1 08 11-16

Service Information Bulletin

SUBJECT	DATE
Camshaft and Idler Gear	August 2016

Additions, Revisions, or Updates

Publication Number / Title	Platform	Section Title	Change
DDC-SVC-MAN-0190	GHG17 DD Platform	Removal of the Camshafts	Added notice and illustrations regarding new camshafts and idler gears. Added illustrations with regards to new camshaft caps.
		Installation of the Camshafts	Added notice and illustrations regarding new camshafts and idler gears. Camshaft timing tools are also discussed.
		Removal of the Intake Rocker Shaft Assembly	Removed specific steps to position engine at No. 1 TDC. Referred to "Camshaft Timing Verification" section for timing steps.
		Installation of the Intake Rocker Shaft Assembly	Removed specific steps to position engine at No. 1 TDC. Referred to "Camshaft Timing Verification" section for timing steps.
		Removal of the Exhaust Rocker Shaft Assembly	Removed specific steps to position engine at No. 1 TDC. Referred to "Camshaft Timing Verification" section for timing steps.
		Installation of the Exhaust Rocker Shaft Assembly	Removed specific steps to position engine at No. 1 TDC. Referred to "Camshaft Timing Verification" section for timing steps.
		Camshaft Timing Verification	Added notice and illustrations regarding new camshafts and idler gears. Timing tools are also discussed.

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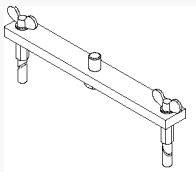
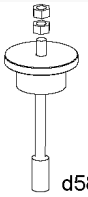
2 Removal of the Camshafts

Table 1.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
J-48883 or W470589023300	Camshaft Bearing Cap Puller	 d580141
J-46375	Injector Unit Pump Puller	 d580140

Remove as follows:

NOTICE: The intake and exhaust camshaft gears changed on March 23, 2016, along with idler gear No. 3 and idler gear No. 5. The main difference is a change to the pressure angle of the gear teeth. The intake camshaft tone wheel also changed to a more robust design to reduce camshaft position fault codes. The easiest way to identify an engine with the new camshafts and idler gears is by inspecting the intake camshaft tone wheel. The new tone wheel has individual fingers. The early tone wheel is more of a plate style with cutouts.

d580174

Figure 1. New Intake Camshaft Tone Wheel

d580175

Figure 2. Early Tone Wheel

New camshafts assemblies must **not** be used with early idler gears No. 3 and No. 5. New idler gears No. 3 and No. 5 must **not** be used with early camshaft assemblies. Always refer to the eParts catalog when parts are needed.

WARNING: PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

WARNING: FIRE HAZARD

Do not power wash or steam clean the engine bay in the area of vehicle electrical components, unless specified by vehicle manuals or service literature. Power washing/steam cleaning can permanently damage these components, which could result in fire, personal injury, or property damage.

2. Steam clean the engine.

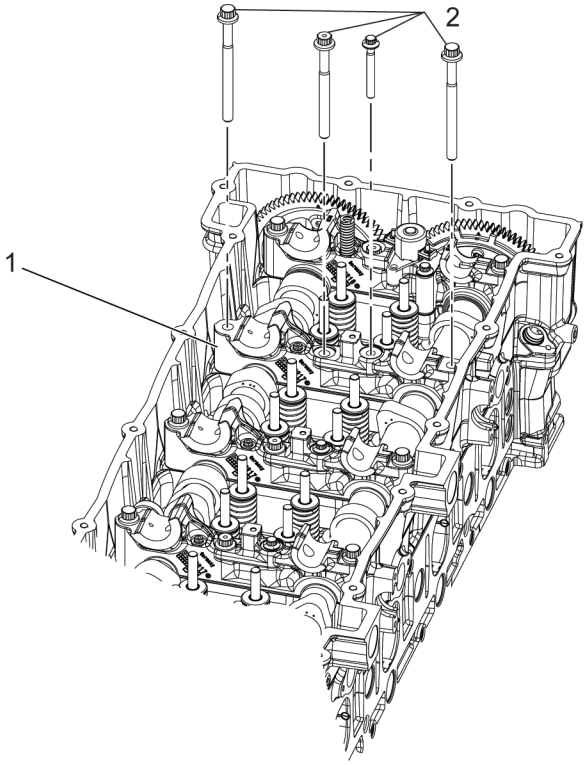
CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

3. Disconnect the batteries. Refer to the Original Equipment Manufacturer (OEM) procedure.
4. Open the hood.
5. If necessary, remove the bumper for access. Refer to the OEM procedure.
6. Remove the intake and exhaust rocker shaft assemblies.
   Refer to section "Removal of the Intake Rocker Shaft Assembly".
   Refer to section "Removal of the Exhaust Rocker Shaft Assembly".
7. Remove the engine brake solenoids.

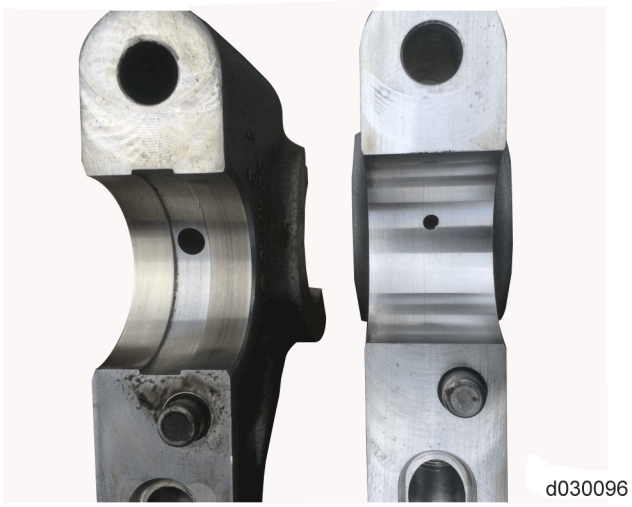
NOTE: Mark the camshaft cap position for proper reassembly. The camshaft caps are machined with the camshaft housing and must be installed to their original locations.

8. Remove the bolts (2) from the camshaft caps (1).

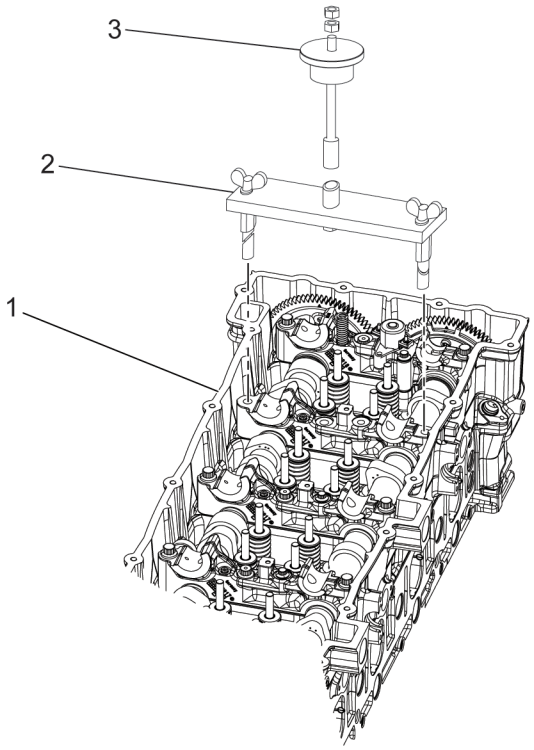


d030114

Table 2.

Old Camshaft Cap with Oil Groove (left) and New Cap w/o Groove (right)
NOTE: There was a change to the camshaft caps to remove the oil grooves for DD13, DD15, and DD16 engines in December of 2015. See illustration below.


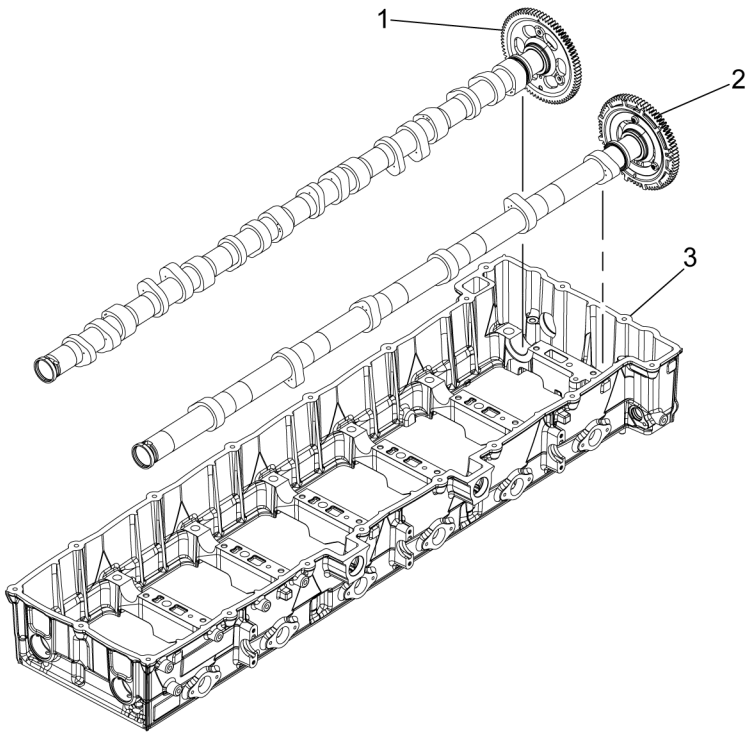
9. Using the camshaft cap puller tool (2) and injector unit pump puller tool (3), remove the camshaft caps from the camshaft housing (1).



d030115

NOTICE: Damage to the intake camshaft tone wheel will result in fault codes.

10. Using care not to damage the intake camshaft tone wheel, remove the intake and exhaust camshaft assemblies (1 and 2) from the camshaft housing (3).

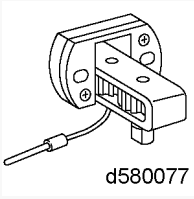
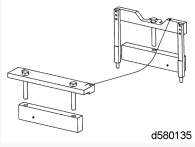
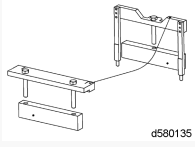
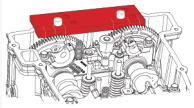
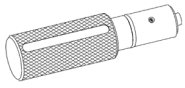


d050054

11. Place the camshafts on a suitable work bench to avoid damage. The best method is to use V-blocks.

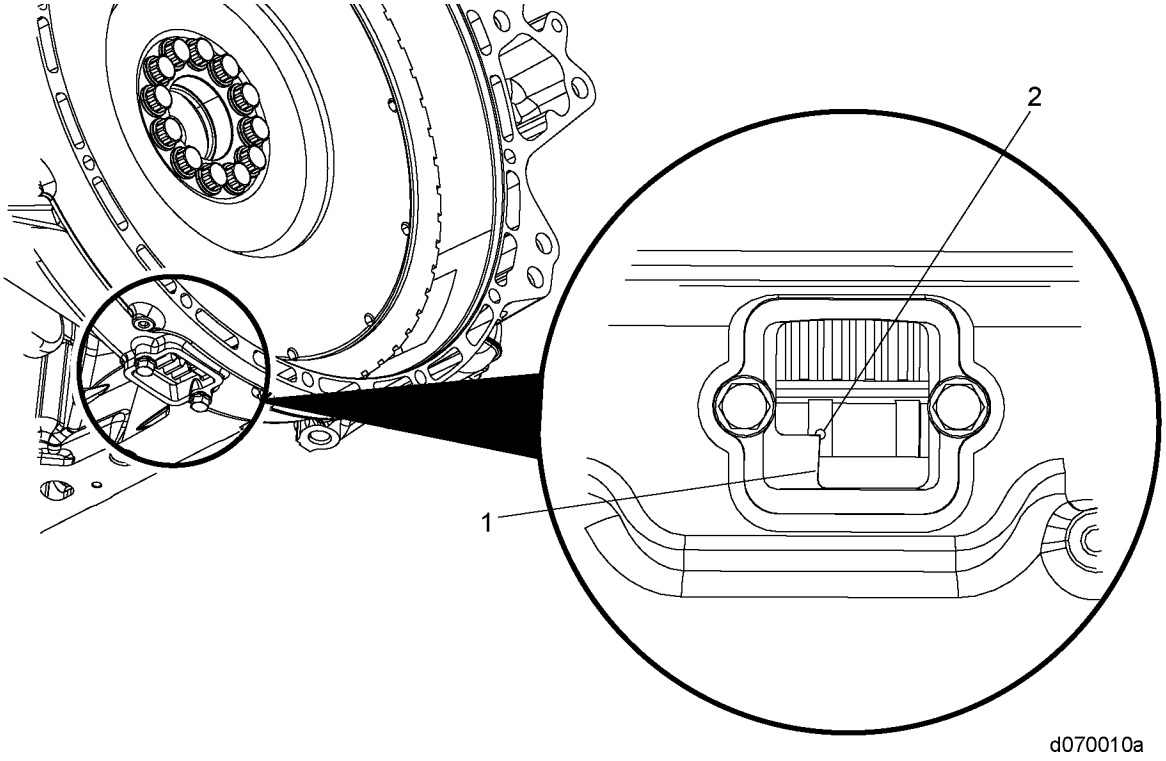
3 Installation of the Camshafts

Table 3.

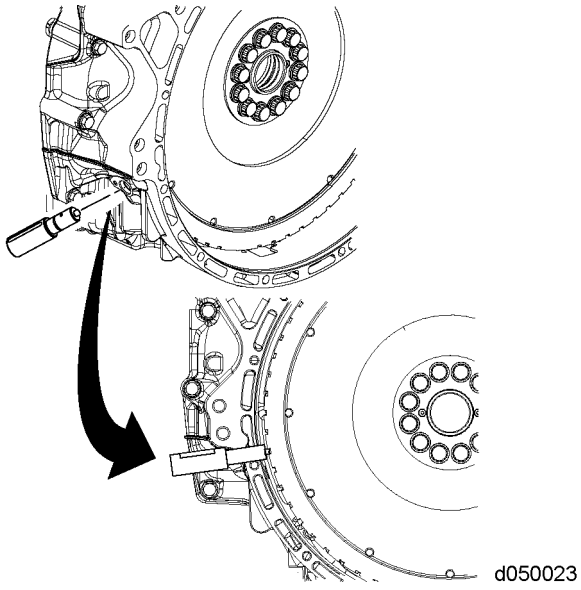
Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W904589046300	Silver Engine Barring Tool	 d580077
W470589114000	Camshaft Timing Tool - DD13	 d580135
W470589104000	Camshaft Timing Tool - DD15/16	 d580135
W470589062300	Camshaft Timing Tool - DD13/DD15/DD16 Built on or after March 23, 2016	 d030118
W470589001500	Top Dead Center Locating Pin	 d580136

Install as follows:

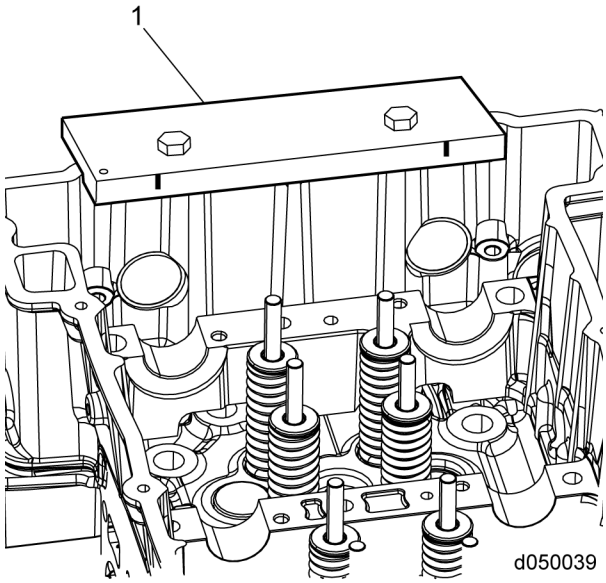
1. Using the engine barring tool, bar the engine to Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. The dot (2) that is located on the flywheel tone ring should be aligned with the edge of the pointer cast into the flywheel housing (1).



2. Remove the Crankshaft Position (CKP) sensor from the rear of the flywheel housing. Refer to section "Removal of the Crankshaft Position Sensor".
3. Install the flywheel TDC locating pin (W470589001500), through the crankshaft position sensor hole in the flywheel housing and engage into the flywheel notch.



4. Install the camshaft timing tool (1) to the rear of the camshaft housing. Tighten the two bolts.



5. Locate the etched triangle on each camshaft gear and mark the corresponding tooth with a paint pen.
6. Lubricate the lower camshaft journal surfaces in the camshaft housing and the camshaft journals with clean engine oil before installing the camshafts.

Table 4.

NOTICE: The intake and exhaust camshaft gears changed on March 23, 2016, along with idler gear No. 3 and idler gear No. 5. The main difference is a change to the pressure angle of the gear teeth. The intake camshaft tone wheel also changed to a more robust design to reduce camshaft position fault codes. The easiest way to identify an engine with the new camshafts and idler gears is by inspecting the intake camshaft tone wheel. The new tone wheel has individual fingers. The early tone wheel is more of a plate style with cutouts. See illustrations below.

Table 5.

New Intake Camshaft Tone Wheel


Table 6.

Early Tone Wheel

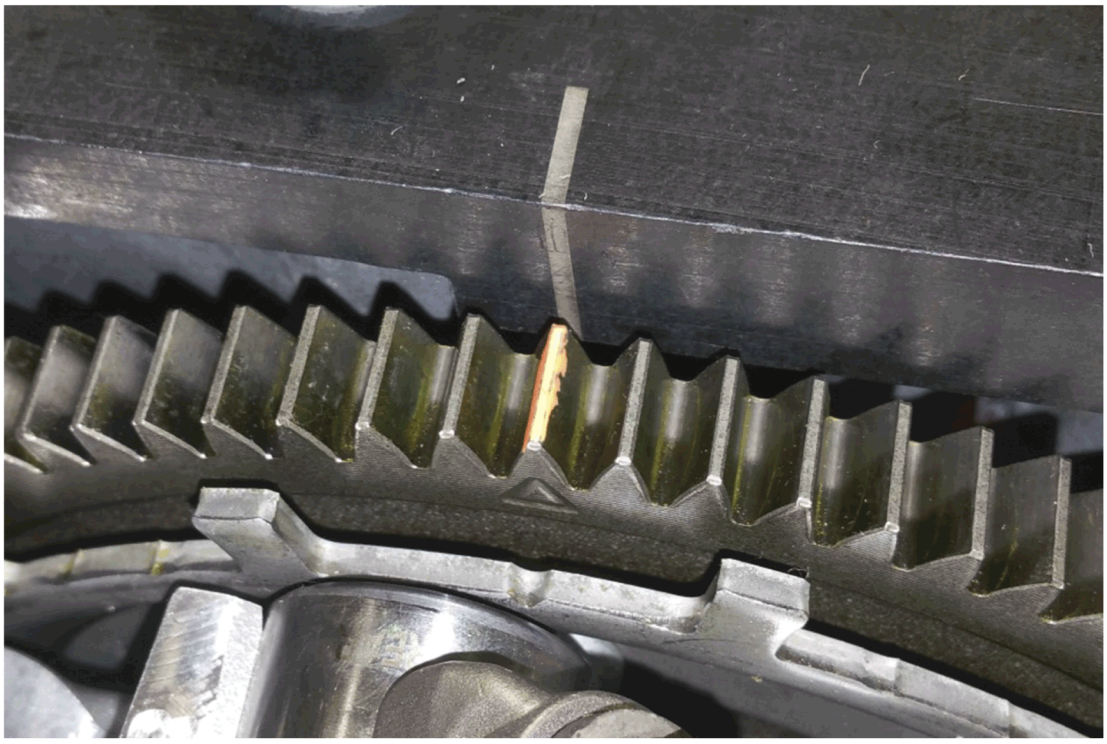

Table 7.

Camshaft Timing Tool (W470589062300)
A new camshaft timing tool (W470589062300) has been developed for use with the new camshafts and idler gears. **If the earlier camshaft timing tools are used**, the exhaust camshaft will **show** to be approximately one-half of a tooth out of time when the engine is positioned at No. 1 Top-Dead-Center (TDC) on the compression stroke. The intake camshaft will **show** to be very close to being in time. See illustrations below.

Table 8.

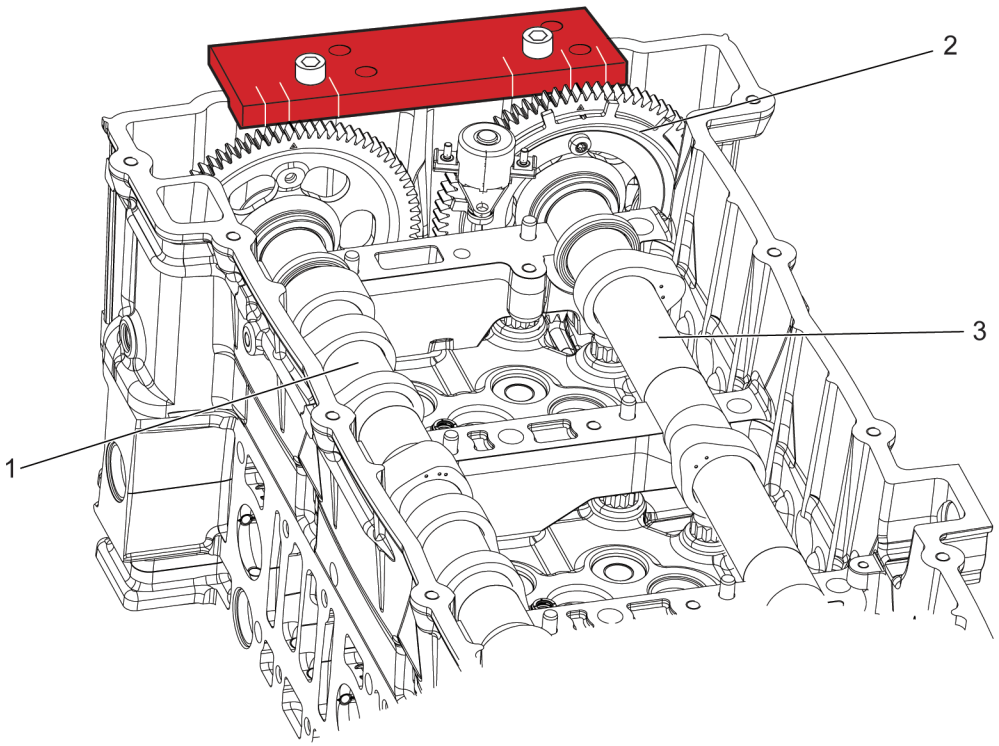
Exhaust Timing Using Early Tools
 d030092

Table 9.

Intake Timing Using Early Tools
 d030093
It should be noted the illustrations above show a new camshaft GHG17 engine that is in time at No. 1 TDC on the compression stroke. The **early** tools can be re-marked for the new GHG17 camshafts if the new tool is not available. The front timing tool (fork) will no longer be required for timing purposes and will not be included with the new timing tool set (W470589062300).

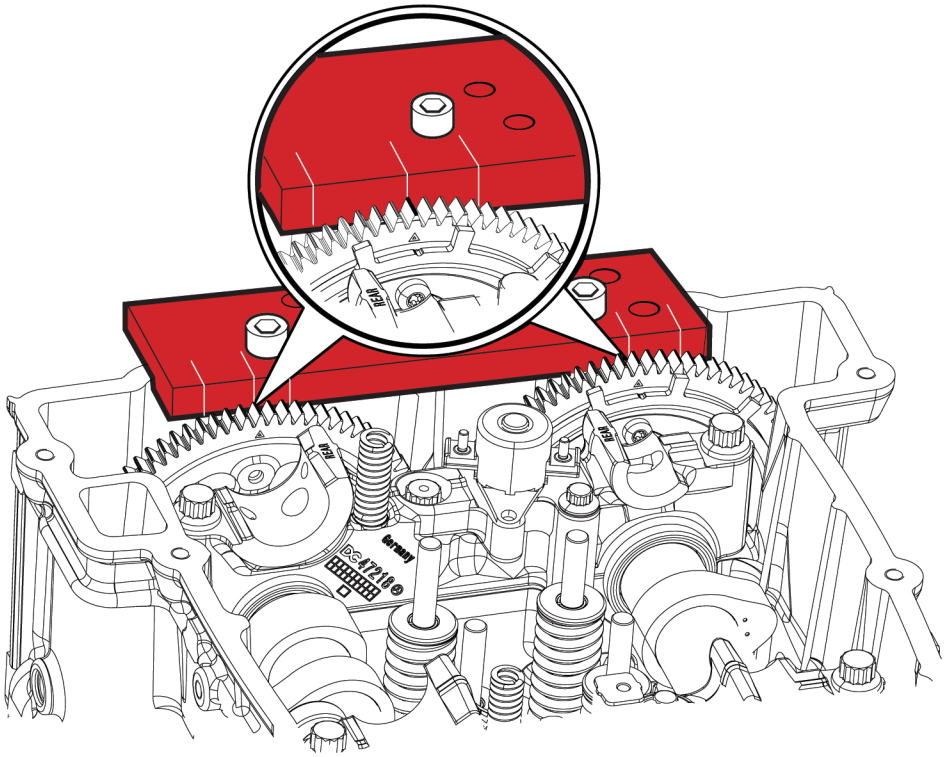
NOTICE: Damage to the intake camshaft tone wheel (2) will result in fault codes.

7. Carefully install the exhaust (1) and intake (3) camshaft assemblies into the camshaft housing.



d030116

8. Align the marked gear teeth with the marks on the timing tool.
9. Verify that the marks on the gear teeth match the marks on the timing tool.

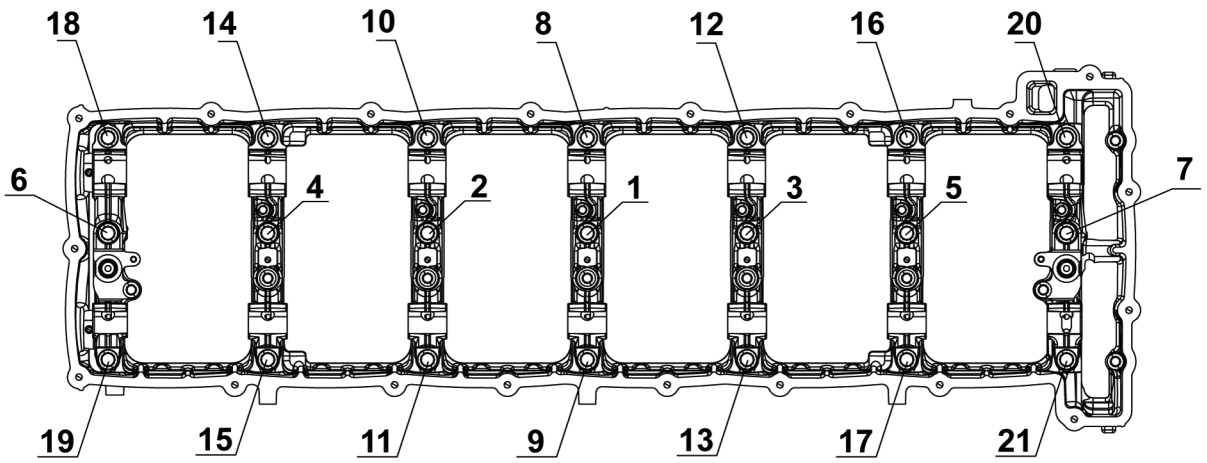


d030117

NOTE: The camshaft caps are machined with the camshaft housing and must be installed in their original locations. They should have been marked during removal.

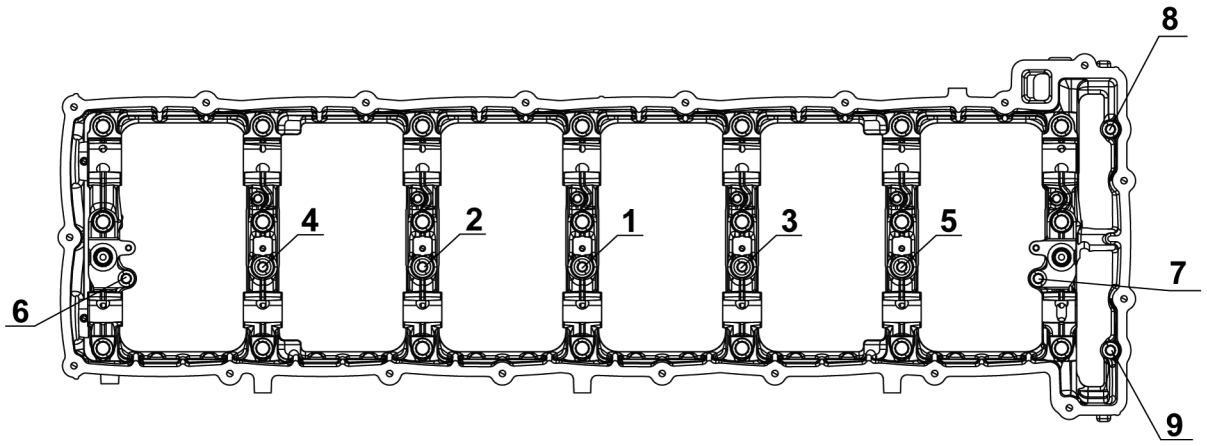
10. Install the seven camshaft caps onto the camshaft housing.

11. Install the 28 bolts securing the camshaft caps to the camshaft housing and the cylinder head; finger-tighten the bolts.
12. Using the torque sequence shown below, torque the twenty-one M10 camshaft cap bolts to the following:
    - Torque all bolts to 20 N·m (15 lb·ft).
    - Then torque bolts to 50 to 55 N·m (37 to 40 lb·ft).



d010091

13. Using the torque sequence shown below, torque the seven M8 bolts (bolts 1 through 7) to 30 N·m (22 lb·ft).



d010092

NOTICE: When installing the engine brake solenoids, do not use the mounting bolt to pull the solenoid into the camshaft cap. Damage will occur to the O-rings on the solenoid.

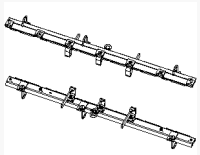
14. Replace the O-rings on the engine brake solenoids prior to reinstallation and lubricate with clean engine oil. Seat the engine brake solenoids into the camshaft caps by hand.
15. Remove TDC locating pin from Crankshaft Position (CKP) sensor hole in the flywheel housing.
16. Install crankshaft position sensor. Refer to section "Installation of the Crankshaft Position Sensor".
17. Remove the camshaft timing tools.

NOTICE: Failure to remove the engine barring tool prior to starting the engine will cause damage to the tool or the flywheel.

18. Remove the engine barring tool from the bottom of the flywheel housing. Reinstall the cover plate and tighten the bolts.
19. Install the intake and exhaust rocker shaft assemblies.
    Refer to section "Installation of the Intake Rocker Shaft Assembly"
    Refer to section "Installation of the Exhaust Rocker Shaft Assembly"
    Follow those procedures to completion.

4 Removal of the Intake Rocker Shaft Assembly

Table 10.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W470589044000	Intake Rocker Arm Lifter/Spacer Tool - DD13	 d580138
W470589004000 or W470589094000	Intake Rocker Arm Lifter/Spacer Tool - DD15/16	 d580046

Remove as follows:

WARNING: PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

WARNING: FIRE HAZARD

Do not power wash or steam clean the engine bay in the area of vehicle electrical components, unless specified by vehicle manuals or service literature. Power washing/steam cleaning can permanently damage these components, which could result in fire, personal injury, or property damage.

2. Steam clean the engine.

CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

3. Disconnect the batteries. Refer to the Original Equipment Manufacturer (OEM) procedure.
4. Open the hood.
5. If necessary, remove the bumper for access. Refer to the OEM procedure.
6. Remove the rocker cover. Refer to section "Removal of the Rocker Cover".
7. Position the engine at Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. Refer to section "Camshaft Timing Verification".
8. Remove the fuel injector wiring harness. Refer to section "Removal of the Two-Piece Fuel Injector Wiring Harness - Two-Filter System".
9. Completely loosen all of the adjusting screws on the intake rocker arms.

NOTICE: Ensure when loosening the rocker shaft bolts that the bolts are loosened from the inside bolts outward, in ½-turn increments. The increment procedure needs to be followed to prevent the rocker shaft from breaking.

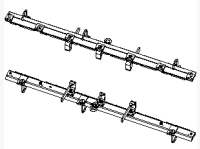
10. Remove the seven bolts securing the intake rocker shaft to the camshaft bearing caps.

NOTICE: Make sure that the camshaft housing is not damaged during removal of the intake rocker shaft assembly.

11. Using the intake rocker arm lifter/spacer tool, carefully remove the intake rocker shaft assembly.
12. Place the intake rocker shaft assembly on a suitable workbench.

5 Installation of the Intake Rocker Shaft Assembly

Table 11.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W470589044000	Intake Rocker Arm Lifter/Spacer Tool - DD13	 d580138
W470589004000 or W470589094000	Intake Rocker Arm Lifter/Spacer Tool - DD15/16	 d580046

Install as follows:

1. Position the engine at Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. Refer to section "Camshaft Timing Verification".

Table 12.

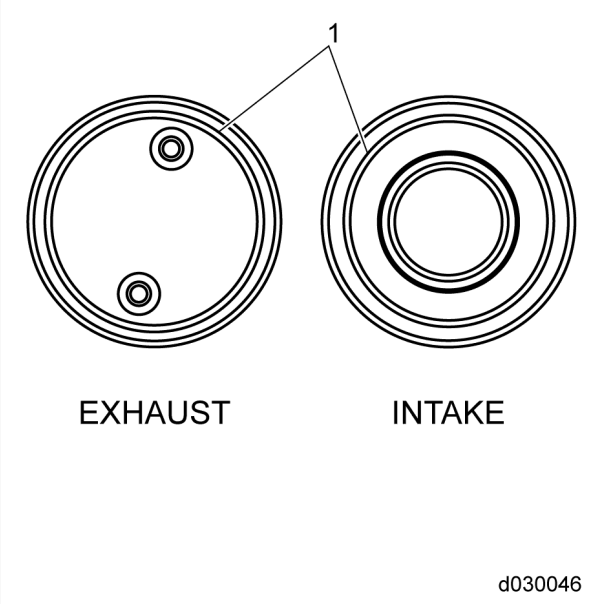
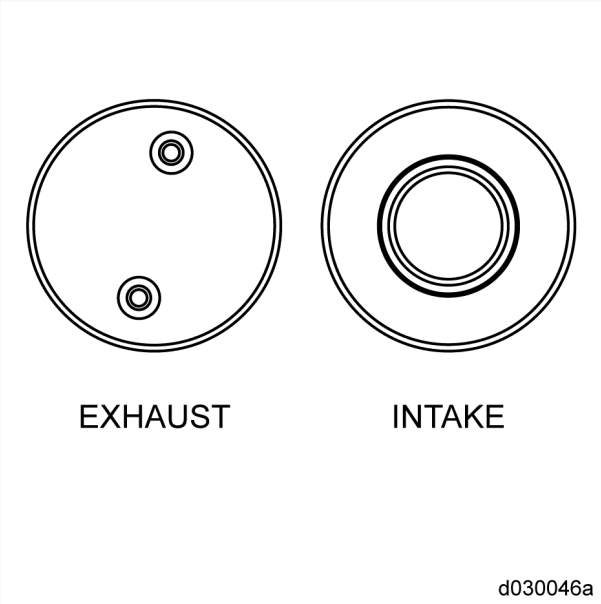
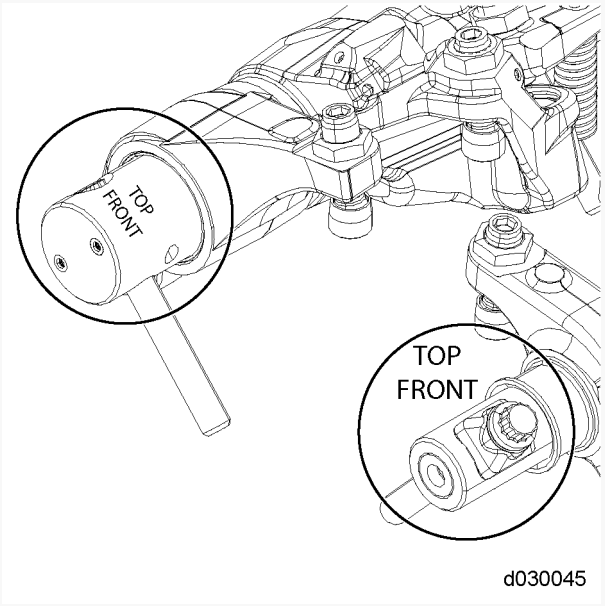
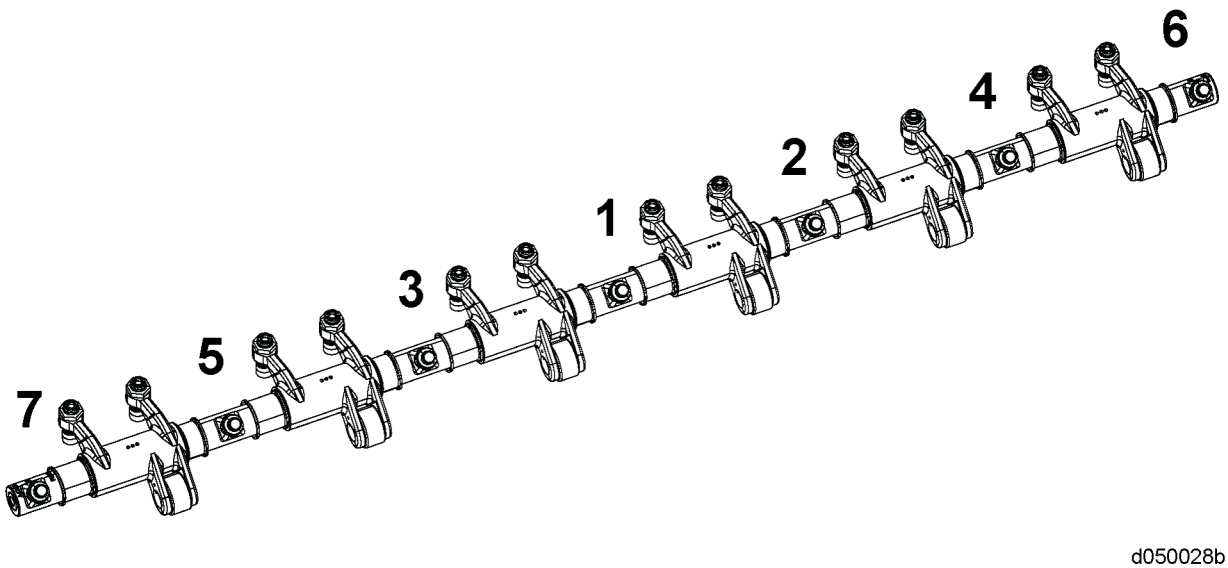
NOTICE: The camshaft journal area is lubricated by engine oil that has to travel through the rocker shaft. If the rocker shaft is installed incorrectly, oil passages will not line up. This results in insufficient lubrication that will damage the camshaft journals. Incorrect rocker shaft installation can also result in the engine brakes not functioning and damage to the rocker arm bushings.
NOTICE: The marking grooves (1) on the rocker shafts must face the REAR of the engine for proper lubrication and engine brake operation.
Rear:

Front:


Table 13.

NOTE: The intake and exhaust rocker shafts are each marked "TOP FRONT". Top Front must face towards the front of the engine.

NOTICE: When tightening the rocker shaft bolts, ensure that the bolts are drawn down from the inside bolts outward, in 1/2 turn increments, before final torque. The rocker shaft can break if the rocker shaft bolt is fully torqued without using the increment procedure. The valve adjusters must also be fully loosened when the shaft assemblies are installed.

2. Using the Intake Rocker Arm Lifter / Spacer tool, install the intake rocker shaft assembly onto the camshaft caps and secure with seven clamping blocks and bolts.
3. Using the torque sequence shown below, torque the bolts to 50 to 55 N·m (36 to 41 lb·ft) + 90°.



4. Adjust the valves and engine brakes. Refer to section "Setting the Valve and Engine Brake Lash".

5. Install the fuel injector wiring harness. Refer to section "Installation of the Two-Piece Fuel Injector Wiring Harness - Two-Filter System".
6. Install the rocker cover. Refer to section "Installation of the Rocker Cover".
7. Install the air filter housing. Refer to the OEM procedure.

CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

8. Connect the batteries. Refer to the OEM procedure.

WARNING: PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

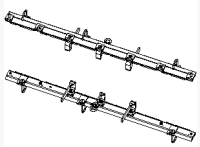
WARNING: ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

9. Start the engine and check for oil leaks.
10. If removed, install the bumper. Refer to the OEM procedure.
11. Close the hood.

6 Removal of the Exhaust Rocker Shaft Assembly

Table 14.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W470589074000 or W470589094000	Exhaust Rocker Arm Lifter/Spacer Tool - DD13	 d580138
W470589004000 or W470589094000	Exhaust Rocker Arm Lifter/Spacer Tool - DD15/16	 d580046

Remove as follows:

WARNING: PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

WARNING: FIRE HAZARD

Do not power wash or steam clean the engine bay in the area of vehicle electrical components, unless specified by vehicle manuals or service literature. Power washing/steam cleaning can permanently damage these components, which could result in fire, personal injury, or property damage.

2. Steam clean the engine.

CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

3. Disconnect the batteries. Refer to the Original Equipment Manufacturer (OEM) procedure.
4. Open the hood.
5. If necessary, remove the bumper for access. Refer to the OEM procedure.
6. Remove the rocker cover. Refer to section "Removal of the Rocker Cover".
7. Position the engine at Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. Refer to section "Camshaft Timing Verification".
8. Remove the fuel injector wiring harness. Refer to section "Removal of the Two-Piece Fuel Injector Wiring Harness - Two-Filter System".
9. Completely loosen all of the adjusting screws on the exhaust rocker arms.

NOTICE: Ensure when loosening the rocker shaft bolts that the bolts are loosened from the inside bolts outward, in ½-turn increments. The increment procedure needs to be followed to prevent the rocker shaft from breaking.

10. Remove the seven bolts securing the exhaust rocker shaft to the camshaft caps.

NOTICE: When removing the exhaust rocker shaft, ensure the rocker arms are in the UP position.

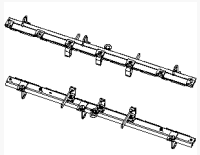
NOTE: Jake rocker return springs will fall when the rocker shaft assembly is removed. Plug the eight open oil return passages in the cylinder head with shop towels so the springs are captured in the overhead when the rocker shaft is removed.

NOTICE: Make sure that the camshaft housing is not damaged during removal of the exhaust rocker shaft assembly.

11. Using the exhaust rocker arm lifter/spacer tool, carefully remove the exhaust rocker shaft assembly.
12. Place the exhaust rocker shaft assembly on a suitable workbench.
13. Remove the six engine brake return springs.

7 Installation of the Exhaust Rocker Shaft Assembly

Table 15.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W470589074000	Exhaust Rocker Arm Lifter/Spacer Tool - DD13	 d580138
W470589004000 or W470589094000	Exhaust Rocker Arm Lifter/Spacer Tool - DD15/16	 d580046

Install as follows:

1. Position the engine at Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. Refer to section "Camshaft Timing Verification".

Table 16.

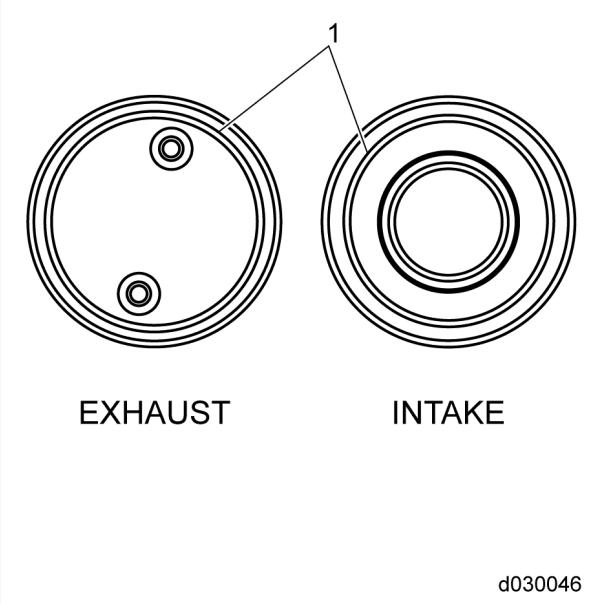
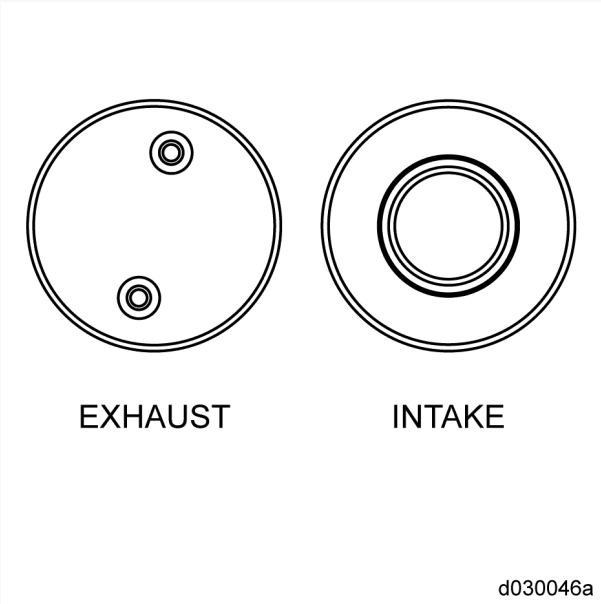
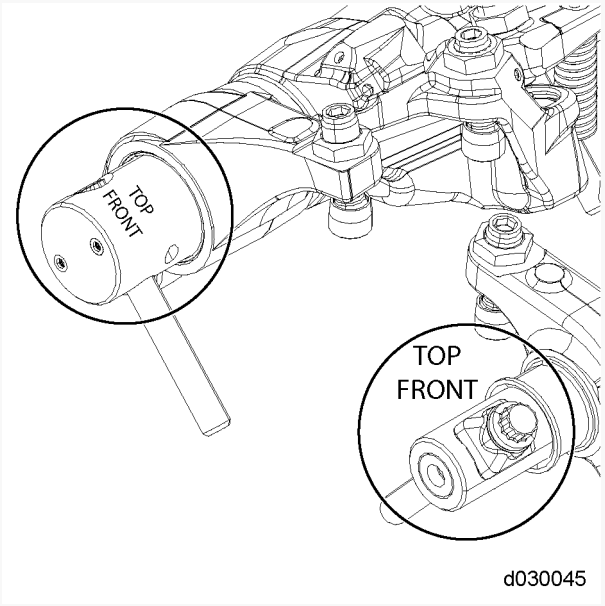
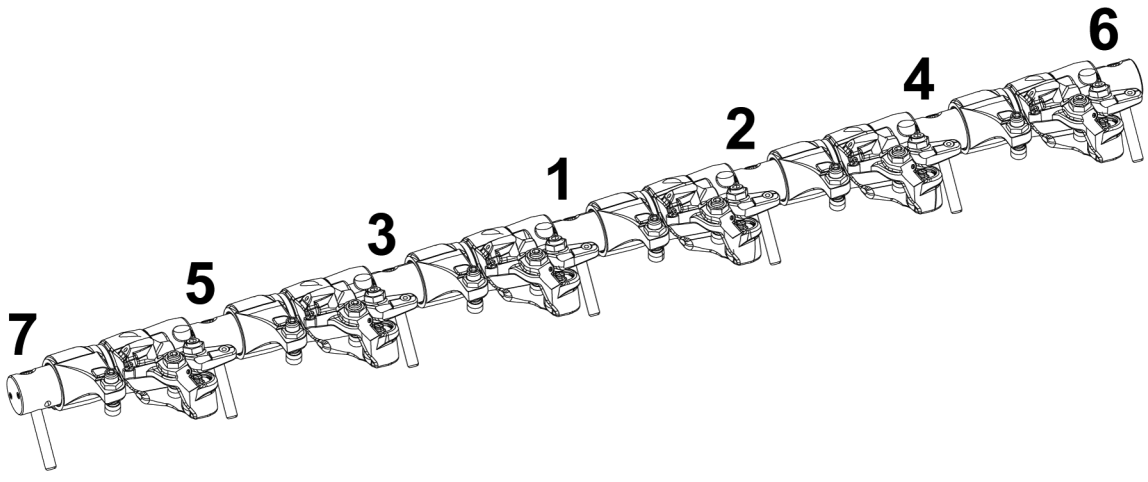
NOTICE: The camshaft journal area is lubricated by engine oil that has to travel through the rocker shaft. If the rocker shaft is installed incorrectly, oil passages will not line up. This results in insufficient lubrication that will damage the camshaft journals. Incorrect rocker shaft installation can also result in the engine brakes not functioning and damage to the rocker arm bushings.
NOTICE: The marking grooves (1) on the rocker shafts must face the REAR of the engine for proper lubrication and engine brake operation.
Rear:

Front:


Table 17.

NOTE: The intake and exhaust rocker shafts are each marked "TOP FRONT". Top Front must face towards the front of the engine.

NOTICE: When tightening the rocker shaft bolts, ensure that the bolts are drawn down from the inside bolts outward, in 1/2 turn increments, before final torque. The rocker shaft can break if the rocker shaft bolt is fully torqued without using the increment procedure. The valve adjusters must also be fully loosened when the shaft assemblies are installed.

2. Using the exhaust rocker arm lifter/spacer tool, install the exhaust rocker shaft assembly onto the camshaft caps and secure with seven clamping blocks and bolts.
3. Using the torque sequence shown below, torque the bolts to 50 to 55 N·m (36 to 41 lb·ft) plus 90°.



4. Adjust the valves and engine brakes. Refer to section "Setting the Valve and Engine Brake Lash".

5. Install the fuel injector wiring harness. Refer to section "Installation of the Two-Piece Fuel Injector Wiring Harness - Two-Filter System".
6. Install the rocker cover. Refer to section "Installation of the Rocker Cover".
7. Install the air filter housing. Refer to the OEM procedure.

CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

8. Connect the batteries. Refer to the OEM procedure.

WARNING: PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

WARNING: ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

9. Start the engine and check for oil leaks.
10. If removed, install the bumper. Refer to the OEM procedure.
11. Close the hood.

8 Camshaft Timing Verification

Verify as follows:

Table 18.

Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Engine**
W904589046300	Silver Engine Barring Tool	DD Platform
W470589001500	Top Dead Center Locating Pin	DD Platform
W470589114000	Camshaft Timing Tool	DD13
W470589104000	Camshaft Timing Tool	DD15/DD16
W470589062300	Camshaft Timing Tool	DD13/DD15/DD16 Built on or after March 23, 2016

WARNING: PERSONAL INJURY

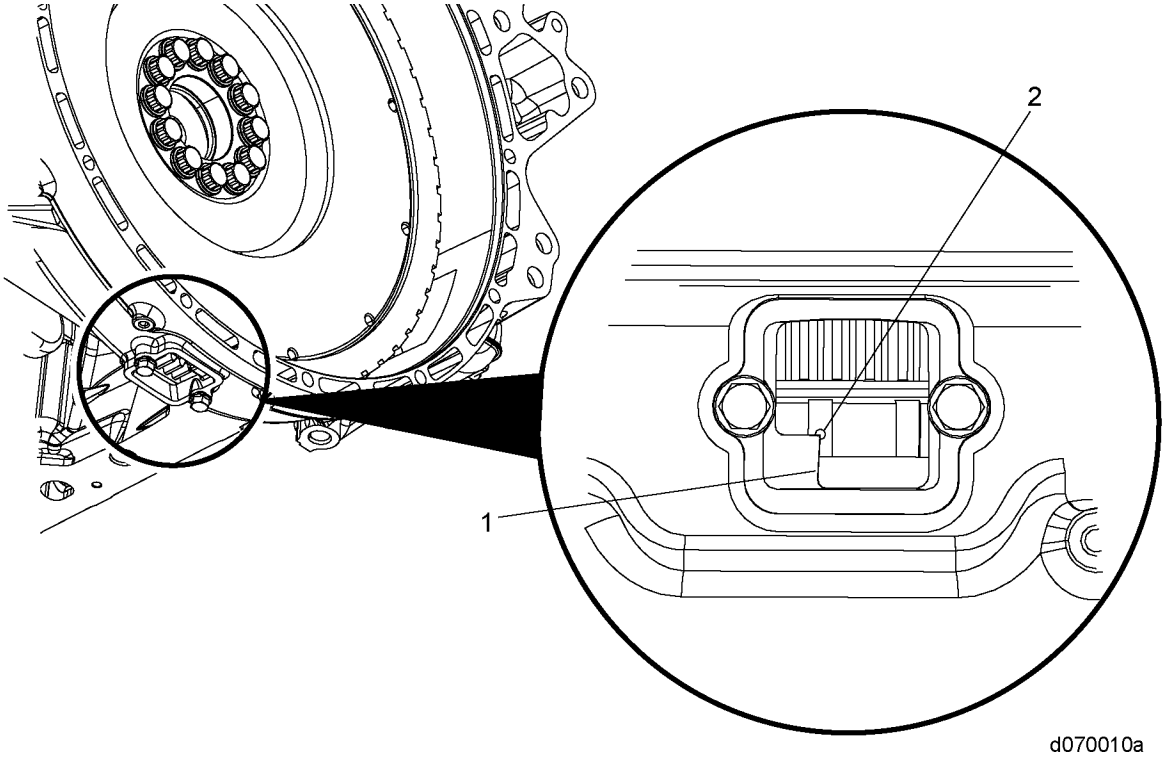
To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION: ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries. Refer to the Original Equipment Manufacturer (OEM) procedure.
3. Open the hood.
4. If necessary, remove the bumper for access. Refer to the OEM procedure.
5. Remove the rocker cover. Refer to section "Removal of the Rocker Cover".
6. Using the engine barring tool, bar the engine to Top Dead Center (TDC) on cylinder No.1 with the No. 6 valves in overlap. The dot (2) that is located on the flywheel tone ring should be aligned with the edge of the pointer cast into the flywheel housing (1).



NOTE: Painted teeth on the camshaft gears are not timing indicators. These are assembly marks used during the manufacturing process.

7. Locate the TDC indicator (triangle) on each camshaft gear and mark the top of the corresponding gear tooth with a light colored paint pen.
8. Remove the Crankshaft Position (CKP) sensor from the flywheel housing. Refer to section "Removal of the Crankshaft Position Sensor".
9. Install the flywheel TDC locating pin (W470589001500) through the crankshaft position sensor hole in the flywheel housing and engage into the flywheel notch. The locating pin should slide in and out freely if the engine is positioned at No. 1 TDC.

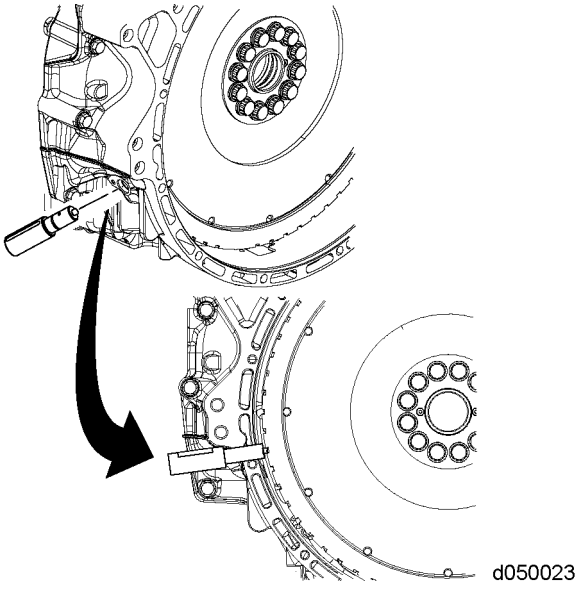


Table 19.

NOTICE: The intake and exhaust camshaft gears changed on March 23, 2016, along with idler gear No. 3 and idler gear No. 5. The main difference is a change to the pressure angle of the gear teeth. The intake camshaft tone wheel also changed to a more robust design to reduce camshaft position fault codes. The easiest way to identify an engine with the new camshafts and idler gears is by inspecting the intake camshaft tone wheel. The new tone wheel has individual fingers. The early tone wheel is more of a plate style with cutouts. See illustrations below.

Table 20.

New Intake Camshaft Tone Wheel
 d580174

Table 21.

Early Tone Wheel
 d580175

Table 22.

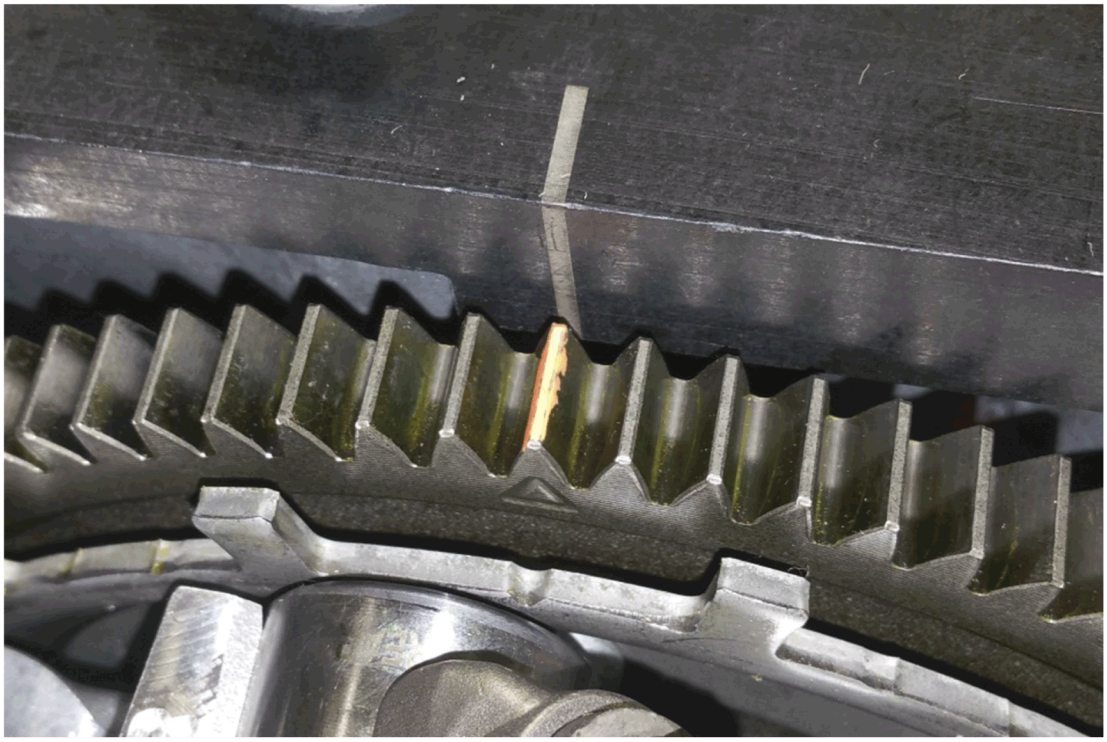
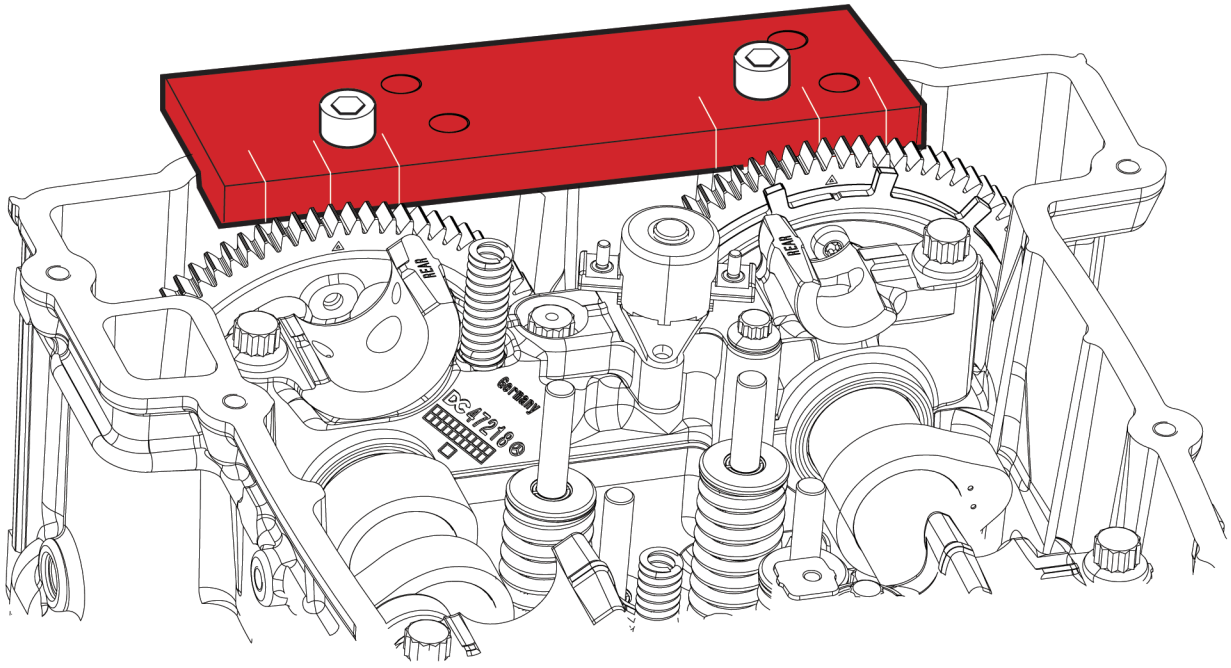
A new camshaft timing tool (W470589062300) has been developed for use with the new camshafts and idler gears. If the earlier camshaft timing tools are used, the exhaust camshaft will show to be approximately one half of a tooth out of time when the engine is positioned at No. 1 Top-Dead-Center (TDC) on the compression stroke. The intake camshaft will show to be very close to being in time. See illustrations below.
 d030092
 d030093

Table 23.

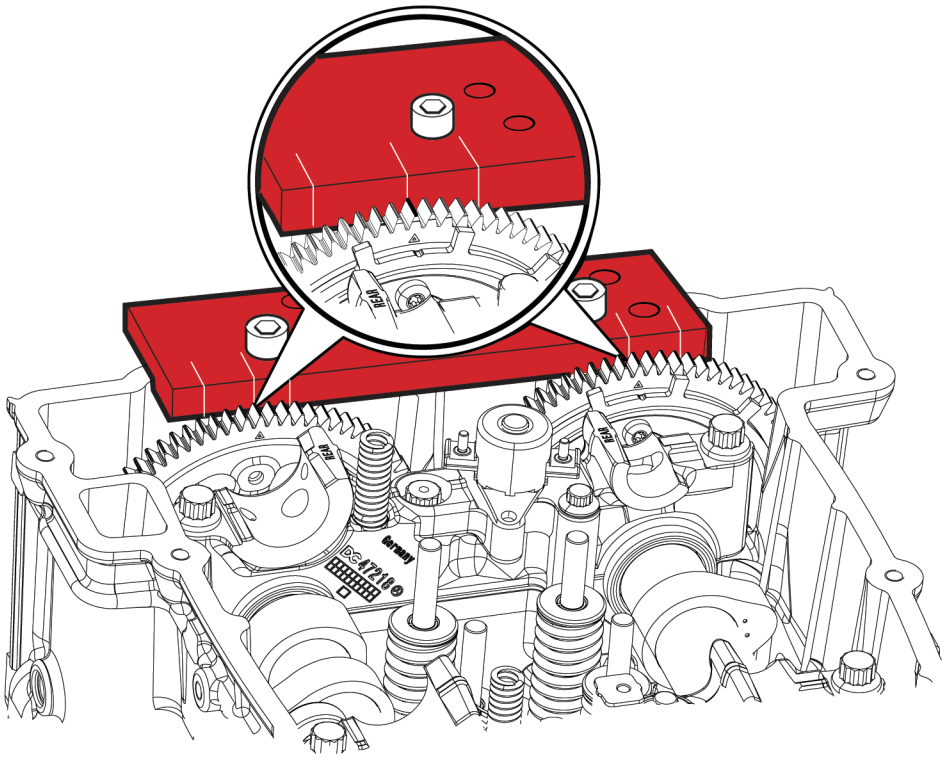
It should be noted the illustrations above show a new camshaft GHG17 engine that is in time at No. 1 TDC on the compression stroke. Do not try to correct the timing on a GHG17 engine with the new camshafts if the camshaft timing shows similar to the illustrations above when using the early tools. The early tools can be re-marked for the new GHG17 camshafts if the new tool is not available.
The front timing tool (fork) will no longer be required for timing purposes and will not be included with the new timing tool set. New camshafts assemblies must **not** be used with early idler gears No. 3 and No. 5. New idler gears No. 3 and No. 5 must **not** be used with early camshaft assemblies. Always refer to the eParts catalog when parts are needed.
NOTE: Install the rear camshaft timing tool with the tool number facing up to avoid incorrect timing verification.

10. Install the rear camshaft timing tool (1) onto the camshaft housing using two bolts.



d030113

11. Verify the marks on the gear teeth added during step 7 match the indicator lines on the rear camshaft timing tool. If the marks do not match, research the root cause of incorrect camshaft timing.



Causes of incorrect camshaft timing:

- Gear train idler gears not timed correctly (shows up in half-tooth increments and affects both camshafts)
- Flywheel indexed incorrectly to the crankshaft (typically occurs during clutch or flywheel repair when the dowel pin is crushed)
- Camshaft installed out of time (shows up in full-tooth increments on the camshaft with incorrect installation)
- Bent dowel pin in the crankshaft gear
- Gear train damage or missing teeth

