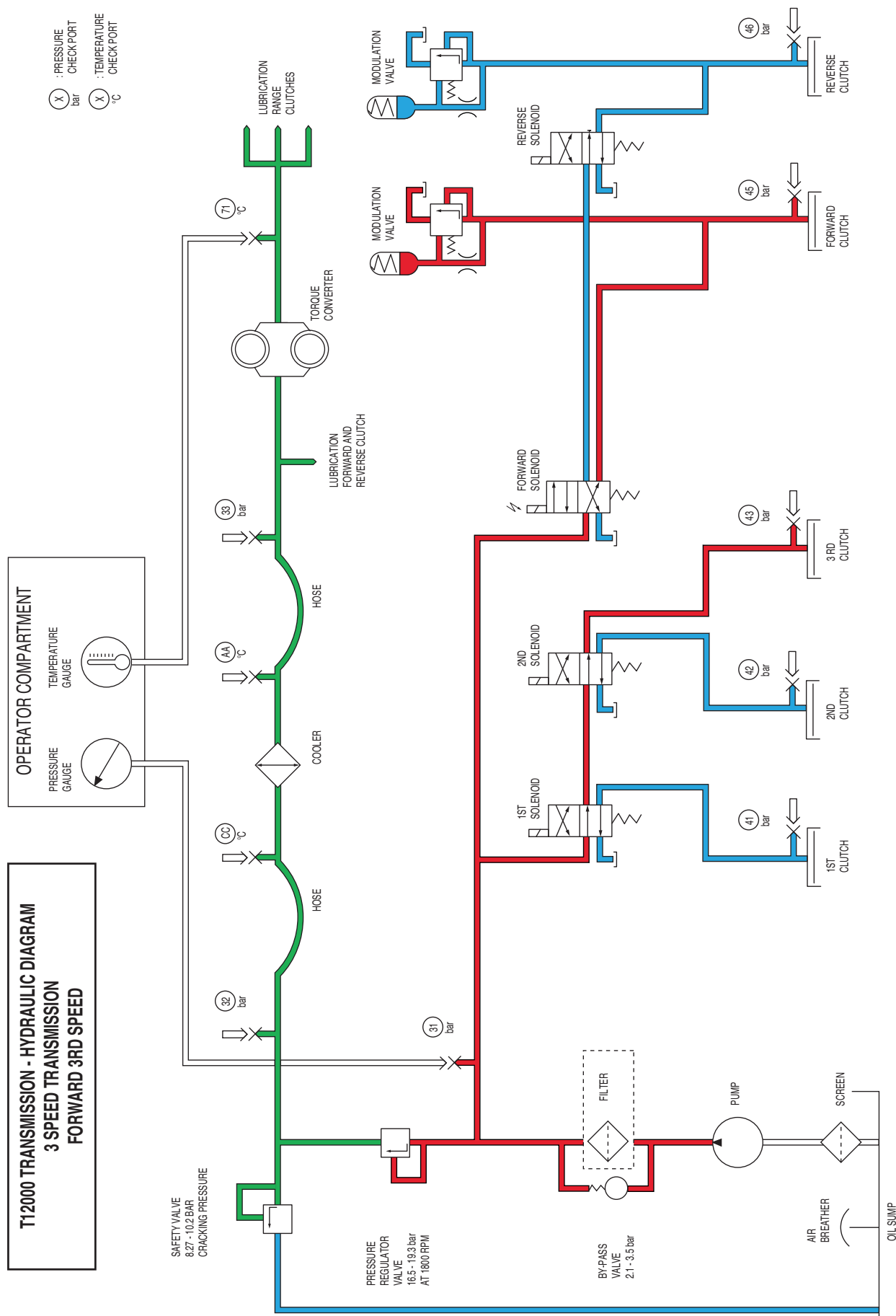
FORWARD 2ND SPEED



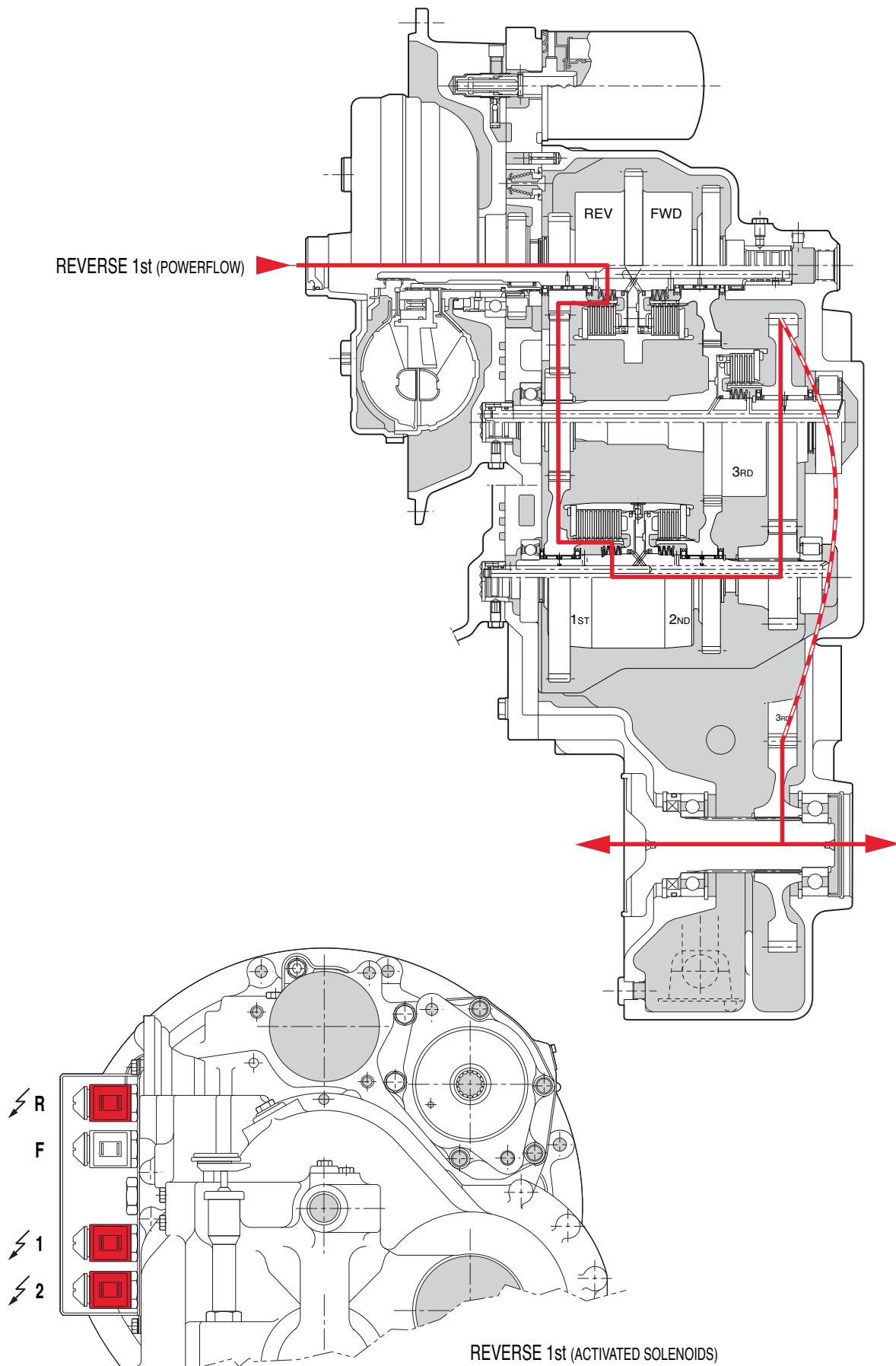


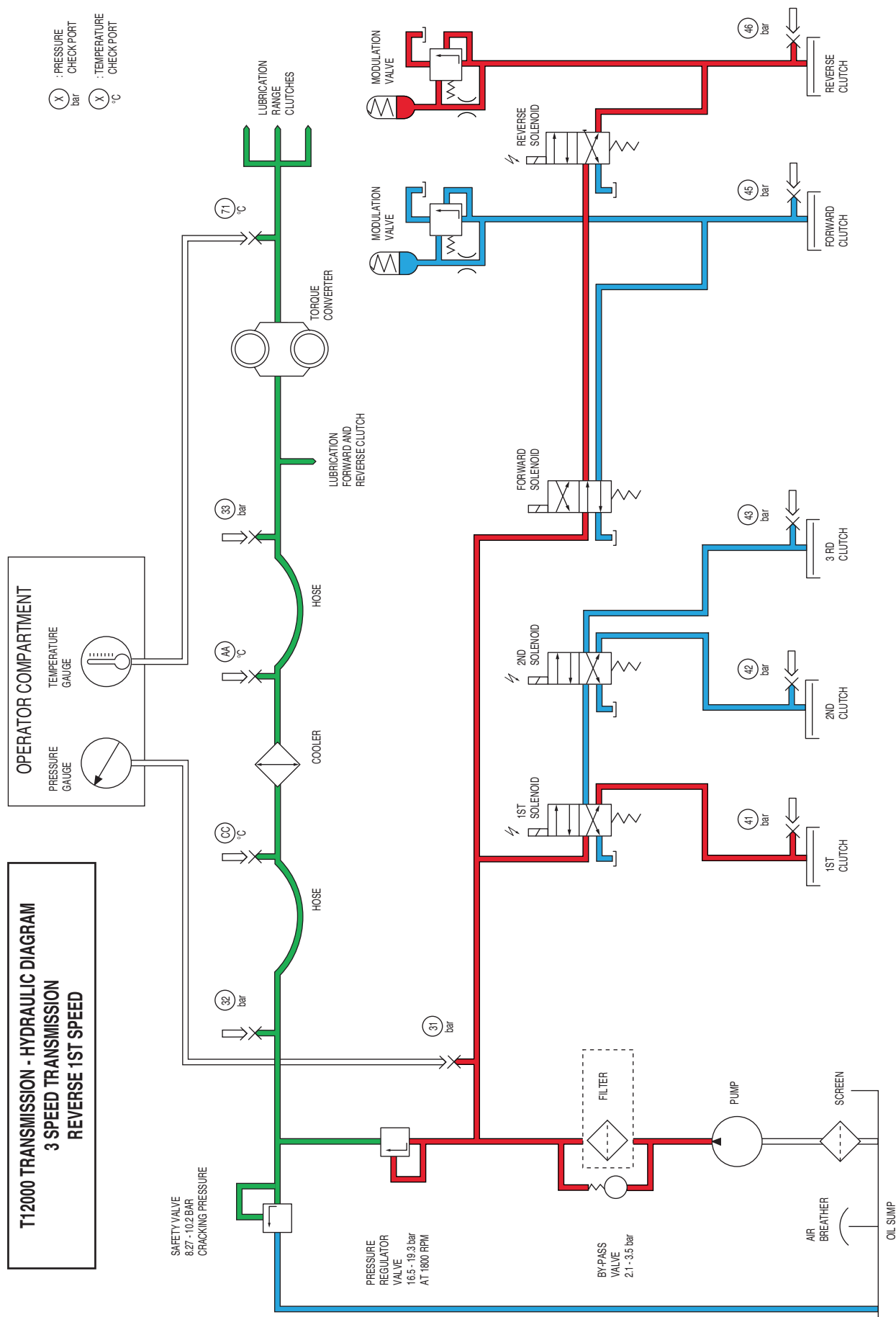
FORWARD 3RD SPEED





REVERSE 1ST SPEED



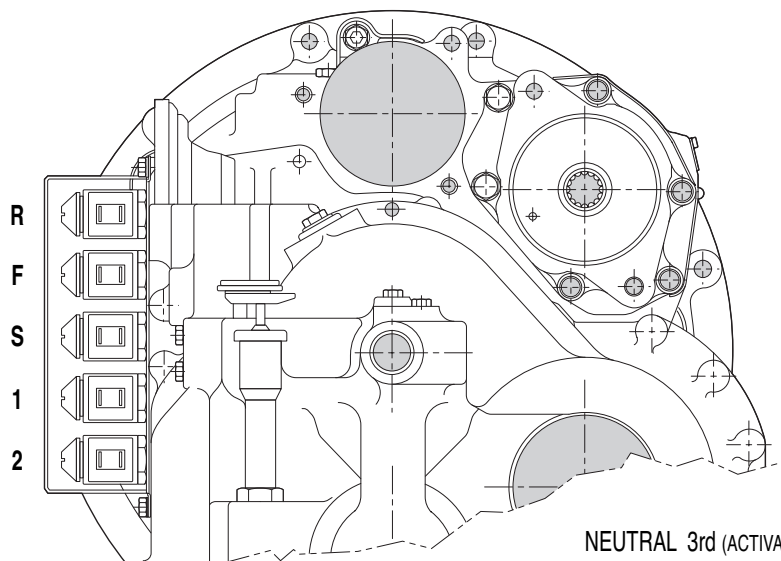
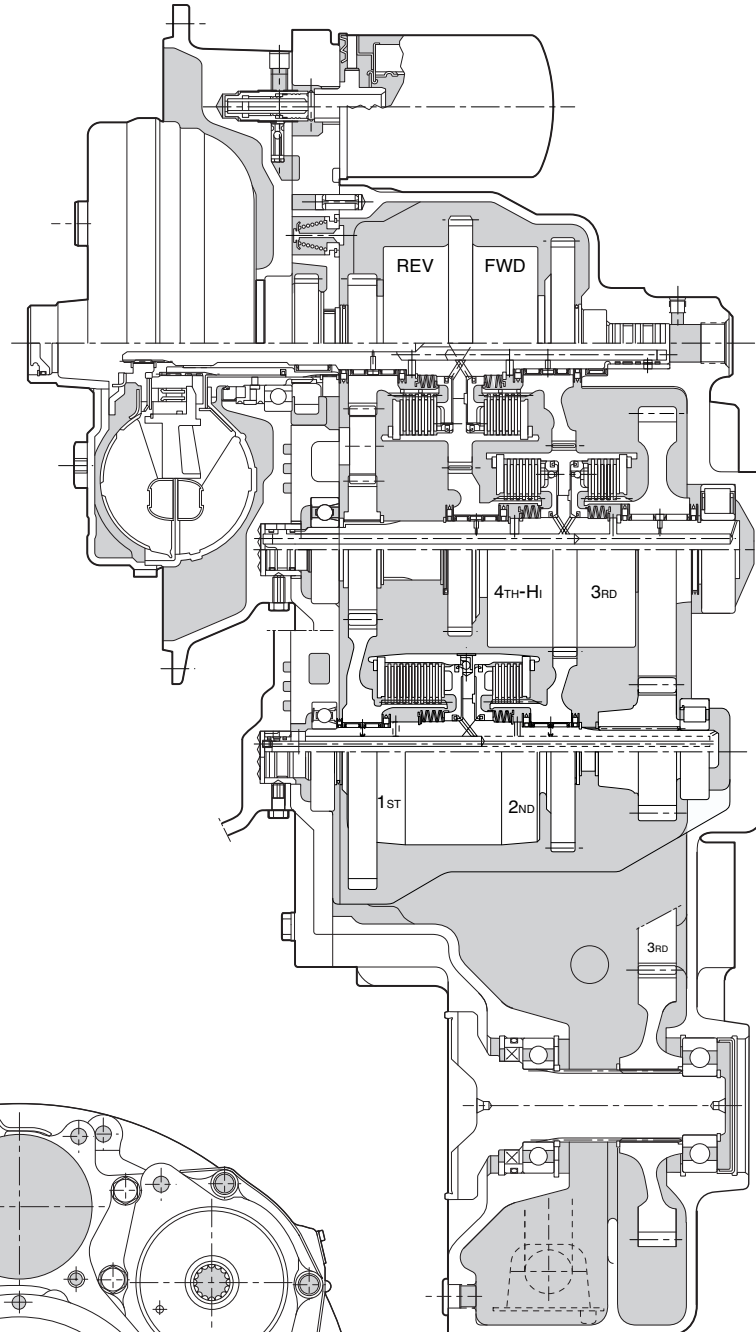


4-SPEED TRANSMISSION

STANDARD 4-SPEED TRANSMISSION

Neutral and 3rd clutch engaged

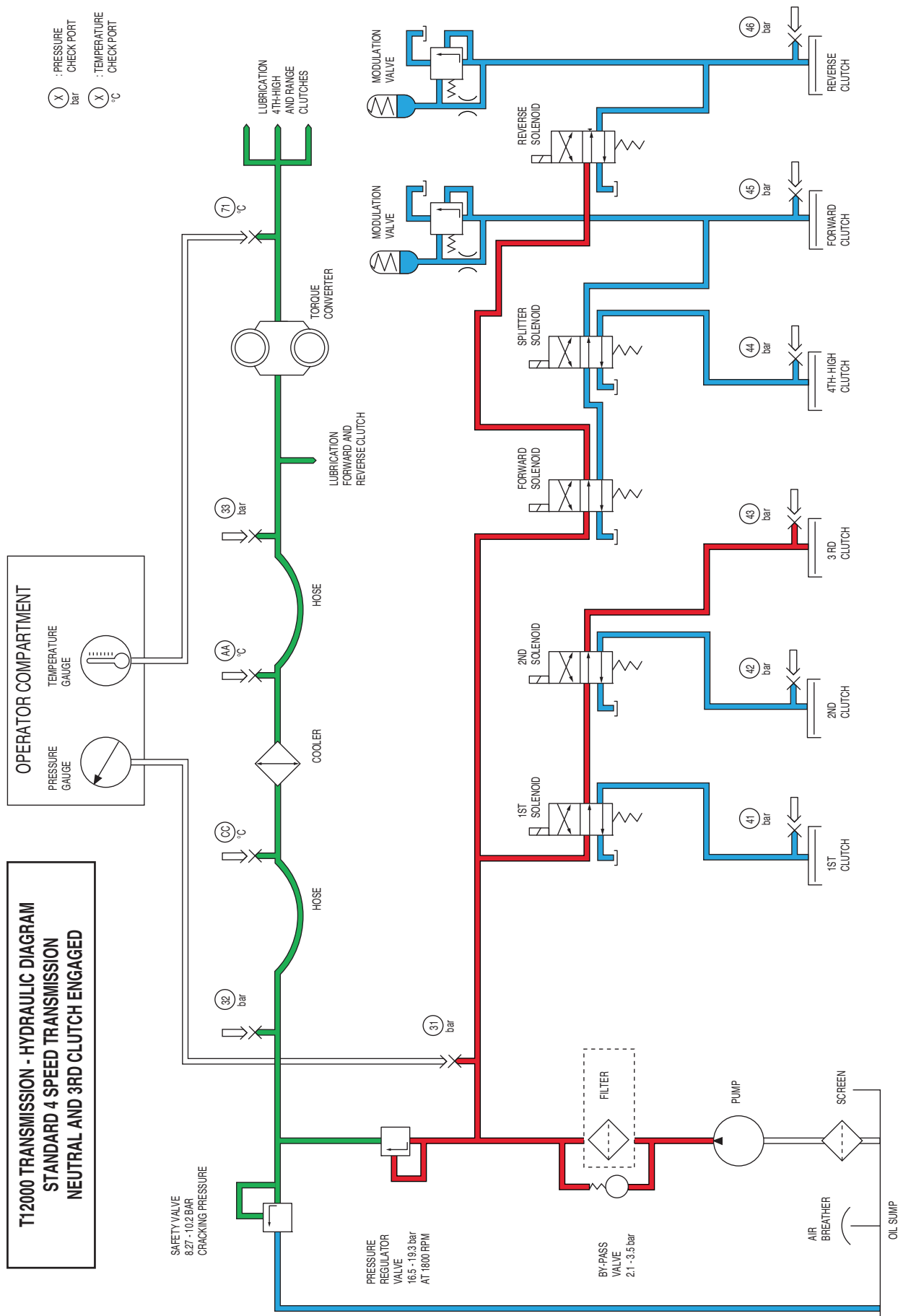
NEUTRAL 3rd (POWERFLOW)

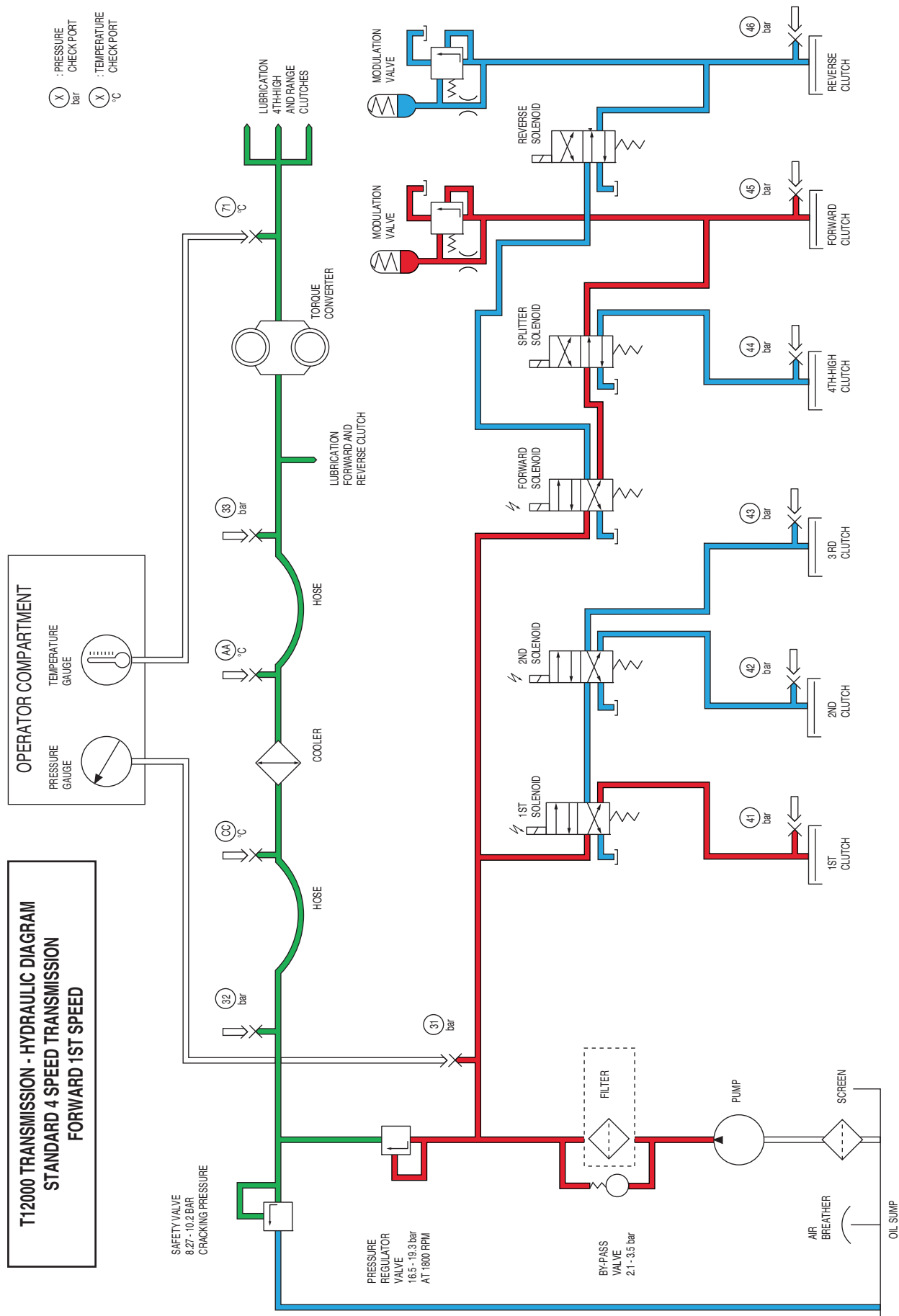


NEUTRAL 3rd (ACTIVATED SOLENOIDS)

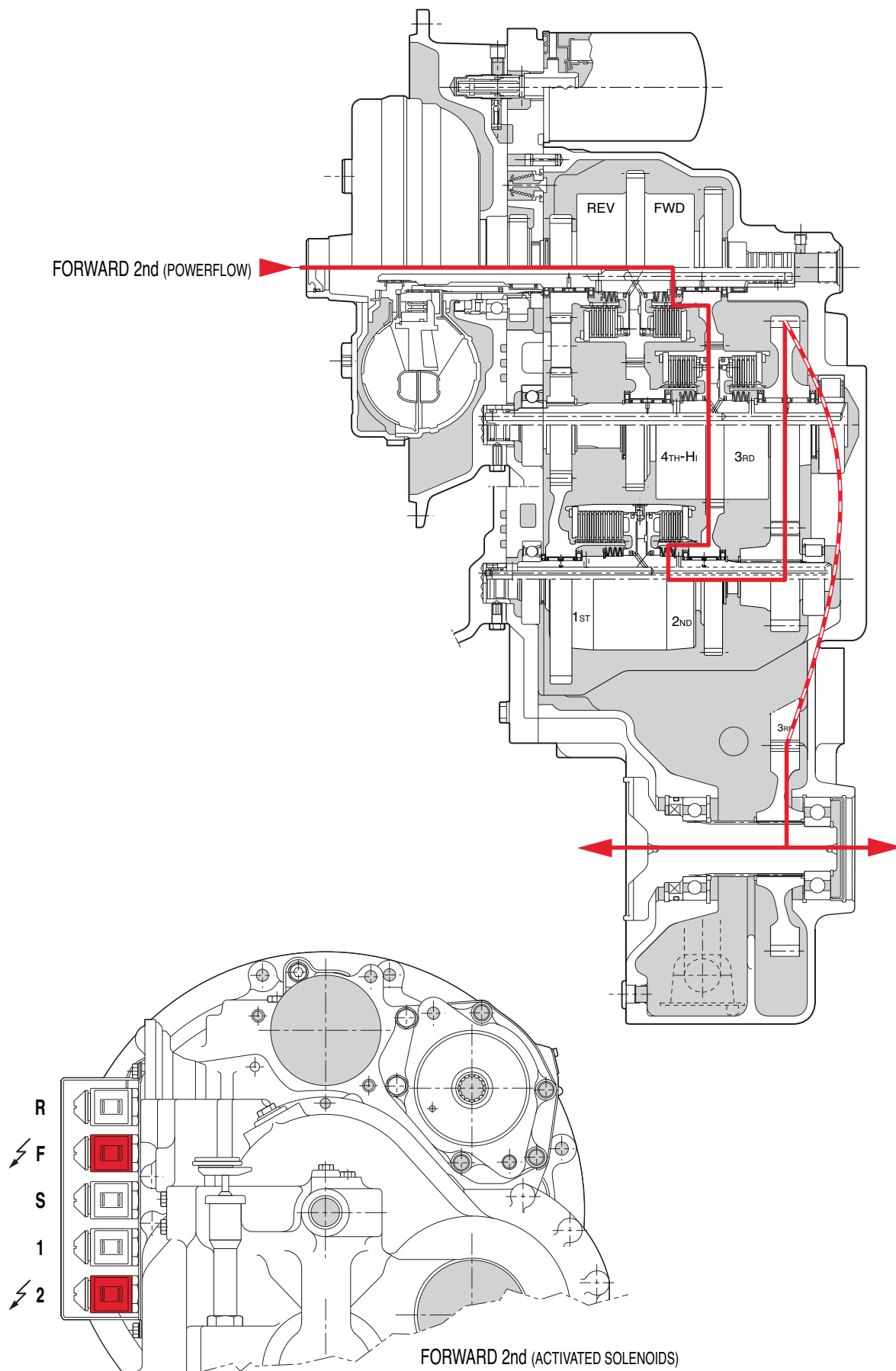
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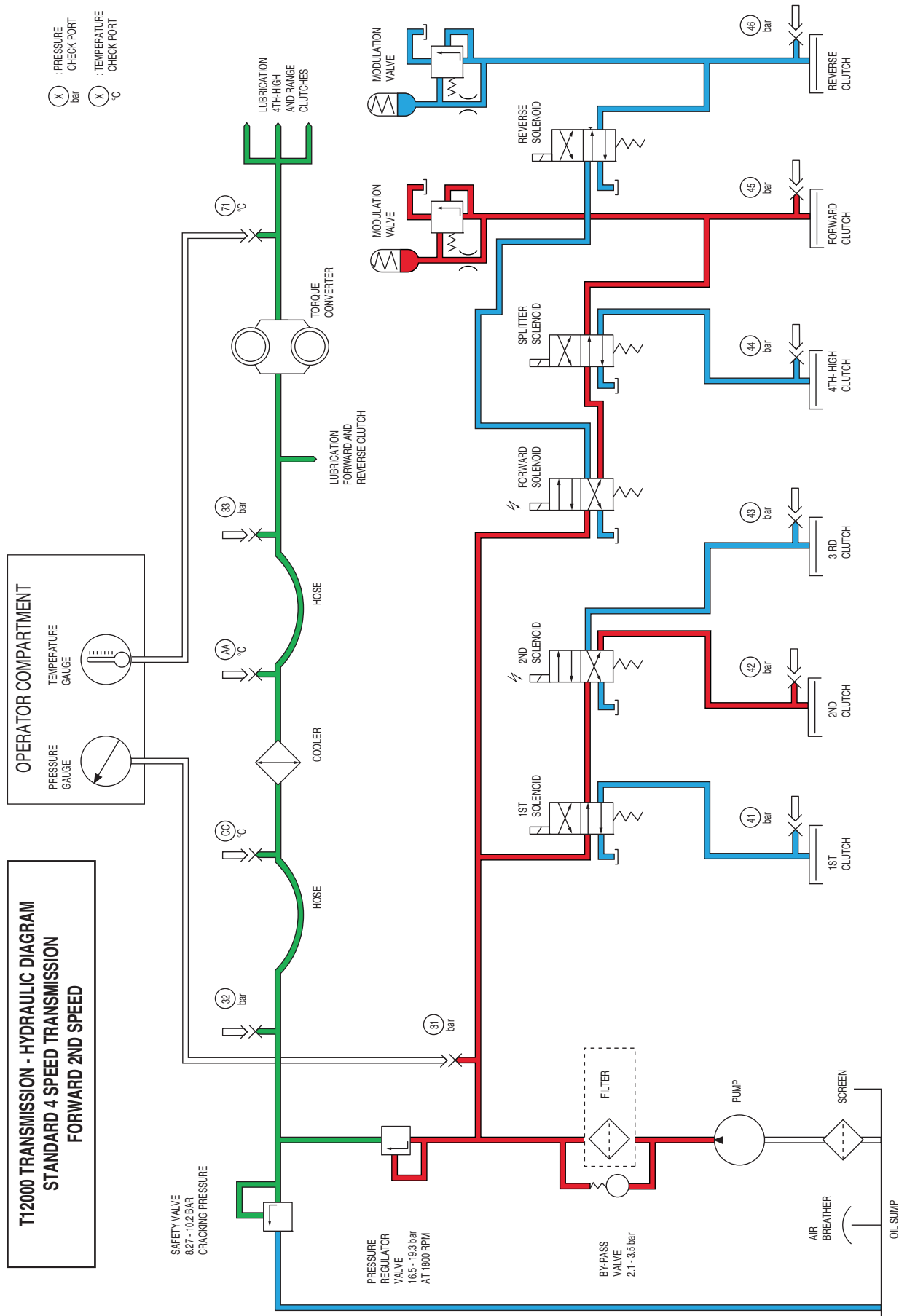
MOT12000T20



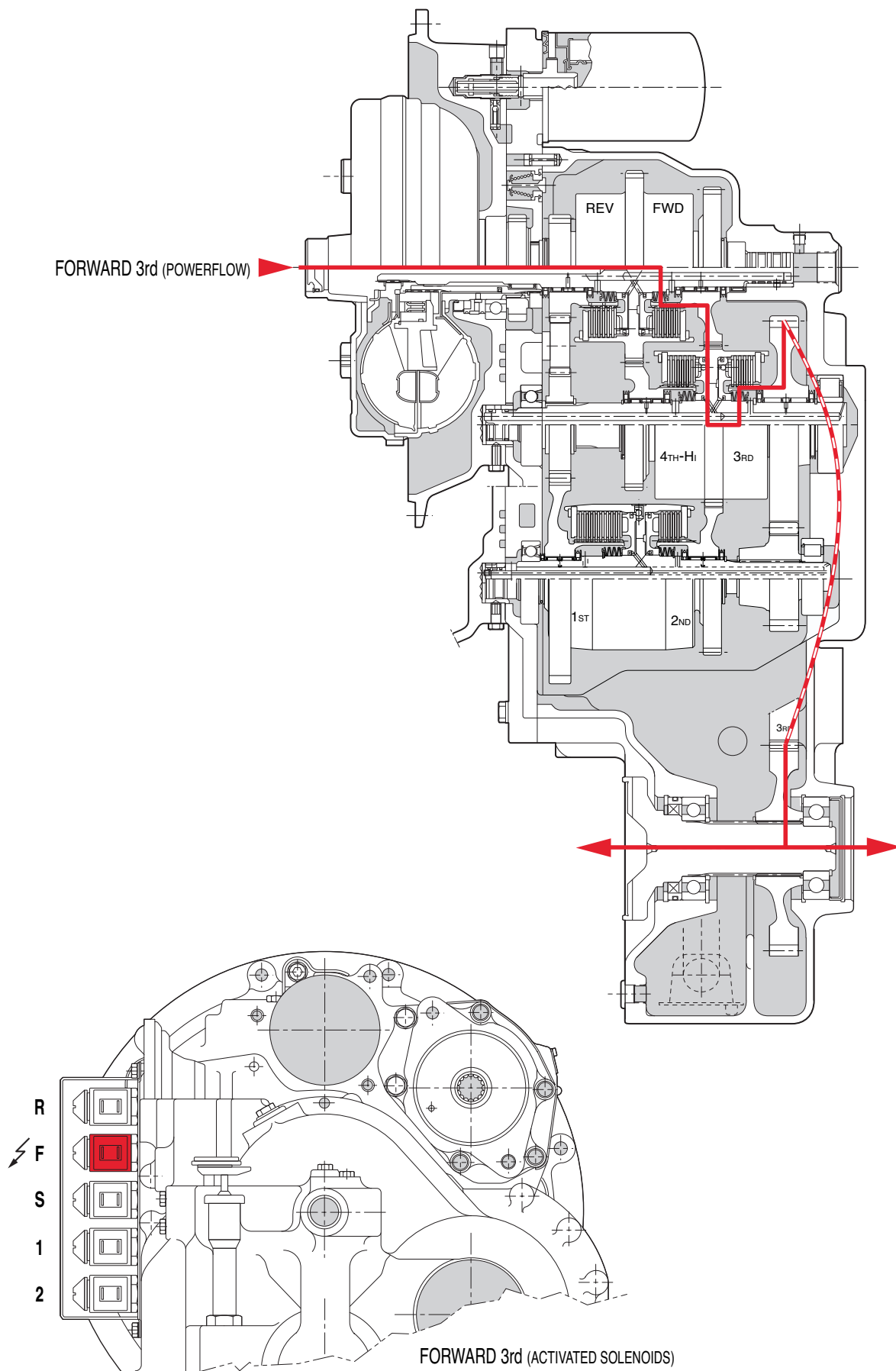


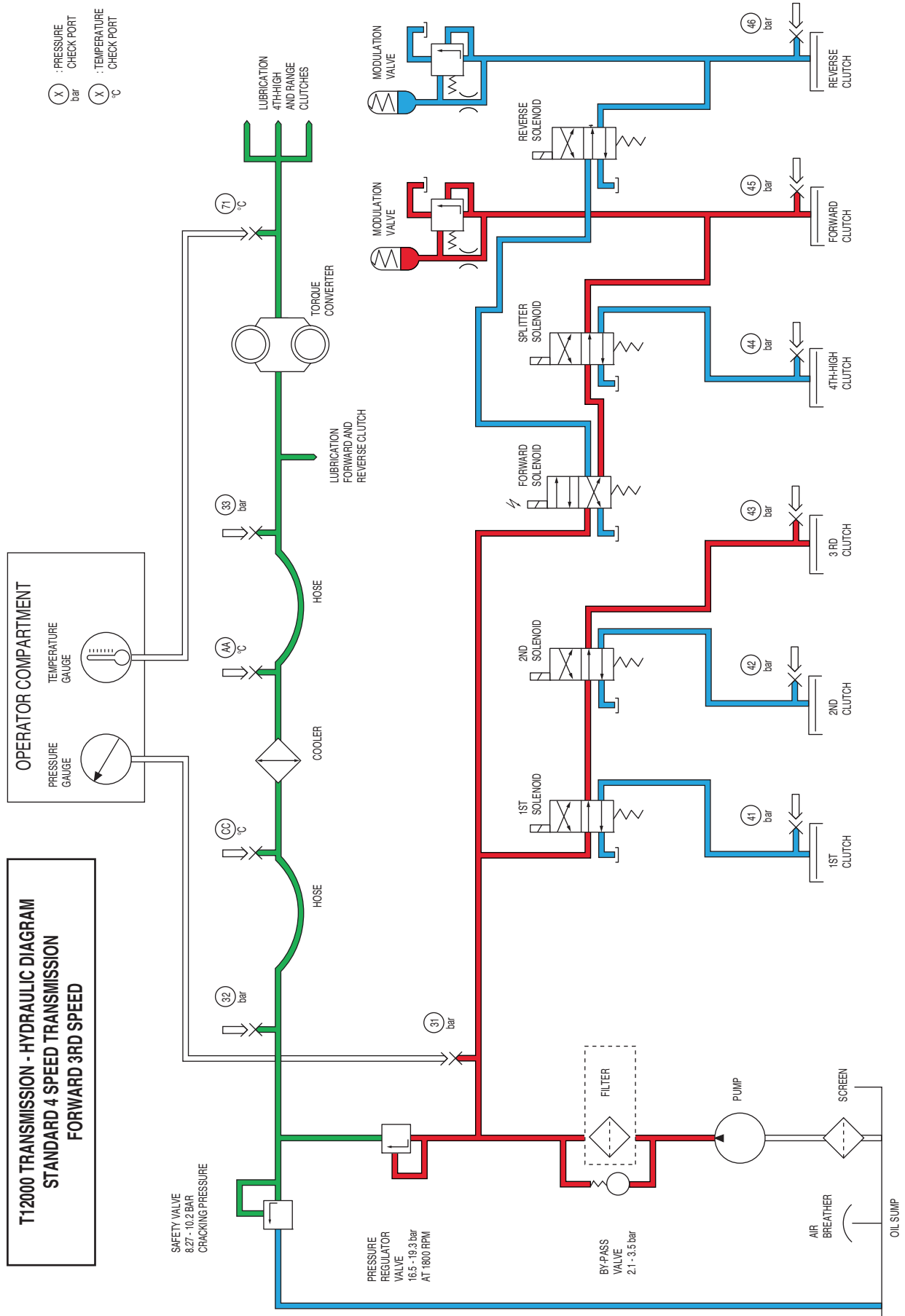
Forward 2nd speed



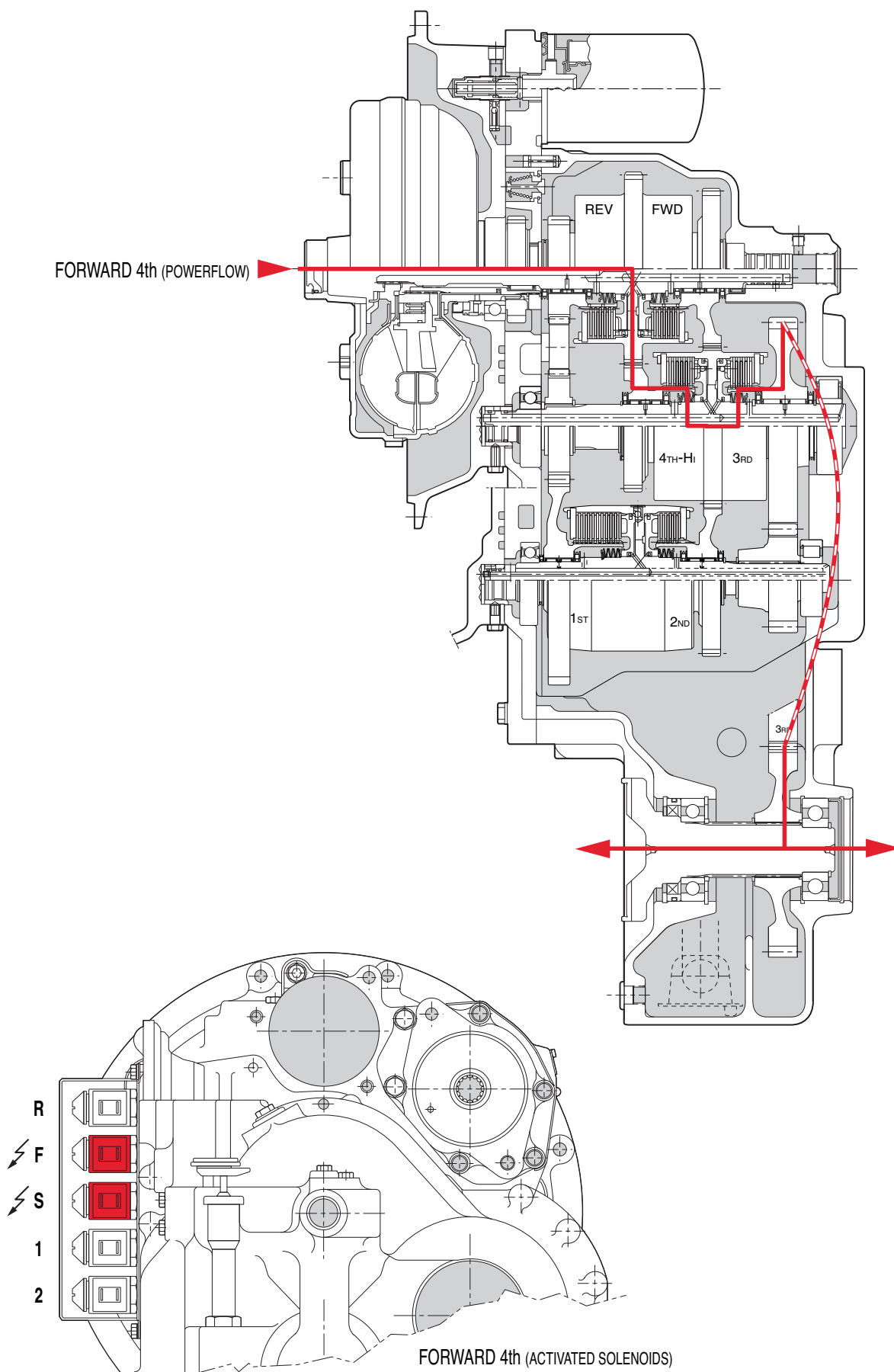


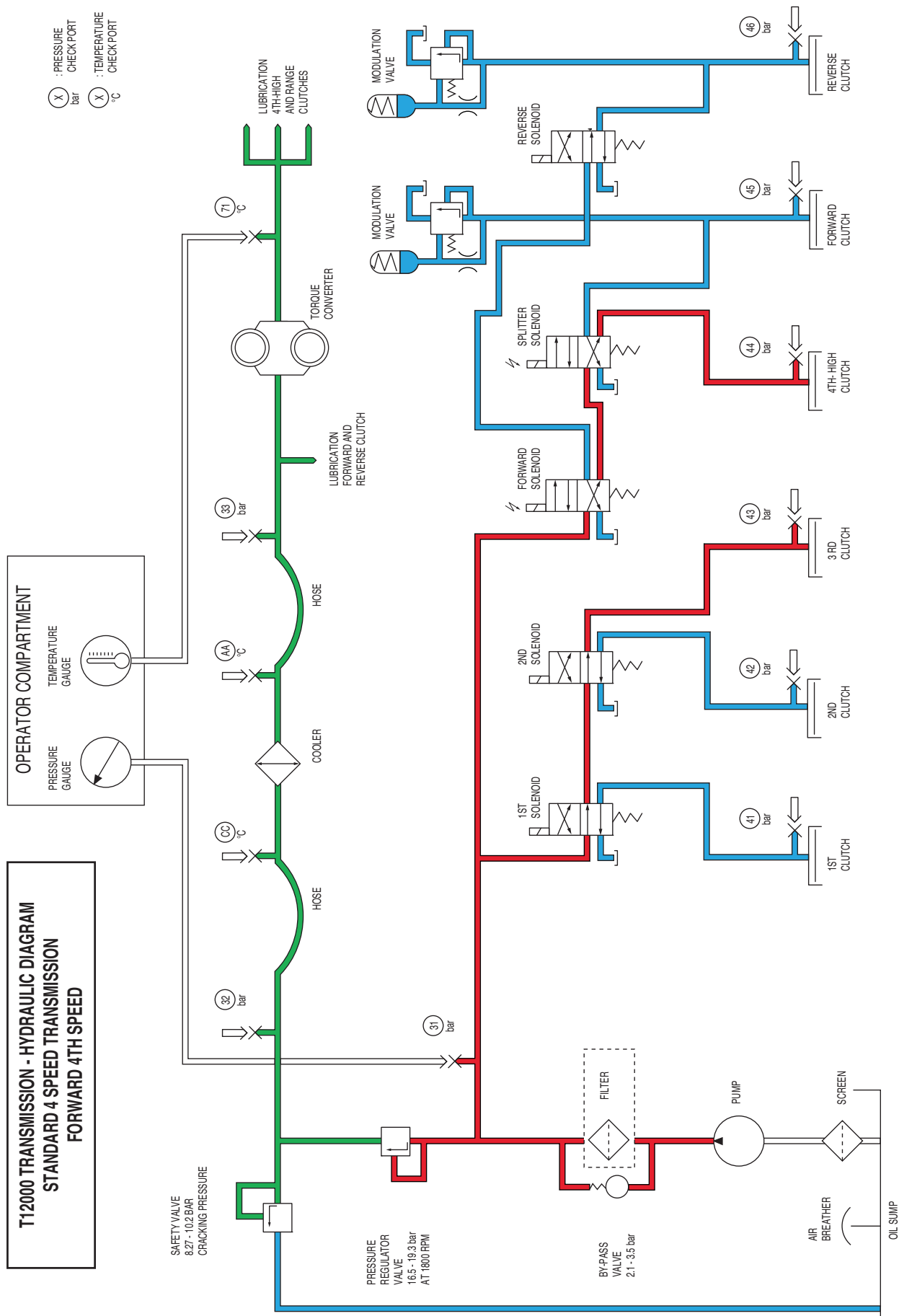
Forward 3rd speed





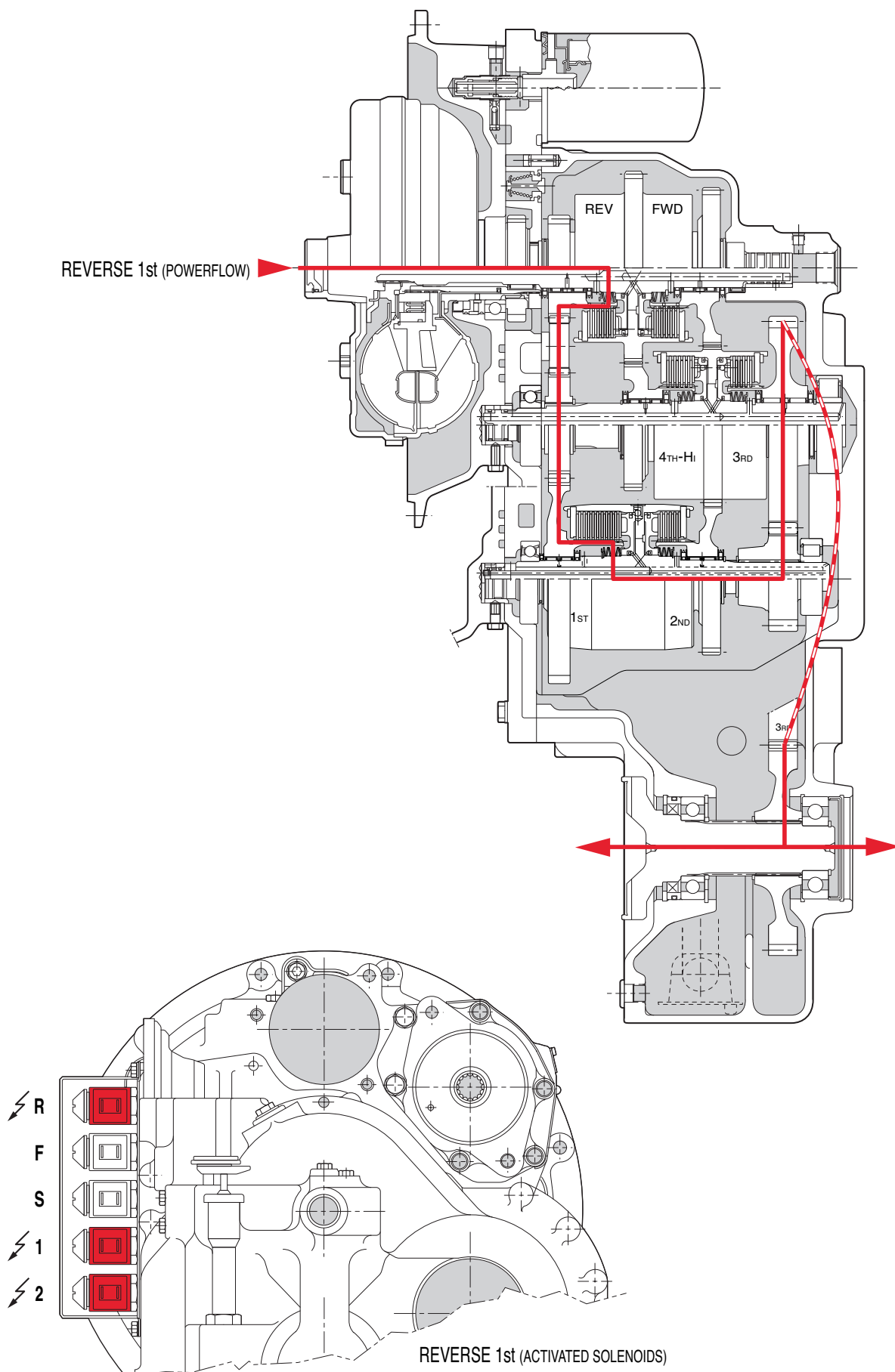
Forward 4th speed

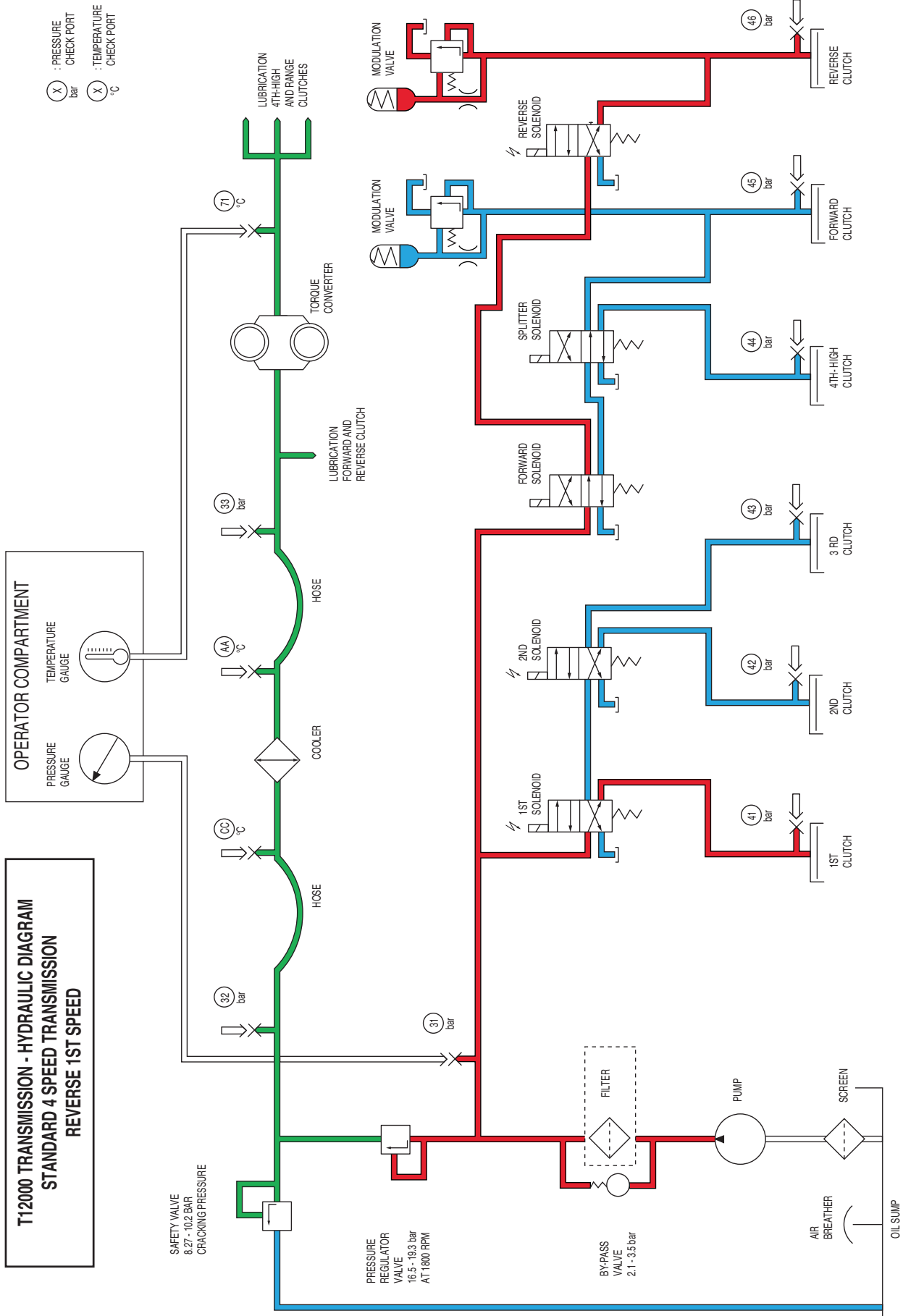






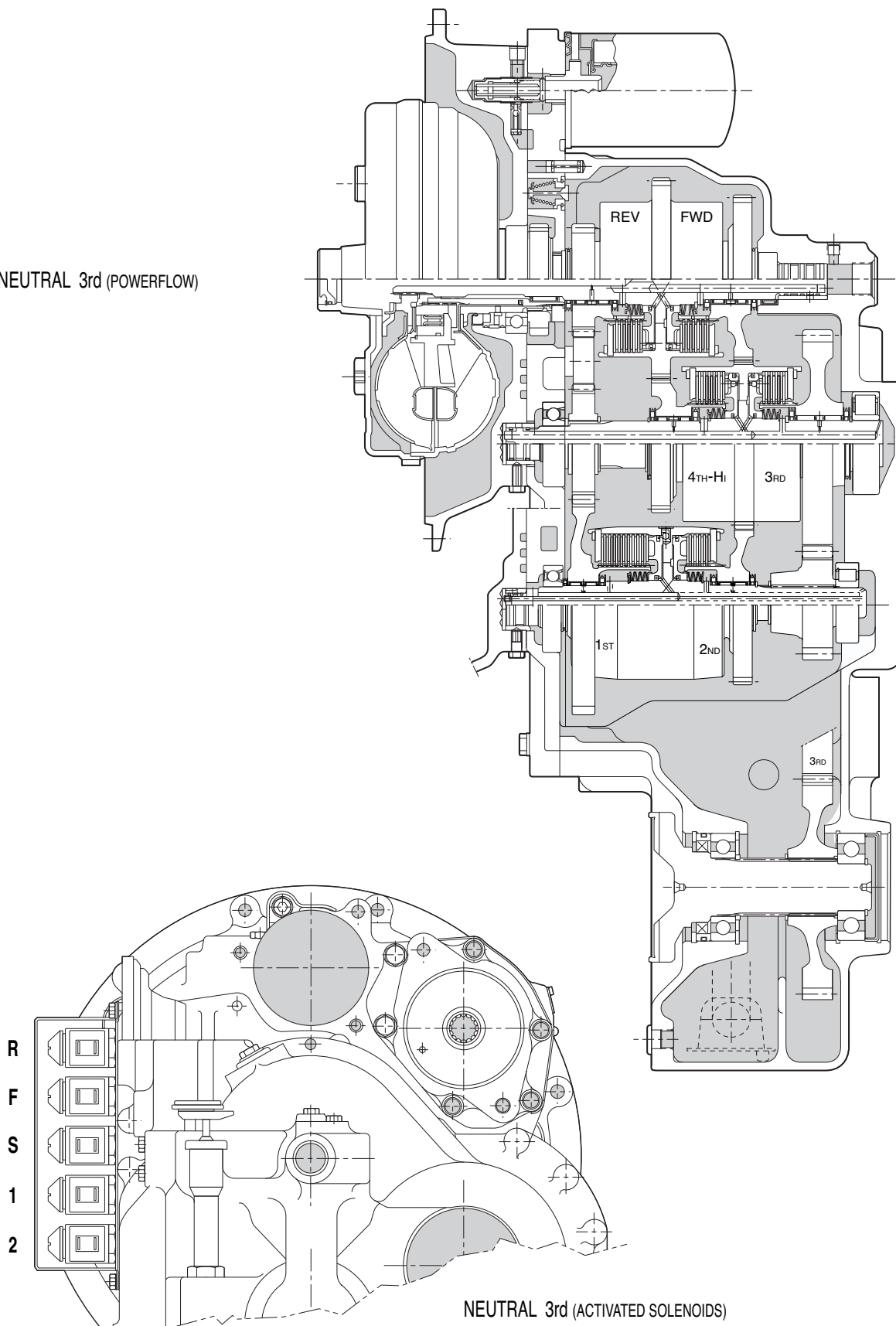
Reverse 1st speed

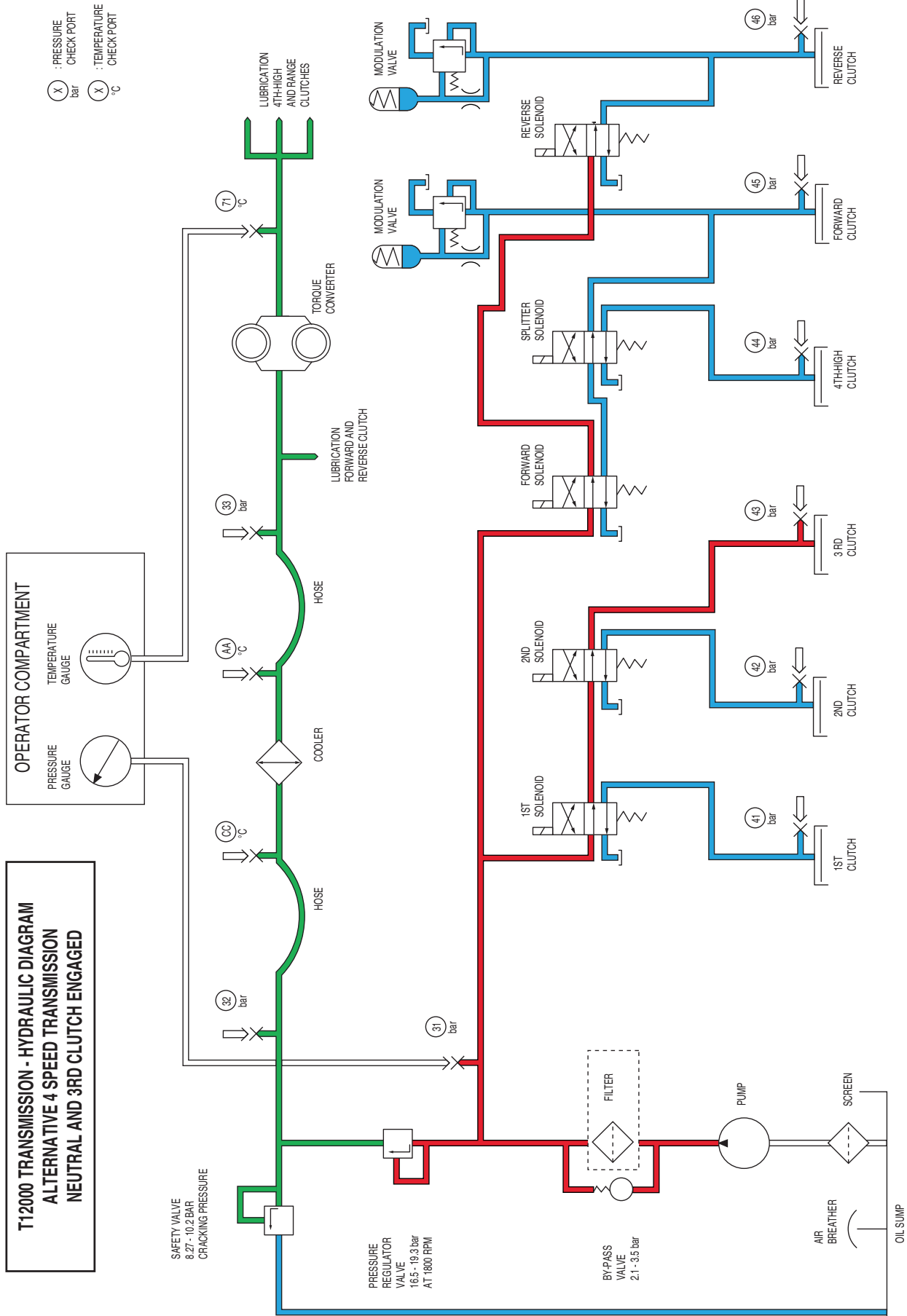


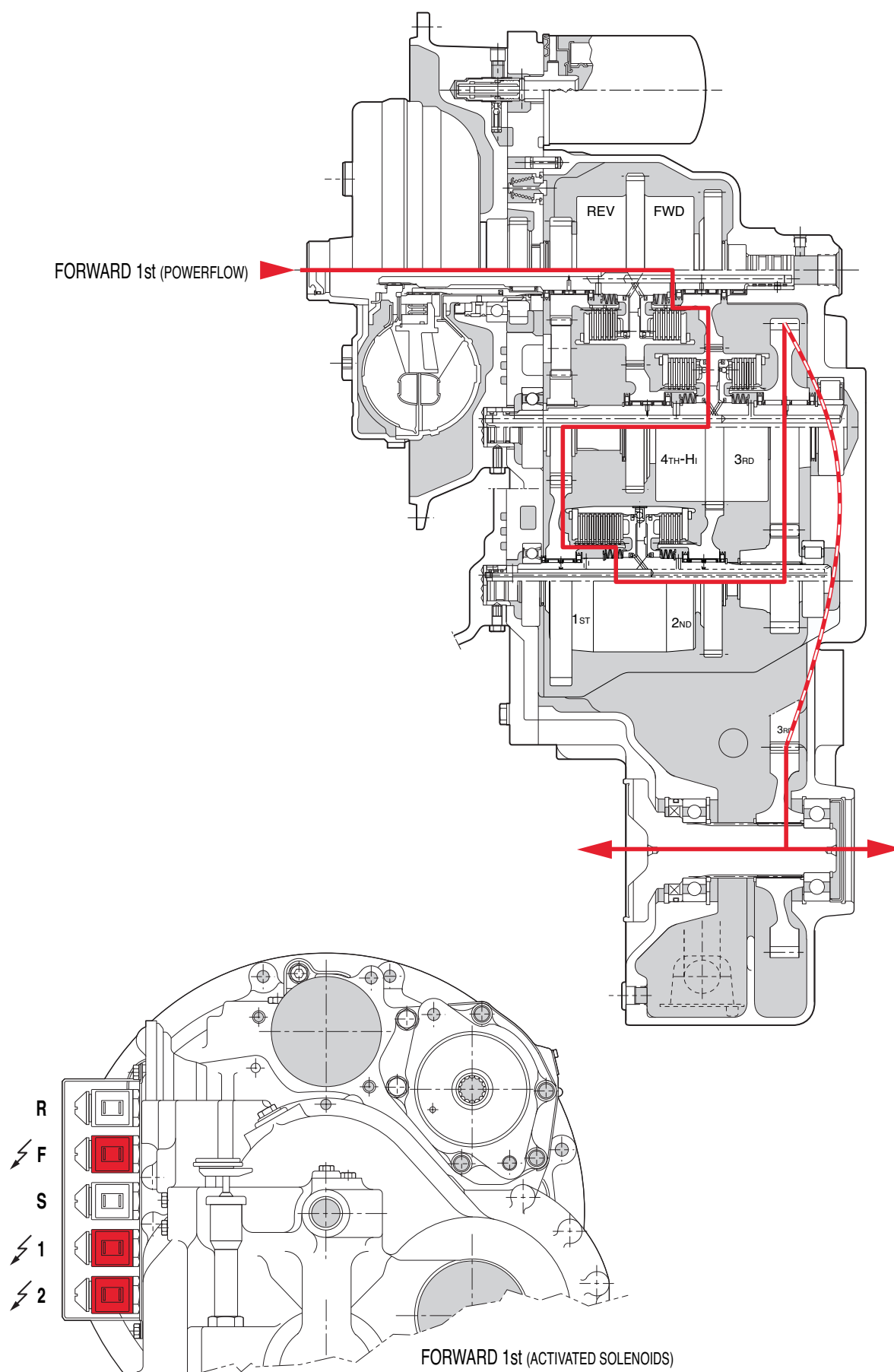


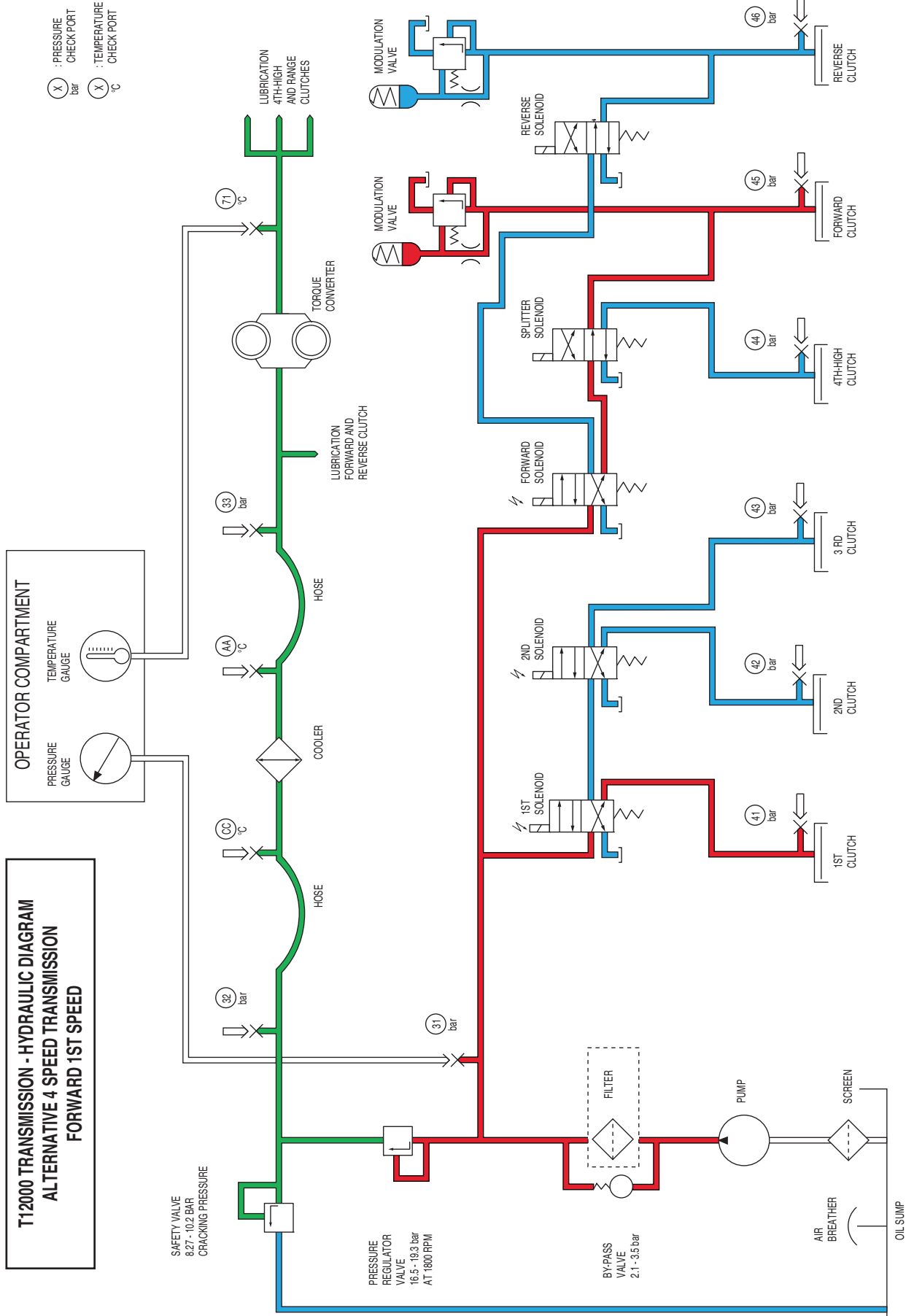
ALTERNATIVE 4-SPEED TRANSMISSION**Neutral and 3rd clutch engaged**

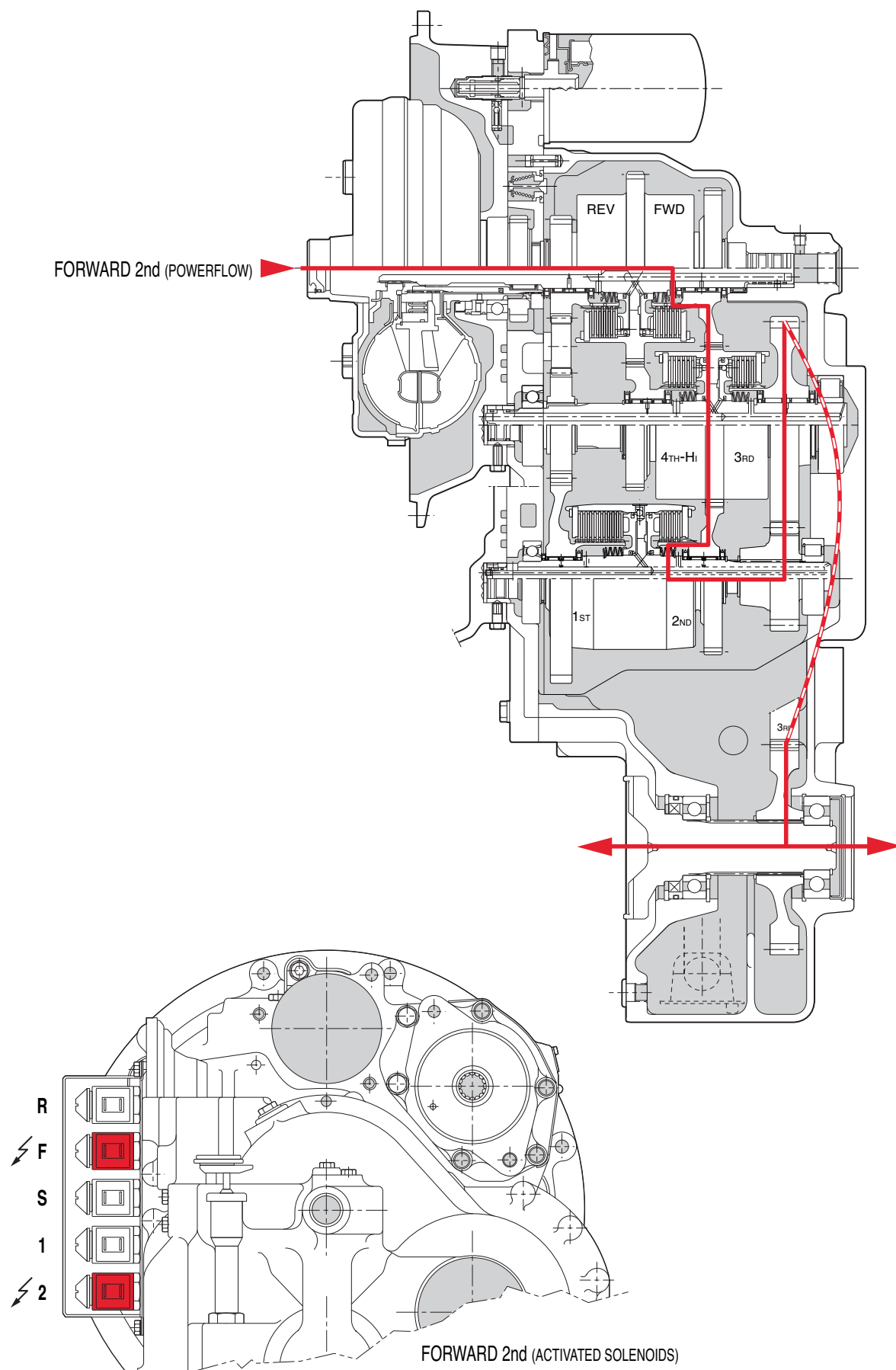
NEUTRAL 3rd (POWERFLOW)



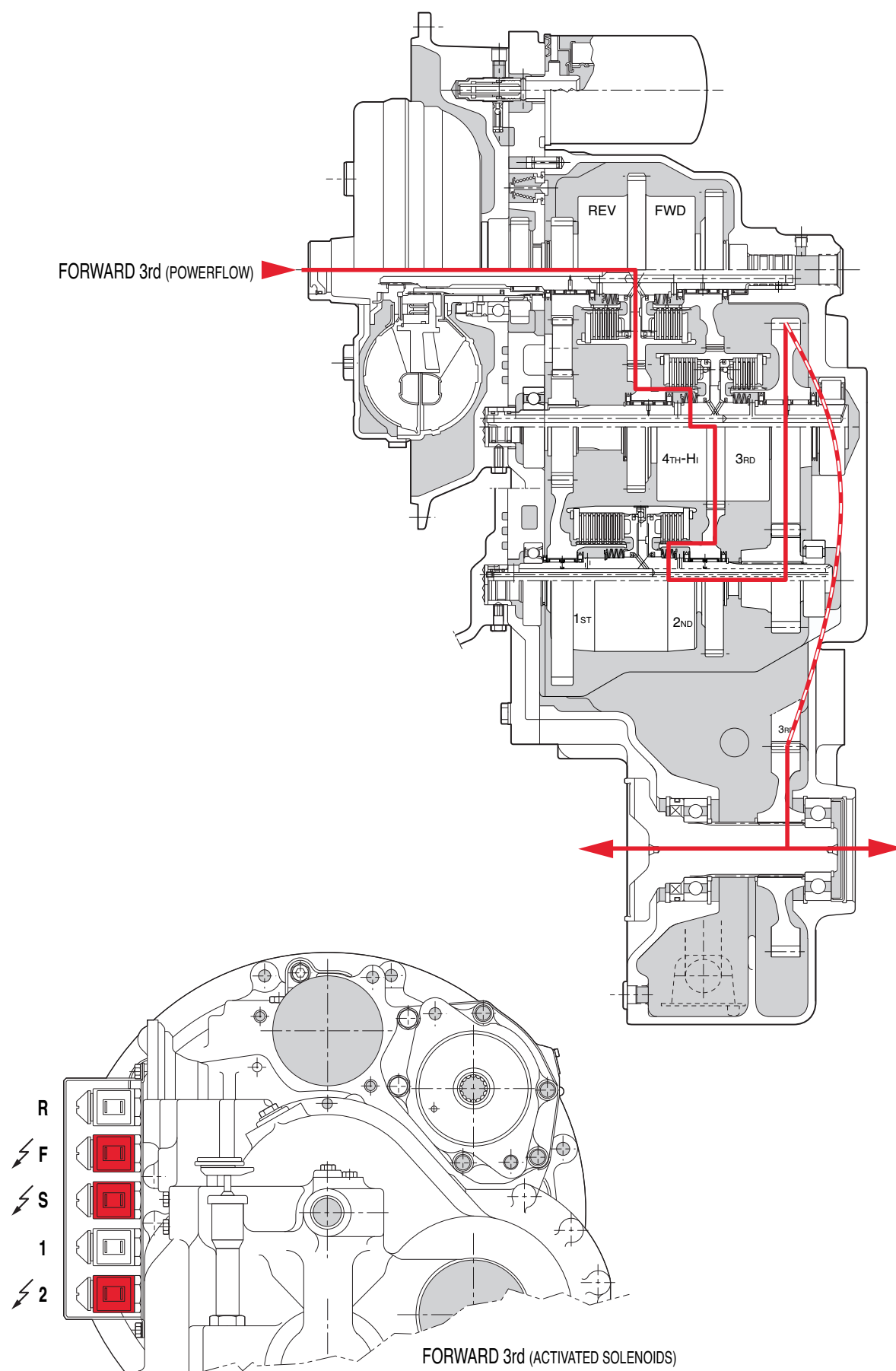


Forward 1st speed

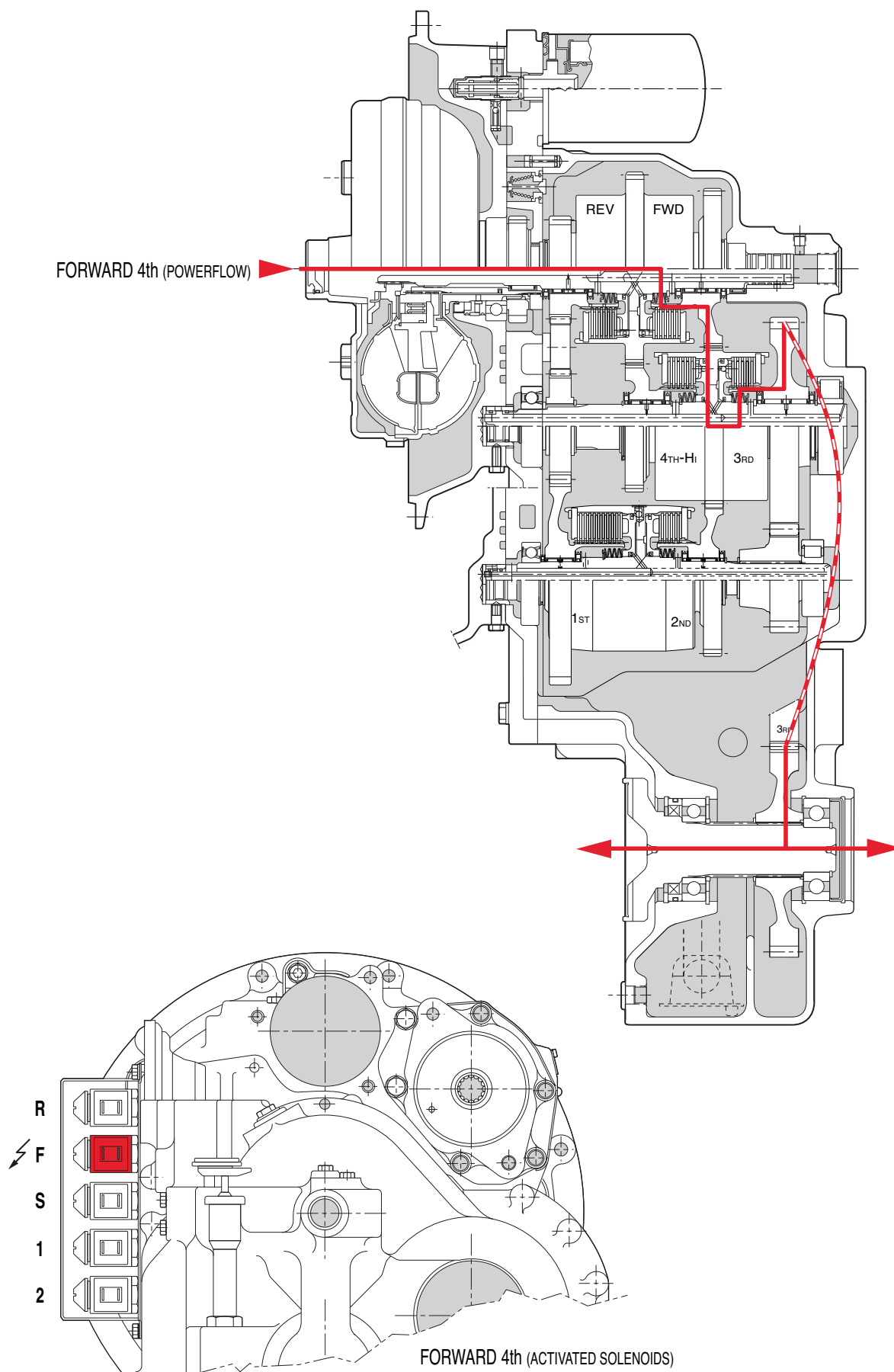


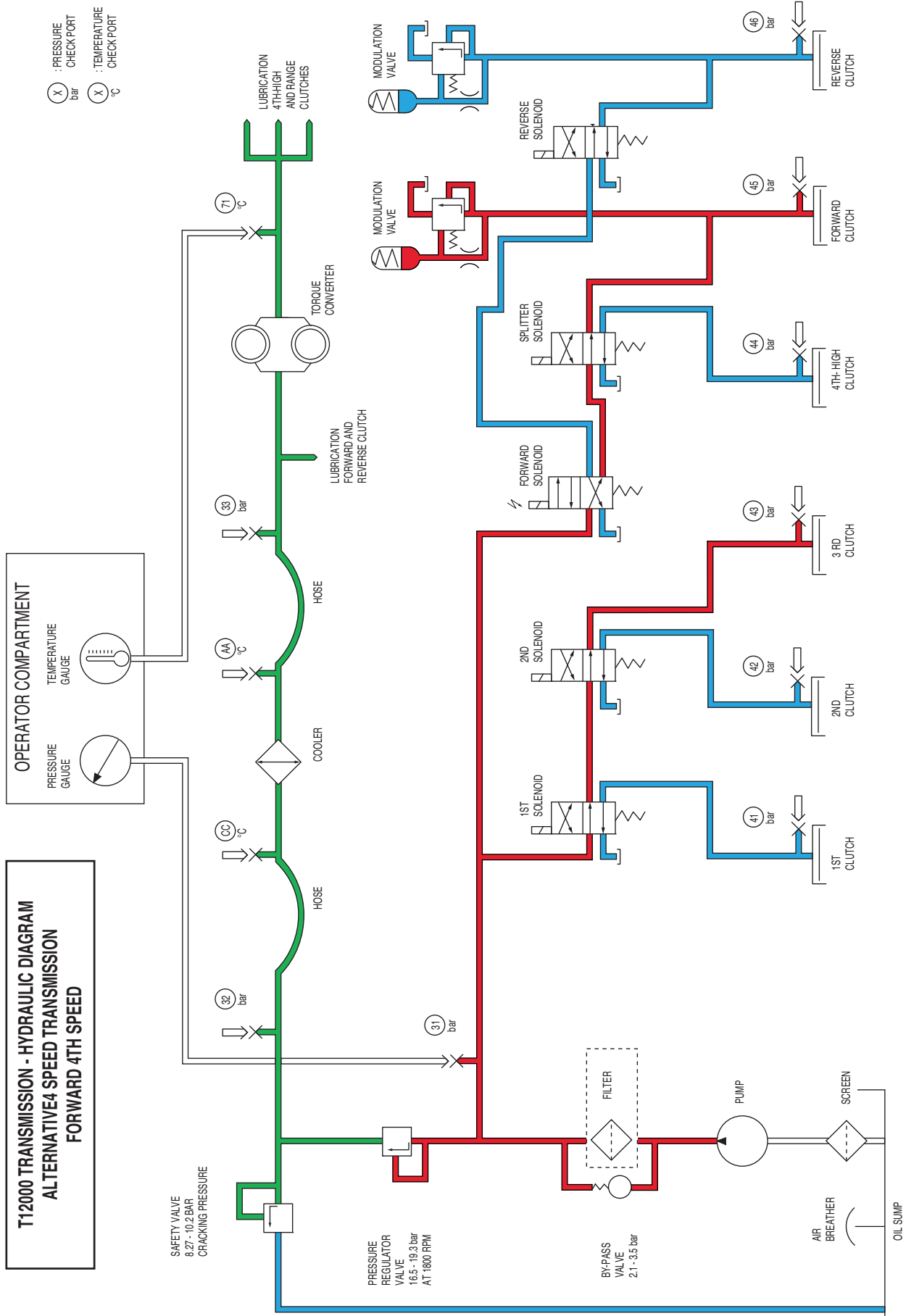
Forward 2nd speed

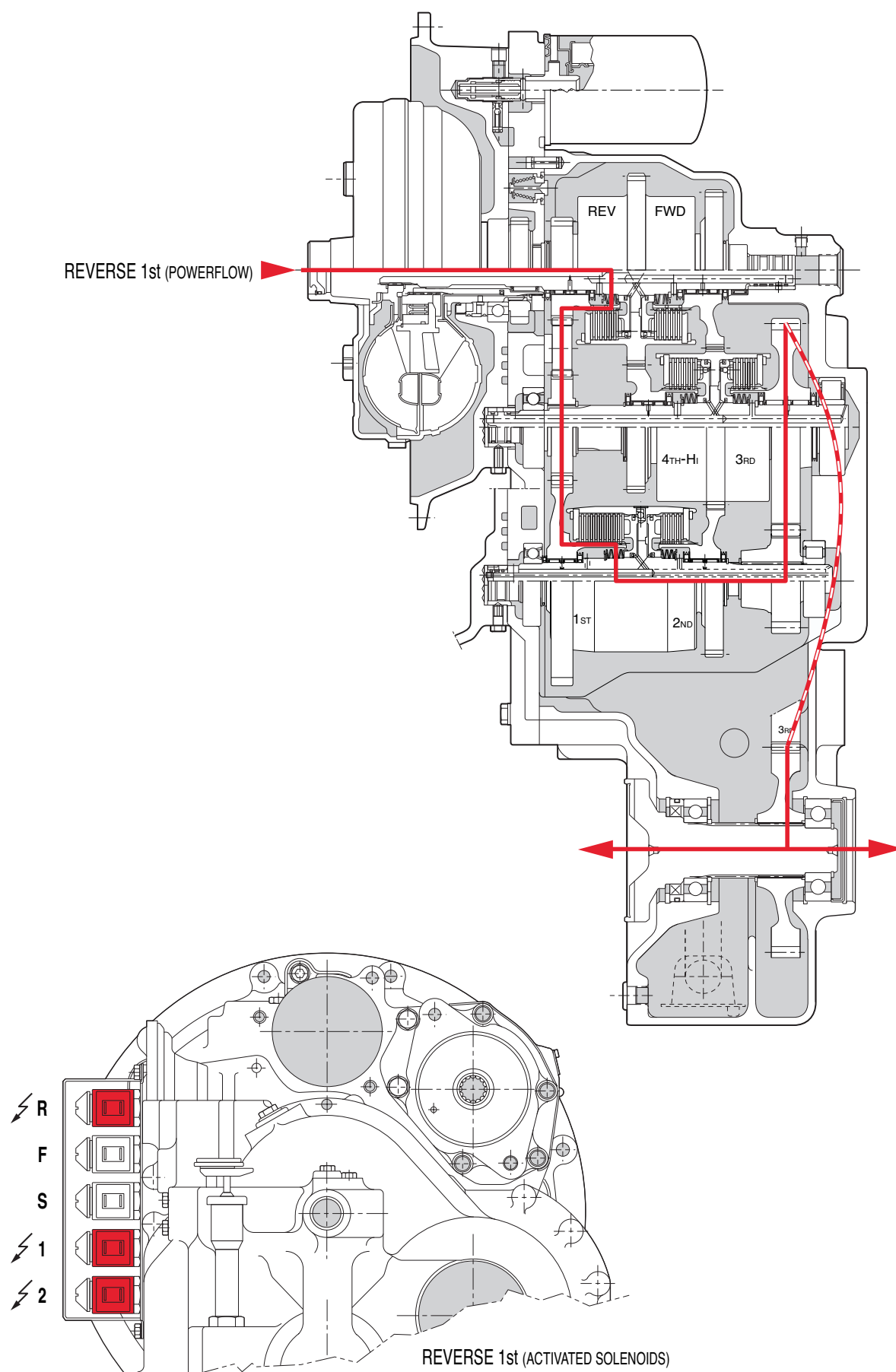


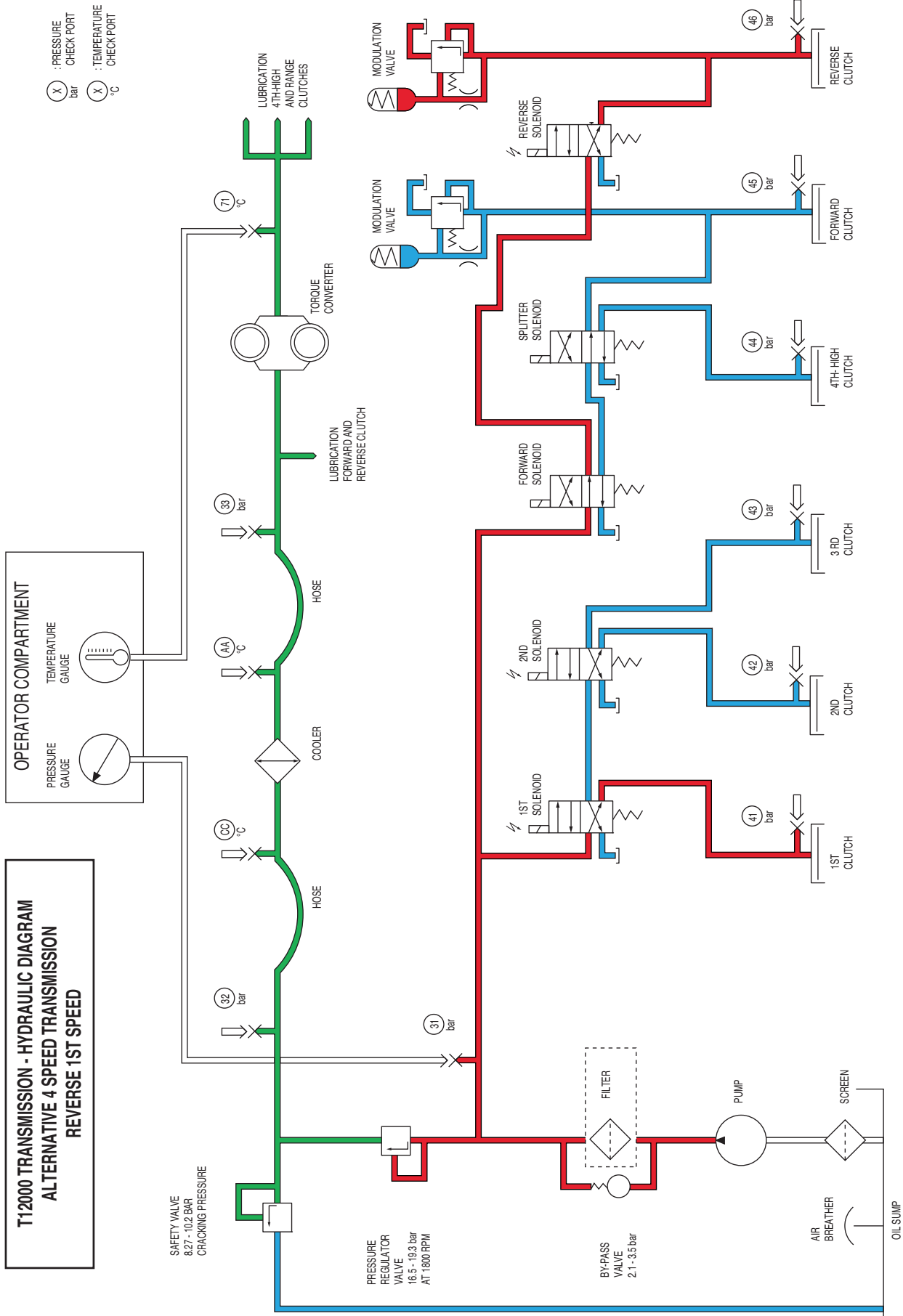
Forward 3rd speed



Forward 4th speed



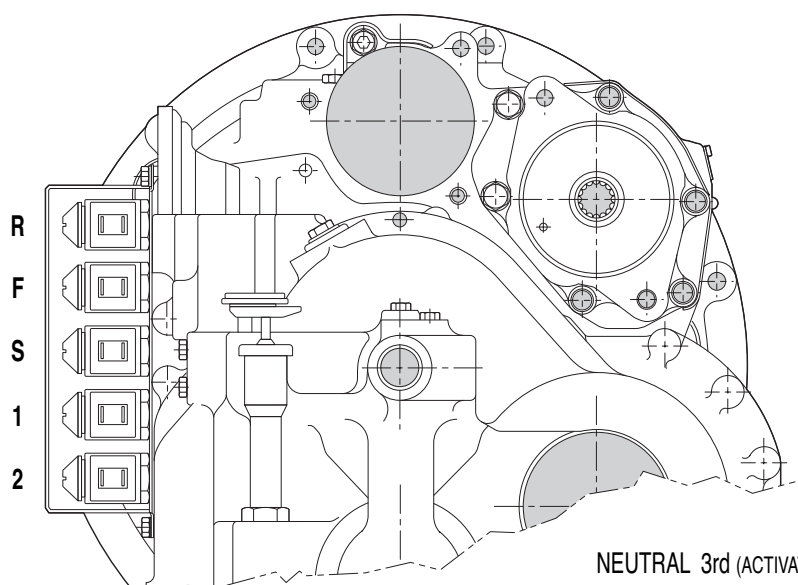
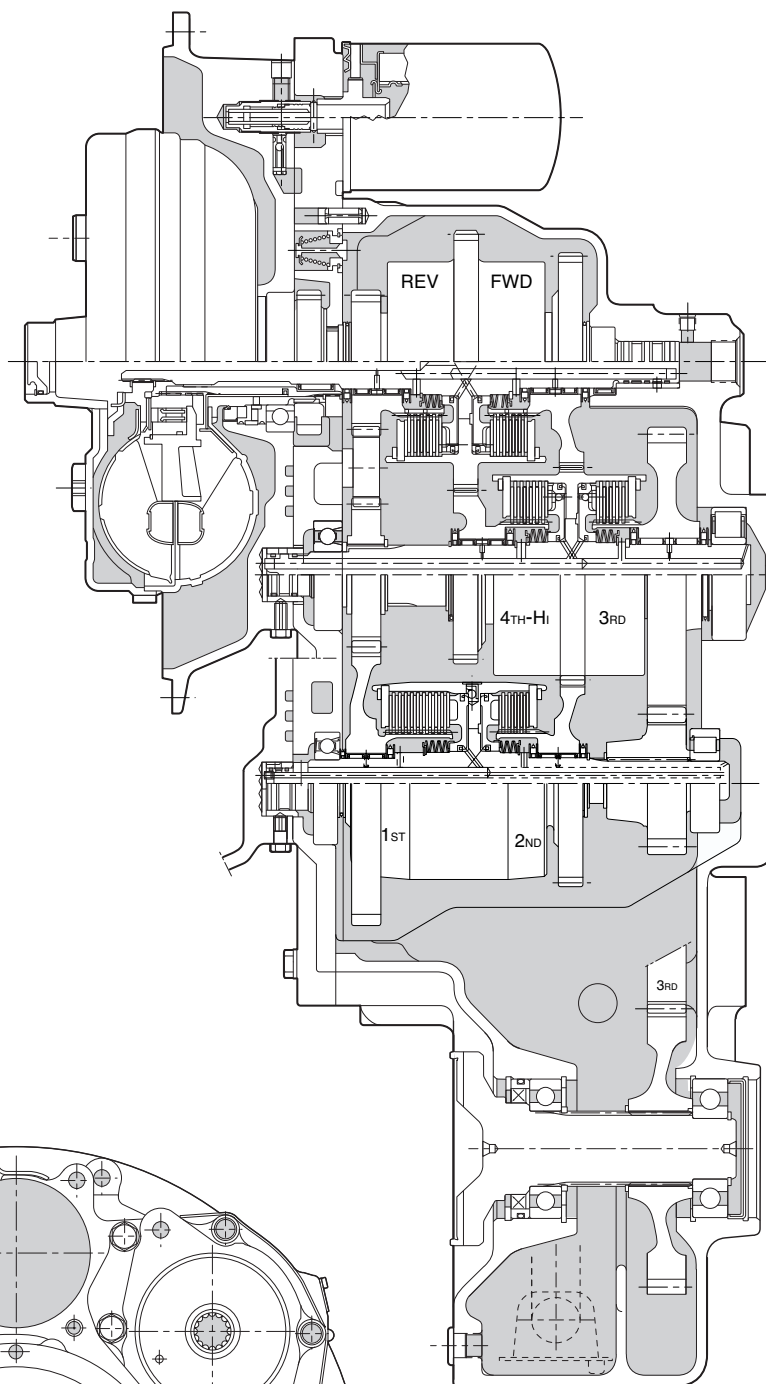
Reverse 1st speed



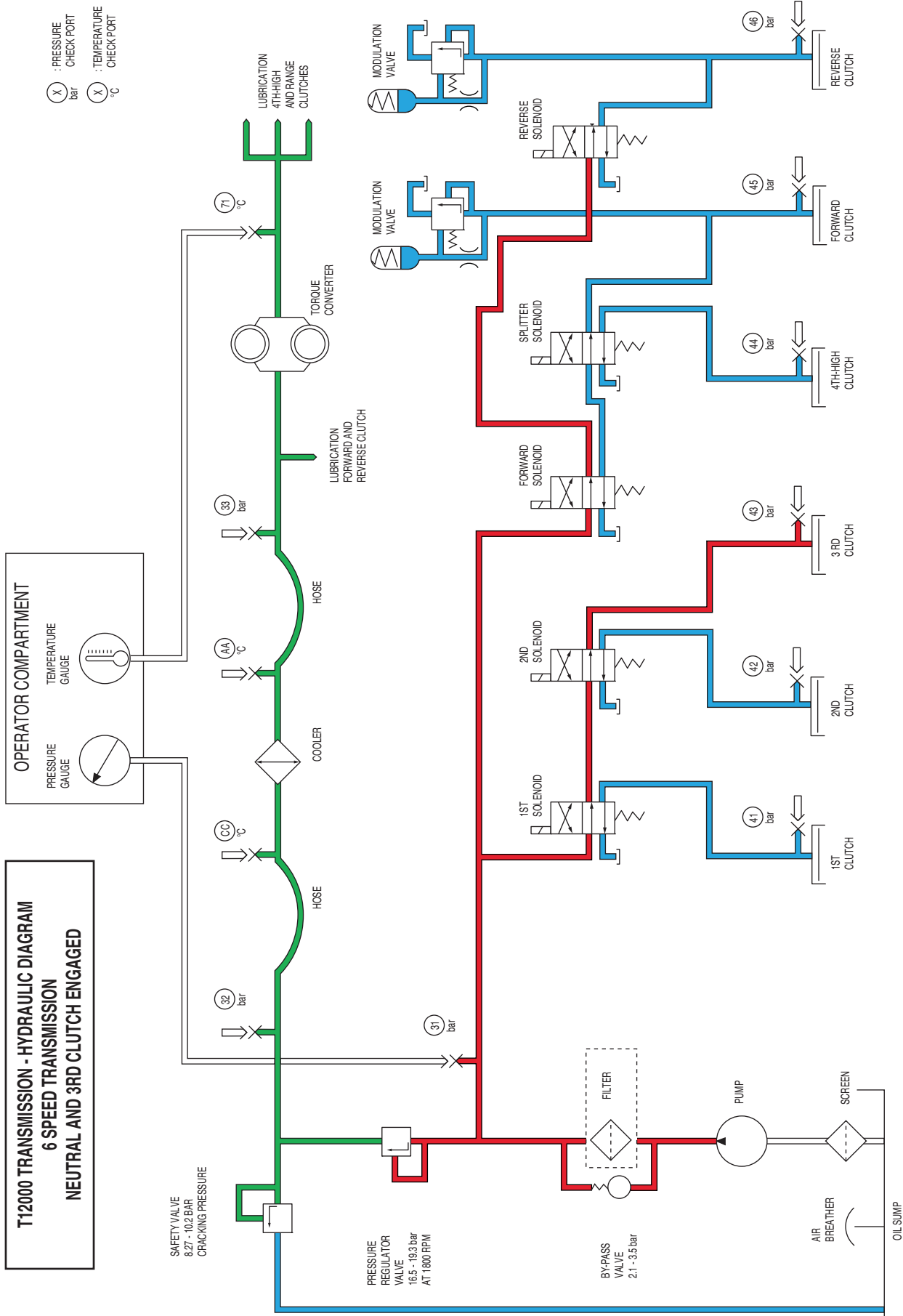
6-SPEED TRANSMISSION

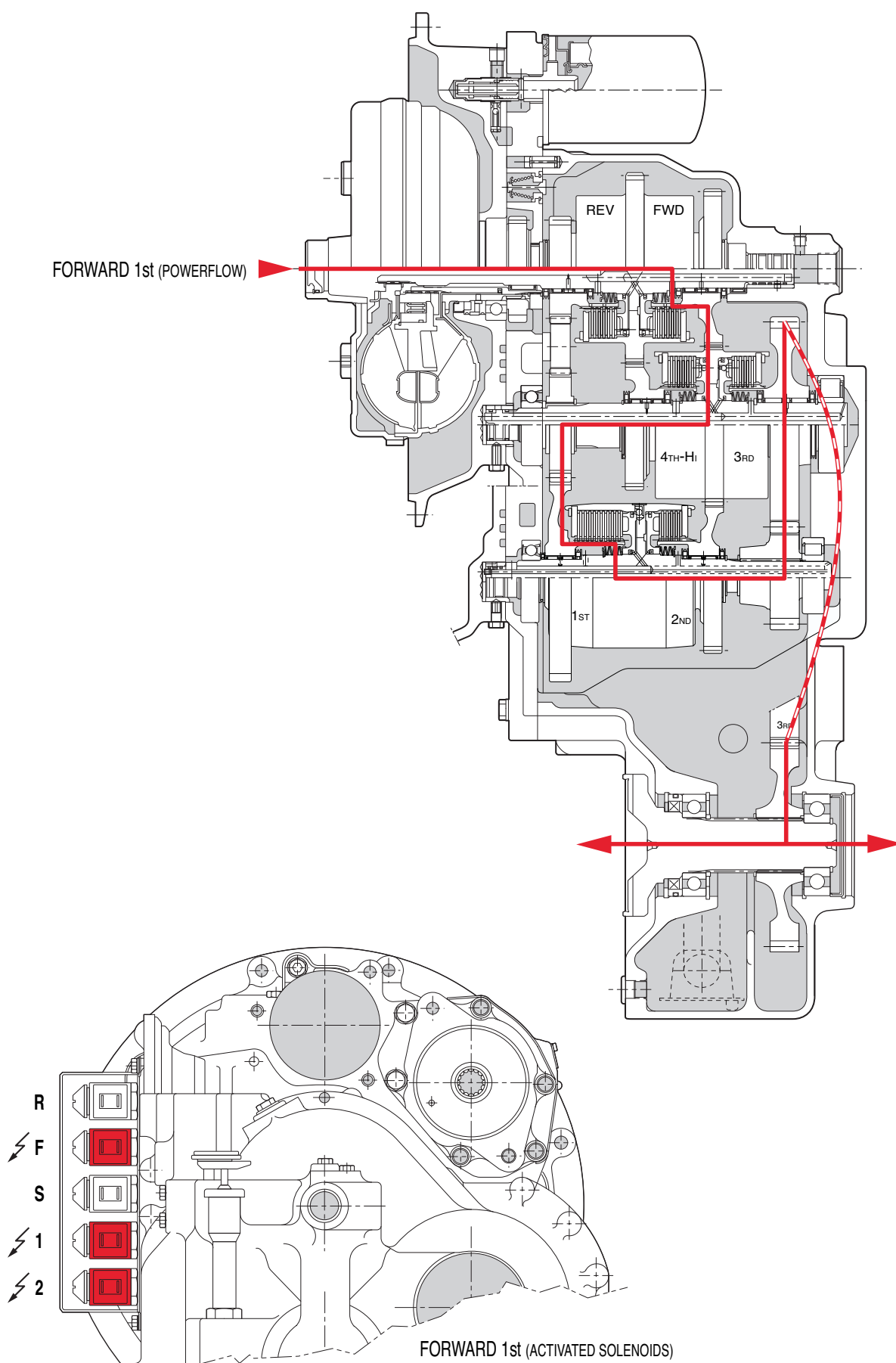
NEUTRAL AND 3RD CLUTCH ENGAGED

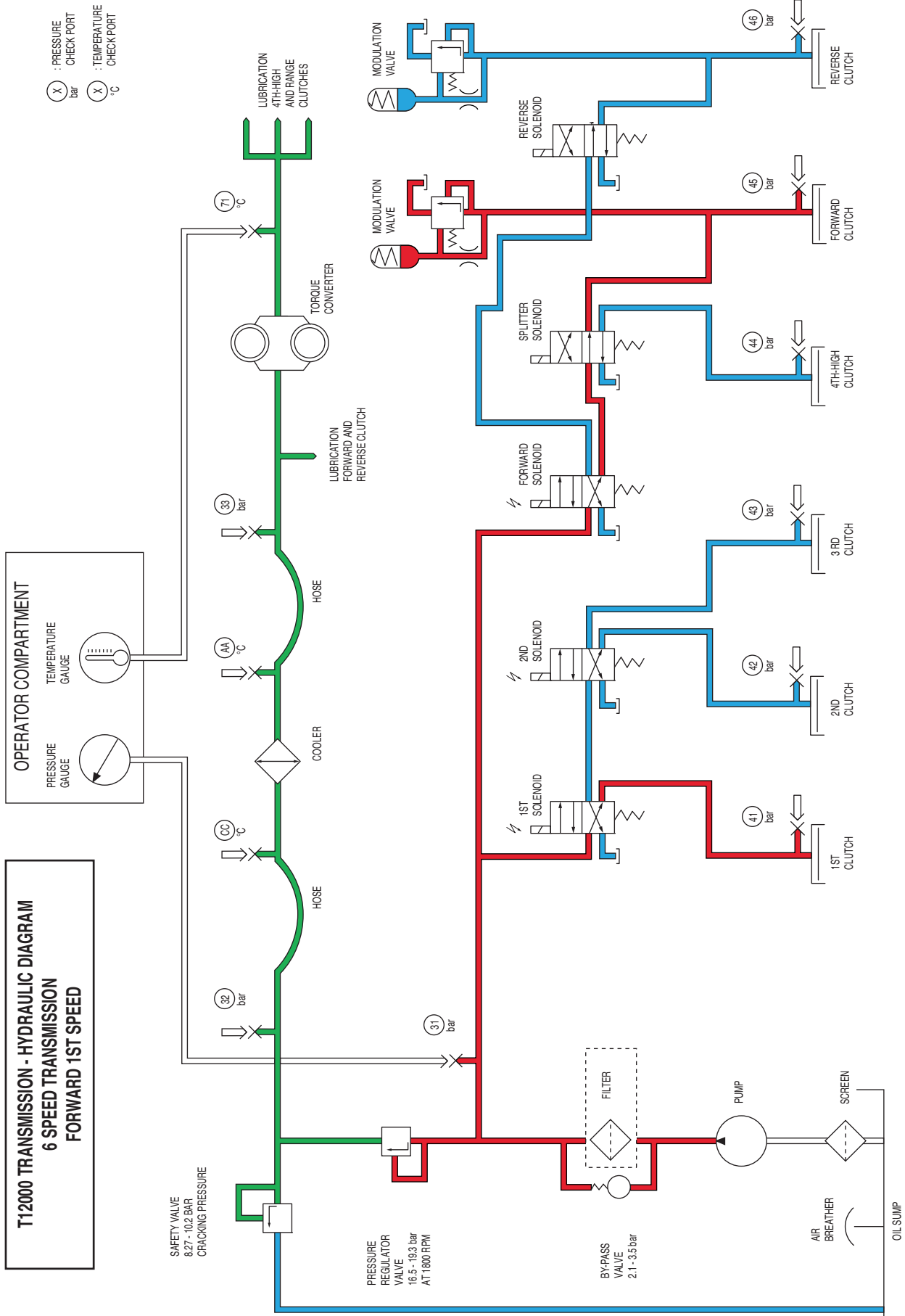
NEUTRAL 3rd (POWERFLOW)

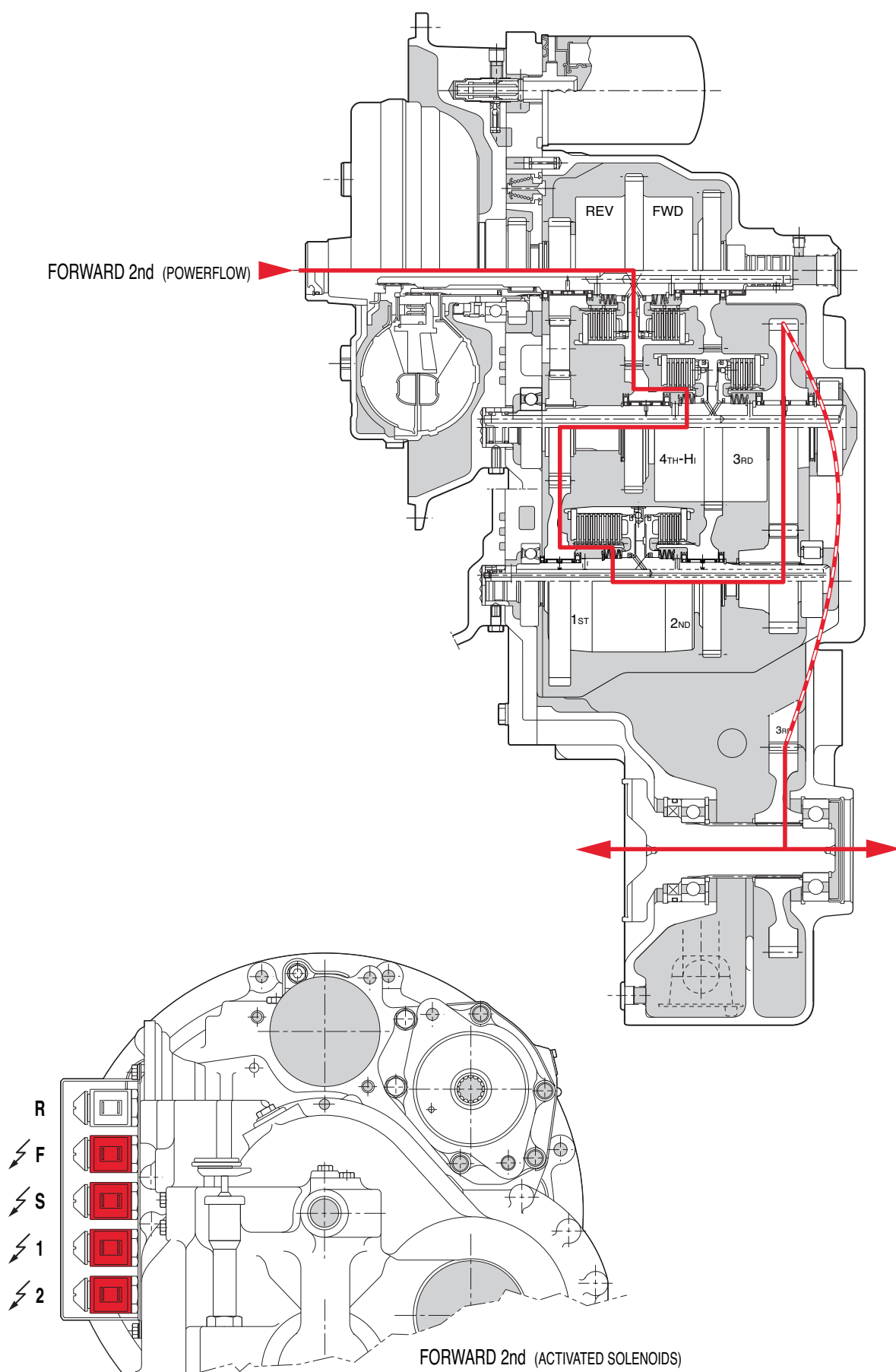


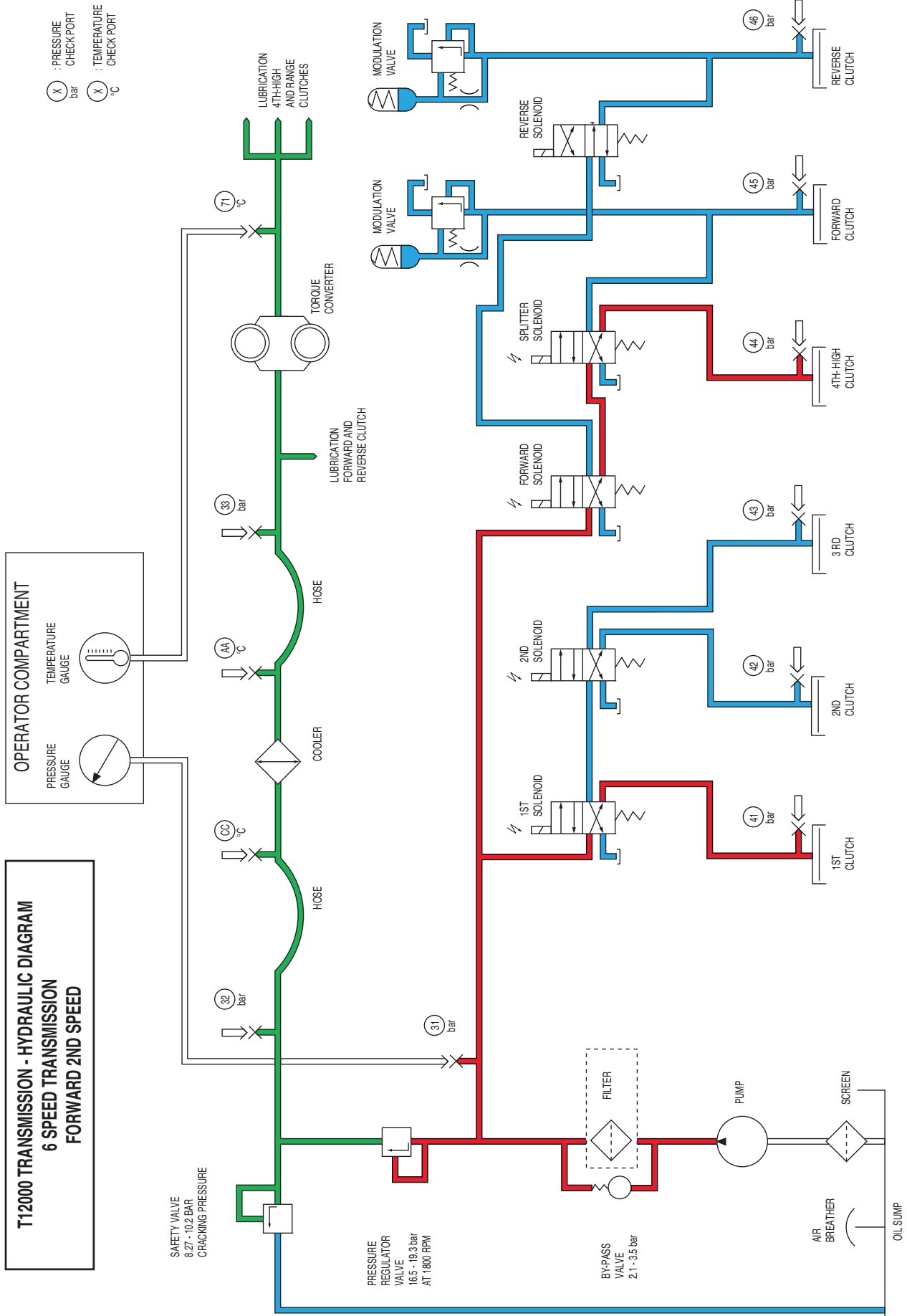
NEUTRAL 3rd (ACTIVATED SOLENOIDS)

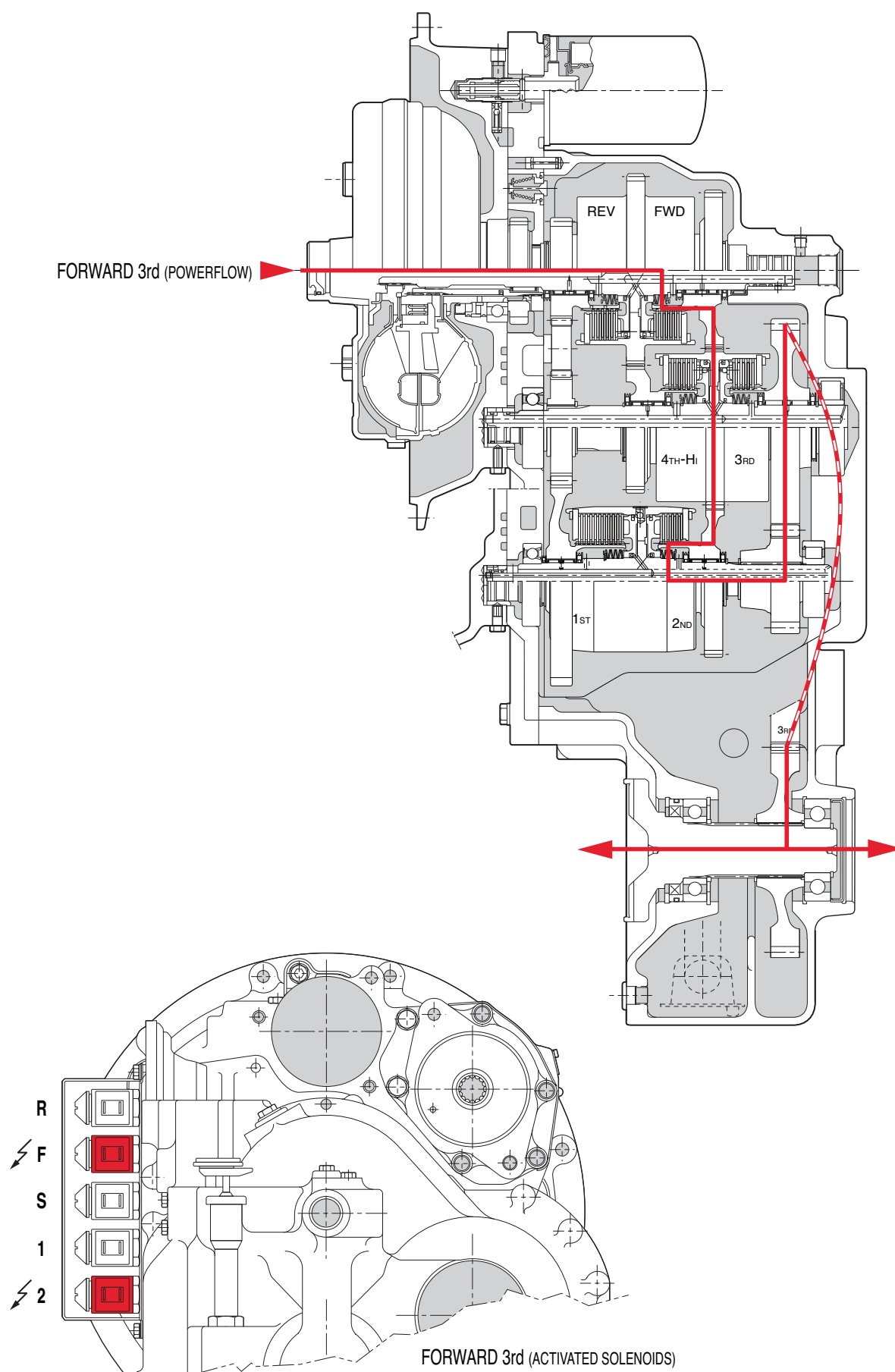


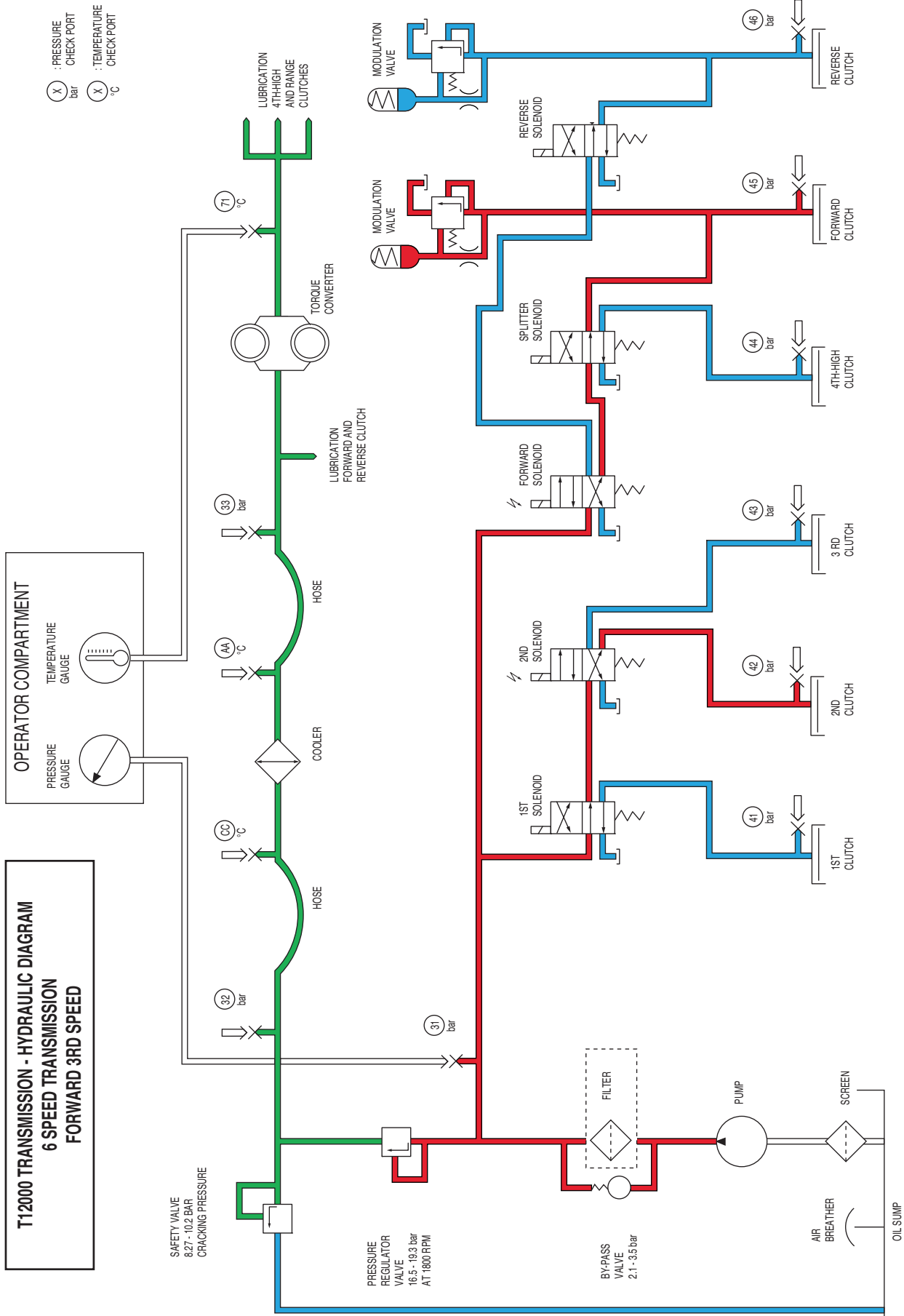
FORWARD 1ST SPEED

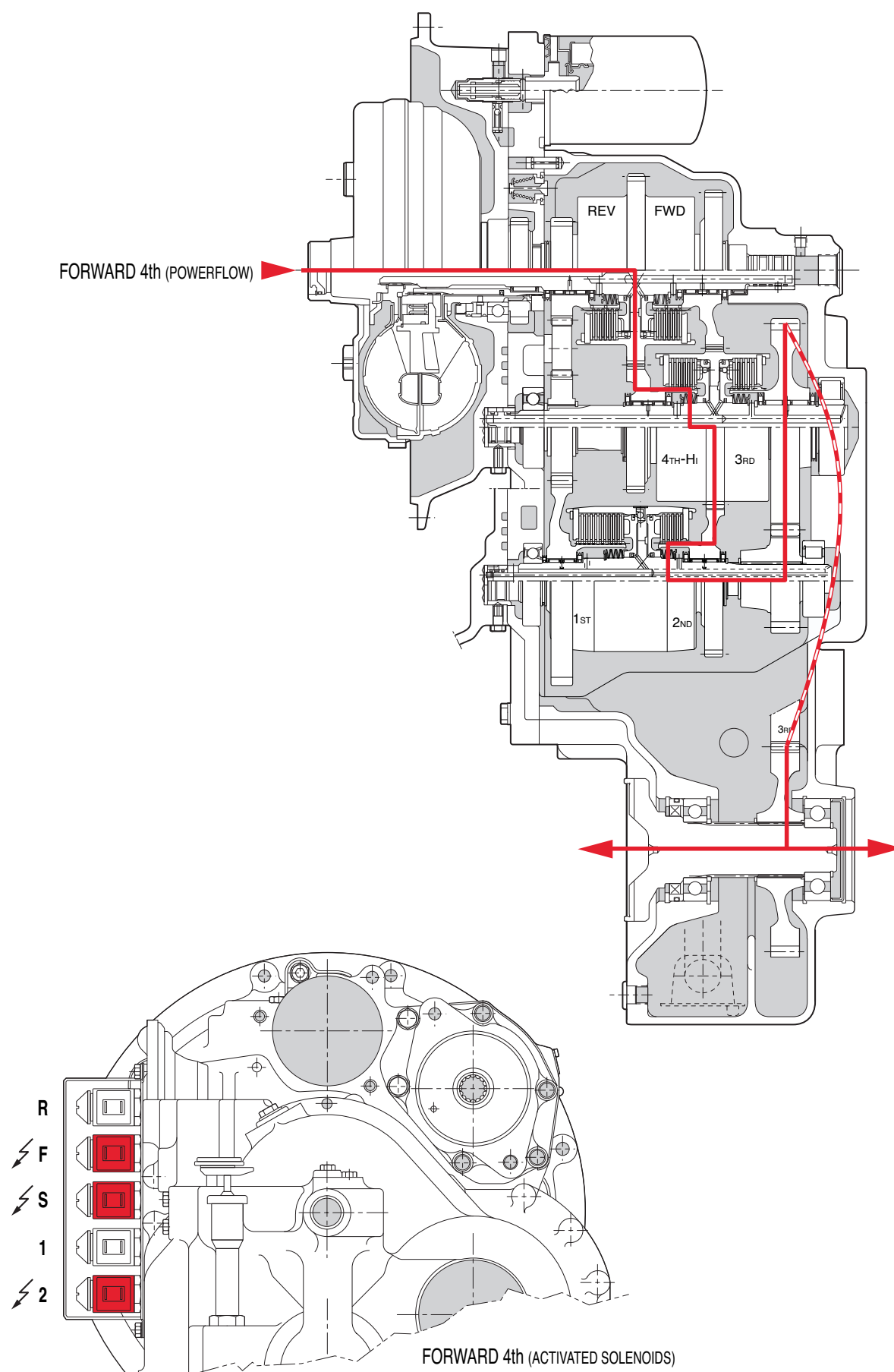


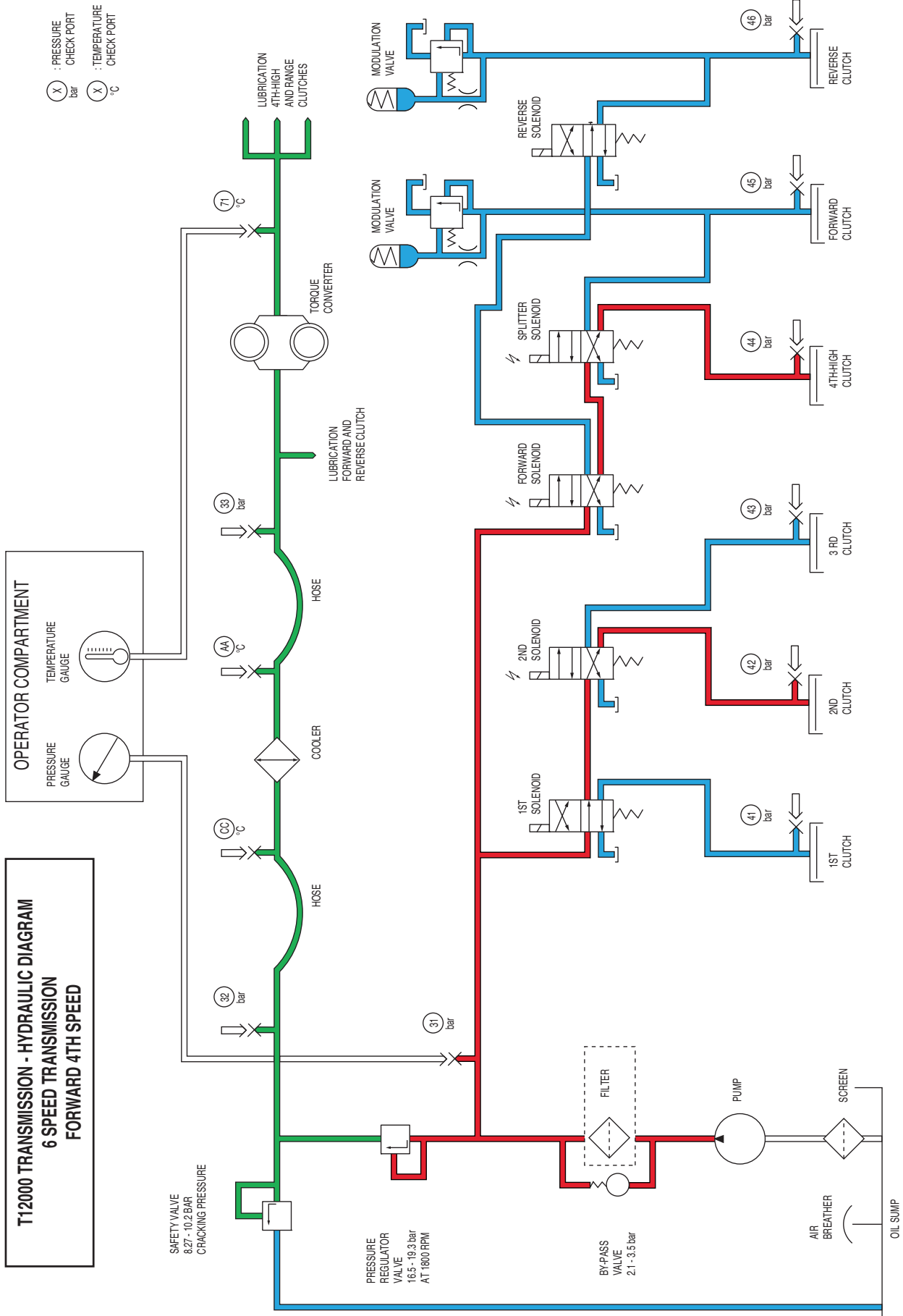
FORWARD 2ND SPEED

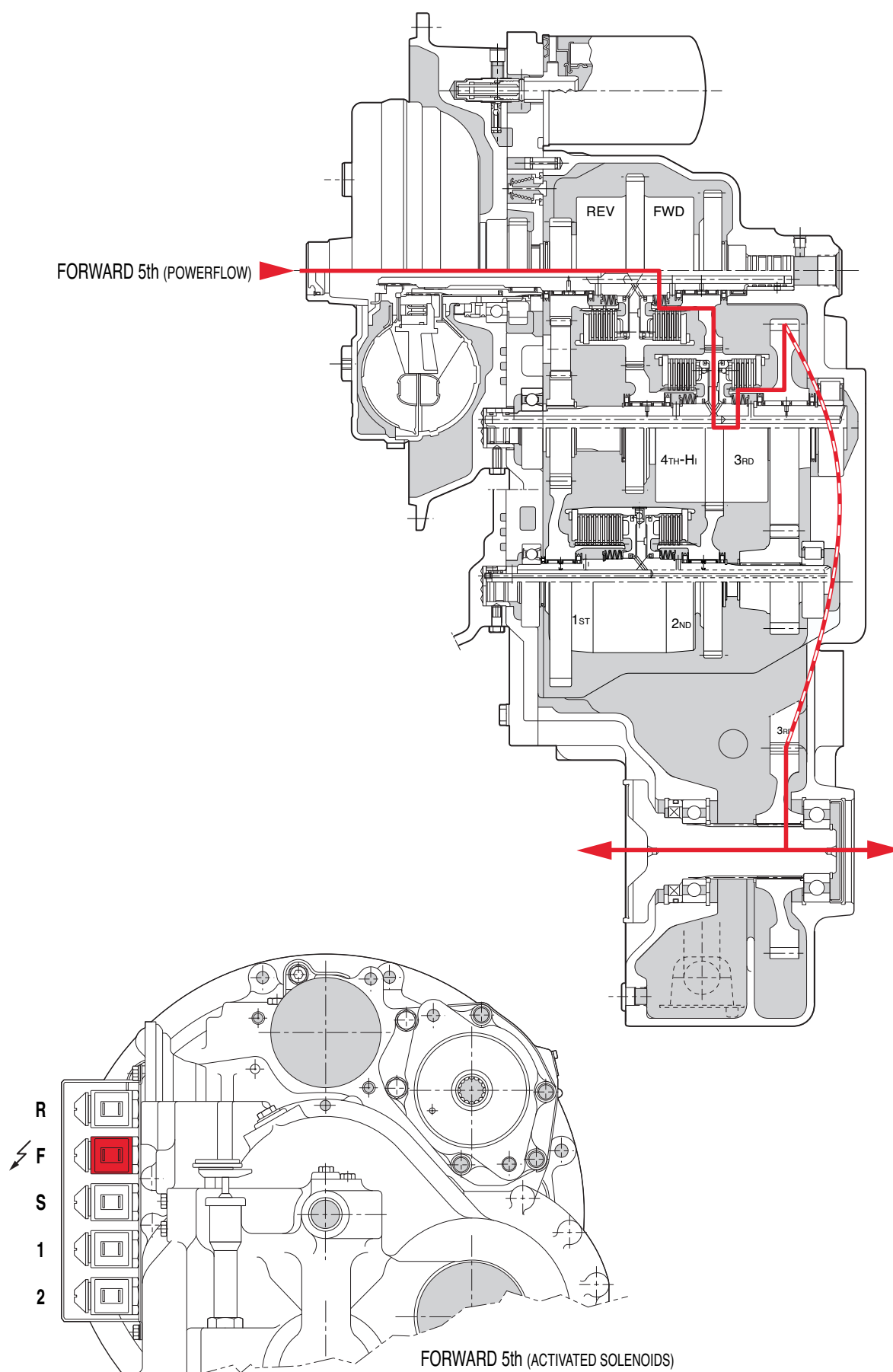


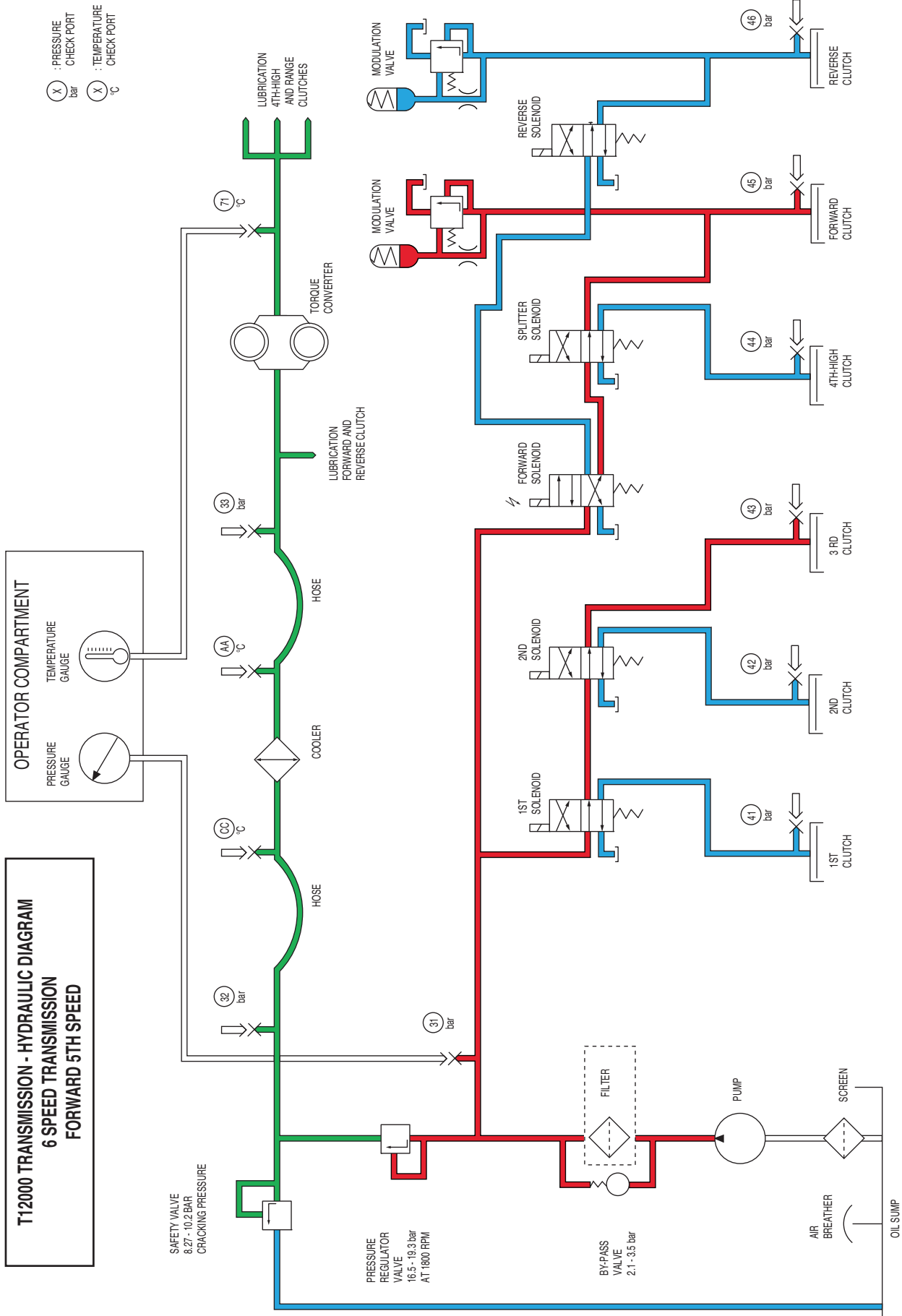
FORWARD 3RD SPEED

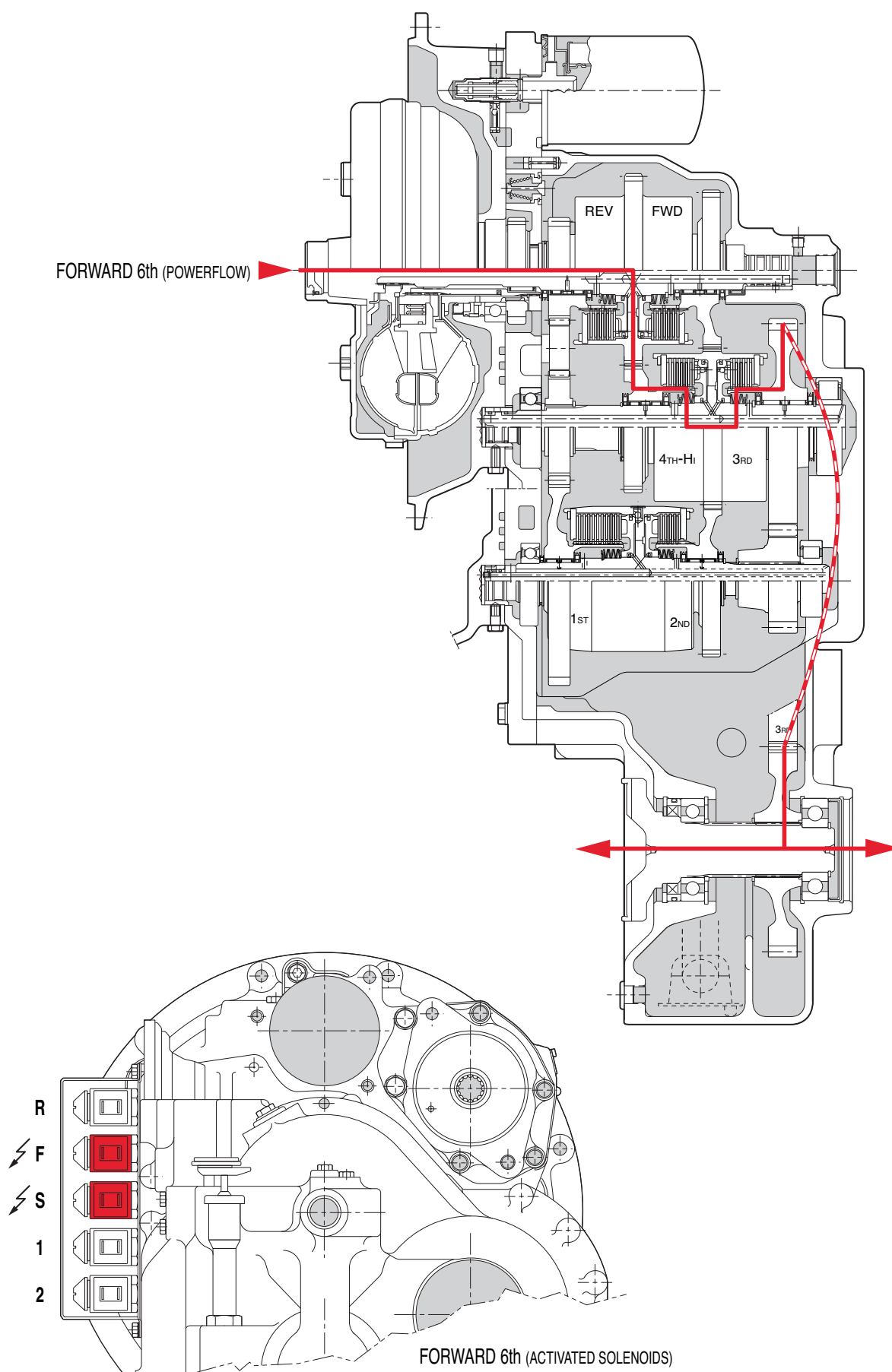


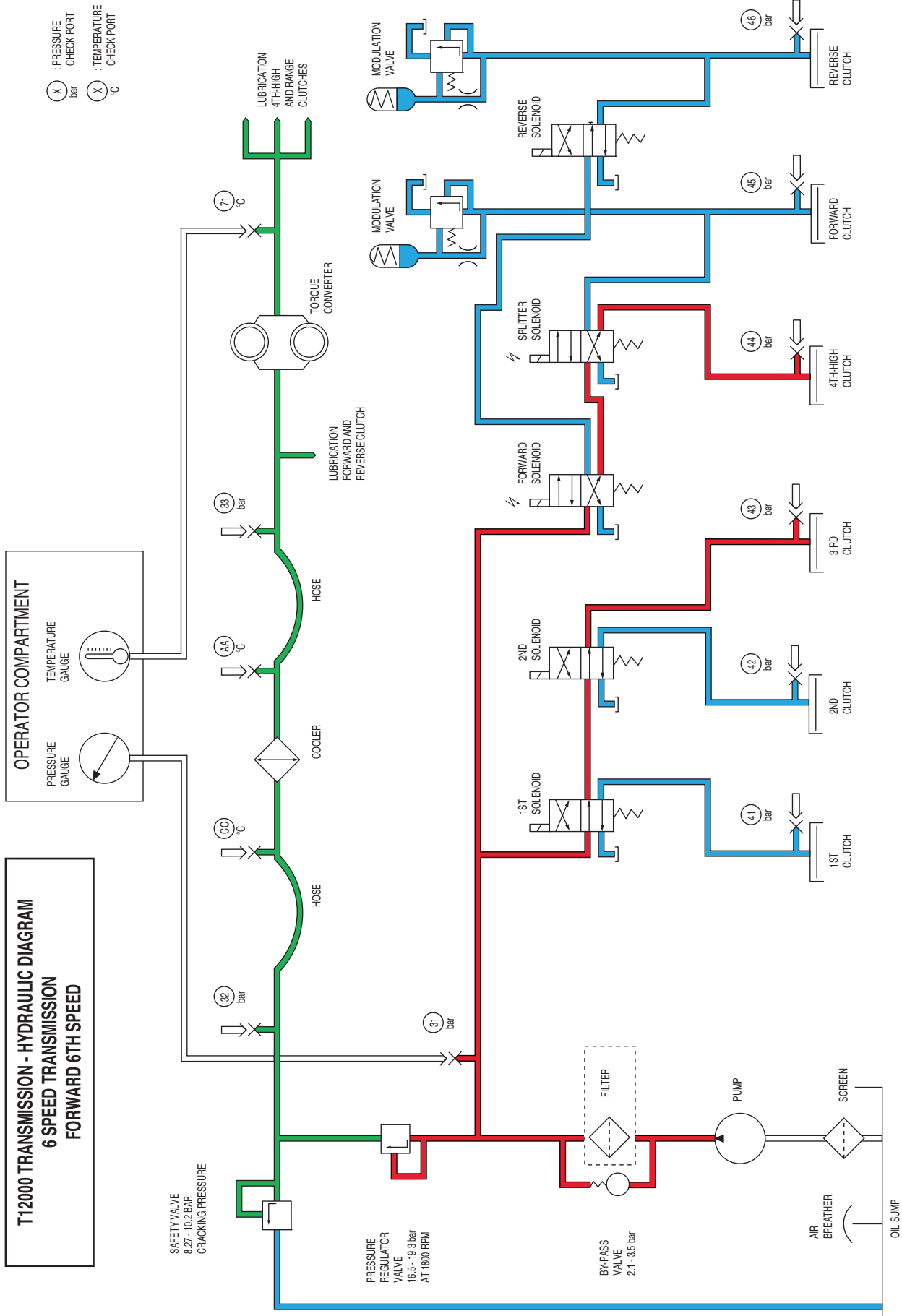
FORWARD 4TH SPEED

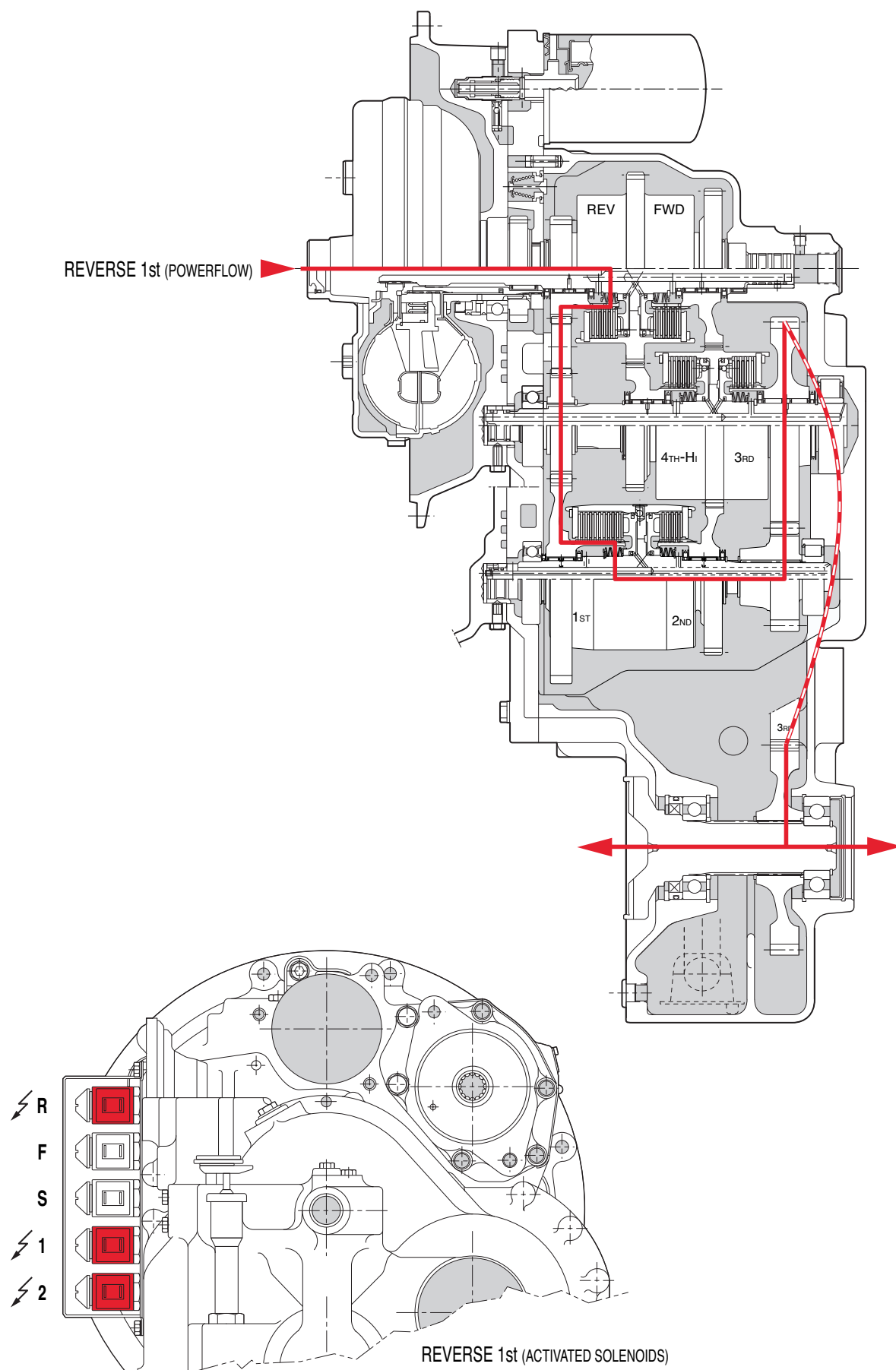


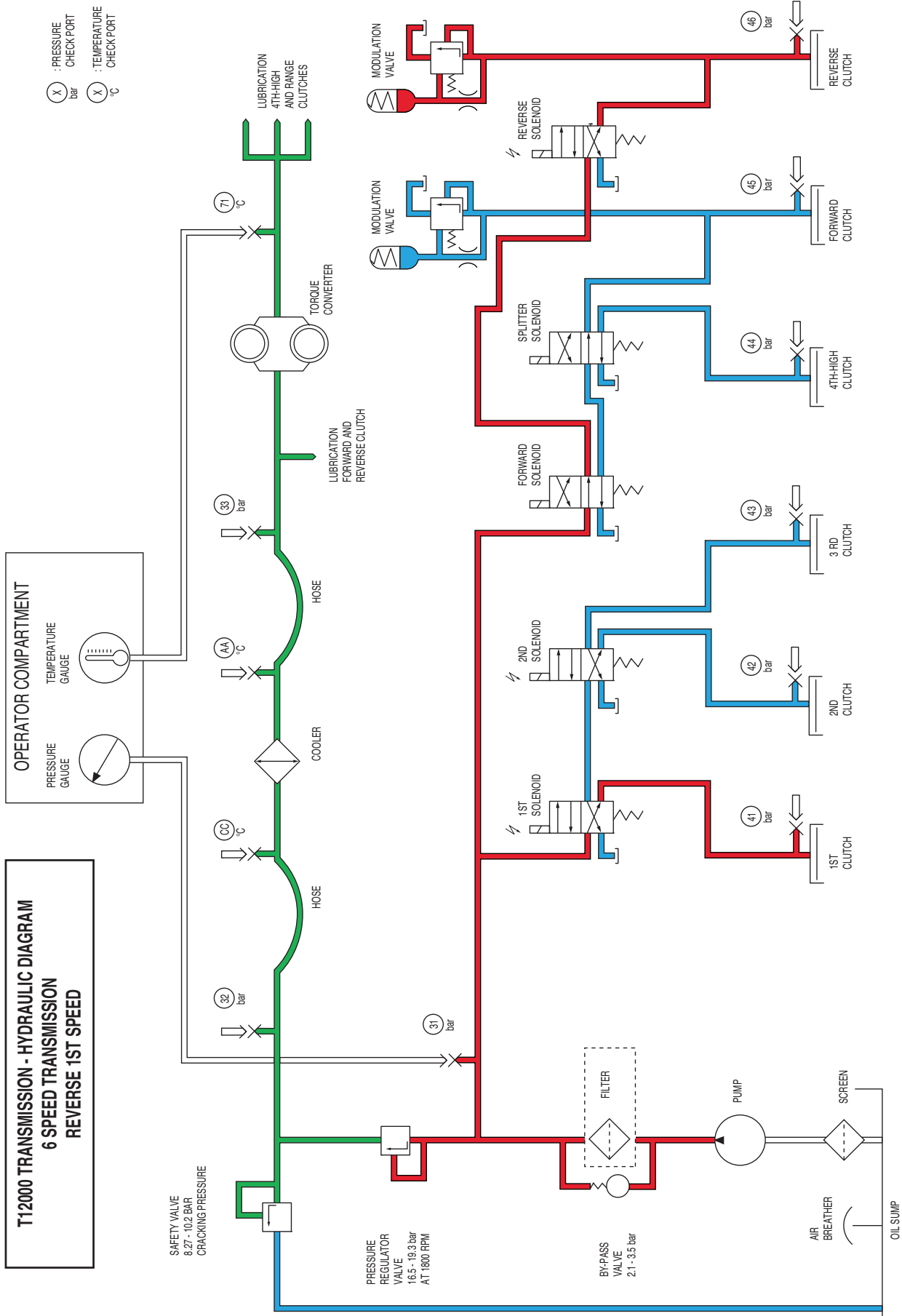
FORWARD 5TH SPEED



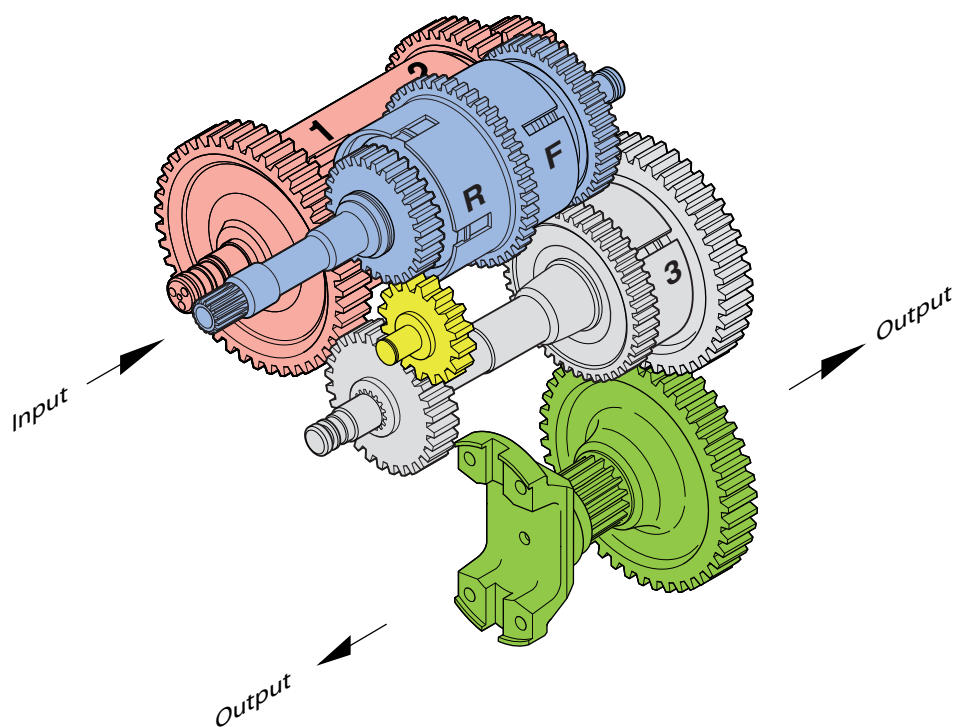
FORWARD 6TH SPEED








REVERSE 1ST SPEED

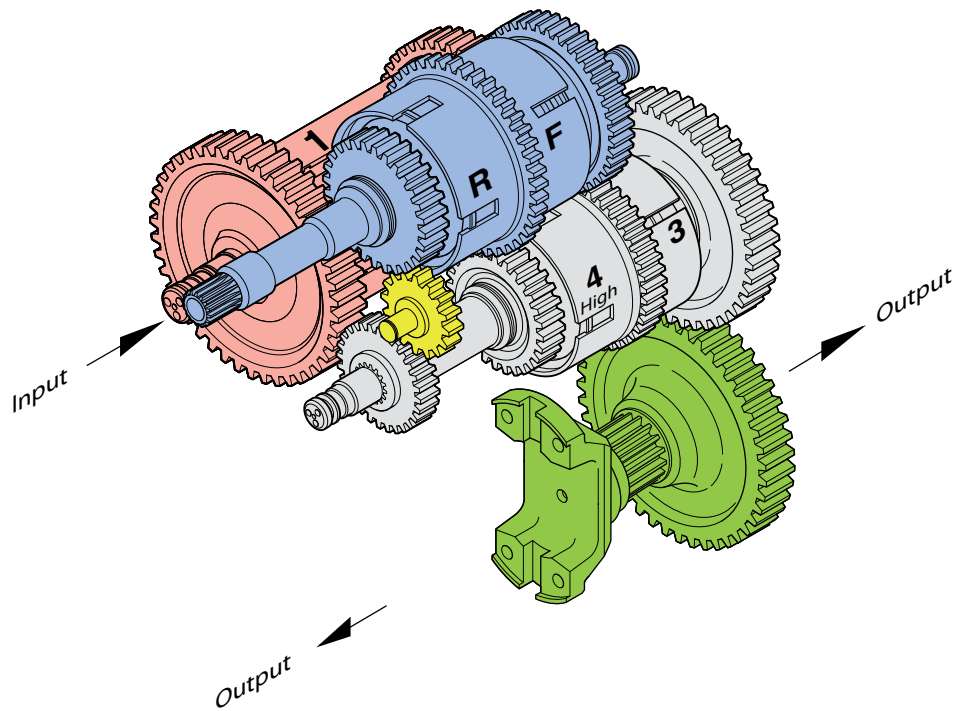


GEAR AND CLUTCH LAY-OUT (3-SPEED)



-  Reverse and Forward
-  1st and 2nd
-  Reverse idler
-  3rd
-  Output Section

GEAR AND CLUTCH LAY-OUT (4-SPEED AND 6-SPEED)

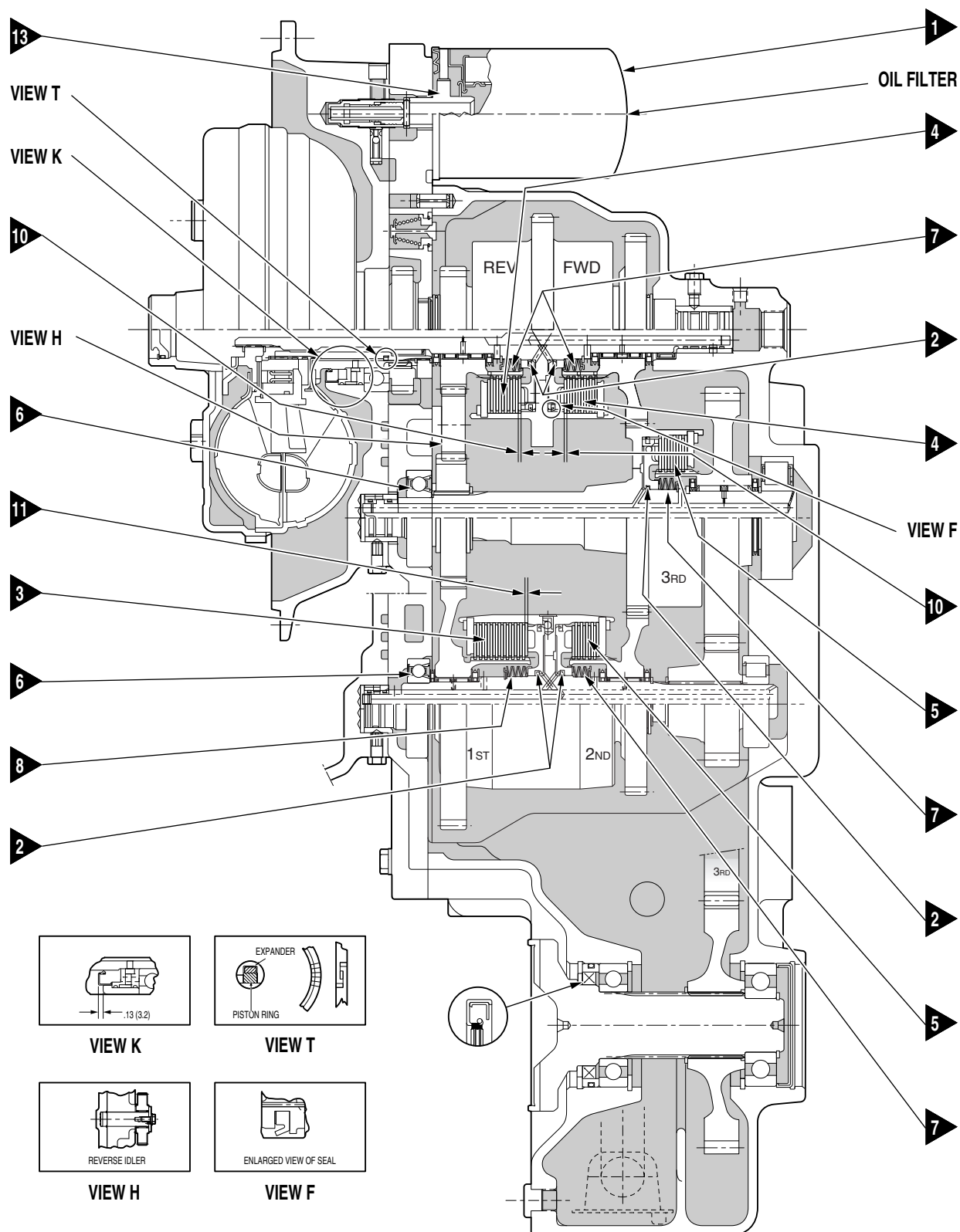


- Reverse and Forward
- 1st and 2nd
- Reverse idler
- 4th-High & 3rd
- Output Section

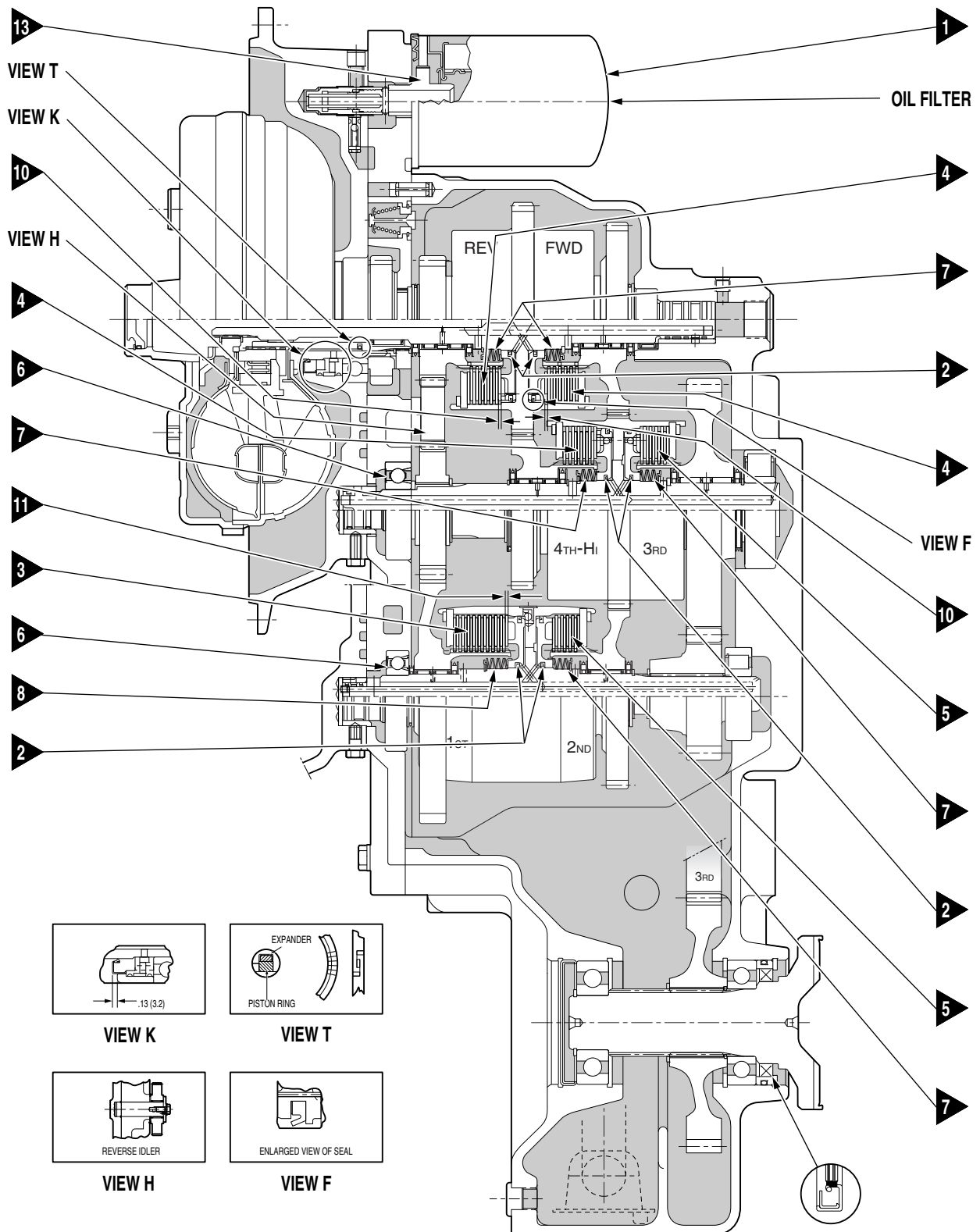
ASSEMBLY INSTRUCTION

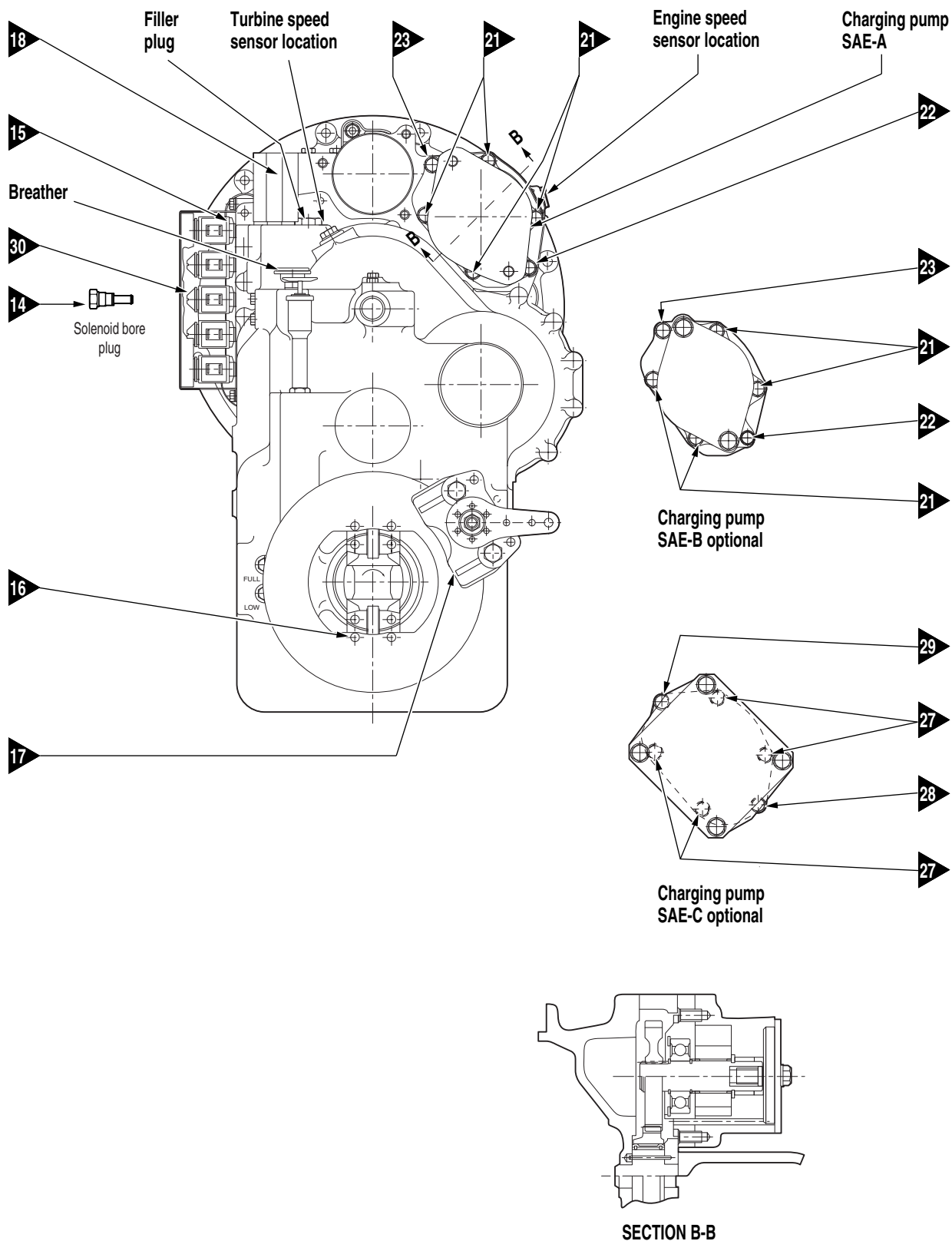
T12000 - 3, 4, 6 speed

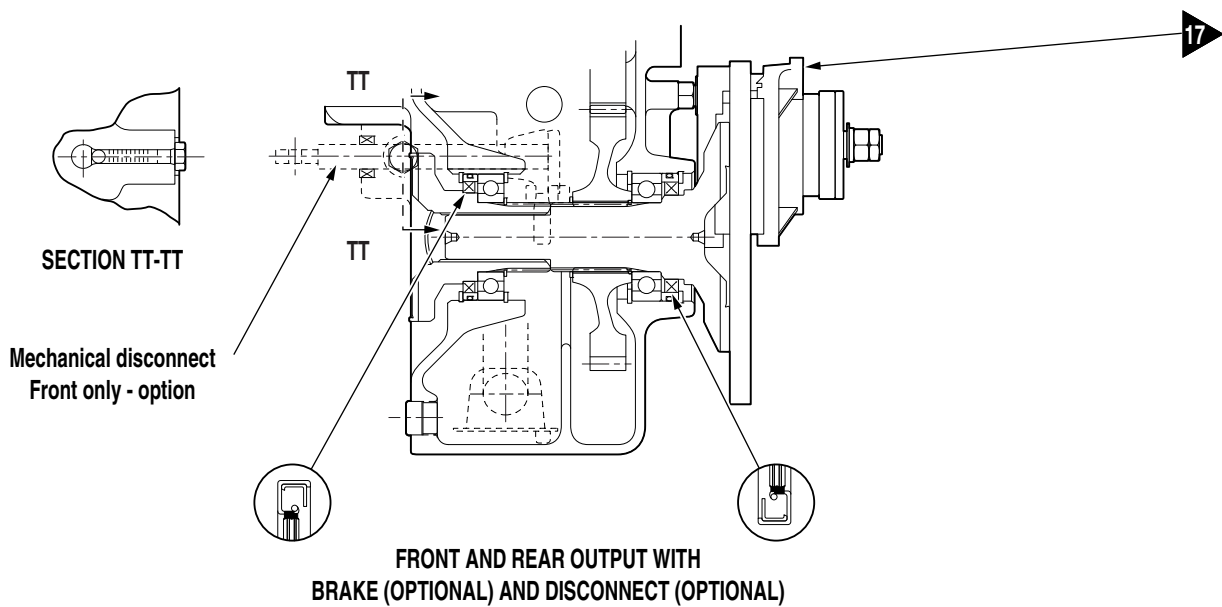
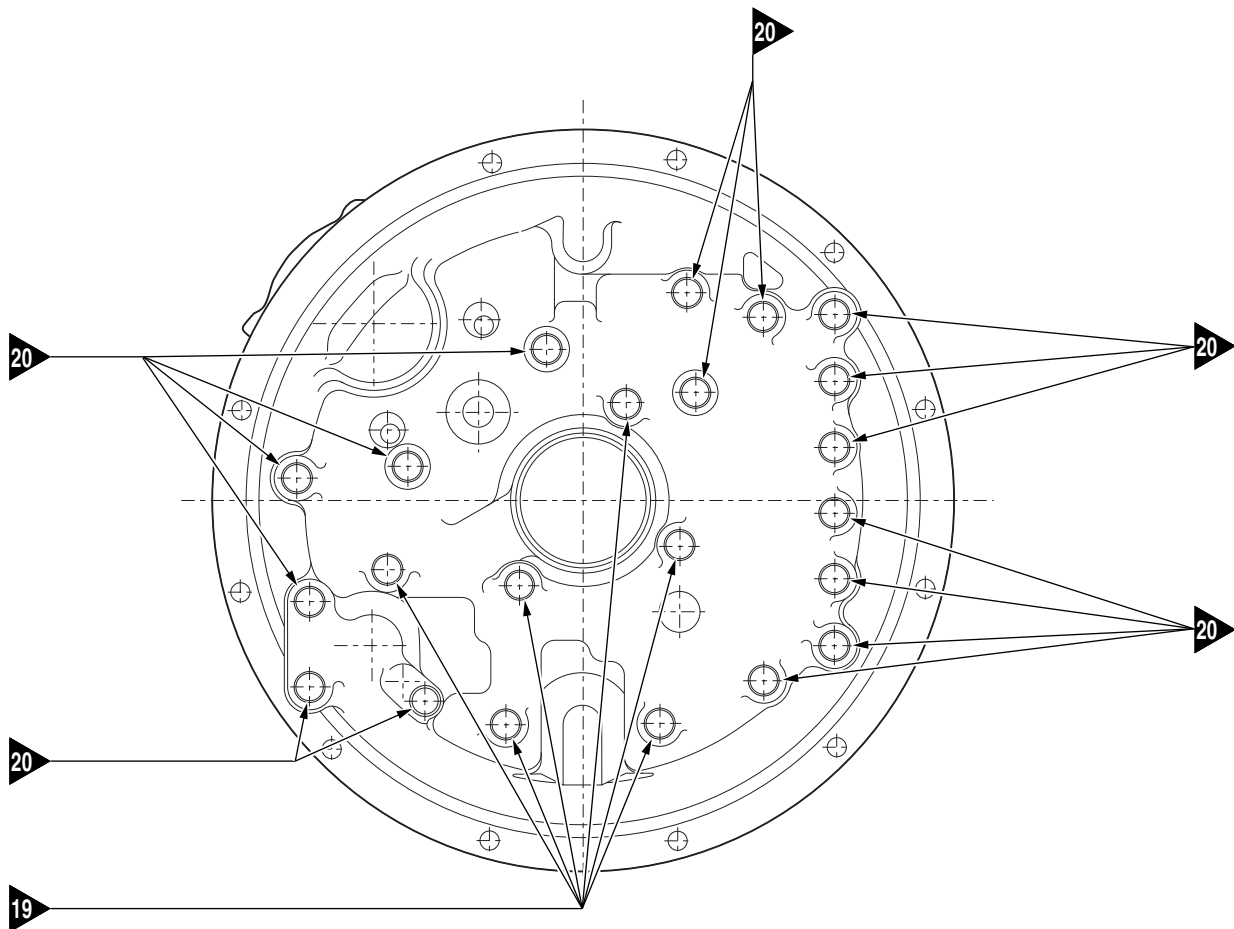
3-SPEED CROSS SECTION



4 AND 6-SPEED CROSS SECTION







Use Permatex and Loctite only where specified.

All lead in chamfers for oil seals, piston rings, and "O"-rings must be smooth and free from burrs. Inspect before assembly.

Lubricate all piston ring grooves and "O"-rings with oil before assembly.

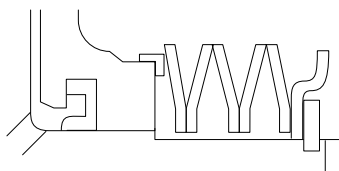
Apply a thin coat of grease between seal lips on lip type seals prior to assembly.

Apply a thin coat of Permatex No. 2 or Loctite No. 641 to O.D. of all oil seals before assembly.

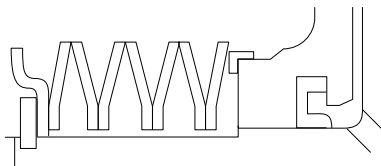
Apply a thin coat of Loctite No. 592 or 506 Dryseal to all pipe plugs.

After assembly of parts using Loctite or Permatex, there must not be any free or excess material which might enter the oil circuit.

- 1 Assemble oil filter and tighten to 20-25 lbf.ft [27-34 N.m].
- 2 Teflon seals must be sized prior to assembly.
- 3 10 outer steel plates, 10 inner plates, alternately assemble, starting with outer steel plate.
- 4 6 outer steel plates, 6 inner plates, alternately assemble, starting with outer steel plate.
- 5 5 outer steel plates, 5 inner plates, alternately assemble, starting with outer steel plate.
- 6 Shield bearing, assembly with shield as shown.
- 7 Add a coating of Loctite 641 to outer diameter of bearings.
- 8 Fwd. ,Rev., 2nd and 3rd. clutch return disc springs. Concave side of first disc spring to be placed against clutch piston wear sleeve. Remaining four springs to be stacked alternately as shown.



- 9 Low clutch return disc springs concave side of first disc spring to be placed against clutch piston wear sleeve. Remaining six springs to be stacked alternately as shown.



- 10 Clearance between clutch piston and steel separator plate to be .048-.108 [1.22-2.74]. If over .108 [2.74] clearance, add one steel outer disc under end plate.
- 11 Clearance between clutch piston and steel separator plate to be .080-.135 [2.03-3.43]. If over .135 [3.43] clearance, add one steel outer disc under end plate.
- 12 Tighten regulator sleeve to 45-50 lbf.ft [61-68 N.m].
- 13 Use solenoid bore plug in middle position for 3-speed version only.
- 14 Solenoid cartridge to be assembled and tightened to 16-20 lbf.ft [22-27 N.m].
- 15 Apply Loctite No. 243 to thread of disc mounting screws.
- 16 See page 4-4 for brake information.
- 17 Tighten modulation valve and inching valve to 60-65 lbf.ft [81-88 N.m].
- 18 M10 x 1.17 - 1.20. [M10 x 30].
- 19 M10 x 2.32 - 2.4. [M10 x 60].
- 20 Use 5/16-18 x 5.00 screw.
- 21 Use 5/16-18 x 3.500 screw.
- 22 Use 3/8-16 x 5.00 screw.
- 23 Use 5/16-18 x 3.250 screw.

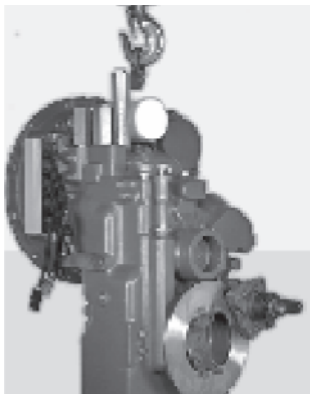


- 24** Use 5/16-18 x 2.00 screw.
- 25** Use 3/8-18 x 3.250 screw.
- 26** Use 5/16-24 nut.
- 27** Use 5/16-24 nut.
- 28** Use 3/8-24 nut.
- 29** Tighten all cartridge nuts to 4-5 lbf.ft [5-7 N.m].

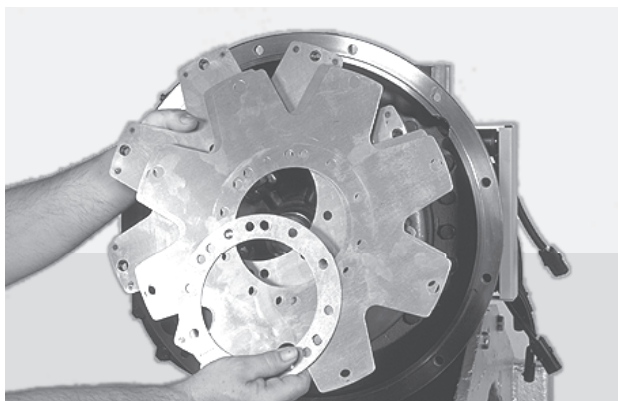
TRANSMISSION COMPLETE

DISASSEMBLY

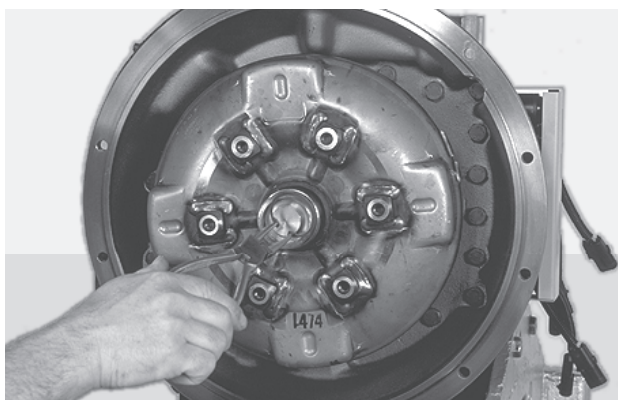
Side view of T12000 intermediate drop transmission.

**21**

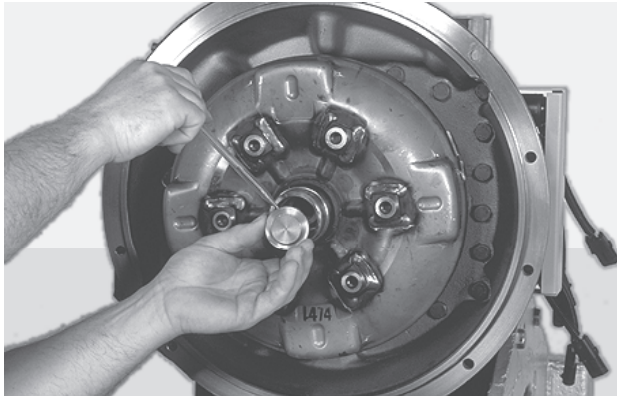
Rear view showing disc brake and electric control.

**22**

Remove drive plate attaching capscrews and washers. Remove drive plate and backing ring.

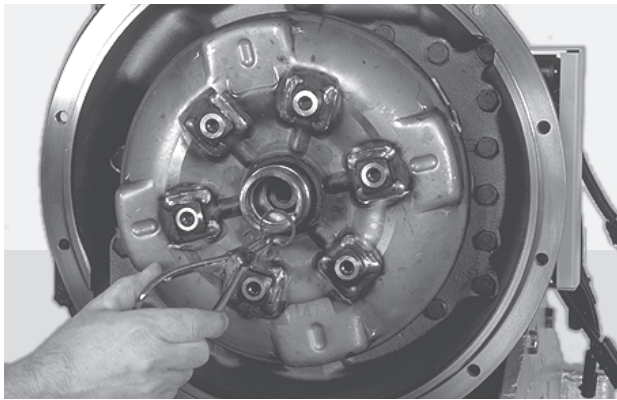
**23**

Remove torque converter plug retainer ring.



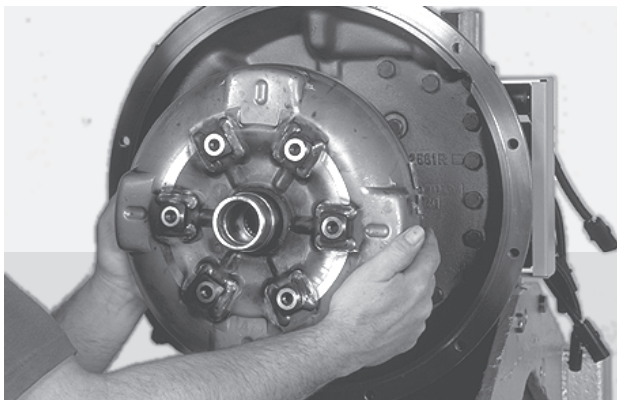
24

Remove plug and "O"-ring.



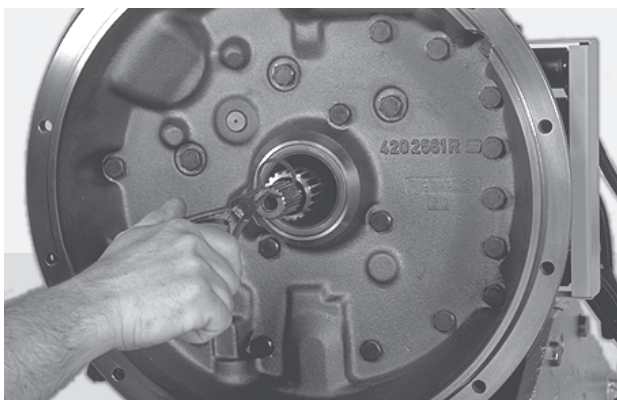
25

Remove torque converter to turbine shaft retainer ring.



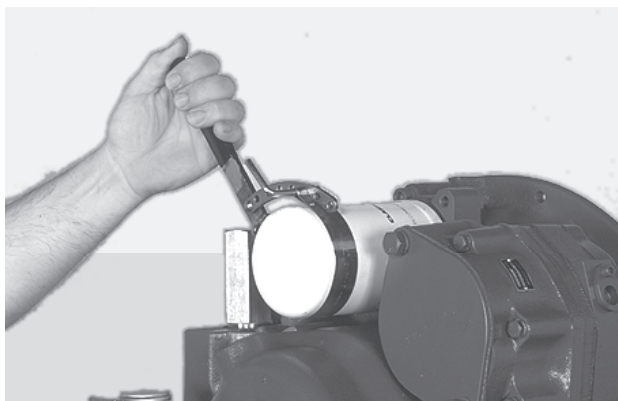
26

Remove torque converter assembly.

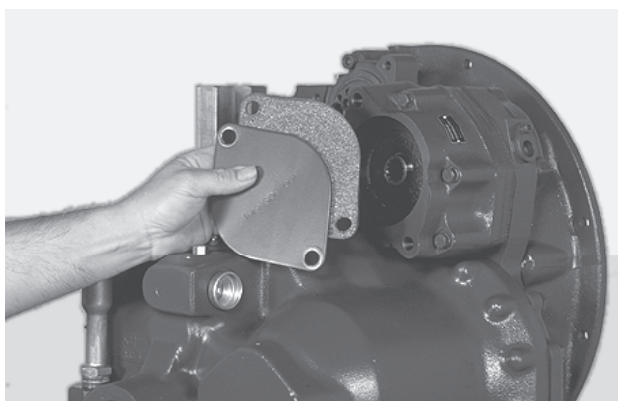


27

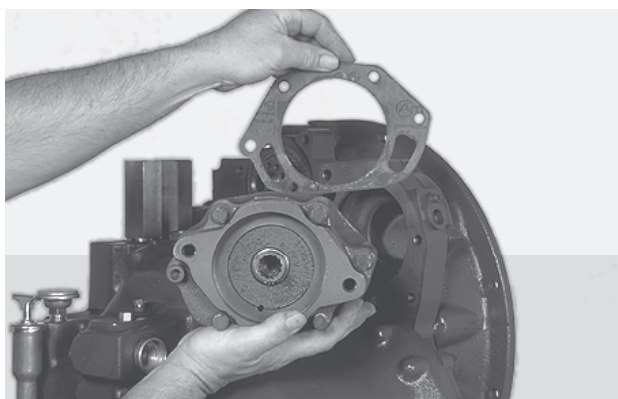
Remove torque converter to shaft locating ring.

**28**

Remove filter assembly.

**29**

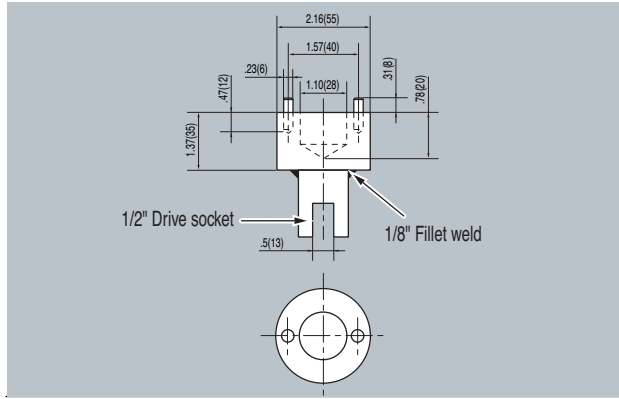
Remove charging pump permanent pump hole cover (not used when auxiliary pump is used).

**30**

Remove pump mounting bolts and washers. Remove pump and gasket.

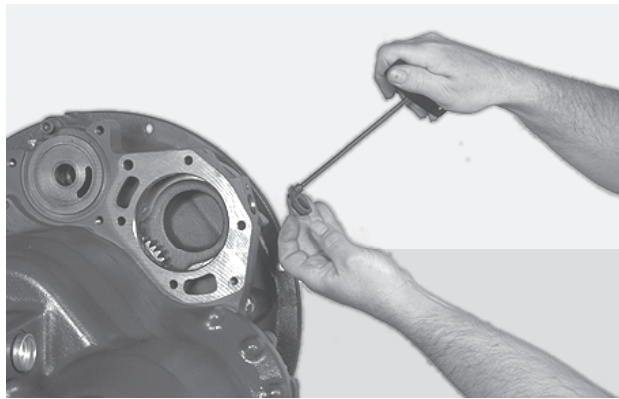
**31**

Remove pressure regulator and regulator sleeve.



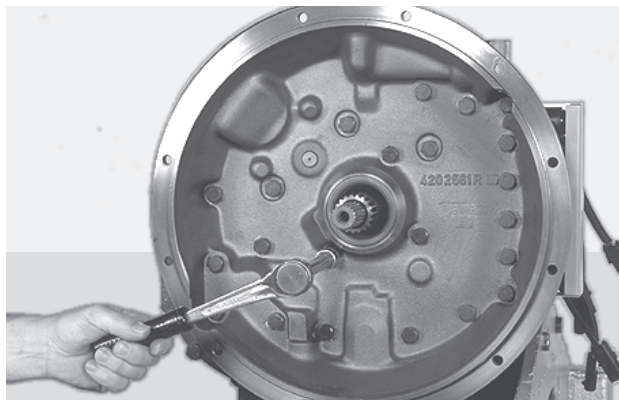
32

Special tool can be fabricated.



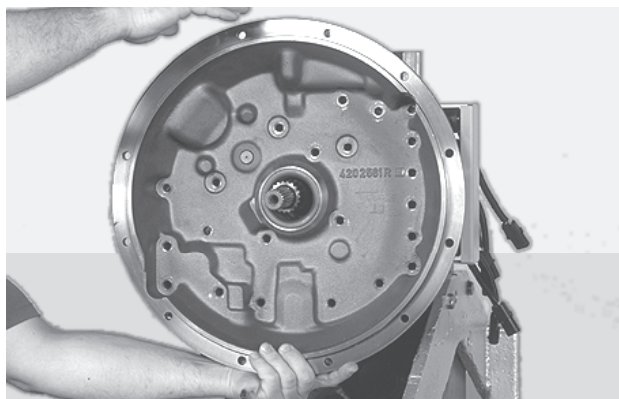
33

Remove sensor port plug and "O"-ring.



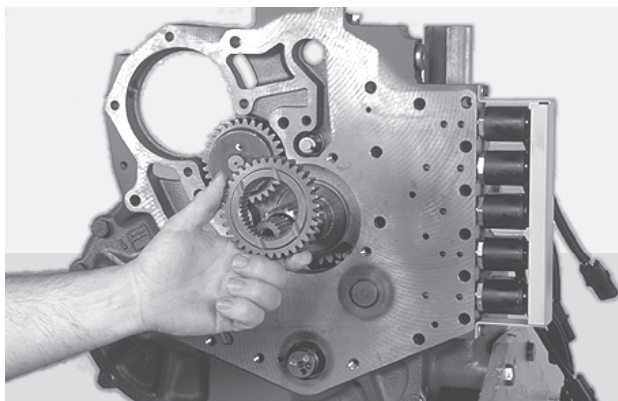
34

Remove converter housing to transmission case bolts and washers.

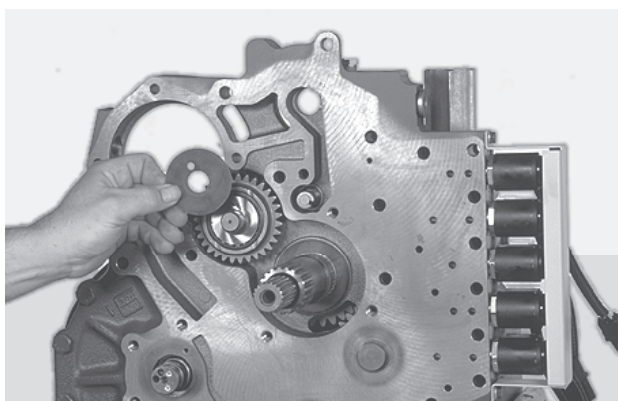


35

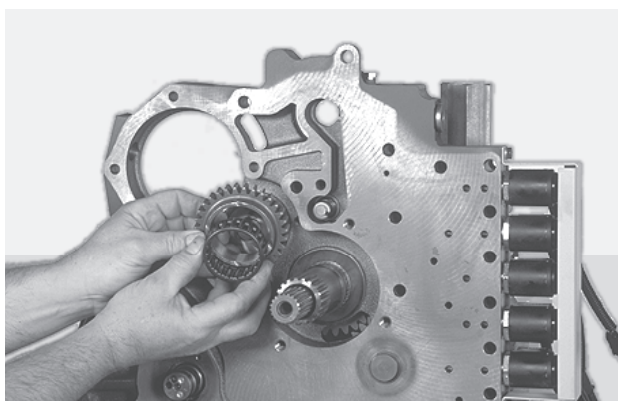
Remove converter housing and gasket.

**36**

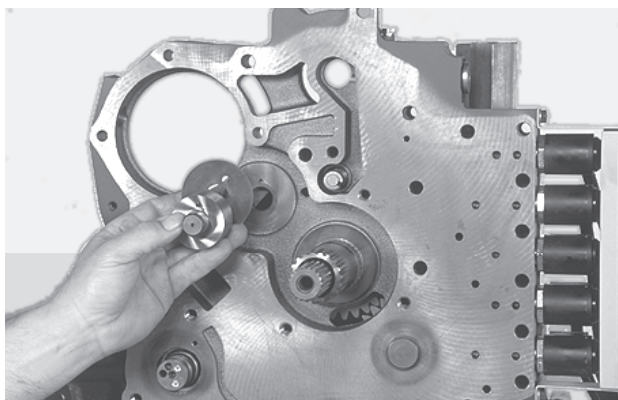
Remove impeller hub gear.

**37**

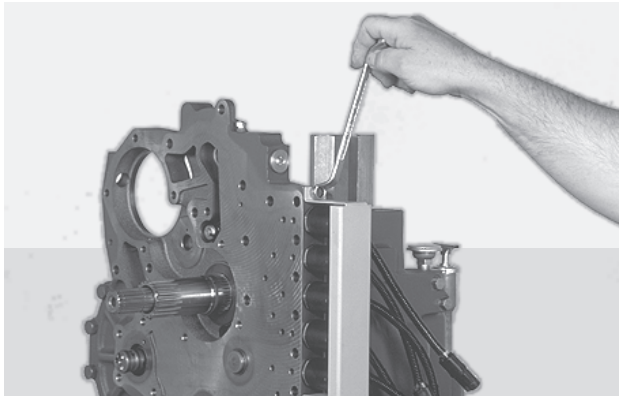
Remove pump drive idler gear washer.

**38**

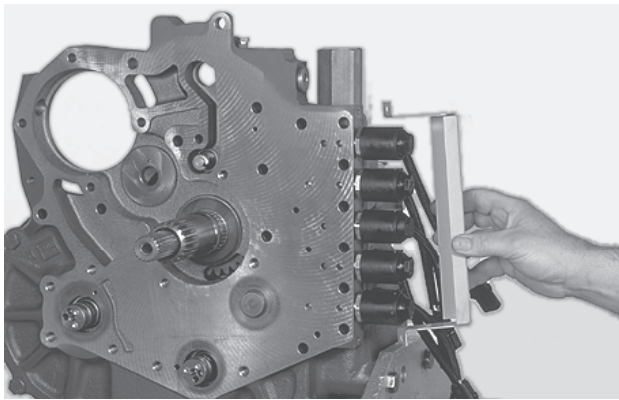
Remove pump drive gear and bearing.

**39**

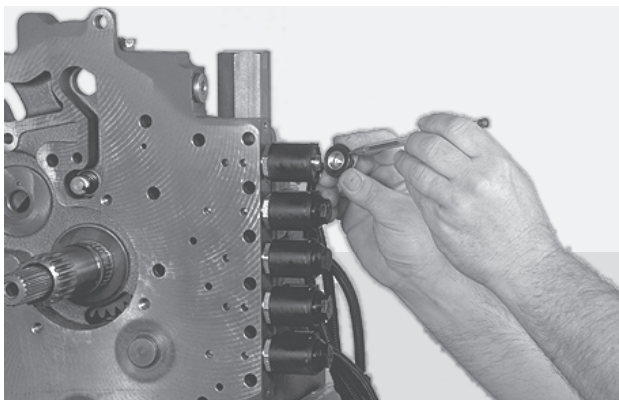
Remove pump drive idler shaft and washer.

**40**

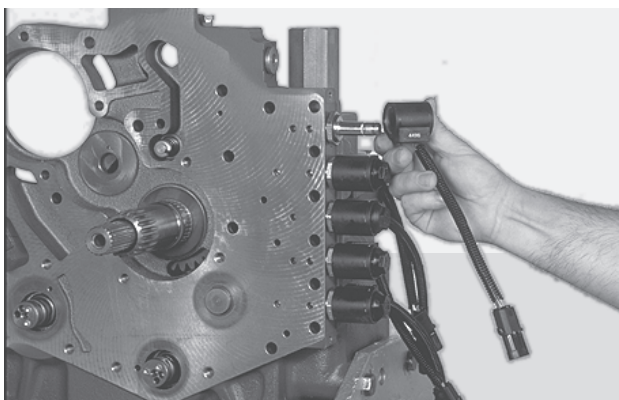
Remove solenoid protection cover screws.

**41**

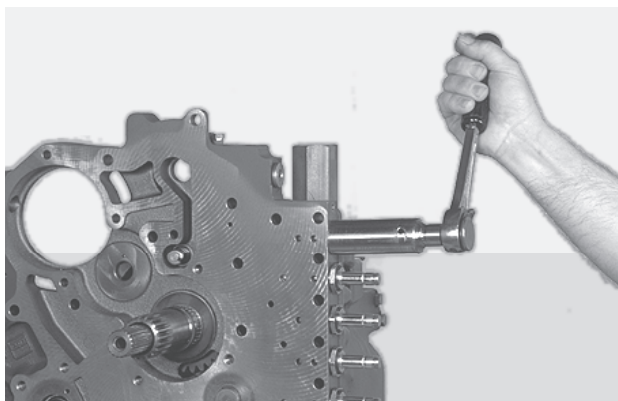
Remove solenoid protection cover.

**42**

Remove solenoid valve cartridge retainer nut and "O"-ring.

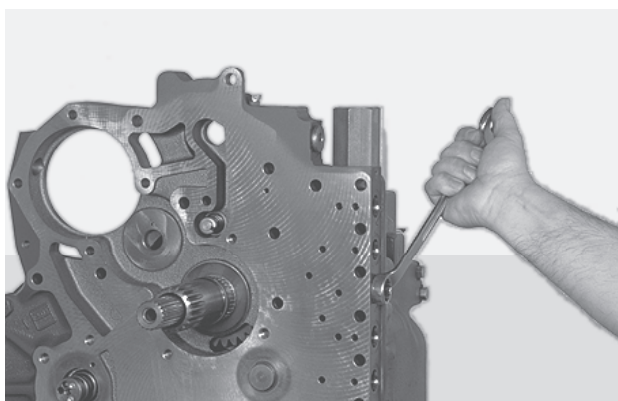
**43**

Remove solenoid coil and "O"-ring.



44

Remove valve cartridge and "O"-ring.

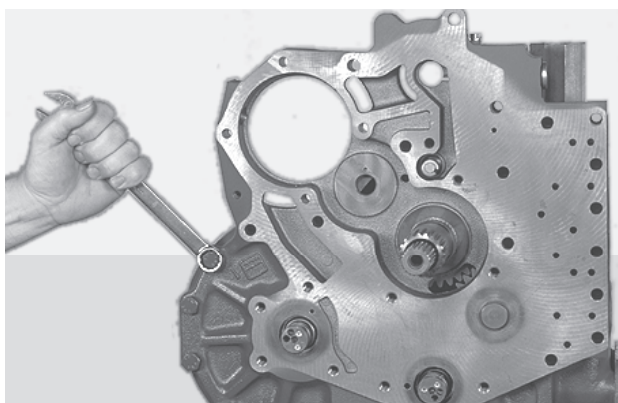


45

Repeat procedures the two previous step for remaining solenoid valves.

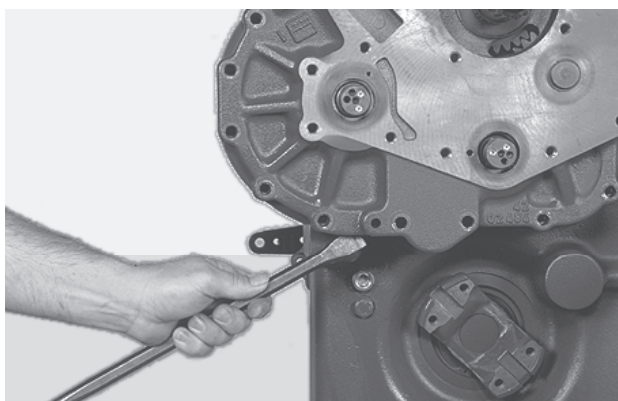


NOTE: A 3-speed will have a bore plug in the center box. Remove bore plug.



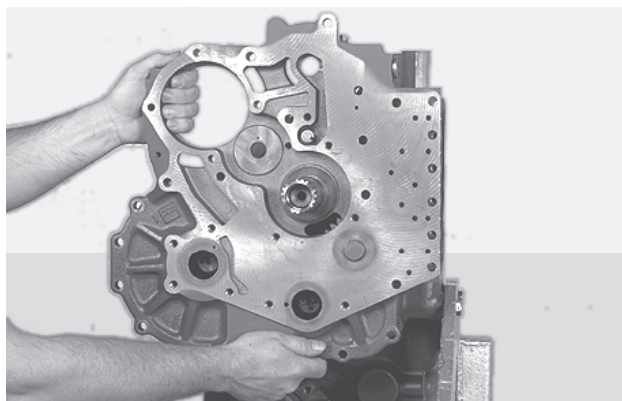
46

Remove spacer plate bolts and washers.



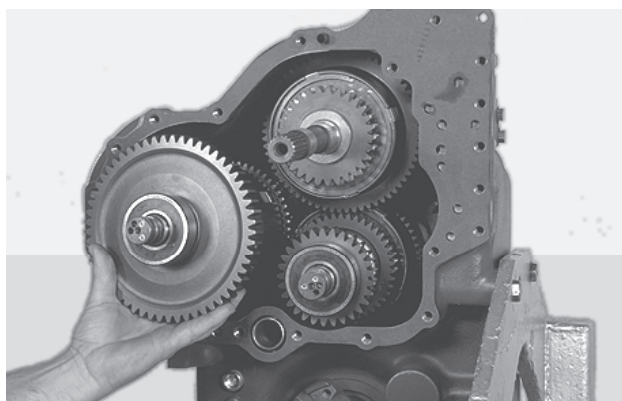
47

Pry spacer plate away from transmission case at dowel pin holes.



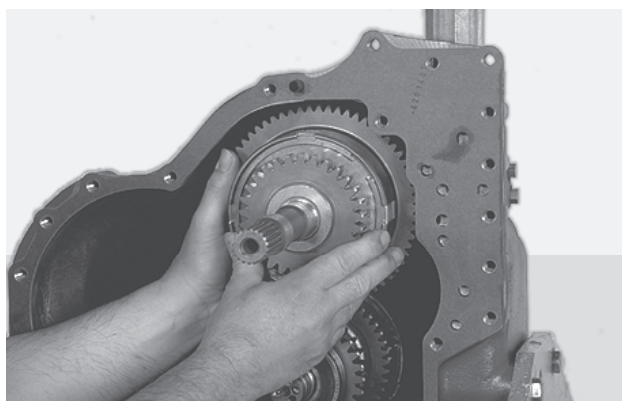
48

Remove spacer plate and gasket.



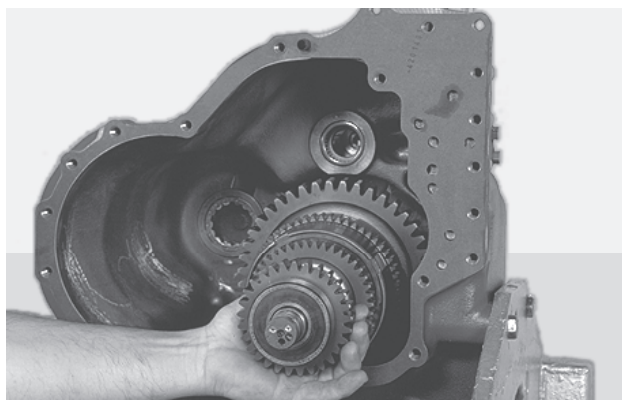
49

Remove 1st and 2nd clutch assembly.



50

Remove forward and reverse clutch assembly.

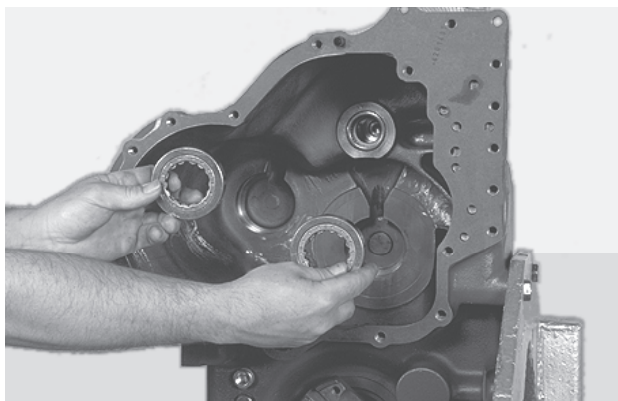


51

Remove high and 3rd clutch assembly.

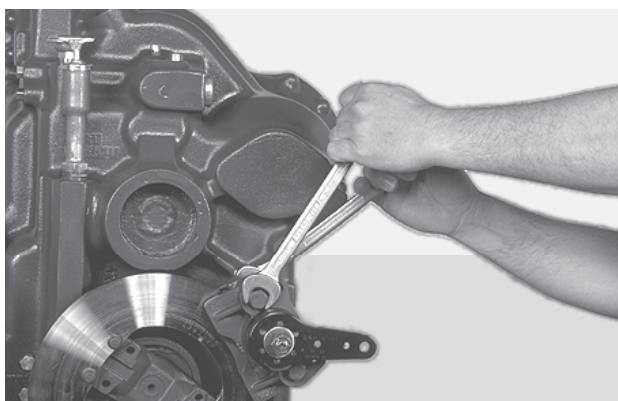


NOTE: A 3-speed will only have 3rd clutch.



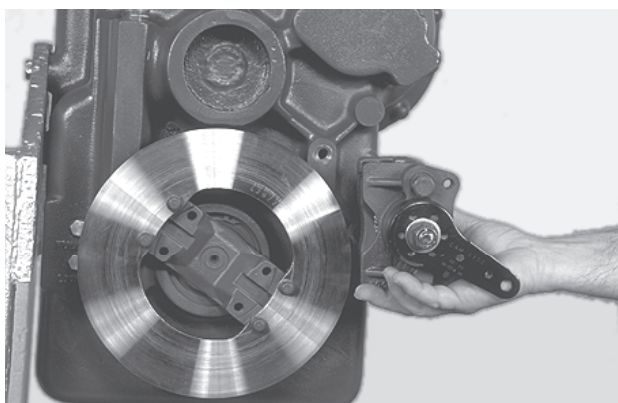
52

Remove clutch shaft rear bearing outer races.



53

Remove brake disc assembly bolts from brake and housing.

**NOTE:** brake is an option and will not be on all units.

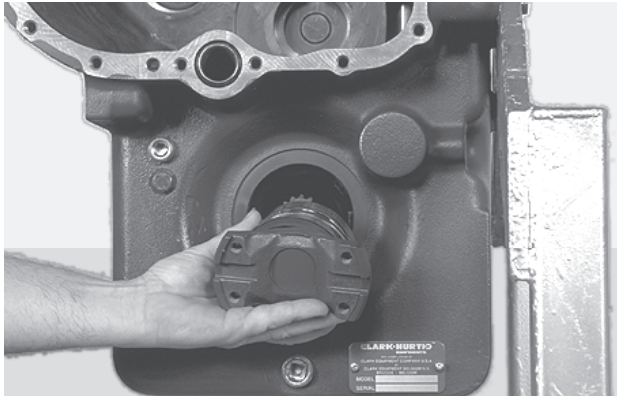
54

Remove brake caliper assembly.



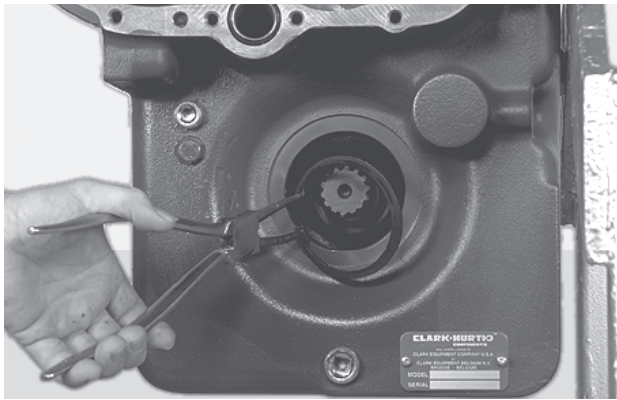
55

Turn front output flange as shown. Remove retainer ring from ring groove and pry output flange from housing.



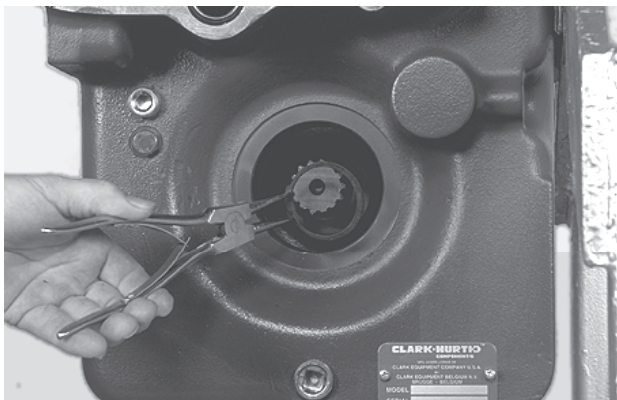
56

Output flange, oil seal sleeve and front bearing removed.



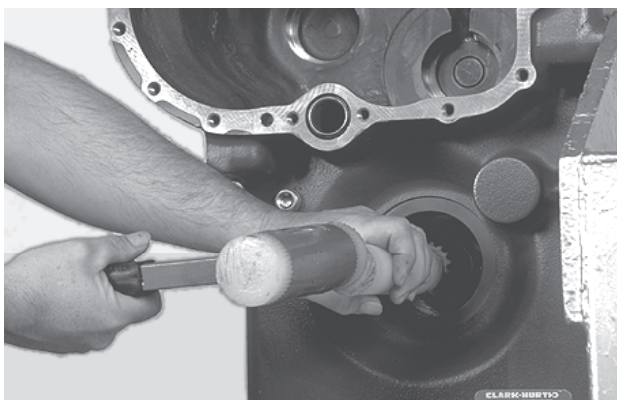
57

Remove bearing locating ring.



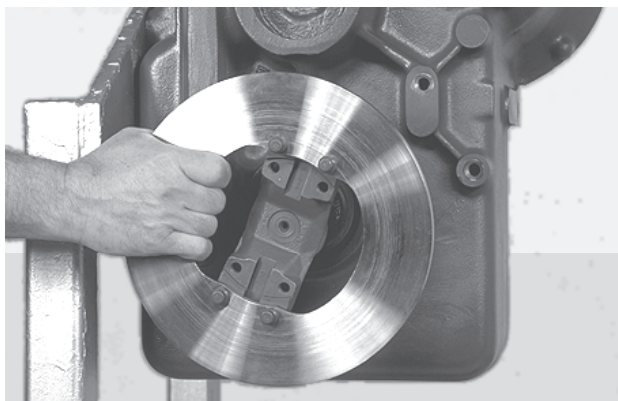
58

Remove output gear to shaft retainer ring.

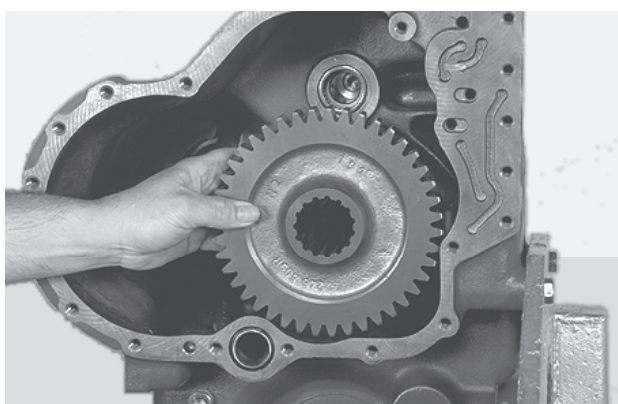


59

Tap output shaft and flange from housing.

**60**

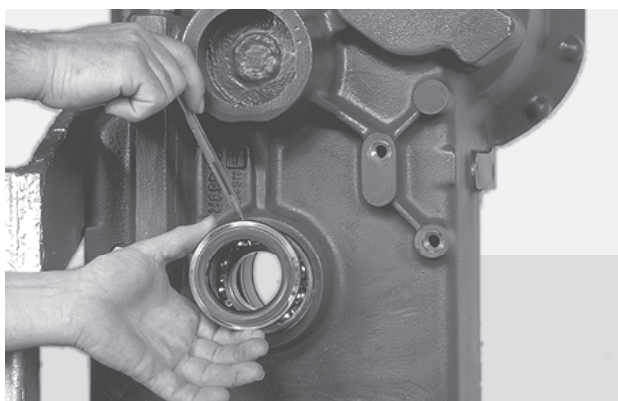
Flange removed.

*NOTE: brake disc is optional and was removed with flange.***61**

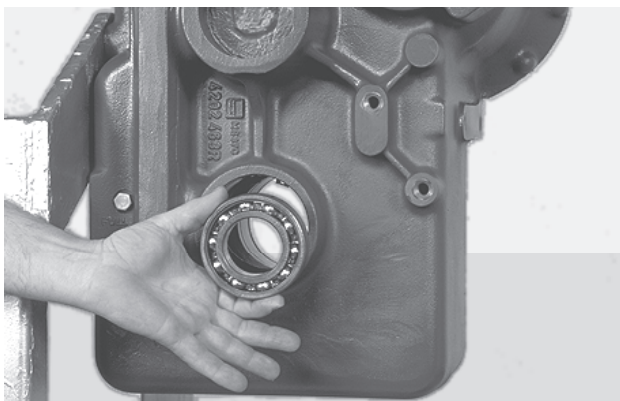
Remove output gear.

**62**

Remove flange oil seal sleeve retainer ring.

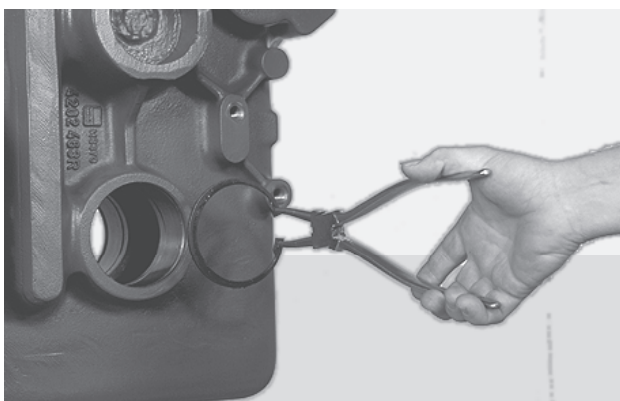
**63**

Remove sleeve and "O"-ring.



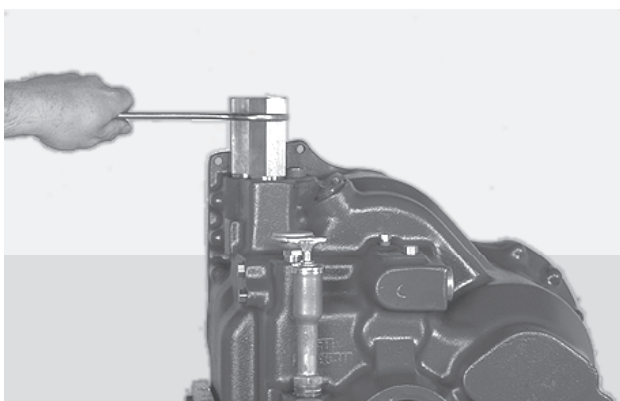
64

Remove output shaft rear bearing.



65

Remove bearing locating ring.

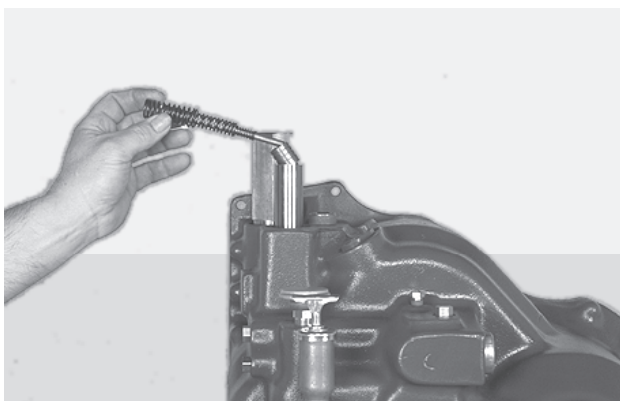


66

Remove modulator valve housing.

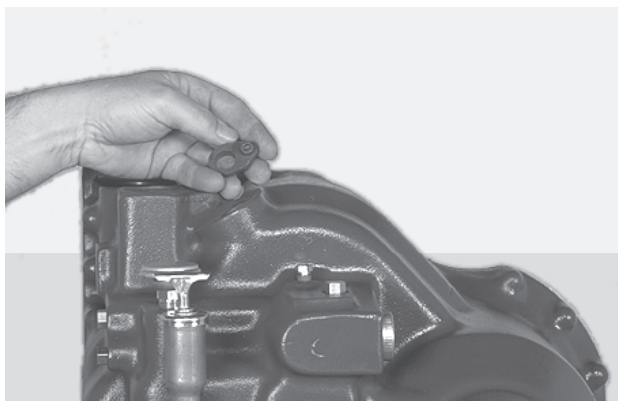


NOTE: for single modulation and hydraulic inching.
See details at section **OPTIONS** (pag. 279).

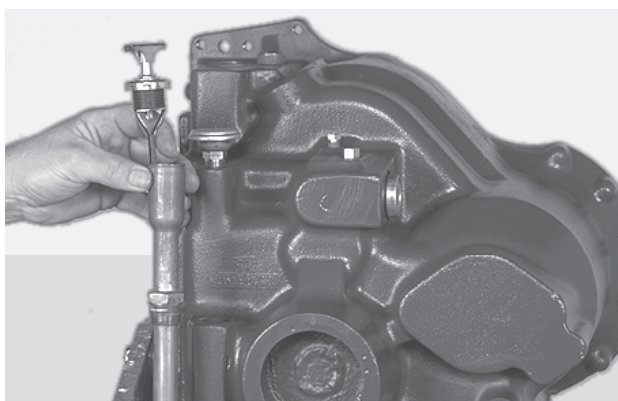


67

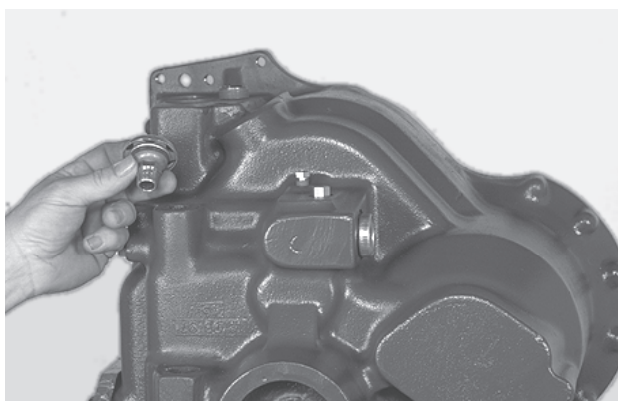
Remove inner, middle and outer springs.
Remove valve stop pin and accumulator spool.
Remove regulator spool and sleeve assembly.

**68**

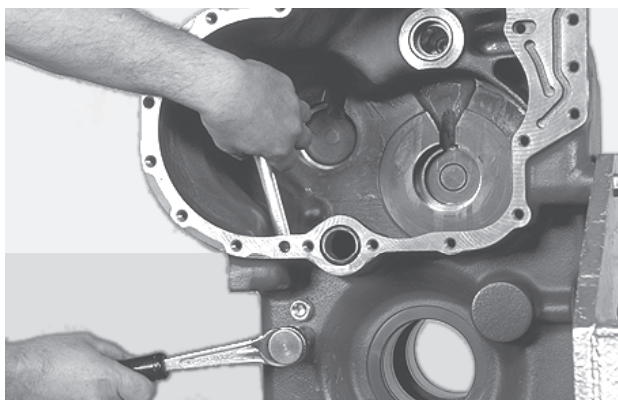
Remove sensor hole plug and "O"-ring.

**69**

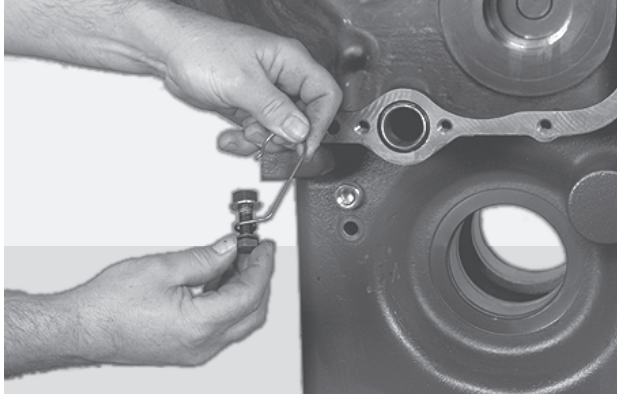
Remove dipstick and dipstick tube.

**70**

Remove air breather.

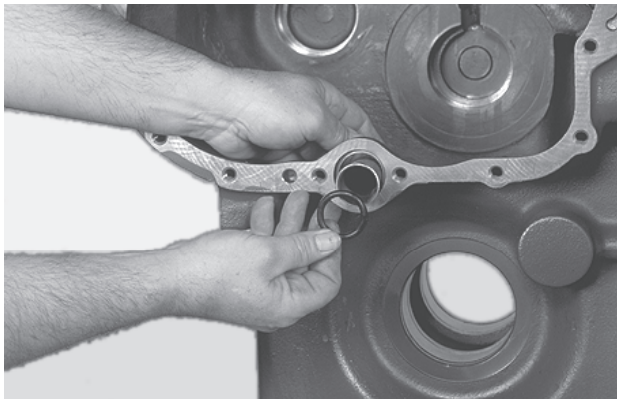
**71**

Remove supply tube retainer screw.



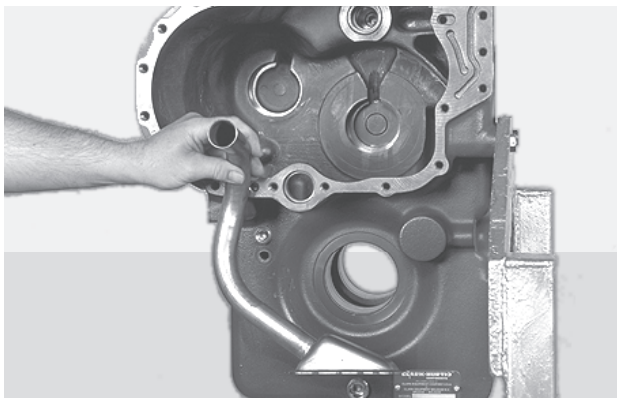
72

Tube retainer, screw, sealwasher, clip, washer and nut removed as shown.



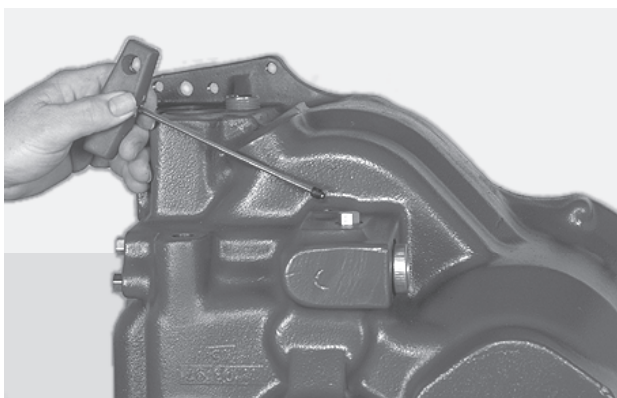
73

Remove supply tube "O"-ring.



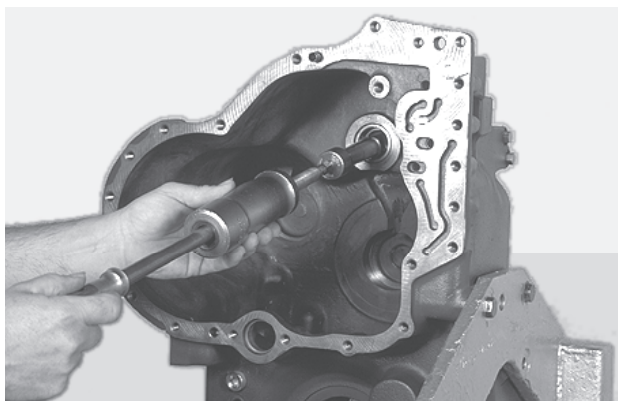
74

Remove supply tube and screen assembly.



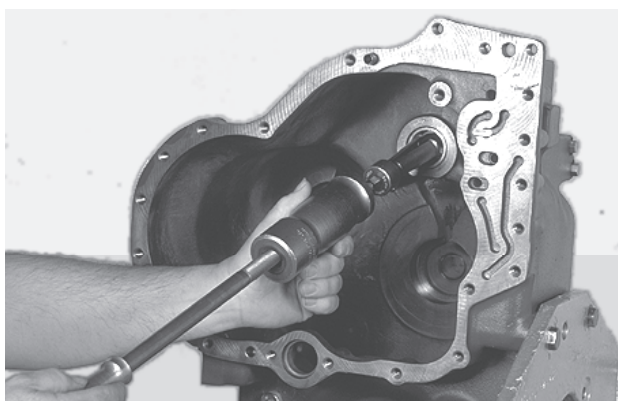
75

Remove oil sleeve distributor lock screw plug. Remove lock screw.



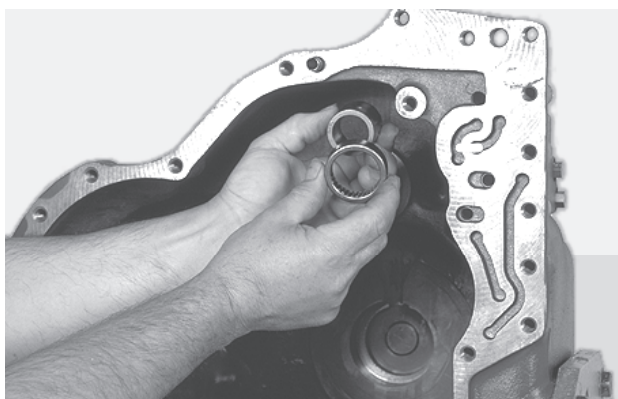
76

Use a hammer puller as shown to remove distributor sleeve.



77

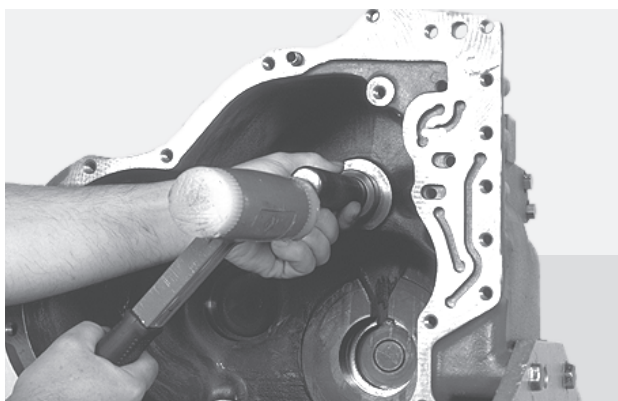
Sleeve being removed. Remove pilot bearing.



78

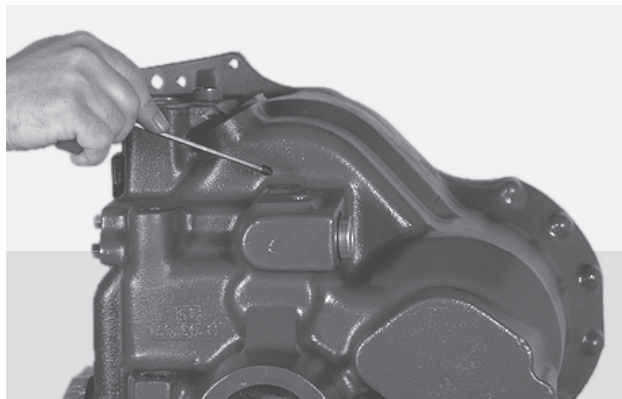
Pilot bearing and oil distributor sleeve removed.

ASSEMBLY



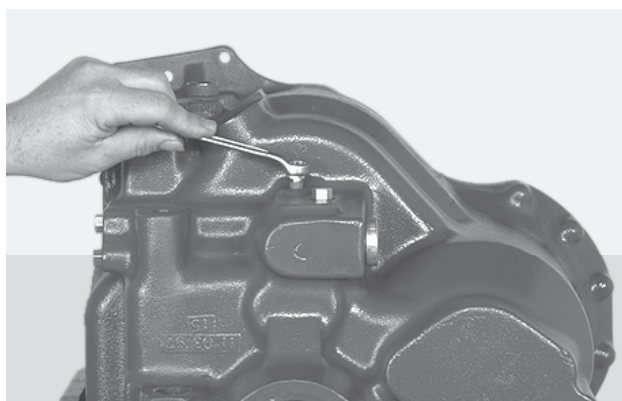
79

Install forward - reverse oil distributor sleeve in transmission case with inside diameter chamfer out (towards front of transmission) and the notch in the distributor aligned up with the retaining set screw hole in the transmission case. Refer to the cleaning and inspection at section CLEANING AND INSPECTION (pag. 2).



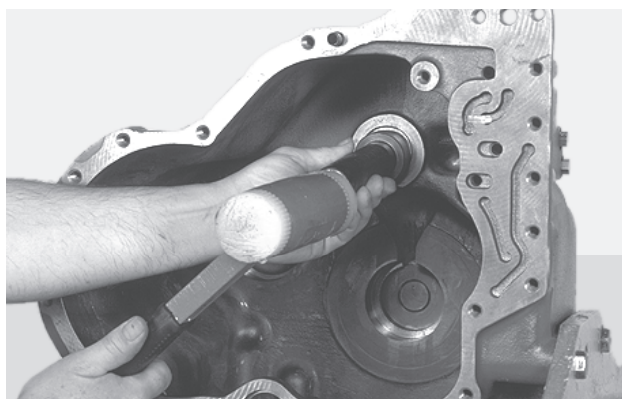
80

Apply Loctite 243 and install set screw in transmission case and in oil distributor sleeve.



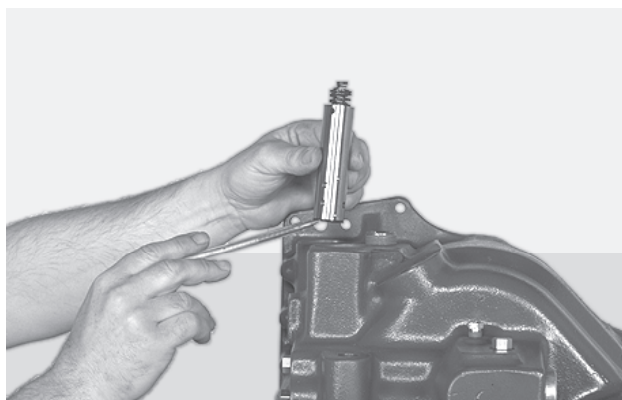
81

Install set screw plug.



82

Install reverse and forward clutch shaft rear bearing in transmission case.

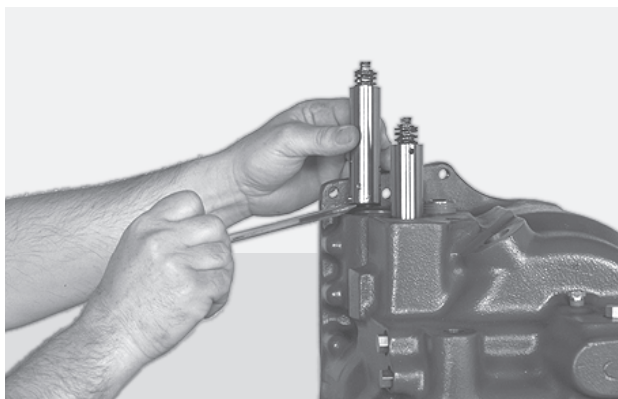


83

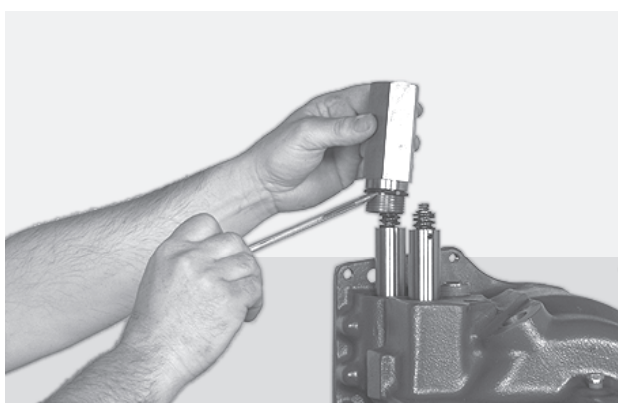
Position a new "O"-ring on lower end of the modulation valve sleeve and spring assembly. Install "O"-ring on other valve sleeve.



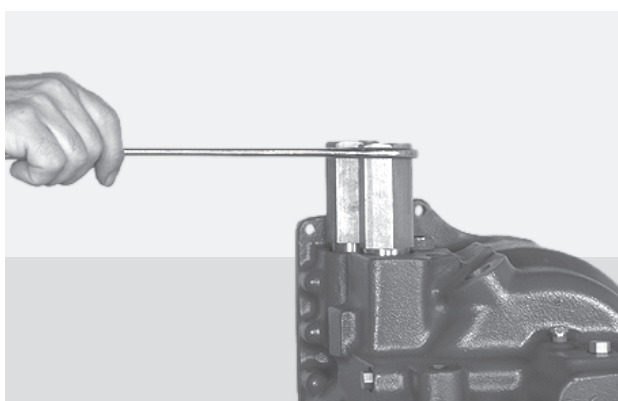
NOTE: for single modulation and hydraulic inching see section *SINGLE MODULATION AND HYDRAULIC INCHING INSTALLATION* (pag. 276).

**84**

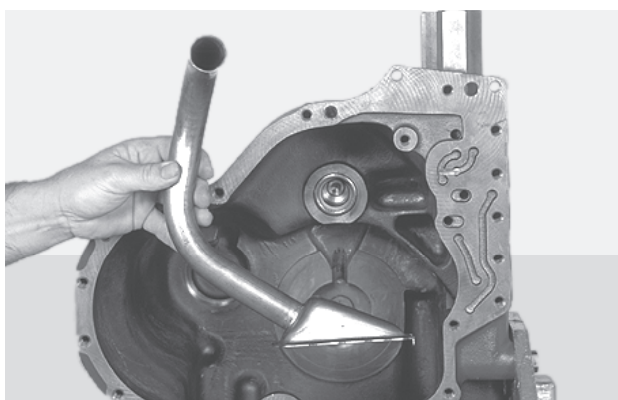
Install valve or valves in transmission case.

**85**

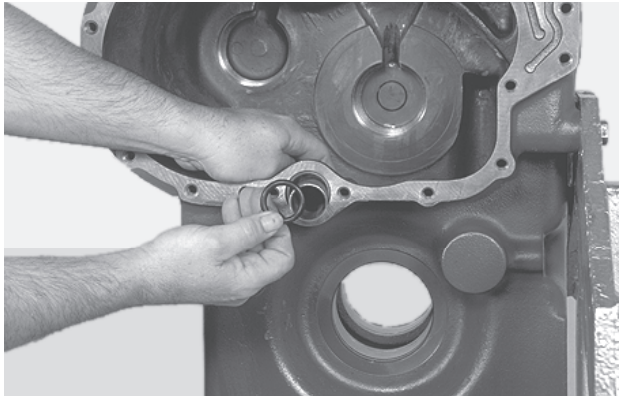
Position a new "O"-ring on modulator valve housing.

**86**

Install housing over sleeve and spring assembly and tighten to 60-65 LBF-FT [81-88 N.m].

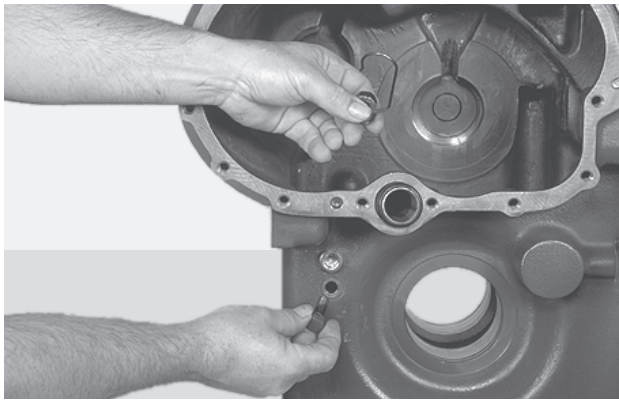
**87**

Position supply tube and screen assembly in transmission case sump.



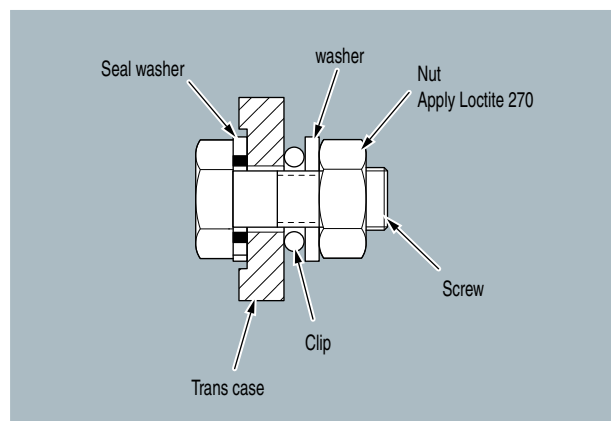
88

Push supply tube through opening in case and install "O"-ring.



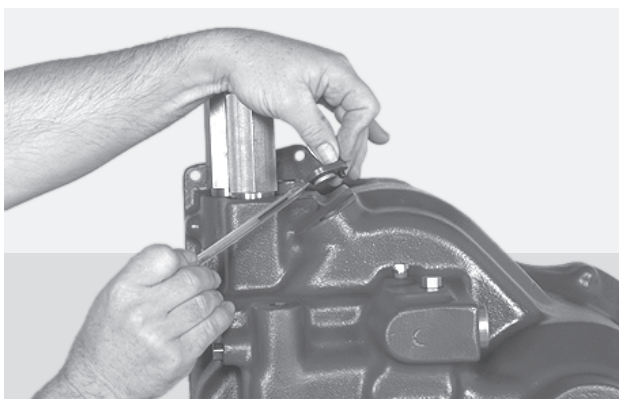
89

Install supply tube mounting screw, seal washer, clip, washer and nut.



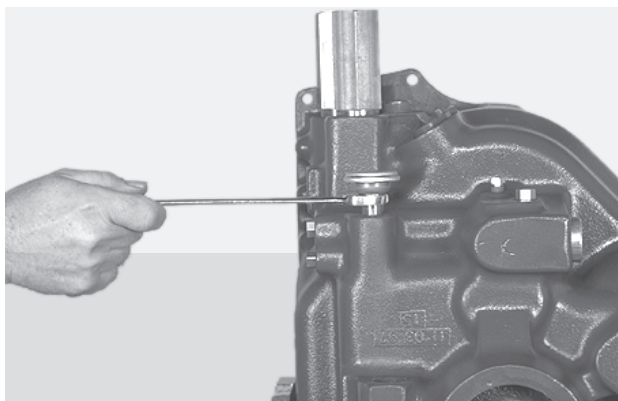
90

Tighten securely.

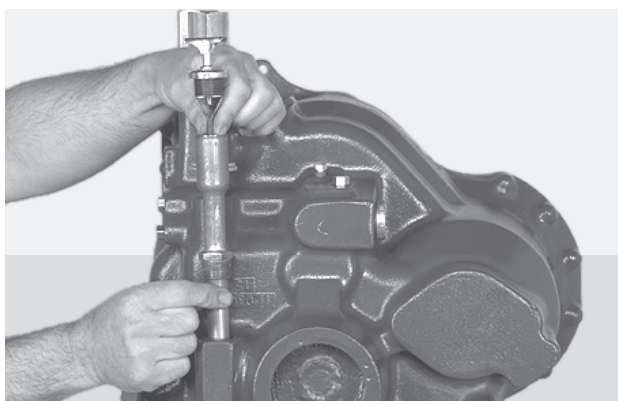


91

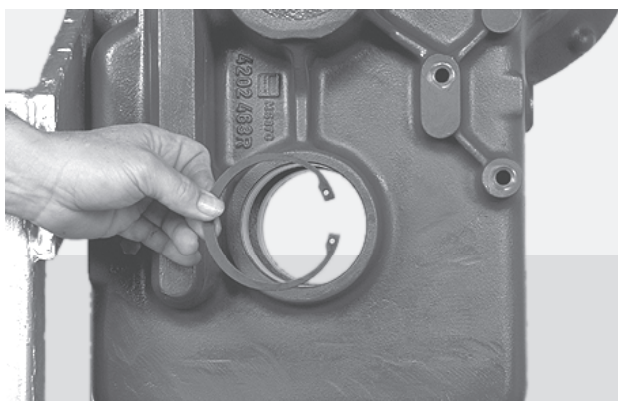
Install sensor hole plug and "O"-ring.

**92**

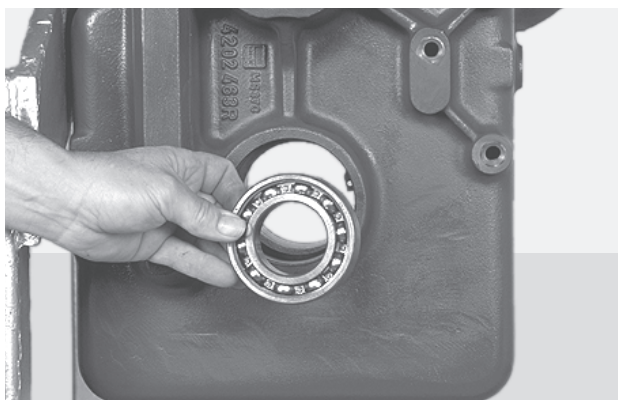
Install air breather.

**93**

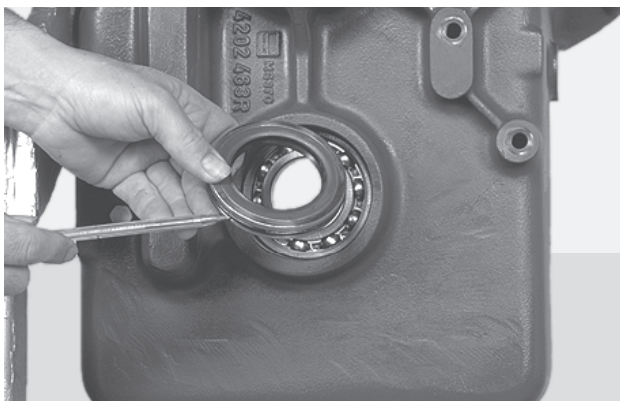
Install dipstick tube and dipstick.

**94**

Install output shaft inner bearing locating ring in rear of transmission.

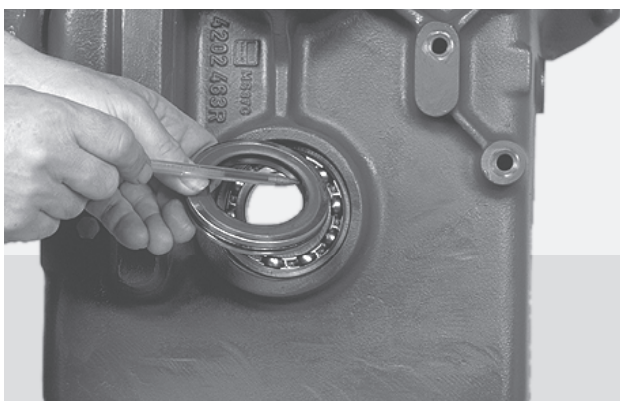
**95**

Install rear bearing in case against locating ring.



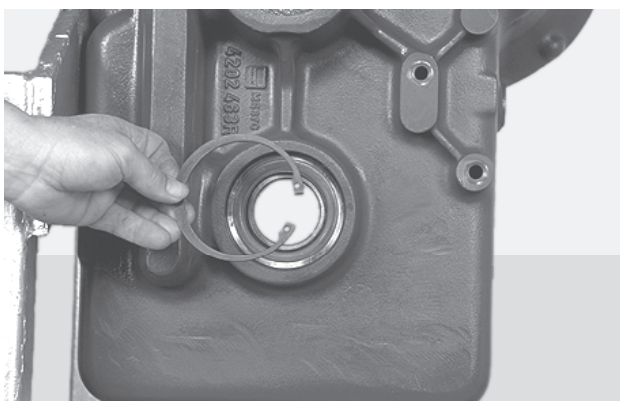
96

Install new "O"-ring on rear oil seal sleeve.



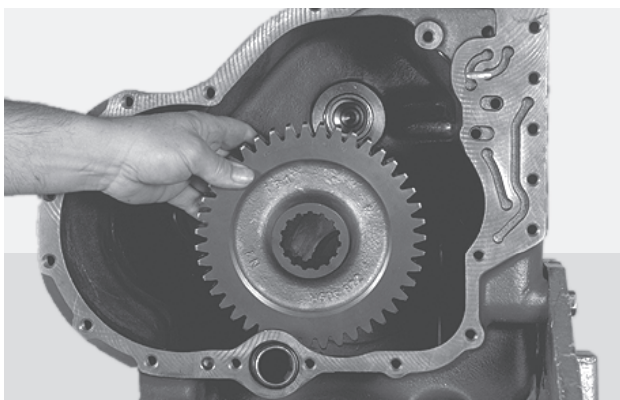
97

Apply a very light coat of Permatex 2 to the outer diameter of the output flange oil seal, press oil seal in oil seal sleeve. Oil seal must be flush with one side of face of oil seal sleeve and lip of seal must be in. Position oil seal sleeve in transmission case with recessed portion of oil seal towards output bearing. This leaves space between oil seal and output bearing.



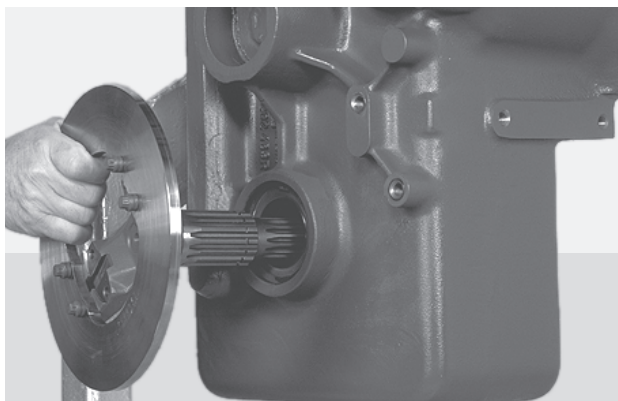
98

Install oil seal sleeve retainer ring.

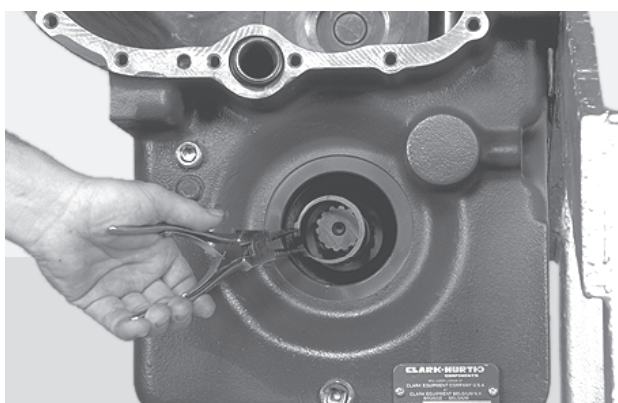


99

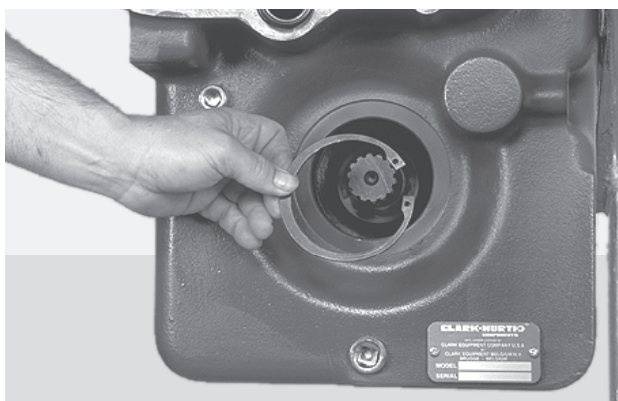
From front of transmission case, position output gear with long hub of gear towards front.

**100**

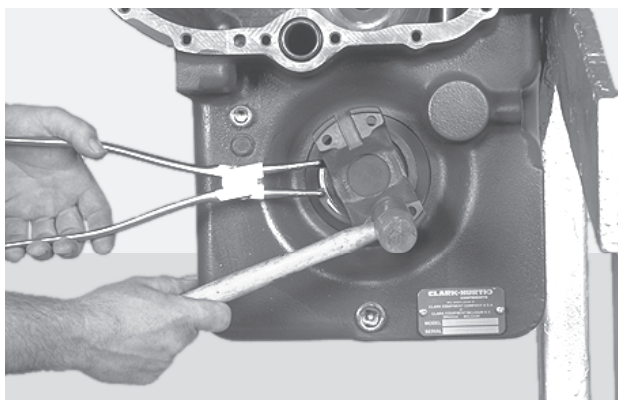
Install rear output flange and shaft through output oil seal. Align splines on shaft with splines on output gear. Install shaft through gear. Use caution as not to damage oil seal. Brake disc is an option and will not be on all units.

**101**

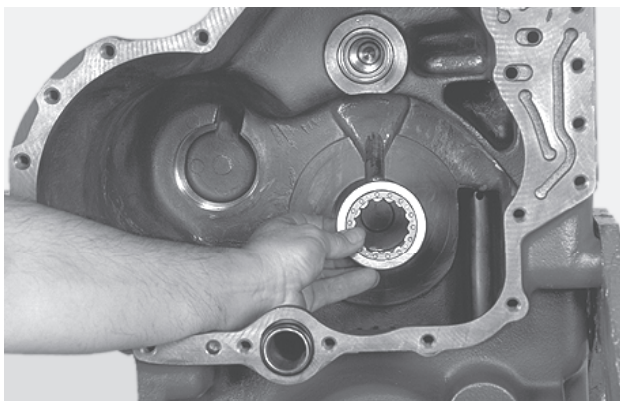
Install output shaft to output gear retainer ring.

**102**

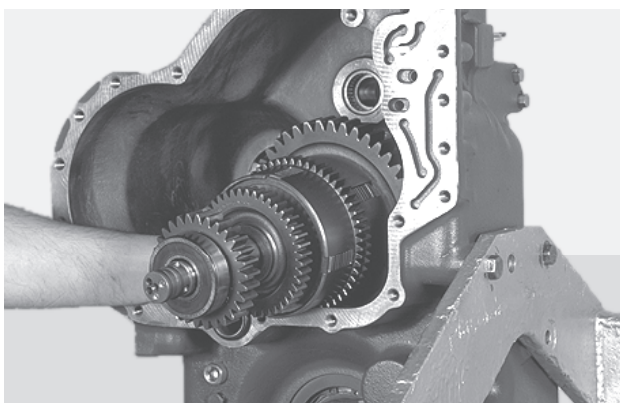
Install front output shaft bearing locating ring.

**103**

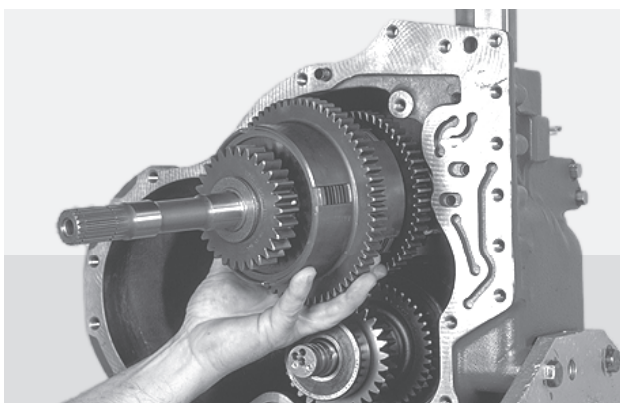
Position front output flange and bearing assembly on output shaft. Using snap ring pliers as shown. Squeeze snap ring ends together and tap flange assembly into case until snap ring can seat in snap ring groove.

**104**

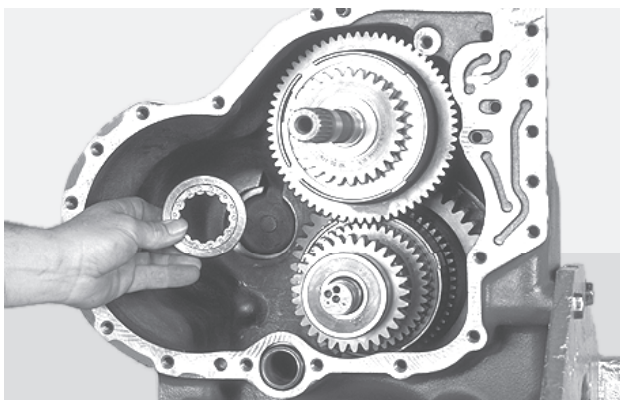
Install high and 3rd clutch shaft rear bearing outer race.

**105**

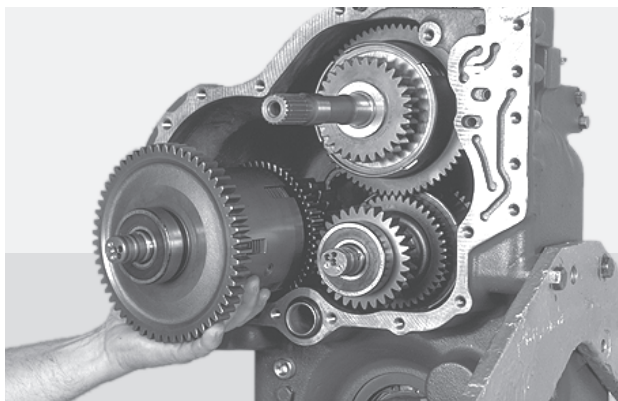
Install high and 3rd clutch assembly.

**106**

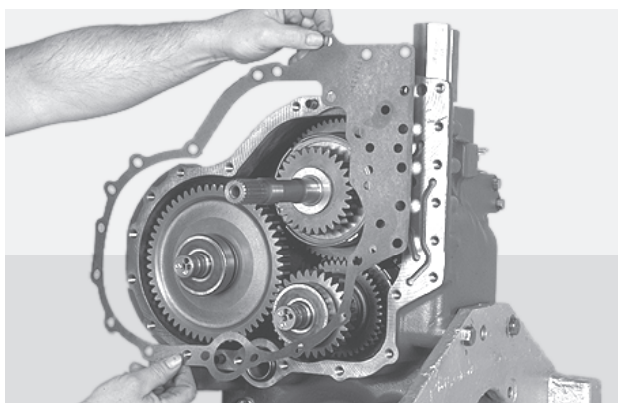
Install forward and reverse clutch assembly.

**107**

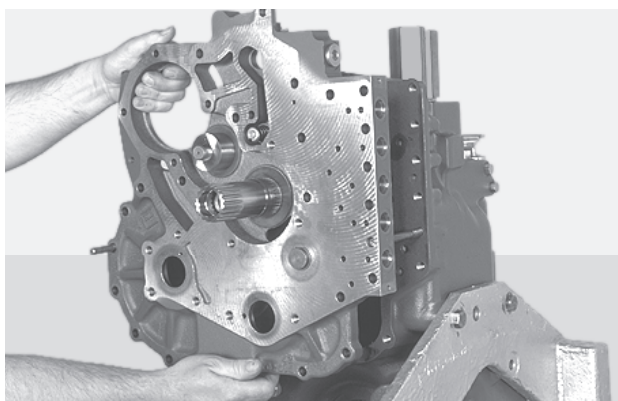
Install 1st and 2nd clutch shaft rear bearing outer race.

**108**

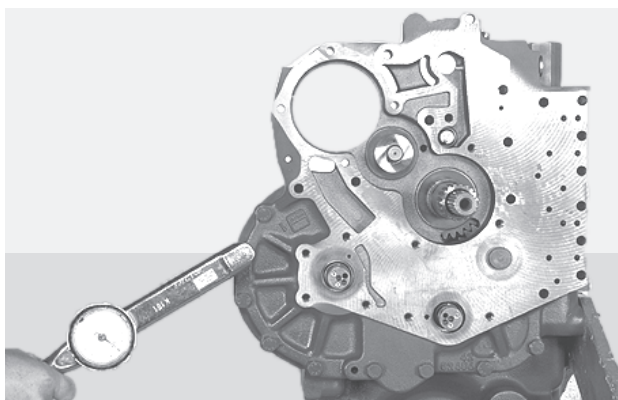
Install 1st and 2nd clutch assembly.

**109**

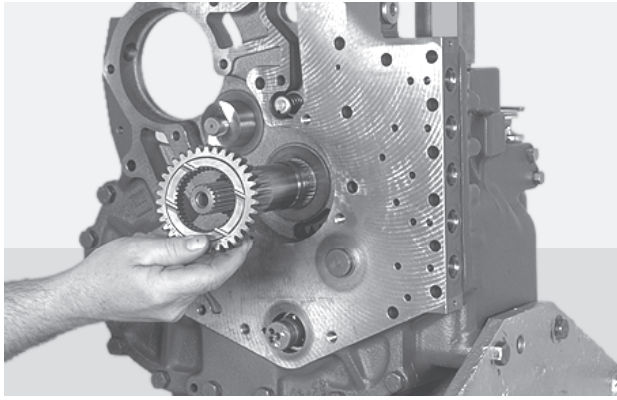
Position new transmission case to converter housing gasket on transmission case. A light coat of grease will hold gasket in position.

**110**

Install spacer plate assembly on transmission, aligning clutch shaft with openings in spacer plate.
Use caution as not to damage oil sealing rings.

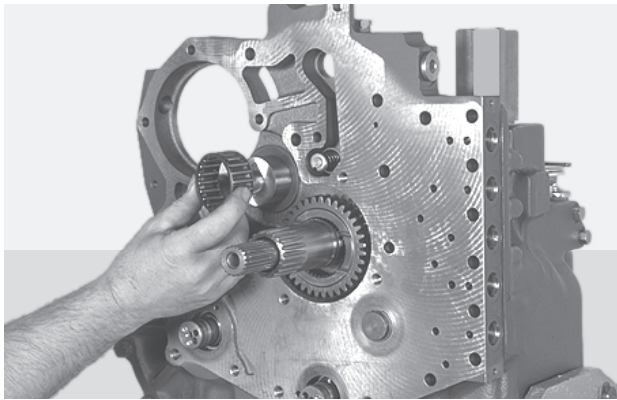
**111**

Spacer plate must be tight against transmission case.
Do not use bolts to pull spacer plate and case together.
Tap spacer plate into position at dowel pins
Install spacer plate to transmission case capscrews
Tighten capscrews to specified torque.



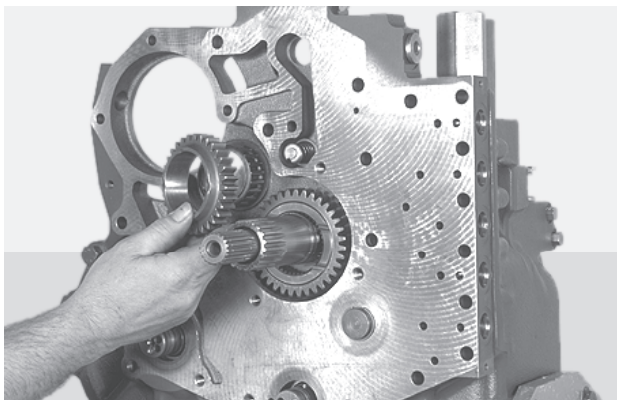
112

Position impeller hub gear on stator support.



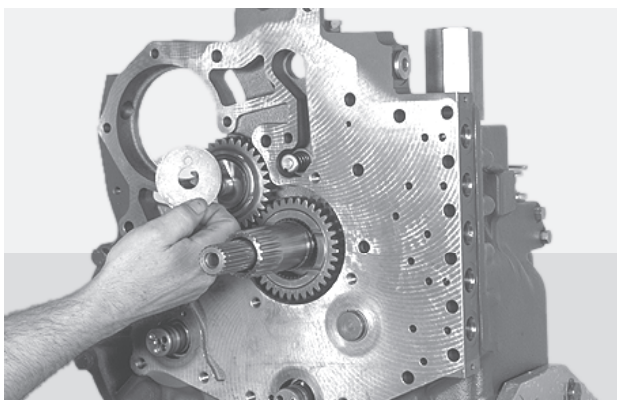
113

Install pump idler gear bearing on idler shaft.



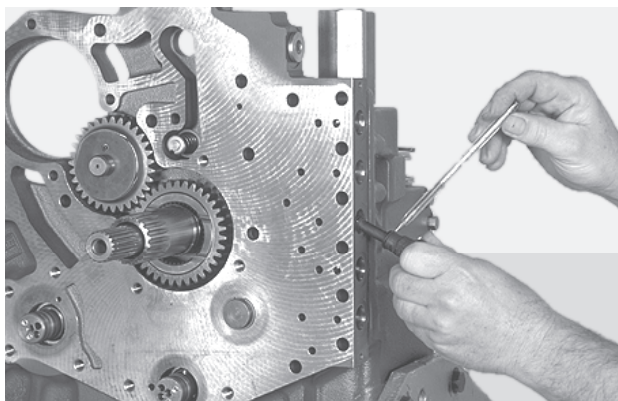
114

Install pump idler on bearing.

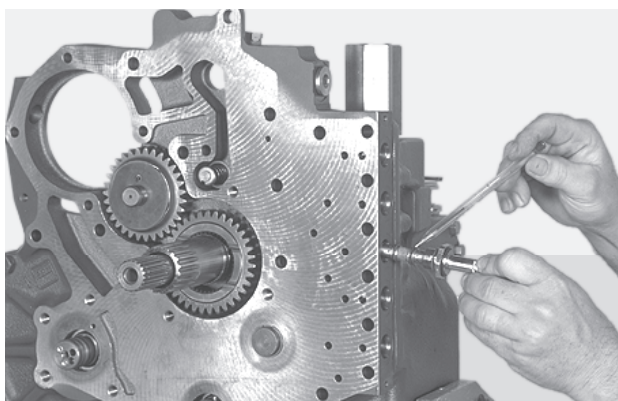


115

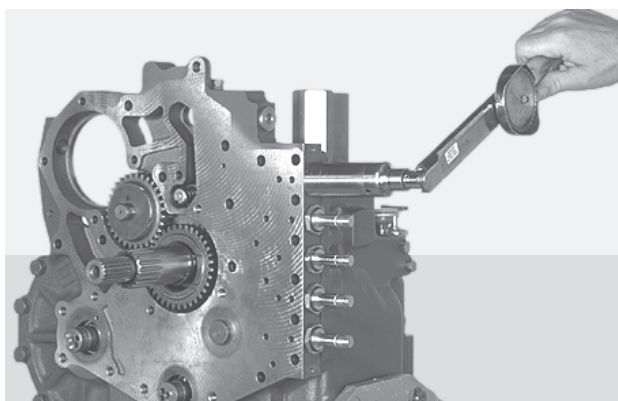
Install idler gear thrust washer, aligning hole with roll pin.

**116**

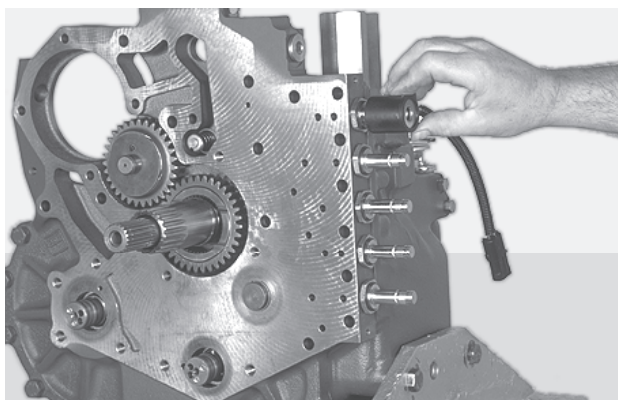
Install bore plug and "O"-rings in center hole on 3-speed transmissions only. Refer to the cleaning and inspection pages art section CLEANING AND INSPECTION (pag. 2).

**117**

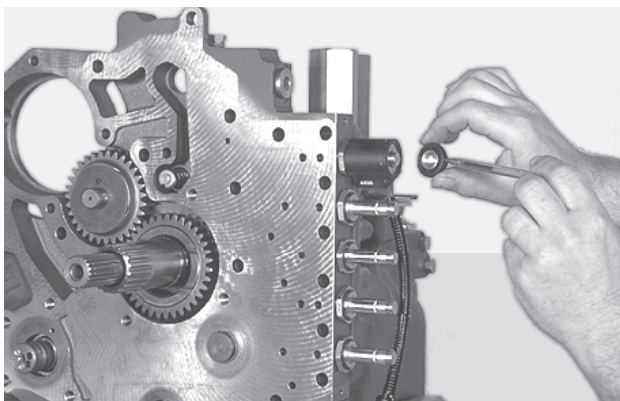
With "O"-rings in position, install solenoid cartridges.

**118**

Tighten cartridges to specified torque.
See assembly instruction drawing T12000 - 3, 4, 6 speed (pag. 135).

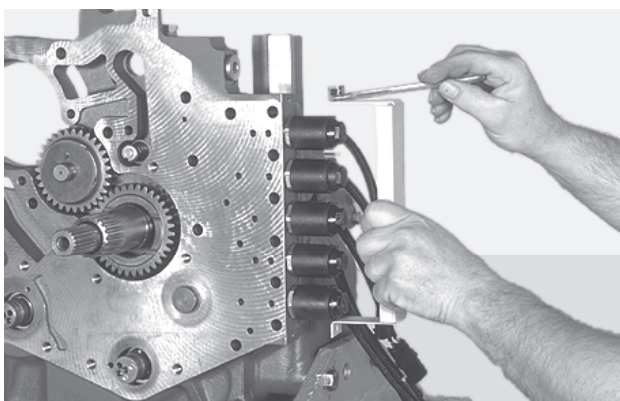
**119**

With cartridge to coil "O"-ring in place, position solenoid coil on cartridge.



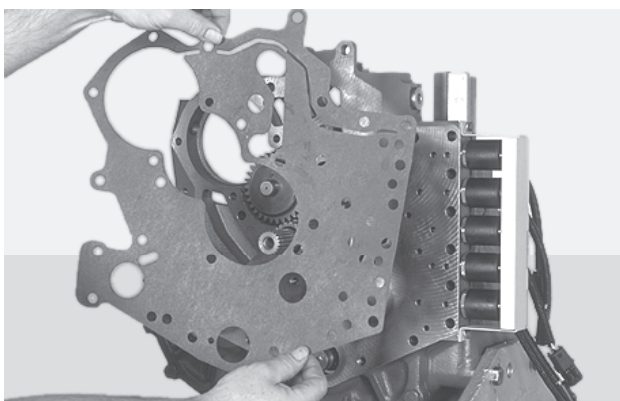
120

With new "O"-ring in position, install coil to cartridge nut. Tighten cartridge nut per assembly instruction drawing T12000 - 3, 4, 6 speed (pag. 135).



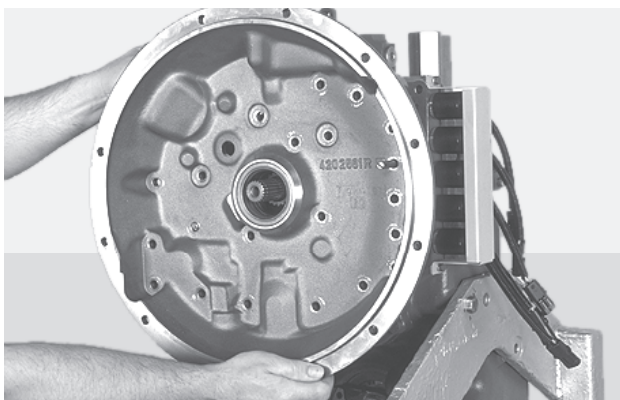
121

Install solenoid protection cover and mounting screws. Tighten screws to specified torque at section TIGHTENING TORQUES (pag. 9).



122

Position spacer to converter housing gasket on spacer. A light coat of grease will hold gasket in place.



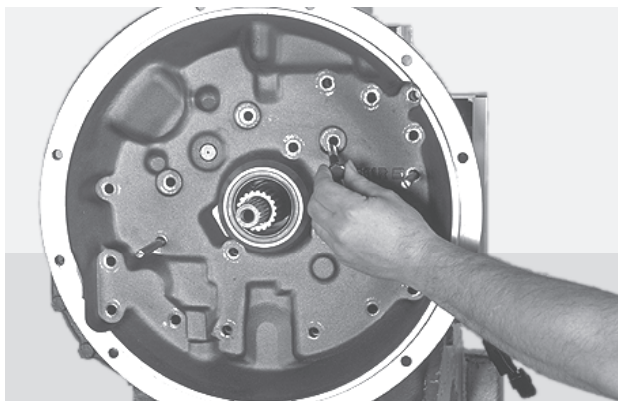
123

The use of aligning studs will facilitate converter housing to spacer installation.

The transmission could be laid down to align the end of the clutch shafts into sealing ring sleeves in converter housing. Do not force this operation. Converter housing must be tight against transmission spacer.

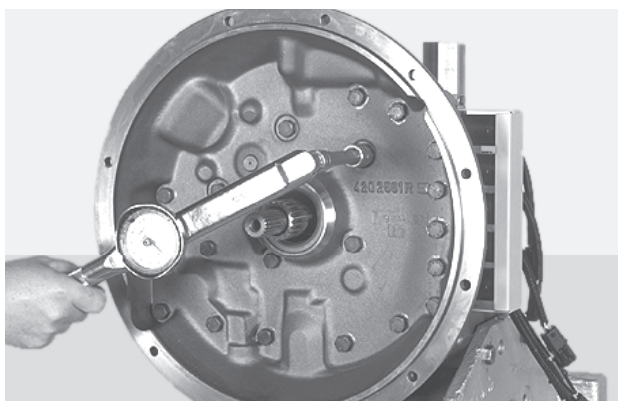


NOTE: Do not use bolts to pull converter housing in place.

**124**

Install converter housing to transmission case screws and lockwashers.

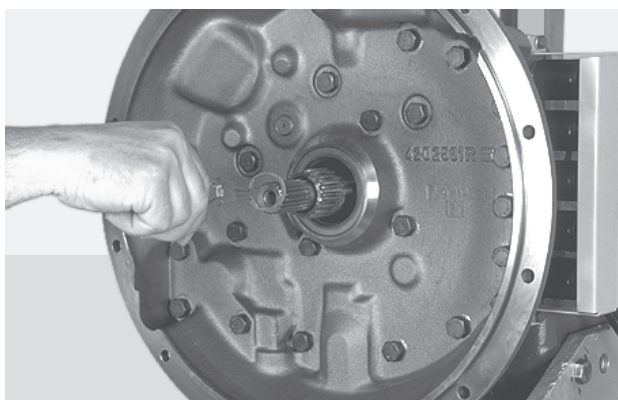
See assembly instructions for proper screw location and installation.

**125**

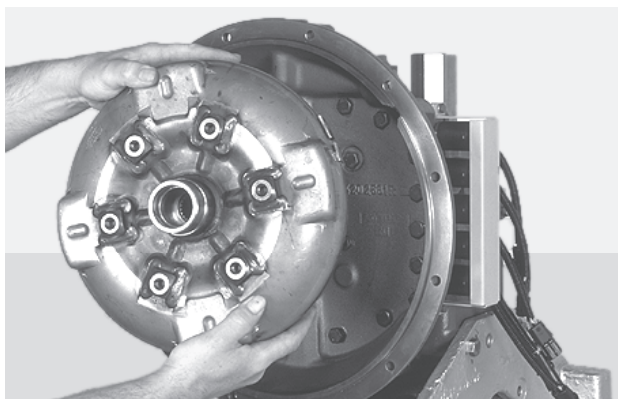
Tighten bolts to specified torque.



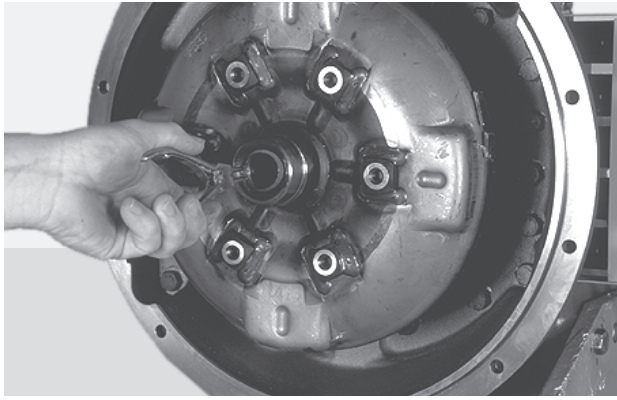
NOTE: Do not use bolts to pull converter housing in place.

**126**

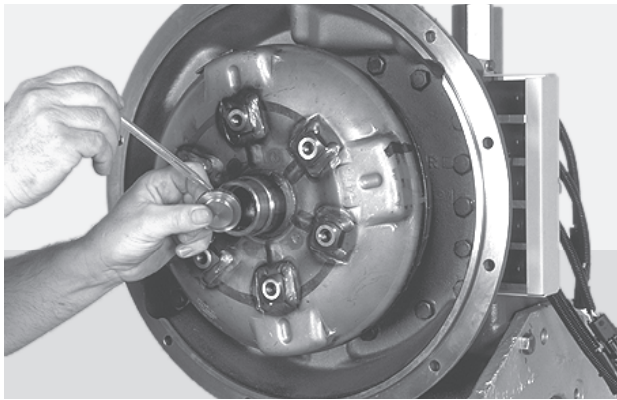
Install converter locating ring on turbine shaft.

**127**

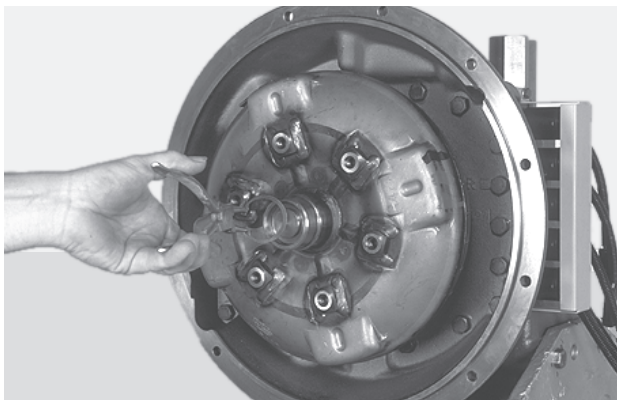
Position converter assembly on stator support and turbine shaft.

**128**

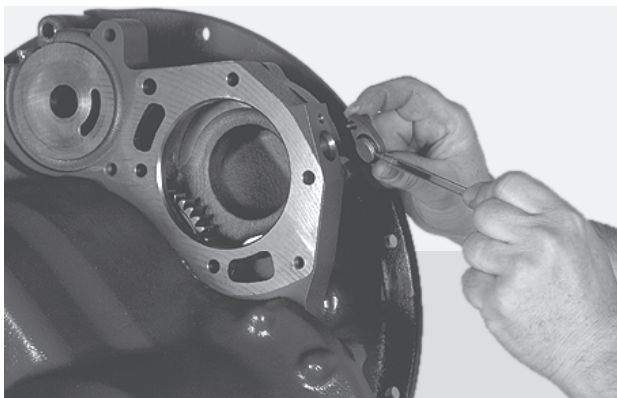
Install converter assembly retainer ring.

**129**

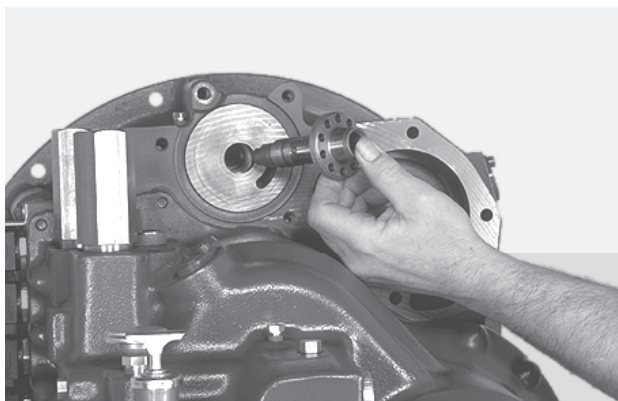
With new "O"-ring in place, install bore plug in converter assembly.

**130**

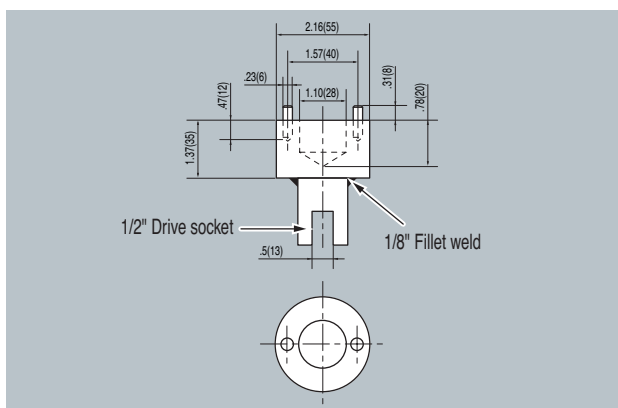
Install bore plug retainer ring.

**131**

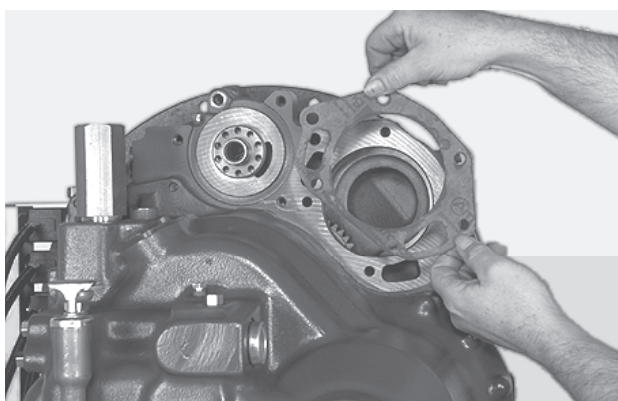
Install sensor hole plug end "O"-ring.

**132**

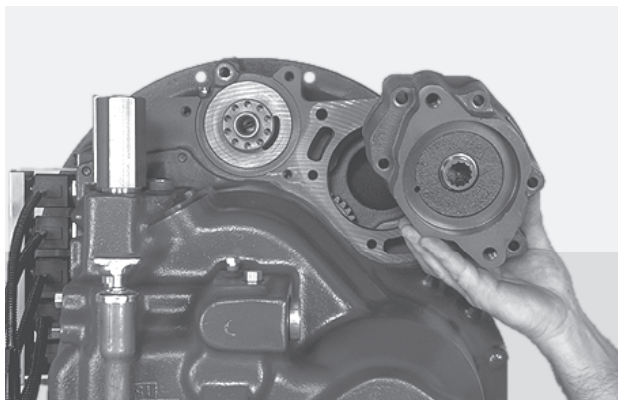
Install regulator sleeve assembly in converter housing.

**133**

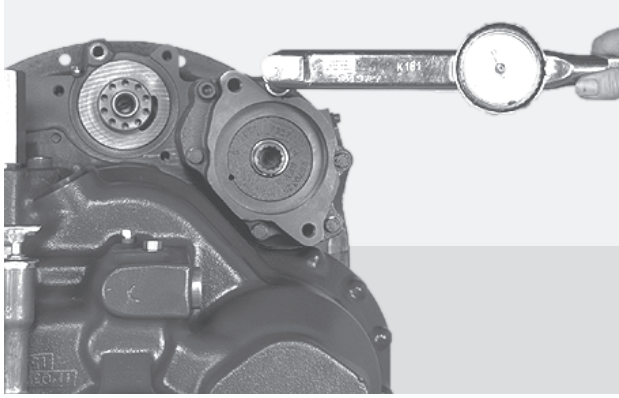
Using a special tool tighten sleeve to 45-50 lbf.ft [61.1-67.7 Nm].

**134**

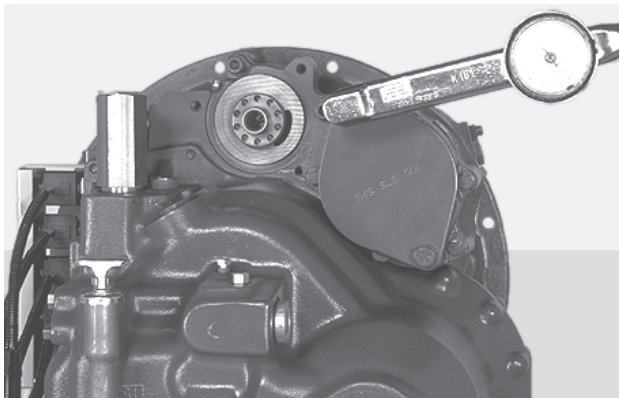
Position new charging pump to converter housing gasket.

**135**

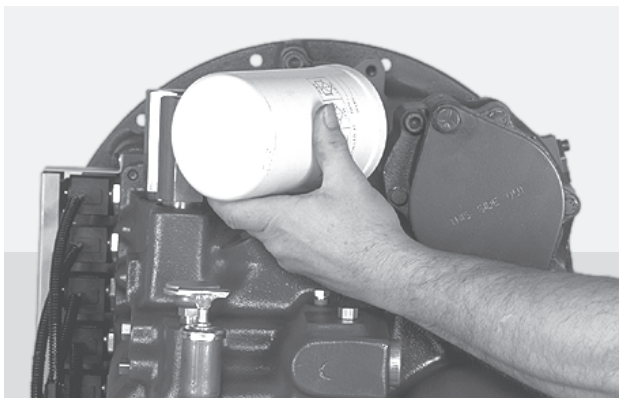
Install charging pump in converter housing.


136

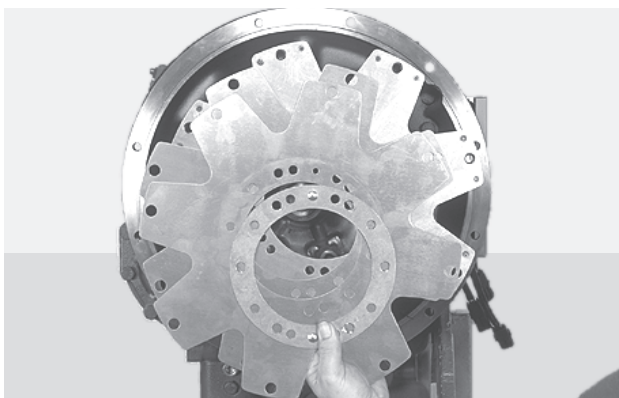
Install charging pump to converter housing bolts and washers and tighten to specified torque. See torque chart at section TIGHTENING TORQUES (pag. 9).


137

If auxiliary pump is used, it is not necessary to install the permanent pump hole cover. With new gasket in place, install pump hole cover on charging pump. Install bolts and washers and tighten to specified torque. See torque chart at section TIGHTENING TORQUES (pag. 9).


138

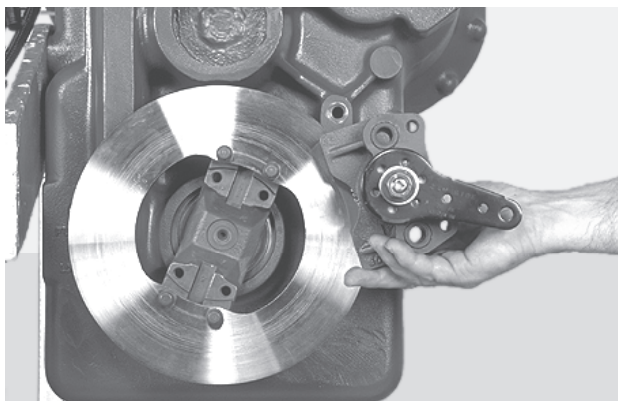
Install oil filter on regulating valve. Tighten filter to 20-25 lbf. ft [27-34 N.m].


139

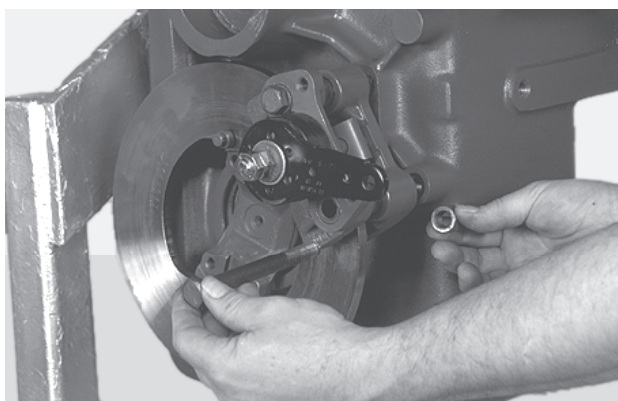
See special section CONVERTER DRIVE COUPLING (pag. 69) for drive plate installation.



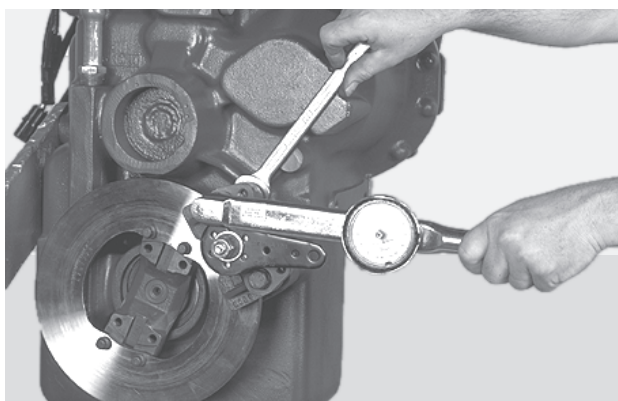
NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**140**

Position calliper brake assembly on brake disc.

**141**

Install calliper brake mounting screw through brake assembly and through lock nut. Apply Loctite 262 to threads and install screw in transmission case.

**142**

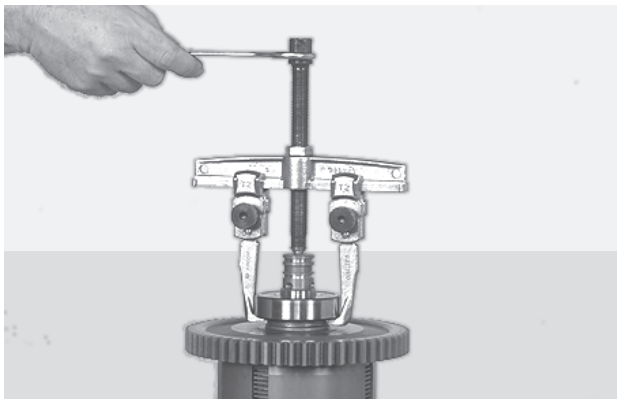
Mounting screws to be installed to allow free movement of calliper pads to disc. Tighten jam nut. See torque chart. See page INSTRUCTIONS FOR LINING REPLACEMENT AND ADJUSTMENT OF PARKING BRAKE ASSEMBLY (pag. 16) for brake information.

1ST CLUTCH

DISASSEMBLY

**1**

Remove clutch shaft oil sealing rings.

**2**

Remove front bearing.

**3**

Remove outer thrust washer, bearing and inner thrust washer.

**4**

Remove clutch gear and disc hub.

**5**

Clutch gear and pilot bearings removed.

**6**

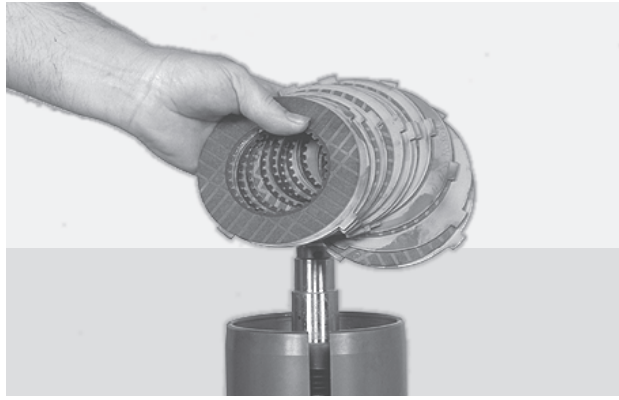
Remove outer thrust washer, thrust bearing and inner thrust washer.

**7**

Remove clutch disc end plate retainer ring.

**8**

Remove clutch disc end plate.



9

Remove inner and outer clutch discs.



10

Compress disc springs and remove retainer ring.



11

Remove retainer ring.



12

Remove retainer ring retainer.



13

Remove disc spring.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.



14

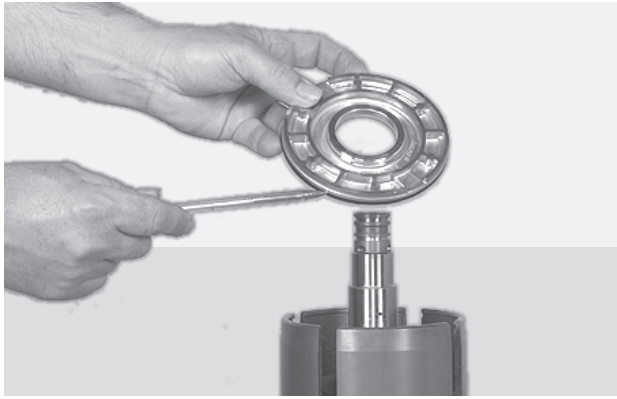
Remove clutch piston wear plate.



15

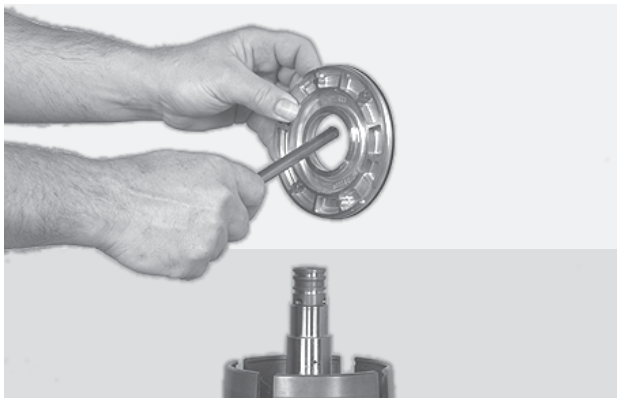
Turn clutch over and tap clutch shaft on a block of wood to remove clutch piston.

ASSEMBLY



16

The two bleed valves in the clutch drum must be clean and free of any foreign material. Refer to the Cleaning and inspection at section CLEANING AND INSPECTION (pag. 2). Install clutch piston outer seal ring.



17

Install clutch piston inner seal ring.



NOTE: Ring must be sized before installing in clutch drum. Sizing is best accomplished by rotating piston while holding a round object against the new seal ring as shown. Rotate piston until seal ring is flush with outer diameter of piston.



18

Position piston in low clutch drum as shown. Use caution as not to damage inner and outer piston sealing rings.

**19**

Position clutch piston wear plate on piston.

**20**

Install piston return disc springs. First spring with large diameter of bevel toward wear plate.

Alternate seven (7) springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**21**

Position return spring retainer on clutch shaft.

**22**

Start ring on shaft with snap ring pliers.



23

Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring.

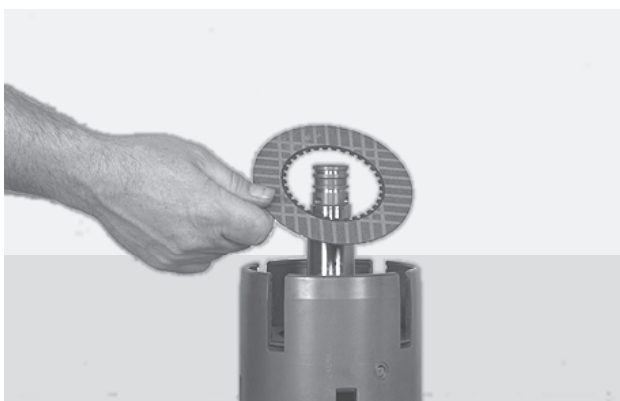
A sharp blow with a soft hammer will compress springs and seat retainer ring.

Be sure ring is in full position in groove.



24

Install first steel outer clutch disc.



25

Install first friction (inner) clutch disc. Alternate steel and friction until ten (10) steel and ten (10) friction discs are in position.



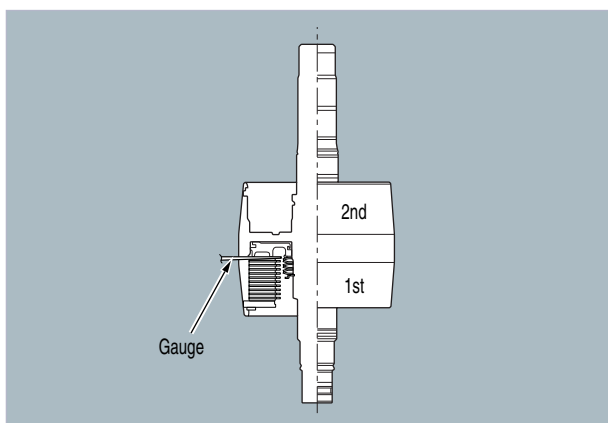
26

Install clutch disc end plate.



27

Install end plate retainer ring.



28

NOTE: Low (1st) clutch pack must be checked for clutch disc clearance. Stand the clutch assembly on end. The clutch discs on the bottom will fall to the end plate. Measure the distance between the clutch piston and the first steel disc by inserting a feeler gauge or taper gauge through the slots in the clutch drum. The required clearance is .080-.135 [2.03-3.43]. If the clearance is greater than .135 [3.43], add one steel disc under the end plate.



29

Position thrust bearing inner washer on clutch shaft.



30

Position thrust bearing on clutch shaft against inner thrust bearing washer.



31

Install outer thrust bearing washer against bearing.



32

Press bearings in clutch gear and disc hub, being certain bearings are pressed flush with face of gear on both sides.



33

Install clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs.

Be sure the clutch hub is in full position in the clutch assembly.

Do not force this operation.



34

Position inner thrust washer on shaft.

**35**

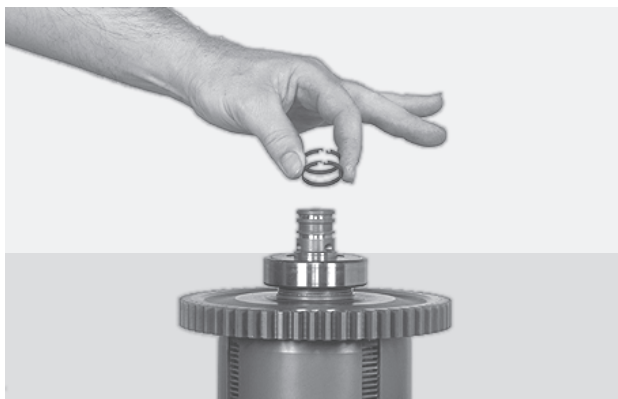
Position thrust bearing on shaft.

**36**

Position outer thrust washer on shaft.

**37**

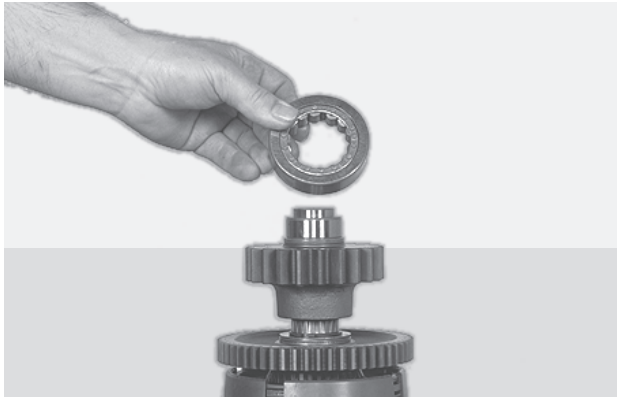
Install clutch shaft front bearing.

**NOTE:** bearing has a shield in it. This shield must be up.**38**

Install clutch shaft oil sealing rings. Grease rings to facilitate reassembly into front housing.

2ND CLUTCH

DISASSEMBLY

**1**

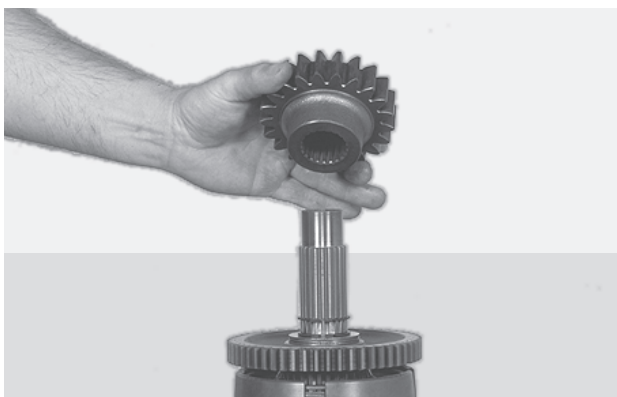
Remove clutch shaft rear bearing outer race.

**2**

Using a gear puller as shown, remove gear and rear bearing inner race.

**3**

Remove inner race from shaft.

**4**

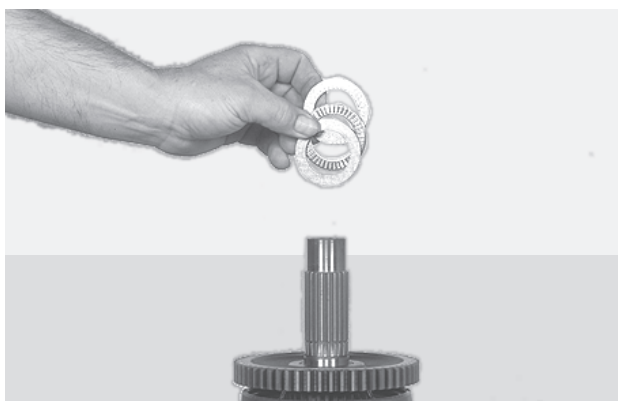
Remove gear from shaft.

**5**

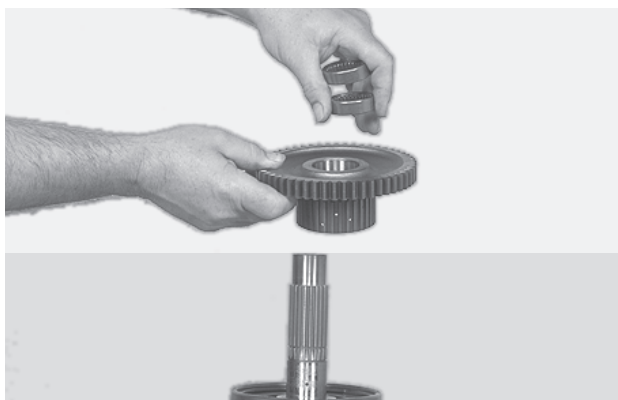
Remove gear locating ring from shaft.

**6**

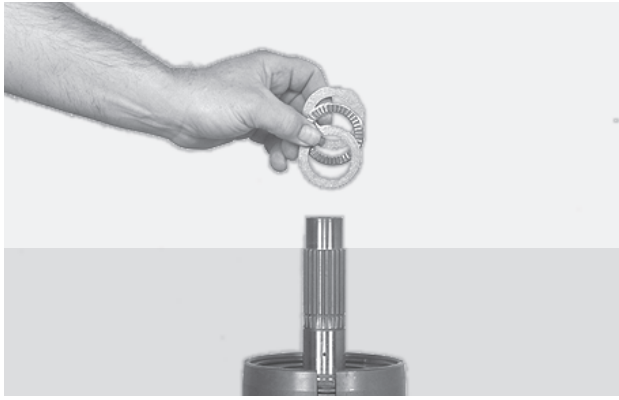
Remove thrust bearing and clutch gear retainer ring.

**7**

Remove outer thrust washer, thrust bearing and inner thrust washer.

**8**

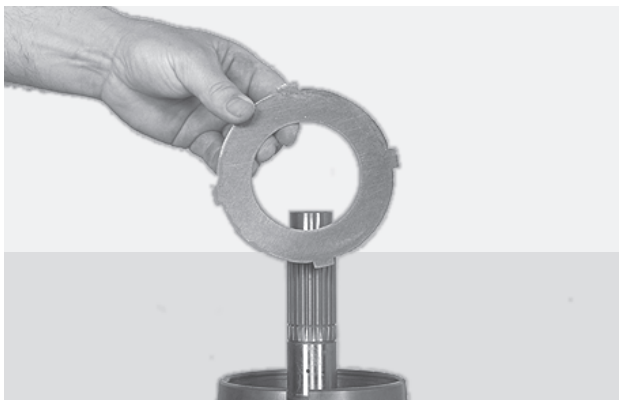
Remove clutch gear and hub and gear bearings.

**9**

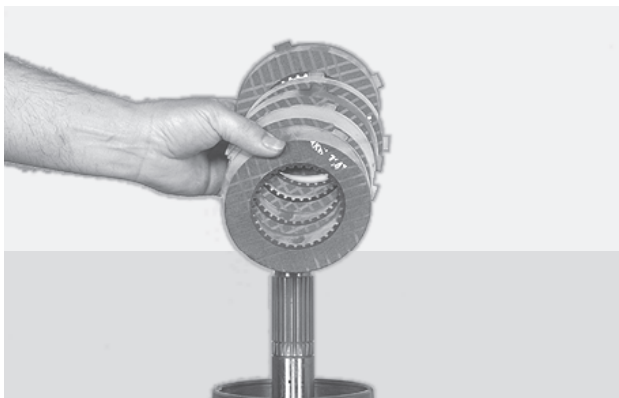
Remove outer thrust washer, thrust bearing and inner thrust washer.

**10**

Remove clutch disc and end plate retainer ring.

**11**

Remove end plate.

**12**

Remove inner and outer clutch discs.



13

Compress disc springs and remove retainer ring.



14

Remove retainer ring.



15

Remove retainer ring retainer.

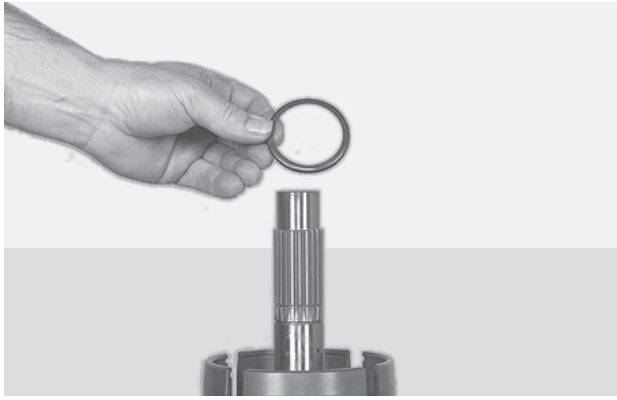


16

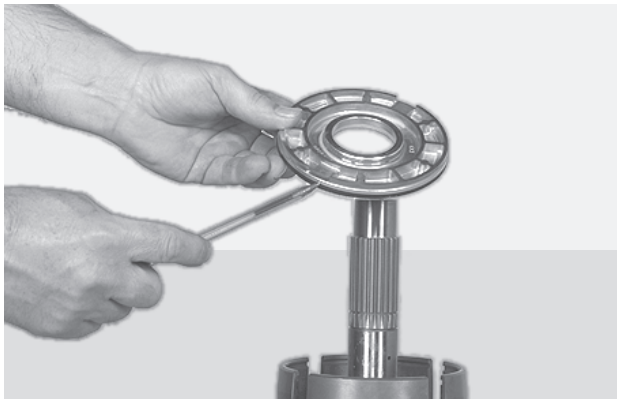
Remove disc springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**17**

Remove clutch piston wear plate.

**18**

Remove clutch piston.

ASSEMBLY**19**

Install inner and outer clutch piston seal rings.

Size inner ring as explained in note below.

Refer to the cleaning and inspection at section **CLEANING AND INSPECTION** (pag. 2).



NOTE: Ring must be sized before installing in clutch drum.

Sizing is best accomplished by rotating piston while holding a round object against the new seal ring as shown. Rotate piston until seal ring is flush with outer diameter of piston.

**20**

Position piston in clutch drum, using caution as not to damage piston sealing rings.

**21**

Install clutch piston wear plate.



22

Install piston return disc springs. First spring with large diameter of bevel towards wear plate.
Alternate (5) springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.



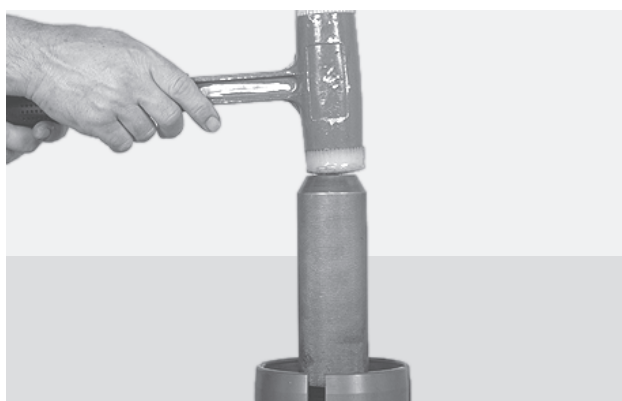
23

Position return spring ring retainer on clutch shaft.



24

Start ring on shaft with snap ring pliers.

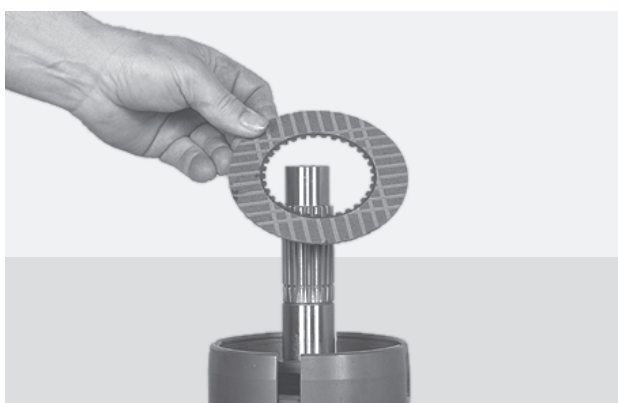


25

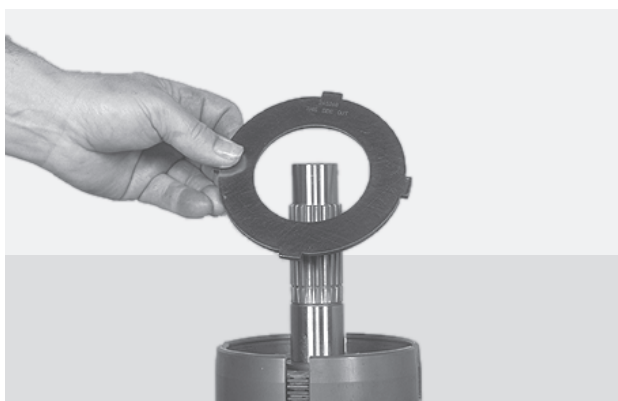
Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring. A sharp blow with a shaft hammer will compress springs and seat retainer ring. Be sure ring is in full position in groove.

**26**

Install first steel (outer) clutch disc.

**27**

Install first friction (inner) clutch disc. Alternate steel and friction until five (5) steel and five (5) friction discs are in position.

**28**

Install clutch disc end plate.

**29**

Install end plate retainer ring.



30

Position thrust bearing inner washer on clutch shaft.



31

Position thrust bearing on clutch shaft against inner thrust bearing washer.



32

Install outer thrust bearing washer against thrust bearing.



33

Press needle bearings in clutch gear and disc hub, being certain bearings are pressed with face of gear on both sides.

**34**

Install the clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs. Be sure the clutch hub is in full position in the clutch assembly. Do not force this operation.

**35**

Position thrust bearing inner washer on clutch shaft.

**36**

Position thrust bearing on clutch shaft against inner thrust bearing washer.

**37**

Install outer thrust bearing washer against bearing.

**38**

Install thrust washer retainer ring.

**39**

Install clutch shaft gear locating ring.

**40**

Install clutch shaft gear on clutch shaft with long hub of gear down.

**41**

Install rear bearing inner race on clutch shaft with bearing race shoulder down.



42

Position rear bearing on bearing race.

4TH CLUTCH

DISASSEMBLY



43

Remove clutch shaft oil sealing rings.



NOTE: The 4th clutch is only used on the 4 and 6 speed models.



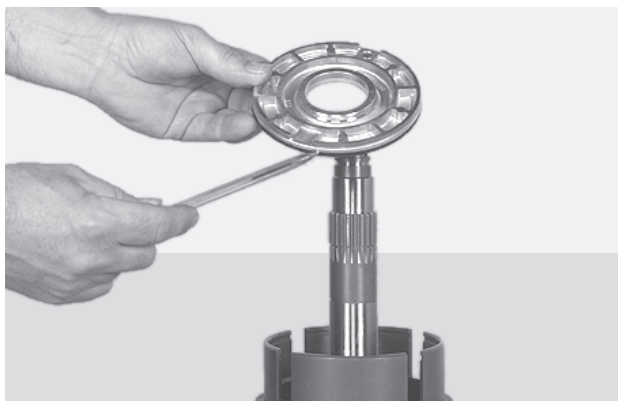
44

Using a gear puller as shown, remove first drive gear and front bearing.



45

Remove first drive gear locating ring. For 3-speed models, proceed to next figure.

**46**

Remove clutch piston.

**1**

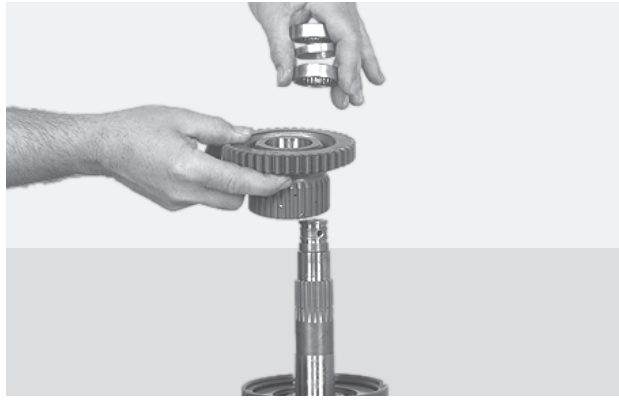
Remove outer thrust washer retainer ring.

**2**

Remove outer washer, thrust bearing and inner thrust washer.

**3**

Remove clutch gear and disc hub.



4

Remove bearings and spacer from clutch gear.



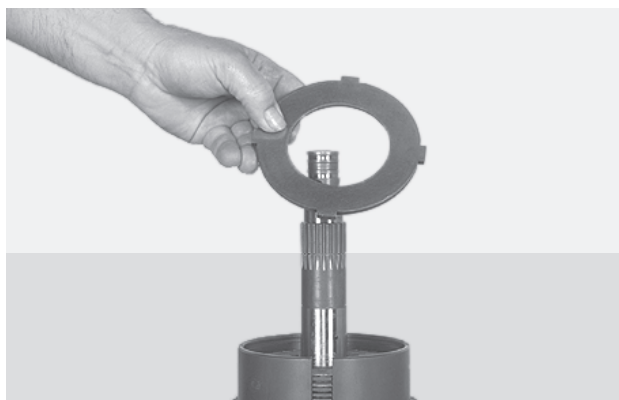
5

Remove outer thrust washer, thrust bearing and inner thrust washer.



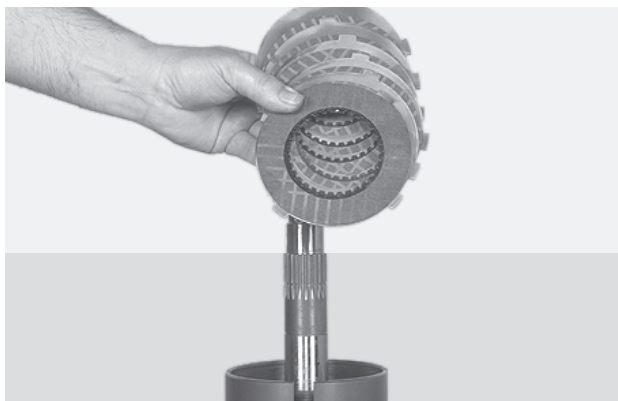
6

Remove end plate retainer ring.



7

Remove end plate.



8

Remove clutch discs.



9

Compress disc springs and remove retainer ring.



10

Remove retainer ring retainer.



11

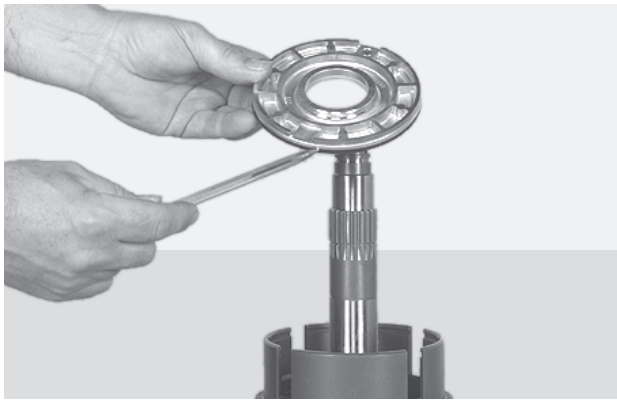
Remove disc springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**12**

Remove clutch piston wear plate.

**13**

Remove clutch piston.

ASSEMBLY**1**

Clutch piston bleed ball must be clean and free of any foreign material. Refer to the cleaning and inspection at section **CLEANING AND INSPECTION** (pag. 2).

For the 3-speed version, proceed to figure 189

**2**

Install inner and outer clutch piston seal rings.

Size inner ring as explained in note below.

Install clutch piston in clutch drum.

Use caution as not to damage sealing rings.

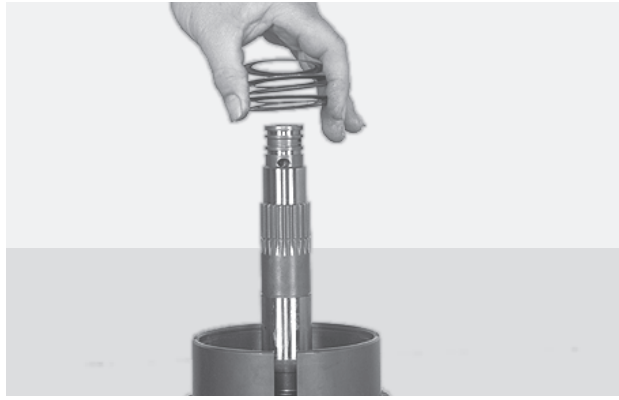


NOTE: Ring must be sized before installing in clutch drum.

Sizing is best accomplished by rotating piston while holding a round object against the new seal ring as shown. Rotate piston until seal ring is flush with outer diameter of piston.

**3**

Install clutch piston wear plate.



4

Install piston return disc springs. First spring with large diameter of bevel towards wear plate. Alternate five (5) springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.



5

Position return spring ring retainer on clutch shaft.



6

Start ring on shaft with snap ring pliers.

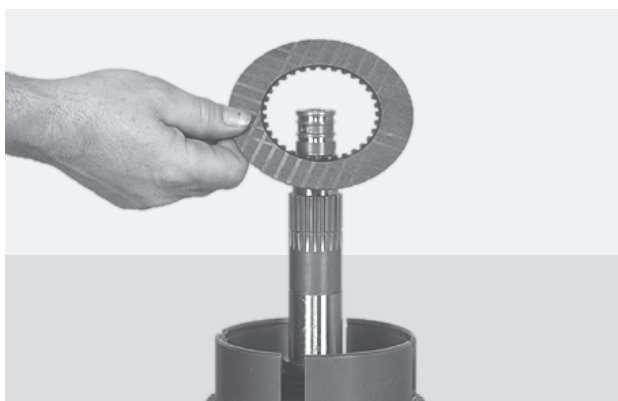


7

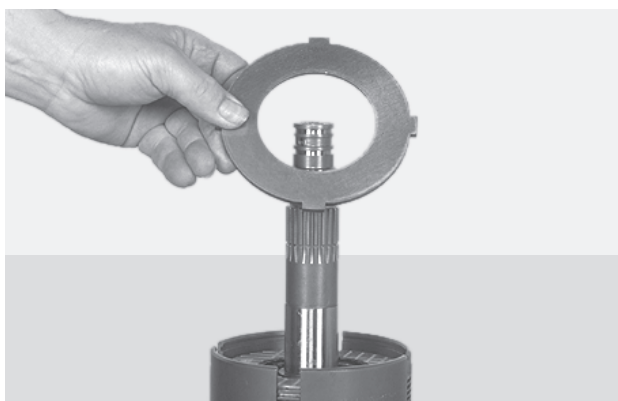
Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring. A sharp blow with a soft hammer will compress springs and seat retainer ring; be sure ring is in full position in groove.

**8**

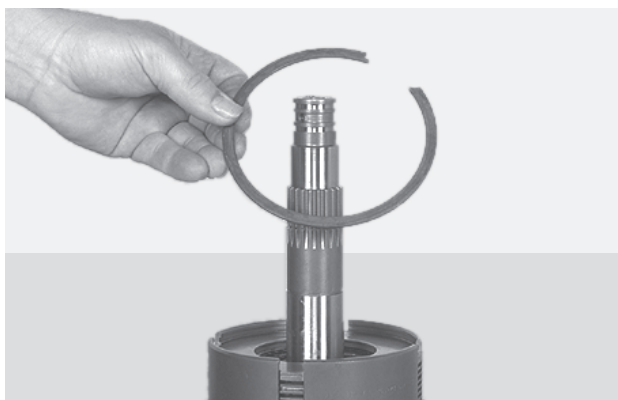
Install first steel (outer) clutch disc.

**9**

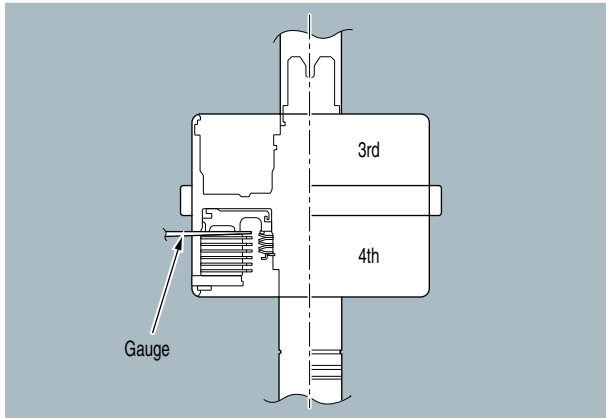
Install first friction (inner) clutch disc. Alternate steel and friction until six (6) steel and six (6) friction discs are in position.

**10**

Install clutch disc end plate.

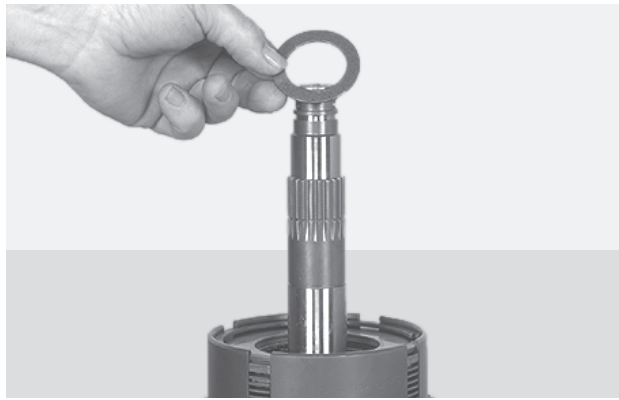
**11**

Install end plate retainer ring.



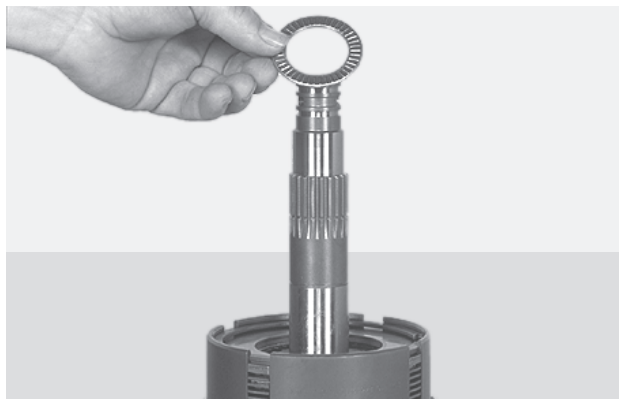
12

NOTE: 4th (high) clutch pack must be checked for clutch disc clearance. Stand the clutch assembly on end. The clutch discs on the bottom will fall to the end plate. Measure the distance between the clutch piston and the first steel disc by inserting a feeler gauge or taper gauge through the slots in the clutch drum. The required clearance is .048-.108 [1,22-2,74]. If the clearance is greater than .108 [2,74], add one steel disc under the end plate.



13

Position thrust bearing inner washer on clutch shaft.



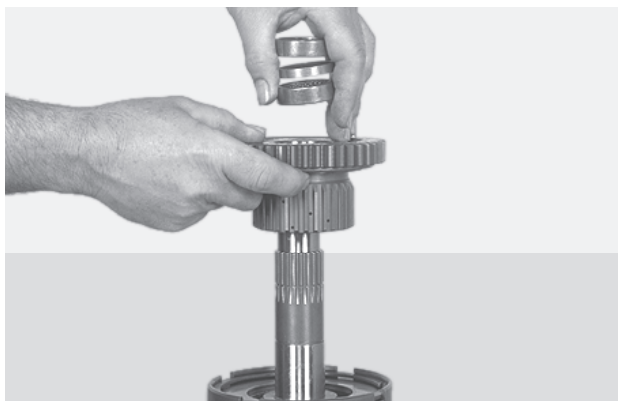
14

Position thrust bearing on clutch shaft against inner thrust bearing washer.

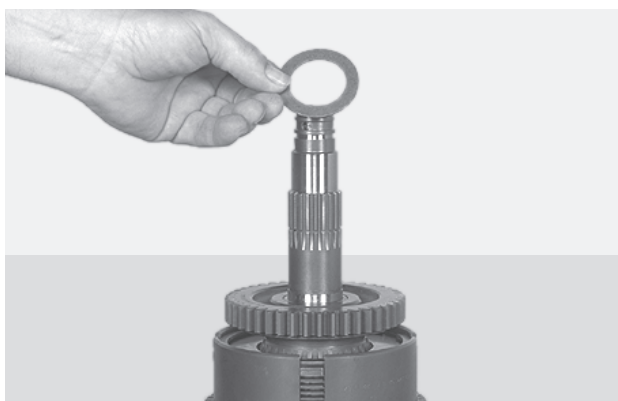


15

Install outer thrust bearing washer against bearing.

**16**

Press one bearing in clutch gear. Install bearing spacer next to bearing. Press second bearing in gear, being certain bearings are pressed flush with face of gears on both sides. Install the clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs. Be sure the clutch hub is in full position in the clutch assembly. Do not force this operation.

**17**

Position thrust washer on shaft.

**18**

Position thrust bearing on shaft.

**19**

Position thrust washer on shaft.

**20**

Install thrust washer retainer ring

**NOTE:** 3-speed clutch drum not as shown.**21**

Install clutch shaft gear locating ring.

**22**

Position gear on clutch shaft.

**23**

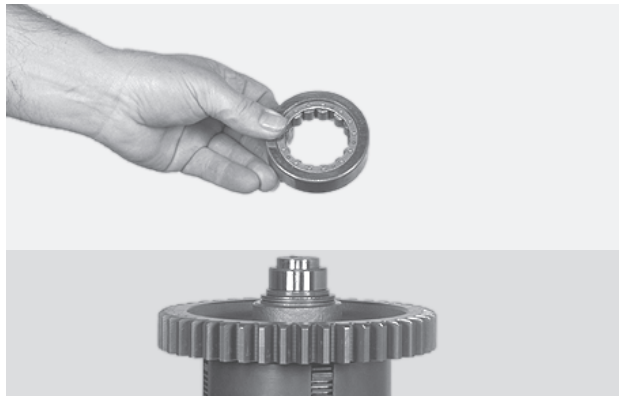
Install clutch shaft front bearing. Note bearing has a shield in it. This shield must be up.

**24**

Install clutch shaft oil sealing rings. Grease rings to facilitate reassembly into front housing.

3RD CLUTCH

DISASSEMBLY



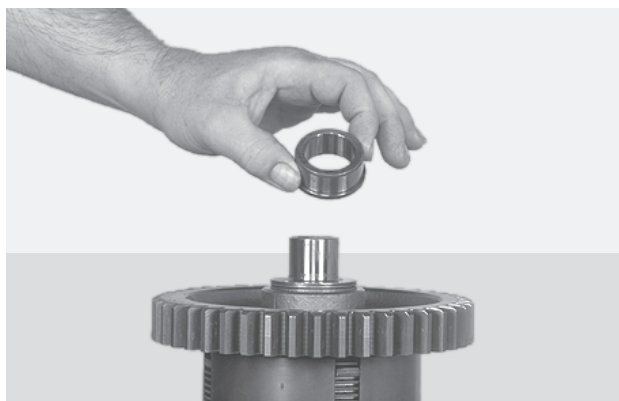
1

Remove clutch shaft rear bearing outer race.



2

Use gear puller to remove clutch gear and bearing inner race.



3

Remove clutch shaft rear bearing inner race.



4

Remove outer thrust washer, thrust bearing and inner thrust washer.

**5**

Remove clutch gear and hub and gear bearings.

**6**

Remove outer thrust washer, thrust bearing and inner thrust washer.

**7**

Remove end plate retainer ring.

**8**

Remove end plate.



9

Remove clutch discs.



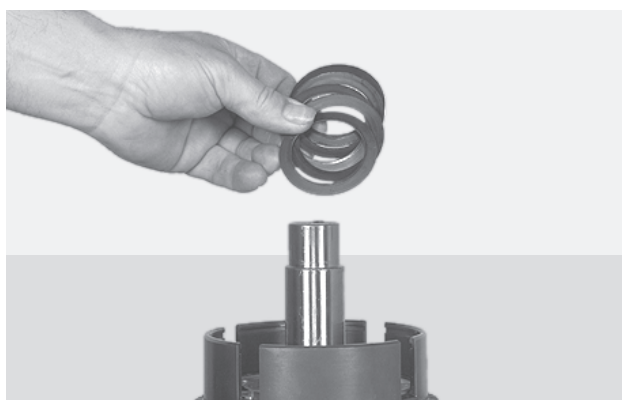
10

Compress disc springs and remove retainer ring.



11

Remove retainer ring retainer.



12

Remove disc springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

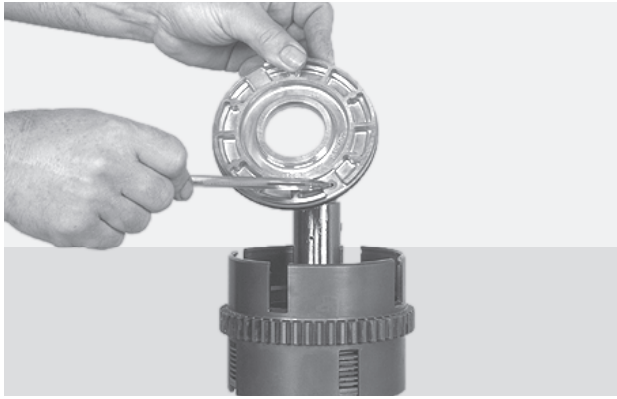
**13**

Remove clutch piston wear plate.

**14**

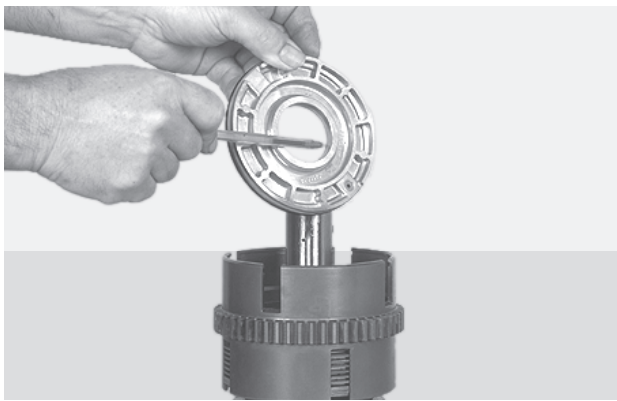
Remove clutch piston.

ASSEMBLY



15

Clutch piston bleed ball must be clean and free of any foreign material. Refer to the cleaning and inspection pages.



16

Install inner and outer clutch piston seal rings. Size inner ring as explained in note below. Install clutch piston in clutch drum. Use caution as not to damage sealing rings.



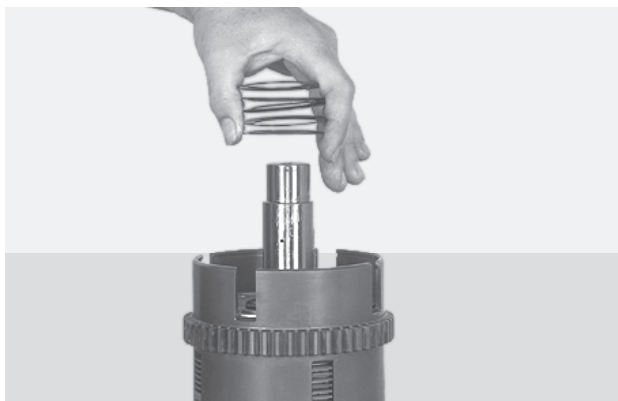
NOTE: Ring must be sized before installing in clutch drum.

Sizing is best accomplished by rotating piston while holding a round object against the new seal ring as shown. Rotate piston until seal ring is flush with outer diameter of piston.



17

Install clutch piston wear plate.

**18**

Install piston return disc springs. First spring with large diameter of bevel towards wear plate.

Alternate five (5) springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**19**

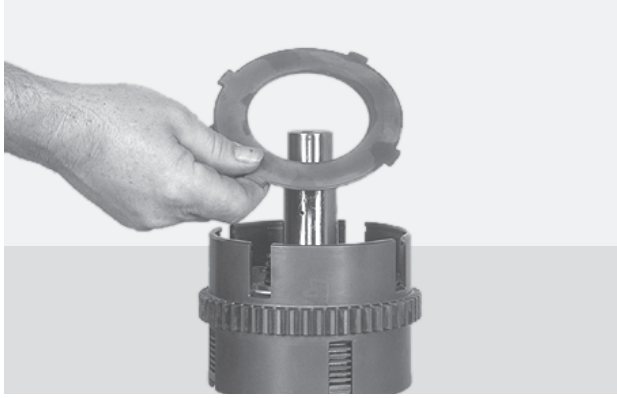
Position return spring ring retainer on clutch shaft.

**20**

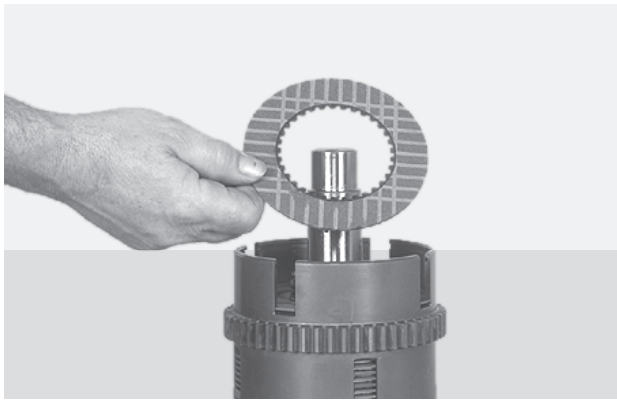
Start ring on shaft with snap ring pliers.

**21**

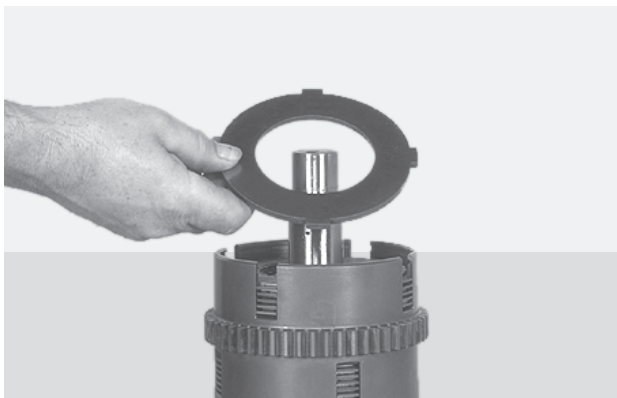
Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring. A sharp blow with a soft hammer will compress springs and retainer ring; be sure ring is in full position in groove.

**22**

Install first steel (outer) clutch disc.

**23**

Install first friction (inner) clutch disc. Alternate steel and friction until five (5) steel and five (5) friction discs are in position.

**24**

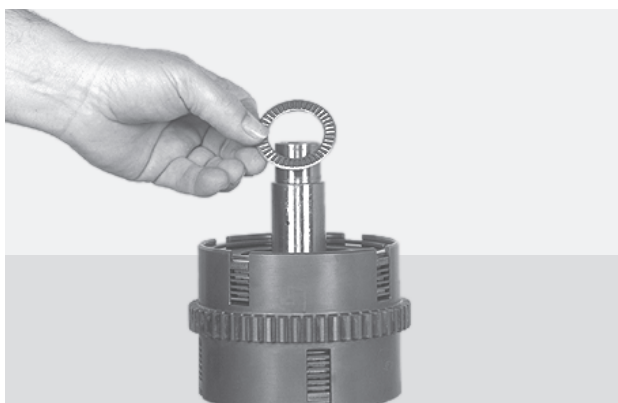
Install clutch disc end plate.

**25**

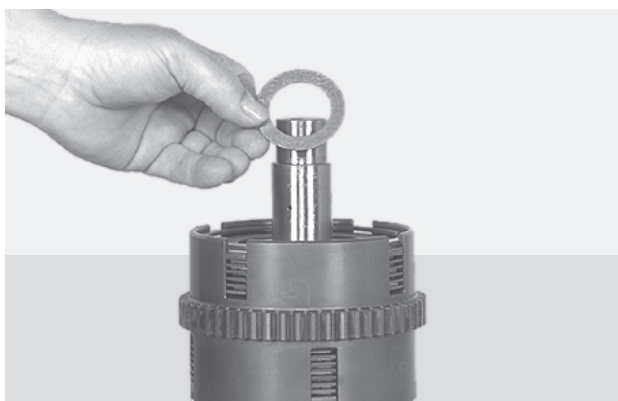
Install end plate retainer ring.

**26**

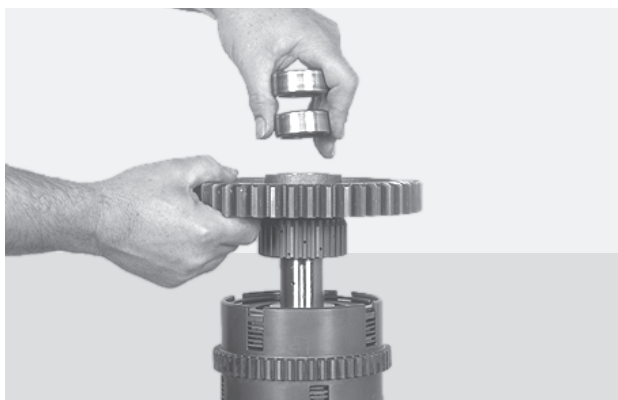
Position thrust bearing inner washer on clutch shaft.

**27**

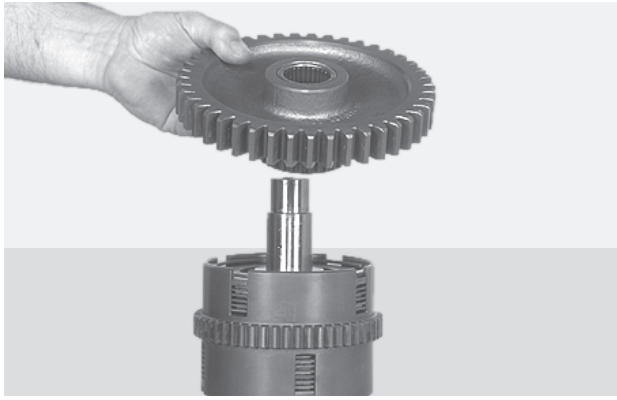
Position thrust bearing on clutch shaft against inner thrust bearing washer.

**28**

Install outer thrust bearing washer against thrust bearing.

**29**

Press needle bearings in clutch gear and disc hub, being certain bearings are pressed flush with face of gear on both sides.



30

Install clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs. Be sure the clutch hub is in full position in the clutch assembly. Do not force this operation.



31

Position thrust bearing inner washer on clutch shaft.



32

Position thrust bearing on clutch shaft against inner thrust bearing washer.



33

Install outer thrust bearing washer against thrust bearing.

**34**

Install clutch shaft rear bearing inner race.

**35**

Install clutch shaft rear bearing outer race.

REVERSE CLUTCH

DISASSEMBLY



1

Remove outer thrust washer, thrust bearing and inner thrust washer.



NOTE: a 3-speed transmission will not have external gear teeth on the forward and reverse clutch drum.



2

Remove clutch gear and disc hub.



3

Remove bearings and spacer from clutch gear.

**4**

Remove outer thrust washer, thrust bearing and inner thrust washer.

**5**

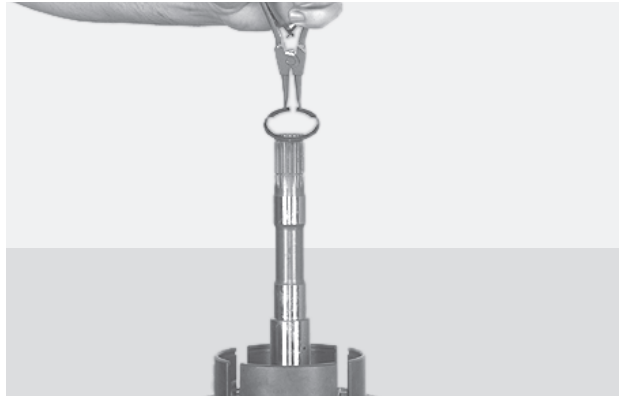
Remove end plate retainer ring.

**6**

Remove end plate.

**7**

Remove clutch discs.



8

Compress disc springs and remove retainer ring.



9

Remove retainer ring retainer.



10

Remove disc springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.



11

Remove clutch piston wear plate.

**12**

Remove clutch piston.

ASSEMBLY



13

Clutch piston bleed orifice must be clean and free of any foreign material. Refer to the cleaning and inspection pages.



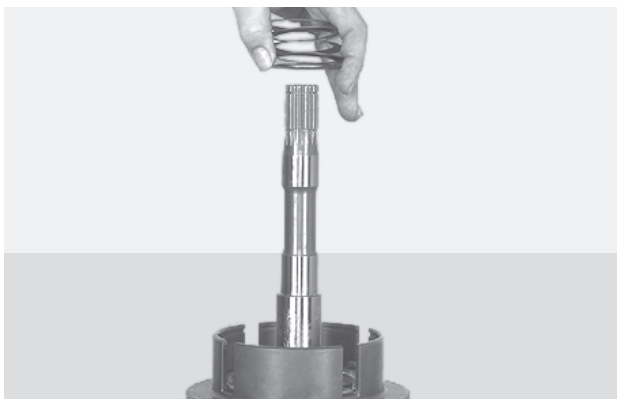
14

Install inner and outer clutch piston seal rings. Size inner ring as explained in figure 93. Install clutch piston in clutch drum. Use caution as not to damage sealing rings.



15

Install clutch piston wear plate.



16

Install piston return disc springs. First spring with large diameter of bevel towards wear plate. Alternate five (5) springs.



NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

**17**

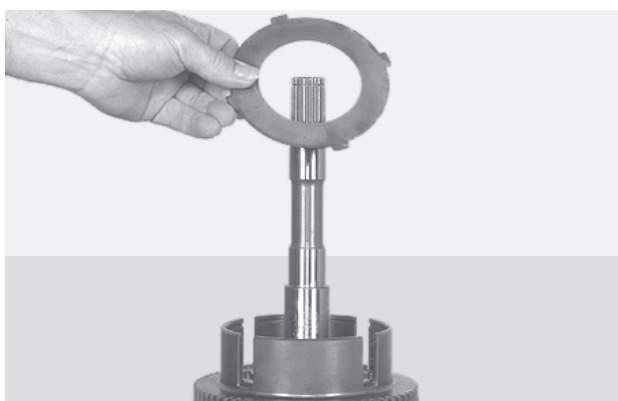
Position return spring ring retainer on clutch shaft.

**18**

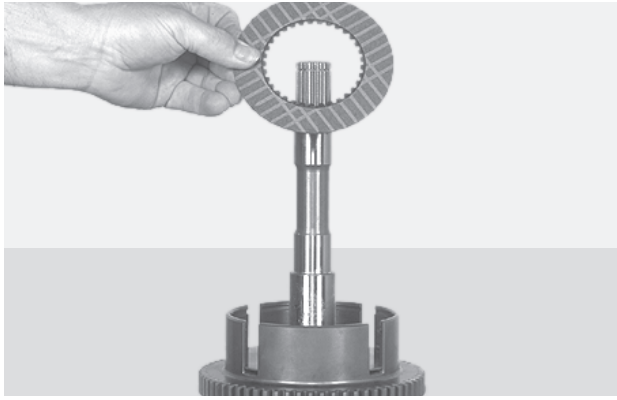
Start ring on shaft with snap ring pliers.

**19**

Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring. A sharp blow with a soft hammer will compress springs and seat retainer ring. Be sure ring is in full position in groove.

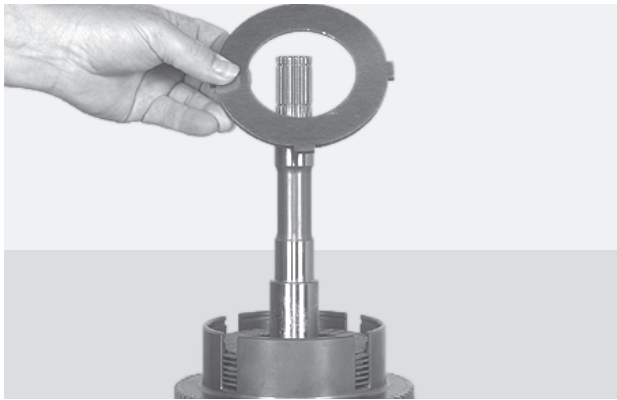
**20**

Install first steel (outer) clutch disc.



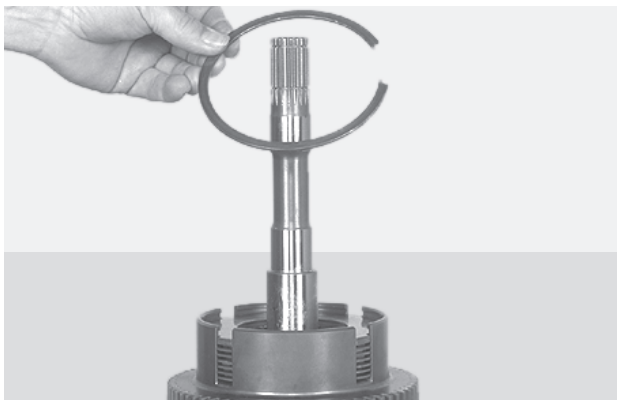
21

Install first friction (inner) clutch disc. Alternate steel and friction until six (6) steel and six (6) friction discs are in position.



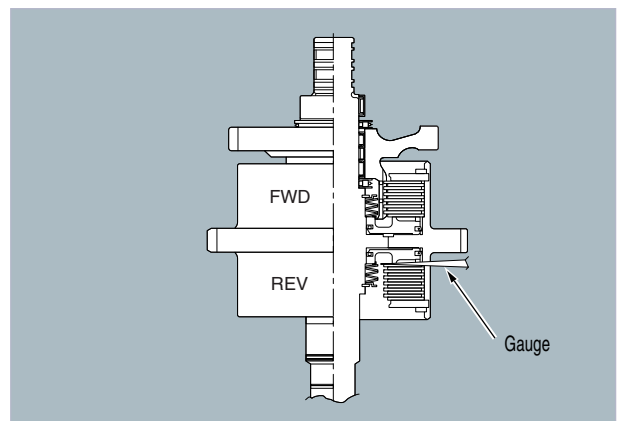
22

Install clutch disc end plate.



23

Install end plate retainer ring.

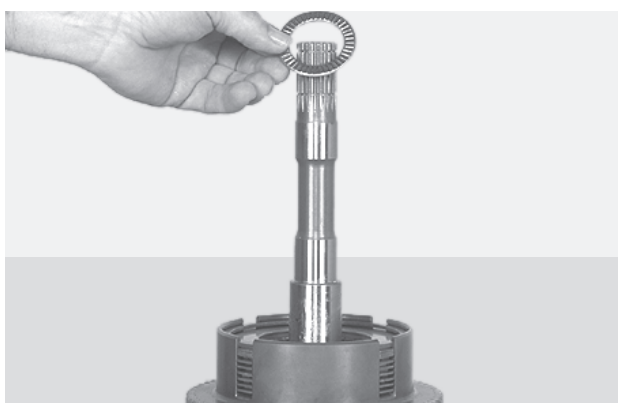


24

NOTE: reverse clutch pack must be checked for clutch disc clearance. Stand the clutch assembly on end. The clutch disc on the bottom will fall to the end plate. Measure the distance between the clutch piston and the first steel disc by inserting a feeler gauge or taper gauge through the slots in the clutch drum. The required clearance is .048-.108 [1,22-2,74]. If the clearance is greater than .108 [2,74] add one steel disc under the end plate.

**25**

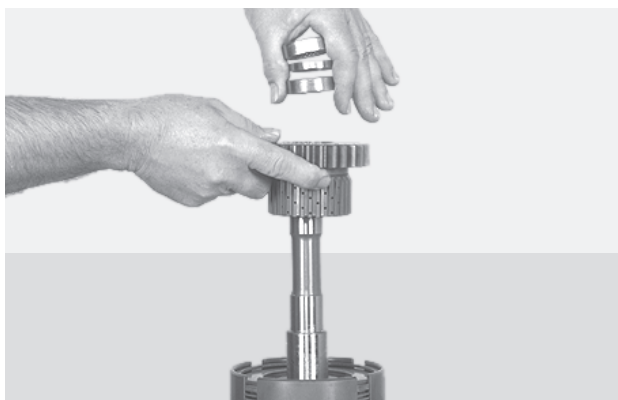
Position thrust bearing inner washer on clutch shaft.

**26**

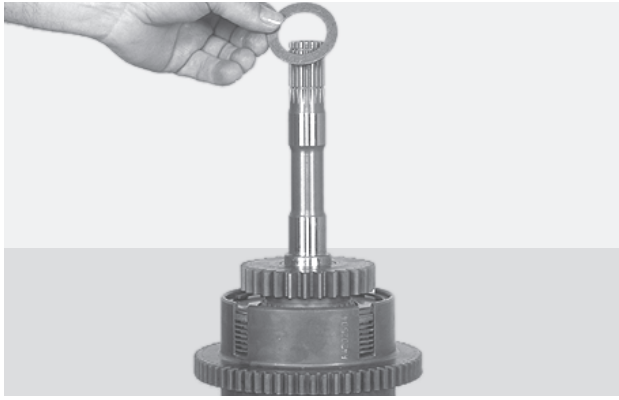
Position thrust bearing on clutch shaft against inner thrust bearing washer.

**27**

Install outer thrust bearing washer against bearing.

**28**

Press one bearing in clutch gear, flush with face of gear. Install bearing spacer next to bearing. Press second bearing in gear, flush with face of gear. Install the clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs. Be sure the clutch hub is in full position in the clutch assembly. Do not force this operation.

**29**

Position inner thrust washer on shaft.

**30**

Position thrust bearing on shaft.

**31**

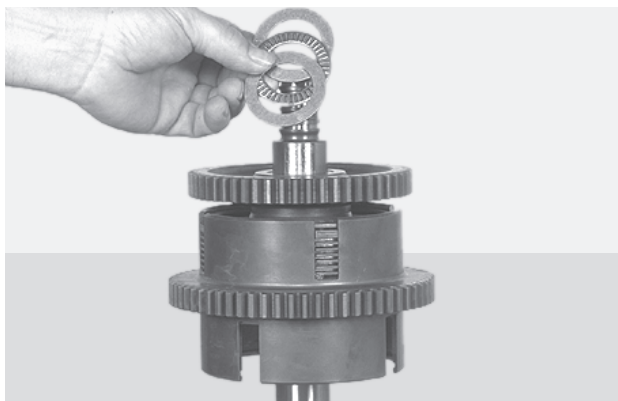
Position outer thrust washer on shaft.

FORWARD CLUTCH

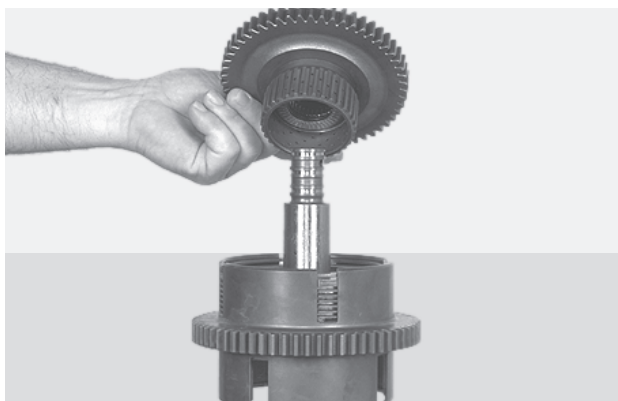
DISASSEMBLY

**1**

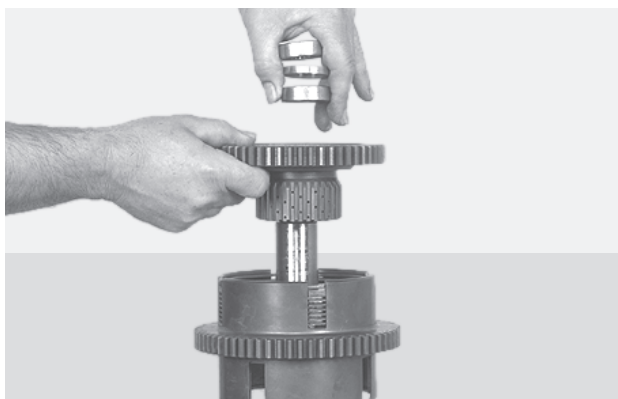
Remove clutch shaft oil sealing rings.

**2**

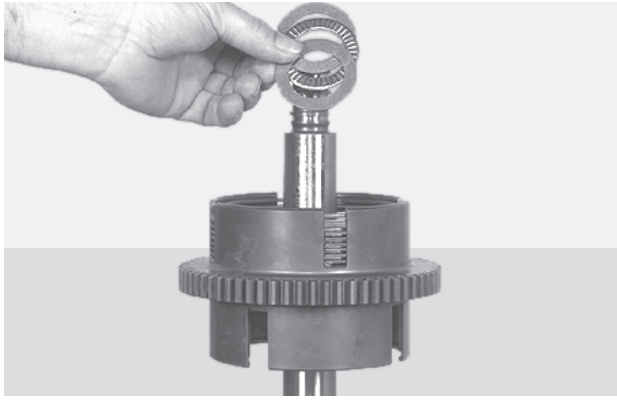
Remove outer thrust washer, thrust bearing and inner thrust washer.

**3**

Remove clutch gear and disc hub.

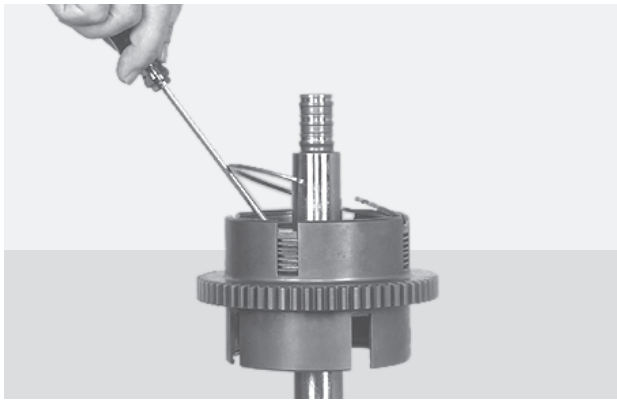
**4**

Remove bearings and spacer from clutch gear.



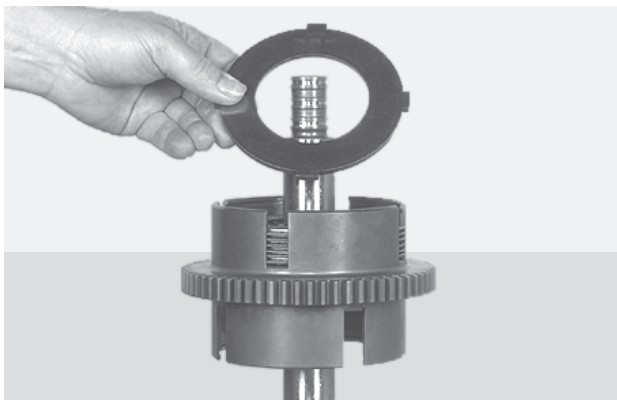
5

Remove outer thrust washer, thrust bearing and inner thrust washer.



6

Remove end plate retainer ring.



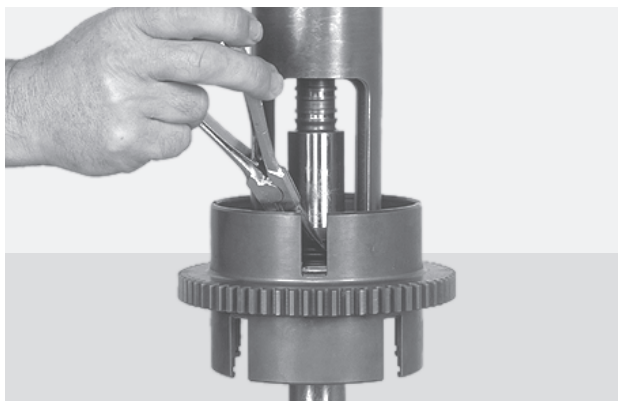
7

Remove end plate.



8

Remove clutch discs.



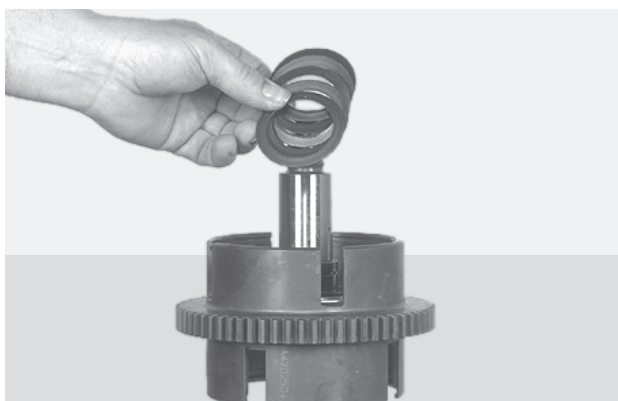
9

Compress disc springs and remove retainer ring.



10

Remove retainer ring retainer.

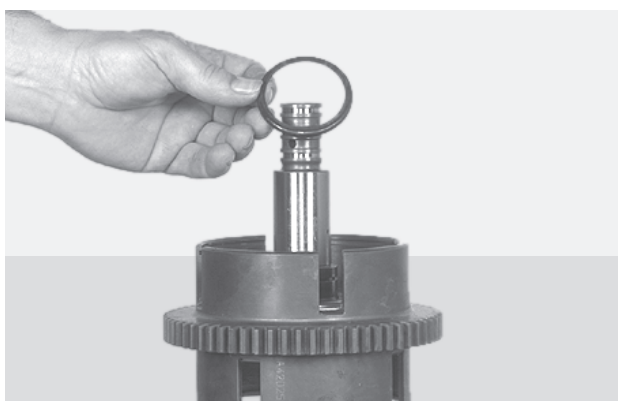


11

Remove disc springs.

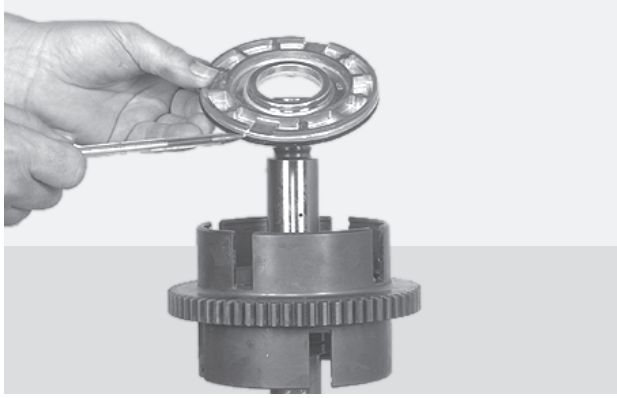


NOTE: The disc springs are to be used as complete assemblies and care should be taken not to intermix the individual disc springs with disc springs in another clutch or disc spring pack. Service replacement assemblies are banded together and must be replaced as assembly.

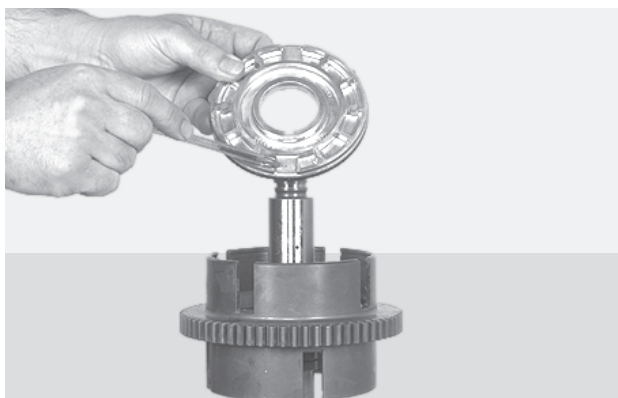


12

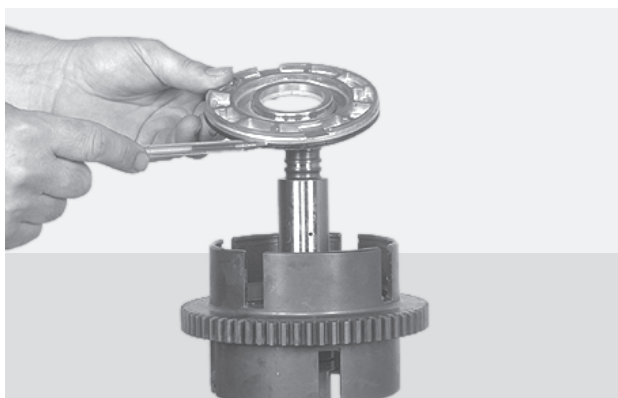
Remove clutch piston wear plate.

**13**

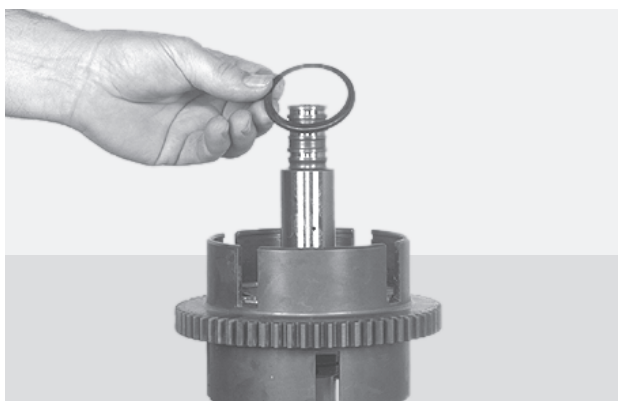
Remove clutch piston.

ASSEMBLY**14**

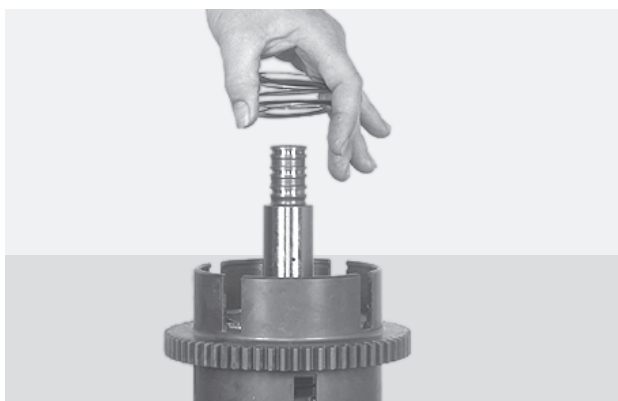
Clutch piston bleed orifice must be clean free of any foreign material. Refer to the cleaning and inspection pages.

**15**

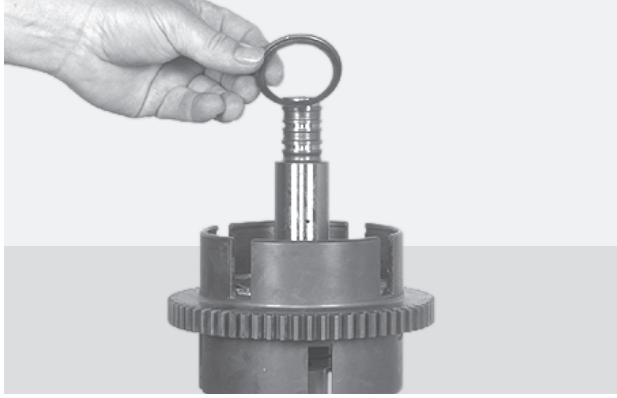
Install inner and outer clutch piston seal rings. Size inner ring as explained in figure 93. Install clutch piston in clutch drum. Use caution as not to damage sealing rings.

**16**

Install clutch piston wear plate.

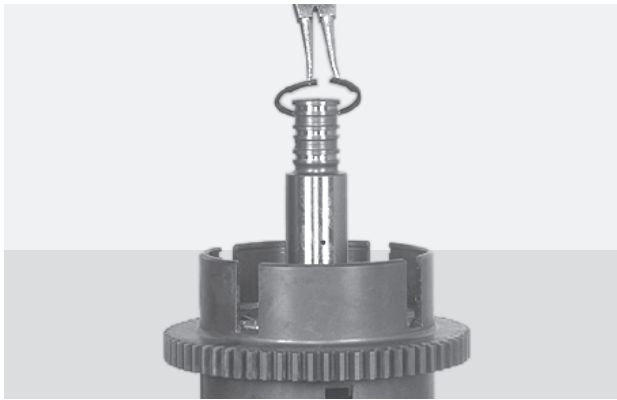
**17**

Install piston return disc springs. First spring with large diameter of bevel towards wear plate. Alternate five (5) springs. NOTE: see page 10-85.



18

Position return spring ring retainer on clutch shaft.



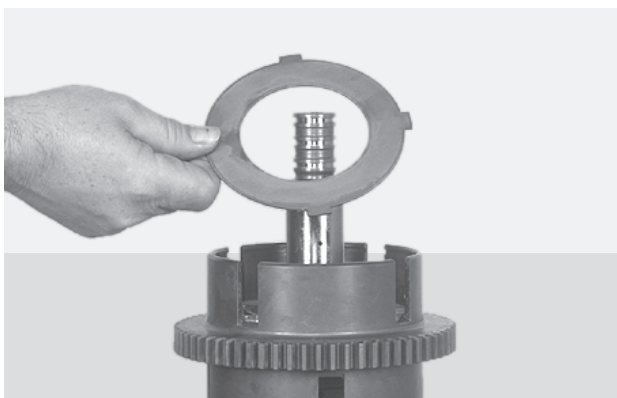
19

Start ring on clutch with snap ring pliers.



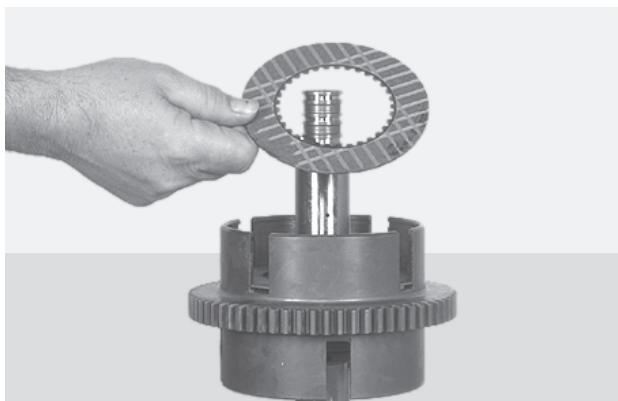
20

Use a sleeve with the proper inner diameter to fit over shaft and against retainer ring. A sharp blow with a soft hammer will compress springs and seat retainer ring. Be sure ring is in full position in groove.



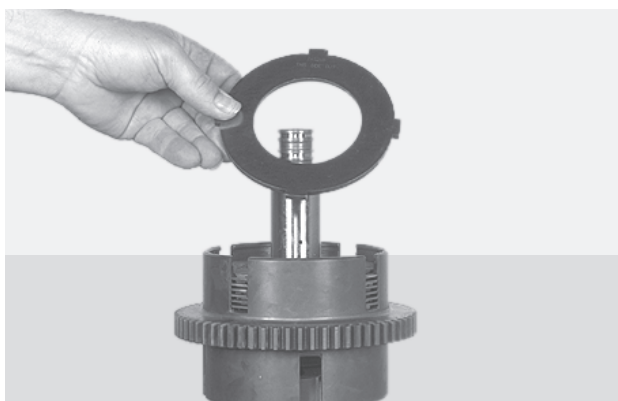
21

Install first steel (outer) clutch disc.



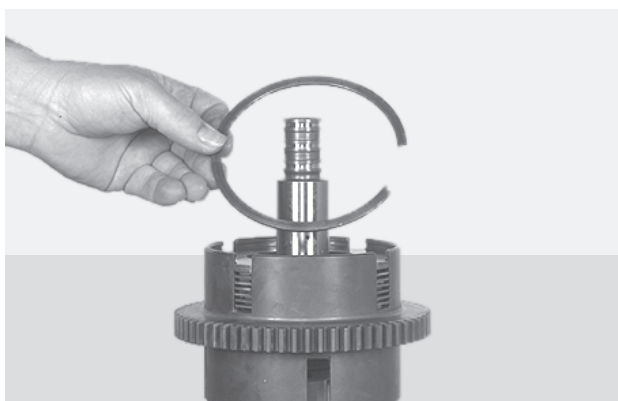
22

Install first friction (inner) clutch disc. Alternate steel and friction until six (6) steel and six (6) friction discs are in position.



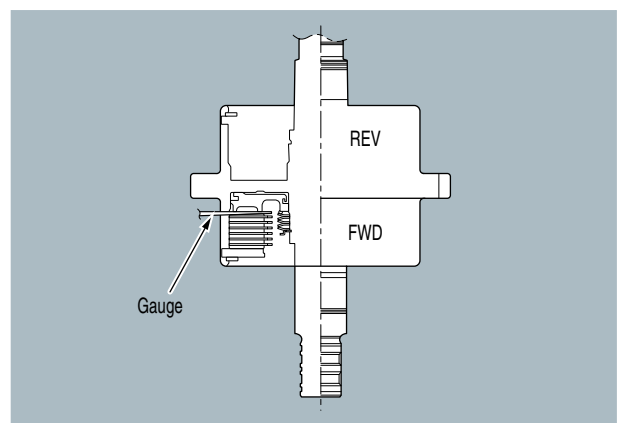
23

Install clutch disc end plate.



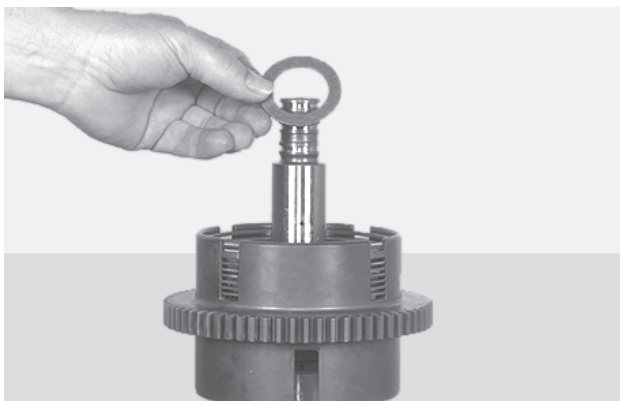
24

Install end plate retainer ring.



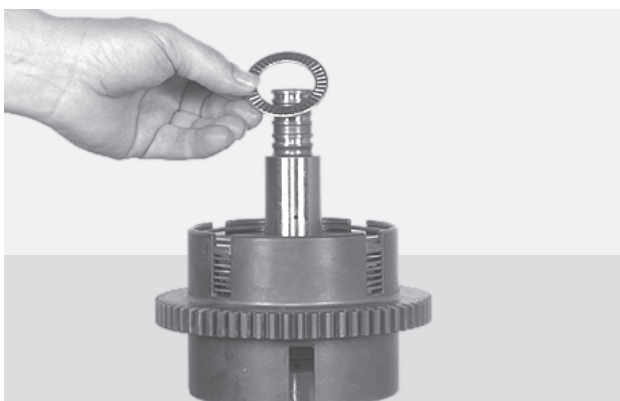
25

NOTE: forward clutch pack must be checked for clutch disc clearance. Stand the clutch assembly on end. The clutch discs on the bottom will fall to the end plate. Measure the distance between the clutch piston and the first steel disc by inserting a feeler gauge or taper gauge through the slots in the clutch drum. The required clearance is .048-.108 [1.22 - 2.74]. If the clearance is greater than .108 [2.74], add one steel disc under the end plate.



26

Position thrust bearing inner washer on clutch shaft.



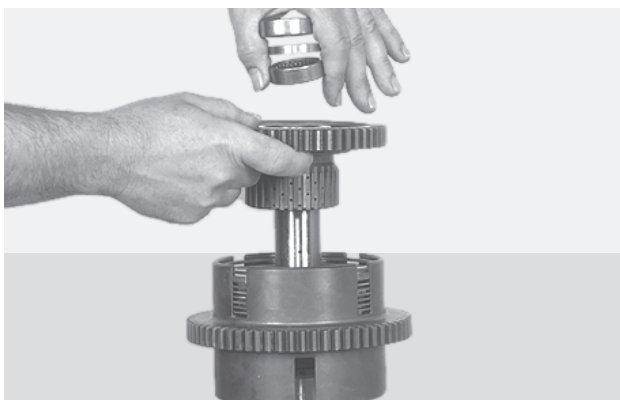
27

Position thrust bearing on clutch shaft against inner thrust bearing washer.



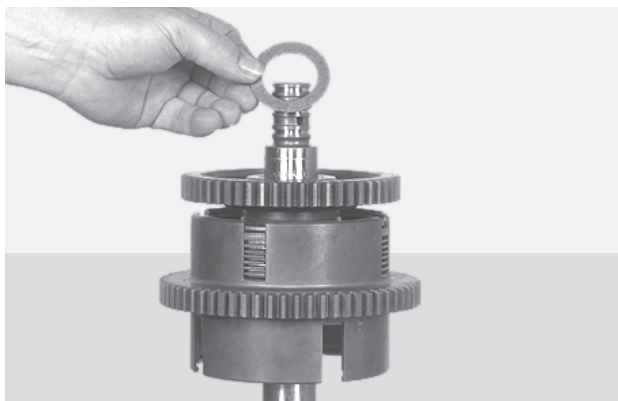
28

Install outer thrust bearing washer against thrust bearing.

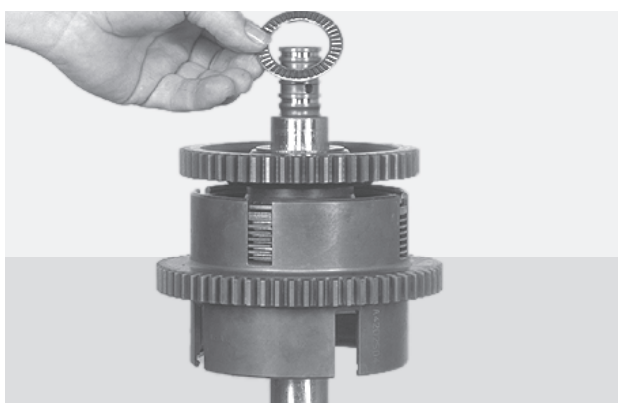


29

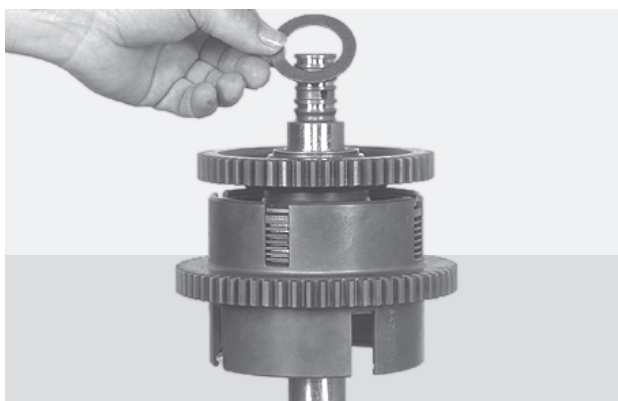
Press one bearing in clutch gear, flush with face of gear. Install bearing spacer next to bearing, press second bearing in gear, flush with face of gear. Install the clutch gear in the clutch assembly by aligning the clutch hub teeth with the clutch inner discs. Be sure the clutch hub is in full position in the clutch assembly. Do not force this operation.

**30**

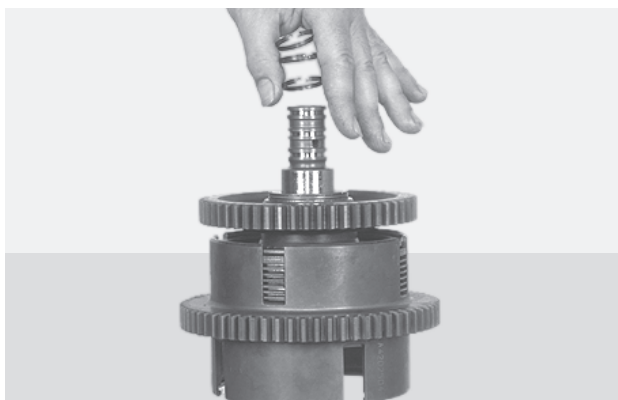
Position inner thrust washer on shaft.

**31**

Position thrust bearing on shaft.

**32**

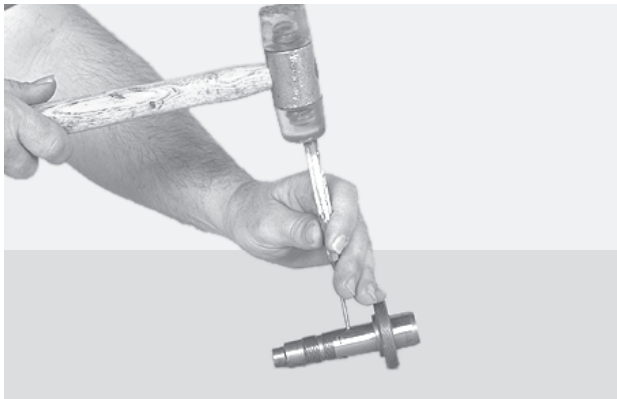
Position outer thrust washer on shaft.

**33**

Install clutch shaft oil sealing rings. Grease rings to facilitate reassembly into front housing.

REGULATOR VALVE

DISASSEMBLY

**1**

Tap pin from regulator valve sleeve. Use caution as valve spool is under spring pressure.

**2**

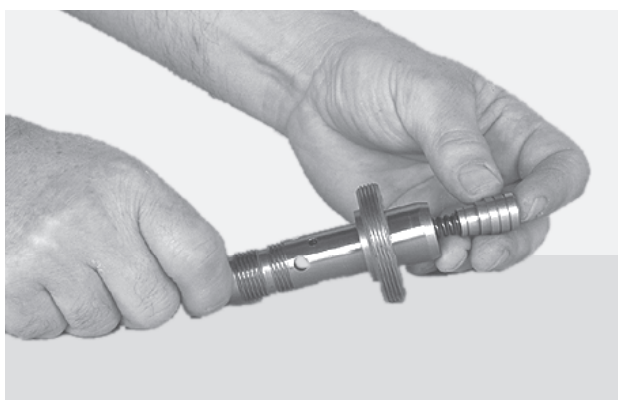
Remove regulator valve piston and pressure regulator valve spring.

**3**

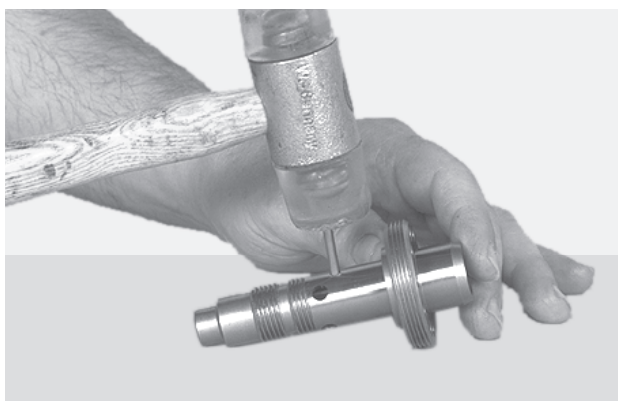
Spring and piston removed.

ASSEMBLY**4**

Position pressure regulator valve spring into regulator valve piston. Refer to the cleaning and inspection pages.

**5**

Install pressure regulator valve spring and regulator valve piston as an assembly into regulator valve sleeve.

**6**

Compress valve spring and valve and install pin into regulator valve sleeve.

DUAL MODULATED VELVE ASSEMBLY

DISASSEMBLY



1

Remove inner, middle and outer spring and stop pin from modulation housing sleeve.



2

Remove accumulator spool.

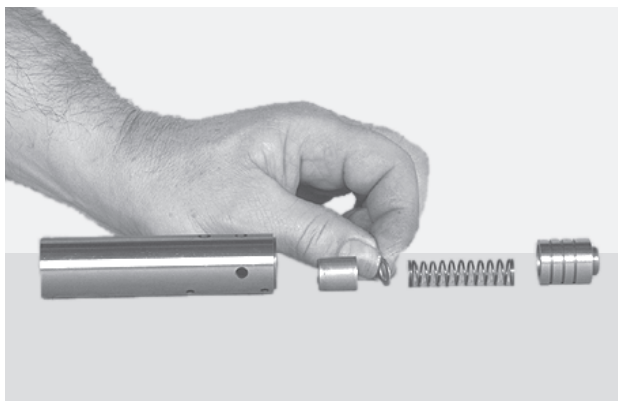


3

Remove cross pin from sleeve



NOTE: Some units will have two cross pins the same length. Some units will have two pins of different lengths. The longest pin goes in the bottom hole.

**4**

Remove regulator spool, spring, retainer spring and spacer spring from housing sleeve.

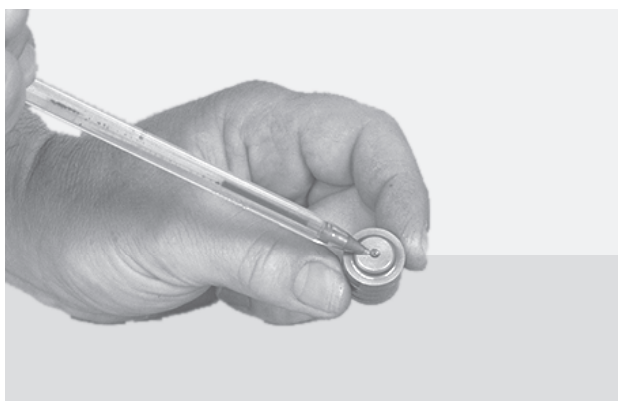
ASSEMBLY

**5**

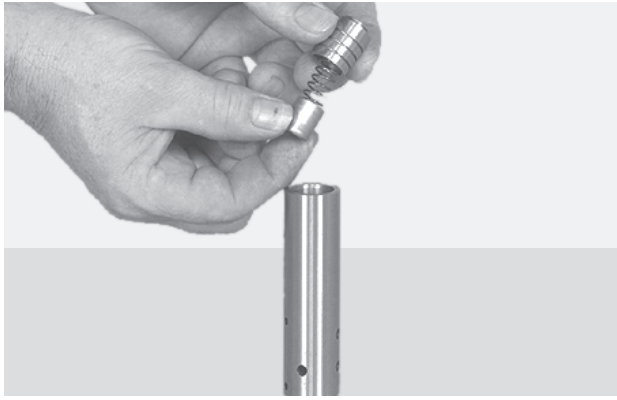
Install spring spacer in spring retainer. Refer to the cleaning and inspection at section **CLEANING AND INSPECTION** (pag. 2).

**6**

Install spring in spring retainer.

**7**

Check orifice in regulator spool to be free and clear of any foreign material.



8

Install spring retainer, spring and regulator valve in sleeve against inner cross pin.



9

Compress regulator spool and spring in sleeve far enough to install cross pin.



10

Install cross pin.



NOTE: Some units will have two cross pins the same length. Some units will have two pins of different lengths. The longest pin goes in the bottom hole.



11

From opposite end, position accumulator spool in sleeve as shown.

**12**

Install outer accumulator spring.

**13**

Install middle spring.

**14**

Install inner spring.

**15**

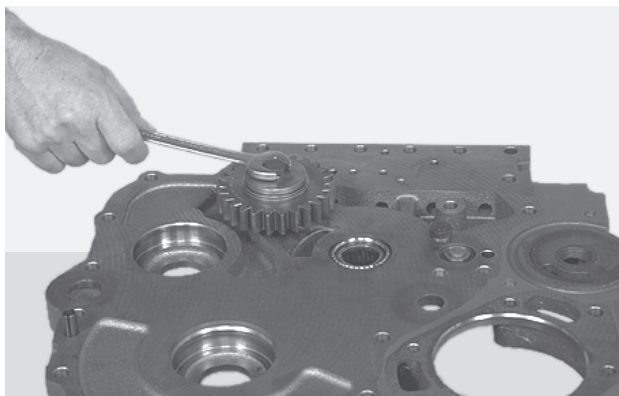
Install stop pin in inner spring.

**16**

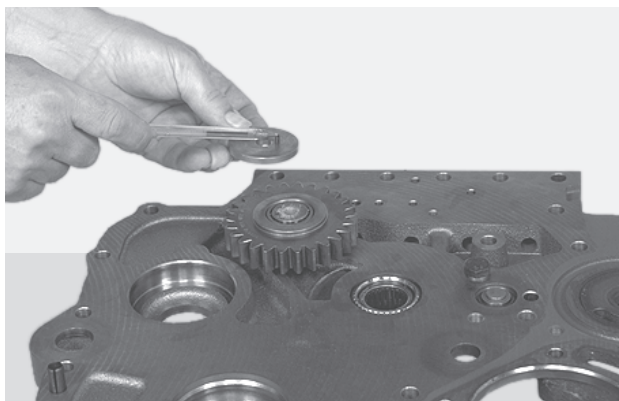
If charging pump or pump drive gear are to be replaced, remove retainer ring and drive gear.

SPACER PLATE

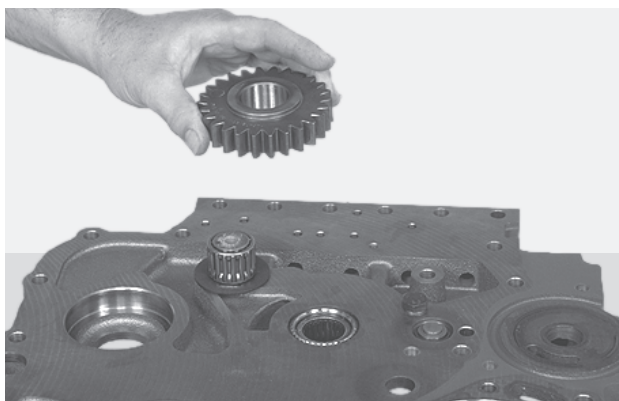
DISASSEMBLY

**1**

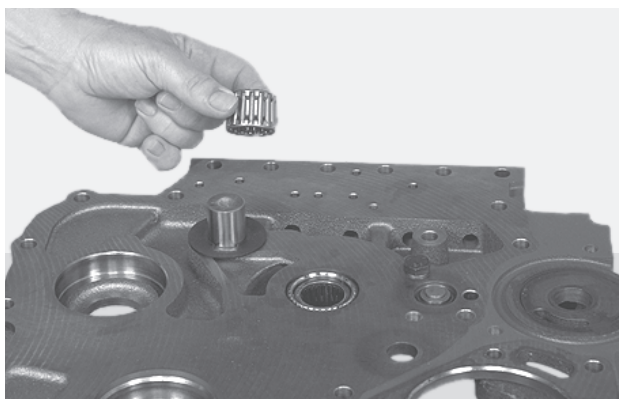
Remove reverse idler gear end plate cap screw and washer.

**2**

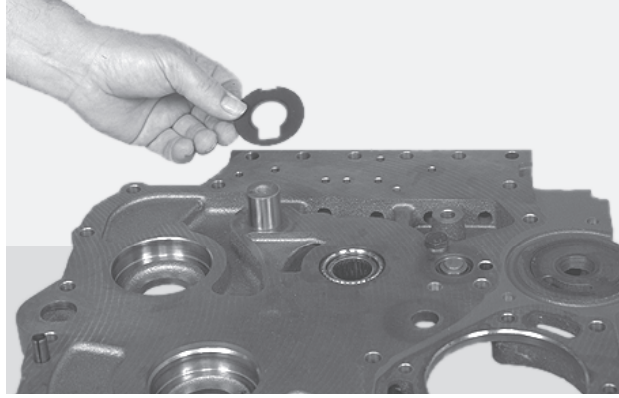
Remove end plate and dowel pin.

**3**

Remove reverse idler gear.

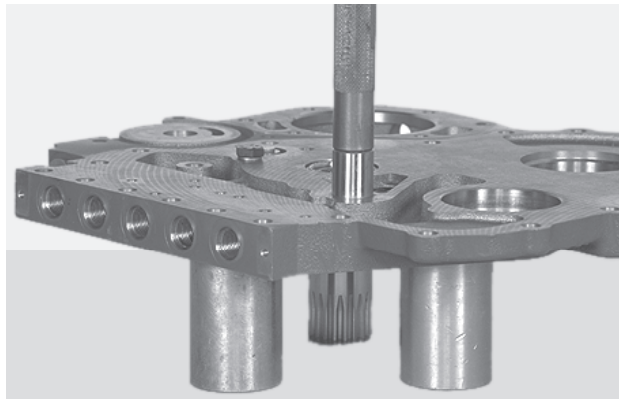
**4**

Remove reverse idler gear bearing.



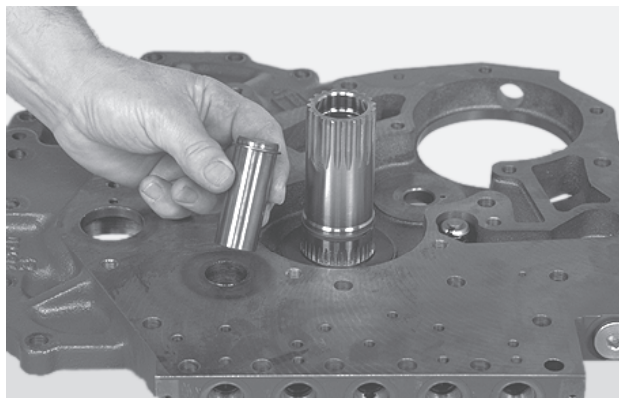
5

Remove idler gear tanged thrust washer.



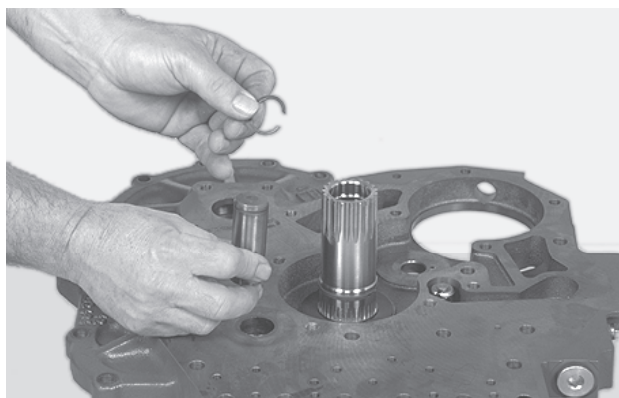
6

If reverse idler shaft is to be replaced, support spacer plate around idler shaft opening and press idler shaft from spacer.



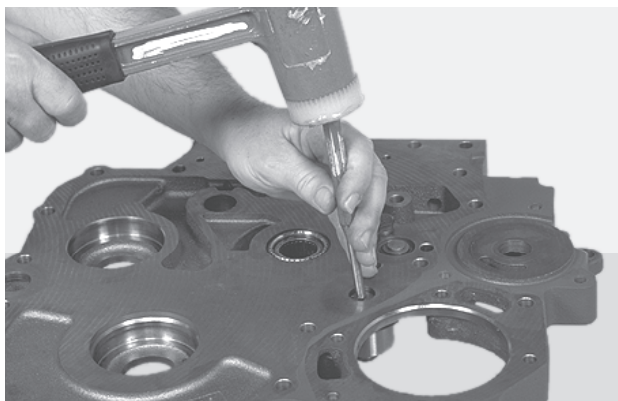
7

Idler shaft and locating ring removed.



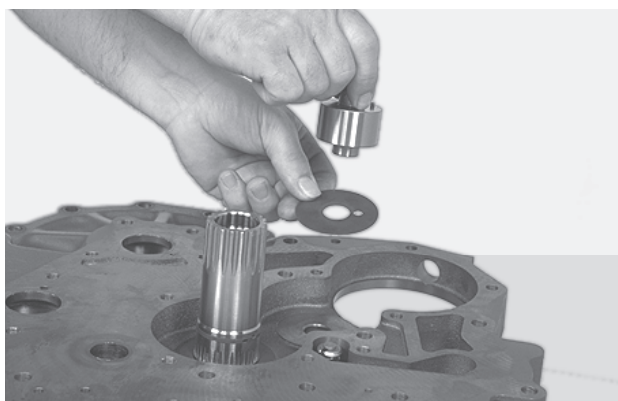
8

Remove locating ring from idler shaft.



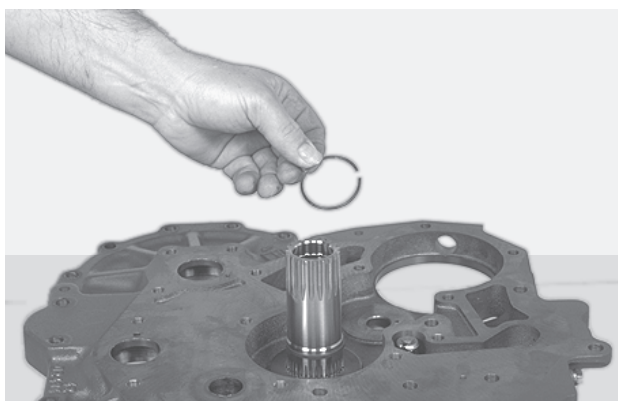
9

Tap pump drive idler shaft from spacer plate.



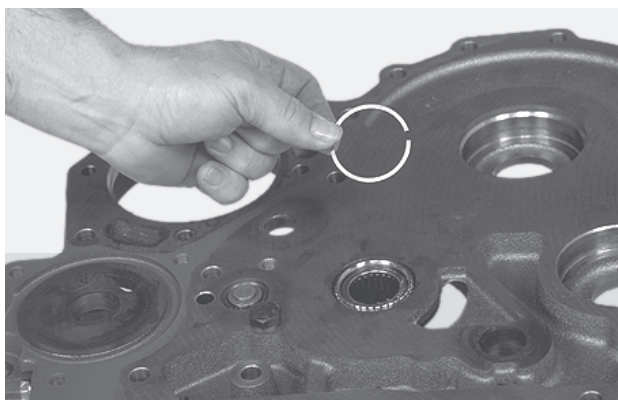
10

Remove pump drive idler shaft and thrust washer.



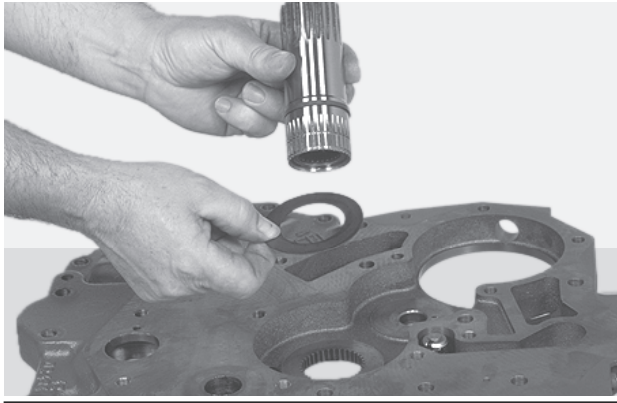
11

The stator support is held in place by two retaining rings. Remove converter end retainer ring from groove.



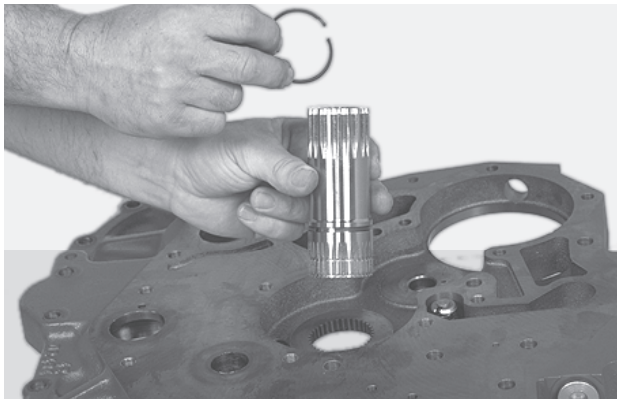
12

Push support towards transmission side far enough to expose retainer ring. Remove retainer ring.



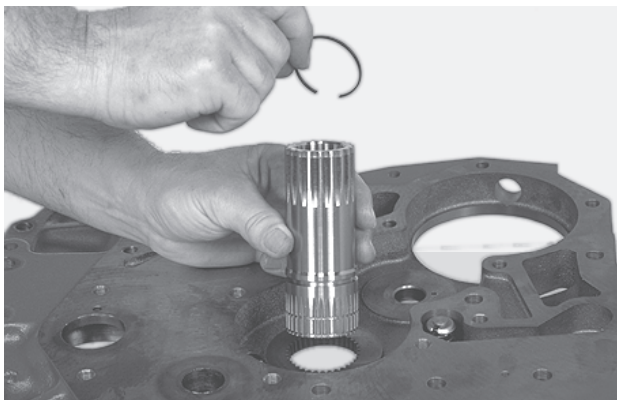
13

From converter end, remove stator support and thrust washer.



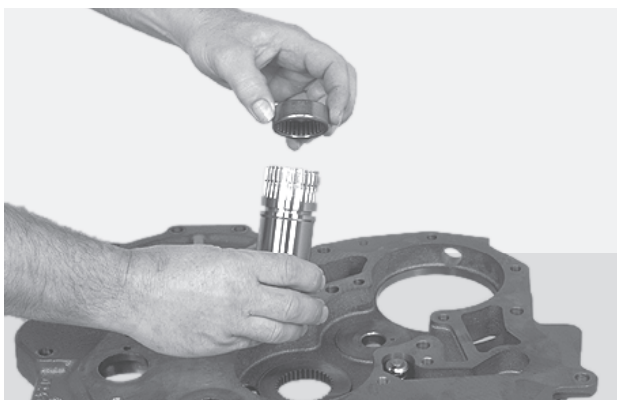
14

Remove stator support oil sealing ring.



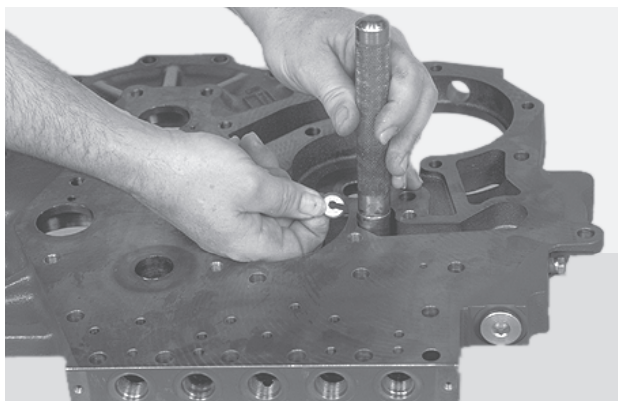
15

Remove sealing ring expander ring.

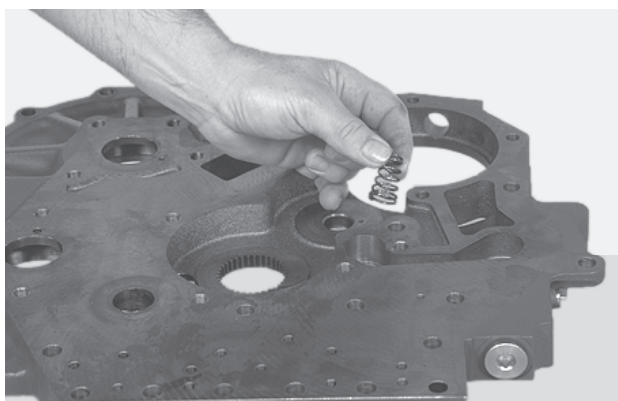


16

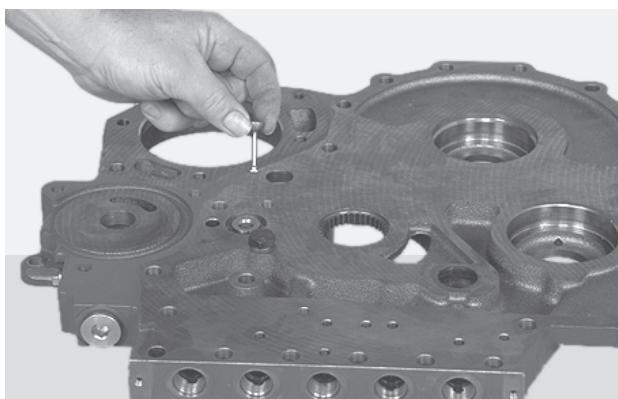
If support bushing or bearing is to be replaced, remove from stator support.

**17**

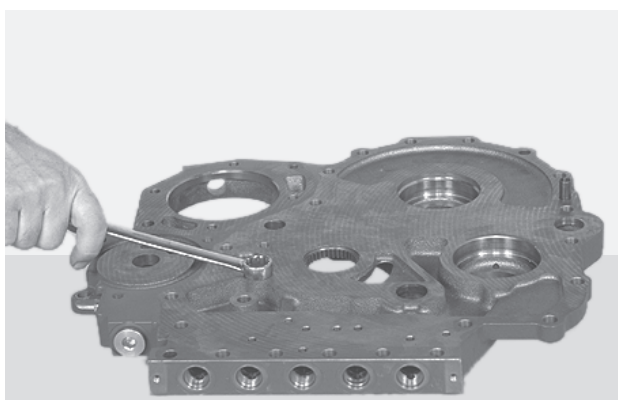
Compress converter safety valve spring and remove retaining washer.

**18**

Remove safety valve spring.

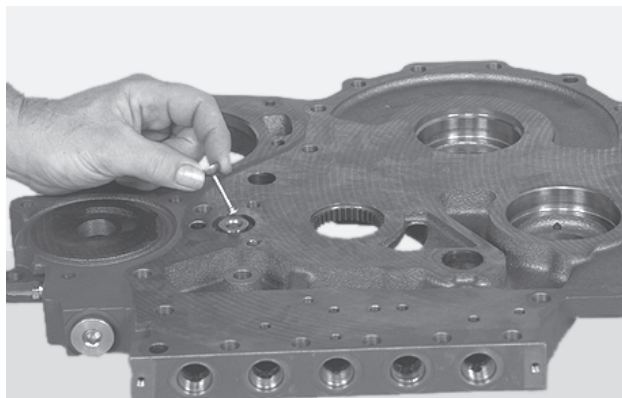
**19**

Turn spacer plate over and remove safety valve poppet.

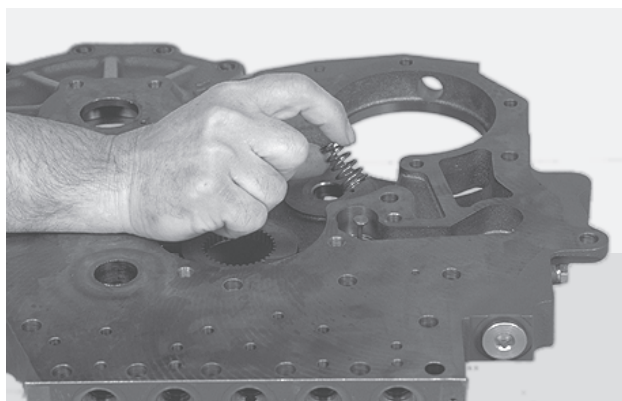
**20**

Remove plug and seal washer from spacer plate.

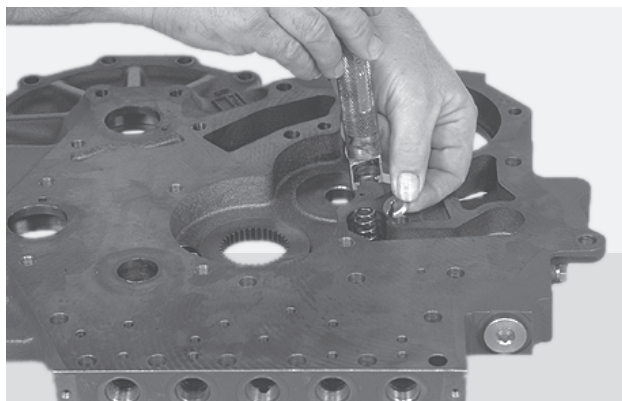
ASSEMBLY


21

From transmission side of spacer plate, position converter safety valve poppet in bore in spacer. Refer to the cleaning and inspection pages.


22

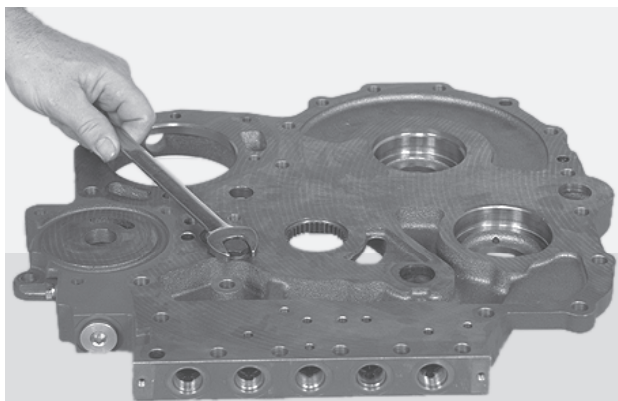
Turn spacer over and position safety valve spring on poppet.


23

Compress spring and install poppet retaining washer.



NOTE: end of spring must go in recessed side of washer.

**24**

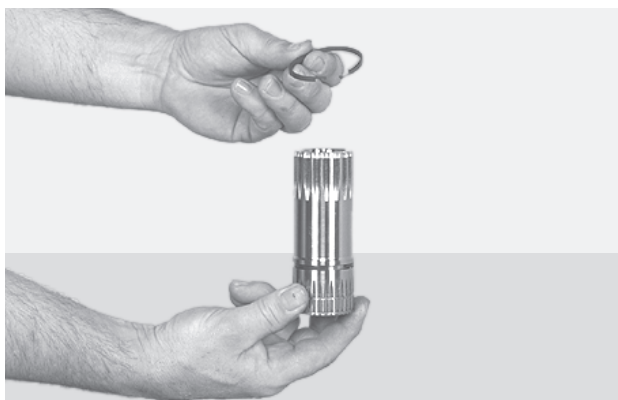
Install plug and seal washer.

**25**

If stator support bushing was removed, install bushing in support. Install needle bearing in stator support.

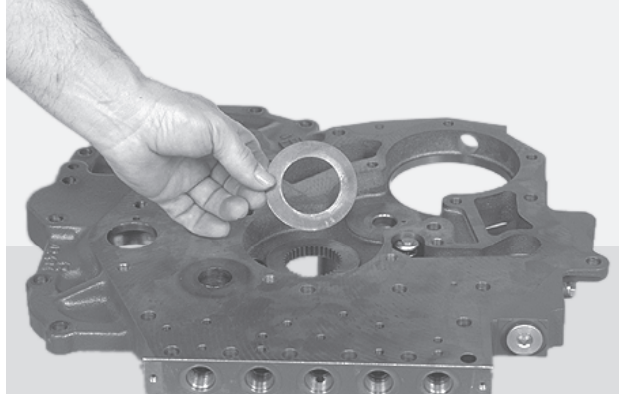
**26**

Install stator support oil sealing ring expander ring.

**27**

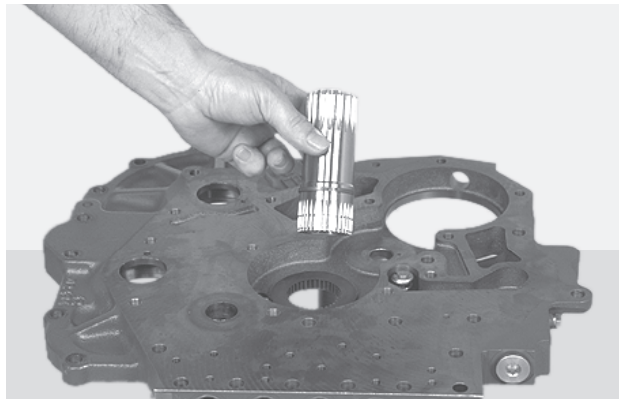
Install oil sealing ring on expander ring.

**NOTE:** Expander spring gap to be 180 degrees from sealing ring hook joint.



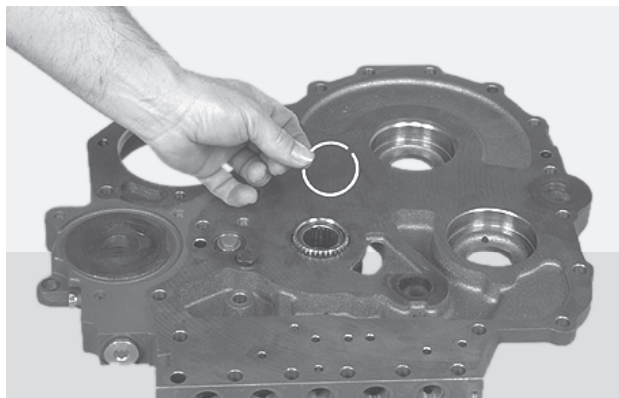
28

Position impeller hub gear washer on spacer plate.



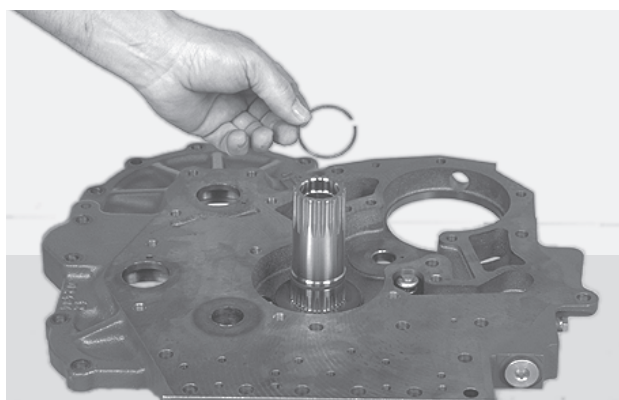
29

Install stator support through washer and spacer plate.



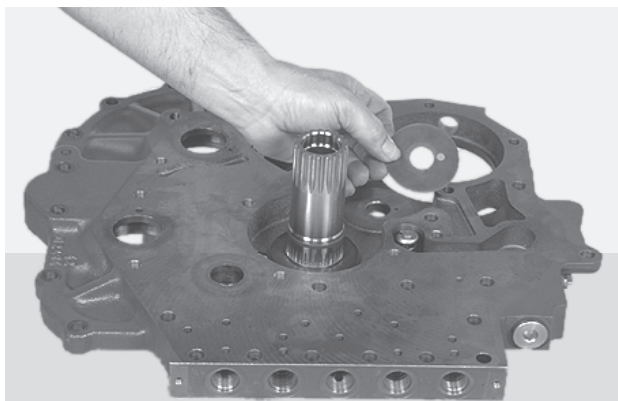
30

Install stator support locating ring.

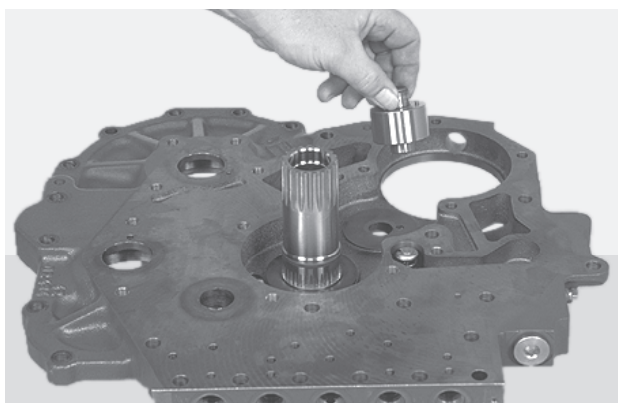


31

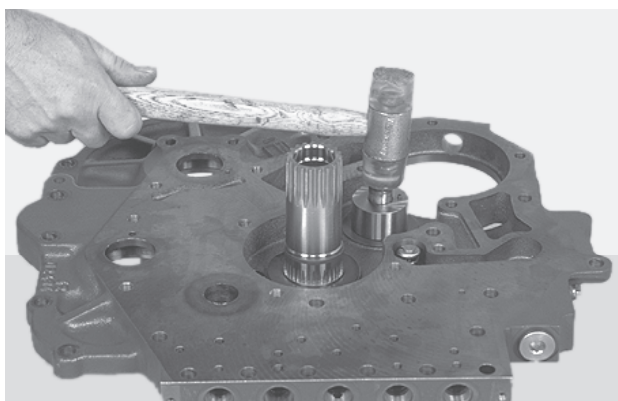
Push support back through spacer until locating ring shoulders in support bore. Turn spacer plate over and install support retaining ring.

**32**

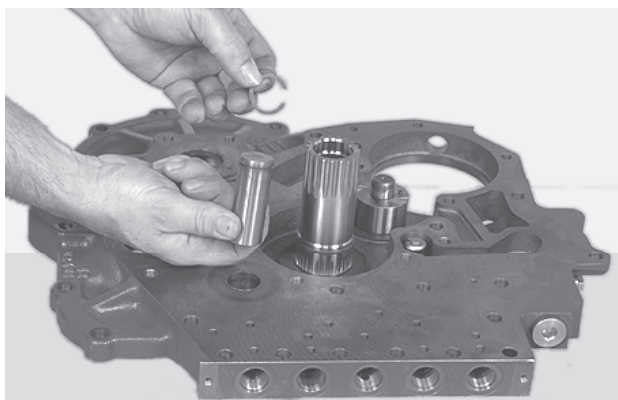
Position pump drive idler shaft washer on spacer plate.

**33**

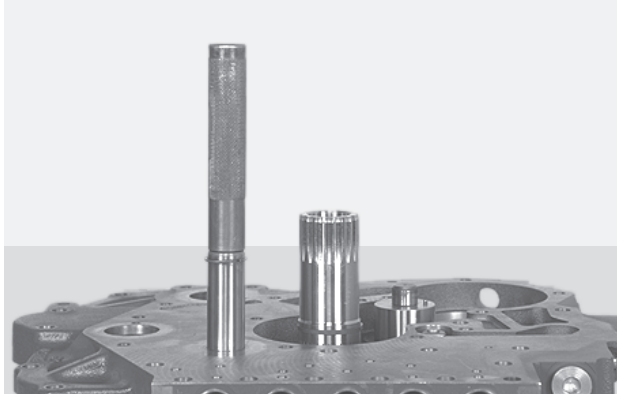
Position pump drive shaft through washer and into spacer plate. Align roll pin in spacer plate.

**34**

Tap shaft into place.

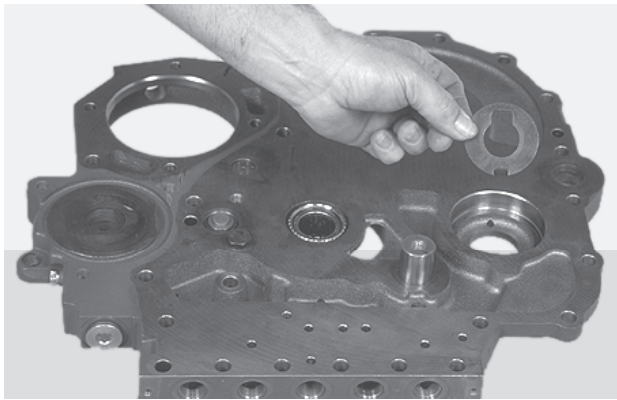
**35**

Install locating ring on reverse idler shaft.



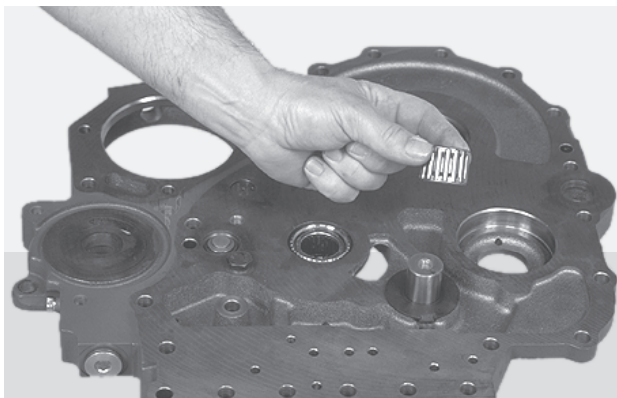
36

Support spacer plate and press reverse idler shaft into position and tight against locating ring.



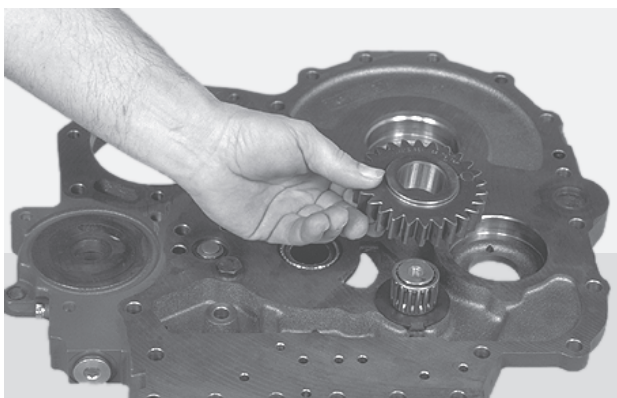
37

Turn spacer plate over and position tanged thrust washer on shaft, being certain tang in washer is in notch in spacer plate.



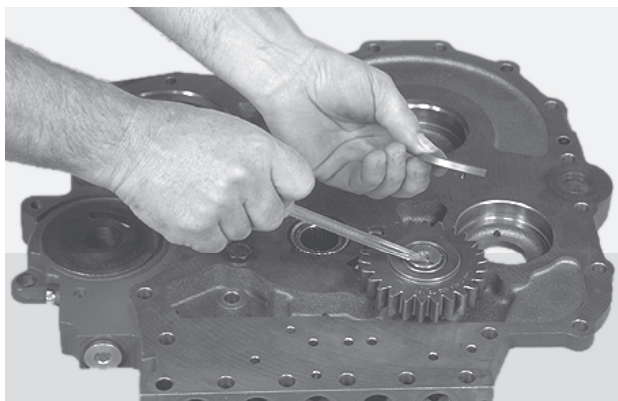
38

Position idler gear needle bearing on shaft. Lubricate bearing.

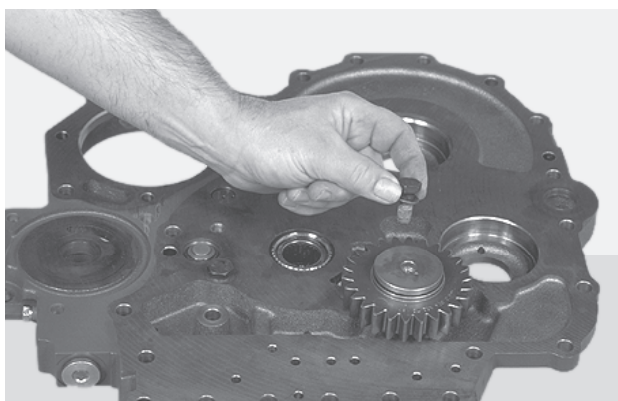


39

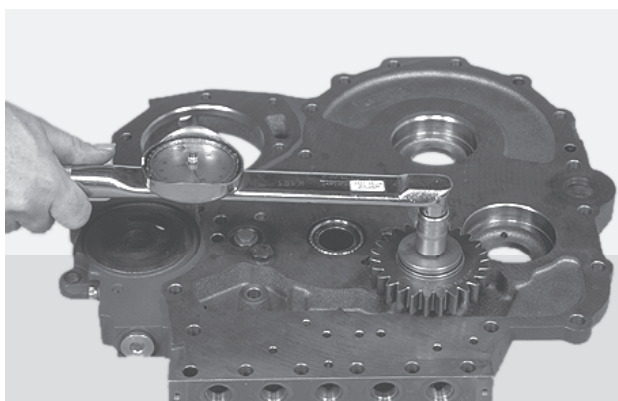
Position idler gear on bearing.

**40**

Position idler gear end plate and roll pin on idler shaft aligning roll pin with hole in idler shaft.

**41**

Install end plate cap screw and washer.

**42**

Tighten cap screw to specified torque (see torque chart).

FRONT OUTPUT FLANGE

DISASSEMBLY



1

Remove flange to bearing retainer ring.



NOTE: do not remove expansion plug unless it is being replaced.



2

Using a bearing puller as shown, remove bearing.



3

Bearing removed.



4

Oil seal sleeve and "O"-ring removed.



5

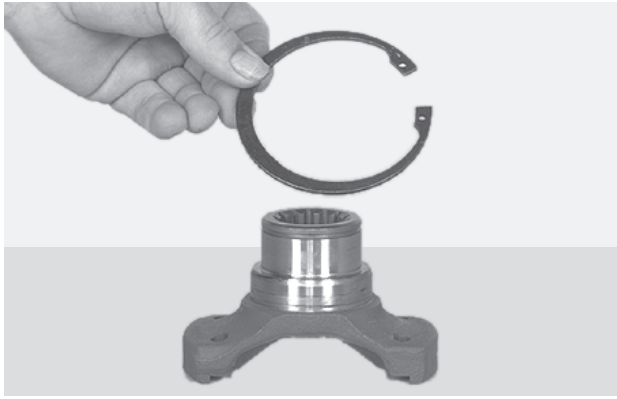
Remove oil seal from sleeve.



6

Remove oil seal retainer ring from output flange.

ASSEMBLY



7

Position bearing retainer ring on output flange. Refer to the cleaning and inspection pages.



8

Apply a very light coat of permatex 2 to the outer diameter of the output flange oil seal, press oil seal in oil seal sleeve. Oil seal must be flush with one side of face of oil seal sleeve, and lip of seal must be in.



9

Install new "O"-ring on oil seal sleeve. Position oil seal sleeve assembly on output flange.



NOTE: recessed position of oil seal and sleeve must be up, with lip of seal up. This leaves a space between oil seal and output bearing.

**10**

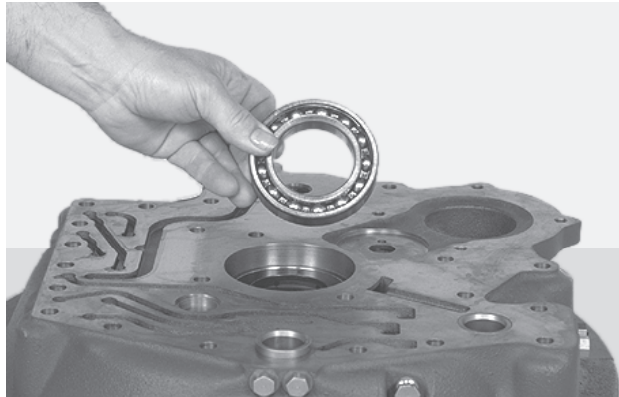
Press bearing on output flange.

**11**

Install bearing to flange retainer ring.

CONVERTER HOUSING

DISASSEMBLY



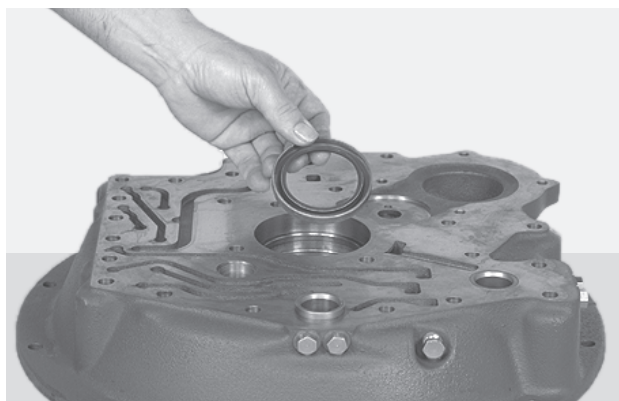
1

Remove torque converter bearing.



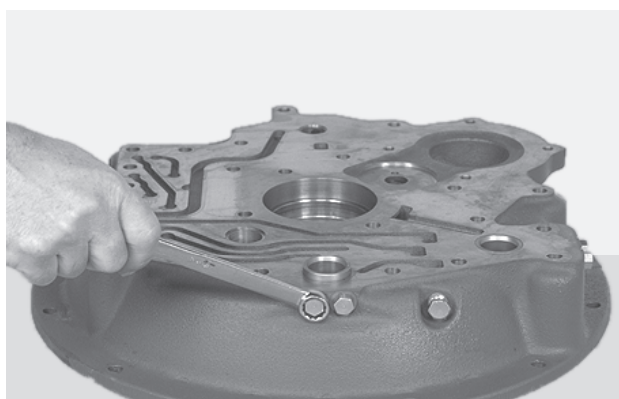
2

Remove oil distributor.



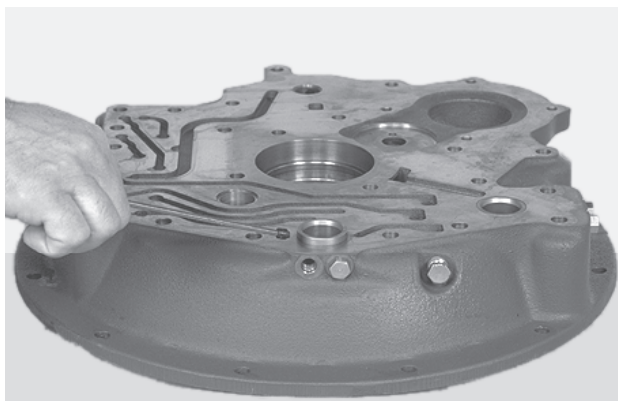
3

Remove converter oil seal.



4

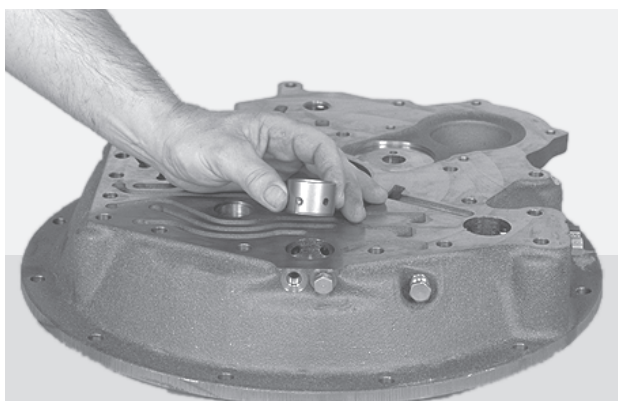
Remove converter housing plug (high and 3rd clutch shaft).

**5**

Remove oil distributor sleeve set screw.

**6**

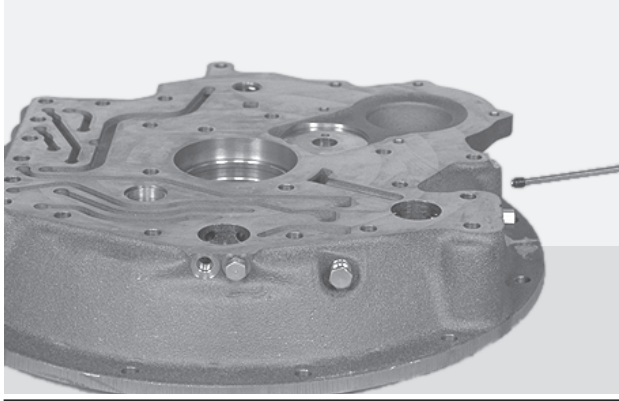
Using a hammer puller as shown, remove oil distributor sleeve (high and 3rd).

**7**

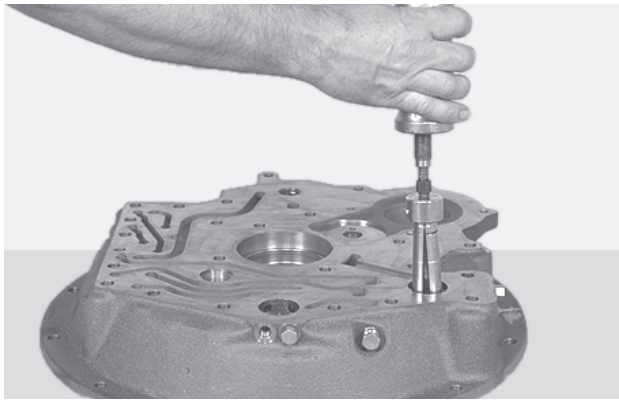
Sleeve removed.

**8**

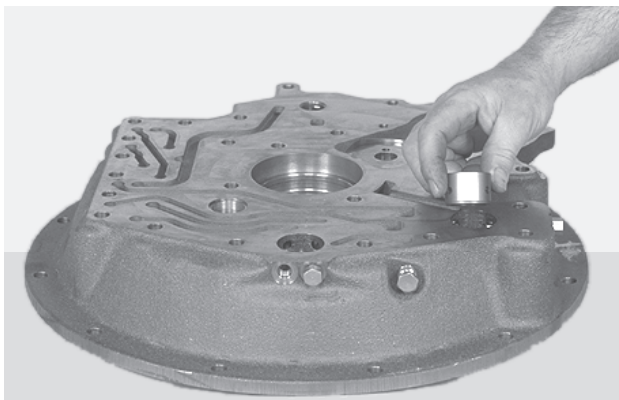
Remove converter housing plug (1st and 2nd clutch shaft).

**9**

Remove oil distributor sleeve set screw.

**10**

Using a hammer puller as shown, remove oil distributor sleeve (1st and 2nd).

**11**

Sleeve removed.

ASSEMBLY**12**

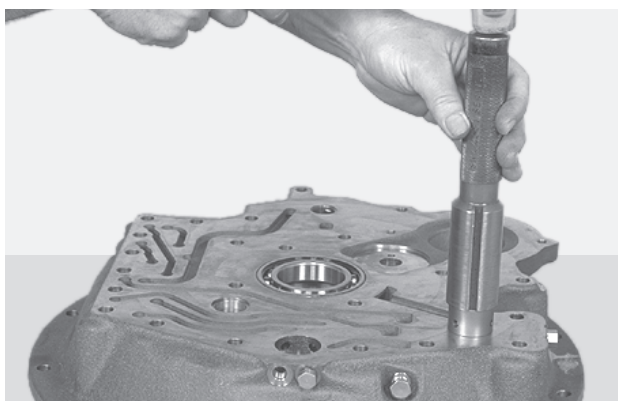
Apply a very light coat of Permatex 2 to the outer diameter of the converter housing oil seal. Press seal in housing with lip of seal in. Refer to the cleaning and inspection pages.

**13**

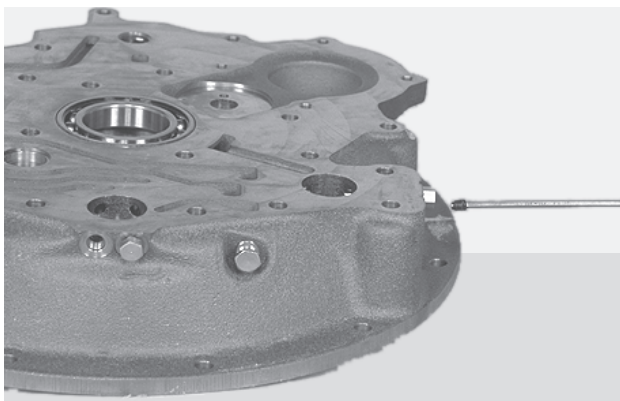
Install oil distributor in converter housing with long hub towards oil seal.

**14**

Press converter bearing in housing against shoulder.

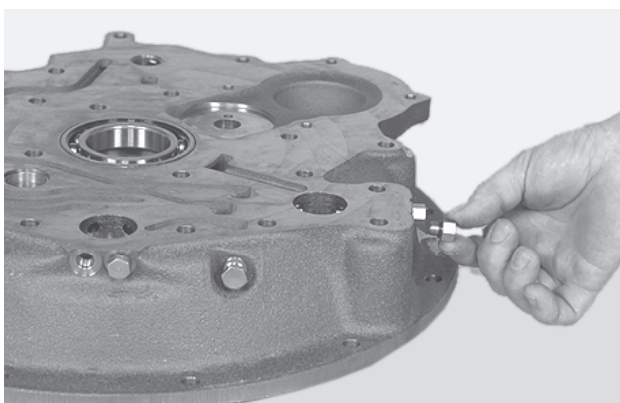
**15**

Install 1st and 2nd clutch shaft oil distributor sleeve in converter housing, with inside diameter chamfer up, and the notch in the distributor aligned up with the retaining set screw hole in the converter housing.



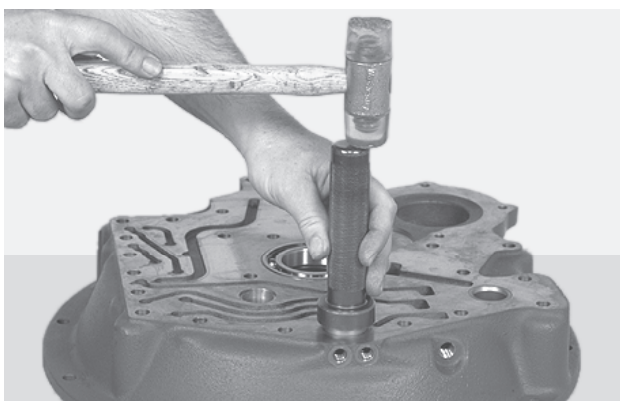
16

Apply Loctite 243 to threads of sleeve set screw (NOTE: this screw has a hole in it. Use caution as not to allow any loctite to plug hole). Install set screw in converter housing and in oil distributor.



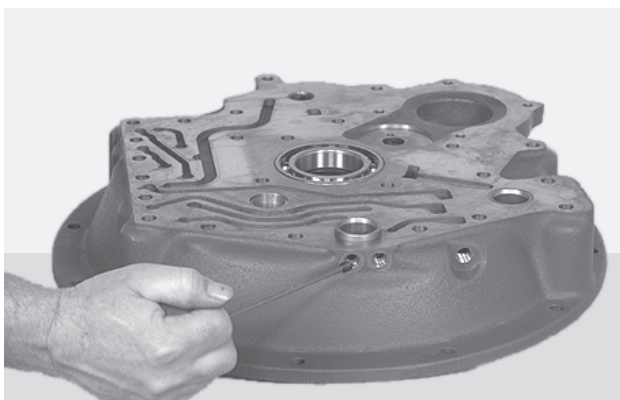
17

Install set screw plug.



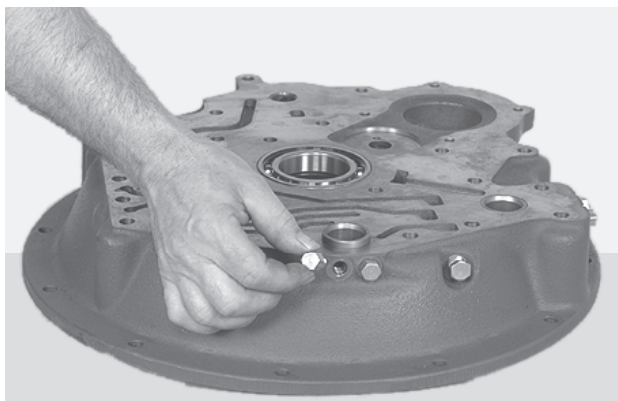
18

Install high-3rd clutch shaft oil distributor sleeve in converter housing with inside diameter chamfer up and the notch in the distributor aligned up with the retaining set screw hole in the converter housing.



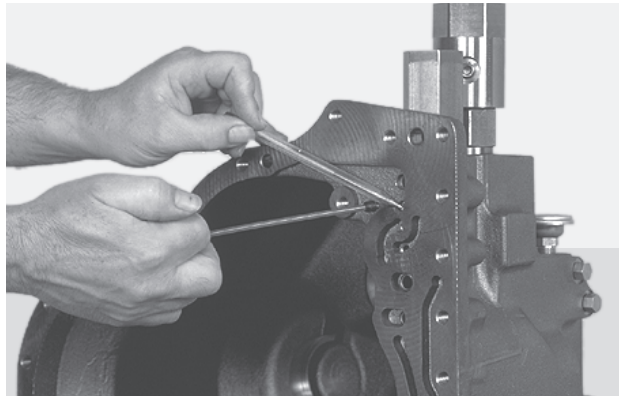
19

Apply loctite 243 to threads of sleeve set screw. (NOTE: this set screw has a hole in it. Use caution as not to allow any loctite to plug hole). Install set screw in converter housing and in oil distributor.

**20**

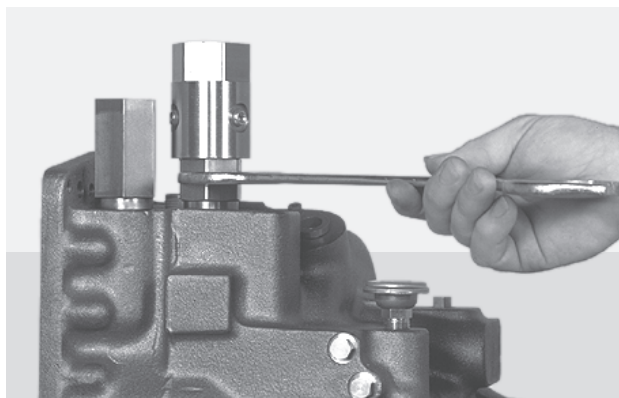
Install set screw plug.

SINGLE MODULATION AND HYDRAULIC REMOVAL



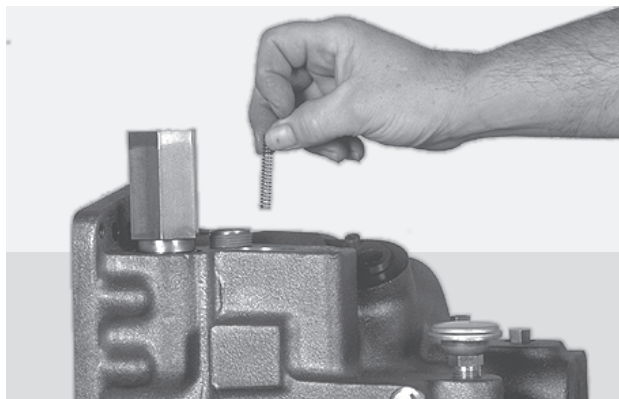
1

If inching is used install plug as shown.



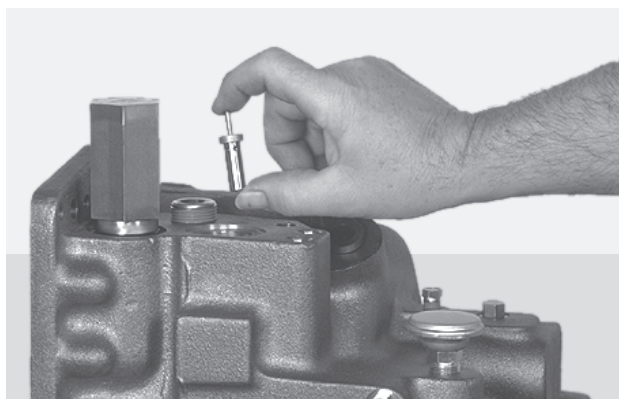
2

Remove hydraulic inching actuator.



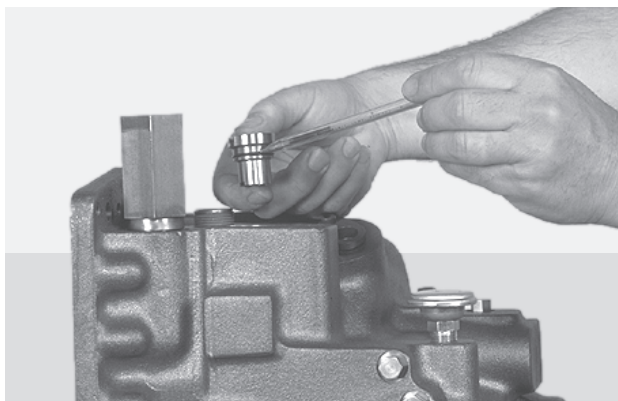
3

Remove inching regulator spring.

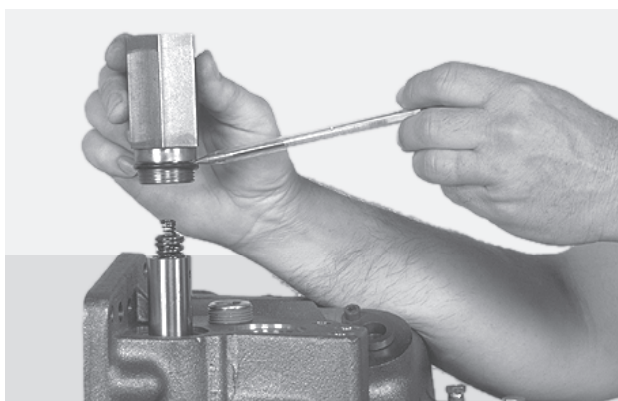


4

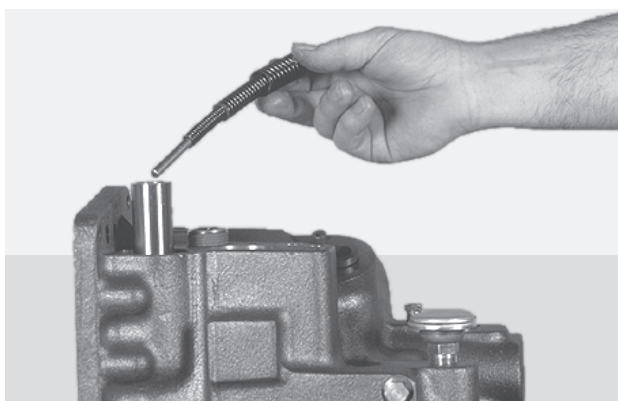
Remove inching spool.

**5**

Remove inching sleeve and "O"-ring.

**6**

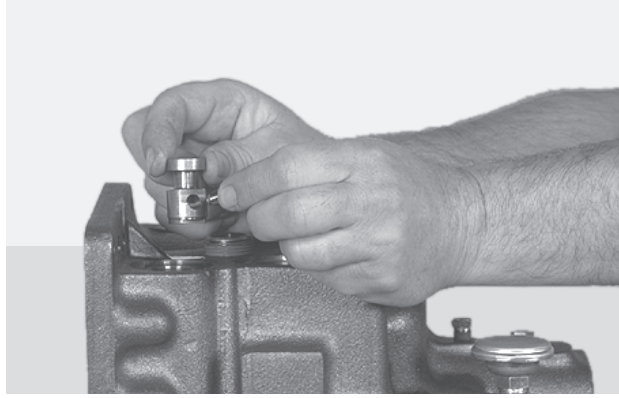
Remove modulator valve housing and "O"-ring.

**7**

Remove modulator valve outer, middle, and inner springs and spring stop.

**8**

Remove modulation housing sleeve and accumulator spool.



9

Remove shuttle sleeve and spool.

SINGLE MODULATED VALVE ASSEMBLY

DISASSEMBLY

**1**

Remove modulator valve body "O"-ring.

**2**

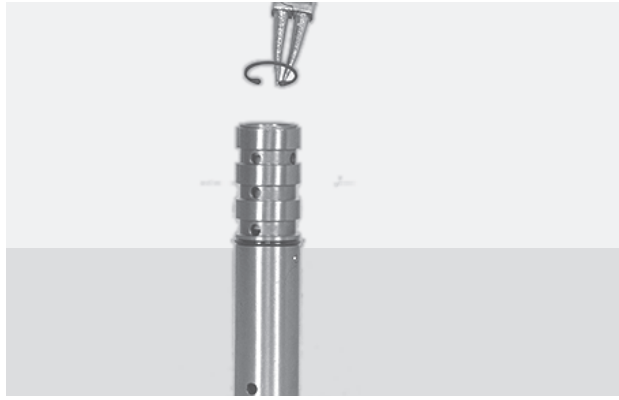
Remove modulator valve outer, middle and inner springs and spring stop.

**3**

Remove accumulator spool.

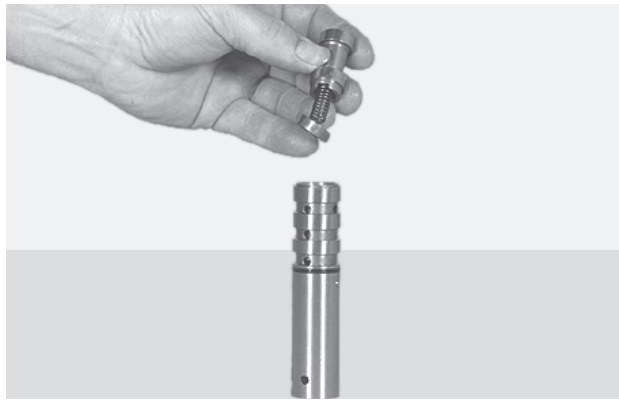
**4**

Remove modulator sleeve pin.



5

Remove regulator spool assembly retainer ring.



6

Remove regulator spool stop, spring and spring and sleeve assembly.



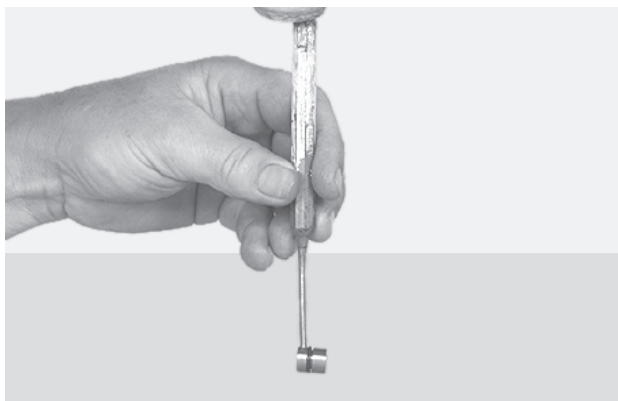
7

Remove regulator spool sleeve retainer ring.

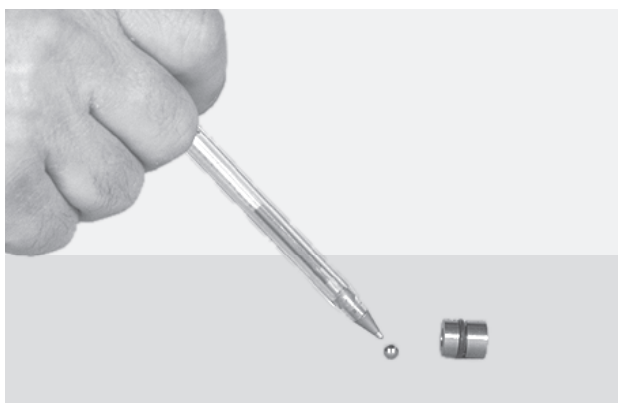


8

Remove regulator spool sleeve assembly. Remove "O"-ring.

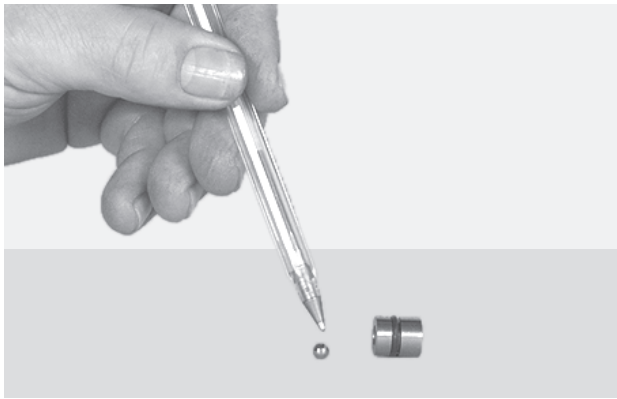
**9**

Remove sleeve check ball retainer pin.

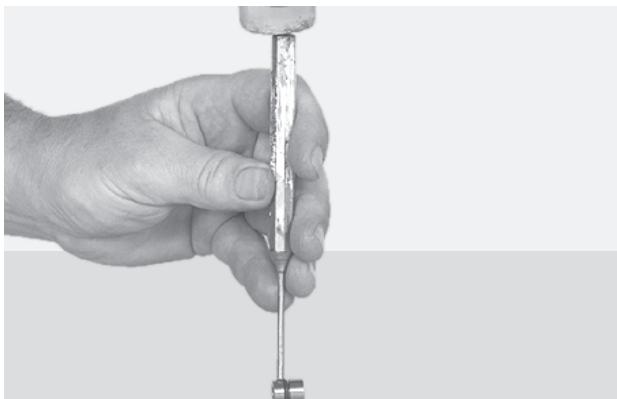
**10**

Remove check ball.

ASSEMBLY

**11**

Install a new "O"-ring on regulator spool sleeve. Position check ball in sleeve. Refer to the cleaning and inspection pages.

**12**

Install check ball retainer pin.

**13**

Position sleeve and ball assembly in regulator spool with check ball retainer pin up.

**14**

Install sleeve retainer ring.

**15**

Install housing sleeve pin.

**16**

Install regulator spool stop, spring and regulator spool and sleeve assembly in housing sleeve.

**17**

Compress regulator spool spring and install retainer ring.

**18**

Position new "O"-ring on modulation sleeve.

HYDRAULIC INCHING REMOVAL

DISASSEMBLY

**1**

Remove hydraulic inching cover.

**2**

Remove inching return spring.

**3**

Remove hydraulic inching upper piston.

**4**

Inching upper piston removed.

**5**

Remove hydraulic piston seal.

**6**

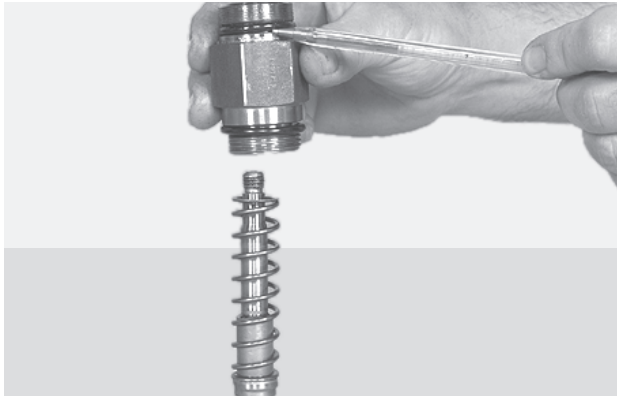
Remove inching lower piston and "O"-ring.

**7**

Remove snap ring.

**8**

Remove hydraulic inching body seal.



9

Remove hydraulic inching body and “O”-rings.



10

Remove inching return spring.

ASSEMBLY**11**

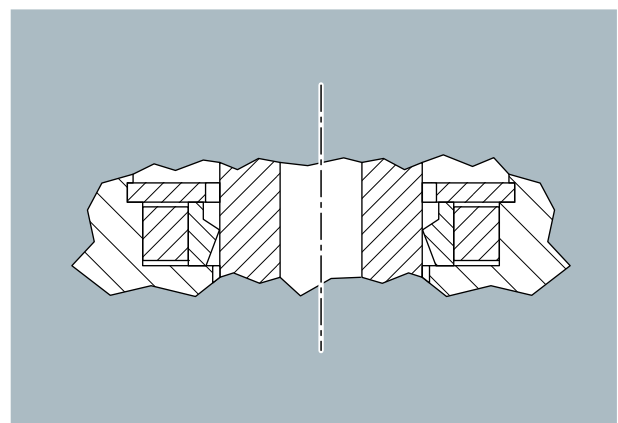
Install inching return spring. Refer to the cleaning and inspection pages.

**12**

Install hydraulic inching body and "O"-rings.

**13**

Install inching body seal. Be sure seal is mounted correctly. See figure below.

**14**

Cross section details.



15

Install snap ring.



16

Install inching lower piston and "O"-ring.



17

Install hydraulic piston seal



18

Apply Loctite nr. 243 to thread of inching actuator rod, install inching upper piston.

**19**

Install inching return spring.

**20**

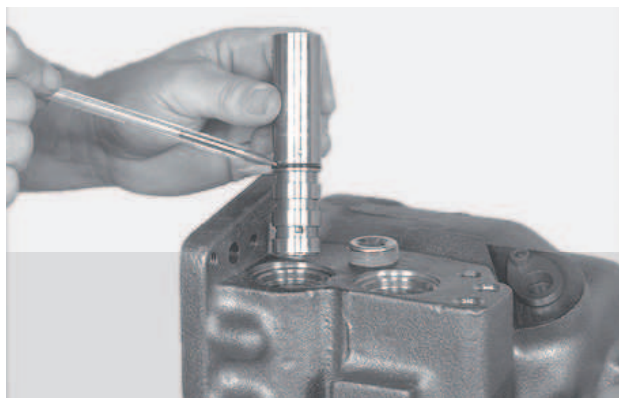
Install inching cover.

SINGLE MODULATION AND HYDRAULIC INCHING INSTALLATION



1

Position shuttle spool in shuttle sleeve. Install spool and sleeve in modulator valve bore. Refer to the cleaning and inspection at section CLEANING AND INSPECTION (pag. 2).



2

With new "O"-ring in position, install modulation housing sleeve assembly in bore.



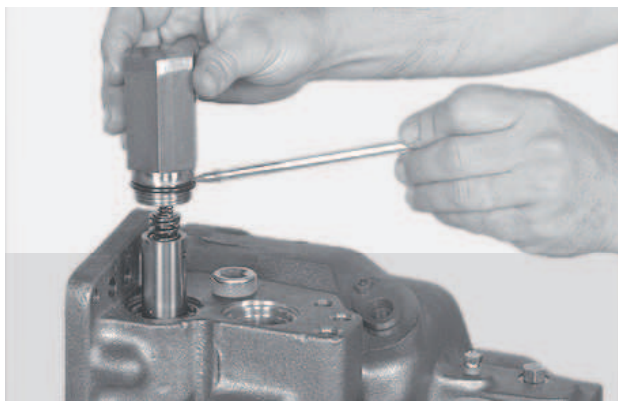
3

Install accumulator spool in housing sleeve as shown.



4

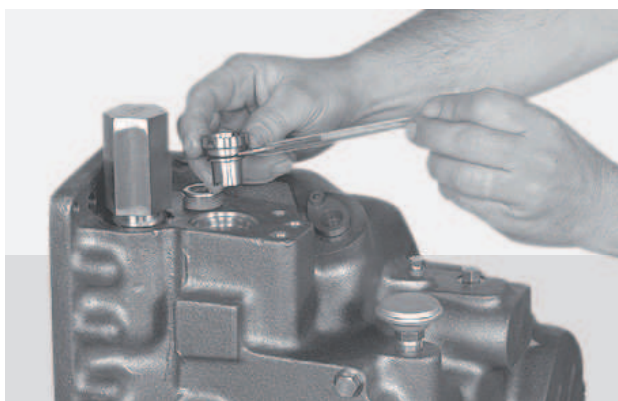
Install stop pin, inner, middle and outer springs in accumulator and housing sleeve.

**5**

Position a new "O"-ring on modulator valve housing. Thread housing into valve bore.

**6**

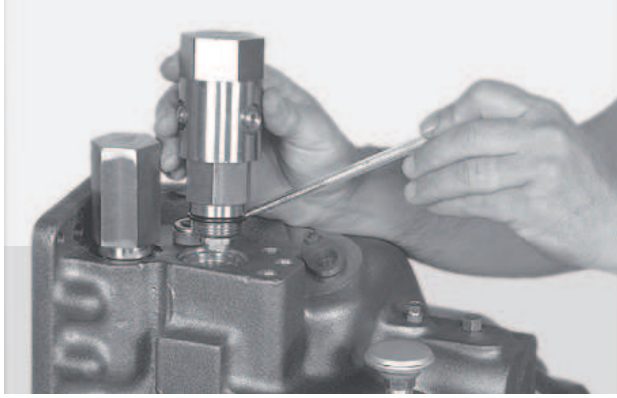
Tighten modulator valve housing to specified torque and tighten to 60-65 LBF-FT [81-88 N.m].

**7**

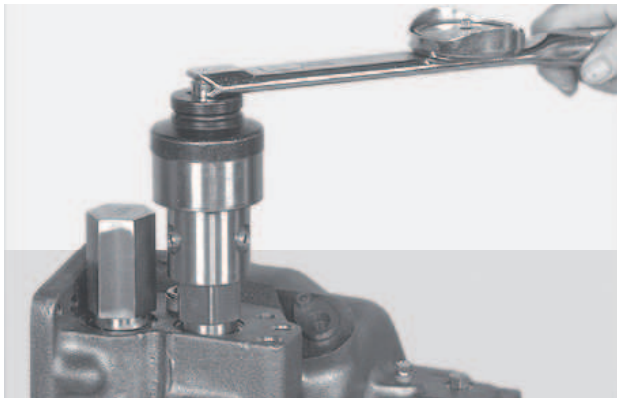
Install inching sleeve and "O"-ring.

**8**

Install inching spool and regulator spring.

**9**

Install hydraulic inching actuator and "O"-ring.

**10**

Tighten inching actuator to specified torque and tighten to 60-65 LBF-FT [81-88 N.m].

OPTIONS

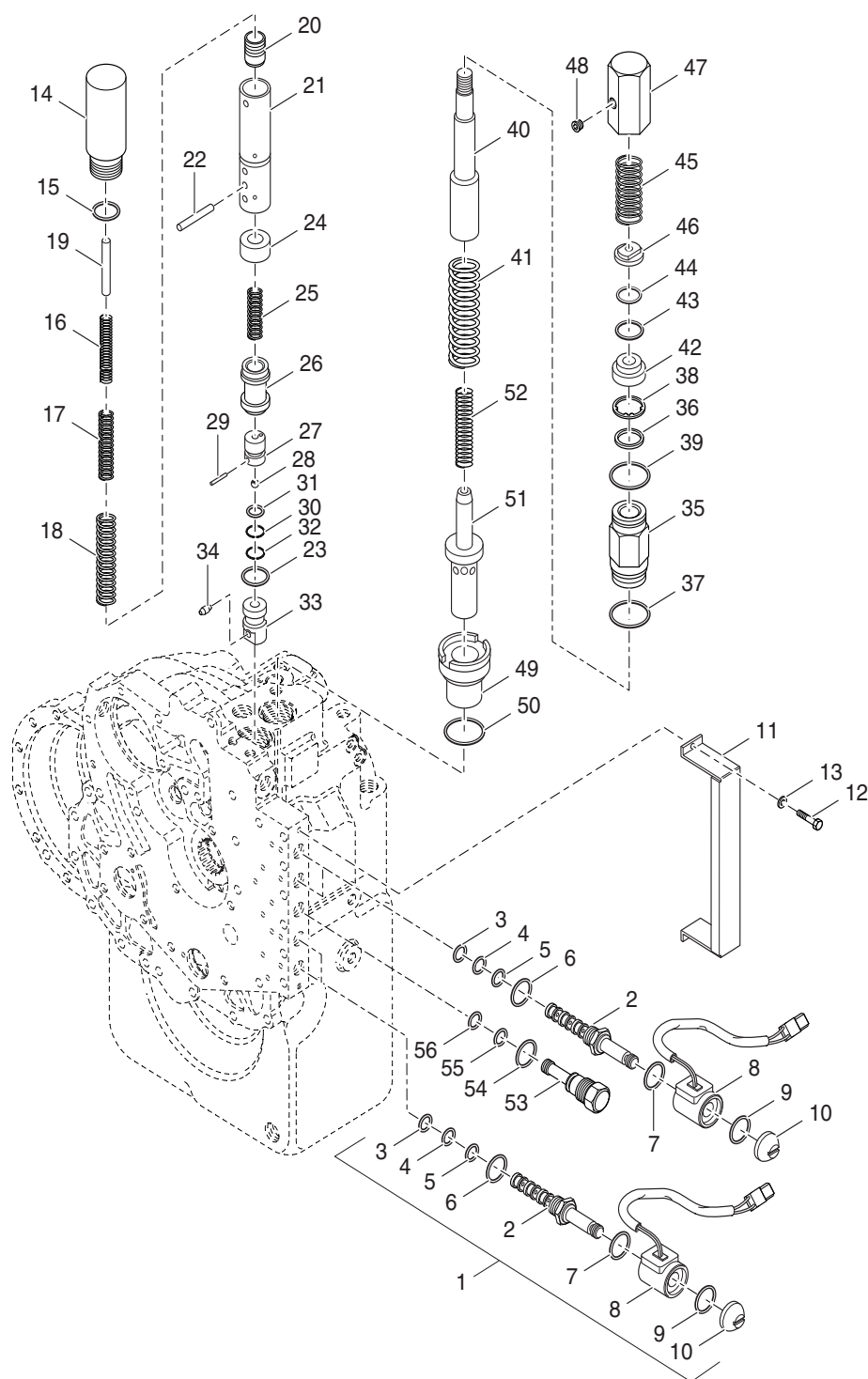
ELECTRIC CONTROL-SINGLE MODULATION HYDRAULIC ACTUATED INCHING

The information contained herein must be used in conjunction with a T12000 ID section.

SECTIONAL VIEWS AND PARTS IDENTIFICATION

Refer to following pages.

GROUP - ELECTRIC CONTROL- SINGLE MODULATION HYDRAULIC ACTUATED INCHING



GROUP - ELECTRIC CONTROL- SINGLE MODULATION HYDRAULIC ACTUATED INCHING

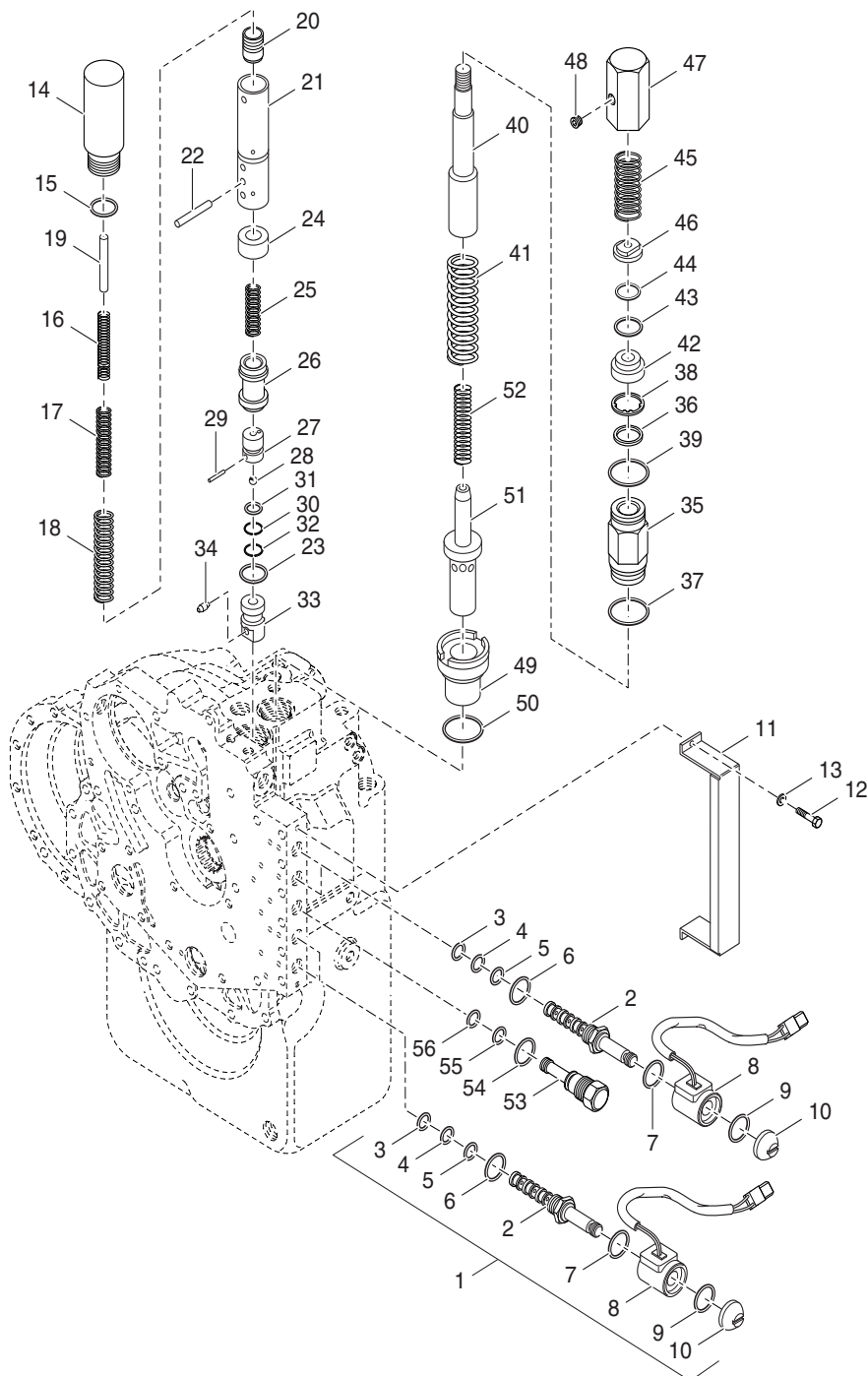
ITEM	DESCRIPTION	QUANTITY
1	Assembly - Solenoid cartridge	5*
2	Cartridge - Valve 4-way including items 3, 4, 5 and 6	5*
3	"O"-ring - Cartridge	5*
4	"O"-ring - Cartridge	5*
5	"O"-ring - Cartridge	5*
6	"O"-ring - Cartridge	5*
7	"O"-ring - Cartridge to coil	5*
8	Coil-Solenoid	5*
9	"O"-ring-Coil to nut	5*
10	Nut - Valve cartridge retainer	5*
11	Cover - Protective	1
12	Screw - Protective cover	2
13	Lockwasher - Protective cover screw	2
14	Housing - Modulation valve	1
15	"O"-ring - Modulation housing	1
16	Spring (Inner)	1
17	Spring (Middle)	1
18	Spring (Outer)	1
19	Pin-Stop	1
20	Spool - Accumulator	1
21	Sleeve - Modulation housing	1
22	Pin - Modulation sleeve	1
23	"O"-ring - Modulation sleeve	1
24	Stop - Regulator spool	1
25	Spring - Regulator spool	1
26	Regulator - Spool	1
27	Sleeve - Regulator	1
28	Ball	1
29	Pin - Regulator spool sleeve	1
30	Snap ring	1
31	"O"-ring - Regulator spool sleeve	1
32	Snap ring	1
33	Sleeve - Shuttle	1
34	Spool - Shuttle	1
35	Body - Hydraulic inching	1
36	Seal - Hydraulic inching body	1
37	"O"-ring - Hydraulic inching body to case	1
38	Snap ring - Hydraulic inching body to cover	1
39	"O"-ring - Hydraulic inching body to cover	1
40	Rod - Hydraulic inching actuator	1
41	Spring - Inching return	1

ITEM	DESCRIPTION	QUANTITY
42	Piston - Hydraulic inching (Lower)	1
43	Seal - Hydraulic inching piston	1
44	"O"-ring - Piston	1
45	Spring - Piston	1
46	Piston - Hydraulic inching (Upper)	1
47	Cover - Hydraulic inching	1
48	Plug - Hydraulic inching conver	3
49	Sleeve - Inching	1
50	"O"-ring - Inching sleeve	1

* quantity= 4, with 3-speed.

** used with 3-speed only.

GROUP - ELECTRIC CONTROL- SINGLE MODULATION HYDRAULIC ACTUATED INCHING



GROUP - ELECTRIC CONTROL- SINGLE MODULATION HYDRAULIC ACTUATED INCHING

ITEM	DESCRIPTION	QUANTITY
50	"O"-ring - Inching sleeve	1
51	Spool - Inching	1
52	Spring - Inching regulator	1
53	Plug - Solenoid bore plug, used at forward-High and Low	1**
54	"O"-ring - Plug	1**
55	"O"-ring - Plug	1**
56	"O"-ring - Plug	1**

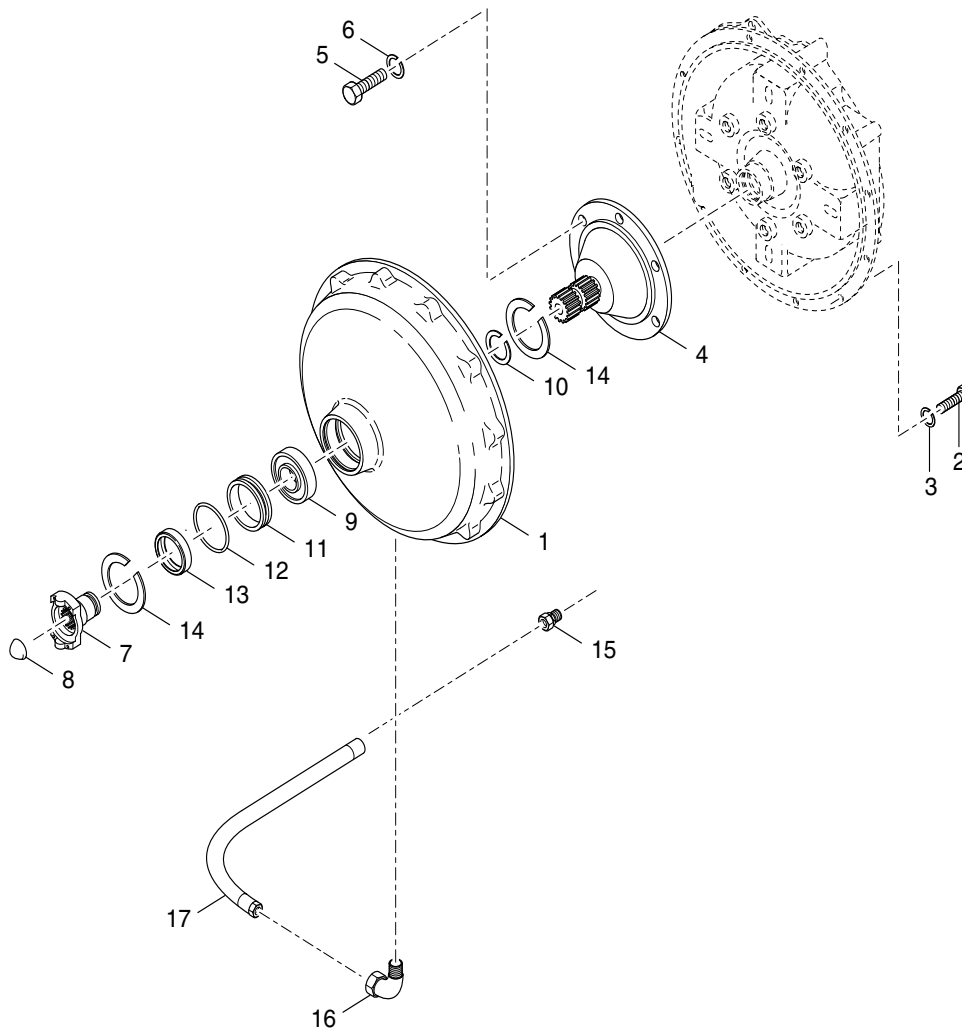
MT SECTION

The information contained herein must be used in conjunction with a T12000 ID section. The MT model is the midship mounted T12000 series transmission with an integral convertor unit.

SECTIONAL VIEWS AND PARTS IDENTIFICATION

ASSEMBLY INSTRUCTIONS

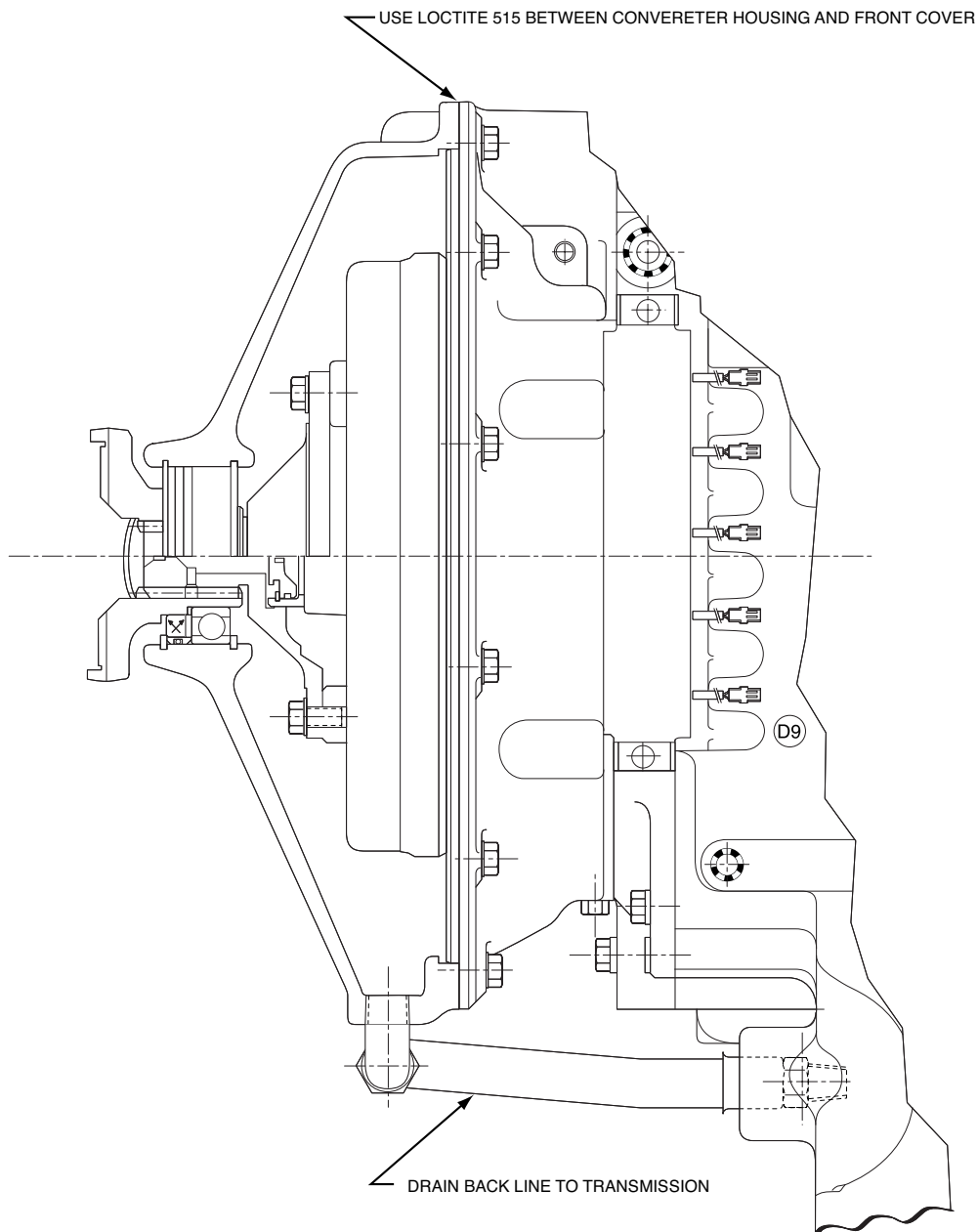
GROUP - FRONT COVER & INPUT DRIVE

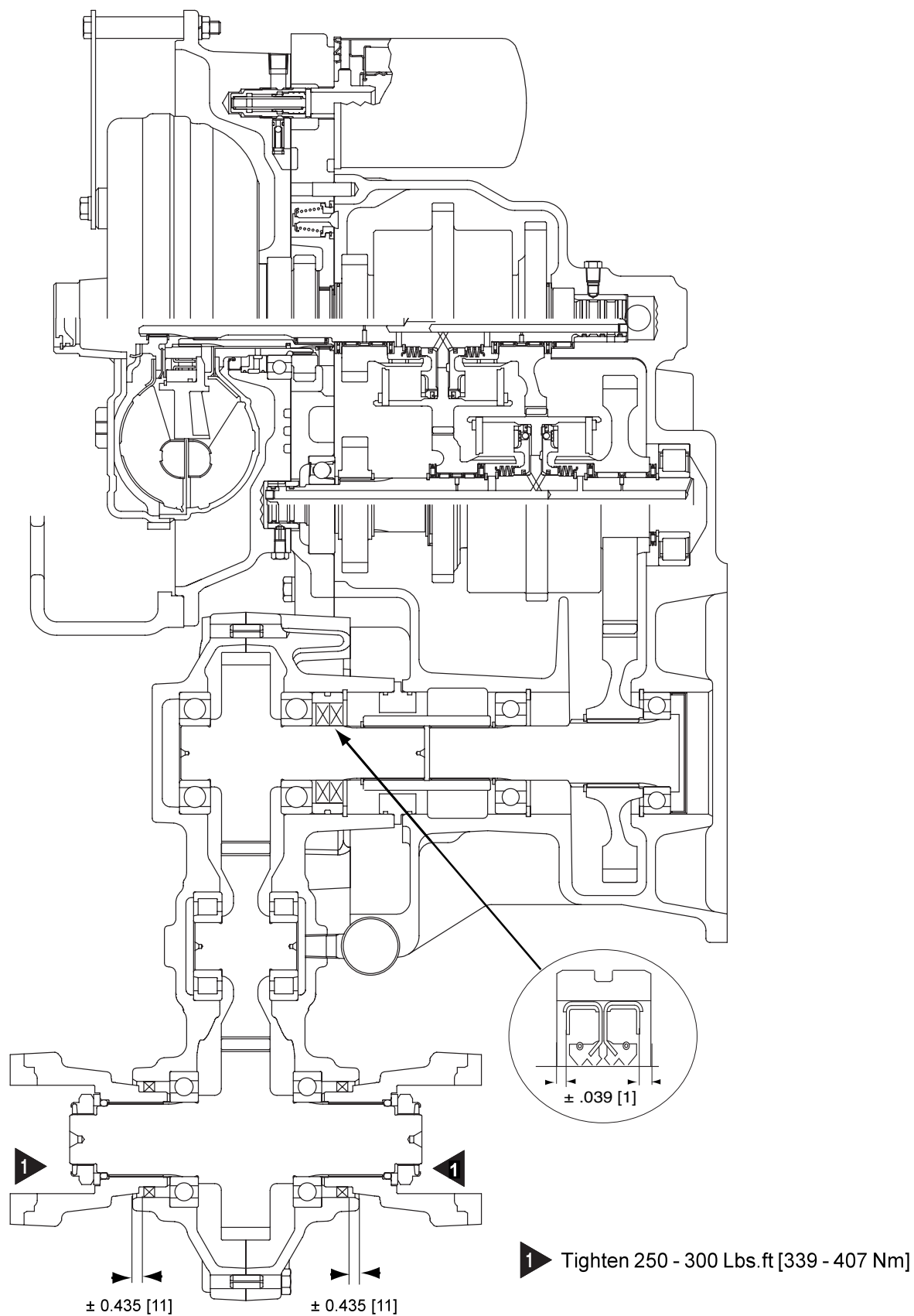


GROUP - FRONT COVER & INPUT DRIVE

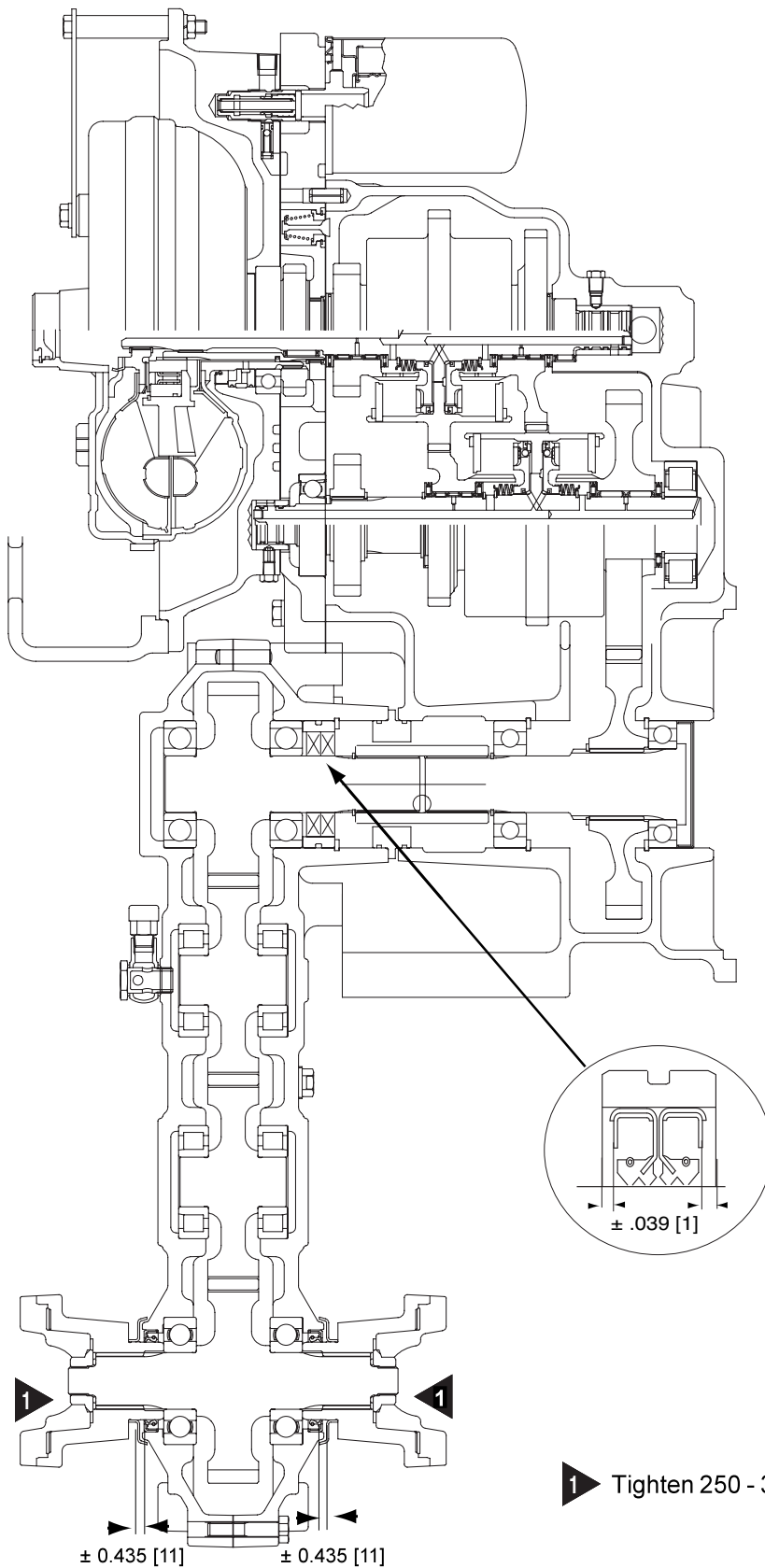
ITEM	DESCRIPTION	QUANTITY
1	Cover - Front	1
2	Screw - Front cover to converter housing	12
3	Lockwasher - Front cover to converter housing	12
4	Shaft - Input Drive	1
5	Screw - Input drive shaft to torque converter	6
6	Lockwasher - Input drive shaft to torque converter	6
7	Flange - Input	1
8	Plug - Flange	1
9	Bearing - Input shaft	1
10	Snap ring - Flang retainer	1
11	Sleeve - Oil seal	1
12	"O"-ring - Oil seal sleeve	1
13	Seal - Input shaft oil	1
14	Snap ring - Input Shaft Bearing	2
15	Fitting	1
16	Fitting	1
17	Tube - Drain	1

MT CROSS SECTION AND ASSEMBLY INSTRUCTIONS



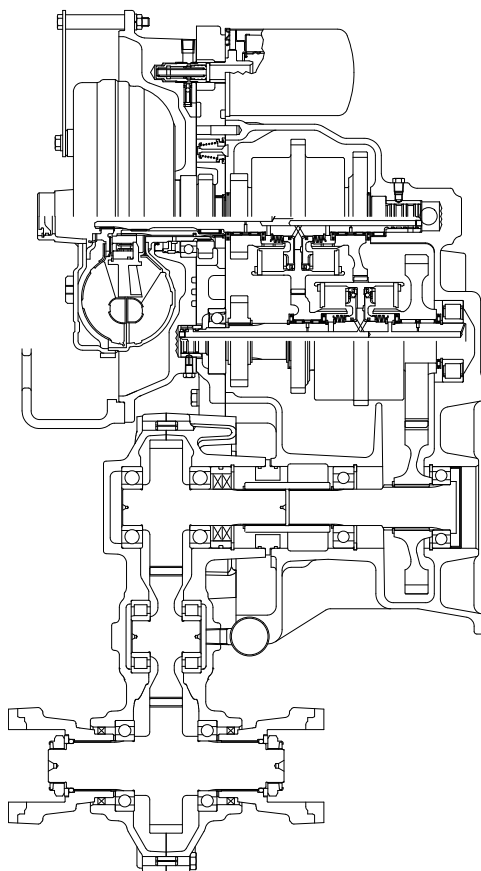
VDT 12000**3 SHAFT DROP BOX**

4 SHAFT DROP BOX

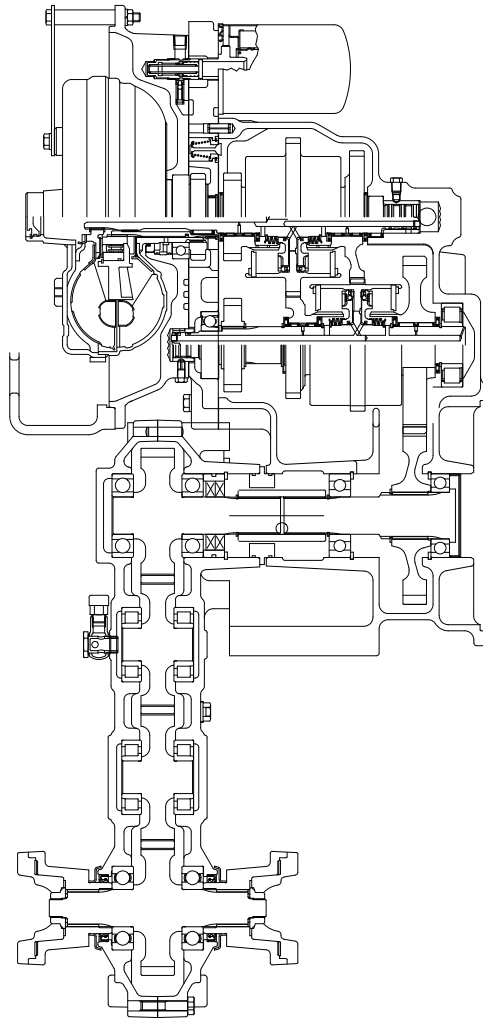


1 Tighten 250 - 300 Lbs.ft [339 - 407 Nm]

3 SHAFT

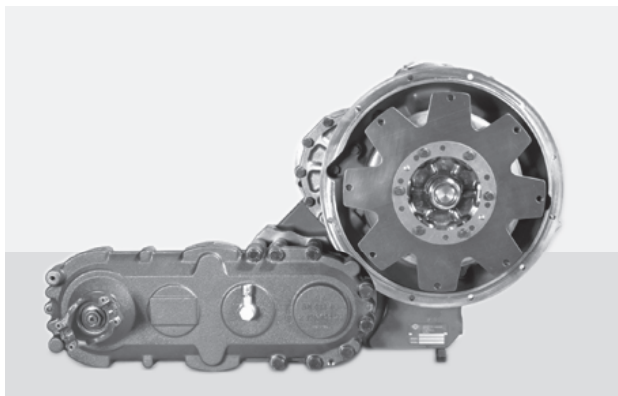


4 SHAFT

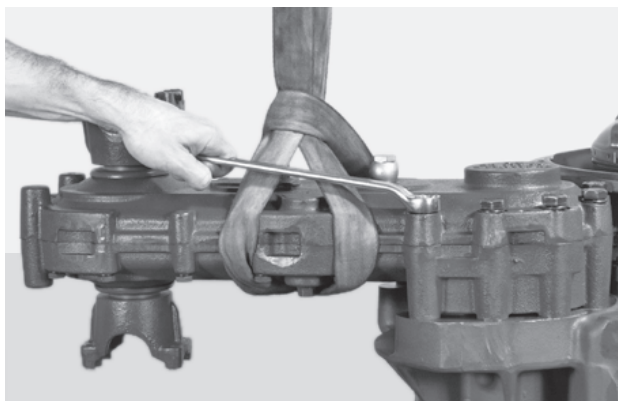


4° SHAFT DROP BOX

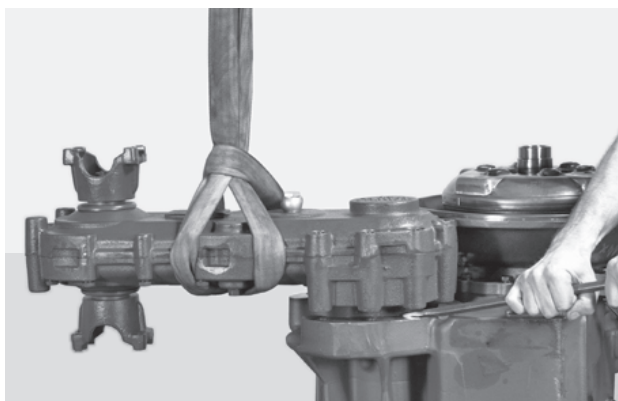
DISASSEMBLY

**1**

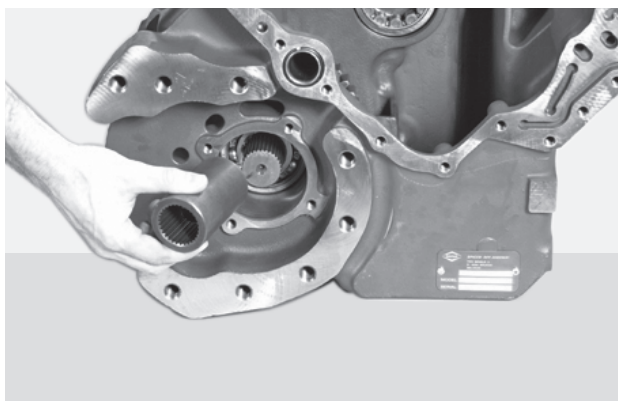
Front view of 4 shaft drop box.

**2**

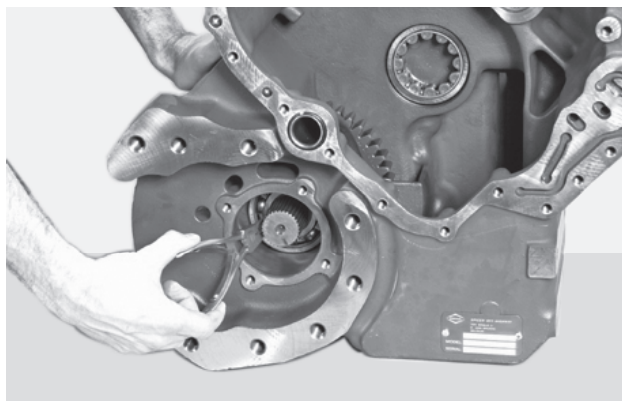
Support box with chain hoist. Remove drop box mounting screws and lockwashers.

**3**

Pry box from transmission housing.

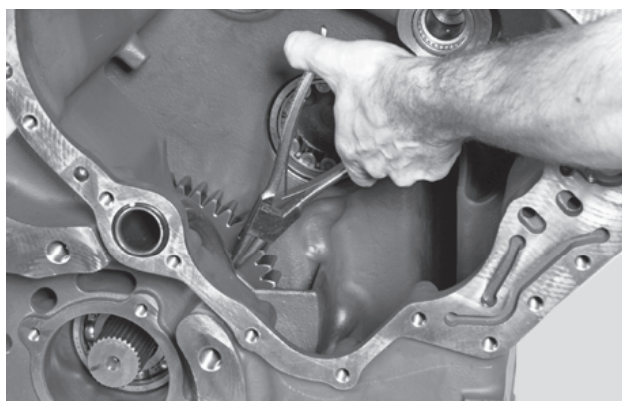
**4**

Remove coupling sleeve.



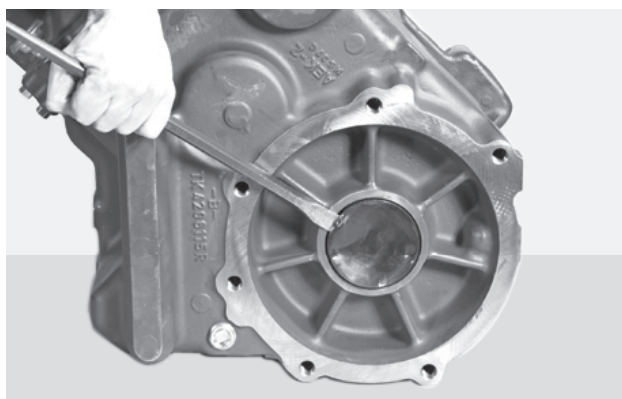
5

Remove output shaft front bearing retaining ring.



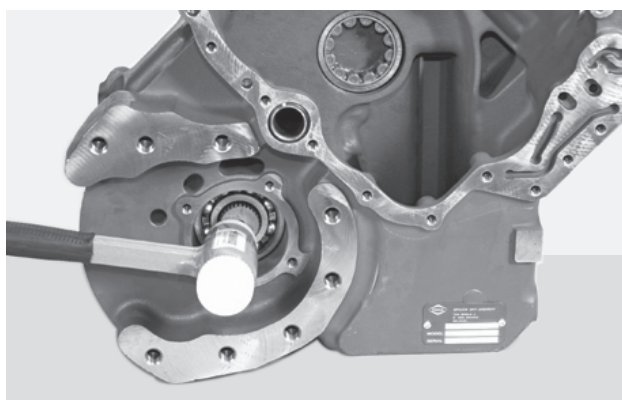
6

Remove output gear retaining ring.



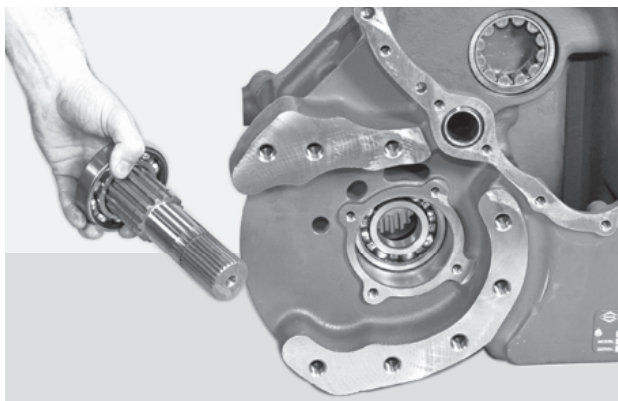
7

From the rear, remove output shaft bore plug.



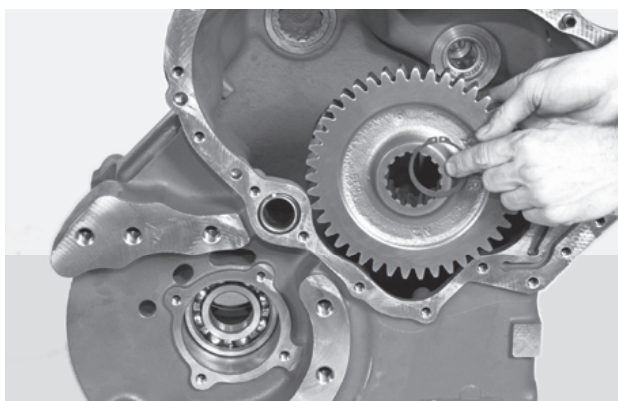
8

From the front tap output shaft and rear bearing from housing.



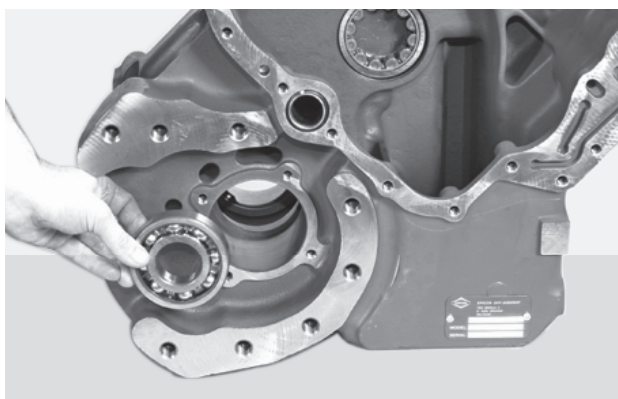
9

Output shaft and rear bearing removed.



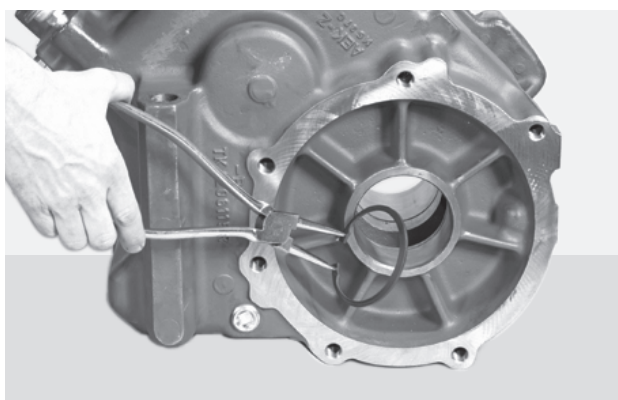
10

Remove output shaft gear and retaining ring.



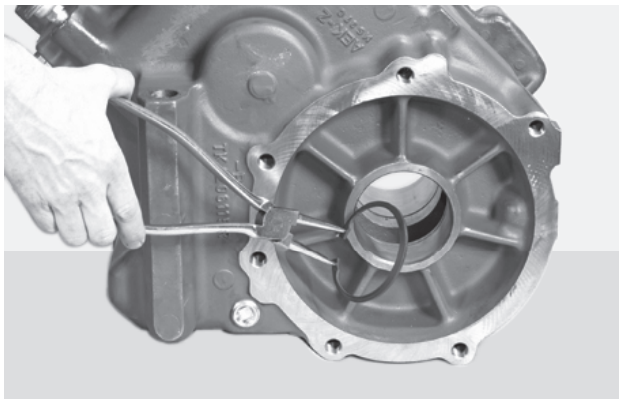
11

Remove output shaft front bearing.

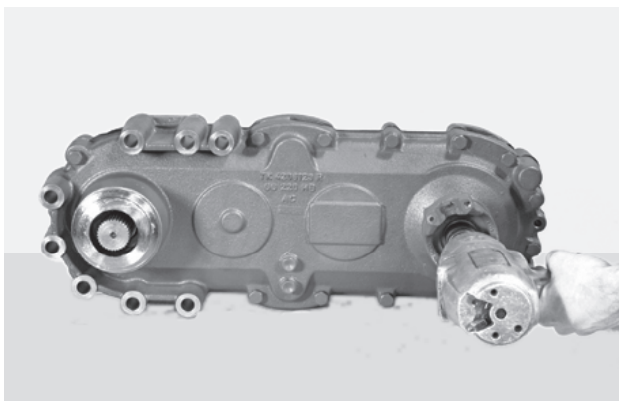


12

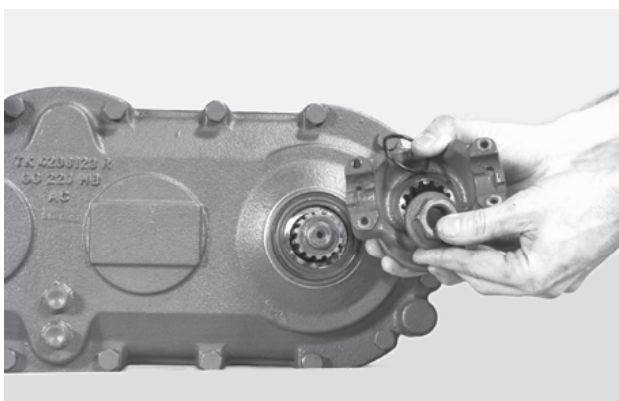
Remove output shaft front bearing retaining ring.


13

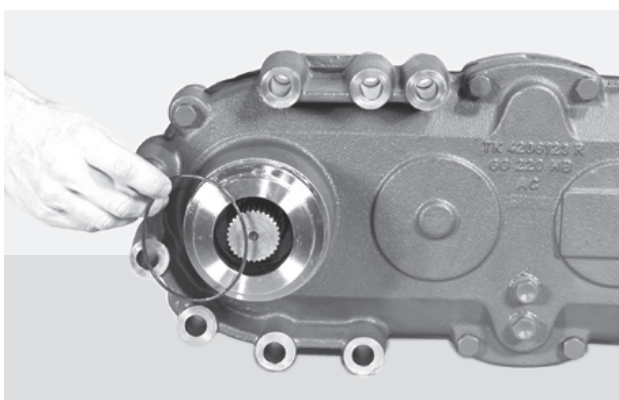
From the rear, remove rear bearing retaining ring.


14

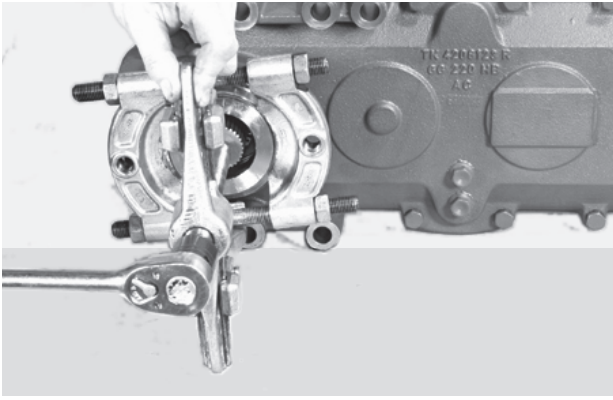
Use an impact wrench to loosen flange nut.


15

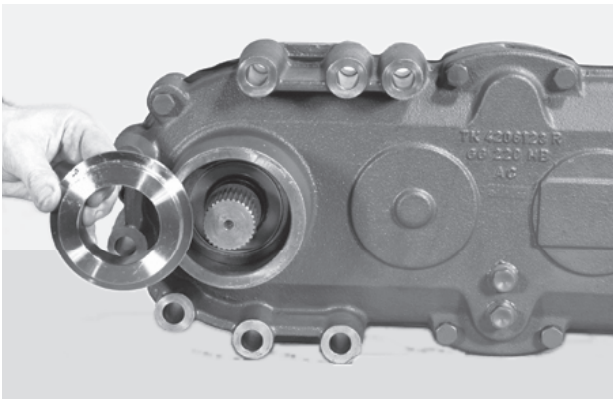
Output flange (rear) "O" ring, washer and nut removed.


16

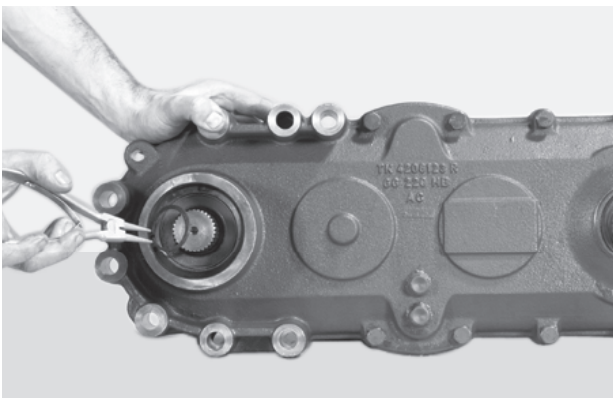
Remove sleeve outer "O" ring.

**17**

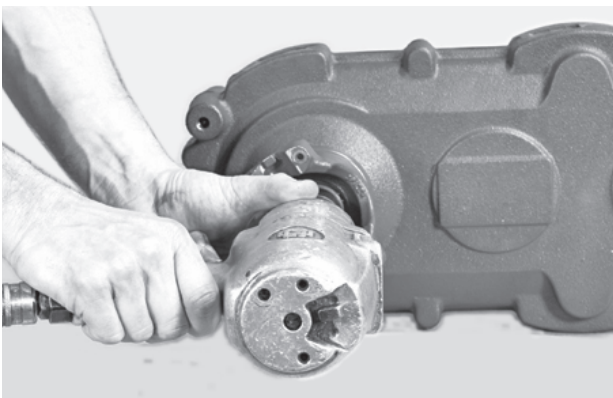
Use a gear puller to remove pilot sleeve.

**18**

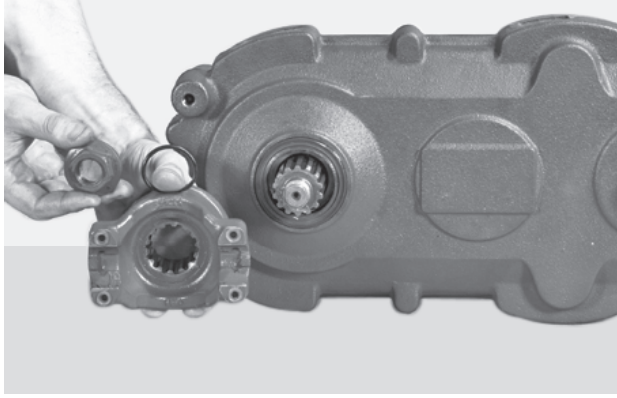
Pilot sleeve and inner "O" ring removed.

**19**

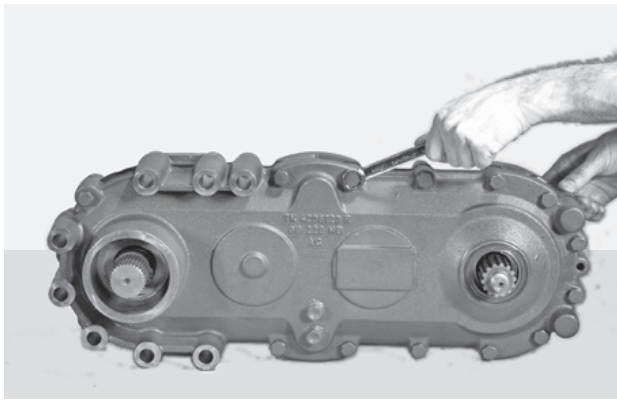
Remove coupling sleeve retaining ring.

**20**

Use an impact wrench to loosen flange nut.


21

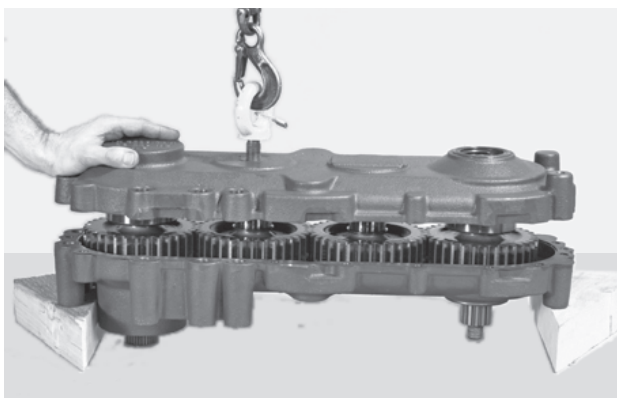
Output flange (front) "O" ring, washer and nut removed.


22

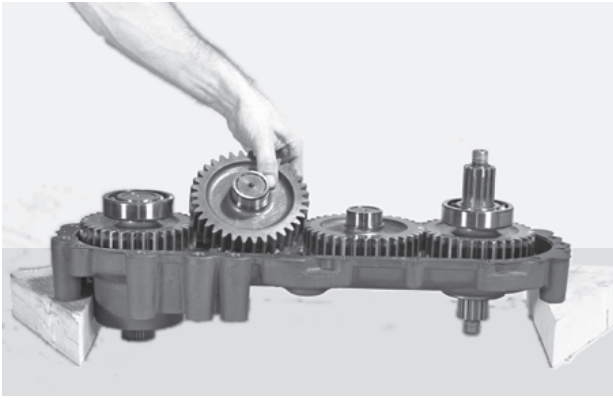
Remove front to rear cover screws and lockwashers.


23

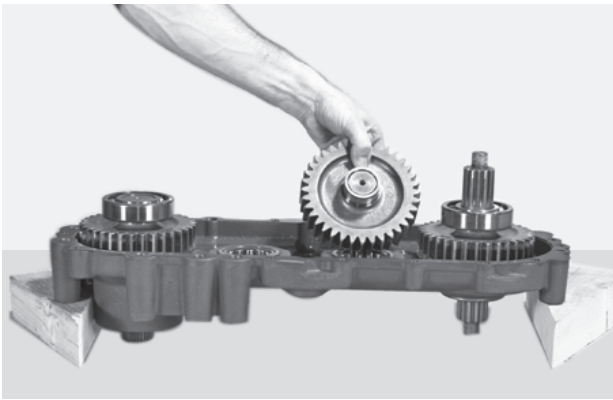
Support front cover with a chain hoist. Pry front cover from rear cover.


24

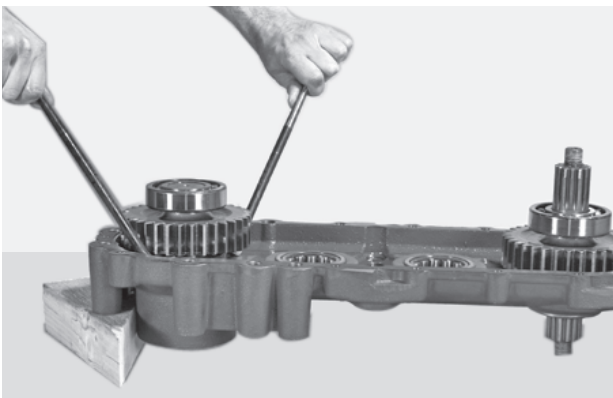
Front cover removed.

**25**

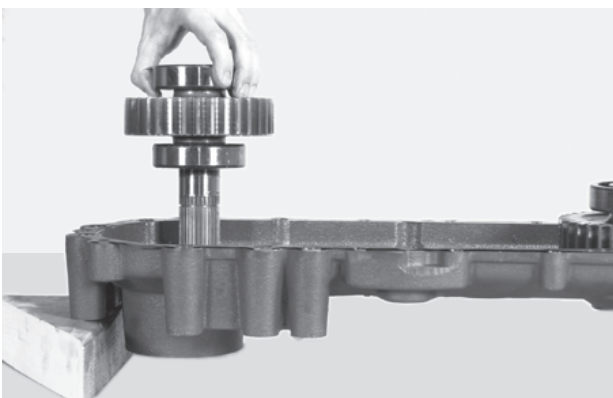
Remove idler shaft and gear.

**26**

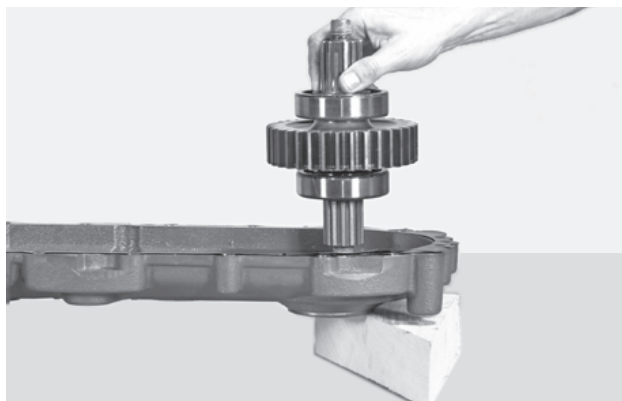
Remove idler shaft and gear.

**27**

Pry input assembly from cover.

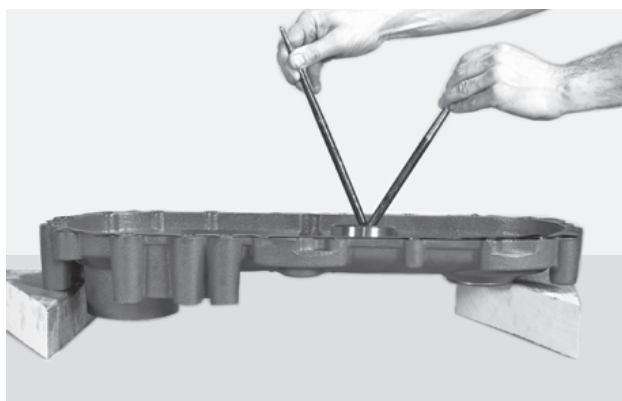
**28**

Input shaft assembly removed.



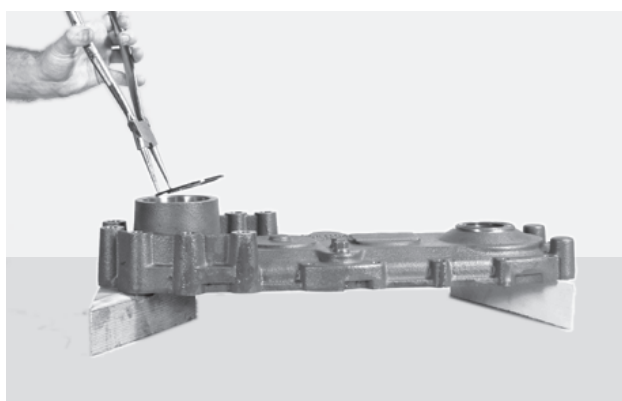
29

Output shaft assembly removed.



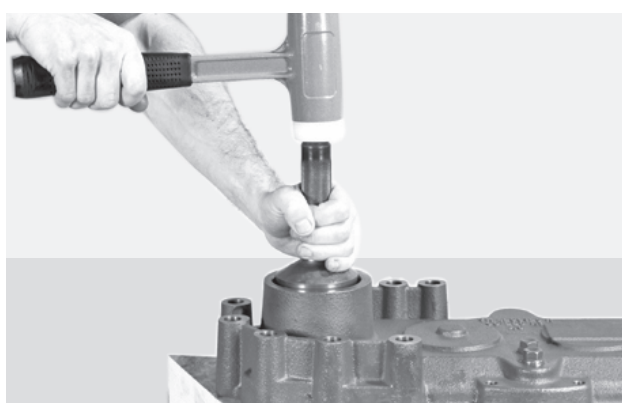
30

If bearing outer races have to be replaced, remove outer races.



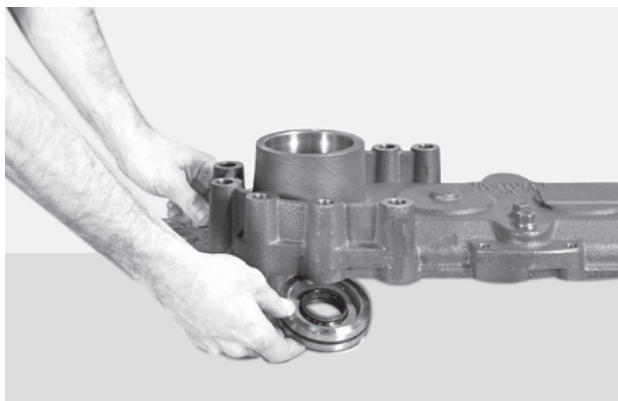
31

Remove seal sleeve retaining ring.



32

Tap seal sleeve from cover.

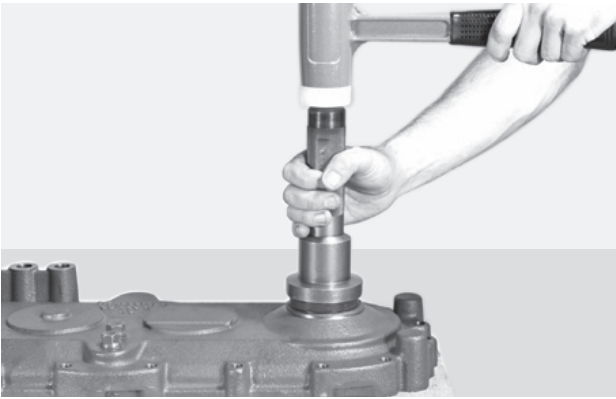
**33**

Seal sleeve removed.

ASSEMBLY


34

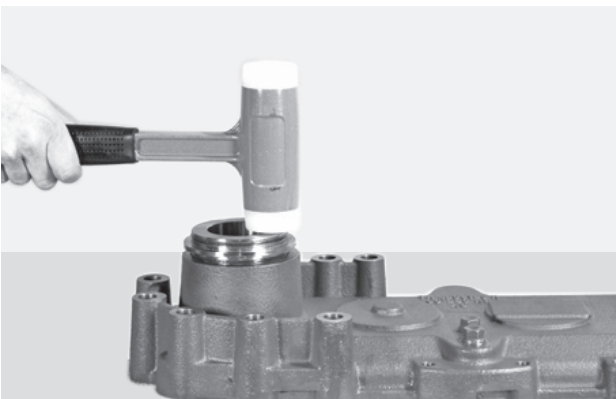
Install two new oil seals in the seal sleeve. See details at section T12000 INSTALLATION DETAILS (pag. 69).


35

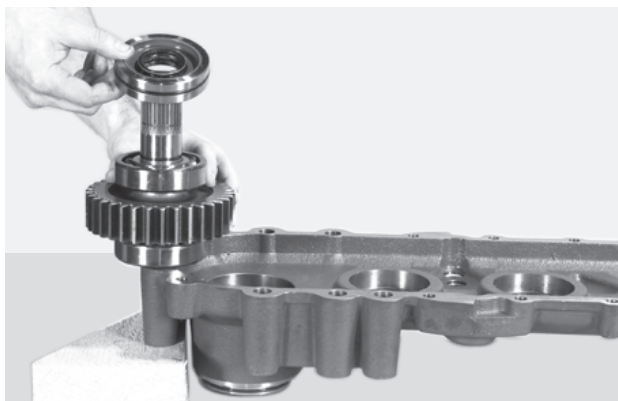
Install two new output shaft oil seals in front and rear cover. See details at section T12000 INSTALLATION DETAILS (pag. 69).


36

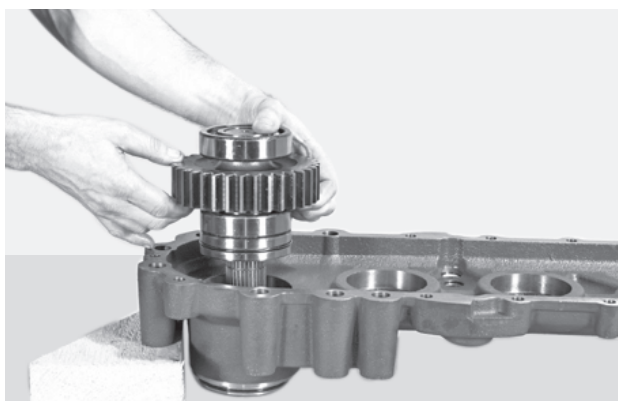
Install seal sleeve retaining ring.


37

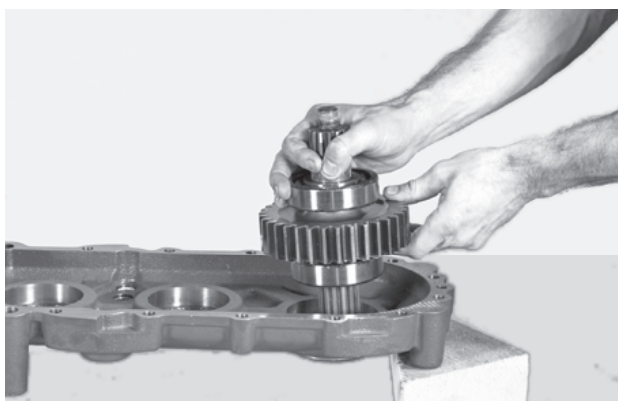
With new "O" rings installed. Tap center sleeve into position.

**38**

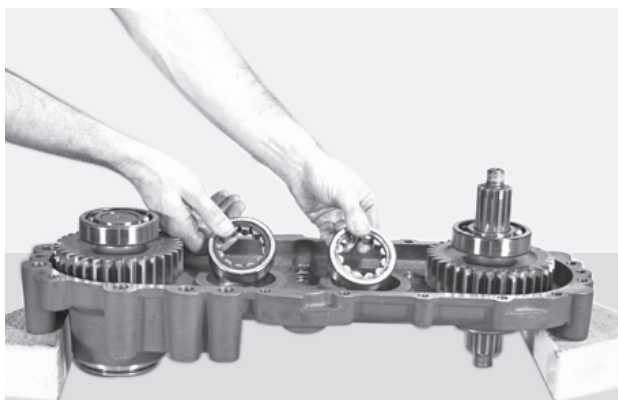
With new "O" ring installed. Install seal sleeve.

**39**

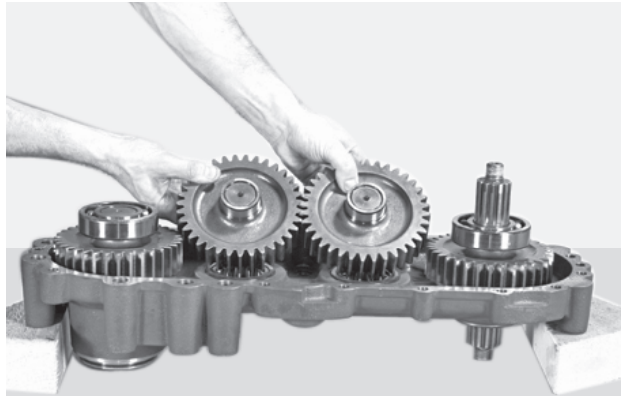
Install input shaft into rear cover. Use caution as not to damage oil seals.

**40**

Install output shaft into rear cover. Use caution as not to damage oil seal.

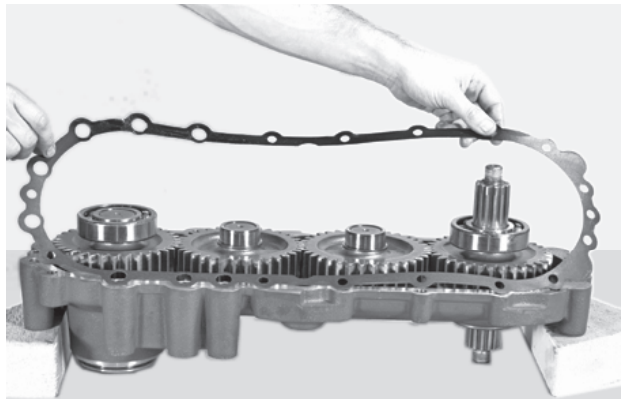
**41**

If bearing outer races have been removed, install bearing outer races.



42

Install idler shafts and gears.



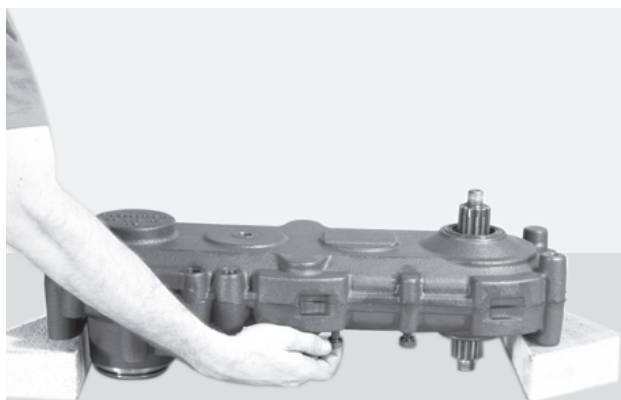
43

Position new gasket on rear cover.



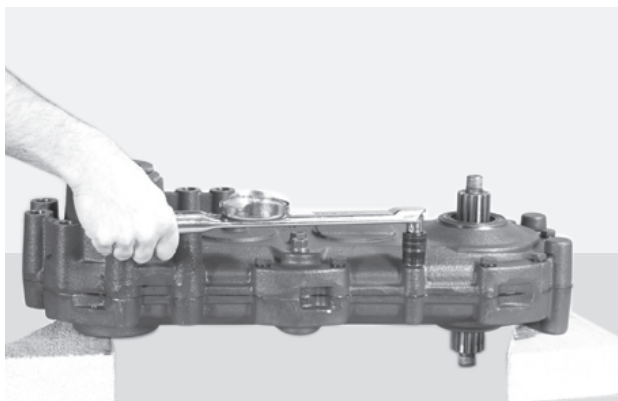
44

Position drop box front cover on rear cover. Use caution as not to damage oil seal.

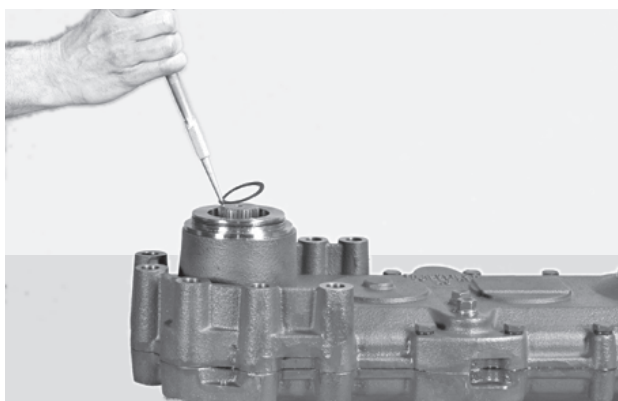


45

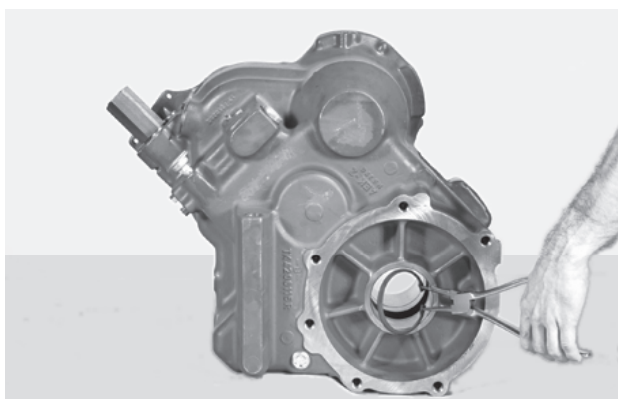
Install capscrews and lockwashers.

**46**

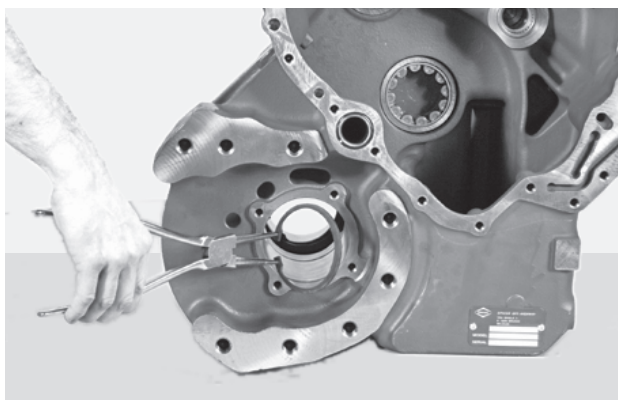
Tighten screws to specified torque. (See torque chart).

**47**

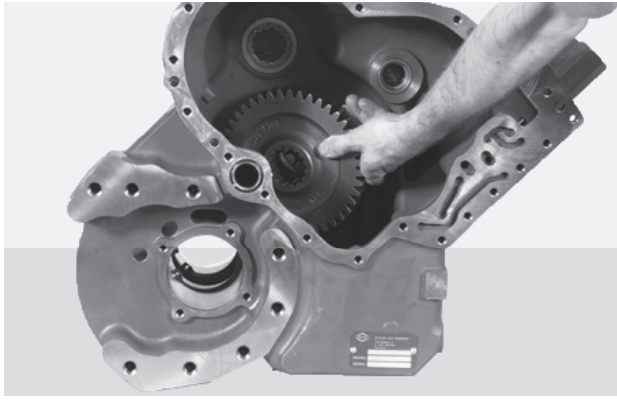
Install coupling sleeve retaining ring.

**48**

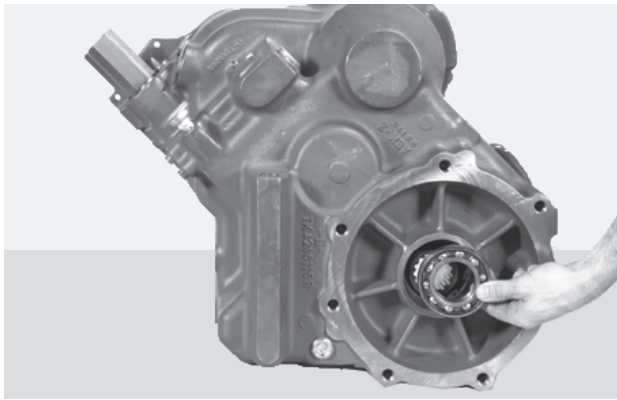
Install output shaft rear bearing locating ring.

**49**

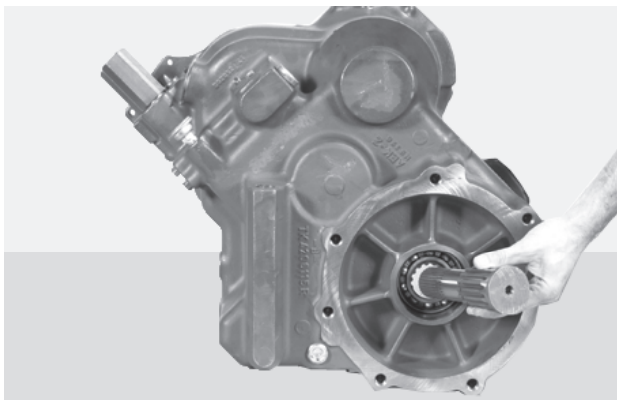
Install output shaft front bearing locating ring.


50

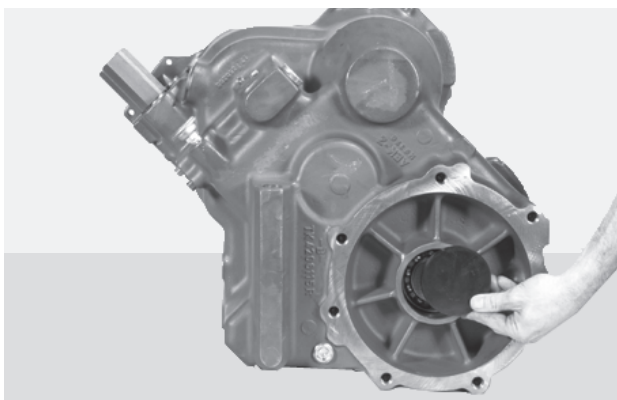
From the front of transmission case, position output gear with long hub of gear towards the front.


51

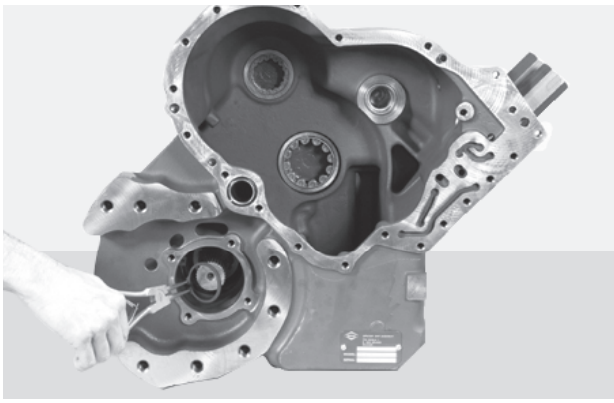
Install output shaft rear bearing in case against locating ring.


52

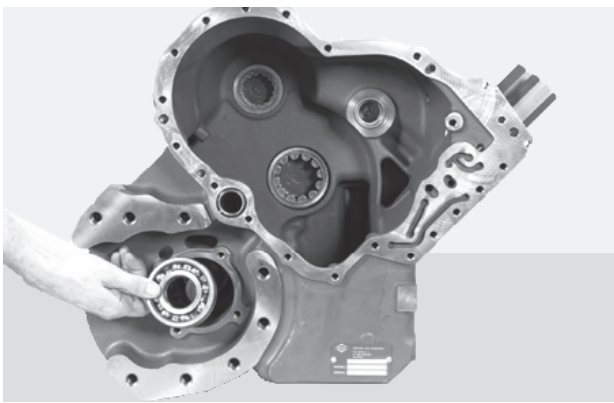
Position output shaft. Align splines on shaft with splines in output gear. Tap shaft into position.


53

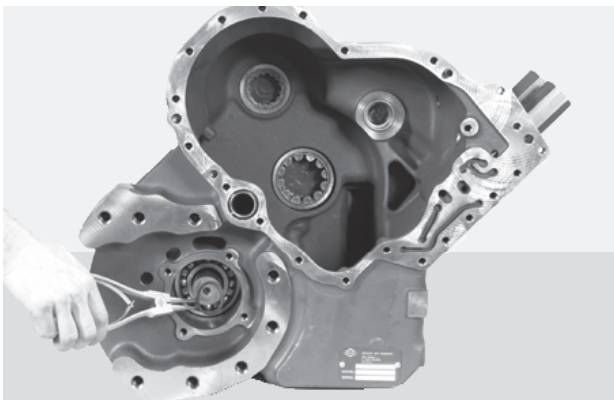
Install new bore plug.

**54**

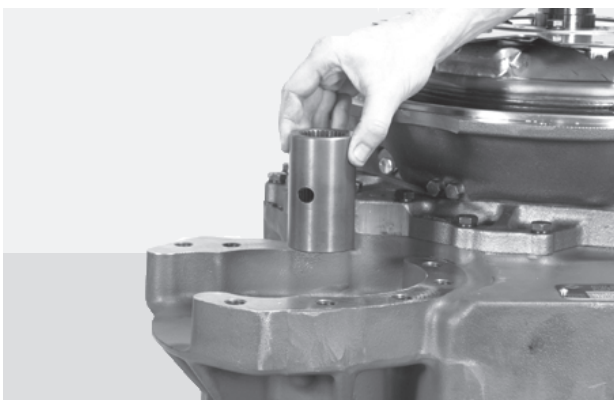
Install output shaft gear retaining ring.

**55**

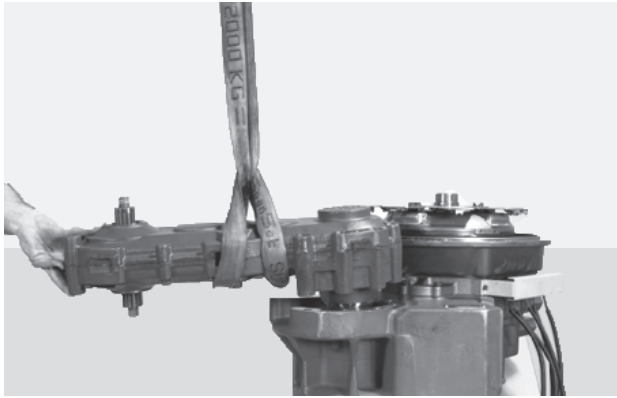
Install output shaft front bearing in case against locating ring.

**56**

Install front bearing retaining ring.

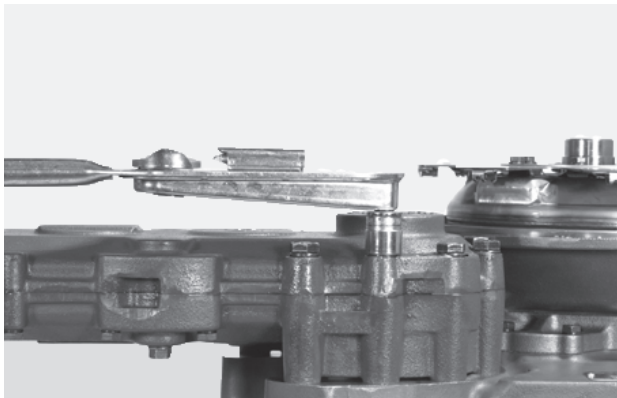
**57**

Install coupling sleeve.



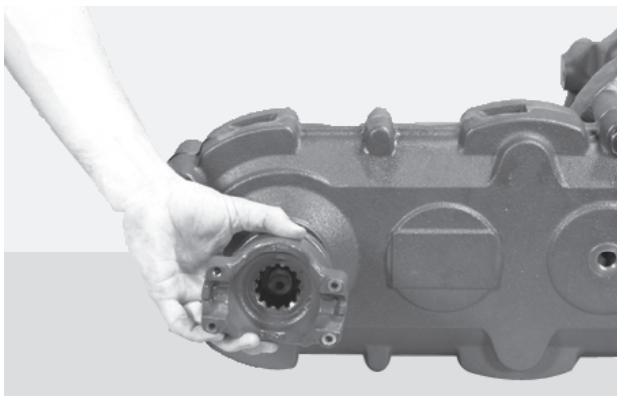
58

Install drop box assembly.



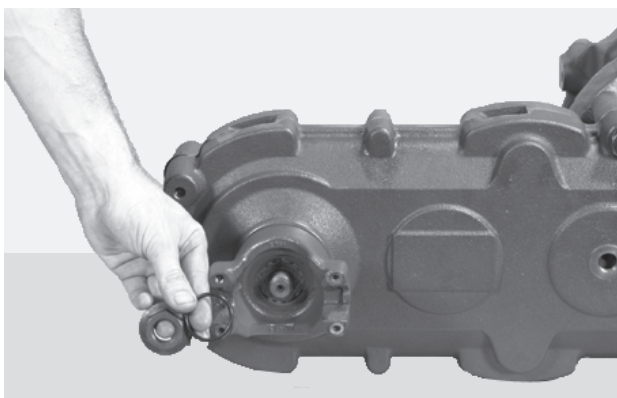
59

Install drop box mounting screws and lockwashers. Tighten to specified torque. (See torque chart).



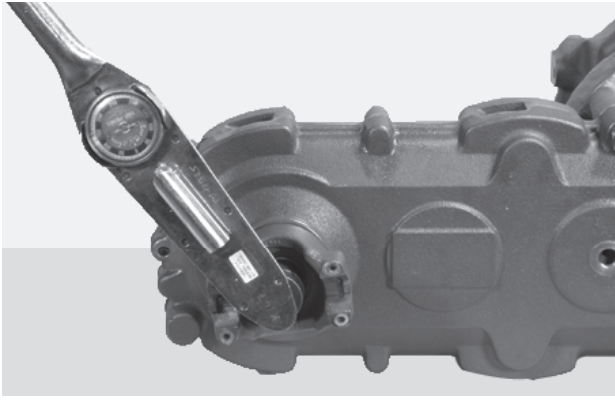
60

Install front and rear output flanges.

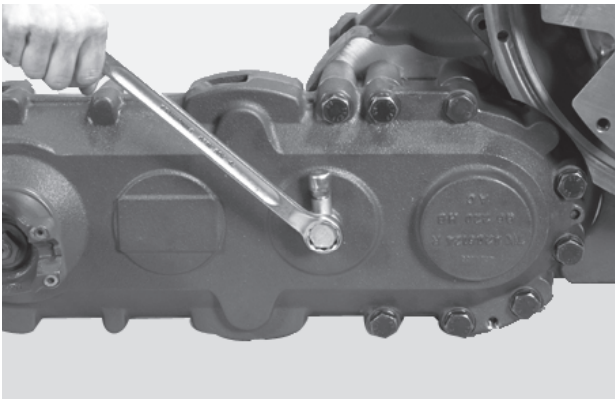


61

Install flange "O" rings, washers and nuts

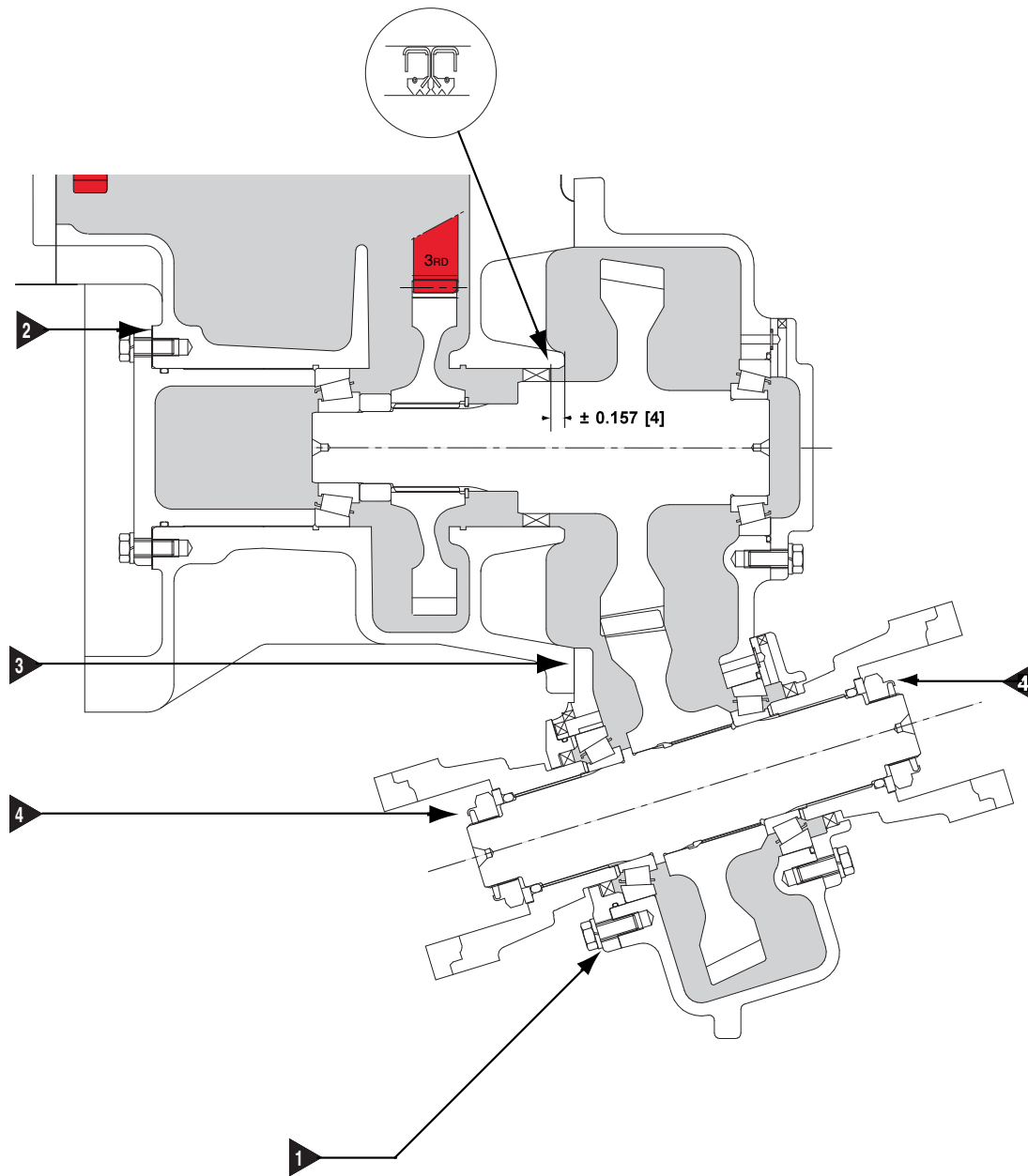
**62**

Block flanges to prevent turning. Tighten flange nuts to specified torque. See assembly instructions page 7-4.

**63**

Install breather.

VDT 17 DEGREES



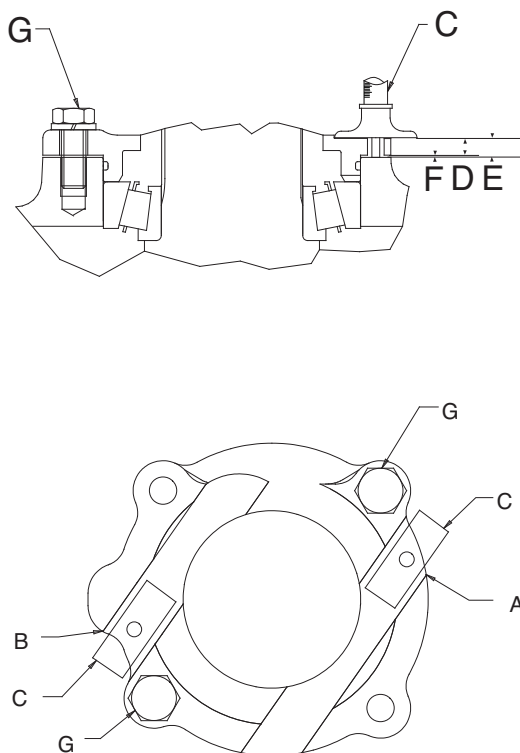
GENERAL BEARING INSTALLATION PROCEDURE

If a thermal assembly aid is used (expand by heating to $135^{\circ}\text{C} \pm 14^{\circ}\text{C}$ [$275^{\circ}\text{F} \pm 25^{\circ}\text{F}$]).

A check must be made after mating parts have reached ambient temperature (within 11°C [20°F]), to be sure bearings are positioned against their respective shoulders before bearing adjustment can start.

This check must be made when installing the front and rear bearings on the drop box output shaft.

TAPER BEARING ADJUSTMENT



Before bearing adjustment can be made, make sure rear bearing cap and output shaft are installed as explained in the assembly section of the service manual.

Place the drop box in a horizontal position with the front output side upwards. Remove temporarily installed bearing cap.

The bearing adjustment must be made without the bearing cap "O" ring.

Measure the thickness of the bearing cap "D" with a micrometer at location "A" and "B". (Remove paint prior to measurement if necessary).

Add the two dimensions together and divide by 2 to obtain an average thickness and record.

EXAMPLE

- "A" 6.990 mm
- "B" 7.000 mm
- $13.990 \text{ mm} \div 2 = \text{"D"} 6.995 \text{ mm}$ average thickness

Lubricate taper bearing OD and bearing cap bore. Be sure the bearing cap "slip-fits" in the bearing bore.

Install bearing cap on drop box using all four (4) bolts.

Tighten bolts in a cross sequence 9.5 - 13.6 Nm [7 - 10 lbs.ft].

Using a mechanical advantage (a socket and extension on the output flange nut) to rotate output shaft and allow taper bearing to seat.

After seating the bearing remove two (2) bolts 180° apart (remove the two (2) bolts which are NOT next to the machined surfaces (see drawing for reference).

Loosen the two (2) remaining bolts "G" until they are finger-tight.

Using a micrometer depth gauge "C" set firmly against machined surfaces "A" and "B", using a calibrated metric or equivalent lbs.in torque wrench, tighten the two (2) remaining bolts in 1.13 Nm [10 lbs.in] increments, from 0.56 Nm [5 lbs.in] through 5.65 Nm [50 lbs.in].

Rotate the output shaft while tightening the bolts. Measure "A" and "B" at each 0.56 Nm [5 lbs.in] increment.

The difference between dimension "A" and "B" must not exceed 0.127 mm [0.005"].

If variation is greather than 0.127 mm [0.005"] occurs, start seating procedure over; beginning at bearing installation procedure.

Plot on the bearing record chart the average measurement of "A" and "B" at each 0.56 Nm [5 lbs.in] increments.

Draw a "best fit" straight line through the data points plotted on the record chart. The gap value where the line crosses "Zero" torque minus the average of previously recorded "A" and "B" is the "no endplay,no preload" shim gap.

(Example only) 17° Drop Box

From this gap, deduct 0.025 ± 0.025 [0.001 \pm 0.001 inch] to equal final shim gap.

Establish the shim pack, using a micrometer, measure each shim to obtain the total shim pack compliment.

Measure the total shim pack to check if it equals exactly the sum of each shim.

If the pack complement does not equal the total sum then repeat the shim pack selection process from the beginning.

After proper taper bearing adjustment is made,remove bearing cap and install new "O" ring on the bearing cap.

Install bearing cap with proper shim pack.

Install bolts and lockwashers and tighten bolts to specified torque (see torque chart).

Rotate output shaft to seat bearings and recheck bolt torque.

SHIM GAP (Example shown)

SHIM GAP DIMENSION "E" taken at "A" & "B" location divided by two (2) for average dimension Inch - Pounds

SHIM GAP (EXAMPLE SHOWN)			
		SHIM GAP "E" taken at "A" & "B" location divided by two (2) for average dimension	
Nm	Inch	mm	Inch
0,56	5	7,442	0,2930
1,13	10	7,430	0,2925
1,7	15	7,409	0,2917
2,27	20	7,396	0,2912
2,84	25	7,379	0,2905
3,41	30	7,366	0,2900
3,98	35	7,356	0,2896
4,55	40	7,338	0,2889
5,12	45	7,320	0,2882
5,69	50	7,305	0,2876

The example below shows the "Best fit" straight line through the data points, where the line crosses zero, is 7,457 mm [0.2936"].

Subtract the average "A" and "B" dimension 6,995 mm [0.2754"] "D". This is 0.462 mm [0.0182"] "F" shim gap. No preload, no endplay.

From this "F" shim gap, deduct $0,025 \pm 0,025$ mm [0.001 \pm 0.001"].

Thus the final shim pack becomes 0,462 - 0,412 mm [0.0182 - 0.0162"] (Example only).

EXAMPLE

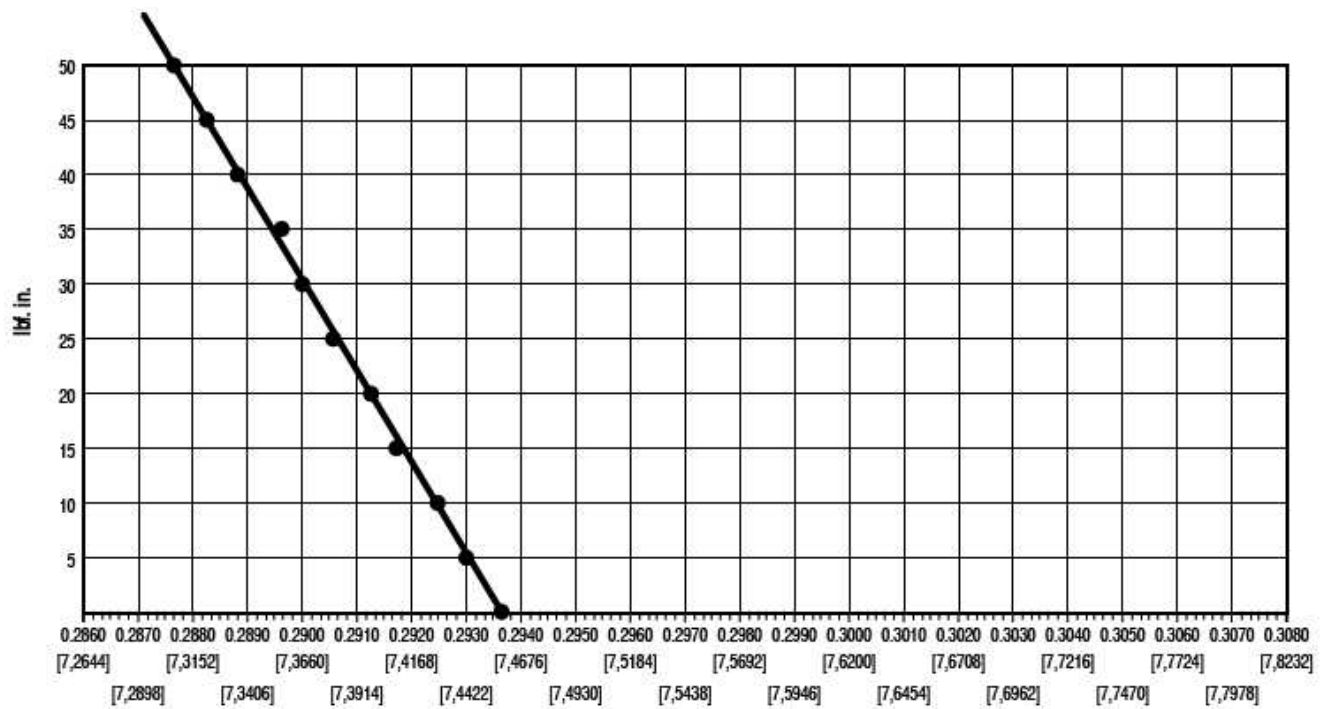
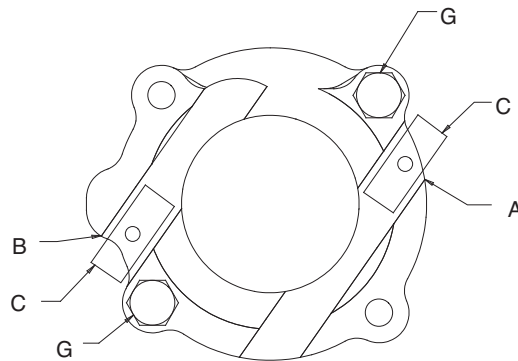
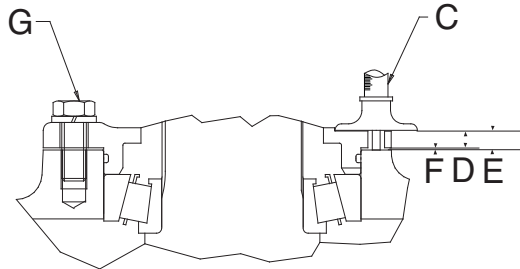


Fig. 8 SHIM GAP in INCHES (mm)

INPUT SHAFT TAPER BEARING ADJUSTMENT

- 1 For adjustment of the input shaft taper bearing, use exactly the same procedure, except use one measurement on the installed bearing cap instead of two.
- 2 Coat transmission housing to drop box housing surface with Loctite® 5205.
- 3 Tighten 250 - 300 lbs.ft [389 - 407 Nm].

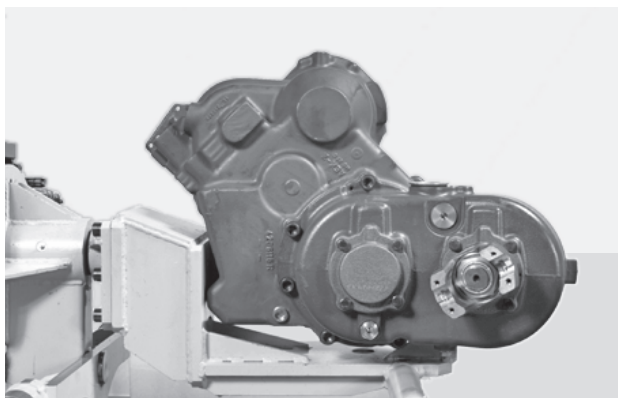


17° DROP BOX

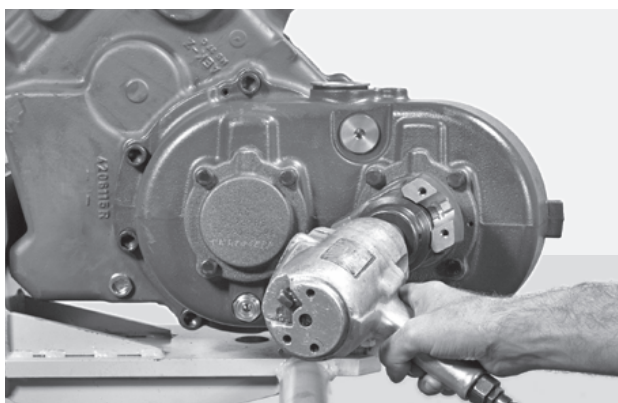


CAUTION: THE GEARS OF THE 17° DROP BOX ARE A MATCHED SET. THEY ARE ONLY AVAILABLE AS A SET. IN CASE A GEAR NEEDS TO BE REPLACED, REPLACE BOTH GEARS AT THE SAME TIME. DO NOT MIX SETS.

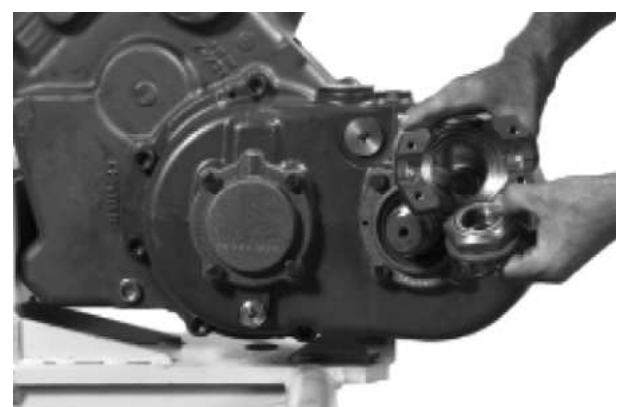
DISASSEMBLY

**1**

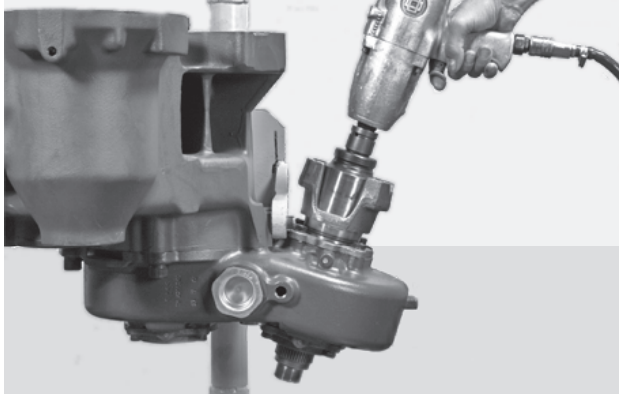
Rear view of 17° Drop Box.

**2**

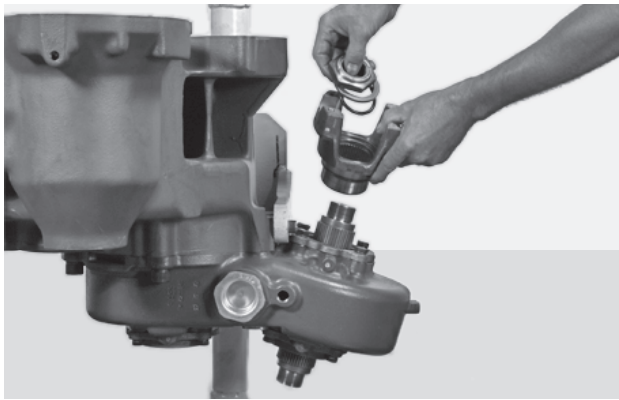
Use an impact wrench to loosen output flange nut (rear).

**3**

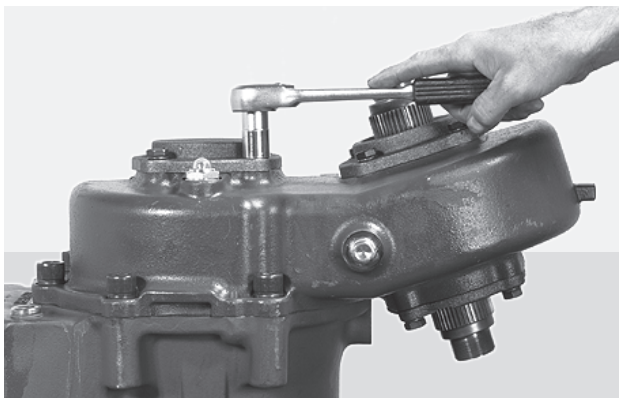
Output flange (rear) "O" ring, washer and nut removed.

**4**

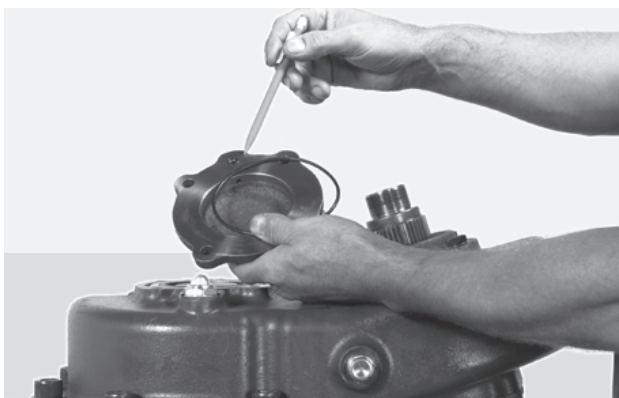
Use an impact wrench to loosen output flange nut (front).

**5**

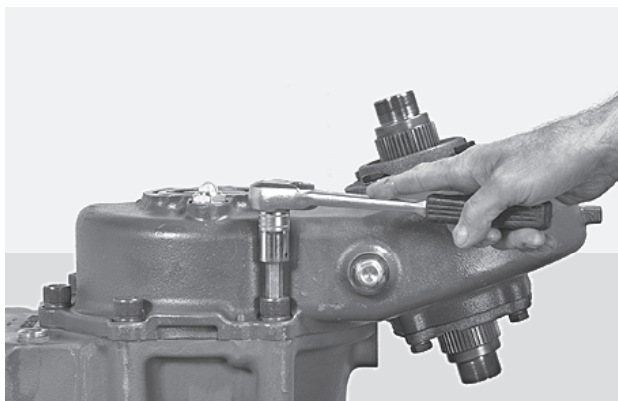
Output flange (front) "O" ring, washer and nut removed.

**6**

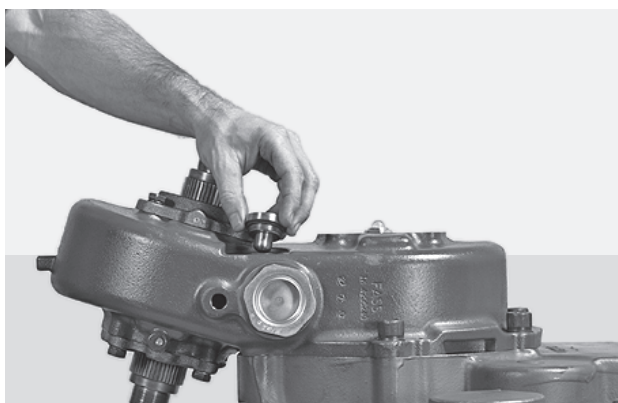
Remove input shaft rear bearing cap mounting screws.

**7**

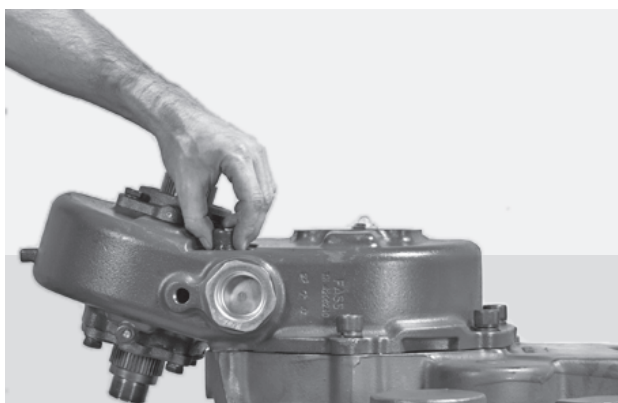
Rear bearing cap and "O" rings removed.

**8**

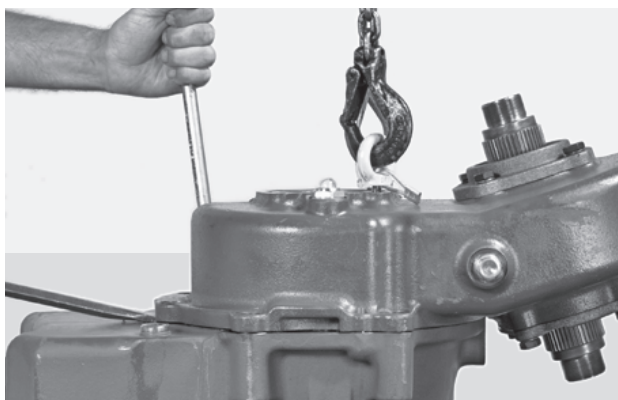
Remove drop box mounting screws and lockwashers (5).

**9**

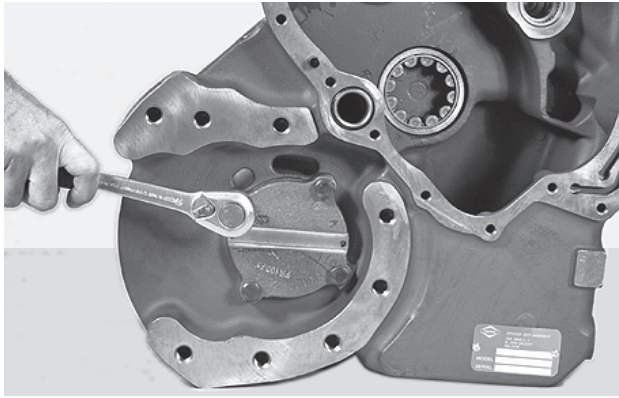
Remove mounting screw hole plug.

**10**

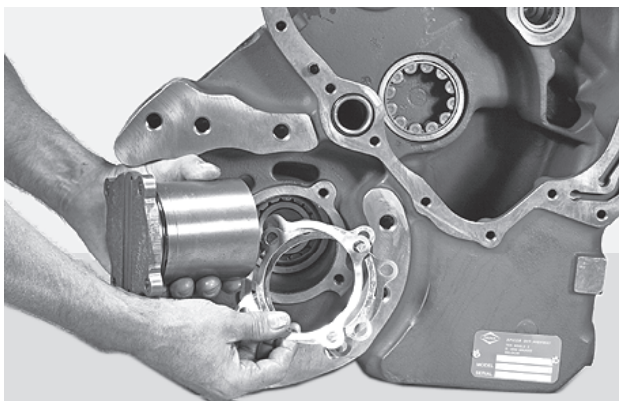
Remove mounting screw and lockwasher (1).

**11**

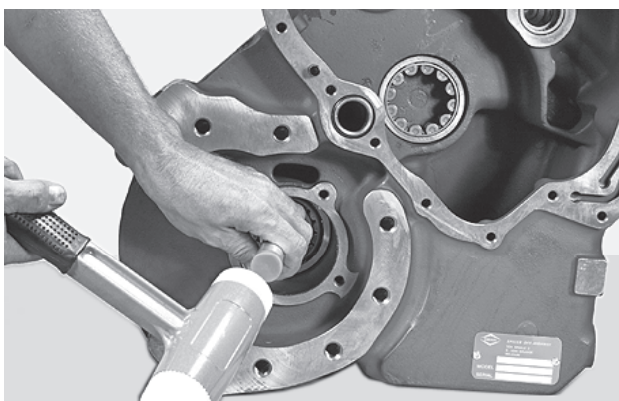
Support box with a chain hoist. Using pry slots provided, pry box from transmission housing.

**12**

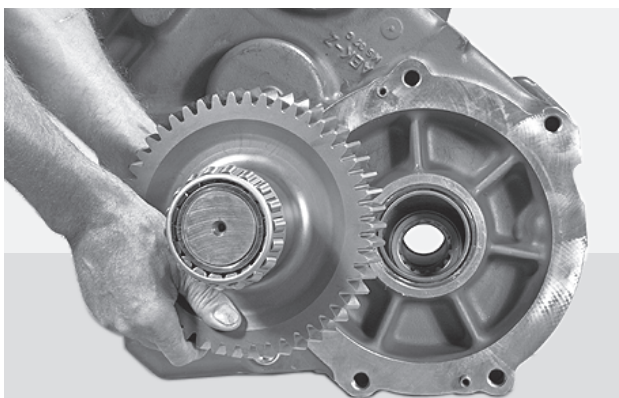
Remove drop box input shaft bearing cap mounting screws and lockwashers.

**13**

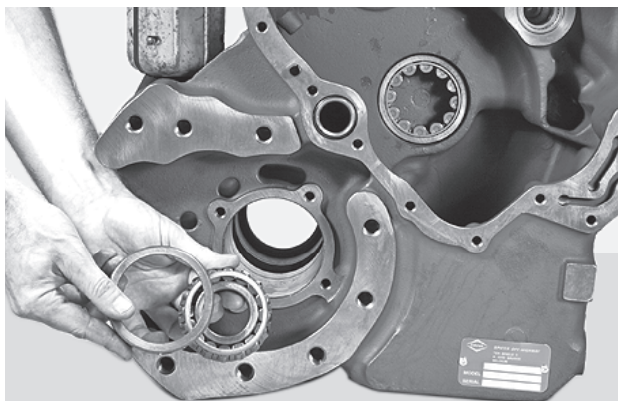
Remove front bearing cap and shims.

**14**

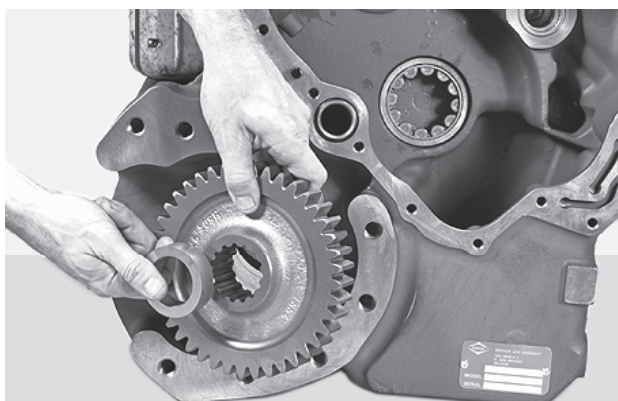
Tap input shaft assembly from transmission housing.

**15**

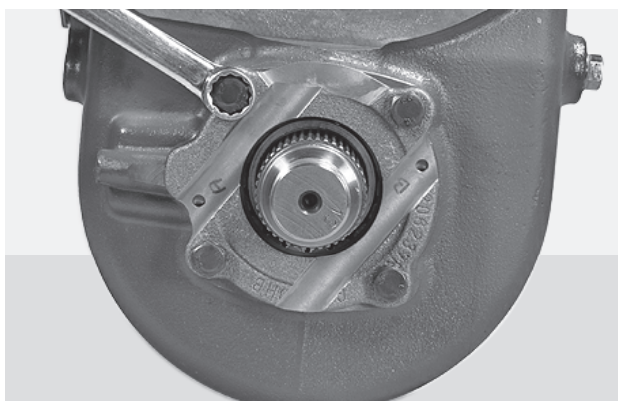
Input shaft assembly removed.

**16**

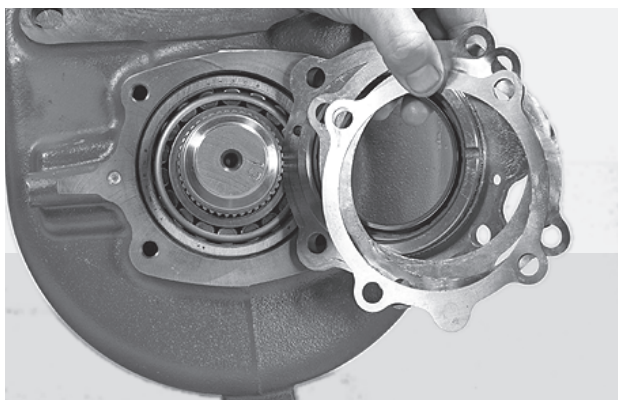
Remove front bearing cup and cone.

**17**

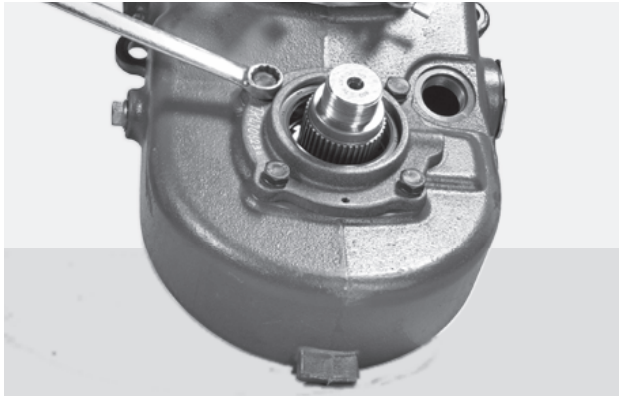
Remove input shaft gear and spacer.

**18**

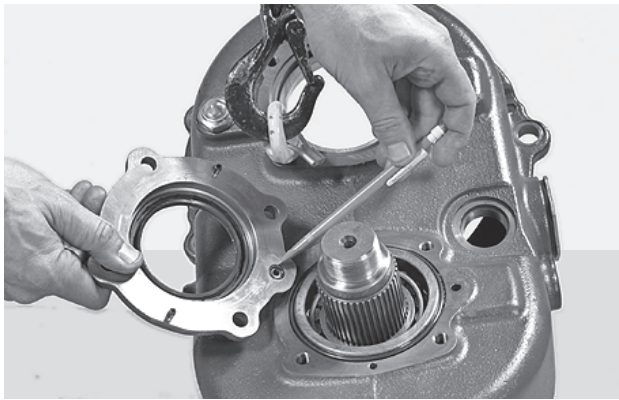
Remove front bearing cap screws and lockwashers.

**19**

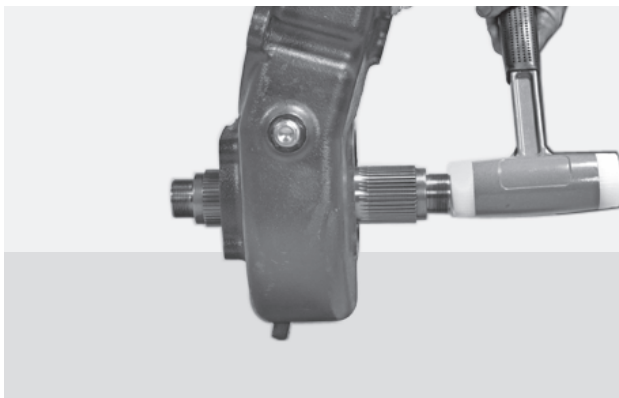
Remove output shaft front bearing cap and shims.

**20**

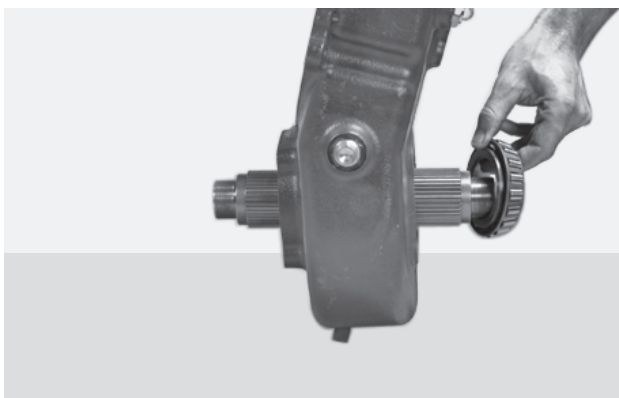
Remove rear bearing cap screws and lockwashers.

**21**

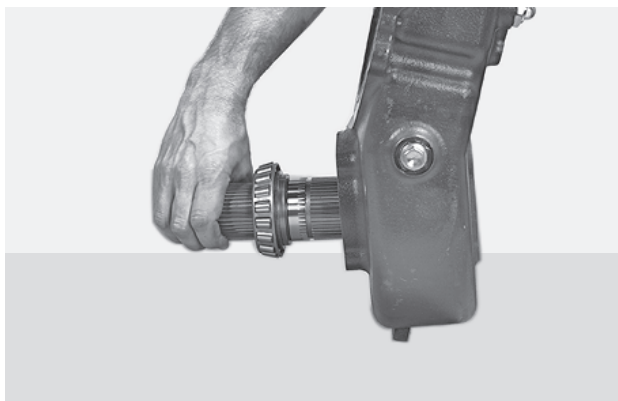
Remove output shaft rear bearing cap and "O" rings.

**22**

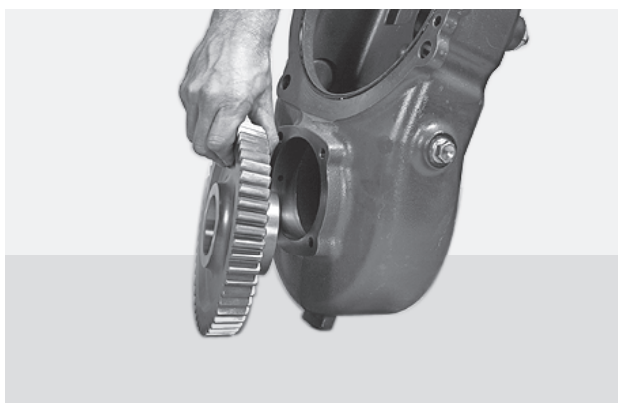
Tap output shaft from housing.

**23**

Remove output shaft rear bearing cone.

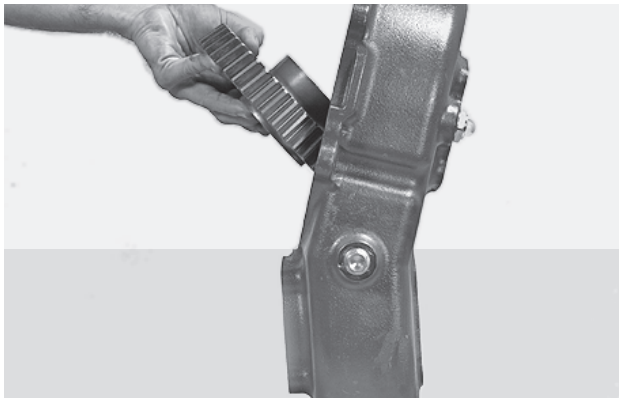
**24**

Remove output shaft and front bearing cone.

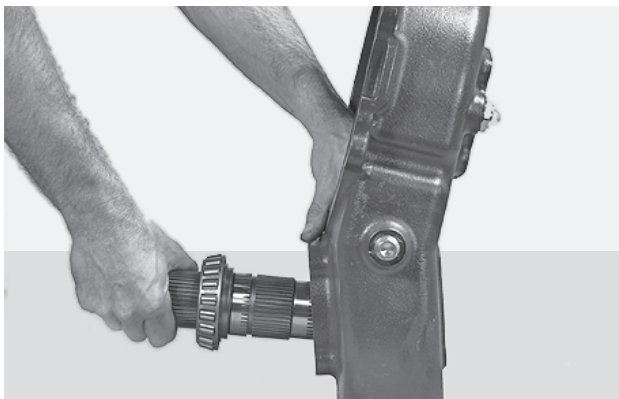
**25**

Remove output shaft gear.

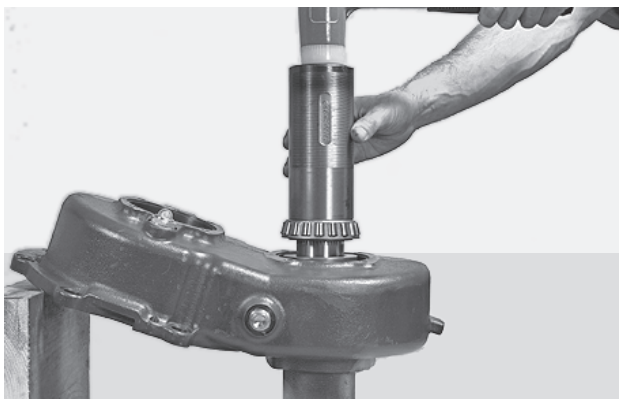
ASSEMBLY

**26**

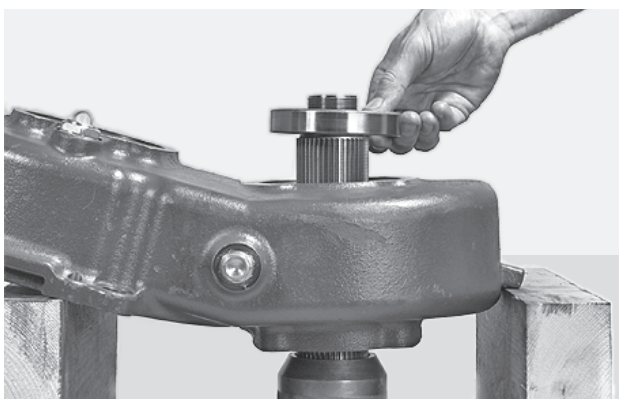
Install output shaft gear.

**27**

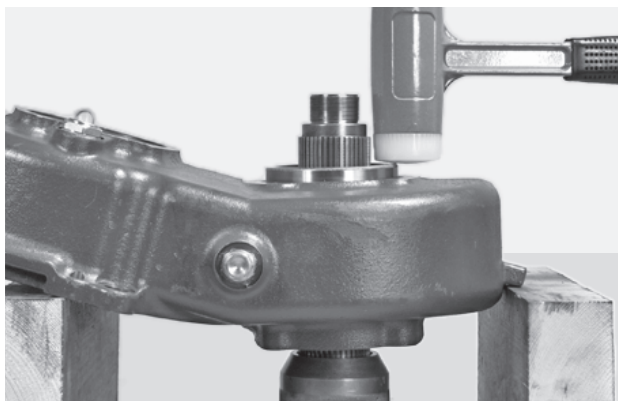
Install output shaft and front bearing cone.

**28**

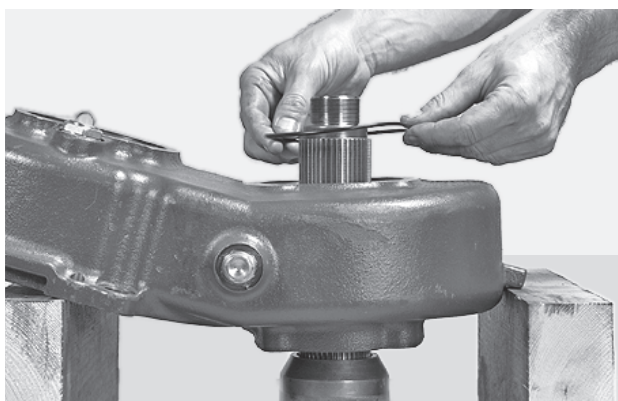
Block output shaft. Tap output shaft rear bearing cone into place.

**29**

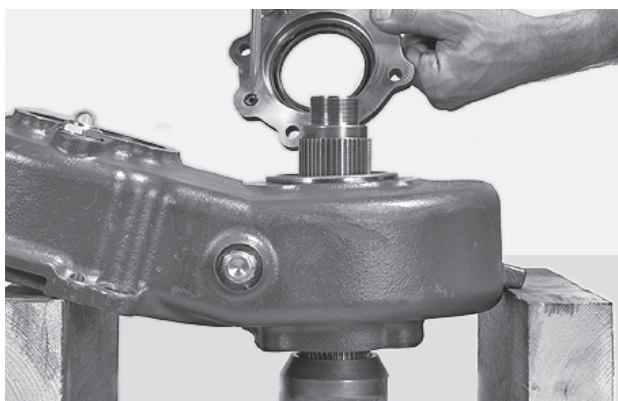
Install rear bearing cap.

**30**

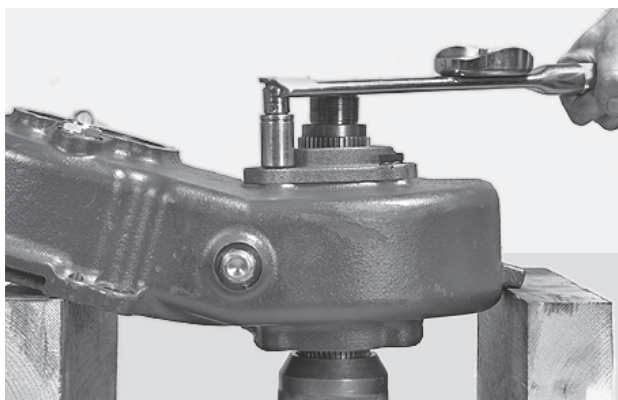
Tap cup into position.

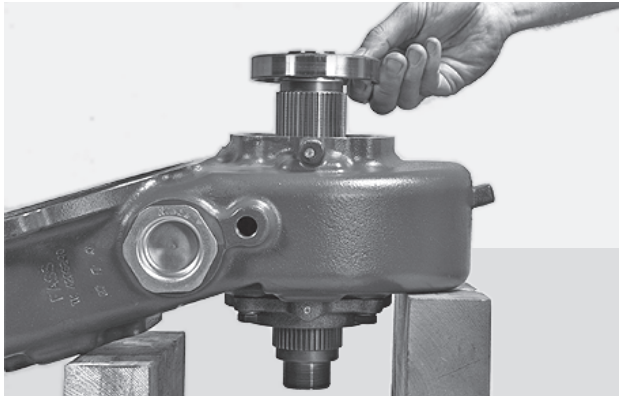
**31**

Install new rear bearing cap "O" ring.

**32**

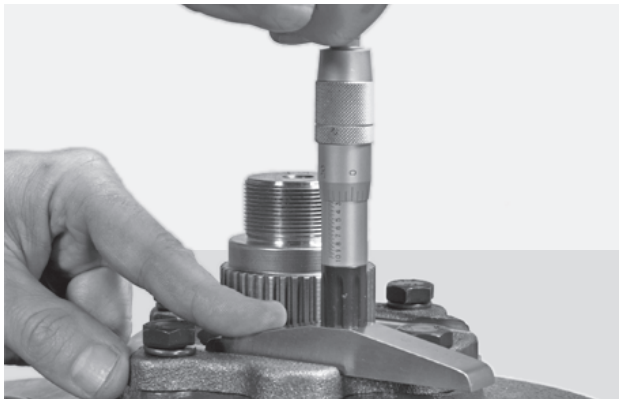
After installing new bearing cap seal and "O" ring, position bearing cap on case.

**33**Install bearing cap screws and lockwashers. Tighten screws to specified torque at section **TIGHTENING TORQUES** (pag. 9).



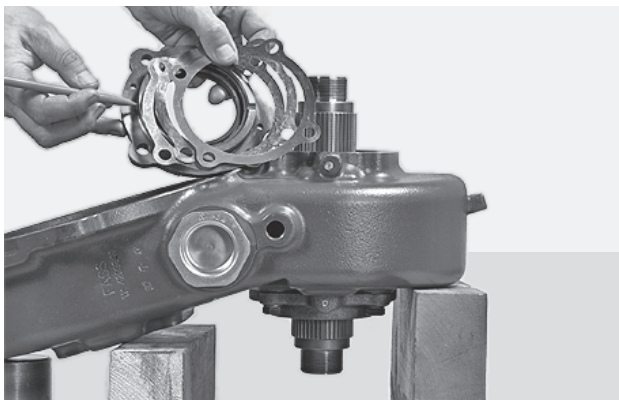
34

Install output shaft front bearing cup.



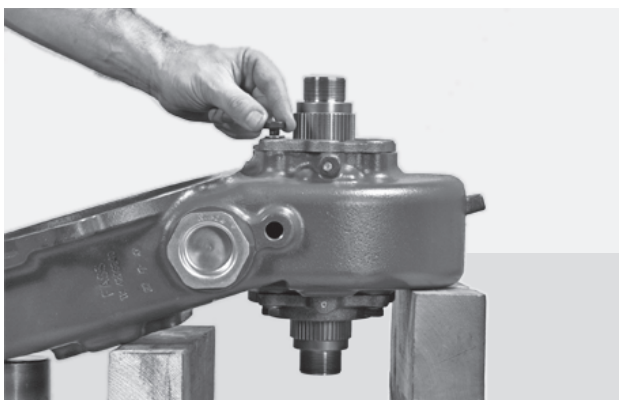
35

Refer to section "Assembly Instructions" for output shaft taper bearing adjustment. After proper taper bearing adjustment is made, remove bearing cap and proceed.



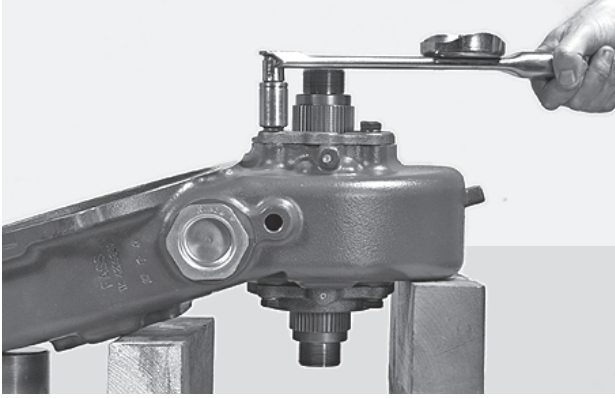
36

Install a new bearing cap seal and "O" ring. Position bearing cap with proper shim pack on drop box.

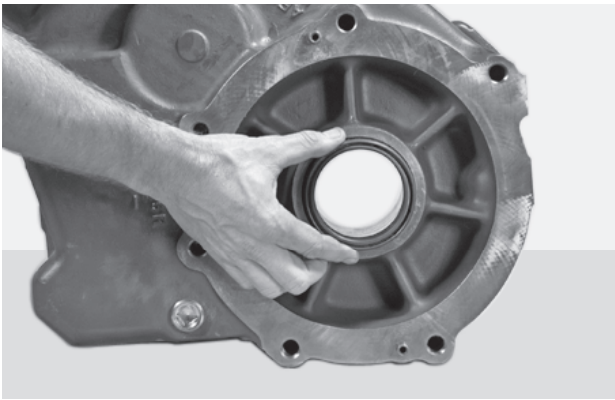


37

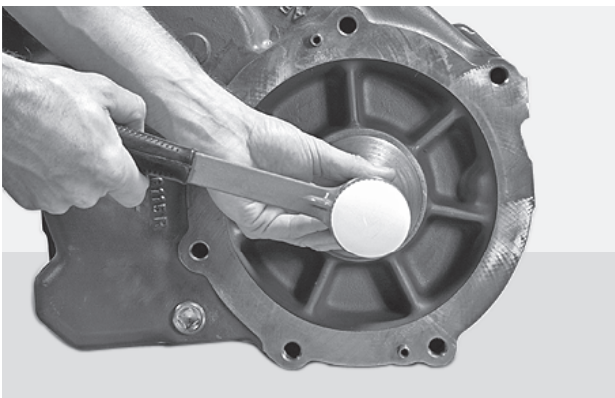
Install bearing cap screws and lockwashers.

**38**

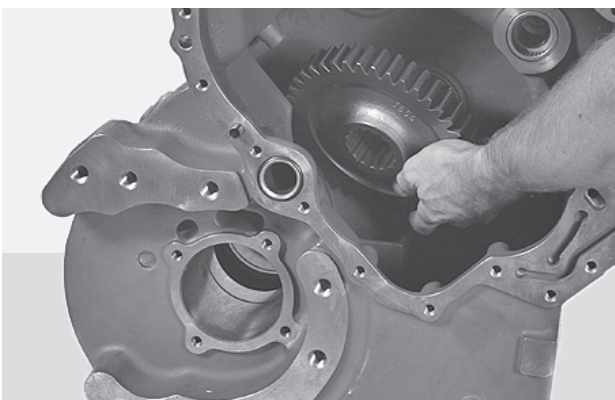
Tighten screws to specified torque (See torque chart).

**39**

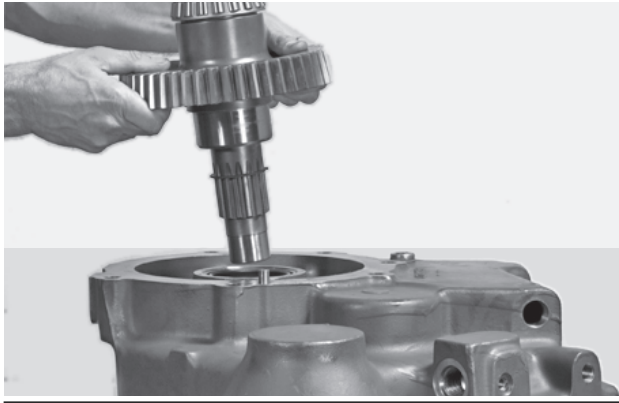
Install new oil seal.

**40**

Tap seal into position.

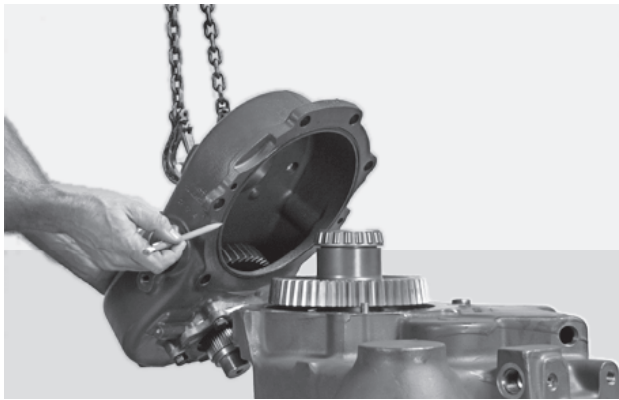
**41**

Position output gear into transmission case.



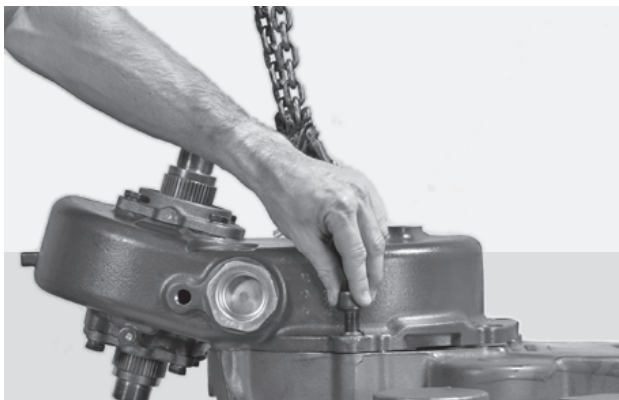
42

Insert input shaft through input gear. Use caution not to damage oil seal.



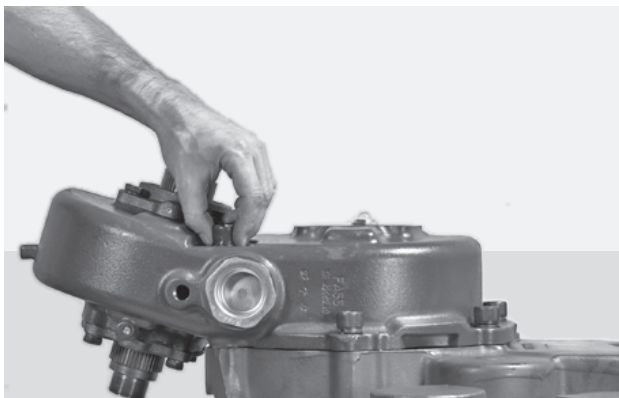
43

Coat transmission housing to drop box housing surface with Loctite® 5205. Install drop box housing on transmission case.



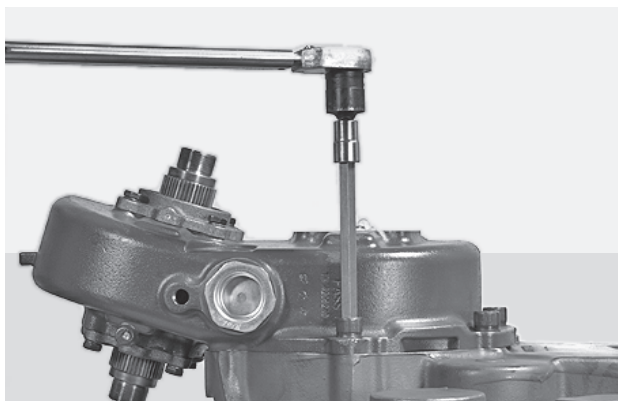
44

Install drop box mounting screws & lockwashers. (5)

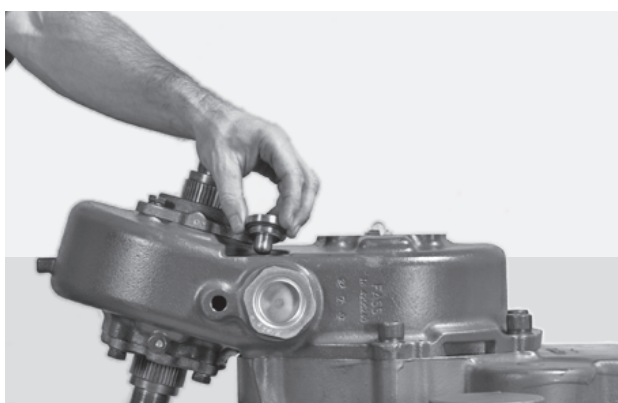


45

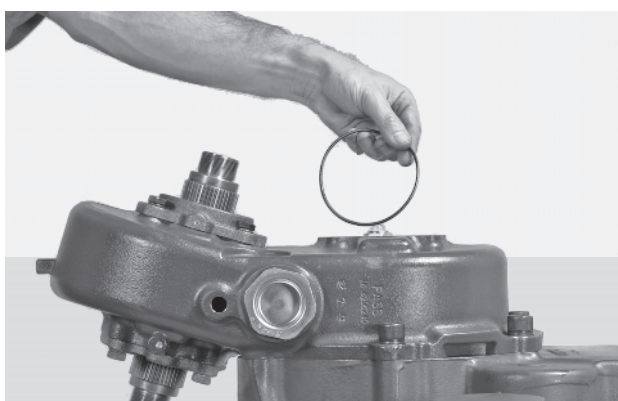
Thru mounting hole, install mounting screw & lockwasher. (1)

**46**

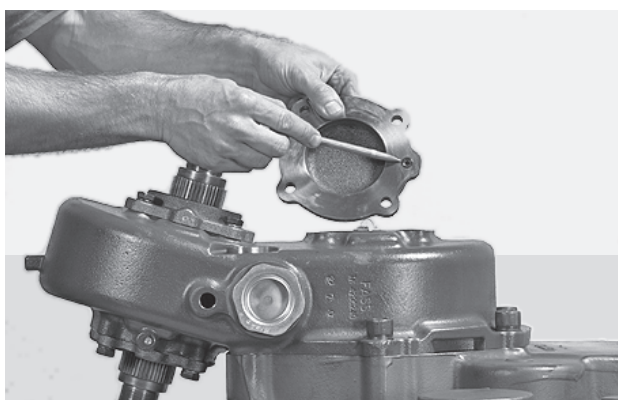
Tighten mounting screws (6) to specified torque. (See torque

**47**

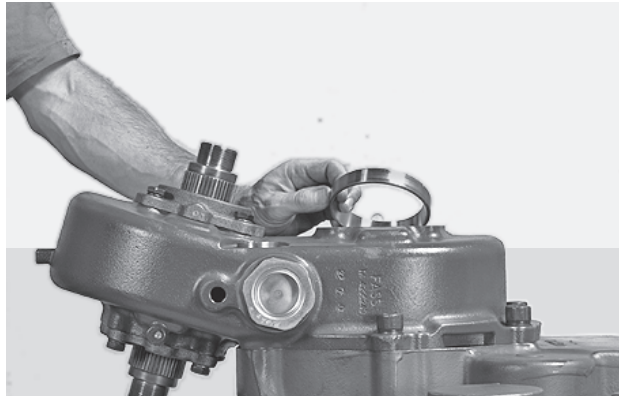
Install bore plug. Tighten plug to specified torque. (See torque chart).

**48**

Install new rear bearing cap "O" ring.

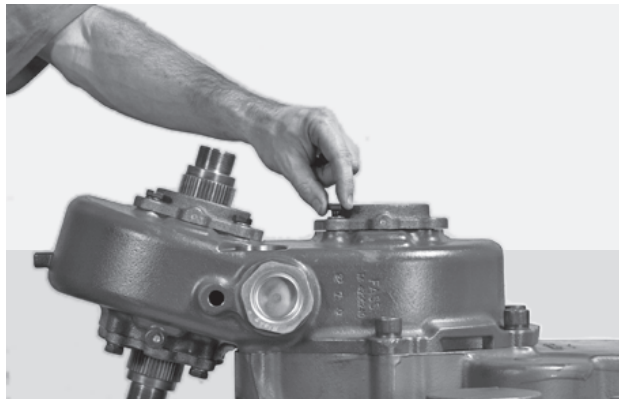
**49**

Install new rear bearing cap "O" ring. Install bearing cap.



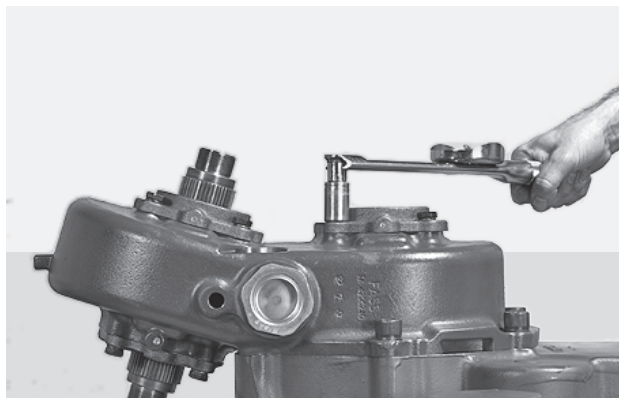
50

Install input shaft rear bearing cup.



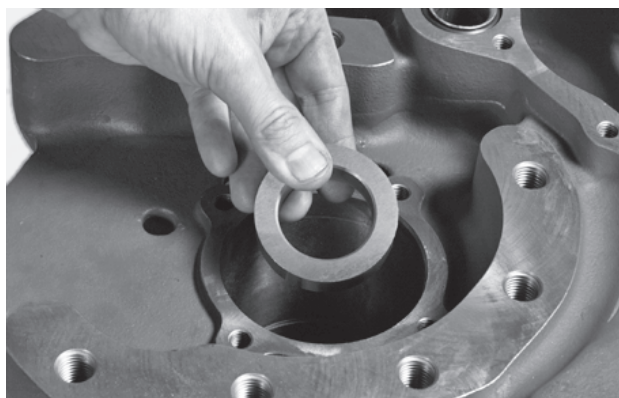
51

Install bearing cap bolts and lockwashers.



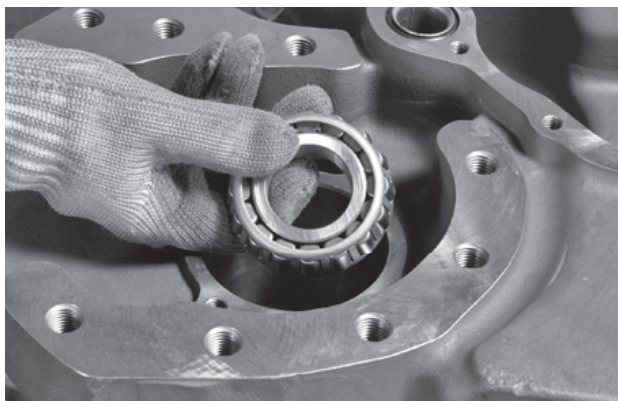
52

Tighten screws to specified torque. See torque at section TIGHTENING TORQUES (pag. 9).

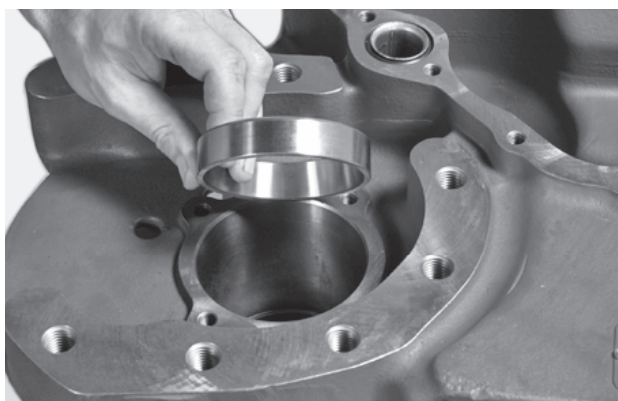


53

Install input gear spacer.

**54**

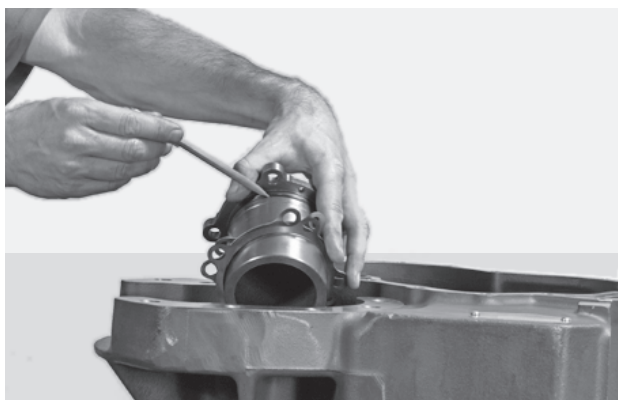
Install input shaft front bearing cone.

**55**

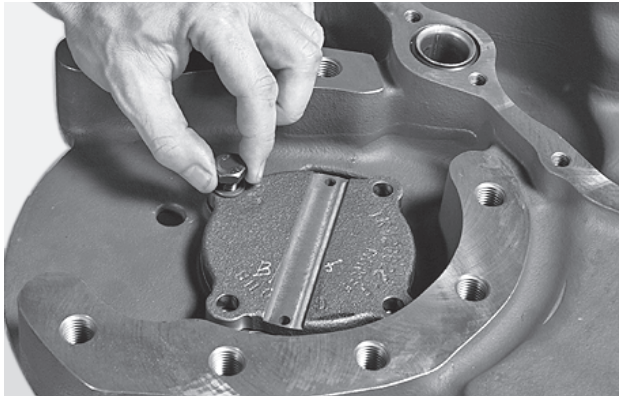
Install input front bearing cup.

**56**

Refer to section "Assembly Instructions" for input shaft taper bearing adjustment. After proper taper bearing adjustment is made, remove bearing cap and proceed.

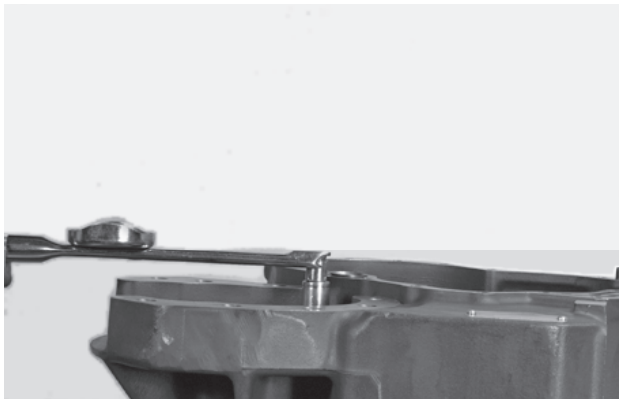
**57**

Install new bearing cap seal and "O" ring. Position bearing cap with proper shim pack on transmission case.



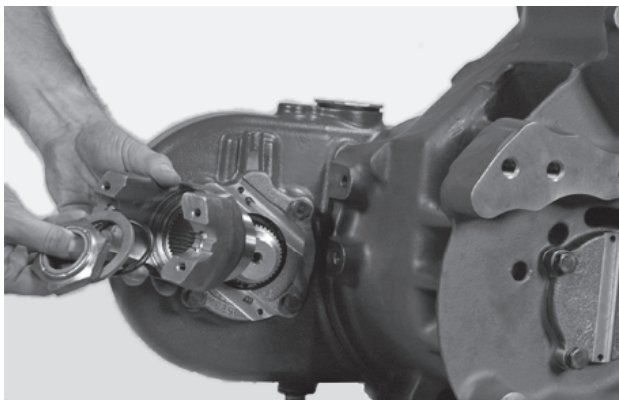
58

Install bearing cap screws and lockwashers.



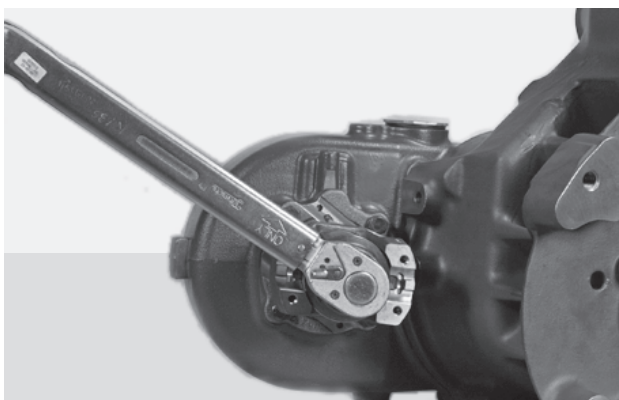
59

Tighten bearing cap screws to specified torque. (See torque chart).



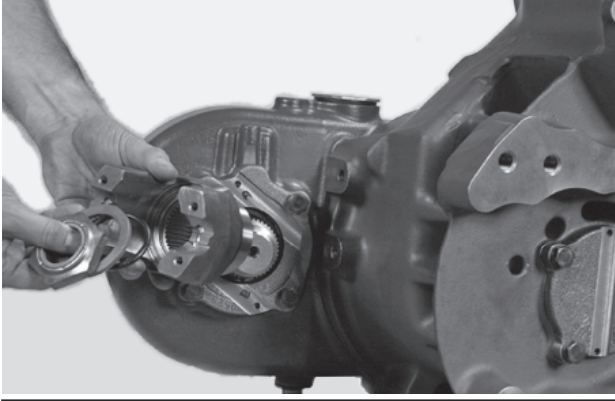
60

Install front flange, new "O" ring, washer and nut.

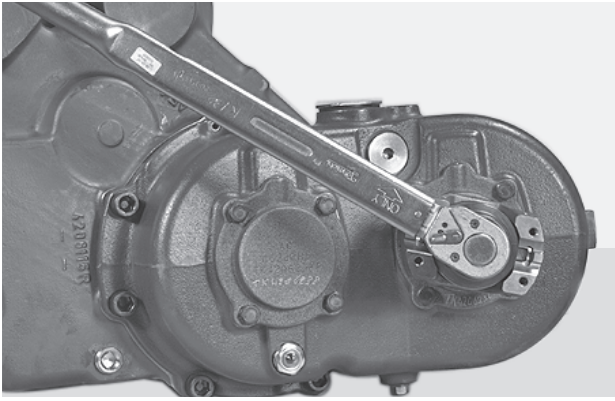


61

Torque flange nut to specified torque. See section "Assembly Instructions".

**62**

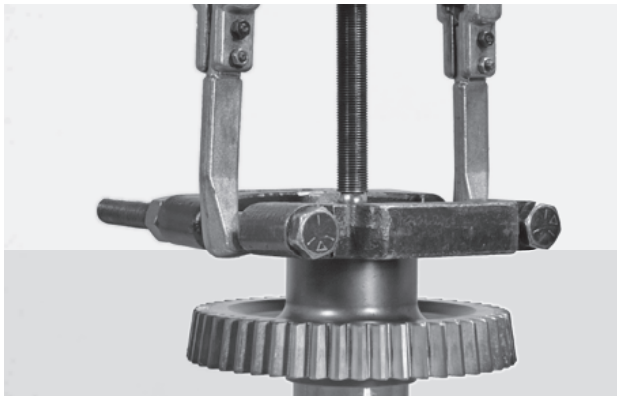
Install rear flange, new "O" ring, washer and nut.

**63**

Tighten flange nut to specified torque. See section "Assembly Instruction".

INPUT SHAFT

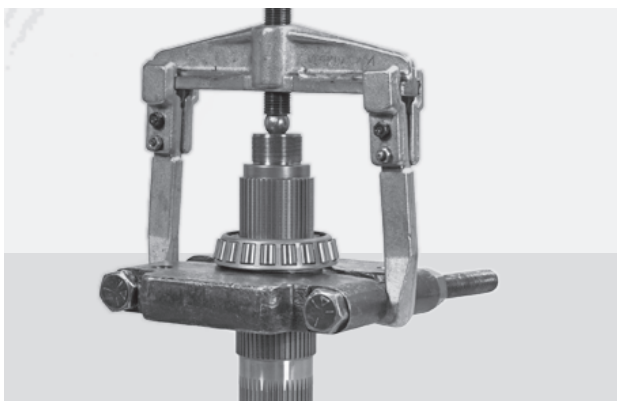
DISASSEMBLY

**1**

Remove input shaft rear bearing cone.

**2**

Remove input shaft gear retaining ring.

**3**

Remove output shaft front bearing cone.

ASSEMBLY**4**

Install input shaft rear bearing cone.

**5**

Install input shaft gear retaining ring.

**6**

Install output shaft front bearing cone. Refer to section "CLEANING & INSPECTION."

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HARDWARE

RD.120

REMOTE DISPLAY SPECIFICATIONS

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RD.120 specification

1. Features

- Microchip PIC16F627 uC
- 2x 7-segments LED display, colour red.
- 2 LED's
- 1 push button
- Environmentally robust
- Communication via a LIN

2. Application


- Remote display for the APC12X

3. Standards and limits

All functions operate as intended when the display is used within specified operating limits. Use beyond this limits can cause structural damage to the display.


PARAMETER	STANDARD	LIMITS, REMARKS
1. Min/Max supply voltage	SAE J1445:2006	9...32 V
2. Operating temperature		-40°C to +85°C
3. Storage temperature		-55°C to +105°C
4. Supply current		
Maximum		0,5 A
5. EMC		
Emission	ISO 13766:2006	
Immunity 1	ISO 13766:2006	
Bulk current injection	ISO 11452-4:2005	20-400 MHz 125 mA
Radiated EM energy AM modulation	ISO 11452-2:2004	V. polarization 80 -1000 MHz 125 V/m H. polarization 400- 1000 MHz 125 V/m
Immunity 2	2004/104/EC	
Radiated EM energy Pulse modulation	ISO 11452-2:2004	V. polarization 800 - 2000 MHz 125 V/m H. polarization 800 - 2000 MHz 125 V/m
Electro-static discharge 1	ISO 13766:2006	
Contact Discharge	ISO 10605:2001	Testlevel IV 8kV class A behaviour
Air Discharge	ISO 10605:2001	Testlevel IV 15kV class A behaviour
Electro-static discharge 2		
Contact Discharge	EN 61000-4-2:2001	Testlevel IV 8kV class A behaviour
Air Discharge	EN 61000-4-2:2001	Testlevel IV 15kV class A behaviour
Conducted Transients	ISO 13766:2006 ISO 7637-2:2004	Testlevel IV class A behaviour for 12 and 24 V applications.
Voltage transient emission test	ISO 7637-2:2004	Supply voltage: 27V ON/OFF switching
6. Short Circuit Protection		
To GND	SAE J1455:2006	All terminals ⁽¹⁾ (short is applied when the unit is powered.)
To GND		All terminals ⁽¹⁾ (short is present when the unit is switched on)
To Vbat	SAE J1455:2006	All terminals ⁽²⁾ (short is applied when the unit is powered.)
To Vbat		All terminals ⁽²⁾ (short is present when the unit

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		is switched on)
7. Steady State Behaviour		
Min/Max operating voltage	SAE J1455:2006	
Reverse polarity	SAE J1455:2006	
Jump start	SAE J1455:2006	48V for 5 minutes
Batteryless operation	Variant on ASAE EP455	12 V system $V = 6.0 + 12.6 \sin(2\pi ft) $ 24 V system $V = 12 + 23.2 \sin(2\pi ft) $ for $f = 150 \text{ Hz to } 1.5 \text{ kHz}$ source impedance : $Z_o = 2.9\Omega + 1.5\text{mH}$
Mutual coupling test	ASAE EP455	Power source lines: $450 \exp[-t/(14\text{E}-6)] \sin(2\pi * 10\text{E}6t) \text{ V}$ Signal lines: $\pm 400 \exp[-t/(14\text{E}-6)] \text{ V}$
8. Sealing	IEC 60529	IP65, IP67, IP69K
9. Dry heat tests		
Storage temperature		24h @ -55°C followed by 24h @ 105°C
High temperature soak test		96h @ 85°C powered
Low temperature soak test		96h @ -40°C powered
Operating temperature		7x 48h cycle, variant on SAE J1445 t° profile between -40°C and 85°C, powered
Thermal shock 1		3x 8h cycle, variant on SAE J1445 t° profile, powered
Thermal shock 2		100 cycle, between -55°C and 90°C, not powered
10. Shock		
Handling drop test	SAE J1445:2006	
Operational shocks 1	IEC 60068-2-29	2000 bumps positive and negative Amplitude: 30 g, ½ sine Duration: 11 ms Rate: 2 bumps/sec Direction: 3 orthogonal axes
Operational shocks 2	IEC 60068-2-29	100 bumps positive and negative Amplitude: 40 g, ½ sine Duration: 6 ms Direction: 3 orthogonal axes
Transit drop test		DANA standard
11. Vibration		
Endurance test	IEC 60068-2-34	Duration: 1 hour at 3 g and 1 hour at 5 g in each direction. Frequency range: 10 to 150 Hz sweep rate: 1 oct/min direction: 3 orthogonal axes
Wide random vibration test 1	IEC 60068-2-35	Frequency range: 5 Hz to 2 kHz Duration: 1 hour Amplitude: 6.5 g RMS Direction: 3 orthogonal axes Profile: 20 Hz : 0.0116515 g2/Hz 20 to 80 Hz: +3 dB/oct 80 to 350 Hz: 0.04602 g2/Hz 350 to 2 kHz: -3 dB/oct 2 kHz: 0.0080541 g2/Hz
Wide random vibration test 2	IEC 60068-2-35	Duration: 24 hours Direction: 3 orthogonal axes Profile:

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		10 Hz : 0.005 g2/Hz 150 Hz : 0,060 g2/Hz 220 Hz : 0.080 g2/Hz 350 Hz : 0.040 g2/Hz
Resonance search test 1		Frequency range from 10 to 150Hz. Constant acceleration 2g. Sweep rate : 1oct/min. Direction: 3 orthogonal axes. Duration: one sweep for each of the three orthogonal axes.
Resonance search test 2		Frequency range from 10 to 2000Hz. Constant acceleration 4g. Sweep rate : 1oct/min. Direction: 3 orthogonal axes. Duration: examine each resonance point Q>=5. Dwell the vibration frequency for 30 minutes at each resonanance point.
12. Corrosive atmosphere		
Humidity		24h cycle, variant on SAE J1445 humidity profile
Humidity soak		240 hours at RH of > 96%
Icing cycle		Between -40°C and +85°C, 24 hours
85/85 relative humidity test		Duration: 21 days @85°C and RH=85%
Salt spray test	IEC60068-2-11	Duration: 48h
Chemical resistance test	BS7691	Coat once a day for a duration of 3 days. Overview chemicals: Diesel, Hydraulic oil, ethylene glycol 50% aqueous solution, Urea Nitrogen, NPK fertilizer 3x 15% each
Ozone chamber test	ASTM D1171-99	Duration: 46 hours


(1) Except the supply voltage terminal. An externally placed series fuse (0.5A) must be used to prevent damage.

(2) Except the GND terminal: an externally placed series fuse (0.5A) must be used to prevent damage.

The RD.120 complies to following standards and directive:

standard	year	
ISO 13766	2006	Earth moving machines
ISO 14982	1998	Agricultural and forestry machines
EN 12895	2000	Industrial trucks
EN 13309	2000	Construction Equipment machines with internal Electrical Power Supply
Commision directive 2004/104/EC	2004	Adapting to technical progress council directive 72/245/EEC

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4. Electrical Characteristics Serial Link

Parameter	
Communication protocol ⁽¹⁾	Local interconnection network
Maximum speed	9600 bits/s
Maximum cable length	15 m
Communication outline	Master CU – slave dashboard

(1) RS232 via a LIN bus driver

5. Wiring harness

Harness needs to be fixed mechanically in the area of the ECU (Distance < 150 mm)
 Harness needs to be fixed in such a way that in case of an excitation, the wiring harness is in-phase with the ECU (e.g. at the fixing point of ECU).

For production the wiring harness has to be ordered from a local supplier.

For prototype vehicles, a 6 m wiring harness can be ordered from Dana. This wiring harness contains the 90° Souriau connector (incl. pins) and 4 wires of 6 m. The numbered wires are connected to the 90° Souriau connector on one end and they are loose on the other end. The part number for the prototype wiring harness is 4503645. Note that this wiring harness can not be ordered for production.

6. Connector layout

The connector on the dashboard is a 4-pole male connector.

The 4-pole **male** connector pin assignment is as follows

Pin	Name	Function
A	Vbatt	Switched battery supply voltage
B	GND	GND connection
C	LIN	Tranceiver signal ⁽¹⁾
D	LIN	Tranceiver signal ⁽¹⁾




Front view of the **male** display connector

(1) Pin C and Pin D are connected together.

The highly recommended connector is the mating **female** connector of SOURIAU with 4 crimp contacts included and has following ordering numbers:

	Branch	Part number
4 pins female connector straight crimp version with 4 crimp contacts included	SOURIAU	851 06 RC 84 SB
4 pins female connector 90° crimp version with 4 crimp contacts included.	SOURIAU	851 08 RC 84 SB

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The main technical information about this female connector is reported in the following picture:


851 Series

Applications

Former connector for military applications.
Now used in the fields of professional and general electronics.

Standards

MIL-C 26482 G Series 1
NFC 93422-He 301 B
VG 95928
BS 9522 F 0017
9AM T1 test
QPL approved (solder version)



Description

- Bayonet coupling
- Environmental and hermetic versions
- Solder, crimp, straight splice and wire wrap versions
- Thermocouple contacts available
- Cadmium free plating (Zinc Cobalt) version

Characteristics

Mechanical

- Shell:
 - environmental version: aluminum alloy plating
 - olive green cadmium
 - black anodized
 - white cadmium
 - satin finish bright nickel
 - zinc cobalt (olive green)
 - hermetic version: steel
- plating: - induscent yellow cadmium, nickel
- Insulator:
 - front section: neoprene elastomer (85 shore)
 - rear section: neoprene elastomer (40 shore)
- Contact:
 - crimp: inserted and removed from rear of insulator retained by metallic clip; solder and straight splice: non removable; wire wrap: removable or not removable
 - material: copper alloy
 - plating: gold overall or gold plated active zone and tin/lead plated termination
 - min retention force of contacts in insulator

contact size	crimp	solder straight splice
20 (Ø 1 mm)	≥ 58 N	≥ 58 N
16 (Ø 1.6 mm)	≥ 113 N	≥ 113 N

- Mechanical endurance:
500 cycles (full mating-unmating)

Electrical

- Dielectric withstanding voltage:
 - at standard pressure:
mated and unmated connectors
 - 1 500 Vrms between size 20 contacts (service 1)
 - 2 300 Vrms between size 16 contacts (service 2)
 - 1 500 Vrms between mixed size 20 and 16 contacts (service 1)
 - at reduced pressure (10 mbar):
connectors mated and unmated
 - 200 Vrms between size 20 contacts (service 1)
 - 300 Vrms between size 16 contacts (service 2)
- Insulation resistance: ≥ 5 000 MΩ under 500 Vdc
- Current rating per contact:
 - size 20 : 7.5 A
 - size 16 : 13 A

- Contact resistance:
 - environmental version:
 - size 20 : 4 mΩ
 - size 16 : 3 mΩ
 - hermetic version:
 - size 20 : 30 mΩ
 - size 16 : 14 mΩ
- Shielding : 70 dB to 5 MHz
40 dB to 100 MHz


Climatic

- Working temperature : -55°C to +125°C
- Sealing:
 - crimp contact version, 1 bar differential pressure, leakage ≤ 8 cm³/hr
 - solder contact version, 2 bar differential pressure, leakage ≤ 16 cm³/hr
- Hermeticity : 1 bar differential pressure leakage ≤ 2.8 mm³/hr
- Chemical resistance:
 - to MIL-C 26482 G Series 1 and
 - NFC 93422-HE 301 B code A
- Resistance to salt spray : 48 hours at environmental temperature
- Damp heat : 21 days
- Vibration : to NFC 20-616

Ordering information - Environmental connectors

basic series	solder version	851	- 00	E	8 -	3A	P	•	50	•••
	crimp version	851	- 00	R	8 -	3A	P	•	50	•••
shell type										
solder	crimp									
00	00	-	square flange receptacle accepting backshells							
01	01	-	cable connecting receptacle							
02R	02R	-	square flange receptacle not accepting backshells							
07	07	-	jam nut receptacle accepting backshells							
07A		-	jam nut receptacle not accepting backshells							
08	08	-	plug for use with straight backshells							
08	08	-	plug for use with 90° backshells							
96	96	-	screened plug for use with straight backshells							
78	78	-	screened plug with lock finger							
backshell type			see table next page							
shell size			8 - 10 - 12 - 14 - 16 - 18 - 20 - 22 - 24							
contact layout			see table p 5							
contact type			P = male - S = female							
orientation			normal (not included in part number) w, x, y, z, see table p 6							
obligatory suffix										
50			gold plated crimp contacts - solder contacts size 20 - contacts with a gold plated active zone and tin plated terminations - other gold plated terminations							
51			solder contacts gold plated size 20							
52			zinc cobalt olive green plated contacts - Idem specif. 50)							
specification										
-			olive green cadmium plate (without specification)							
02			white cadmium plate							
29			black anodized (solder contacts)							
091			black anodized (crimp contacts)							
44			nickel plate							
98			nickel plate							
42			olive green cadmium plate							
			backshell type T* and RT*							

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The recommended connector is the mating female connector from COMMITAL and has following order number:

	Branch	Part number
4 pins female connector straight solder version	COMMITAL	IPT06A8-4PHM7

This mating **female** connector can also be ordered from Dana under part number 4505148. 1x part 4505148 contains 5 connectors:

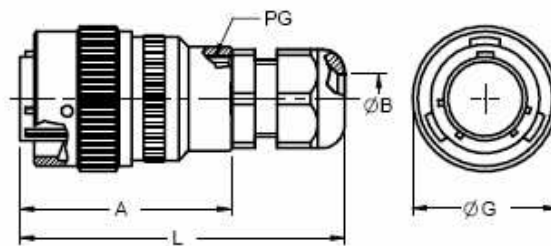
DANA partnumber	Commital part number	Qty
4505148	IPT06A8-4PHM7	5

The main technical information about this female connector is reported in the following picture:

IPT 06 A ... PH _ _



Connettore volante diritto
Straight plug



Es. / Ex : IPT06A18-11SPH16

Dimensione Guscio Shell size	A	B	Fil. PG PG thread	L	G
	Max	min. ÷ max.		Max.	Max
8	40	3÷8,5 / 4÷8	7 / 9	65	19,05
10	40	4÷8	9	65	21,80
12	40	5÷10	11	65	28,20
14	45	5÷10 / 6÷12 / 9÷14	11 / 13,5 / 16	75	29,40
16	45	5÷10 / 6÷12 / 9÷14	11 / 13,5 / 16	75	32,55
18	45	6÷12 / 9÷14	13,5 / 16	75	35,35
20	52	6÷12 / 9÷14	13,5 / 16	82	38,90
22	60	6÷12 / 9÷14 / 13÷18	13,5 / 16 / 21	95	42,10
24	60	6÷12 / 9÷14 / 13÷18	13,5 / 16 / 21	95	45,10

Connettore da cavo diritto.
Fornito completo di custodia e serracavo PG plastico.
Altri tipi di PG possono essere forniti nelle varie taglie a richiesta.

*Straight plug with backshell and plastic PG cable gland. Other PG sizes and types available upon request.
No grommet supplied.*

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Note that the wiring harness of the RD.120 (as shown on above picture) will not be supplied together with the RD.120.

The wiring harness can be ordered from a local supplier (for production) or can be ordered from Dana under separate part number 4503645 (for prototype vehicles only).

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7. Mounting advice

- Permitted installing area: passenger car, off highway vehicles.
- Foresee a minimal space of 90 mm behind the display front for mounting the connector.
- Permitted mounting location: cabin.
- It has to be assured that water cannot infiltrate through the wiring harness into the control unit.
- Bouncing of ECU in mounting position is not allowed.
- The ECU has to be mounted in such a way that its connector is freestanding in order to allow its female counterpart to be connected without obstructions.
- Dana's consent is required if the mounting instructions are not followed.

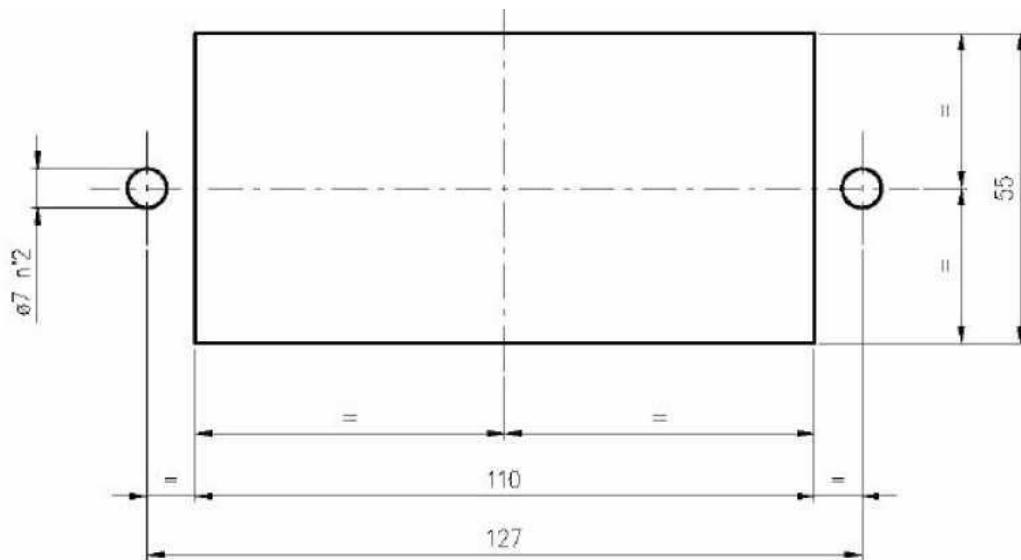



Fig. 1 – Mounting holes

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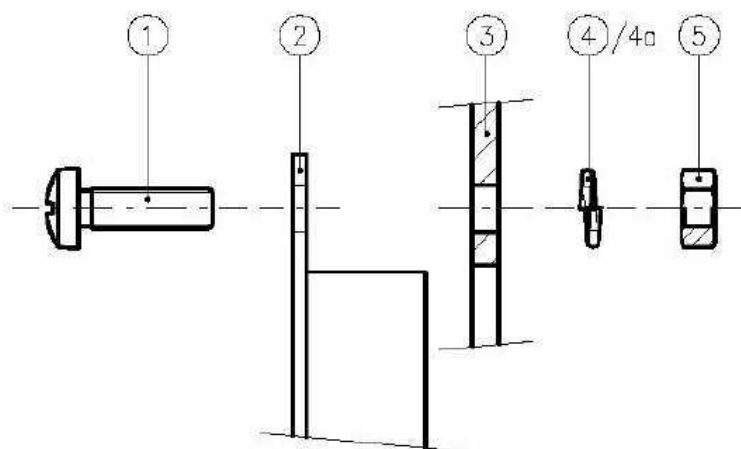



Fig. 2 - Mounting procedure

1	Screw M6x16 UNI 7687/DIN 7985
2	ECU RD120
3	Fixing panel with a thickness of 2 – 4 mm
4	Elastic washer M6 UNI 1751/DIN 127
4a	Toothed external washer M6 UNI 8842-A/DIN6798-A
5	Hexagonal nut M6 UNI 5588/DIN934

The torque to apply on the screws is 3 Nm for class 4.8 models and 7 Nm for class 8.8 screws.

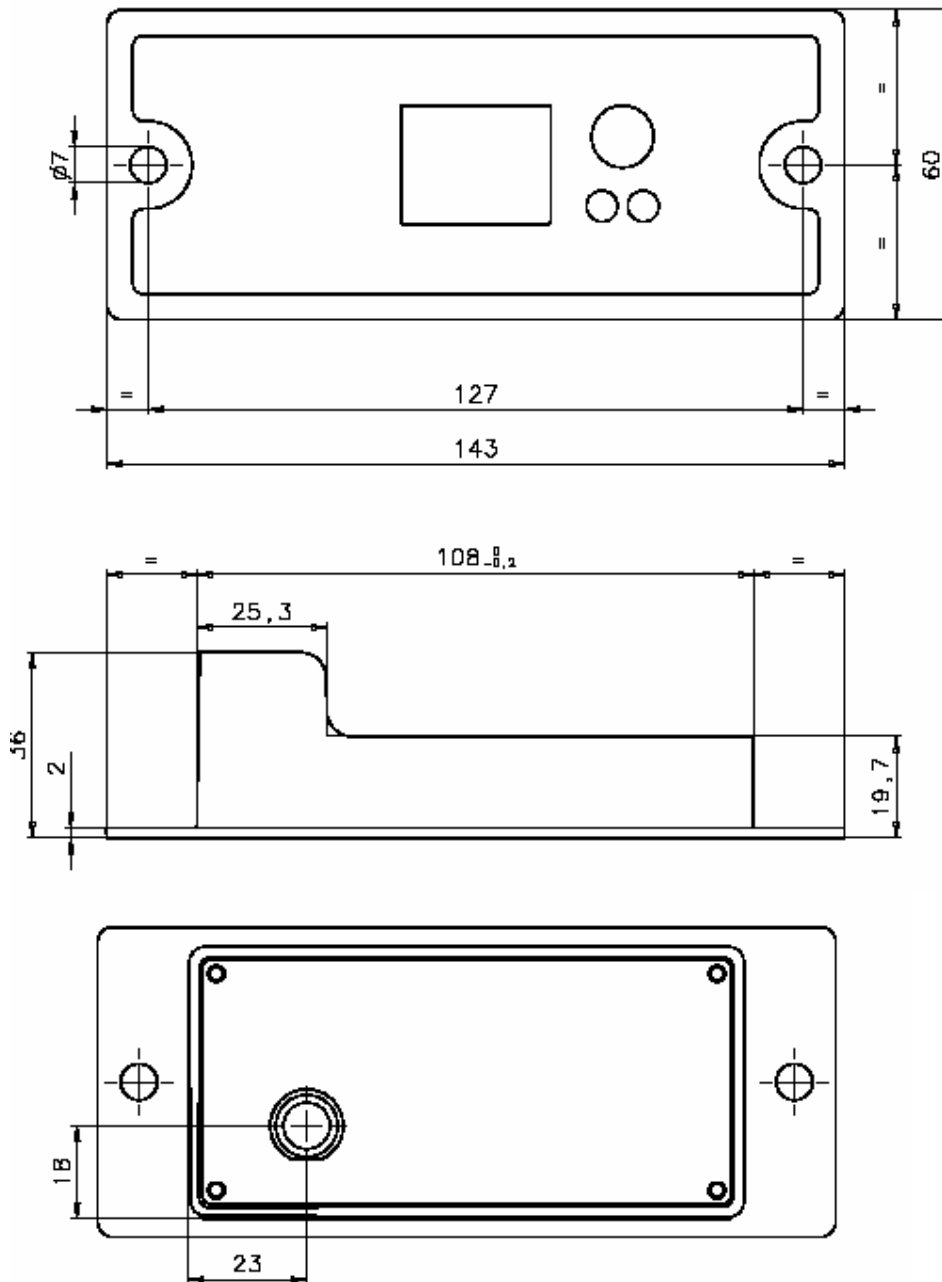
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8. Physical dimensions

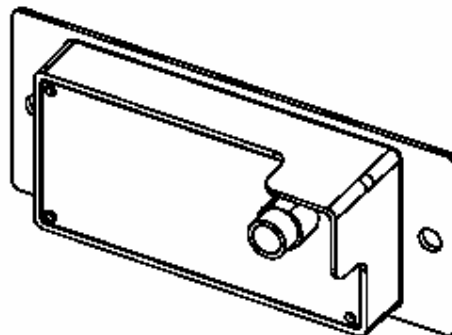
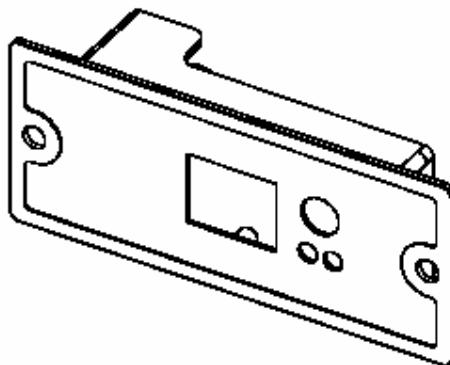
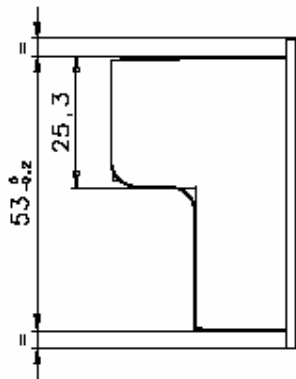
Max. dimensions: L x W x D = 143 X 60 X 36 mm³

Weight: approx. 0,4 kg




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9. Partnumber

In case the RD.120 is selected, for production it will be delivered as part of the APC121 or APC122 kit. For spare parts it has to be ordered as separate part under Dana part number 4210492.

10. Disclaimer


APPLICATION POLICY

Capability ratings, features and specifications vary depending upon the model type of service. Application approvals must be obtained from Spicer Off-Highway Systems. We reserve the right to change or modify our product specifications, configurations, or dimensions at any time without notice.

SPICER OFF-HIGHWAY SYSTEMS

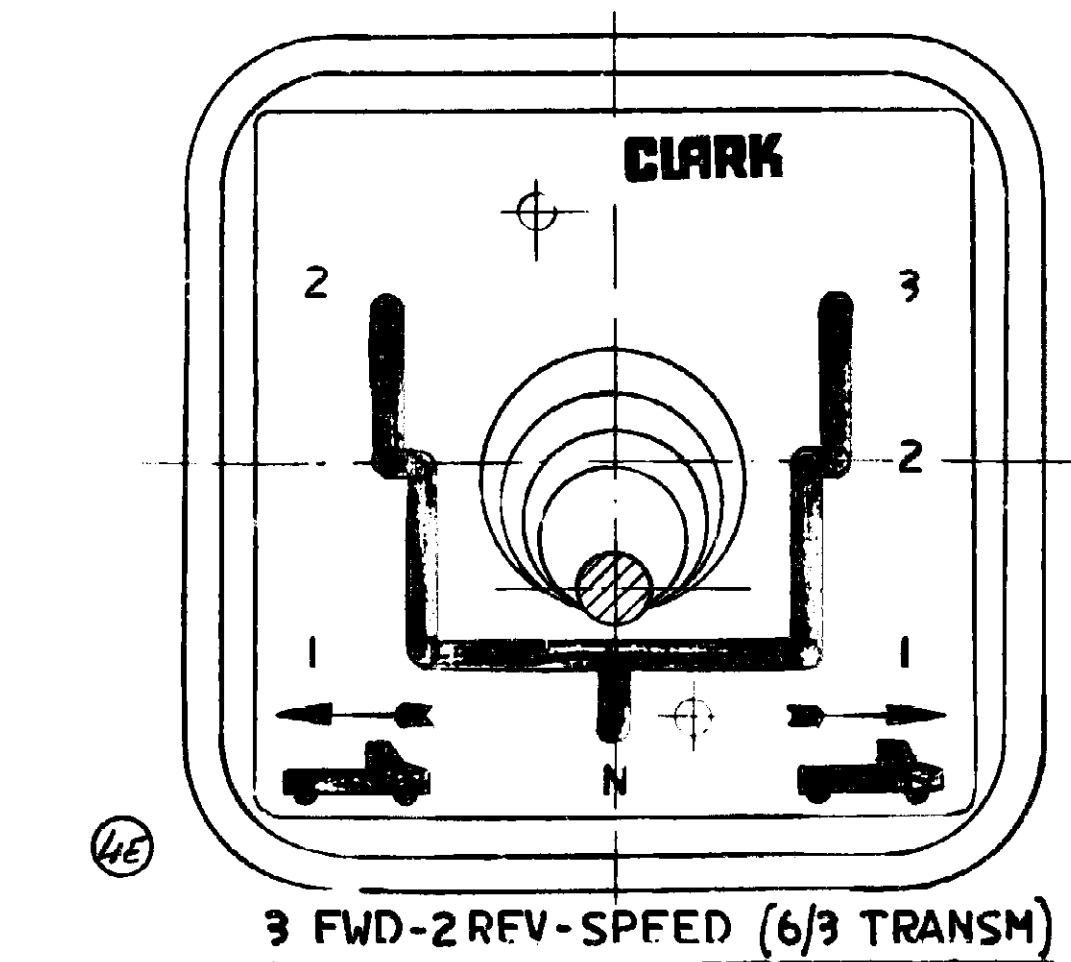
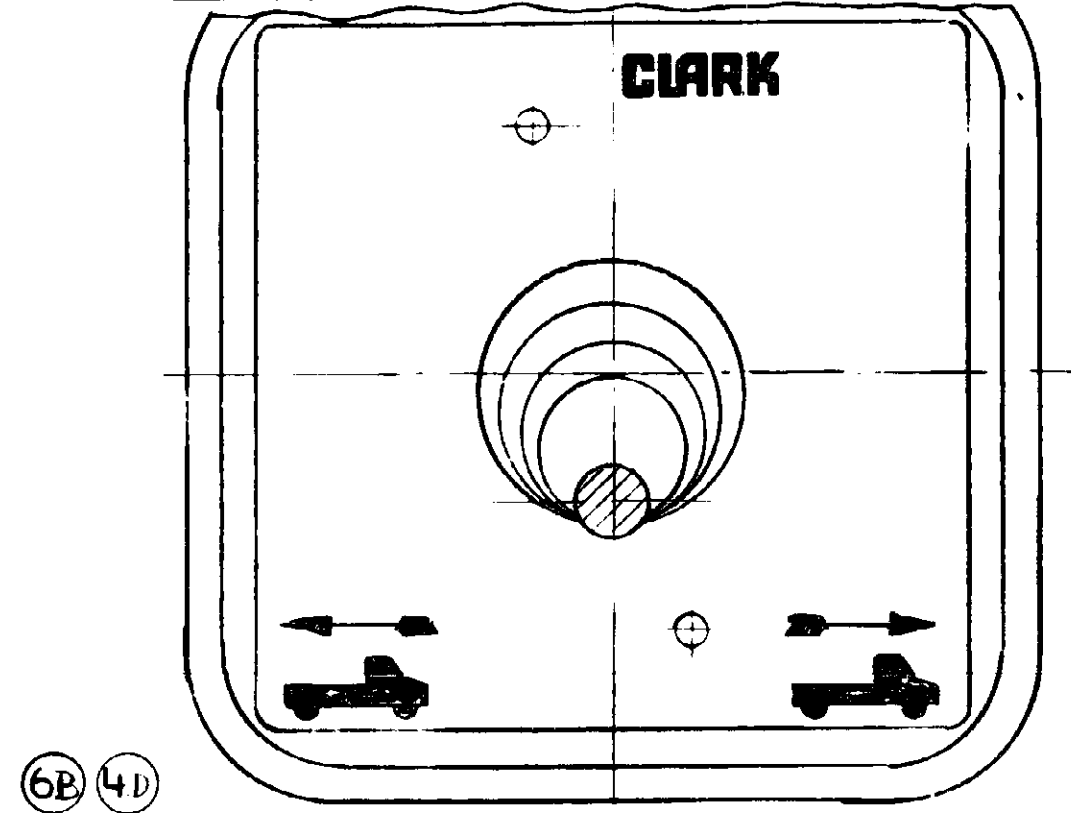
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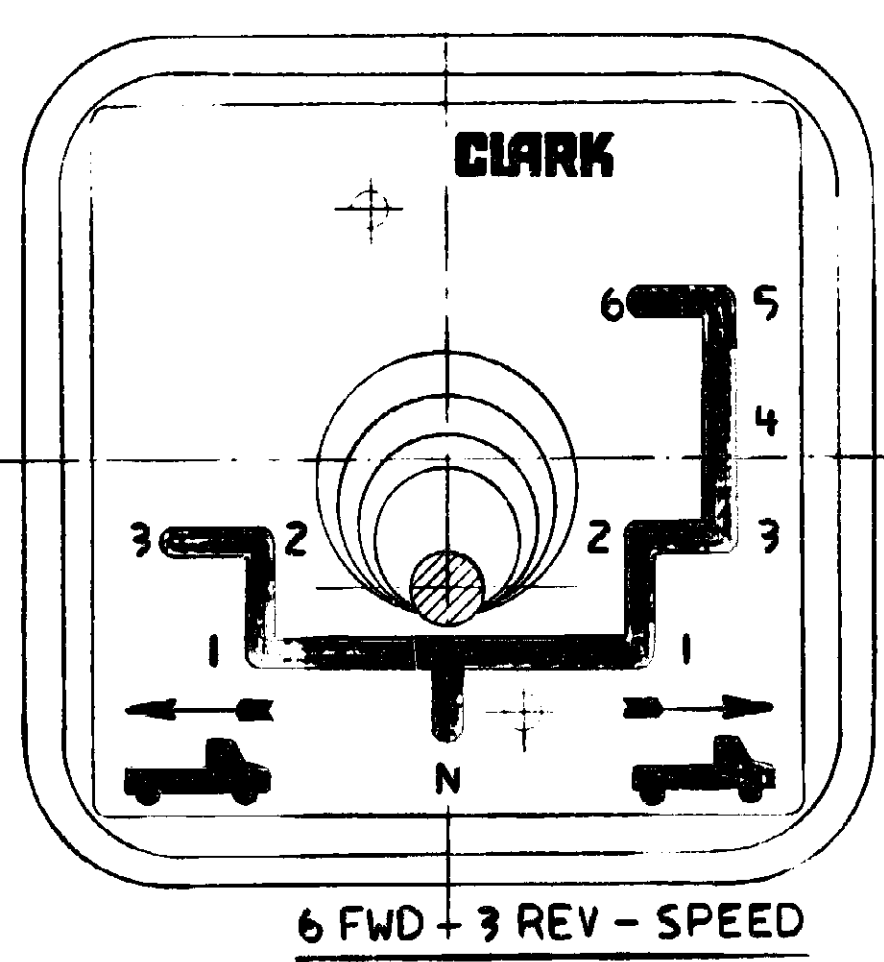
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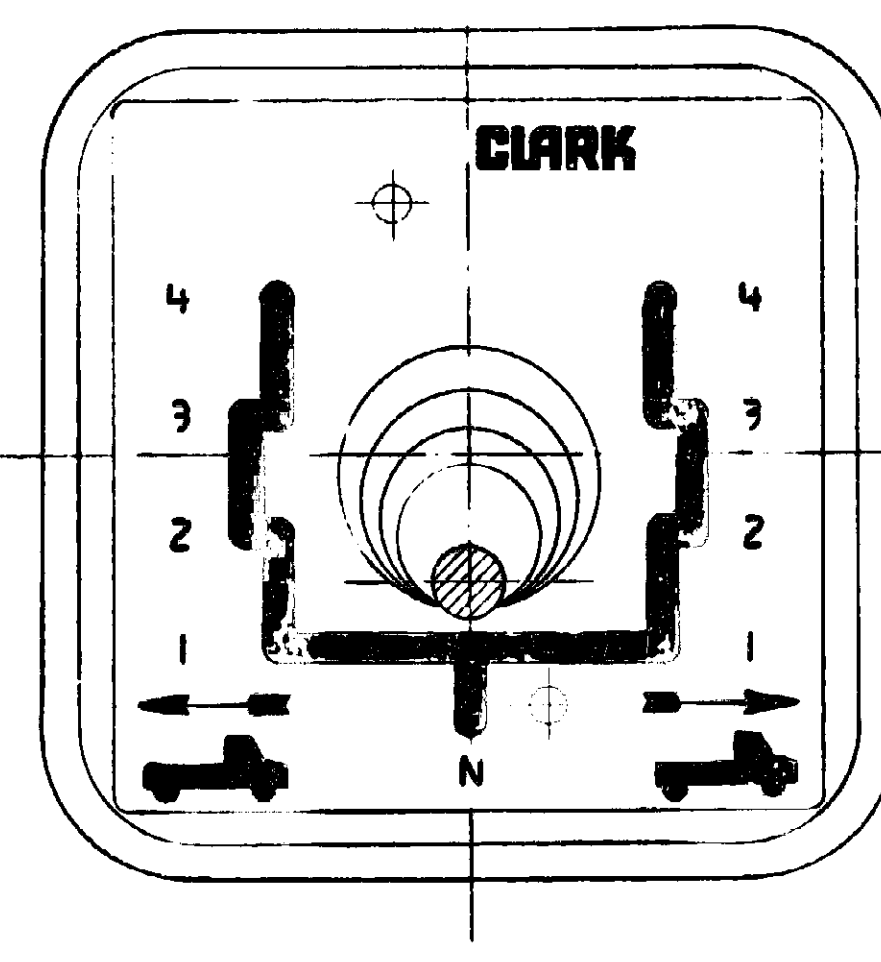
PART NUMBER	NUMBER OF SPEED FWD./REV.	DIRECTION SHIFT FWD. REV. 1 ST. AND 2 ND.	DIRECTION SHIFT FWD. REV. 1 ST. ONLY	LOCK-UP PROVISION	TOTAL NEUTRAL PROVISION	USE WIRING DIAGRAM		
						18 000 24 000 32 600 FPS 34 000	26 000 32 000	30 000 40 000 50 000 80 000 160 000
4200372	2/2	x				W4200402	W4200392	
4200382	2/2		x	x	x	W4200402	W4200392	
4200373	3/3-3+3/3+3	x				W4200403	W4200393	IPW/1000-B ④A
4200383	3/3-3+3/3+3		x	x	x	W4200403	W4200393	IPW/1000-B ④A
4200374	4/4-4+4/4+4	x					W4200394	IPW/1000-A ①
4200384	4/4-4+4/4+4		x	x	x		W4200394	IPW/1000-A ②
4200375	4/3	x				W4200405		
4200385	4/3		x	x		W4200405		
4200386	6/3		x	x		W4200406		
② 4200464	4/4-4+4/4+4	x		x	x		W4200394	IPW/1000-A
④B 4200571	3/2 (6/3 TRANS)		x			W4200590		
④C								
⑥A 4200789	3/3 (8/4 TRANS)		x					W4200770



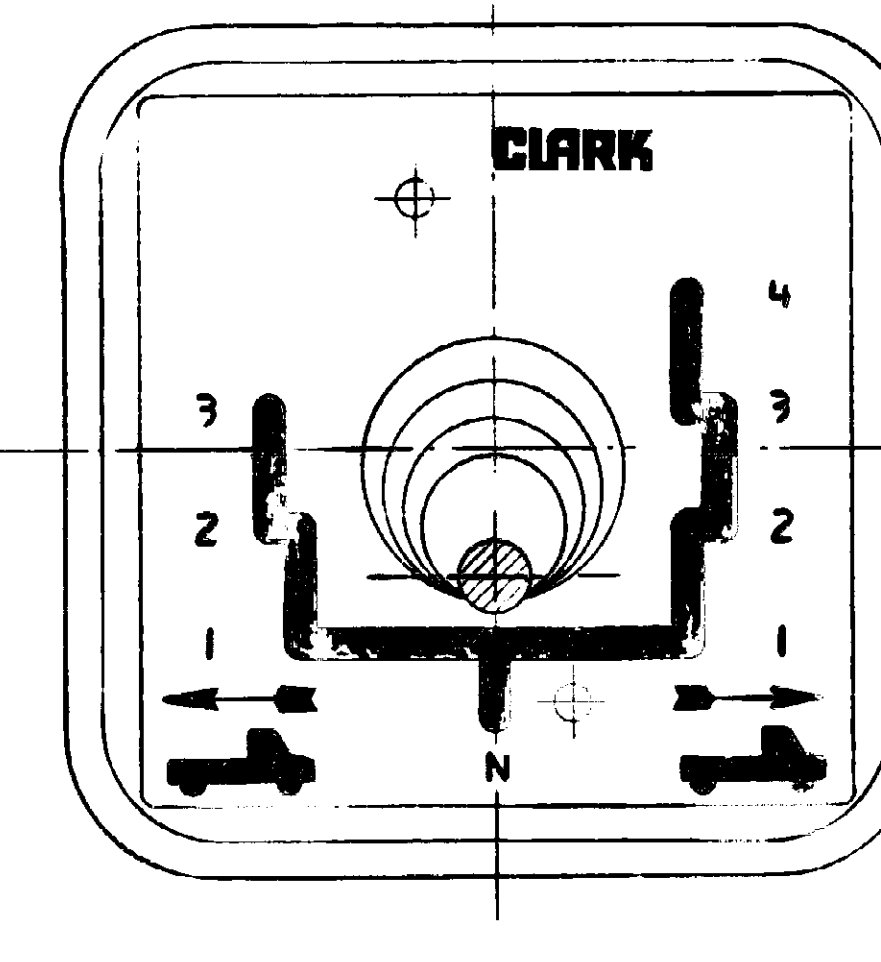
3 FWD-2 REV-SPEED (6/3 TRANS)



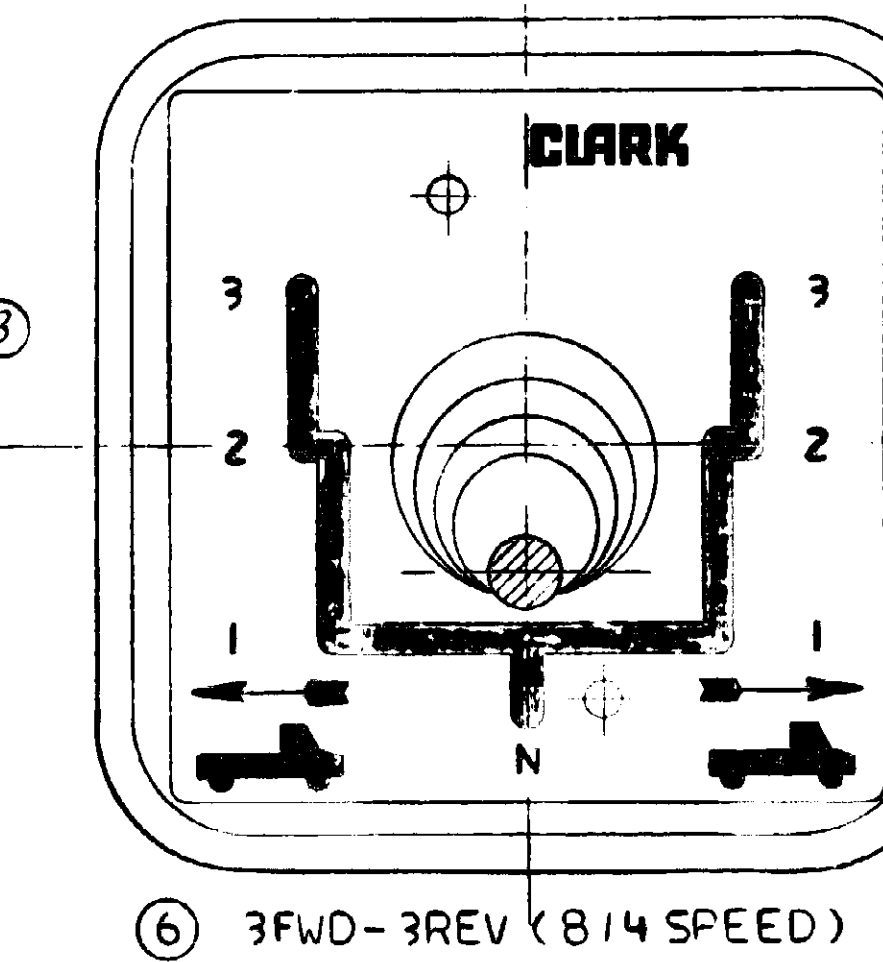
6 FWD + 3 REV - SPEED



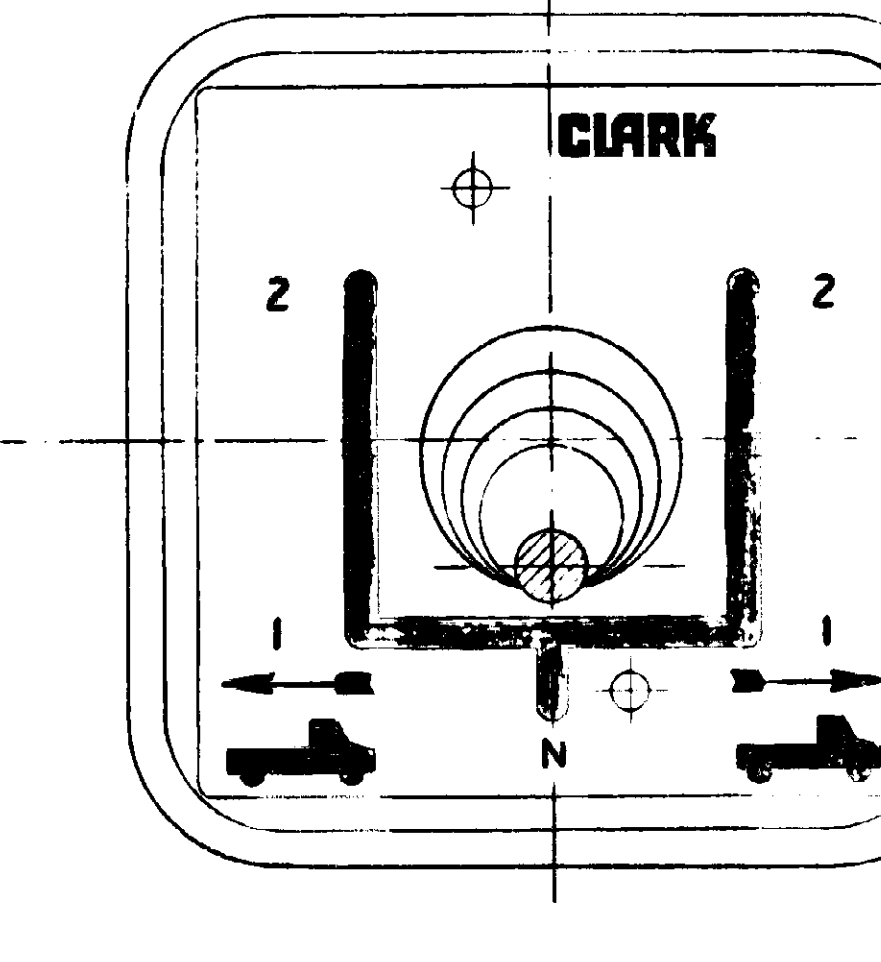
4-SPEED



4 FWD - 3 REV-SPEED

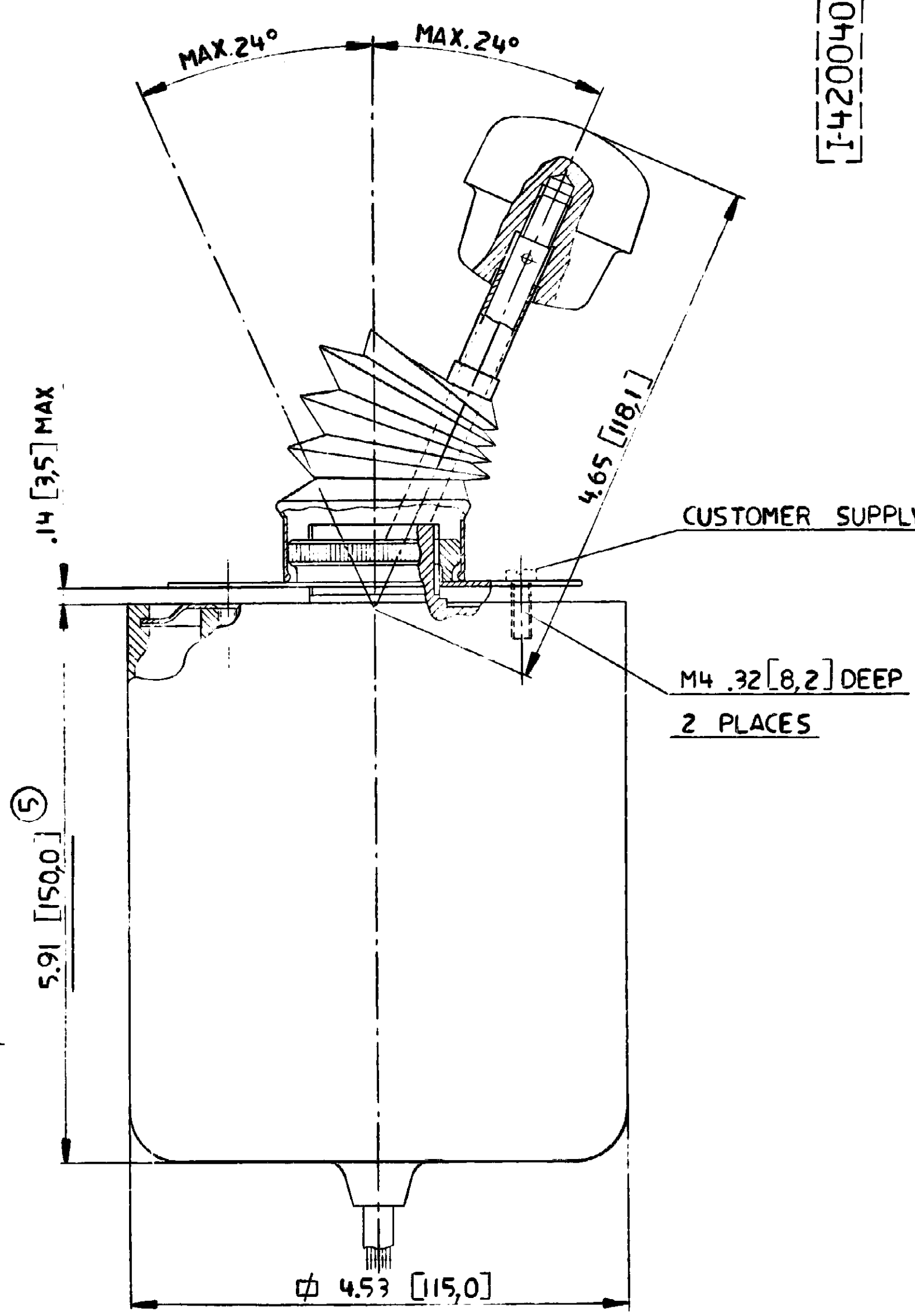
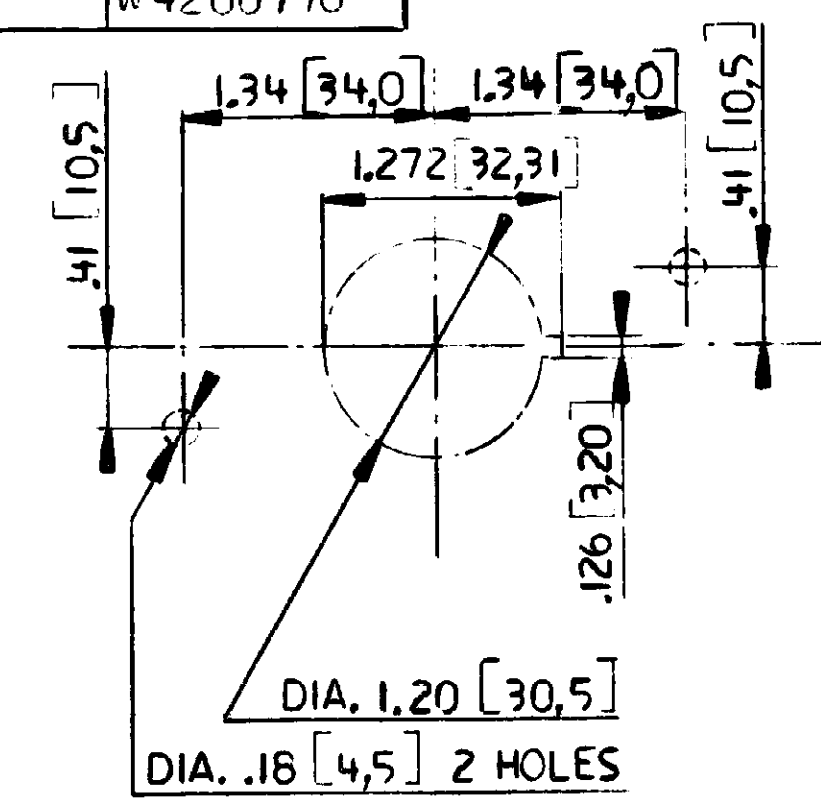


3-SPEED

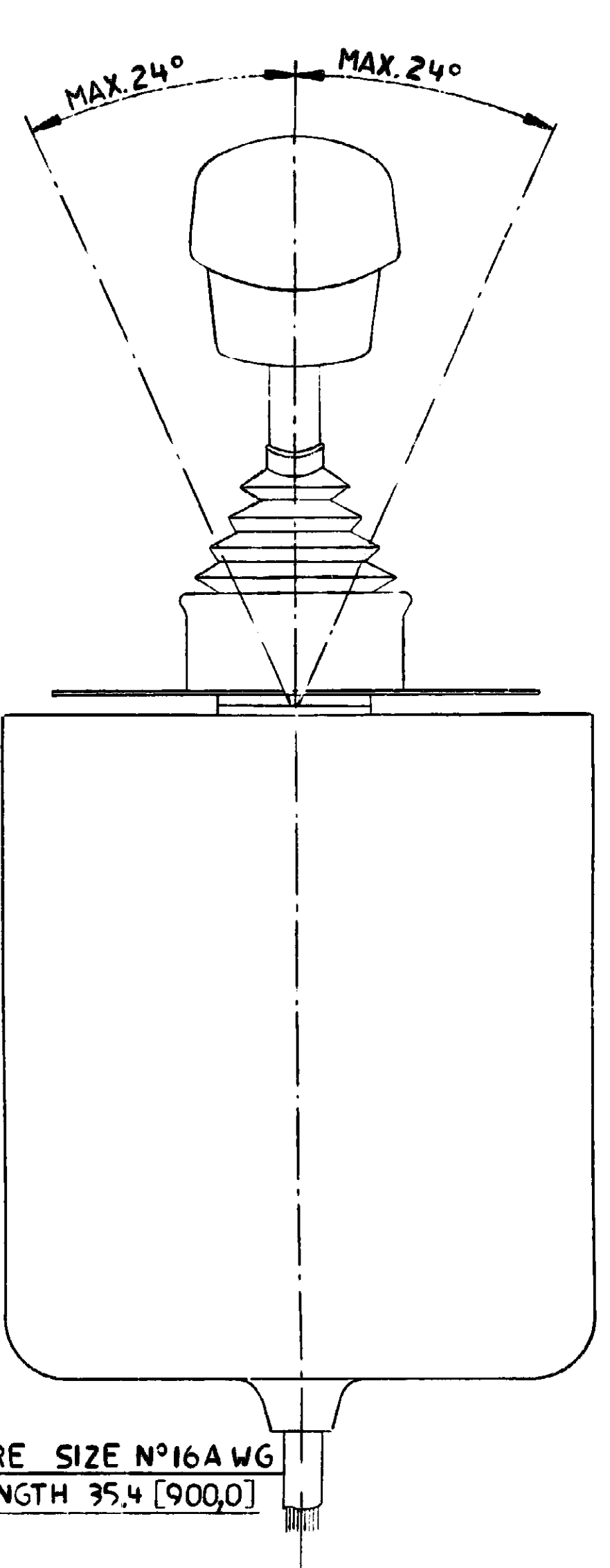


2-SPEED

INSTALLATION DIMENSIONS



I-4200400



WIRE SIZE N°16A WG
LENGTH 35.4 [900.0]

REV	DESCRIPTION	CHG NOTICE	DATE	APPROVAL
6B	ADDED & REMOVED	IC 8700 50	21.04.87	6K
6P	ADDED AND REMOVED	IC 8700 50	08.04.87	PF
5	WAS 5.12 [132.0]	IC 8700 50	01.04.86	LT
4E	ADDED	IC 8700 50	08.01.86	LT
3	REVISED CHIT - ATTEM	IC 8700 50	22.01.85	LT
2	ATL-4200464	IC 8700 50	01.02.85	AP
1	WAS IPW/4200770	IC 8700 50	28.08.84	6Z

VOLTAGE 12 AND 24 VDC
AMBIENT TEMPERATURE MAX. +176°F [+80°C]
MIN. - 40°F [-40°C]

DIM ARE IN INCHES DIM IN [] ARE MM UNITS IN [] ARE ISO METRIC EXCEPT AS NOTED		DWN G.2. CHK L.T. REL	29.03.84 09.04.84
ELECTRIC CAB CONTROL INSTALLATION DRAWING		CLARK I-4200400	
SHEET 1 OF 1			



HARDWARE

APC312 : Advanced Programmable Controller

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1. Hardware block diagram

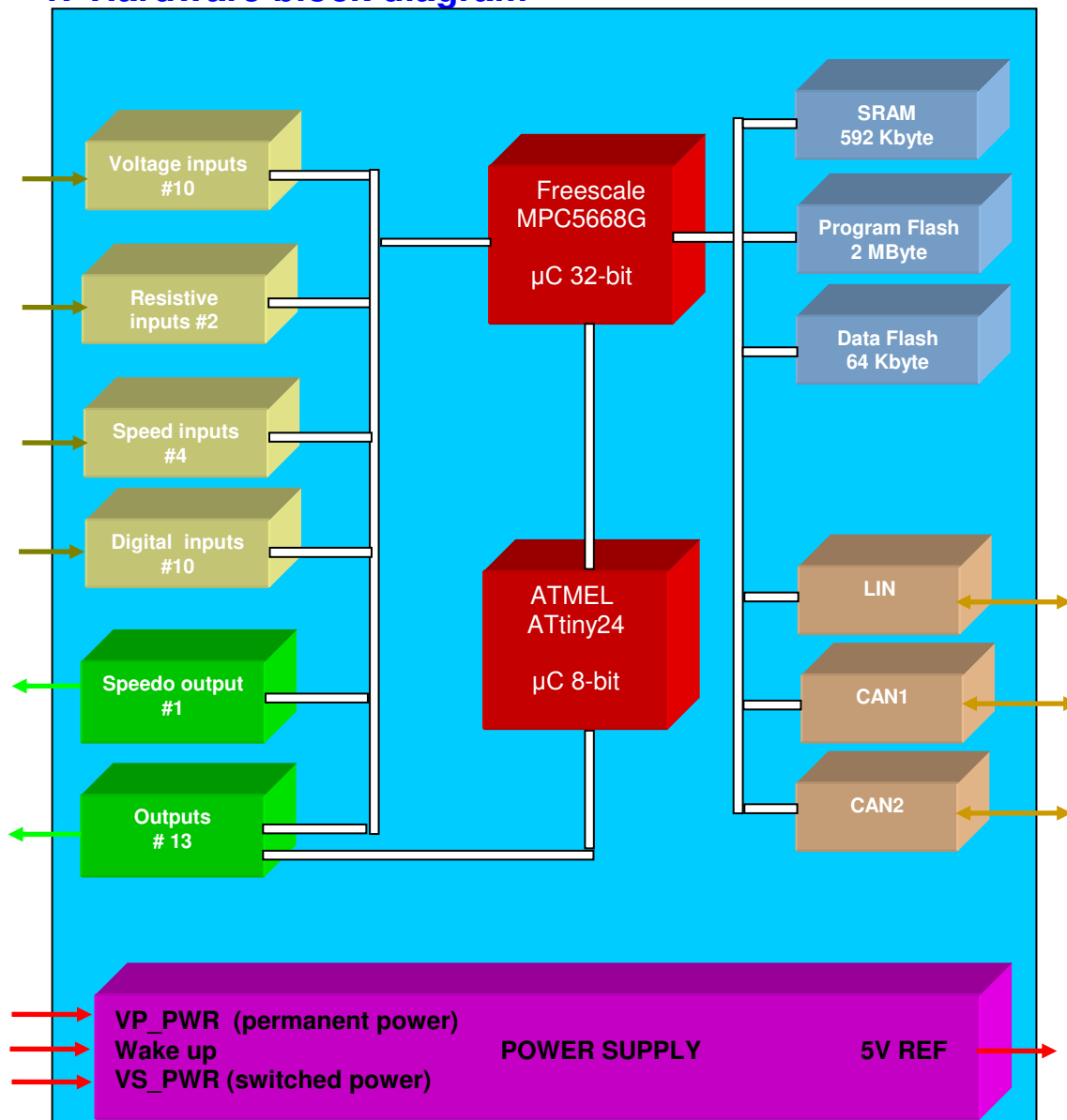


Figure 1 : APC312 Blockdiagram

- Power supply input 12/24V DC
- Maintaining minimum functionalities in low voltage conditions (core and communication lines stay active)
- Protection against reversed battery polarity
- User diagnostics by CAN or by Remote Display RD.120
- Proportional control of valves via current measurement
- Both CAN V2.0B are J1939 compliant
- LIN for remote display
- Auto power-off

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1.1 Limits and standards

1.1.1 Functional status classification

The following functional classes are used to indicate how the control unit performs during the environmental tests in table 2.

Class A: All functions of a device/system are performed as designed during and after exposure to interference.

Class B: All functions of a device/system are performed as designed during exposure, however, one or more of them can go beyond specified tolerance. All functions return automatically to within normal limits after exposure is removed.

Class C: A function of a device/system is not performed as designed during exposure but returns automatically to normal operation after exposure is removed.

Class D: A function of a device/system is not performed as designed during exposure and does not return to normal operation until exposure is removed. The device system is reset by simple action of the operator.

Class E: One or more functions of a device/system are not performed as designed during and after exposure and cannot be returned to proper operation.

1.1.2 Absolute maximum ratings

Operation outside these limits causes damage to the controller.

APC312	
Vbatt (supply voltage)	9...32 V
Operating temperature	-40°C to +85°C
Storage temperature	-55°C to +85°C
Max. Power supply current	15 A
Short Circuit to GND	All terminals except power supply terminals
Short circuit to Vbatt	All terminals except GND terminals

Table 1 : APC312 Absolute ratings

All functions operate as intended when the controller is used within specified operating limits. Use beyond this limits can cause structural damage to the controller.

PARAMETER	STANDARD	LIMITS, REMARKS
1. Min/Max supply voltage	SAE J1445:2006	9...32 V, class A
2. Operating temperature		-40°C to +85°C, class A
3. Storage temperature		-55°C to +85°C
4. Supply current		
Maximum		15 A
Standby current		Max current of 1 mA, Off state, consumption on VBATP (permanent power supply) only
5. EMC		
Emission	ISO 13766: 2006 ISO 14892: 1998 EN 12895: 2000 EN 13309: 2000	EN12895 uses different emission test setup Compliant to all referred standards
Conducted Emission (voltage method)	CISPR 25:2008	CISPR25 Class 3 compliant

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Electro-magnetic immunity 1	ISO 13766: 2006 ISO 14892: 1998 EN 12895: 2000 EN 13309: 2000	EN 12895 uses different immunity test setup
Bulk current injection	ISO 11452-4:2005	1-400 MHz 150 mA class A for 12 and 24 applications
Radiated EM energy AM modulation	ISO 11452-2:2004	V. polarization 80 -1000 MHz 150 V/m H. polarization 400- 1000 MHz 150 V/m Class A for 12 and 24 applications
Electro-magnetic immunity 2	2004/104/EC	
Radiated EM energy Pulse modulation	ISO 11452-2:2004	V. polarization 800 - 2000 MHz 150 V/m H. polarization 800 - 2000 MHz 150 V/m Class A for 12 and 24 applications
Magnetic field immunity	ISO11452- 8:2007 / Covers SAEJ1113-22	15 to 1000 Hz: 162 dBpT or 100 A/m 1 KHz to 10 KHz: 162 to 139 dBpT 10 KHz to 150 KHz: 139 to 122 dBpT Class A for 12 and 24 applications
Electro-static discharge 1		Unit either isolated from ground plane or mounted on ground plane
Contact Discharge	ISO 10605:2001	Testlevel IV 8kV Class A for 12 and 24 applications
Air Discharge	ISO 10605:2001	Testlevel IV 15kV Class A for 12 and 24 applications
Electro-static discharge 2		Unit either isolated from ground plane or mounted on ground plane
Contact Discharge	EN 61000-4-2:2001	Testlevel IV 8kV Class A for 12 and 24 applications
Air Discharge	EN 61000-4-2:2001	Testlevel IV 15kV Class A for 12 and 24 applications
6. Transient behaviour		
Conducted Transients Pulse 1 (inductive load switching)	ISO 7637-2:2004	Class C for 12 V applications with Us= -100V / 5000 cycles Class C for 24 V applications with Us= -600V / 5000 cycles
Conducted Transients Pulse 2A (positive inductance transient)	ISO 7637-2:2004	Class A for 12 and 24V applications with Us= +50V / 5000 cycles
Conducted Transients Pulse 2B (positive inductance transient)	ISO 7637-2:2004	Class C for 12 V applications with Us= 10V / 10 cycles Class C for 24 V applications with Us= 20V / 10 cycles
Conducted Transients Pulse 3A & 3B (positive and negative coupling)	ISO 7637-2:2004	Class A for 12 V applications with 3a: Us= -150V / 1 hour 3b: Us= +100V / 1 hour Class A for 24 V applications with 3a Us= -200V / 1 hour 3b Us= +200V / 1 hour
Conducted Transients Pulse 4 (cranking)	ISO 7637-2:2004	12 V applications: Class A for core and CAN and class C for other functions with Us= -7V / Ua= -6V / 10 times 24 V applications: Class A for core and CAN and class C for other functions with Us= -16V / Ua= -12V / 10 times

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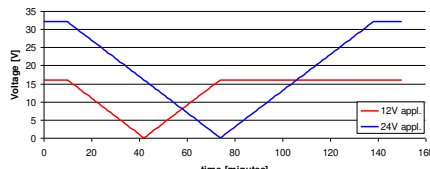
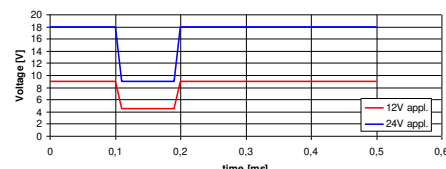
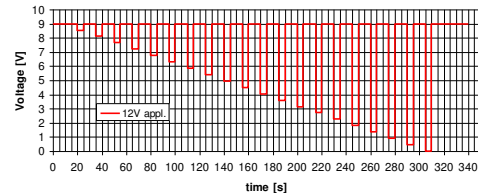
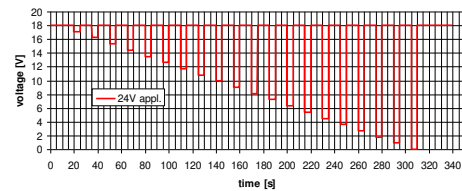
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Conducted Transients Pulse 4 (cranking)	ISO16750-2:2006	12V applications: Level I, Class A for core and CAN interfaces Class C for other functions Level II, class C Level III, class C 24V applications: Level I, Class A for core and CAN interfaces. Class C for other functions Level II, class C Level III, class C
Conducted Transients Pulse 5A (load dump)	ISO 7637-2:2004	Class C for 12 V application: $U_a = 14V$, $U_s = 87V$, $R_i = 2\Omega$, $T_d = 400ms$, $T_r = 5ms$ 5 cycles Class C for 24 V applications: $U_a = 28V$, $U_s = 123V$, $R_i = 2\Omega$, $T_d = 350ms$, $T_r = 5ms$ 1 cycles
Voltage transient emission test	ISO 7637-2:2004	Supply voltage: 27V ON/OFF switching
Immunity to slow decrease and increase of the supply	ISO 16750-2:2006	 Class C for 12 and 24V applications
Immunity to momentary drops In supply voltage	ISO 16750-2:2006	 Class C for 12 and 24V applications
Reset behaviour at voltage drop	ISO 16750-2:2006	 Class C for 12V applications  Class C for 24V applications
7. Short Circuit Protection		
To GND	SAE J1455:2006	All terminals ⁽¹⁾ (short is applied when the unit is powered.)
To GND		All terminals ⁽¹⁾ (short is present when the unit is switched on)
To Vbat	SAE J1455:2006	All terminals ⁽²⁾ (short is applied when the unit is powered.)

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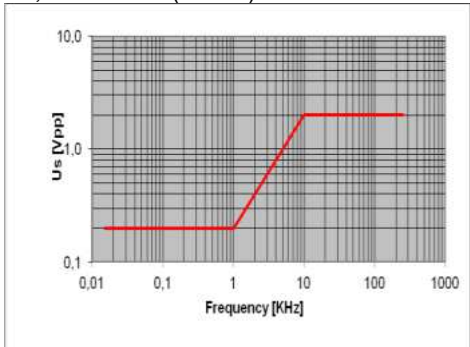
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To Vbat		All terminals ⁽²⁾ (short is present when the unit is switched on)
8. Steady State Behaviour		
Min/Max operating voltage	SAE J1455:2006	
Reverse polarity	SAE J1455:2006	No current flow during reverse polarity Class C for 12V applications: -18V / 5 minutes maximum Class C for 24V applications: -36V / 5 minutes maximum
Jump start	SAE J1455:2006	Class C for 12V applications: 28V / 5 minutes maximum Class C for 24V applications: 48V / 5 minutes maximum
Immunity to accessory noise or superimposed alternating volt.	ISO 16750-2:2006	14.0 + 2.0 sin (2 pi ft) V (12 V systems) 27.0 + 3.0 sin (2 pi ft) V (24 V systems) Source impedance 0.1 Ohm Frequency from 50Hz to 20KHz 10 cycles Class A for 12 and 24 applications
Mutual coupling test	ASAE EP455:2003	Power source lines: 450 exp[-t/(14E-6)]sin(2π*10E6t) V Signal lines: +/-400 exp[-t/(14E-6)] V Class A for 12 and 24V applications
Immunity to transients on supply and signals lines pulse a and b (capacitive coupling clamp)	ISO7637-3 or SAEJ1113-12:2006	Class A for 12 and 24V applications with Vs= -80V, 10 min test, 90ms<Burst cycle time<110ms Class A for 12 and 24V applications with Vs= 80V, 10 min test, 90ms<Burst cycle time<110ms
Immunity to continuous power line disturbance	ISO11452-10:2009	Class A for 12 applications with 13,5 + Us*sin (2*π*ft) V Class A for 24 applications with 27,0 + Us*sin (2*π*ft) V 
Immunity to continuous ground offset voltage		Class A for 12 and 24 applications
Immunity to transient ground offset voltage		Class A for 12 and 24 applications
9. Sealing (dust and water ingress)	IEC 60529:1992	IP66, IP69K ⁽³⁾
10. Dry heat tests		
High temperature soak test		96h @ 85°C powered Class A for 12 and 24 applications
Low temperature soak test		96h @ -40°C powered Class A for 12 and 24 applications

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Operating temperature		7x 48h cycle, variant on SAE J1445 t° profile between -40°C and 85°C, powered Class A for 12 and 24 applications
Thermal shock		4x 24h cycle, variant on SAE J1445 t° profile, powered Class A for 12 and 24 applications
11. Shock		
Handling drop test	Dana standard	1m on concrete surface , no hidden damage
Operational shocks	IEC 60068-2-29:1987	2500 bumps positive and negative Amplitude: 50 g, ½ sine Duration: 11 ms Rate: 2 bumps/sec Direction: 3 orthogonal axes Class A for 12 and 24 applications
Transit drop test	Dana standard	Drop test with unit in cardboard package 122cm on concrete surface , no hidden damage.
12. Vibration		
Wide random vibration test on road conditions	SAE J1455:2011	Frequency range: 5 Hz to 2 kHz Duration: 1 hour Amplitude: 6.5 g RMS Direction: 3 orthogonal axes Profile: 20 Hz : 0.0116515 g2/Hz 20 to 80 Hz: +3 dB/oct 80 to 350 Hz: 0.04602 g2/Hz 350 to 2 kHz: -3 dB/oct 2 kHz: 0.0080541 g2/Hz Class A for 12 and 24 applications
Wide random vibration test off-road conditions	IEC 60068-2-35:1983	Duration: 24 hours Direction: 3 orthogonal axes Profile: 10 Hz : 0.005 g2/Hz 150 Hz : 0,060 g2/Hz 220 Hz : 0.080 g2/Hz 350 Hz : 0.040 g2/Hz Class A for 12 and 24 applications
Resonance search test		Frequency range from 10 to 2000Hz. Constant acceleration 4g. Sweep rate : 1oct/min. Direction: 3 orthogonal axes. Duration: examine each resonance point Q>=5. Dwell the vibration frequency for 30 minutes at each resonanance point. Class A for 12 and 24 applications
13. Gravel bombardment	SAJ E400:2001	No degradation of the unit after the test
14. Corrosive atmosphere		
Icing cycle		Between -40°C and +100°C, 24 hours Class A for 12 and 24 applications
85/85 relative humidity test		Duration: 42 days @ 85°C and RH= 85% Class A for 12 and 24 applications
Salt spray test	IEC60068-2-11	Duration: 48h Remark: tested on same housing but different hardware.

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Chemical resistance test	BS7691 section 6.11.2.4:1994	Coat once a day for a duration of 3 days. Overview chemicals: Diesel, gasoline, transmission oil, weak battery acid, Hydraulic oil, ethylene glycol 50% aqueous solution, Urea Nitrogen, NPK fertilizer 3x 15% each,...
Ozone chamber test	ASTM D1171-99	The used materials are covered by certification of compliance.
Resistance to fungus	SAE J1455 - 4.6.3	Limited to PCB certification
15. HALT (Highly Accelerated Life Testing) ⁽⁴⁾	GMW8287	Thermal stress test above operating limits Vibration stress test above operating limits Combined thermal and vibration stress test above operating limits

Table 2 : APC312 Operating limits

- (1) Except the supply voltage terminals. An externally placed series fuse (15A) must be used to prevent damage.
- (2) Except the GND terminals: an externally placed series fuse (15A) must be used to prevent damage.
- (3) It is not allowed to aim the high pressure water jet directly towards the connector.
- (4) The purpose of the HALT is to evaluate the design robustness. To support this, each step of the sequence is stressing the product beyond its specification. Therefore each step of the sequence could lead to a product failure.

Remark on auto power-off:

During the auto power-off procedure it takes maximum 5 seconds to save parameters into the memory. After this time it is allowed to disconnect the permanent power without losing data. Permanent power removal within this period may result in flash corruption!


The APC312 complies to following standards and directive:

standard	year	
ISO 13766	2006	Earth moving machines
ISO 14982	1998	Agricultural and forestry machines
EN 12895	2000	Industrial trucks
EN 13309	2000	Construction Equipment machines with internal Electrical Power Supply
Commission directive 2004/104/EC	2004	Adapting to technical progress council directive 72/245/EEC

Table 3 : APC312 standards and directives

The APC312 has CE-marking for off-highway applications and E-marking in accordance to the United Nation Regulation: ECE R10.04.

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1.2 Electrical Characteristics

1.2.1 Digital inputs (DI0 – DI9)

All inputs are activated when switched to plus.

Parameter	APC312 DI0-DI7
Number	8
Low level maximum voltage ⁽¹⁾	< 2,25 V
High level minimum voltage ⁽¹⁾	> 3,80 V
Pull down resistor value	10K
High level input current	< 5 mA
Input 3 db cut-off frequency	50 Hz
Maximum input voltage	48 V (5 minutes)
Fault detection capability ⁽²⁾	No

⁽¹⁾ 8 inputs are connected via an analog multiplexer to the controller.

⁽²⁾ Faults can only be detected by combining several inputs redundantly.

Table 4 : APC312 digital input limits

The inputs DI8 and DI9 are activated when switched to plus and are able to measure the duty cycle of a PWM signal.

Parameter	APC312 DI8-DI9
Number	2
Low level maximum voltage	< 2,25 V
High level minimum voltage	> 3,80 V
Maximum PWM frequency	1000 Hz
Duty cycle measurement resolution	0,01%
Pull down resistor value	10K
High level input current	< 5 mA
Input 3 db cut-off frequency	10 KHz
Maximum input voltage	48 V (5 minutes)
Fault detection capability	No

Table 5 : APC312 digital inputs for duty cycle measurement

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1.2.2 Resistive inputs (ANIR0-ANIR1)

There are 2 analogue resistive inputs.

Parameter	APC312
Range	0 – 5K Ω
Resolution	10 bits
Accuracy full scale	$\pm 100\Omega$
Maximum input voltage	32 V
Fault detection capability	Related to input range

Table 6 : APC312 Resistive input limits

1.2.3 Voltage inputs type 2B (ANI_2B0-ANI_2B4)

These voltage inputs are typical used to measure the output voltage from pressure sensors on the valve block. The inputs have a pull-up resistor of 12K to an internal 8 V reference voltage.

Parameter	APC312
Number	5
Range	0 – 5000 mV
Resolution	10 bits
Accuracy full scale	± 100 mV
Input impedance 0 - 5V	12 K Ω (pullup to 8.0V)
Maximum input voltage	32 V
Resolution	10 bits
Fault detection capability	Related to input voltage range

Table 7 : APC312 Voltage input type 2B limits

1.2.4 Voltage inputs type 2C (ANI_2C0-ANI_2C4)

These voltage inputs are typical used to measure the output voltage from potentiometers. The inputs have a pull-up resistor of 100K to an internal 8 V reference voltage.

Parameter	APC312
Number	5
Range	0 – 5000 mV
Resolution	10 bits
Accuracy full scale	± 100 mV
Input impedance 0 - 5V	100 K Ω (pullup to 8.0V)
Maximum input voltage	32 V
Fault detection capability	Related to input voltage range

Table 8 : APC312 Voltage input type 2C limits

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1.2.5 Speed inputs (SPIN0–SPIN3)

The APC312 supports sensors with integrated electronics like magneto resistive and hall sensors and without electronics like inductive sensors. For all types, open circuit and short circuit detection is implemented. The sensor type is software programmable and depends on the application.

1.2.5.1 Speed sensor with integrated circuit

The following table shows the common specification of the speed input channels for speed sensors with integrated circuit.

Parameter	APC312
Maximum input frequency	25 KHz
Accuracy	±1 % of the reading
Fault detection capability	Yes
Protection to short to plus (32V) for sensor and input	Yes
Protection to short to ground for sensor and input	Yes
Reverse polarity protection (-28V)	Yes
Bidirectional capability	Yes (pulse width measurement)

Table 9 : Speed input limits for electronic sensors

The speed inputs and sensor must withstand the maximum battery supply voltage without time limit.

1.2.5.2 Speed sensor without integrated circuit

The following table shows the common specification of the speed input channels for inductive or variable reluctance sensors.

Parameter	APC312
Maximum input frequency	10 KHz
Accuracy	±1 % of the reading
Fault detection capability	Yes
Protection to short to plus (32V) for sensor and input	Yes
Protection to short to ground for sensor and input	Yes
Reverse polarity protection (-28V)	Yes

Table 10 : Common speed input channel requirements

The speed inputs and sensor withstand the maximum battery supply voltage without time limit.

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1.2.6 Voltage reference

The 5 volt reference output voltages is used to supply sensors. It protected against shortcuts to ground and battery supply.

Parameter	APC312
Output voltage	5 V +/- 100 mV
Max output current	100 mA

Table 11 : APC312 Voltage reference limits

1.2.7 Speedometer output (SPEED0_OUT)

Parameter	APC312
Number	1
Max. output current	10 mA
Nominal output level OFF	< 1 V
Nominal output level ON	+12±10% V
Frequency range	16 – 10000 Hz
PWM Capability	Yes
Fault detection capability	No

Table 12 : APC312 Speedo meter output limits

1.2.8 Low side outputs

Low side switches can be used:

- As redunant switch to switch off high side outputs when a functional disorder is recognized.
- to control a load connected to battery supply.

These switches are controlled by the application program and the external 8-bit watchdog.

Parameter	APC312
Number	4
Current range	0 – 4 A
Fault detection capability*	Open, short to battery + and GND
PWM Modulation frequency	Fixed to 100 Hz
Duty cycle	OFF, ON or 50 %

* maximum resistance of a load to detect that a load is connected to the output is 400 Ω.

Table 13 : APC312 Low side output limits

1.2.9 High side outputs

Parameter	APC312
Number	4
Current range	0 – 4 A
Fault detection capability*	Open, short to battery + and GND
PWM frequency range	62-1000 Hz
Duty cycle	Can change between 1 and 99%

* maximum resistance of a load to detect that a load is connected to the output is 400 Ω.

Table 14 : APC312 High side output limits

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1.2.10 High side outputs with current feedback

Parameter	APC312
Number	5
Current range	0 – 2000 mA
Minimum Load resistance	2 Ω
Fault detection capability*	Open, short to battery + and GND
PWM frequency range	0 – 1000 Hz
Duty cycle	Can change between 1 and 99%

* maximum resistance of a load to detect that a load is connected to the output is 400 Ω .

Table 15 : APC312 High side output with current feedback limits

1.2.11 Communication interfaces

The APC312 has following communication interfaces:

Parameter	APC312
CAN interfaces	2
LIN	1

Table 16 : APC312 communication interfaces

Both CAN interfaces are from the type V2.0B and are J1939 compliant. The physical layer of the LIN interface is implemented on the board. The protocol is written for the communication with the remote display RD.120 from Dana.

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1.3 Safety features

The controller is designed to be **category 2 and PLd compliant** (per ISO13849 definition), based on:

- a feared event being the unintended activation of the safety related outputs.
- the safe state of the controller being the shut-down of all high and low side output.

1.3.1 Securisation of outputs

The APC312 provides securisation of the high side outputs by the use of low side outputs to remove the ground current return from the loads. See following figure. With this configuration low side outputs can be deactivated to protect connected loads to put the APC312 in safe mode by two mechanisms:

- Monitoring based on HSD diagnostic features: the application software deactivates the LSD. This is opened to any diagnostic information combination (for example one of the load short circuit, sum of measured currents on all HSD/loads above a given limit...).
- Auxiliary microcontroller control, described in the related section. Each low side output can be used with several high side outputs, provided it matches its maximum current capacity.

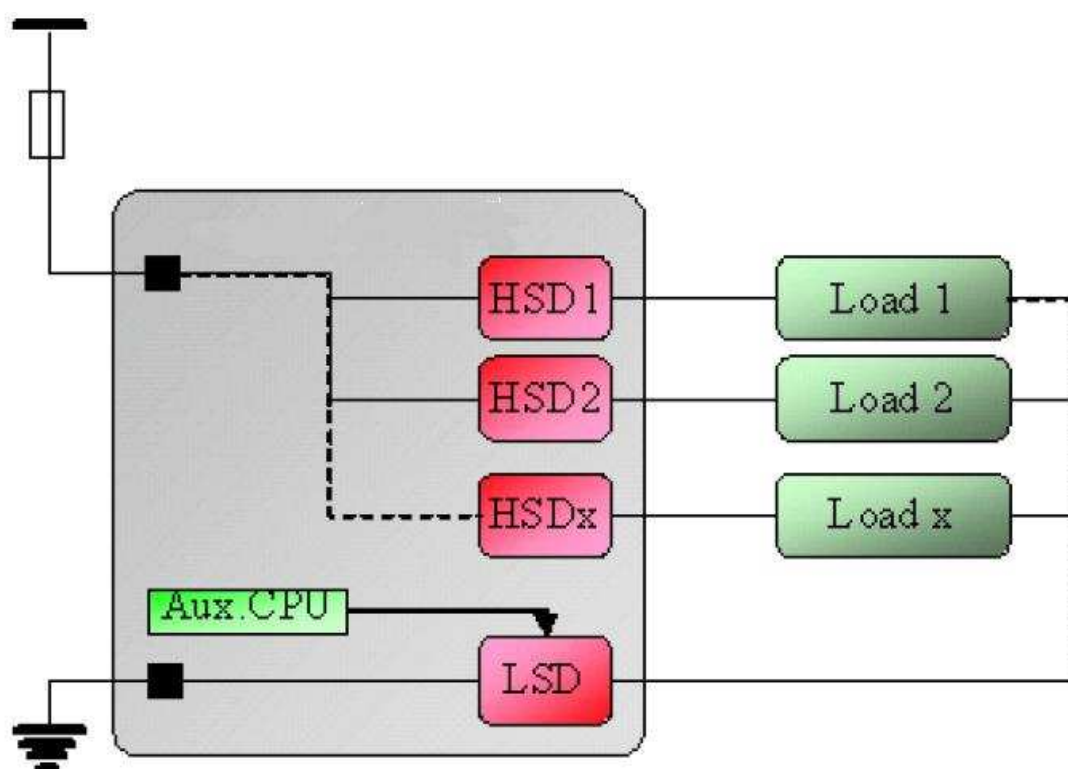



Figure 2 : Safety concept diagram

1.3.2 Securisation of inputs

The APC312 provides securisation of the inputs through redundancy. Additional inputs can be used to connect redundant sensors. Inputs are designed so that common elements between inputs (that could become a common cause of failure) are either avoided (for example connectors, passive networks, ICs ...) or diagnosed (for example power supplies, ADC...).

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1.3.3 Auxiliary μ C

An external auxiliary μ C monitors the main microcontroller activity. By this external watchdog role, it can detect a failure of the main microcontroller and put the APC312 in the safe mode by resetting the main microcontroller. It has its own power supply to avoid common cause of failure. The toggling of the watchdog shall be done by the application software and shall be 10ms \pm 20%.

The auxiliary microcontroller also interfaces with the low side outputs as a low side output watchdog to deactivate them directly in case of the main microcontroller failure. This de-activation can also be done by the application software separate from the command used in normal operations to reduce the reaction time to an hazardous event.

1.3.4 Health monitor

The basic support package of the control unit integrates a monitoring of several key hardware parameters like internal voltages, global current consumption, global temperature, ADC calibration, loss of SPI communication with the high side switches, loss of ground presence, execution and memory errors and provides a status of the unit to the application software among the following:


- **Green zone:** the unit operates normally within its specification.
- **Yellow zone:** The unit is in a over-power situation, due either to that the total current consumption delivered to the high side switches is too high or the internal temperature is above the specification. The controller however continues to fully operate. This zone is defined to allow a possible reaction from the application to for example shut down some non critical outputs. If the current consumption and temperature returns to normal, the controller will return to the green zone. In case of an over-current that does not return within specifications within 5 seconds, or an over temperature that does not return within specification within 30 seconds, the controller moves to red zone.
- **Red zone:** one or more key parameters are outside the controller specifications. To prevent a dangerous situation, the controller is moved to the safe state by shutting down outputs. However, the application will continue to operate including the communication on the CAN. The parameters involved in the red zone comprise internal voltage supplies malfunction, ADC malfunction, over-current/temperature/power, loss of communication between main microcontroller and high side switches, ground loss. The controller will remain in red zone until it is restarted.
- **Black zone:** the controller has encountered in its main microcontroller a core failure or a non correctable flash or RAM memory error. Considering the software can not run correctly and safety, the execution is halted. This leads to the external watchdog triggering the main microcontroller reset and restart of the controller.

1.3.5 Data Integrity

The data integrity and corruption detection is ensured by the Error Correcting Code (ECC) embedded in the main microcontroller. It applies only to its internal flash and RAM memories.

1.3.6 Additional features

Faults on internal supply voltages and voltage references are detected.
The availability of the ground loss detection input (ECU_GND_SENSE).

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1.3.7 Safety architectural metrics

The **category 2 and PLd compliant** is based on calculations and the hardware architecture following the ISO 13849 standard and the MIL-HDBK-217-F handbook. The calculation takes into account an average ambient temperature of 25°C. The failure probabilities calculated for the overall controller are:

Failure probabilities		Result
Probability of failure	λ	2,77E-06 per hour
Mean time to failure	MTTF	41,2 years
Probability of dangerous failure	λ_d	8.76E-07 per hour
Mean time to dangerous failure Note: it is recommended to use 100 years as maximum value in case the calculation result is beyond	MTTF _d	100 years
Diagnostic Coverage	DC	90,6 %
Probability of undetected dangerous failure	λ_{du}	8,26E-08 per hour
Assumptions on mission profile: controller powered on 50 hours per week, 52 weeks per year @ 28V, 25°C average ambient temperature		

Table 17 : APC312 failure probabilities

The above table provides an overall value of λ_d , considering all functions of the controller are involved into the safety channel being evaluated. It is intended to simplify the system evaluation by using a single information for the controller to be used as a sub-system for each individual safety channel evaluation. This value is maximized considering one safety channel will actually include only a limited number of functions, securing that the channel will complies with the performance targets.

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1.4 Physical dimensions

Dimensions: 140,5 x 195,5 x 50,2 mm³

Weight : approx. 0,72±10% kg

Material housing: ALU EN AC-46000 (AlSi9Cu3)

Cover: Plastique (PA66+20%GF)

Gasket: Silicone

Note that the mating connectors and wiring harness of the APC312, as shown in the drawings and pictures will not be supplied together with the APC312.

The mating connectors can be ordered from a local supplier for example RS-components.

The wiring harness has to be ordered from a local supplier.

See section 2.3 Mating connector and wiring harness.

TOP VIEW :

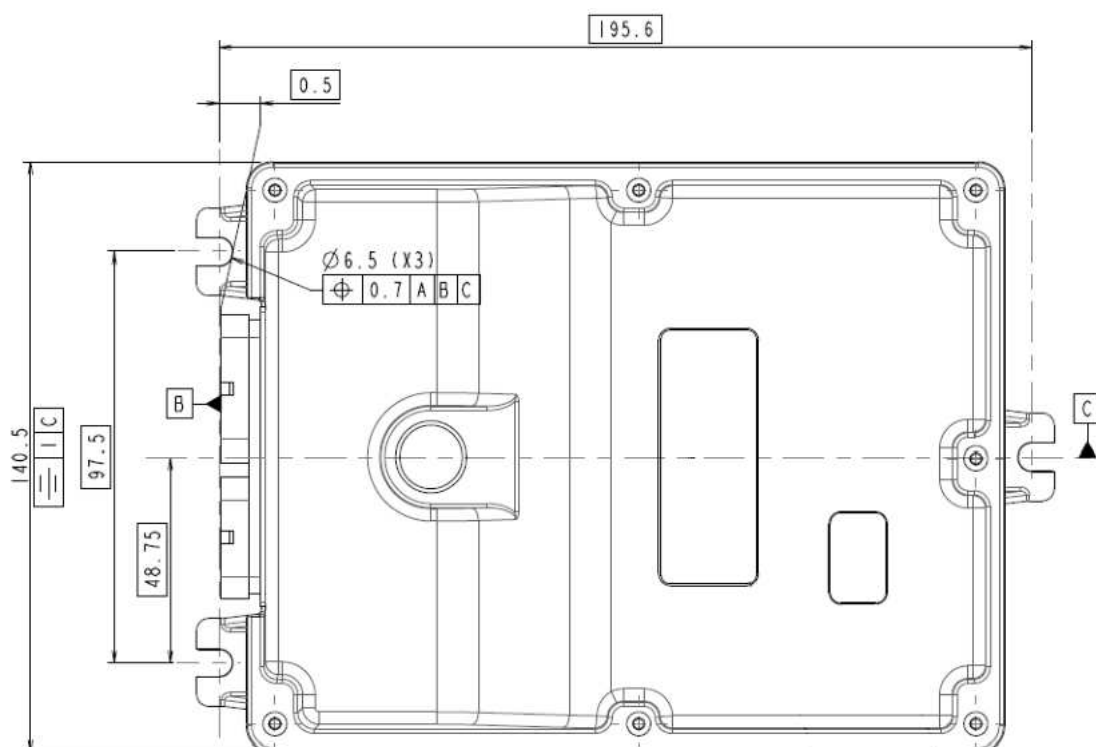


Figure 3 : APC312 – TOP VIEW APC312

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SIDE VIEW :

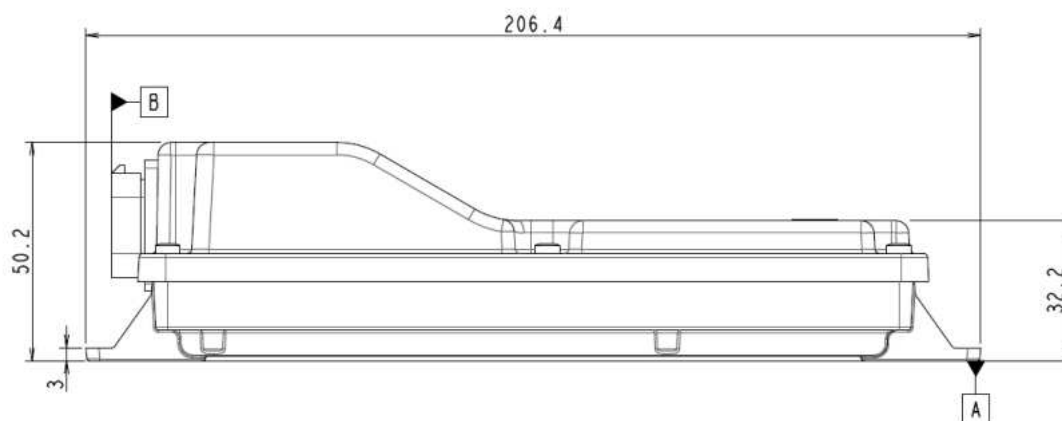


Figure 4 : Side view APC312

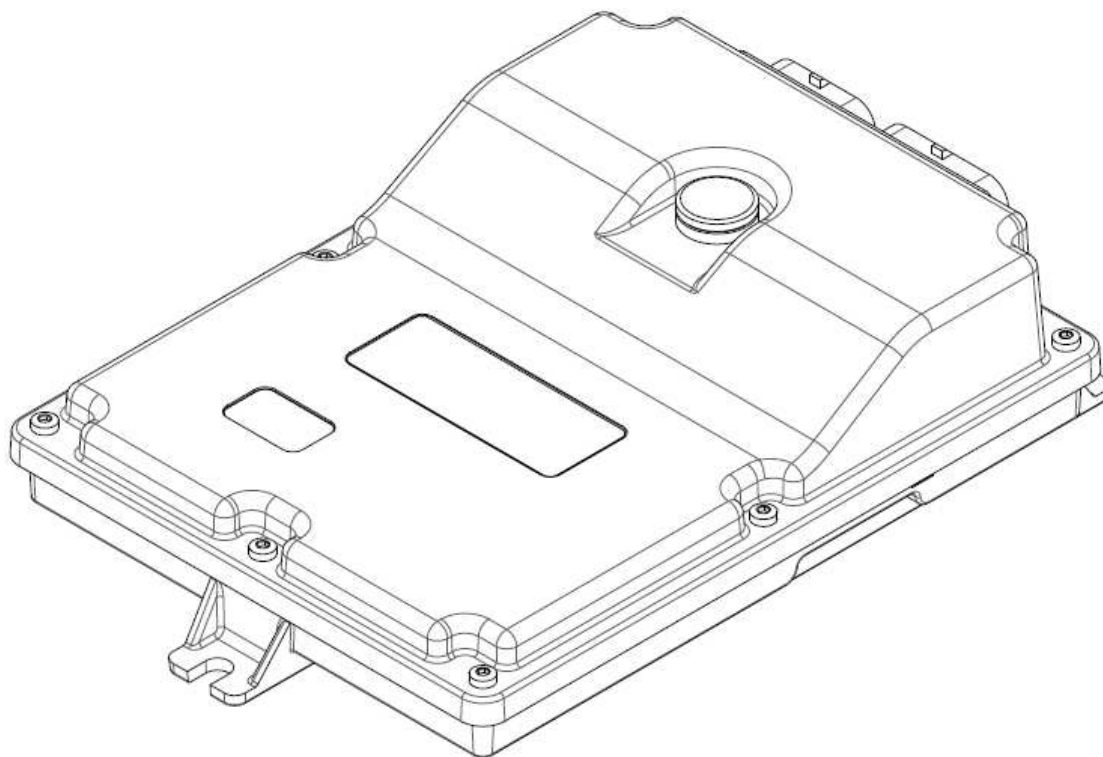


Figure 5 : 3D view APC312

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BOTTOM VIEW :



Figure 6 : Bottom view with and without view on the connector

FRONT VIEW :

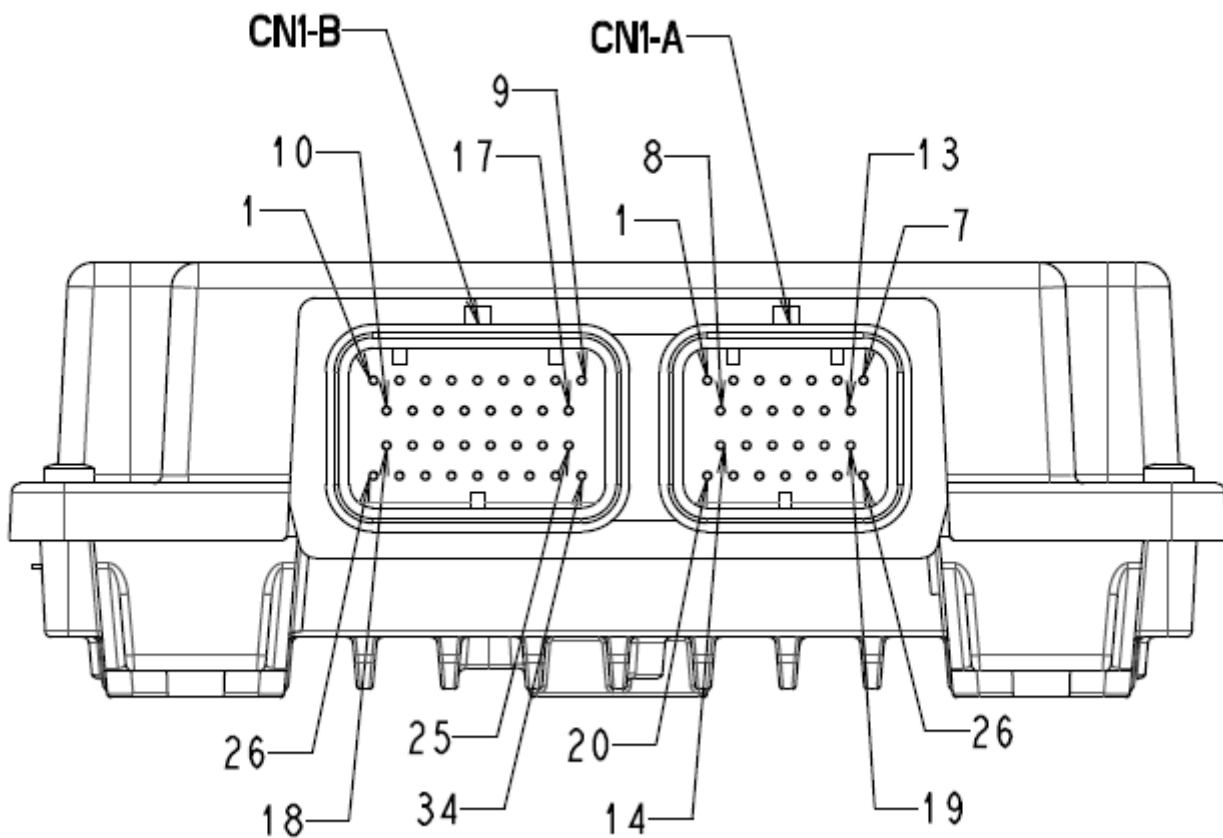


Figure 7 : Front view connector

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2. INSTALLATION GUIDE

2.1 Connectors

For the connection to the vehicle A 26-pole and 34-pole connector is used, TYCO brand, partnumbers are:

- TYCO 1473416-1 (26 pins connector)
- TYCO 4-1437290-1 (34 pins connector)



Figure 8 : Connectors APC312

The contacts for the both connectors are:

3-1447221-3 for a wire size range of 0,75 to 1,25 mm².

The recommended insulation diameter of the wire is between 1,8 and 2,4 mm.

The part number of cavity plugs for not connected pins is 4-1437284-3.

Cavity Plug

Part No. 4-1437284-3

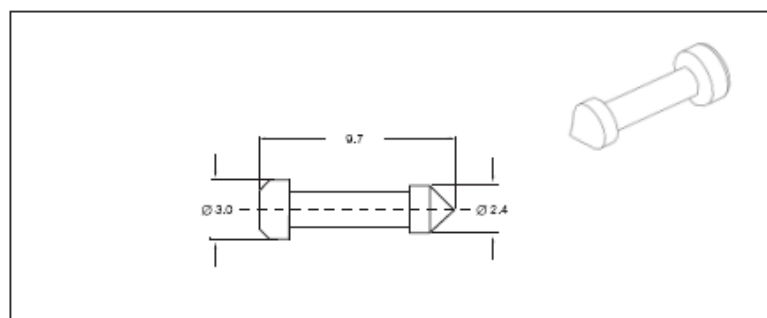


Figure 9 : Cavity pin for connector APC312

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2.2 Mechanical mounting

2.2.1 General advices

- It has to be assured that water cannot infiltrate through the wiring harness into the control unit.
- The pressure compensation element (DAE) as well as the sealing may not be submersed in water. To ensure sealing, the complete harness shall be connected to the unit and unused pins shall be fitted with TYCO cavity plugs. See Figure 9.
- Dana's consent is required if the mounting instructions are not followed.

2.2.2 Mounting

- 3 Screws with diameter M6, torqued at 9 Nm \pm 10%.
- Permitted applications: passenger car, trucks and off-highway vehicles.
- The pressure compensation element (DAE) as well as the sealing may not be submersed in water.
- Avoid water stagnation around Gore-Tex cell area.
- Avoid dust accumulation in the cooling fins.
- Permitted mounting location: chassis, cabine and engine compartment.
- Bouncing of ECU in mounting position is not allowed.
- The ECU should be mounted in such a way, that the pressure compensation element and the connector for the wiring harness are not exposed to direct splashing water.
- The ECU has to be mounted in such a way that its connector is freestanding in order to allow its female counterpart to be connected without obstructions.
- The ECU has to be mounted on a totally flat surface (flatness 0,5/100x100 mm) in order to ensure its cooling.
- Avoid water ingress via the wires of the mating connectors into the connector of the unit by mounting the unit in such way that no water stagnation on the mating connectors is possible. The following picture shows the mounting position of the control unit to avoid water ingress in the connector of the unit.
- Direct high pressure jet (IP69K) must be avoided on both connectors. Add additional external protection in order to avoid direct exposure to the connector.

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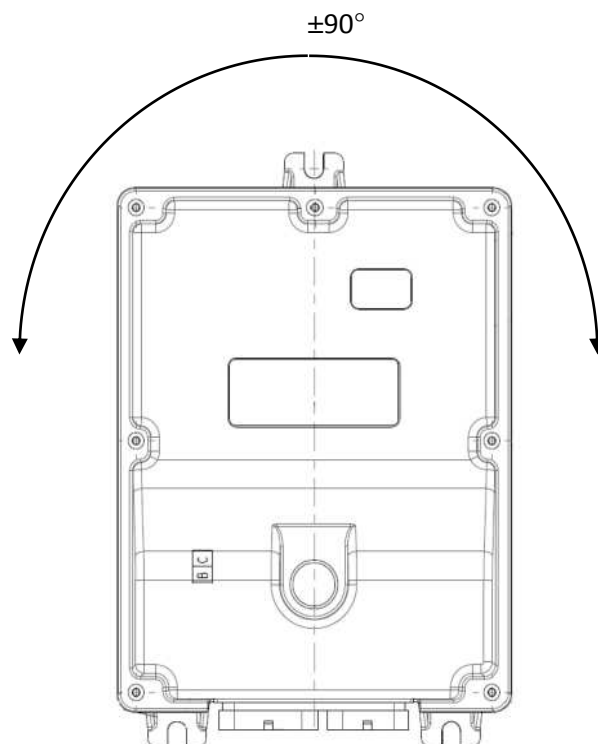



Figure 10 : Mounting position of the control unit

2.2.3 Wiring Harness

- Harness needs to be fixed mechanically in the area of the ECU (Distance < 150 mm)
- Harness needs to be fixed in such a way that in case of an excitation, the wiring harness is in-phase with the ECU (e.g. at the fixing point of ECU).

2.3 Connector pin assignment

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The 60-pole connector pin assignment from the control unit is as follows:

Wire	Pin	Name	Function	Wire	Pin	Name	Function
W1	A1	AO 3 ⁽¹⁾	High side output 3 (I-feedback)	W31	B5	ANI V(B) 3	Analog voltage type 2B input 3
W2	A2	SPWR 1	Switched battery supply	W32	B6	LSO 3 ⁽⁴⁾	Low side output 3
W3	A3	SS 0	Speed sensor input 0 +	W33	B7	SPWR 2	Switched battery supply
W4	A4	SPWR 1	Switched battery supply	W34	B8	ANI V(C) 3	Analog voltage type 2C input 3
W5	A5	LSO 0 ⁽⁴⁾	Low side output 0	W35	B9	SPWR 2	Switched battery supply
W6	A6	SS 1	Speed sensor input 1 +	W36	B10	5V REF	5V reference output
W7	A7	PPWR	Permanent power supply	W37	B11	DI 4 ⁽²⁾	Digital input 4
W8	A8	LSO 1 ⁽⁴⁾	Low side output 1	W38	B12	DI 9 ⁽³⁾	Digital input 9
W9	A9	ANI V(B) 0	Analog voltage type 2B input 0	W39	B13	DI 5 ⁽²⁾	Digital input 5
W10	A10	ANI V(B) 4	Analog voltage type 2B input 4	W40	B14	DO 3 ⁽⁵⁾	High side output 3
W11	A11	ANI V(B) 1	Analog voltage type 2B input 1	W41	B15	DI 6 ⁽²⁾	Digital input 6
W12	A12	5V REF	5V reference output	W42	B16	NC	Not connected
W13	A13	WAKE	Wake up active high	W43	B17	DI 7 ⁽²⁾	Digital input 7
W14	A14	LSO 2 ⁽⁴⁾	Low side output 2	W44	B18	AO 1 ⁽¹⁾	High side output 1 (I-feedback)
W15	A15	DI 0 ⁽²⁾	Digital input 0	W45	B19	DO 0 ⁽⁵⁾	High side output 0
W16	A16	ANI V(C) 0	Analog voltage type 2C input 0	W46	B20	ANI V(C) 4	Analog voltage type 2C input 4
W17	A17	DI 1 ⁽²⁾	Digital input 1	W47	B21	AO 4 ⁽¹⁾	High side output 4 (I-feedback)
W18	A18	ANI V(C) 1	Analog voltage type 2C input 1	W48	B22	AO 0 ⁽¹⁾	High side output 0 (I-feedback)
W19	A19	DI 2 ⁽²⁾	Digital input 2	W49	B23	GND	Battery ground
W20	A20	GND	battery ground	W50	B24	GND	Battery ground
W21	A21	DI 3 ⁽²⁾	Digital input 3	W51	B25	DO 2 ⁽⁵⁾	High side output 2
W22	A22	ANI R0	Resistive input 0	W52	B26	LIN	LIN interface
W23	A23	CAN2 HIGH	CAN V2.0B BUS	W53	B27	SS 2	Speed sensor input 2 +
W24	A24	CAN2 LOW	CAN V2.0B BUS	W54	B28	SGND	Signal ground
W25	A25	DI 8 ⁽³⁾	Digital input 8	W55	B29	SS 3	Speed sensor input 3 +
W26	A26	GND	Battery ground	W56	B30	DO 1 ⁽⁵⁾	High side output 1
W27	B1	CAN1 HIGH	CAN V2.0B BUS	W57	B31	AO 2 ⁽¹⁾	High side output 2 (I-feedback)
W28	B2	CAN1 LOW	CAN V2.0B BUS	W58	B32	ANI R1	Resistive input 1
W29	B3	ANI V(B) 2	Analog voltage type 2B input 2	W59	B33	SPEEDO OUT	Speed output signal
W30	B4	ANI V(C) 2	Analog voltage type 2C input 2	W60	B34	GNDSE	Ground sense input

(1) 2A high side switches with current feedback


(2) Digital input that are internally pulled low and must be connected to plus to activate

(3) Digital input but additionally with the capability of pulse width measurement

(4) 4A Low side outputs and can be used as a redundant switch to disconnect a load connected via high side switch

(5) 4A high side switches

Table 18 : Connector pin assignment APC312

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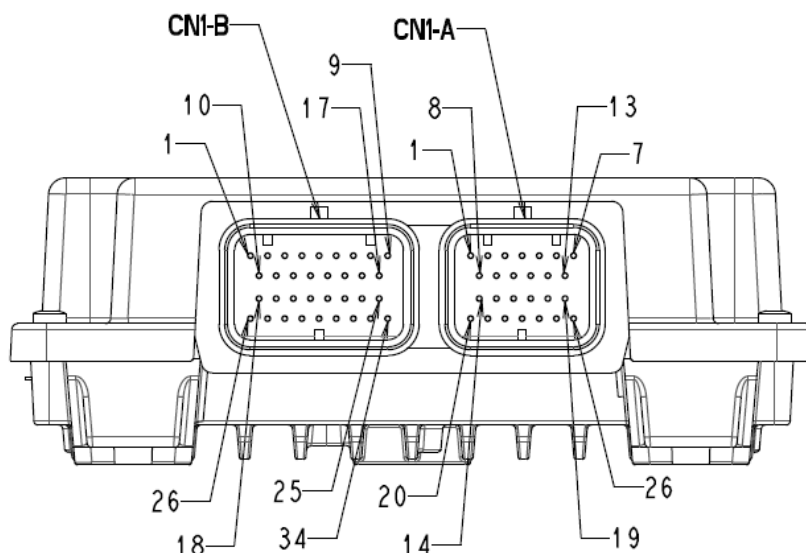


Figure 11 : Pin assignment of the APC312 control unit

2.3.1 Overview of input pin assignments

name	connector pin	comment
DI0	A15	Digital input
DI1	A17	Digital input
DI2	A19	Digital input
DI3	A21	Digital input
DI4	B11	Digital input
DI5	B13	Digital input
DI6	B15	Digital input
DI7	B17	Digital input
DI8	A25	Digital input with possibility of the duty cycle measurement
DI9	B12	Digital input with possibility of the duty cycle measurement
ANI0	A22	resistive input 0-5 KΩ
ANI1	B32	resistive input 0-5 KΩ
ANI_2B0	A9	Voltage input type 2B with pull-up 12K to 8V
ANI_2B1	A11	Voltage input type 2B with pull-up 12K to 8V
ANI_2B2	B3	Voltage input type 2B with pull-up 12K to 8V
ANI_2B3	B5	Voltage input type 2B with pull-up 12K to 8V
ANI_2B4	A10	Voltage input type 2B with pull-up 12K to 8V
ANI_2C0	A16	Voltage input type 2C with pull-up 100K to 8V
ANI_2C1	A18	Voltage input type 2C with pull-up 100K to 8V
ANI_2C2	B4	Voltage input type 2C with pull-up 100K to 8V
ANI_2C3	B8	Voltage input type 2C with pull-up 100K to 8V
ANI_2C4	B20	Voltage input type 2C with pull-up 100K to 8V

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SPIN0	A3	Speed input 0 for different kind of sensors
SPIN1	A6	Speed input 1 for different kind of sensors
SPIN2	B27	Speed input 2 for different kind of sensors
SPIN3	B29	Speed input 3 for different kind of sensors

Table 19 : Overview of input pin assignment

2.3.2 Overview of output pin assignments

name	connector pin	supply rail	comment
AO0	B22	SPWR2 (B7,B9)	2A PWM 1KHz with advanced current sense
AO1	B18	SPWR2 (B7,B9)	2A PWM 1KHz with advanced current sense
AO2	B31	SPWR2 (B7,B9)	2A PWM 1KHz with advanced current sense
AO3	A1	SPWR1 (A2,A4)	2A PWM 1KHz with advanced current sense
AO4	B21	SPWR1 (A2,A4)	2A PWM 1KHz with advanced current sense
HSO0	B19	SPWR2 (B7,B9)	4A PWM 1KHz
HSO1	B30	SPWR2 (B7,B9)	4A PWM 1KHz
HSO2	B25	SPWR1 (A2,A4)	4A PWM 1KHz
HSO3	B14	SPWR1 (A2,A4)	4A PWM 1KHz
LSO0	A5	SPWR1 (A2,A4)	4A PWM 100Hz (ON-OFF-50%)
LSO1	A8	SPWR1 (A2,A4)	4A PWM 100Hz (ON-OFF-50%)
LSO2	A14	SPWR1 (A2,A4)	4A PWM 100Hz (ON-OFF-50%)
LSO3	B6	SPWR1 (A2,A4)	4A PWM 100Hz (ON-OFF-50%)
SPEED_OUT	B33	PPWR	speedo meter output 0-10 V Fmax = 10 KHz
VREF5V	A12/B10	PPWR	5V reference output 100 mA

Table 20 : Overview of outputs pin assignments

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2.4 Mating connectors and wiring harness

The Mating connectors can be ordered from a local supplier for example [RS Components](#):

	Tyco Part number	RS Components part number
Receptacle 26 pins	1473416-1	718-9191
Receptacle 34 pins	4-1437290-1	726-7014
Pin for 0.75 – 1.25 mm ²	3-1447221-3	712-2075
Cavity plug	4-1437284-3	712-2343
Crimp tool	58583-1	314-1362

Table 21 : Mating connectors part numbers

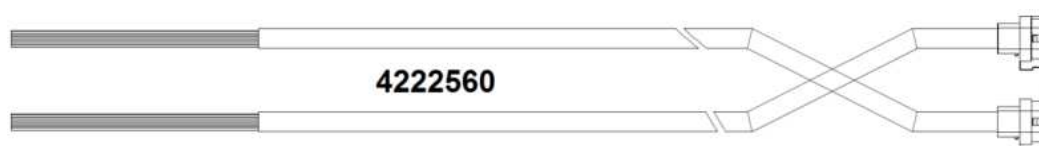
The following picture shows the crimp tool



Figure 12 : Superseal crimp tool

For production, the wiring harness has to be ordered from a local supplier.

For prototype vehicles, an 8 m wiring harness can be ordered from Dana. This wiring harness contains the Tyco connector (incl. pins) and 60 wires of 8 m. The numbered wires are connected to the Tyco connector on one end and they are loose on the other end. The part number for this prototype wiring harness is 4222560. Note that this wiring harness can not be ordered for production.



To reduce the noise picked up by the inputs of the control unit, it is necessary to separate output wires and input wires. The supplier of the wiring harness has to make a separate tree with all inputs and communication signal from the control unit. The inputs of the APC312 are the digital, resistive, voltage and speed inputs. The communication lines are CAN and LIN.

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2.5 Wire thickness and cable trees

TE Connectivity recommends a maximum wire size of 1,25 mm² and an insulation outer diameter between 1,6 and 2,2 mm.

As mentioned in previous paragraph, it is necessary to separate output wires and input wires. Therefore two cable trees are made named A and B. The wires of cable tree A are fed through an expandable braided sleeve even so for the wires of cable tree B (See Table 24 and Table 25). If necessary, both cable trees can be fed through a third expandable braided sleeve.

2.5.1 Maximum ratings of the connector

The following ratings are valid for the connector:

Item	Rating & Condition
Current	See table below
Maximum voltage	250V (AC,DC)
Temperature range	-40°C to +125°C
Wire conductor thickness	0,5 to 1,25 mm ²
Insulation cover	Ø 1,6 to 2,2 mm

Table 22 : Maximum ratings of the connector

2.5.2 Connector allowable current

The allowable maximum temperature in the vicinity of the contacting point is 150°C. For a wire of minimum size of 0,85 mm² the following values are valid:

Set up	Ambient temperature [°C]			
	60	80	100	125
All positions active	7 A	6 A	5 A	3 A
Only single position active	15 A	13A	11 A	6 A

Table 23 : Maximum allowable current

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2.5.3 Wire thickness for 26-pins connector

Pin Nr	wire thickness [mm ²]	wire thickness [AWG]	cable tree
A1	1,00	AWG17	A
A2	1,00	AWG17	A
A3	0,75	AWG18	B
A4	1,00	AWG17	A
A5	1,00	AWG17	A
A6	0,75	AWG18	B
A7	1,00	AWG17	A
A8	1,00	AWG17	A
A9	0,75	AWG18	B
A10	0,75	AWG18	B
A11	0,75	AWG18	B
A12	1,00	AWG17	B
A13	0,75	AWG18	A
A14	1,00	AWG17	A
A15	0,75	AWG18	B
A16	0,75	AWG18	B
A17	0,75	AWG18	B
A18	0,75	AWG18	B
A19	0,75	AWG18	B
A20	1,00	AWG17	A
A21	0,75	AWG18	B
A22	0,75	AWG18	B
A23	0,75	AWG18	B
A24	0,75	AWG18	B
A25	0,75	AWG18	B
A26	1,00	AWG17	A

Table 24 : Wire thickness connector A

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2.5.4 Wire thickness for 34-pins connector

pin nr	wire thickness [mm ²]	wire thickness [AWG]	cable tree
B1	0,75	AWG18	B
B2	0,75	AWG18	B
B3	0,75	AWG18	B
B4	0,75	AWG18	B
B5	0,75	AWG18	B
B6	1,00	AWG17	A
B7	1,00	AWG17	A
B8	0,75	AWG18	B
B9	1,00	AWG17	A
B10	1,00	AWG17	B
B11	0,75	AWG18	B
B12	0,75	AWG18	B
B13	0,75	AWG18	B
B14	1,00	AWG17	A
B15	0,75	AWG18	B
B16	CAVITY PIN	CAVITY PIN	
B17	0,75	AWG18	B
B18	1,00	AWG17	A
B19	1,00	AWG17	A
B20	0,75	AWG18	B
B21	1,00	AWG17	A
B22	1,00	AWG17	A
B23	1,00	AWG17	A
B24	1,00	AWG17	A
B25	1,00	AWG17	A
B26	0,75	AWG18	B
B27	0,75	AWG18	B
B28	1,00	AWG17	B
B29	0,75	AWG18	A
B30	1,00	AWG17	A
B31	1,00	AWG17	A
B32	0,75	AWG18	B
B33	0,75	AWG18	B
B34	0,75	AWG18	B

Table 25 : Wire thickness connector B

2.6 Battery Plus Connections (terminal A2,A4,B7,B9,A7)

The APC312 has two supply rails. Each supply rail has two pins. The loads that are connected to the outputs are divided over the two supply lines. Each supply rail has two pins to limit the current per pin and to increase the reliability of the power supply connection to the battery plus.

The APC312 pins **A2 and A4 of switched power supply rail 1 and the pins B7 and B9 of switched power supply rail 2** are connected **straight** to the 12V / 24V battery plus via **the ignition switch and an automotive fuse of 15 A (SAE J1284)**. The maximum allowable resistance between the connector of the APC312 and the battery plus is **100 mΩ**. These terminals provide power for the shift logic and the outputs that typically control the transmission solenoids. When the ignition key is opened all outputs are disconnected from the battery supply.

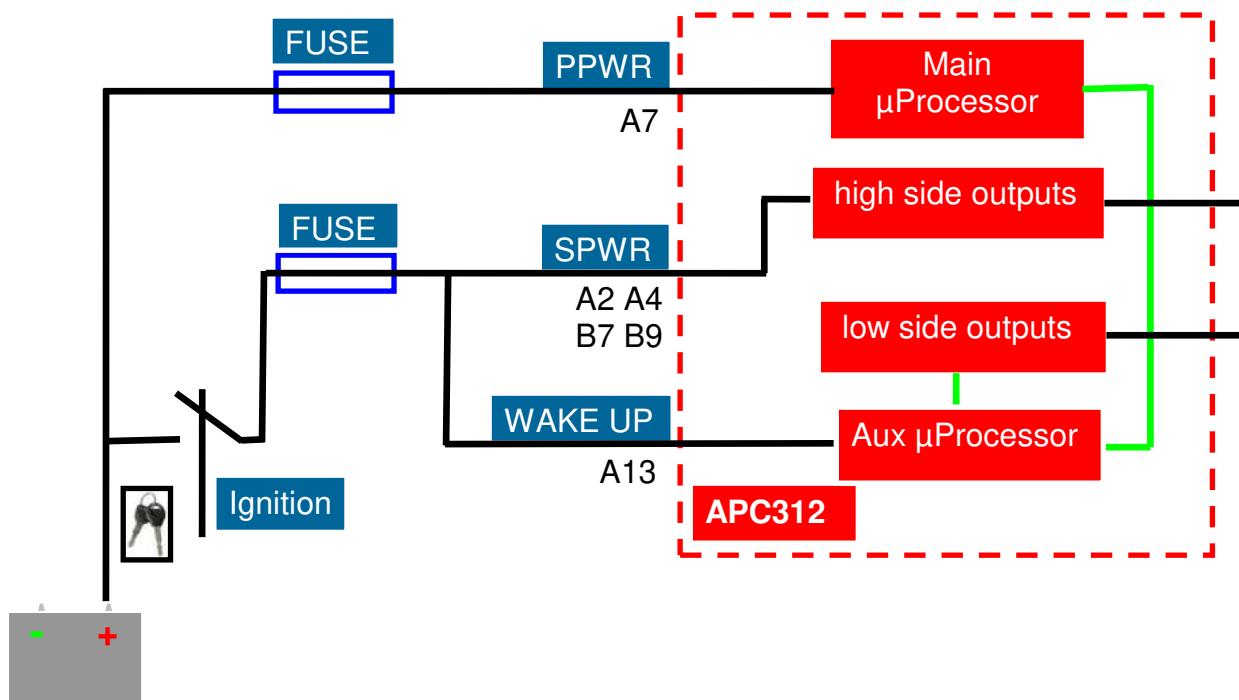


Figure 13 Supply connection diagram of APC312

The terminal **A7 (permanent supply terminal)** must be connected directly to the 12V/24V battery via an **automotive fuse of 15 A (SAE J1284)**. However the power consumption of the electronics via the permanent supply is limited, the large fuse is necessary to protect the whole unit during a load dump. Because the APC312 is connected to the permanent battery supply it can save valuable information during power down periods (auto power-off functionality).

Remark on auto power-off:

During the auto power-off procedure it takes maximum 5 seconds to save parameters into the memory. After this time it is allowed to disconnect the permanent power without losing data. Permanent power removal within this period may result in flash corruption!

2.7 Power ground terminals (terminal A20,A26,B23,B24)

The APC312 has four ground terminals (two on each connector). These terminals must be connected to a well-defined battery ground potential. This means that **each wire must be connected straight to the battery minus**.

Improper grounding may degrade the control system's operation. The fact that most outputs conduct pulsed signals tends to generate switching noise on the ground lines. If the ground lines have insufficient quality or are shared with other loads, serious degradation of the analogue input signal quality may result.

2.8 Signal ground terminal (terminal B28)

Remark:

Using this pin for returning solenoid load current or carrying high currents (> 20 mA) from other non-APC312 loads can seriously degrade the function of the control system.

As quite some pins use these ground lines, and considering the fact that the common resistance in this line can cause significant measurement errors, it is recommended to use a short lead from the APC312 connector pin to the split point and go from there with dedicated wires to the individual sensor return paths.

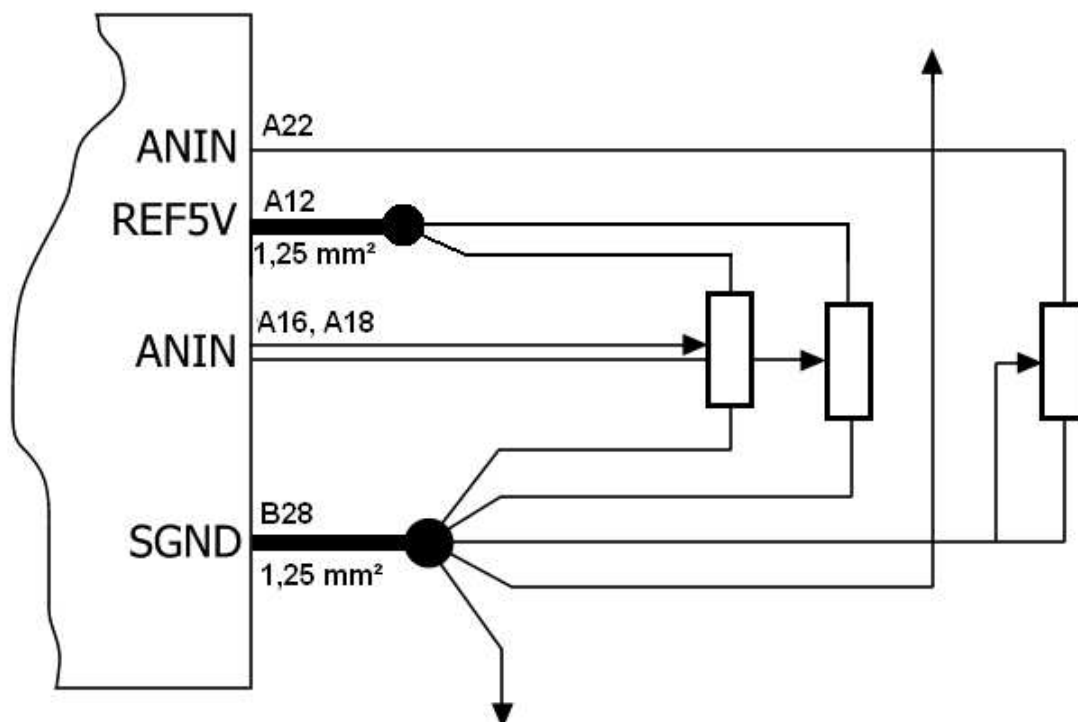


Figure 14 : APC312 signal ground terminal B28

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2.8.1 Analogue inputs ground connection

Potentiometers or sensors with a resistive output use the signal ground B28.

Sensor connected to the voltage inputs use the signal ground B28. A distance of maximum a few centimeters is allowed. Each sensor must have a dedicated wire to the ground connection point.

2.8.2 Speed inputs ground connection

Speed inputs are connected to one of the battery ground pins. The connection must be always be in the near vicinity of the connector. A distance of maximum a few centimeters is allowed. Each sensor has a dedicated wire to the ground connection point.

2.8.3 Communication links ground connection

For CAN if required and LIN signals, one of the battery ground signals is used.

2.9 Ground sense input (terminal B34)

The ground sense input terminal detects when the resistance between the battery ground and the control unit is out of range. The controller ground terminals (A20,A26,B23,B24) must be wired to system ground. The ground loss detection input (ECU_GND_SENSE) terminal B34 must be wired together with the ground signals (A20,A26,B23,B24) in the system to procure efficient detection.

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2.10 WAKE-UP signal (terminal A13)

To switch on the controller, the WAKE-UP signal must have high level that must be equal to the minimum battery supply voltage and must stay above this value for at least 100 ms. To powerdown the controller the level of this signal must drop below this voltage. The unit can stay longer active to store statistical data into the data RAM.

Normally when the ignition key is opened, the voltage on this supply line drops to zero. It drops to zero because of the internal resistance to ground of the connected devices. In this case it is not necessary to have a connection to the battery minus to powerdown the controller. However, when using this connection diagram, it is **necessary** to check whether the voltage drops below 9 volts fast enough. It is required that this occurs in less than 0,5 seconds.

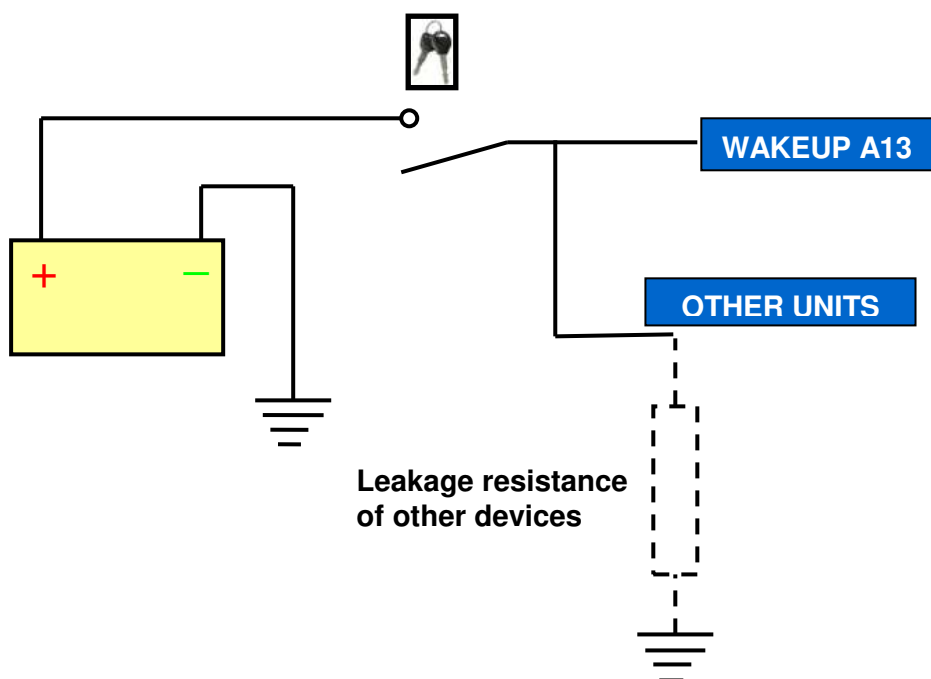


Figure 15 : Wake up signal connection with low leakage to battery plus supply

However, if there is a high leakage current to battery plus and it takes too long time for the voltage to drop below 9 volt, it is required to connect the wakeup signal to ground in the off-state as shown in following figure.

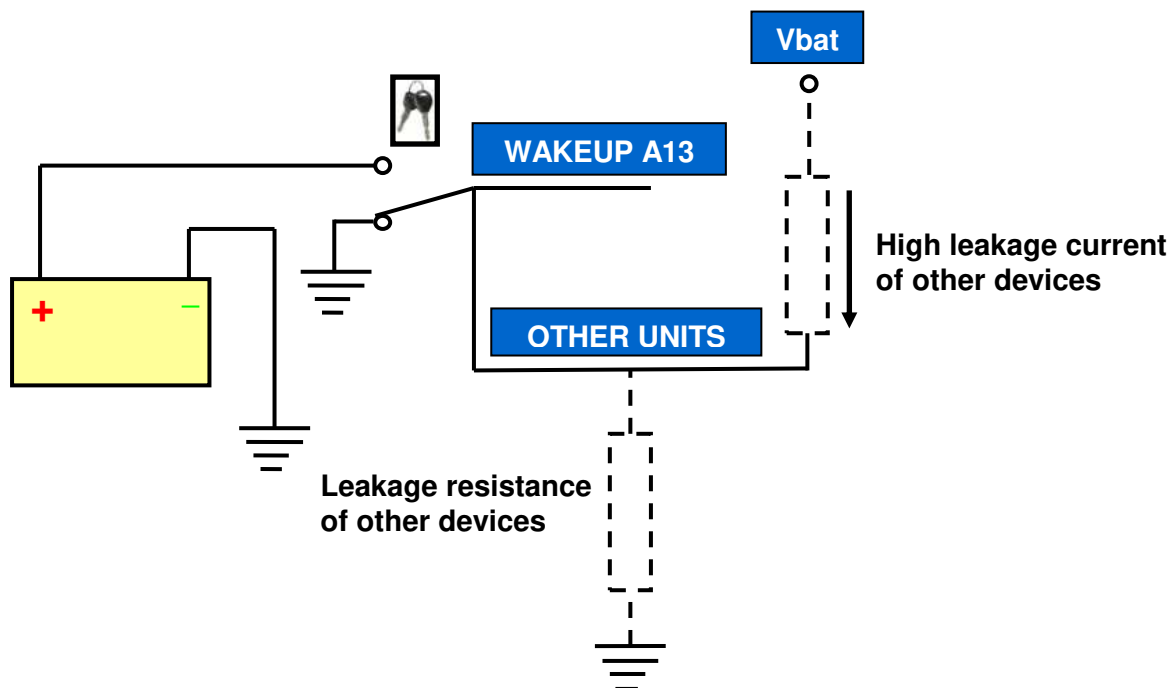


Figure 16 : Wake up signal connection with high leakage to battery plus supply

2.11 Voltage reference VREF 5V (terminal A12, B10)

The 5V reference is intended to provide power to pressure sensors or potentiometric sensors such as throttle pedal position and brake pedal position sensors. See Figure 14.

These sensors have typically impedances in the range of 500 – 5000 Ohms. As such the total current requirement is generally quite low (< 30mA). **If more then one device is connected to this pin, it is recommended to also use a short 1,25 mm² lead from the connector pin to the split point and go from there with dedicated wires to the individual sensors.**

To reduce the picked-up noise on the VREF 5V it is necessary to twist the signal ground and the 5V reference wire with 60 turns per meter.

It's not acceptable to use this output to power auxiliary 5 V appliances.

2.12 Digital inputs (terminal A15,A17,A19,A21,B11,B13,B15,B17)

The connection of discrete inputs is typically not critical in this respect that the input should be connected to switched battery supply or left open.

If however the input is connected to a voltage source switching between two levels, it's important to realize that the switching threshold of these inputs lies somewhere between 2 and 4 V. So for a well defined low level, the input must be pulled below 2V. For a guaranteed high level, the input must be pulled above 4V.

2.13 Digital inputs with PWM duty cycle measurement (terminal A25,B12)

If these connection are switched to the battery supply or left open, it is not critical.

If however the input is connected to a voltage source switching between two levels, it's important to realize that the switching threshold of these inputs lies somewhere between 2 and 4 V. So for a well defined low level, the input must be pulled below 2V. For a guaranteed high level, the input must be pulled above 4V. The maximum PWM frequency is limited to 1000 Hz and for example a sensor can produce a duty cycle that can vary between 10 and 90 % in normal operation. Above and below these values it indicates that something is wrong with the sensor.

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2.14 Analogue resistive inputs (terminal A22,B32)

Potentiometers or sensors with a resistive output can be connected to the 2 resistive inputs of the APC312. In order to be able to correctly measure the sensor's resistance, it's important that **each sensor** has a dedicated ground wire going as direct to the signal ground of the controller as possible. To increase the signal to noise ratio, it is recommended to twist the signal and ground wire. Sixty turns per meter is recommended.

2.15 Voltage inputs type 2B (terminals A9,A11,B3,B5,A10)

Voltage inputs type 2B are analogue inputs designed to measure voltages from 0 – 5 V. These inputs are often used to measure the pressure on the valve block and have an internal 12 K Ω pull-up resistors to a voltage source of 8 volts. The pull-up resistor is used to detect an open load. The inputs are often connected to an absolute pressure sensor with a ratiometric output from 0 to 5 V. The problem to detect a short to ground occurs when an underpressure occurs and the voltage drops to zero without the pull up resistor.

The pull-up resistor shifts the output voltage of the sensor so that it never can drop to zero volt and a short to ground can be detected. The value of the resistor was determined by the pressure sensor manufacturer for an internal supply voltage of the control unit of 8V.

2.16 Voltage inputs type 2C (terminals A16,A18,B4,B8,B20)

Voltage inputs type 2C are analogue inputs designed to measure voltages from 0 – 5 V. Typically however the used range is restricted somewhat to allow open connections to be detected. For this reason, the inputs have internal 100 K Ω pull-up resistors to a voltage source of 8.0 volts.

2.17 Speed sensor inputs (terminals A3,A6,B27,B29)

The APC312 supports sensors with integrated electronics like magneto-resistive and hall sensors and without electronics like inductive sensors. For all types, open circuit and short circuit detection is implemented. The sensor type selection is software programmable and depends on the application.

2.17.1 Speed sensor with integrated circuit

2.17.1.1 Magneto-resistive sensors with current output

The magneto-resistive sensors used with the APC312 are of a Spicer Off Highway proprietary design and offer some advantages over inductive sensors. They sense speeds down to standstill even with a sensor to gear gap of 1.7 mm. Furthermore, they exhibit far better EMC behaviour then inductive sensors. The use of twisted pair cables is recommended to further increases EMC immunity. Use at least 60 turns per meter as shown in following figure.

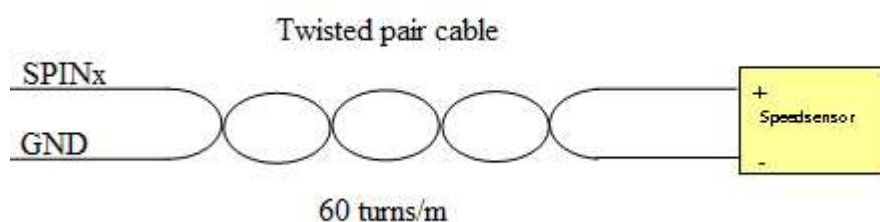


Figure 17 : APC312 speed sensor connection

They have some disadvantages too however : the sensors have an **electrical polarity** and must be **correctly oriented** relative to the gear's turning direction in order to operate properly. For this purpose, each sensor has to be mounted according to the indication mark. See the transmission user manual for more details.

Make sure to observe the polarity indicated on the application specific wiring diagram. Failure to do so causes loss of the speed signal. The APC312 will report the fault as a short circuit. Incorrect mounting also results in loss of speed, but is not detected by the APC312 hardware, and thus can cause improper transmission control.

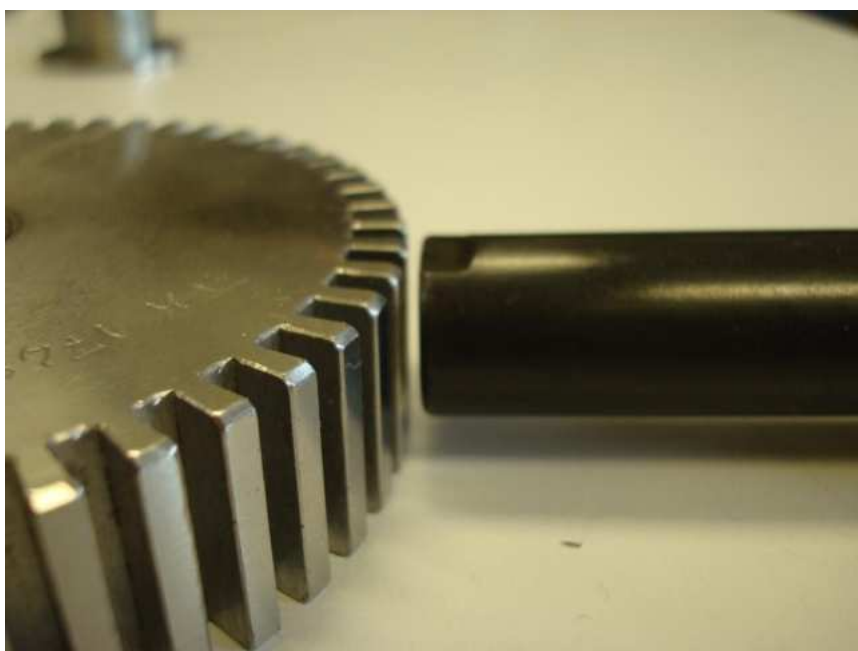


Figure 18 : APC312 Magneto Resistive sensors

2.17.1.2 Hall sensors with direction and current output


The speed sensors inputs are connected to the ATS692LSH hall sensor from Allegro. The low-current state lays between 5 and 8,5 mA with a nominal value of 6,5 mA at running mode and the high-state current lays between 12 and 16,5 mA with a nominal value of 14,0 mA at running mode. The direction of the movement is indicated by the pulse width of the sensor output. The pulse width value is reported to the application to determine the direction of the gear. The value can change between 38 and 207 us.

2.17.1.3 1.3 Hall sensors with open collector

The following two hall sensor types are used:

2.17.1.4 Hall sensor with build-in resistors

Sensors with build-in resistors to detect shorts and open connections. The following figure shows the interface. The supply voltage of these sensors is connected to the battery supply. The two resistors are integrated in the speed sensor. These sensors are custom made for DANA.

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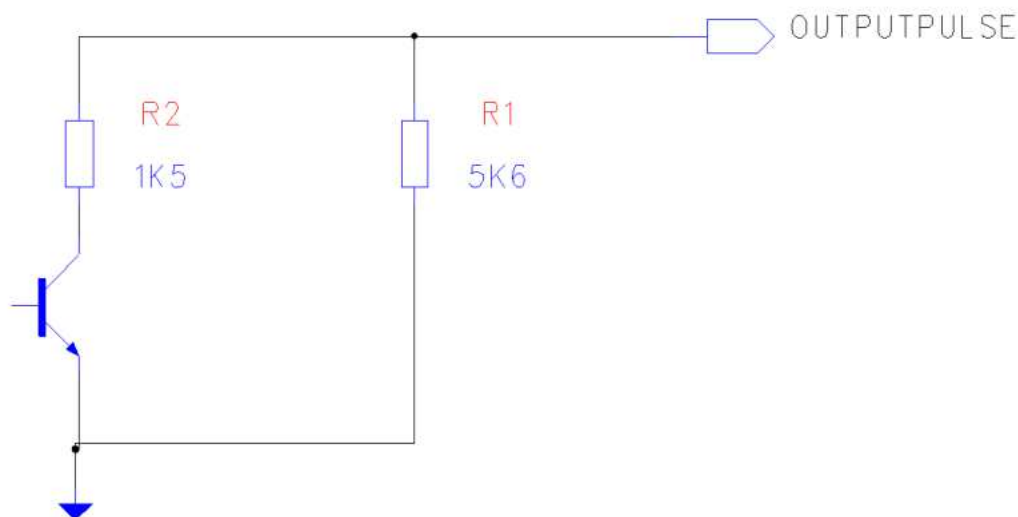


Figure 19 : Hall sensor interface with separate supply.

2.17.1.5 Hall sensor with open collector and external resistor

The sensor is supplied by the controller via the input connection. The pulse of the sensor is detected by a current change in the supply. The resistor R2 is integrated in the wiring. The hall sensor that is used for the interfaces is 1GT101DC from Honeywell. The value of the external resistor R2 depends on the supply voltage of the sensor and the series resistor R1 with the hall sensor. With a good choice of the resistor R2, the current through the sensor changes between $9,0 \pm 5,0$ mA and $23,0 \pm 5,0$ mA.

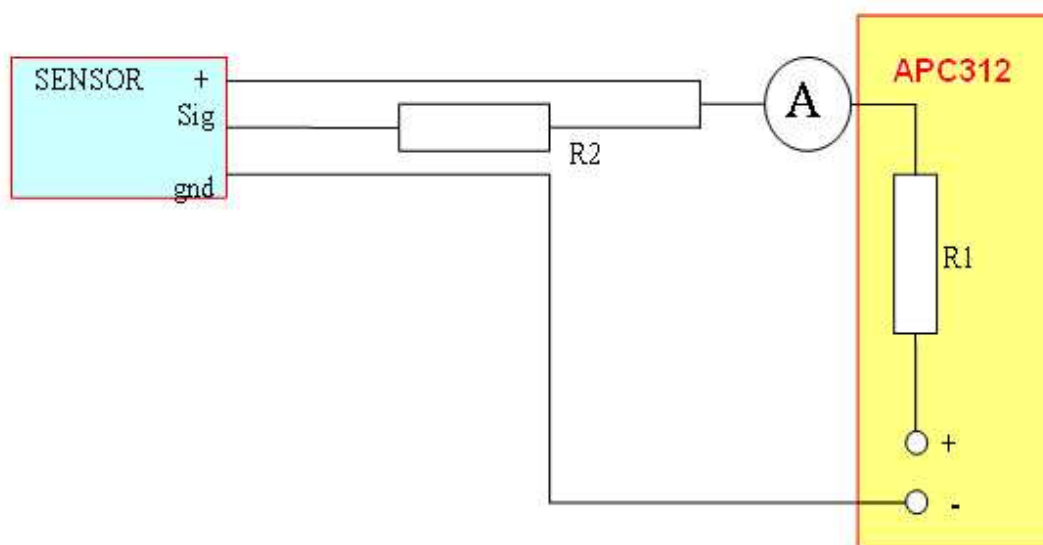


Figure 20 : Hall sensor interface with 1GT101DC .

2.17.2 Inductive or variable reluctance sensors

These sensors are the most mechanically robust, but do not read zero speeds, and require an amplifier in the control for pulse shaping. For these sensors, the wiring and sensor to gear gap setting is quite critical. The next picture shows the connection diagram to the controller.

As the output signal for these sensors is an AC voltage, it's quite susceptible to electromagnetic influences. The use of shielded or twisted cables is **necessary**. The next picture shows the connection diagram to the controller.

If shielded cable is used, the shield must at the sensor side be connected to one terminal and on the other side to the correct ground terminal.

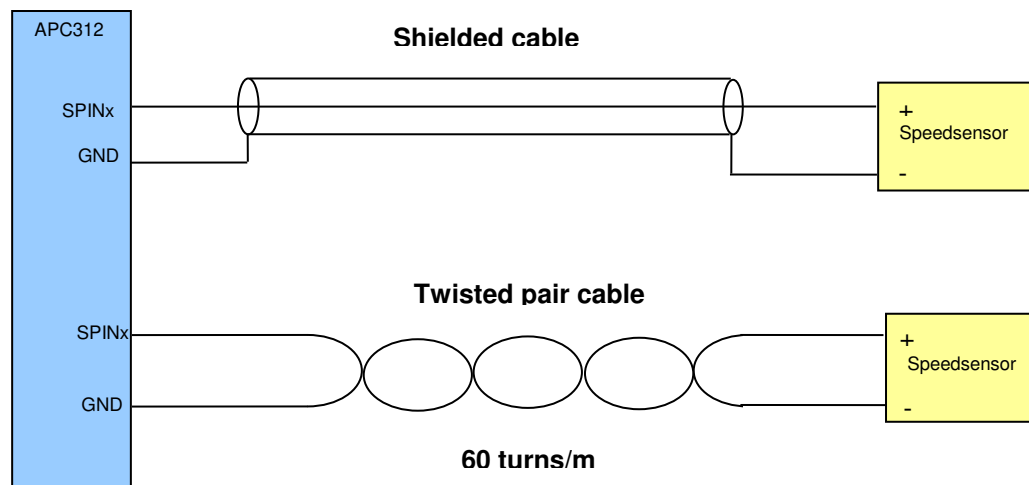


Figure 21 : APC312 inductive speed sensor connection

The central conductor connects the other pin to the sensor input. In case of twisted cables, use at least 60 turns per meter. See the transmission user manual for more details about the 'sensor to gear gap' distances.

The circuitry is able to read sensors with the following characteristics.

- The inductive sensors from Siemens VDO that are used are the following types:
 - 340-804-005-002
 - 340-804-005-007

The difference between to two types is the length of the sensor.

The internal resistance is $1050 \pm 100 \Omega$ and a voltage output of at least 0,8 Veff.

- The inductive sensors from DEUTA that is used is the following type:
 - BM 7/2a from DEUTA

The internal resistance is $\pm 330 \Omega$.

- The inductive sensor from Bendix
 - type 801552

The internal resistance is between 1500 and 2500 Ω and a voltage output of at least 0,4 Veff

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- Inductive sensors with characteristics defined in following table.

Parameter	Minimum	Typical	Maximum	Units
Input frequency	3	-	3000	Hz
Input voltage at 10 Hz	0,5	-	250	Vpp
Input voltage at 400 Hz	2,5	-	250	Vpp
Input voltage at 1500 Hz	5,0	-	250	Vpp
Input voltage at 3000 Hz	15,0	-	250	Vpp

Table 26 : Inductive sensors voltage reference Limits

2.18 High side outputs (terminals B19,B30,B25,B14)

The four outputs are single ended high side outputs. This means that they switch the battery supply to a ground sided load. At first sight, there's no need for a disciplined special grounding practice for these outputs. The common practice is to connect their ground returns anywhere to the chassis. From an EMC point of view however, doing so increases the system's susceptibility and together with it the RFI radiation level. The grounding of the load needs therefore as close as possible to one of the ground pins of the control unit.

In addition to this, PWM outputs typically only draw current from the battery part of the time. The other time, the current flows through the ground wires back into the APC312. Having the ground anywhere else than directly on one of the APC312 ground terminals, requires the current to flow all the way to the battery and from there through the connected ground terminals into the APC312. This causes ground noise which can significantly degrade the measurements of the analogue inputs.

The following table gives an overview of the supply terminals for each high side output.

High side output terminal	+ Supply rail pins	Ground pins to be used
B19	B7 and B9	A20, A26, B23, B24
B30	B7 and B9	A20, A26, B23, B24
B25	A2 and A4	A20, A26, B23, B24
B14	A2 and A4	A20, A26, B23, B24

Table 27 : Supply pins for high side switches

It is important to devide the loads over the different ground pins of the control unit.

2.19 Low side outputs (terminals A5,A8,A14,B6)

The low side outputs are used for switching non-safety critical loads of the control unit or as a safety switch for safety critical loads connected to high side switches.

The low side outputs switches the gound supply to a battery connected load. The load must be connected to the supply pin A2 or A4 of the control unit. Connecting the load to one of these pin is required because the freewheeling diode is connected between the low side output and this supply rail pin. The output can be switched on, off or with a duty cycle of 50% at a frequency of 100 Hz. The main purpose of switching the load with a 50% duty cycle is to reduce the supply voltage by 50% to use 12V solenoids with a battery supply of 24V. The following table gives an overview of the connector pin for each output.

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Low side output terminal	+ Supply rail pins to be used
A5	A2 or A4
A8	A2 or A4
A14	A2 or A4
B6	A2 or A4

Table 28 : Supply pins for low side switches

It is important to divide the loads over the two supply pins of the control unit

2.20 Analog Outputs (terminals B22,B18,B31,A1,B21)

The five outputs are single ended high side outputs. This means that they switch the battery supply to a ground sided load. At first sight, there's no need for a disciplined special grounding practice for these outputs. The common practice is to connect their ground returns anywhere to the chassis. From an EMC point of view however, doing so increases the system's susceptibility and together with it the RFI radiation level. The grounding of the load needs therefore as close as possible to one of the ground pins of the control unit.

PWM outputs with inductive loads typically only draw current from the battery a part of the time. The other time, the current flows through the ground wire back into the APC312. Having the ground anywhere else than directly on the ground terminals of the APC312, requires the current to flow all the way to the battery and from there through the terminals A20, A26, B23, B24 into the APC312. This causes ground noise which can significantly degrade the measurements of the analogue inputs. The following table gives an overview of the supply terminals for each high side output with current feedback.

High side output terminal	+ Supply rail pins	Ground pins to be used
B22	B7 and B9	A20, A26, B23, B24
B18	B7 and B9	A20, A26, B23, B24
B31	B7 and B9	A20, A26, B23, B24
A1	A2 and A4	A20, A26, B23, B24
B21	A2 and A4	A20, A26, B23, B24

Table 29 : Supply pins for high side switches with current feedback

It is important to divide the loads over the different ground pins of the control unit

2.21 Display

It is possible to connect a display to the APC312. The display gets its info via a serial link from the controller, which is called the LIN bus. The display is connected to the controller as follows:

- The supply voltage of the display is connected to the ignition switch of the vehicle or to the battery power terminal A13.
- The ground terminal is connected to battery ground of the control unit for example B24.
- The serial bit info is connected to terminal B26.

Remark: A fast fuse of 1000 mA must be placed in series with the display supply line.

2.22 Communication lines

The CAN interface shall be wired according to SAE J1939-11 (using shielded twisted pair) or SAE J1939-15 (using unshielded twisted pair). The signal to noise ratio will be much better and this will result in less retransmissions on the bus. An overview of the connection terminals is shown in the following table:

Bus	CAN LO	CAN HI	Twisting
CAN1	B2	B1	B1 with B2
CAN2	A24	A23	A23 with A24

Table 30 : CAN connections

When a shielded twisted cable is used for the CAN bus, the shield is connected to pin A26 for CAN2 and B23 for CAN1.

Attention: There are no termination resistors mounted in the APC312 unit. The CAN bus must be terminated with a 120 ohm resistor at both ends of the bus.

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2.23 General wiring diagram

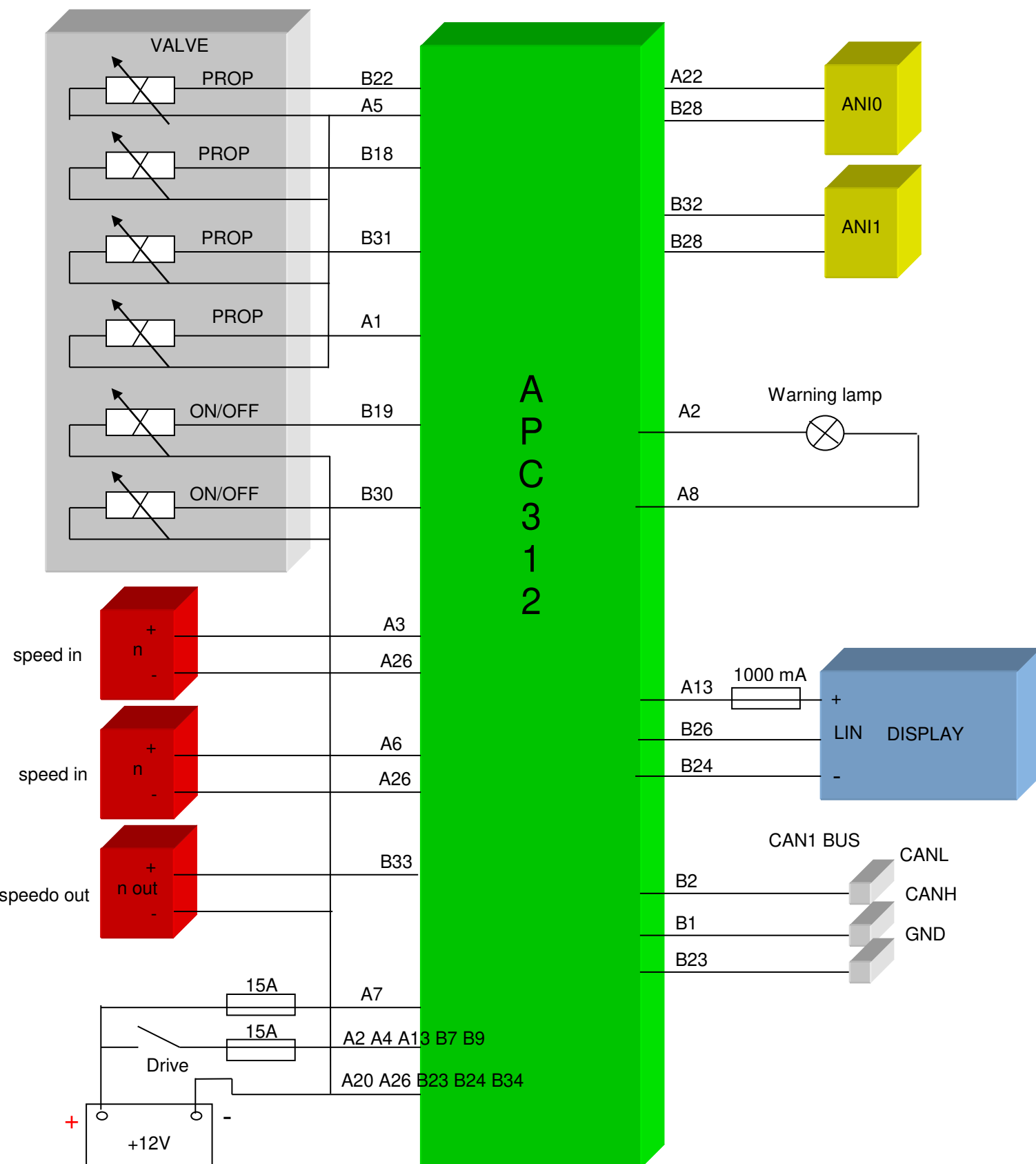



Figure 22 : APC312 general wiring diagram

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3. SAFETY REQUIREMENTS FOR WIRING AND SYSTEM INTEGRATION

- All safety critical actuators/loads must be wired to an high side output, and must have their ground return wired to a low side output.
- Consequences of a sudden de-activation of a safety critical actuator/load wired to HSO/LSO have to be managed in the system if they can be critical (for example negative break device progressive release).
- The controller ground (GND) must be wired to system ground. The ground loss detection input (ECU_GND_SENSE) must be wired together with the other ground signals (GND) in the system to procure efficient detection.
- The sensitive signals delivered by sensors in the system must be properly referenced to ground, particularly frequency signals applied on the frequency inputs. This can be ensured using the signal ground (SIG_GND) from the controller.
- The CAN buses shall be wired according to SAE J1939-11 (using shielded twisted pair) or SAE J1939-15 (using unshielded twisted pair).
- The system shall detect when the controller does not operate anymore (including the cases where the controller is not able to notify it) and manage the safe state of the system in addition to the safe state ensured by the controller.

4. Safety remarks

4.1 General instructions

- Reliable operation cannot be guaranteed if samples or prototypes are used in series production machines.
- The suggested circuits do not imply any technical liability for the whole system on the part of Dana.
- Incorrect connections could cause unexpected signals at the outputs of the controller.
- Dangerous malfunctions may result if the control electronics are opened or modified or the wiring is adapted without authorization.
- In addition, the application-specific documents (connection diagrams, software descriptions, etc.) are to be observed.
- No components that are defective or not working properly should be used. If components fail and/or exhibit malfunction, they must be replaced immediately.
- The controller warms up above regular ambient temperature during operation. To prevent risks due to high temperatures, it should be attached and protected before it is touched.
- Incorrect programming of the APC may create potential sources of danger while the machine is in operation. It is the responsibility of the machine manufacturer to determine dangers of this type in a risk assessment. Dana assumes no liability for risks of this type.

4.2 Conventional use

- Operation of the controller APC must generally occur within the operating ranges specified and released in this data sheet, particularly with regard to voltage, temperature, vibration, shock and other described environmental influences. Use outside of the specified and released boundary conditions may result in danger to life and/or cause damage to components which could result in consequential damage to the complete system.

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- Damages which result from improper use and/or from unauthorized, unintended interventions in the device not described in this data sheet render all warranty and liability claims with respect to the manufacturer void.

4.3 Notes on the installation point and position

- Do not install the controller near parts which generate considerable heat (e.g. exhaust).
- Install the controller in such a way that the connector is pointing downwards. This ensures that any condensation water can drain.
- A sufficiently large distance to radio systems must be maintained.
- All connectors must be unplugged from the electronics during electrical welding operations.
- The controller must not be electrostatically charged, e.g. during painting operations.
- Radio equipment and mobile telephones must not be used in the driver's cab without a suitable antenna or near the control electronics.
- Cables/wires must be sealed individually to prevent water from entering the controller.

4.4 Notes on transport and storage

- Controllers must be stored in mean relative humidity of 60% at a temperature between -10°C and +30°C. Briefly, for 100 hours, a storage temperature range of -20°C to +40°C is permissible.
- For control units that are stored for more than one year, the unit must be put in a dry packing.
- After a storage time of more than 5 years, the controller must be examined by the manufacturer before it is used.
- The controller must not be used if it has been dropped, as damage that is not visible could still affect its reliability.

4.5 Notes on circuitry and on wiring

- The lines used for speed sensors are to be twisted.
- Cables to the electronics must not be routed close to other power-conducting lines in the machine or vehicle.
- The electronics and the power outputs of a controller must be fed from the same power source.
- The wiring harness should be fixated mechanically in the area in which the controller is installed (spacing < 150 mm). The wiring harness should be fixated such that a phase excitation with the controller occurs (e.g. at the controller mounting point).

5. Decommission and Disposal plan

The control unit is designed to facilitate a proper dismantling and allow components and materials to be reused, recycled and /or recovered. The used materials are in compliance with the European directive about the Restriction of Hazardous Substances (ROHS).

The control unit can be easily dismantled in following parts for recycling or re-use:

- Case: ALU EN AC-46000 (AlSi9Cu3)
- Cover: Plastique (PA66+20%GF)
- Gasket: Silicone
- Screws:
- Printed circuit board with mounted components is lead-free soldered

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6. Warranty and repair

6.1 Warranty

The product is granted a warranty period from the date when the product is shipped. The warranty includes failures due to defective material, workmanship or design. It does not cover the costs associated with the removal and refitting of the unit on the vehicle.

Failures due to use outside the requirements of the above specifications will not be covered by the warranty.

6.2 Failures

Failed units are always sent back to find out the root cause of the problem before the warranty is granted. Units that are exchanged under warranty are replaced by a brand new one, which carries the same warranty.

7. Disclaimer

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Application Policy

Capability ratings, features and specifications vary depending upon the model type of service. Application approvals must be obtained from Spicer Off-Highway Systems. We reserve the right to change or modify our product specifications, configurations, or dimensions at any time without notice.

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SPICER OFF-HIGHWAY PRODUCTS



APC312

Ten Briele 3, 8200 Brugge, Belgium

Rev 1.03 released 26/05/2016

26/05/2016

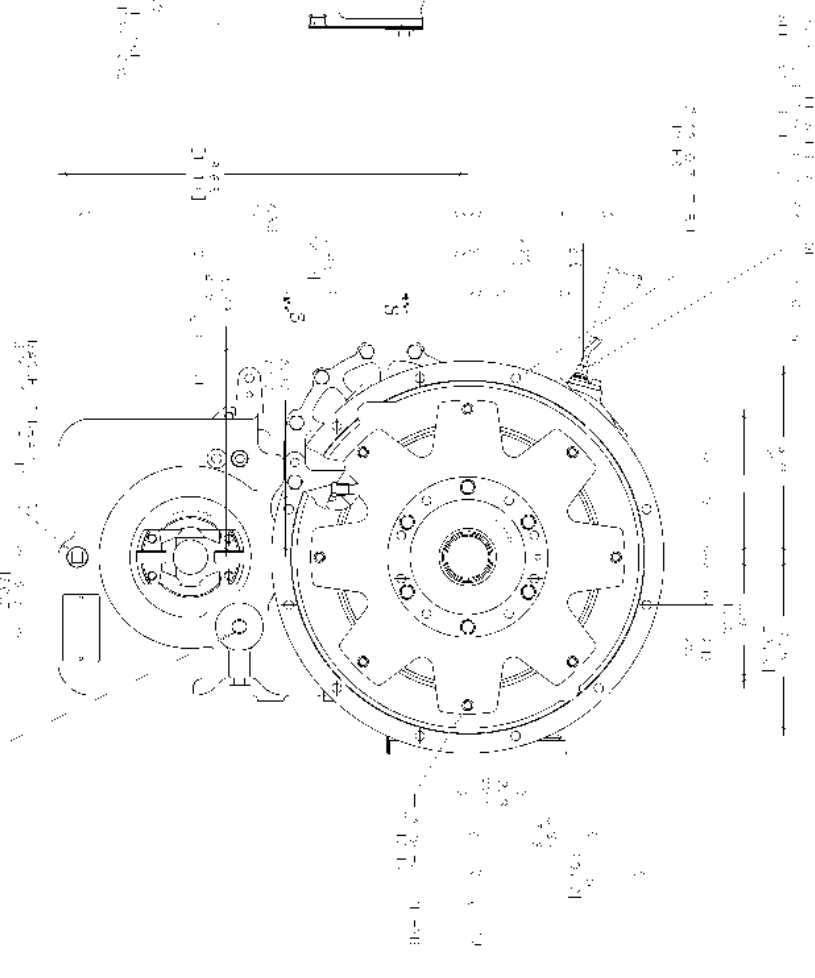
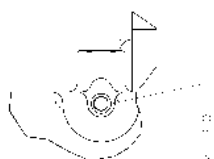
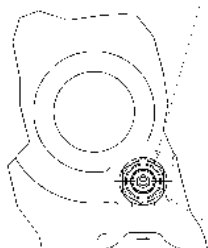
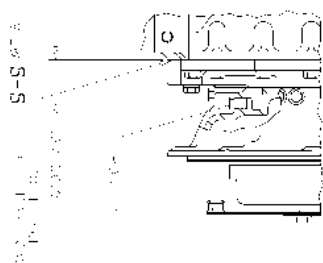
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[illegible]

Figure 1. The effect of the number of trials on the number of correct responses.

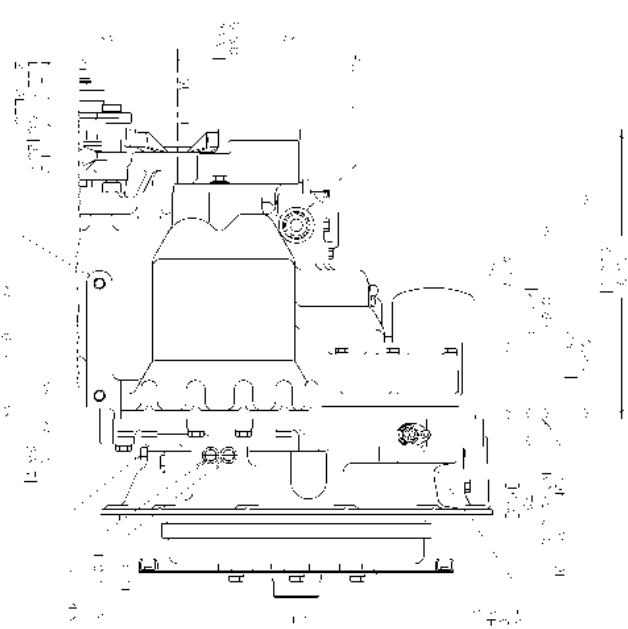
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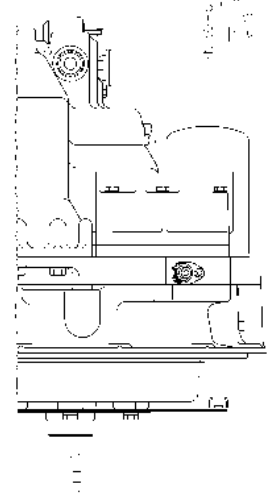
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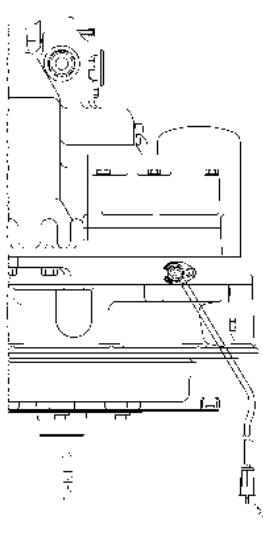
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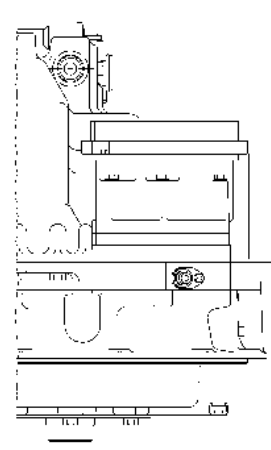
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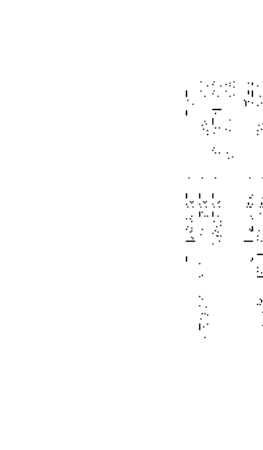
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Architectural drawing notes and specifications.

Architectural drawing notes and specifications.

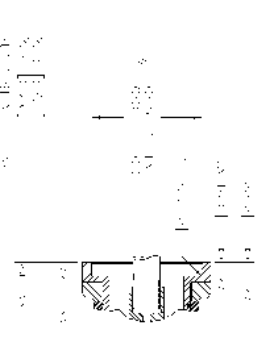
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DETAIL OF WINDOW



DETAIL OF WINDOW



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