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1935 Harley VL - Engine Oiling & Crankcase Breathing System

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The author created this document to record observations made on the subject systems during the disassembly of a 1935 Harley VLD. This document does not address the oil pump and its adjustments since those subjects are not relevant to the routing of oil within the engine or the crankcase breather system. Because changes occurred continuously in these systems over the 7 years of VL production (1930-1936), the information provided herein is limited solely to the 1935 VL model, thus the functions described herein may not be applicable across all model years.

Without a schematic of flow within the entire system, i.e., the flow of oil and air within the engine, it may be challenging for the reader to follow solely a written description. Bearing that in mind, the oiling/breathing system will be presented via labeled images with accompanying written descriptions that delve into more detail.

Background and General Overview

Before presenting relevant images, an explanation of the overall oiling system and its general function should provide the reader with relevant background.

A feed line from the oil tank feeds a mechanical oil pump mounted on the cam cover and driven by #4 cam. This mechanical oil pump has only a single inlet and 2 outlets, one that feeds the engine's pinion shaft (pinion shaft bushing and crankpin), and the other feeds the primary chain oiler. The oil pump has no means of returning oil to the tank; hence, the description of the oiling system as "a total loss system" - once out of the tank, oil is pumped to the engine and never returned to the pump or the tank. The oil pump also has no means of recirculating oil within the engine, i.e., once oil from the tank enters and exits the pump into the engine, the pump never "sees" that oil again. Since the oil pump delivers only fresh oil from the tank, one of Harley's advertisements of the era for VL models suggested something akin to "Harleys always receive, clean, fresh, cool oil".

The other component required to deliver oil to the engine is a hand pump on the oil tank that feeds oil directly into the top of the left crankcase and is the primary means of lubricating the bottom end and pistons.

As quoted below, the standard procedure for lubricating a VL engine in regular service was provided in the 1934-1936 Rider's Handbook.

Draining and Flushing Crank Case

*Drain and flush the crank case, and give it a supply of fresh oil at least every 750 miles. Do this while the motor is hot. To drain oil from crank case, press downward on drain valve rod at base of rear cylinder on left side of motor, and turn lever on top end until it catches under bracket attached to cylinder base as shown in Illus. 3. After draining off the old oil, close drain and inject about 4 pumpfuls of fresh oil into crankcase with hand oil pump. Start motor and run for one or two minutes ; then drain again. This will flush all the old oil out of case. Close drain, inject 3-1/2 pumpfuls of oil into case, and motor is again ready for service. *

Modern riders report that the 3-1/2 pumpful recommendation is ~ 4 oz of oil. The subject Handbook also informs about the expected oil consumption rate and special operating conditions, as follows.

Normal oil consumption depends entirely on driving speed. A motorcycle driven at low speeds the majority of the time may run 1000 miles per gallon while one driven considerably at high speeds may run only 400 miles or less. The average is about 700 miles per gallon.

It should not be necessary to supply motor with extra oil with hand pump for a normal amount of high-speed running ; however, as a safety factor, when running at high speed for a long distance, it is advisable to supply a little extra oil with hand pump - about 1/2 pumpful every two miles.

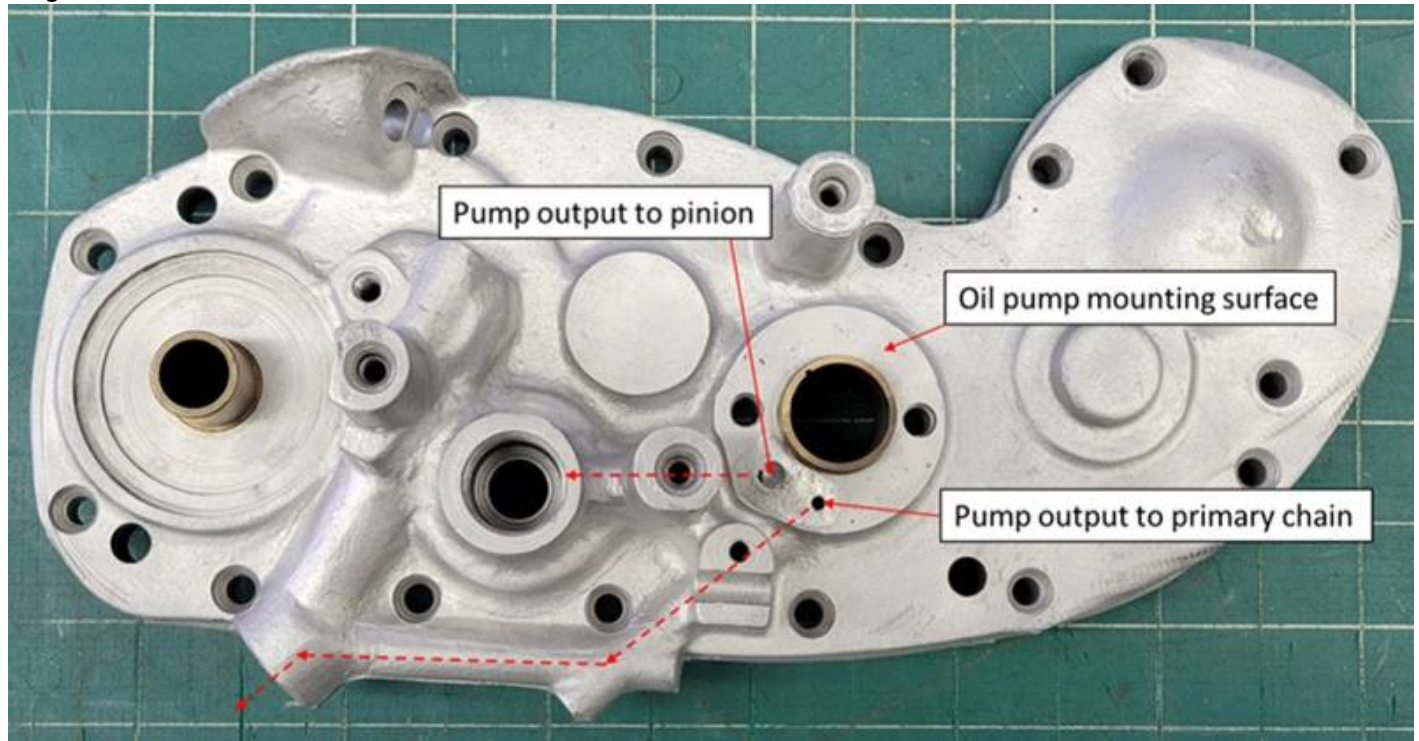
The ~ 4 oz of oil delivered to the engine via the hand pump is the primary means of lubricating the engine. The mechanical oil pump is more akin to a controlled bleed, intended to supply only the amount of oil lost via oil passing the piston rings, oil blown out via crankcase blowdown, and the mechanical pump output that lubricates the primary chain. If this were not the case, and the pump supplied oil amounts greater than those leaving the engine via the above-described routes, the engine would overflow with oil and overheat due to excess shearing of the oil by the crankshaft.

Let's consider the mechanical pump rate if a 1000-mile trip begins with a full oil tank (~ 1 gal) and consumes the entirety in 1000 miles. The engine begins with ~ 4 oz of oil in the crankcase, and presumably ends with 4 oz of oil in the crankcase, assuming the mechanical pumping rate is set properly. The mechanical pump emptied the oil tank, thus pumped 128 oz (1 gal) of oil. Therefore, the oil pump delivers 128 oz oil/1000 mi, or restated, ~ 0.13 oz/mi is fed via the mechanical pump. Assuming a traveling speed of 60 mph, the pump delivers 0.13 oz/minute. However, when traveling at a high rate of speed, e.g., 60 mph, we know the pumping rate is increased (500 mi/gal?) and the engine would likely consume oil at twice the previously stated rate, so the rate of delivery may be as high as 0.26 oz/min. Bear in mind that some of this oil is directed to the primary chain; thus, the engine internals never see this fraction of the pump output. To provide context to modern Harley engines, which circulate between 1-3 gallons/minute when operated at 3000 rpm, the VL oil pump volume is tiny, i.e., there is no highly pressurized oil, no high flow volumes, no oil stream, just a controlled bleed into the pinion shaft that ultimately escapes from the rod bearings into the engine case.

Oil Flow Within the Engine

With that introduction to the oiling system let's follow the oil through the system pictorially from the time it leaves the mechanical oil pump until it exits the engine to the primary chain. The pump output is partitioned between engine oil and primary chain oil as shown in Figure 1 below.

Figure 1



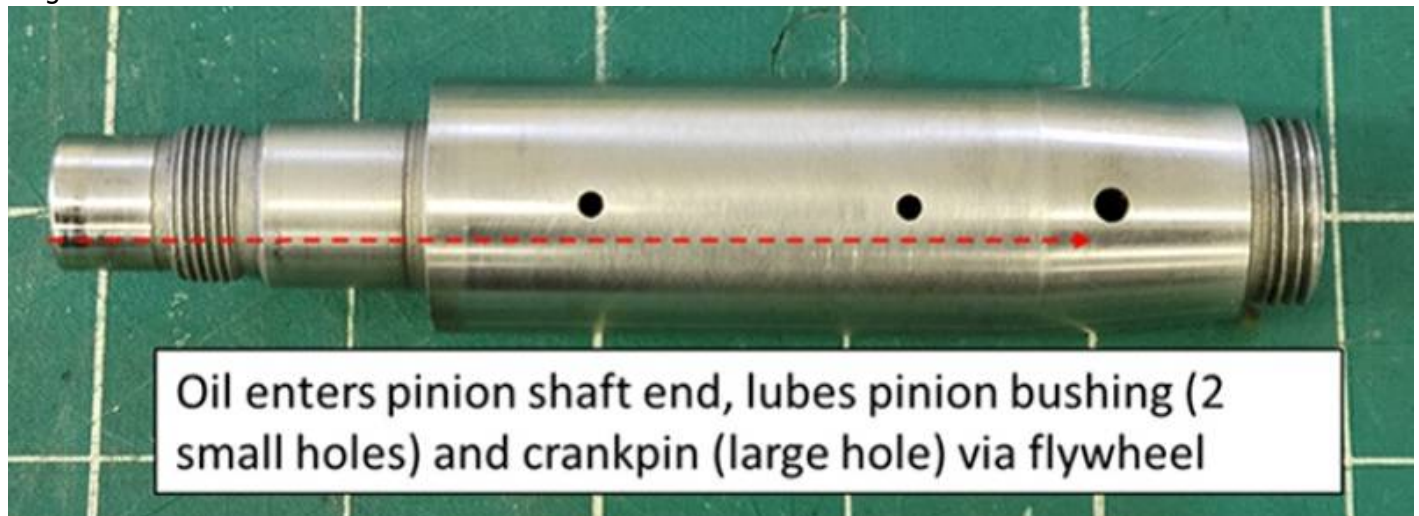
Note that the cam cover has no bushing for the pinion shaft, but rather, allows the pinion shaft end to float in the large chamber where pumped oil enters. This chamber is sealed by the components shown below in Figure 2, where a leather seal is compressed under the steel sleeve at the bottom of the well to seal the shaft in the chamber.

Figure 2



As shown in Figure 3, oil enters the end of the hollow pinion shaft and continues along its length to lubricate the pinion bushing and ultimately to the flywheel taper where it feeds the crankpin and rods.

Figure 3



Figures 4 and 5 show the pinion bushing having 2 gravity feed holes above the bushing (one on the flywheel side and one on the cam side of the case) as well as a broached full-length groove along its top side. Figure 6 is a magnified view of the pinion bushing and groove therein.

Figure 4

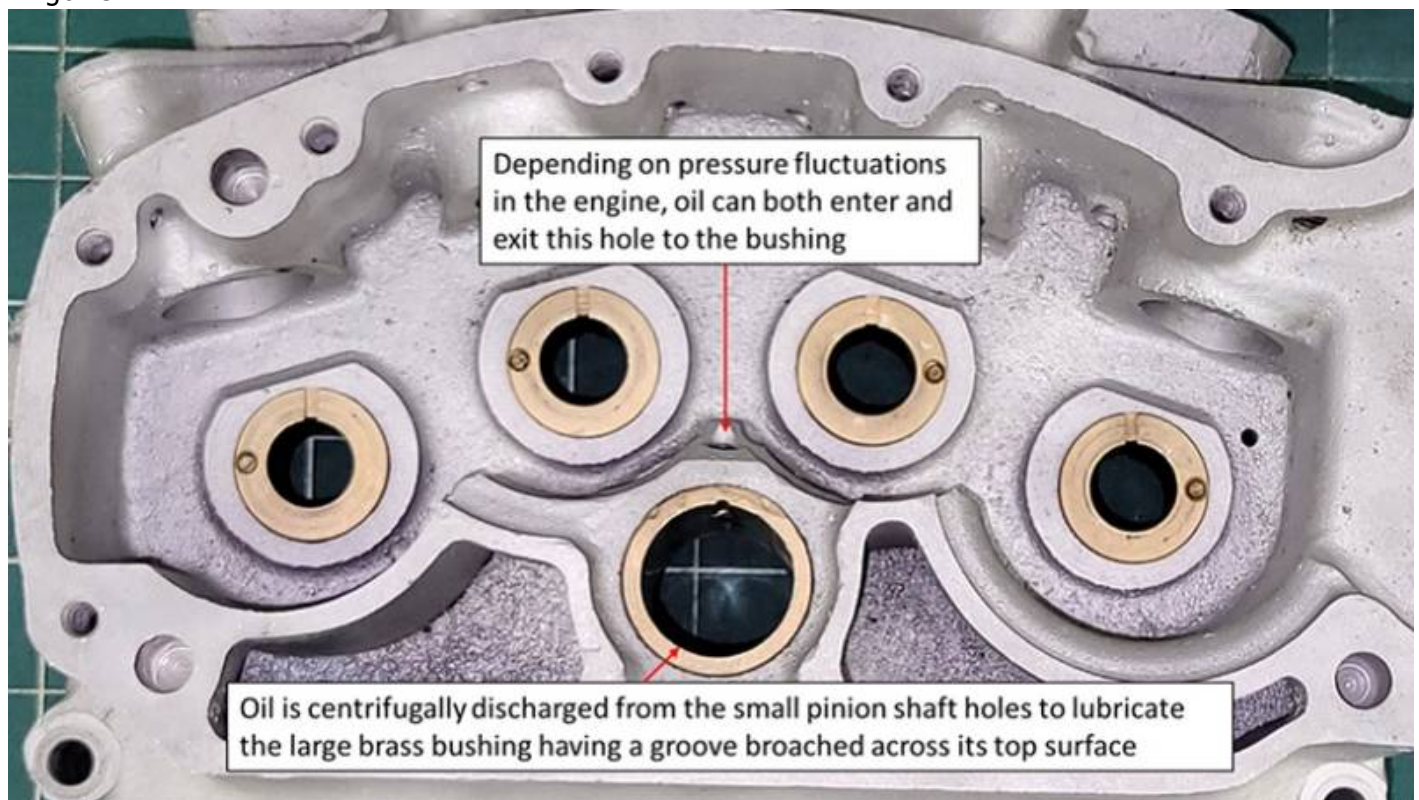


Figure 5

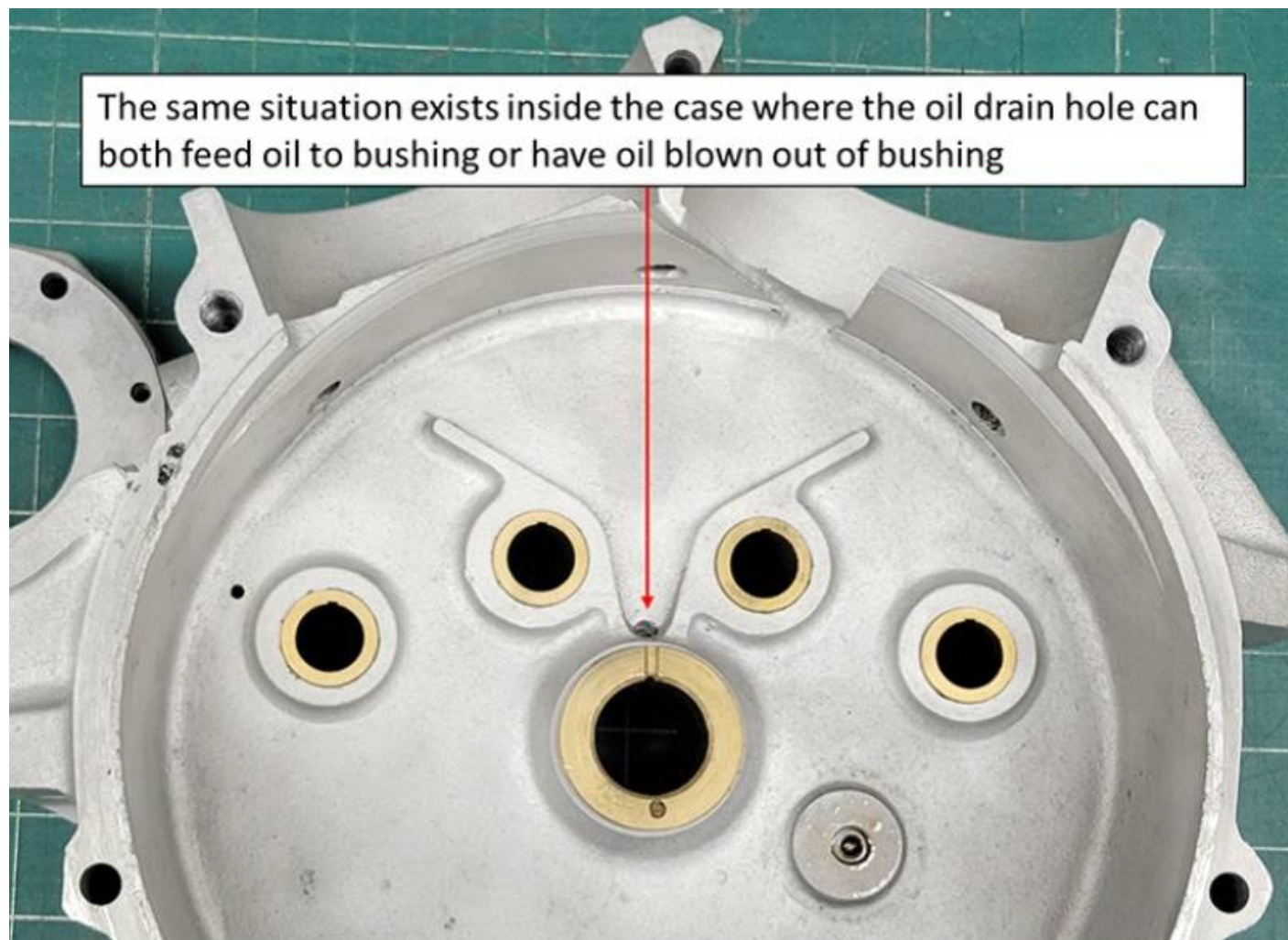


Figure 6



As the mechanically pumped oil enters the crankcase it has now arrived at it's nearly final destination where it mixes with oil already present in the crankcase (originally delivered by the hand pump). In addition to lubricating the pistons, rods, bearings, and bushings inside the crankcase, the oil has one additional lubrication task, and that is to lubricate the components in the cam chest – cam gears/lobes/shafts, tappet rollers, tappet guides, bushings, valves, and springs, i.e., all the moving components in the cam chest. Aside from those lubrication tasks, 3 fates lie ahead for the crankcase oil, 1) oil passes by the piston rings and gets burned in combustion, 2) oil is partially exhausted out of the crankcase/cam chest via the engines breathing apparatus, or 3) the operator opens the crankcase drain and empties the crankcase of oil before fresh oil is added, via the hand pump, and the cycle begins anew.

A reasonable question to pose at this juncture might be, “How does the oil get from the crankcase to the

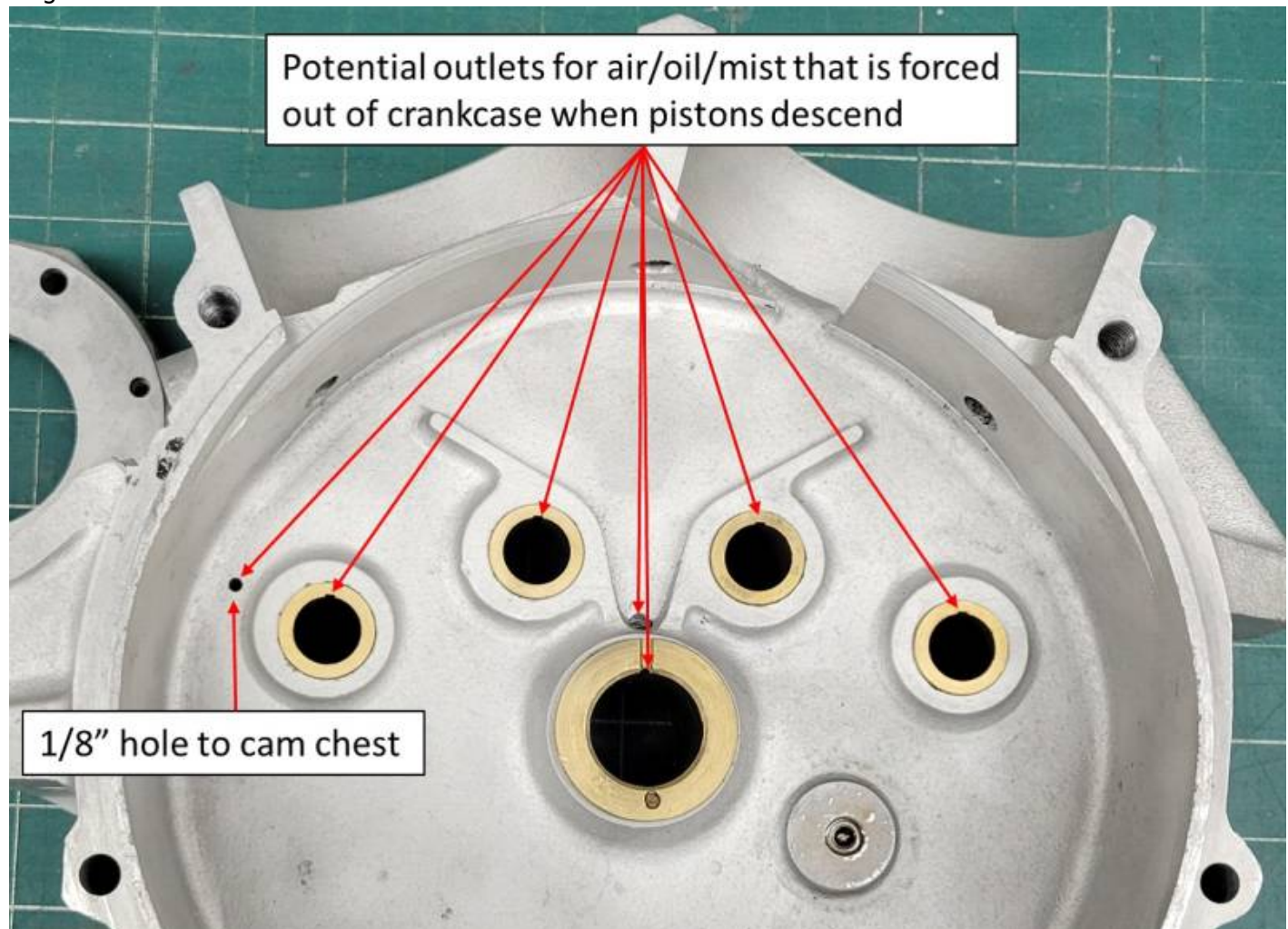
cam chest, and to the primary chain?”, which provides a timely segue to shift the discussion from oil delivery to the closely related topic of VL engine breather function.

VL Crankcase Breather Function

The following discussion explains how oil transfers from the crankcase to the cam chest and primary chain case, as well as how the pressure cycle within the crankcase, caused by the pistons rising and falling with engine rotation, is managed.

The left crankcase is sealed, with the exception that the labyrinth seal on the sprocket shaft allows a small amount of air to escape; thus, essentially all pressure created in the crankcase when the pistons descend exits the right crankcase into the cam chest. Figure 7 below shows the potential egress routes that air/oil mist may take to exit the right crankcase.

Figure 7



Note that the cam bushings as well as the pinion bushing have grooves across their top edge. When the

pistons descend on the downstroke and create positive pressure in the crankcase, air/oil mist is blown out of these grooves into the cam chest where it lubricates all the components therein. In addition to the grooved bushings, there is a 1/8" hole forward of the #4 cam bushing that also passes air/oil mist to the cam chest.

There is an additional route air takes out of the crankcase to the cam chest and that is via the 2 hollow camshafts, #1 and #3. These hollow camshafts have a 5/16" hole through them and are cross-drilled 5/16" dia at their outside end, which is positioned in the cam cover bushings. The cam bushings and bushing bosses for camshafts #1 and #3 are likewise drilled at 5/16" to allow air/oil mist to exit the camshaft/cam cover into the cam chest. The alignment of the cam cover holes relative to the holes in the rotating camshafts creates breather timing that when open on the downstroke allows the crankcase to be efficiently evacuated into the cam chest, and on the upstroke when the holes are closed, creates a slightly negative crankcase pressure to minimize leaks and maintain relatively neutral crankcase pressure.

Figure #8 below shows the 5/16" dia cross-drilling in camshafts #1 and #3 (pin gauges are through the holes). These cross-drilled holes account for ~ 32.5% of the circumference of the 39/64" dia camshaft, or restated, the cross-drilled holes each provide a breather timing window of ~ 235° crankshaft. Although this stated breather timing appears to be of excessively long duration, we must remember that the breather window opens very slowly due to the geometry of the device, i.e., one hole rotating across a 2nd stationary hole. The consequence of this type of valve opening is that very little airflow occurs across the tiny elliptical openings occurring at opening/closing. Thus, the effective duration of the breather system (when significant airflow occurs at wider openings) is significantly shorter than 235° crankshaft degrees.

Figure 8



Figures 9 and 9A below show the complementary drilling in the cam chest cover/bushings that allow the cam breather holes to expel air/oil mist into the cam chest. The air expelled into the cam chest then enters the 6 holes surrounding the #2 cam bushing boss, where it descends straight down and exits a 7/16" ID pipe into a small crankcase chamber rearward of the pinion shaft. \\

Figure 9

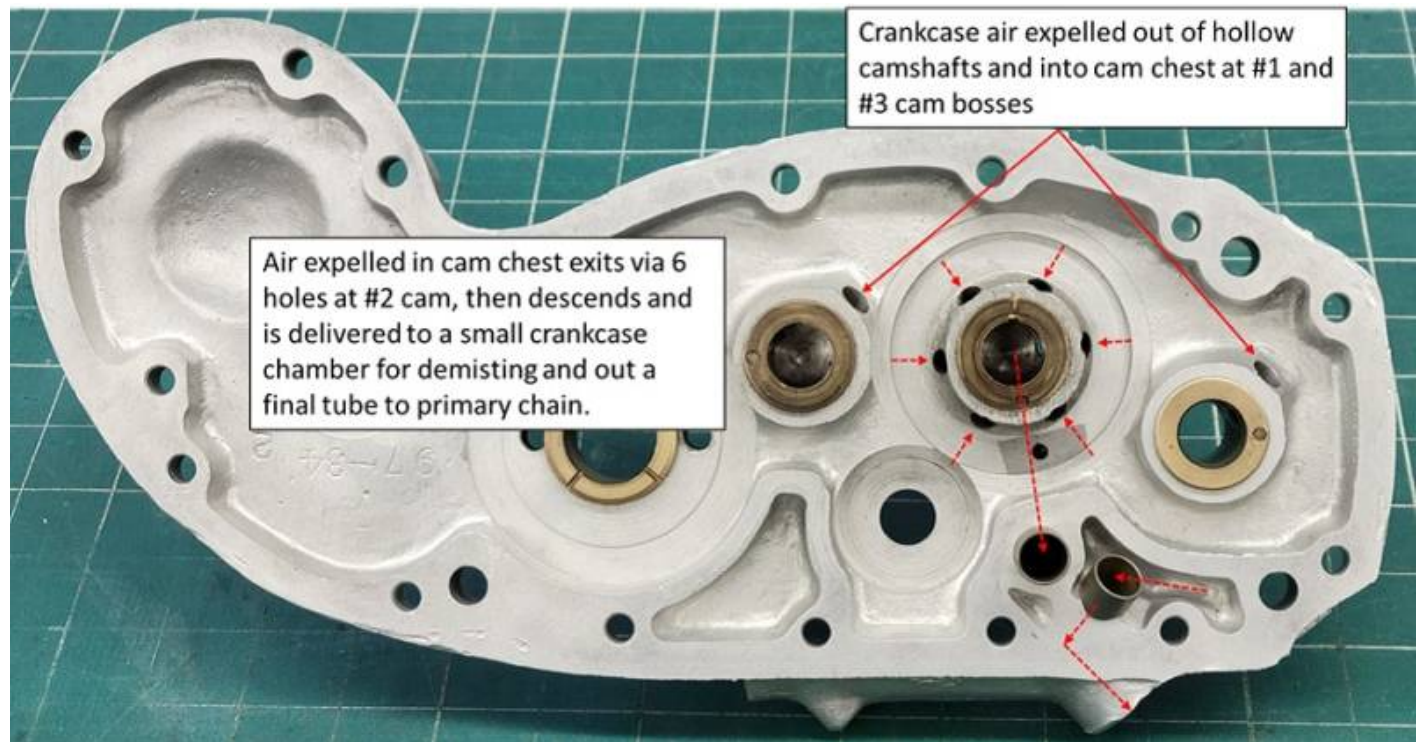
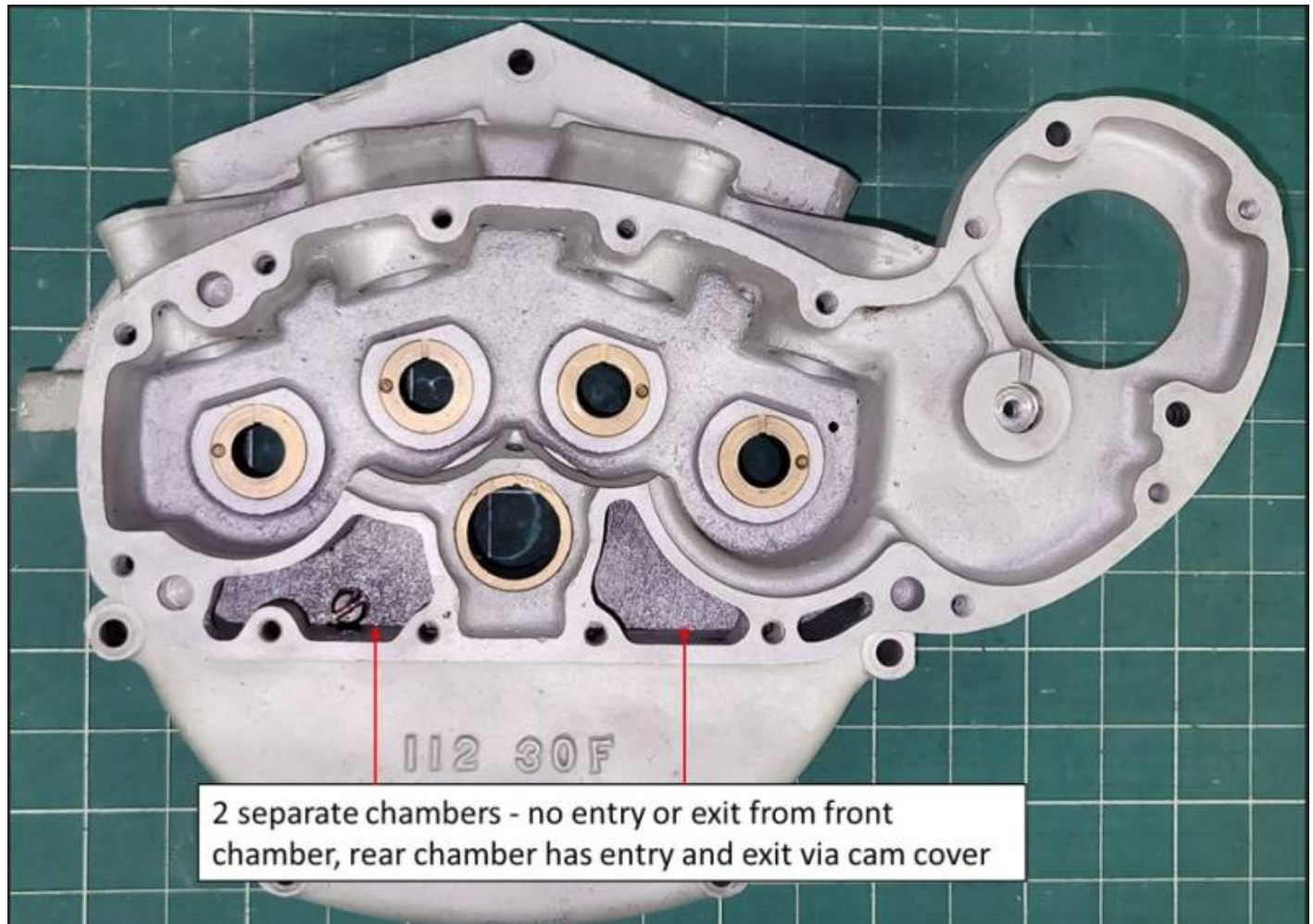


Figure 9A



In the subject rear chamber, the air/oil stream navigates a tortuous path around a louvered stainless-steel deflector, and due to the significant volume of the chamber, slows down as it passes through several layers of fine brass screen that demist the stream by knocking oil droplets out of suspension. The following image, 9-1, shows the spring steel deflector and the brass mesh mounted in the rear chamber of the engine case, and, in a subsequent series of pictures, 9-2 through 9-5, the subject components are removed from the case to provide the reader a better appreciation for the shape and layout of these components.

Figure 9-1

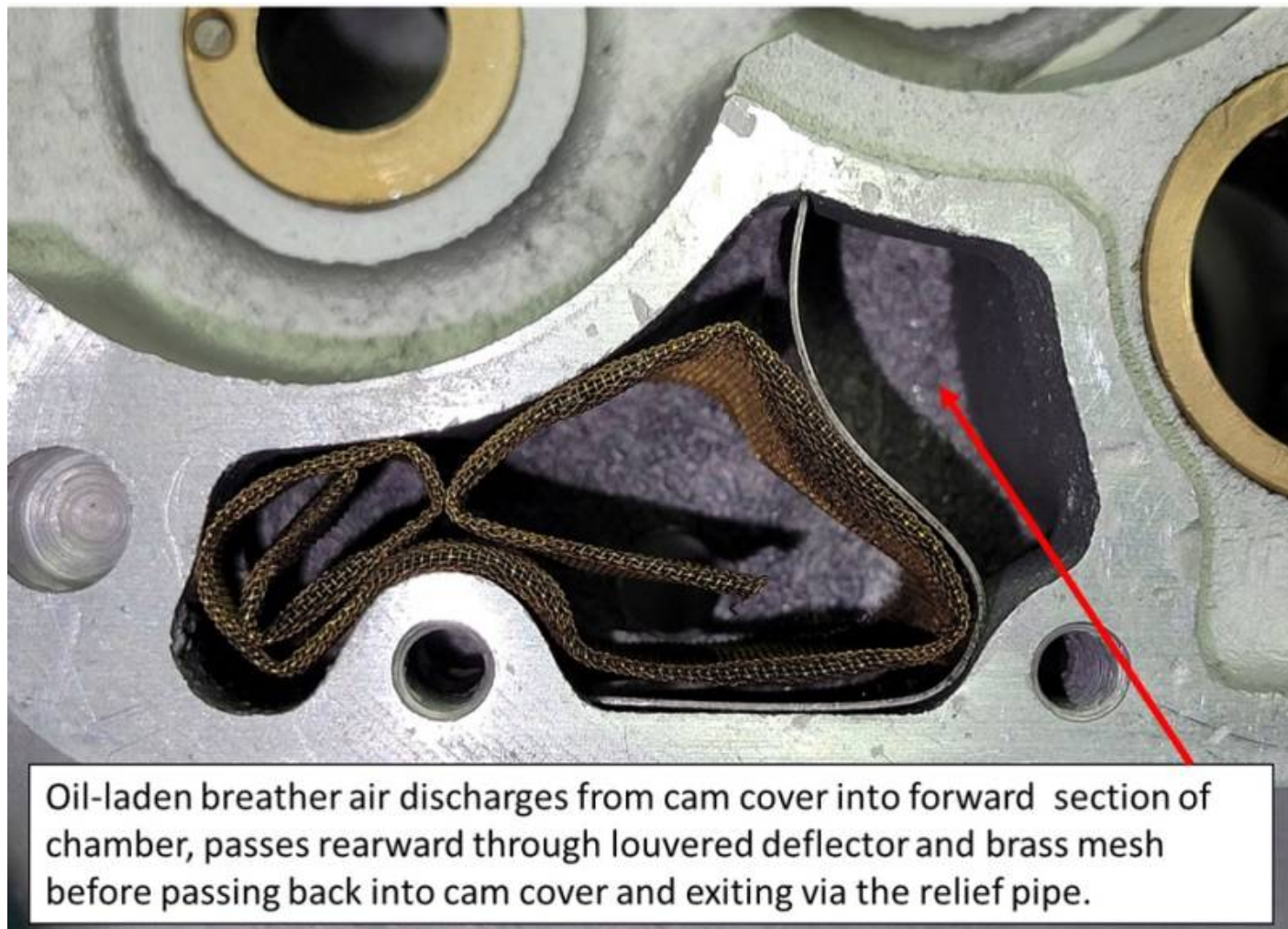


Figure 9-2 (L), Figure 9-3 (R)



Figure 9-4 (L), Figure 9-5 (R)



The demisted air exits this chamber via the cam cover, as shown in Figures 1 and 9, where it receives the fraction of primary chain oil provided by the mechanical pump, and continues via the Relief Pipe, P/N 543-34, across the frame to the primary chain.

One additional event that merits further discussion occurs in this rear chamber. As mentioned above, oil from the demisted air stream settles into the rear chamber. The collecting oil can conceivably fill the rear chamber to the level shown in Figure 9B (solid red line) before it overflows and gravity feeds out of the rear chamber via a short piece of 7/16" ID pipe, and into the cam cover where it exits the lower rear corner of the cover into the Relief Pipe that conveys the air/oil/vapor composite to the primary chain.

Overflow and gravity feed out of the rear chamber is an undesirable outcome since there is already a provision to control the quantity of primary chain lubrication via an adjustment on the mechanical oil pump. Thus, any additional oil overflow from this rear chamber alters the intended fraction of oil both in the crankcase and being delivered to the primary chain by the mechanical oil pump.

Figure 9B



However, Harley provided a means of minimizing the quantity of oil collecting in the rear chamber, so that oil did not gravity feed out of the chamber; instead, it was returned to the crankcase. The Gear Case Breather Valve, P/N 504-34 - the final component of the breathing system to be discussed here - is the device that returns oil from the rear chamber to the crankcase. Valve 504-34 is a one-way, flutter-style valve that flows only in one direction (from cam chest to crankcase). In this application, it might more accurately be referred to as a transfer valve, as it transfers oil from the rear chamber back to the crankcase. Figure 9C shows the valve and Figures 9D and 9E show the valve installed in the crankcase.

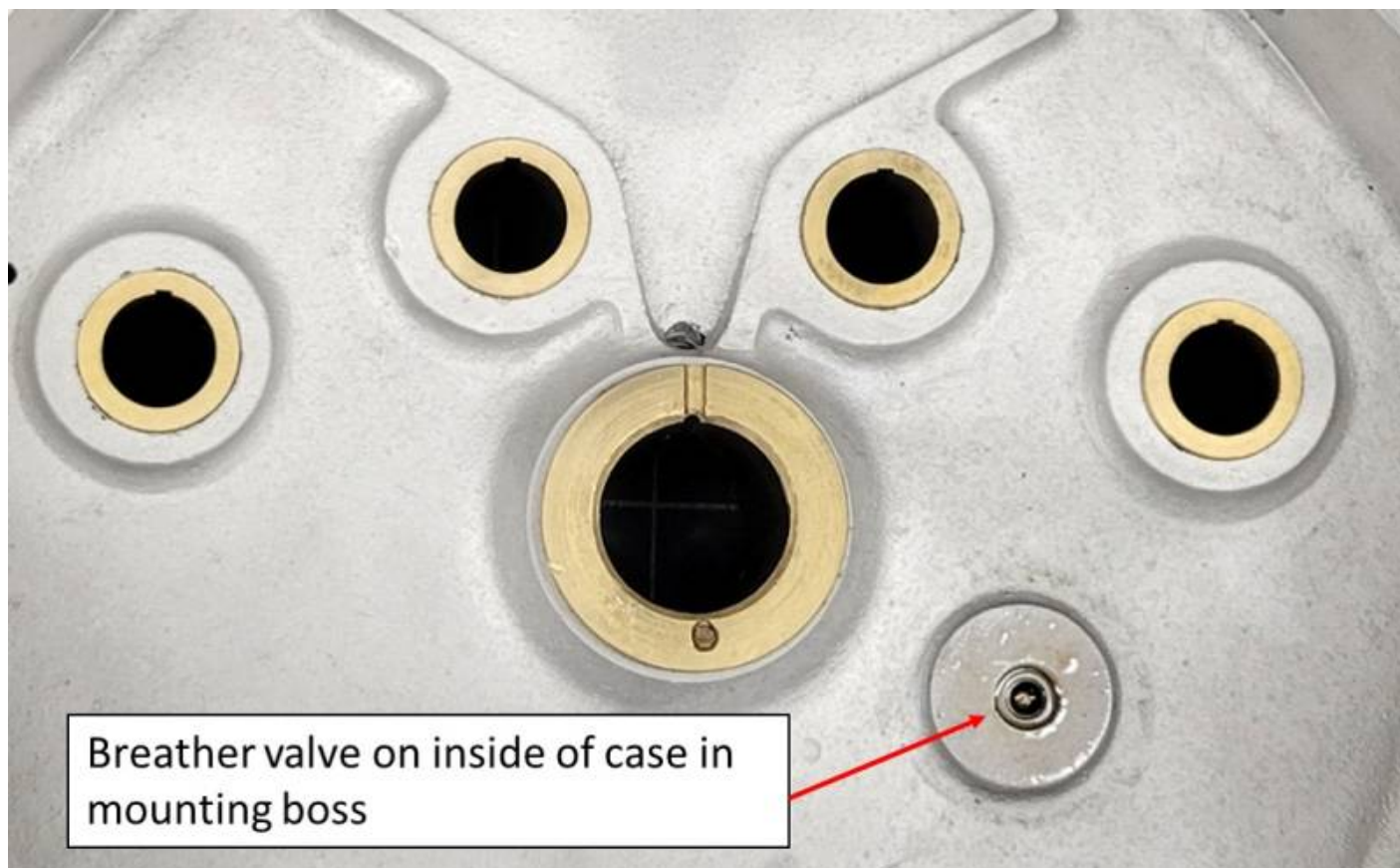
Figure 9C



Figure 9D



Figure 9E



The valve body is a steel slug with a screwdriver slot on one end and a 1/8" NPT-27 male thread on the other end. The valve body is relieved on the threaded end to provide a cavity in which the flutter element resides. The body has a 0.074" dia hole drilled axially from the threaded end, the full length of the threaded section. Just below the threads, a cross-drilling intersects the central drilling. The small flutter element, a triangular-shaped piece of stainless steel ~ 0.009" thick, that measures ~ 0.225" corner to corner, is secured/swaged in the cavity where it opens and closes in response to changes in crankcase pressure.

The subject valve was deconstructed to reveal the internal workings by carefully lathe-cutting it apart. The images in Figure 9F show the construction and components of the valve. The threads around the cavity holding the flutter element were carefully lathe-cut off to release the flutter valve. The left image shows the valve body with the threads removed. The top of the stem is the surface the flutter valve seals against to stop oil from passing through the valve on the engine downstroke when descending pistons create positive crankcase pressure. Carefully examining the central portion of the flutter valve revealed a circular pattern where it was sealed against the valve body. On the engine upstroke, when pistons create negative pressure in the crankcase, the flutter valve is sucked off it's seat and any oil residing at, or above, the cross-drilled hole in the valve body is pulled from the cam chest cavity back into the crankcase.

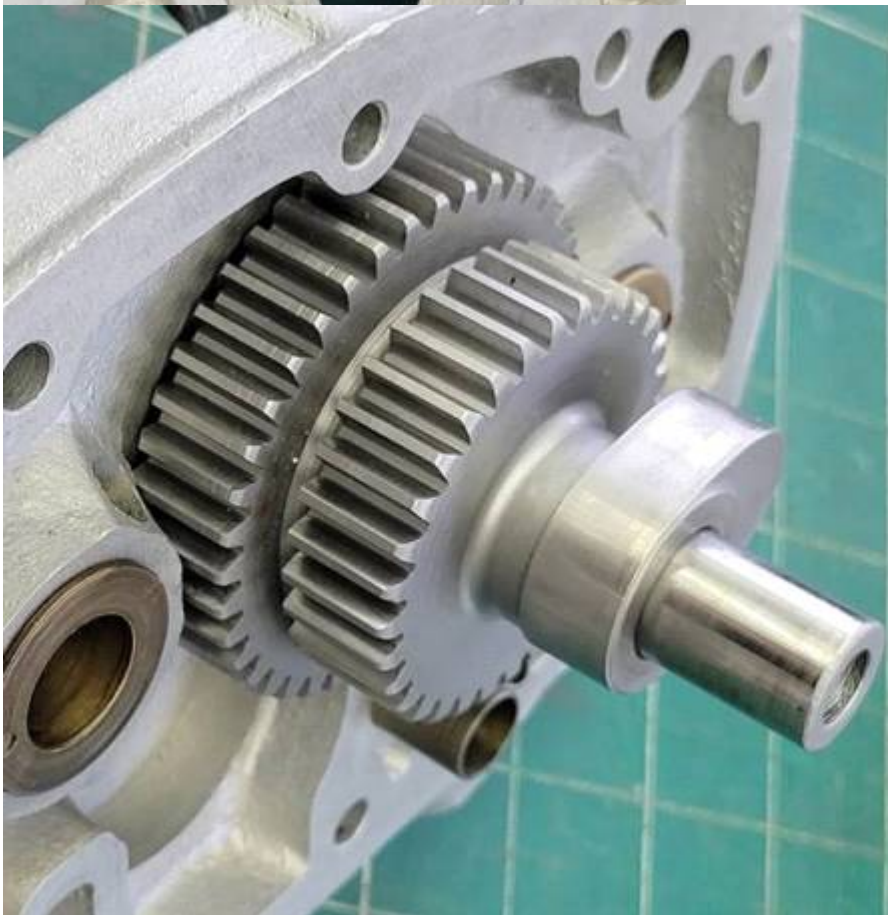
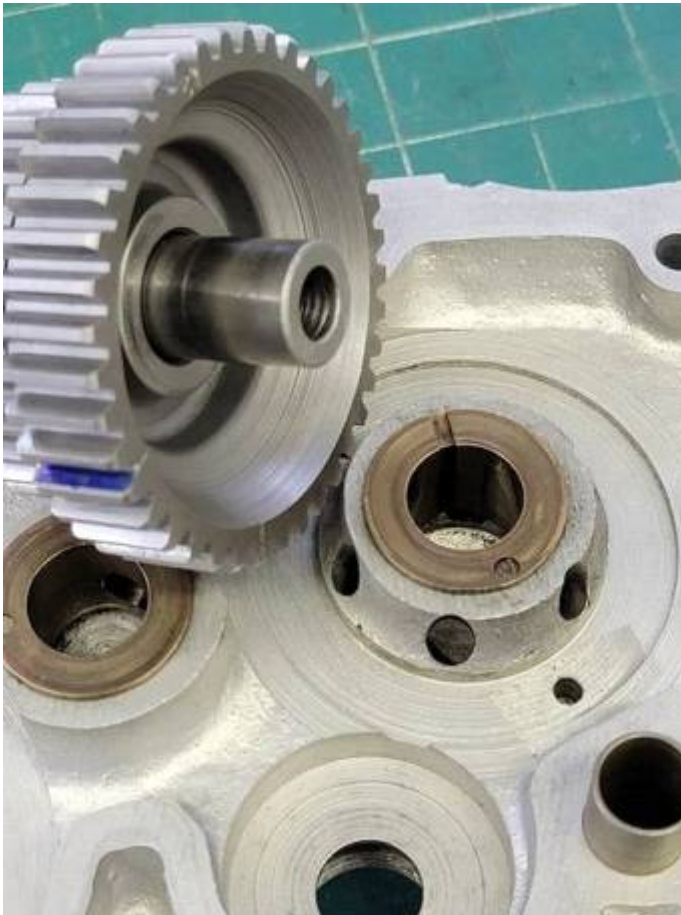
Figure 9F



One final comment on this subject is that, according to Steve Slocombe's VL Restoration Guide, the Gear Case Breather Valve, 504-34, was introduced in early 1934. In late 1934 after case 9000, a stiffening boss was added to the crankcase around the breather valve which increased case thickness and allowed greater thread depth for mounting (see Figure 9E).

An additional breathing point of interest concerns the 6 holes at the #2 cam boss and the fit of the cam gear over this large perforated conical boss area. Figures 10 and 11 provide the reader with a feel for the fit of the gear over the boss as well as the clearance between the gear and cover when installed. Note that the generous concave relief on the gear hub provides substantial clearance around the boss, thus allowing air to flow relatively unimpeded into the 6 exit holes. In contrast, when the cam is fully inserted into the cover, the clearance between the cover and the outermost circumference of the gear is minimal. This tight clearance provides a centrifugal slinger that helps reduce the oil content of air passing through this high shear gap to the cam cover outlet.

Figure 10 (L) and Figure 11 (R)



Another observation of the VL breathing system relates to the various “breather hole areas” relative to one another, i.e., the x-sectional area of holes in the camshafts relative to the area of the 6 holes around the #2 cam boss and the area of the 7/16” dia tube that allows air to exit the cam cover to the primary chain. Table 1 below shows the area of the subject holes. Interestingly, the 2 camshafts introducing air to the cam cover are nearly identical in area to the 7/16” tube that allows air to exit the cam cover. However, the 6 holes at the #2 cam boss, that convey air from the cam cover to the rear chamber, have ~ 2X the area of either the hollow camshafts or the 7/16” tube exiting the cover. It is presumed that the 2X extra area behind the #2 cam exists to both 1) allow the air to slow down and be demisted via #2 cam centrifugal slinger action, and 2) provide full radial access to the 6 holes behind the #2 cam.

Table 1 – VLD Cam Chest Breather Hole Areas

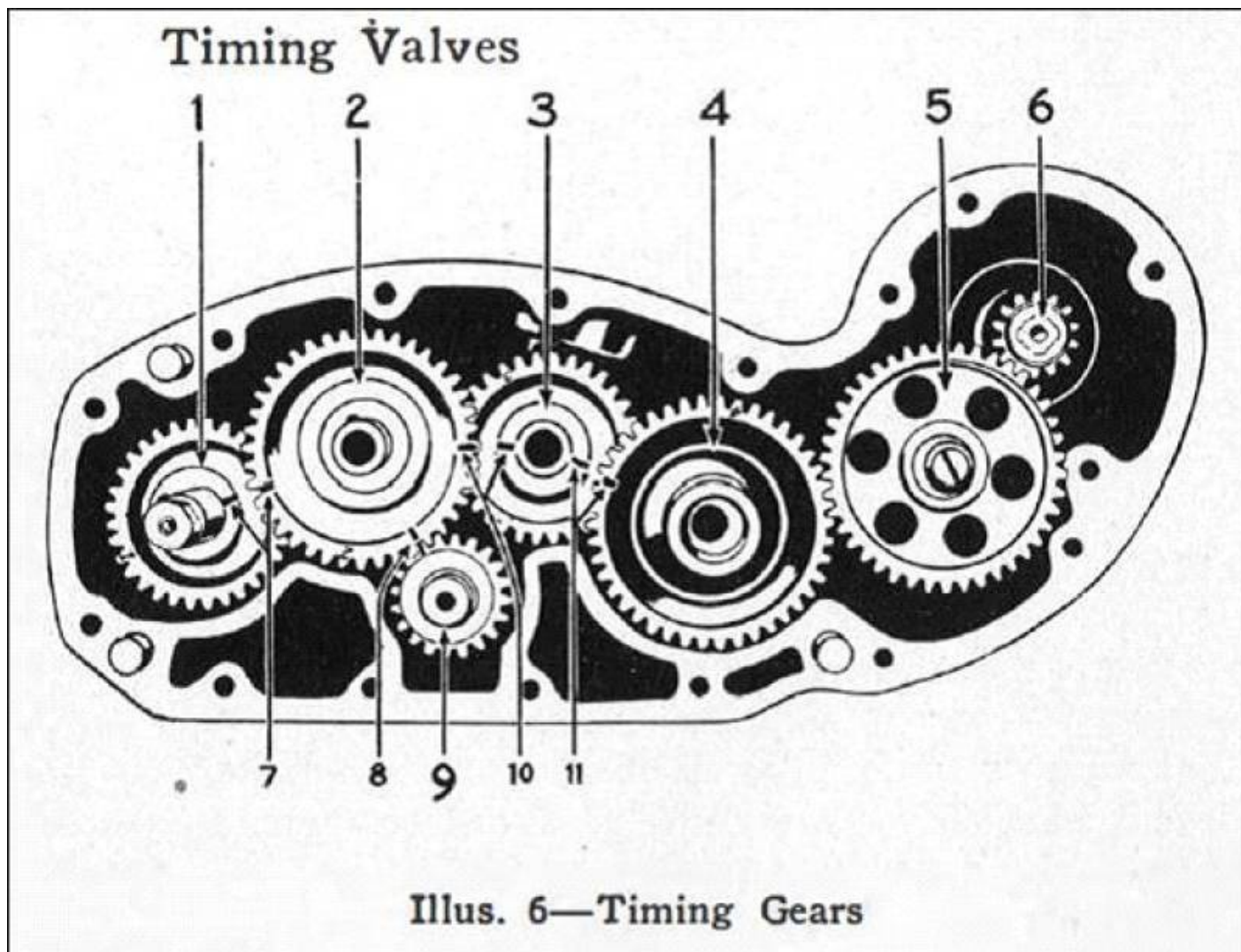
Breather Item	Area (in ²)
Camshaft ID hole area (5/16" dia hole)	0.077
Camshaft total hole area of cam #1 and #3	0.155
Hole area around #2 cam conical boss (6 x 0.253" dia holes)	0.301
Breather hole area of 7/16" ID tubing in cam cover	0.150

VL Crankcase Breather Timing

To this point, the crankcase breather discussion has focused on how air is routed as it moves through the engine and exits. Another consideration relating to the breather system is the timing of the breathing events relative to the crankshaft angle. Making such measurements requires that a timing disk be fit to the pinion shaft so the crankshaft angle can be related to breather opening/closing events.

The procedure to determine breather timing begins with the cam installation process, since we are correlating the camshaft angle (breather hole timing) to the crankshaft angle. Figure 12, from the 1934-36 Rider's Hand Book, shows the typical appearance of pinion and camshaft gear timing marks when a 4-cam Harley is timed correctly.

Figure 12



Unlike more recent Harley models, e.g., UL, WL, K/XL, where camshaft timing marks are aligned with the crankshaft positioned at cylinder #1 (rear) TDC, when the VL timing marks align, the crankshaft is positioned 45° BTDC on cylinder #1. It is believed the “modern” cam timing convention (crankshaft at cylinder #1 TDC), was standardized by Harley circa 1937. The significance of the cited difference in crankshaft angle when timing cams is, that when setting up the timing disk on a VL engine, this 45° difference in crankshaft angle must be accounted for.

The factory VL breather timing specifications are referenced to piston position; thus, to correlate breather opening/closing to crankshaft angle, we must start by converting piston position to crankshaft angle. The factory breather timing specification for a 1936 80 cu in Harley model VLH, from Harley Shop Dope dated Dec 9, 1935, is shown below.

BREATHER TIMING: Opens top center plus or minus 1/8", and closes 1-1/32" plus or minus 1/8" after bottom center. Timing should be done on front cylinder, both breathers opening and closing at same time, with no more than 1/32" difference.

Table 2 below shows the results of converting the “piston position breather timing” to crankshaft angle.

Table 2 - Breather Timing Given in Piston Position, Converted to Crankshaft Angle

Breather Event	Front Cylinder Piston Position (in)	Decimal	Calculated Crankshaft Angle	Angle Reference
Open	TDC $\pm 1/8$ "	0.000"	0° ± 17.5 °	BTDC
Close	1-1/32 $\pm 1/8$ ", ABDC	1.031"	67° ± 4 °	ABDC

To visually assess VL breather timing requires a clear line of sight to the holes in the cam cover where #1 and #3 camshafts rotate and result in opening/closing events. Such visual observations can occur only if the cam cover is removed from the engine with properly timed cams and pinion gear present. The bullet points below describe the test rig employed and the general procedure for determining the crankshaft angle at which breather opening/closing events occur.

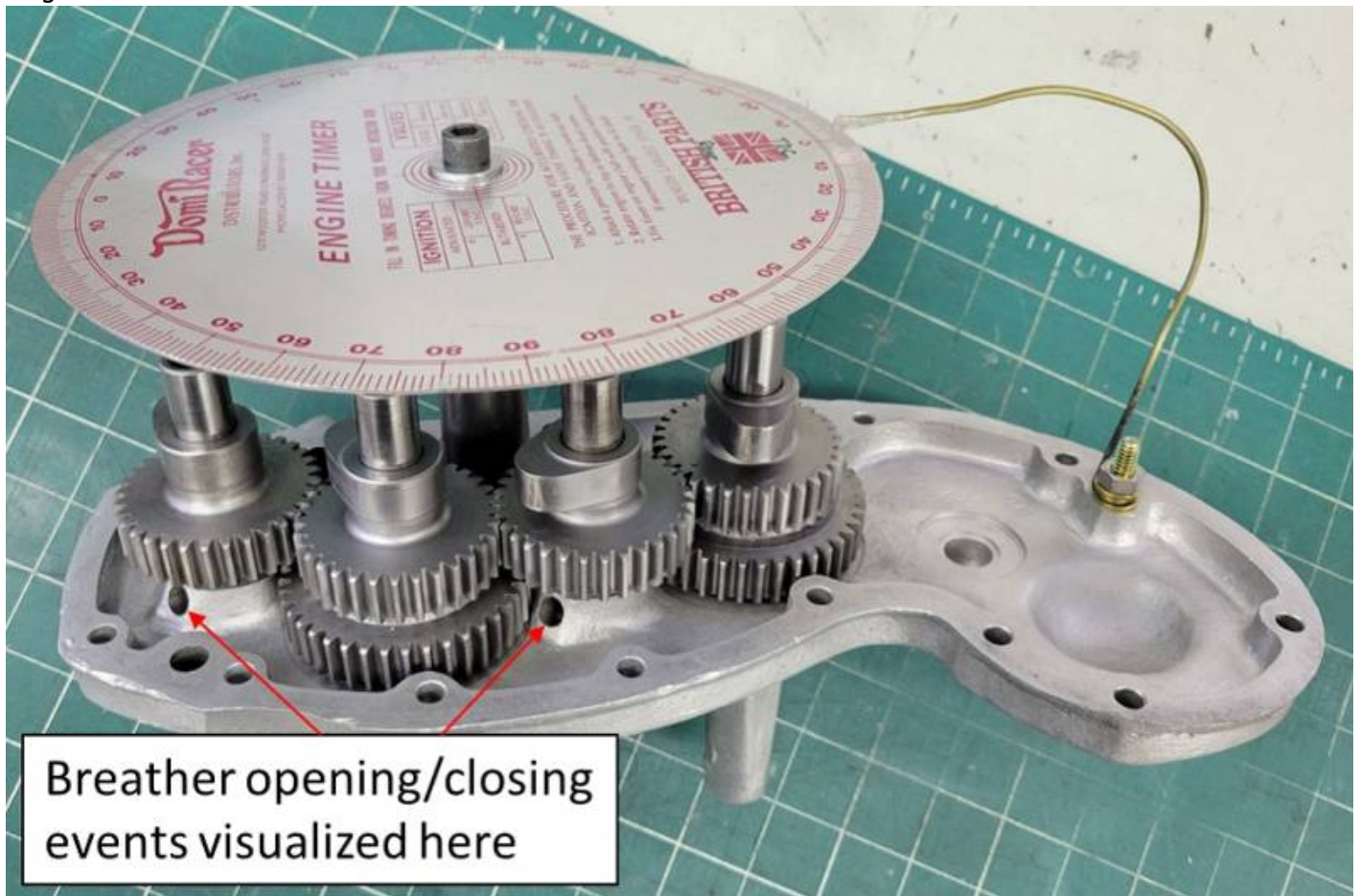
- Create a shaft on which the pinion gear can be installed and bush the cam cover to support said shaft
- Mark the pinion tooth timing mark on the back of the pinion gear, so it can be viewed from the backside, and glue the pinion gear to the new shaft with a drop of super glue
- On cam #2 mark the center timing mark on the back of the gear so it can be viewed from the backside, for subsequent alignment with the pinion gear
- In the right engine case, properly mesh the pinion gear/shaft and camshafts, and install the cam cover
- Invert the crankcase so the cam cover is at the bottom and carefully lift the crankcase to transfer the properly timed cams and pinion gear/shaft to the cam cover.
- Affix a timing disk to the pinion shaft and as the pinion shaft is rotated, record the crankshaft angle at which the breather holes in the camshafts open and close as they pass by their complementary holes in the cam cover.

The images below show the setup used to record breather timing opening/closing events. Recall from the discussion above for VL engines, that cam timing/installation occurs with the crankshaft positioned 45° BTDC cylinder #1, which is a total of 90° BTDC on cylinder #2 (45° cylinder separation + VL cam timing done 45° BTDC cylinder #1 = 90°). When the backside gear markings of the pinion shaft and #2 cam are aligned, the timing disk pointer is set to 90° BTDC on cylinder #2, which provides the proper reference to the factory breather timing given for cylinder #2.

Figure 14



Figure 16



The timing disk was rotated in the direction of engine operation and the crankshaft angle at which opening/closing events occur was recorded. Table 3 shows the factory-specified breather timing and breather timing results recorded with the test fixture.

Table 3 - VL Breather Timing Results		
Breather	Crankshaft Angle - Cylinder #2	
Valve	Factory	Experimental
Position	Specification	Result
Open	$0^{\circ} \pm 17.5^{\circ}$ BTDC	6° BTDC
Close	$67^{\circ} \pm 4^{\circ}$ ABDC	70° ABDC

The breather timing results agree very favorably with the factory specifications, especially in light of the factory specification allowing a difference in piston position of $+ 1/8"$. One other consideration relating to this test is the difficulty in visually determining exactly when the breather valve opening and closing occur, because the overlap of 2 identical circles occurring down a small dark hole makes it very difficult to define the exact instant overlap begins and ends, even with excellent illumination.

To the best of this author's ability, the above summary provides an accurate description of the entire oil path within the VL engine from the point of oil entry at the cam cover to the various points where oil leaves the engine. Likewise, the subject of the breather system and timing thereof have been described in their entirety. None of the information recited here is new and has been known since 1935. Nevertheless, this author found it challenging to uncover such information, so he opted to document his findings as he explored the subject systems.

Kurt

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