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REF: Engine Mechanicals

IH Crankcase Pressure and Engine Breathing

Engine Breathing

1957-1976 engines have a different breathing cycle than 1977-up engines. The end result is the same. However, the means to get there is different.
Below are the two systems explained.
You can also reference the sub documents under each particle subject heading. These pages are more detailed information on certain subjects.
Simply click on any one of them to research more information.

1957-1976

Sub Documents

- How Piston Swept Volume Compares When the Breather Opens as to When It Closes

> The shallow sump, timed breather system, comes from the aviation world of old. [1)]
> Piston driven aircraft had to be able to evacuate the oil from the crankcase regardless of engine altitude and that system does that.
> At the time Harley adapted that system they were copying the highest engine technology of the day.
> They just took too long to abandon it as technology advanced.
> Documents from HD Racing from the period show no HP gain between the 2 ironhead systems when the breather is properly timed (which didn't happen a lot).

The rotary breather valve is integrated with the oil pump. The gear on top of the valve also operates the oil pump.
The breather valve connects the flywheel area to the gearcase.

The rotary breather valve functions to relieve pressure in the crankcase caused by the downstroke of the pistons and it controls the flow of oil in the lubrication system.

It is timed to engine rotation and opens after the downstroke of the pistons begins.

Engine Breathing Cycle:
A mixture of crankcase air and oil mist is produced on each piston down stroke.
Upstroke pulls this mixture up into suspension but in tiny particles to mix with the air moving around and thrown here to there for lubrication.
The oil is separated from the air by way of collision. Everything the air/oil mix touches on the way to the vent separates some oil from the air.

1957-1976 engines breath and scavenge oil from the same hole.
On piston down stroke, drain oil is pushed into the oil galley (slot) in the rear of the crankcase and toward the oil trap beside the breather gear.
When the breather window opens after downstroke, both drain oil and crankcase air pressure are pushed into the rotating breather gear.
The oil and air is slung out from the center of the gear into the gearcase where it bounces on cam gears, case walls, etc.
Air / oil mist flows toward the vent and the oil gets spun out of suspension by the oil slinger on the generator drive gear.
Crankcase exhaust air is then sent out the breather tube.
The breather valve then closes on after the pistons rise (after BDC), creating vacuum in the crankcase and the cycle repeats.

1977-1985

The one way breather style system is more like a car PCV system. [2)] Unlike an auto PCV, a Sportster has a faster acting type one way valve.
A deep (dry) sump was added to 77> casings and the scavenge side of the oil pump pulls the oil from the scavenge port in the rear of the sump area.
Holes were added between the crankcase and the gearcase wall (much the way your car's crankcase is vented out the top thru the valve covers)
Those holes in the walls are an open passage for crankcase pressure into the gearcase.
So the gearcase is also pressurized. Crankcase pressure is sent thru the one way valve in the cover and then vented to atmosphere out the vent.

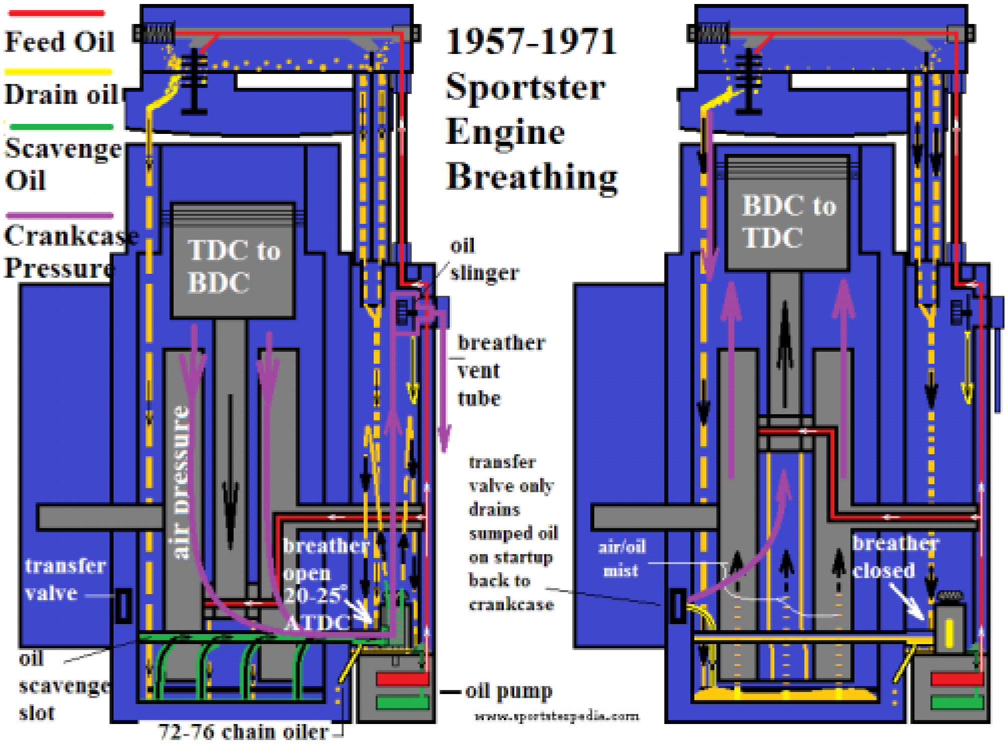
However, crankcase ventilation works a little differently on these motors than a Chevy. [3)]
What you see on cars is an inlet, generally coming from the air filter, into the motor. Then an outlet, regulated by a PCV valve, going into the intake manifold.
So it's designed to flow a little air through the system.
The other thing is that a V8 crankcase stays at a constant volume, because for every piston going up there's a piston going down.
On a Sportster motor there's no air inlet. The engine vents into the intake flow on the upstream side of the carb instead, where there's much less vacuum.
It's not designed to flow air through it. What's more, the crankcase volume is constantly changing. There are check valves in line with the breather outlets.
Their function is to expel the air when the pistons go down but then restrict the air from entering the motor when the pistons go up.

The result is that beyond the first revolution, if the check valves are working properly, all you see out the breathers is the pulsating pressured air.
On a good motor, it's very little. But if the check valves are not working properly, the motor goes into an inhale/exhale mode.
That causes a whole lot air movement and it also causes a lot of oil to get carried out at the same time.
Many cases of excess breather oil is caused by poorly functioning check valves.

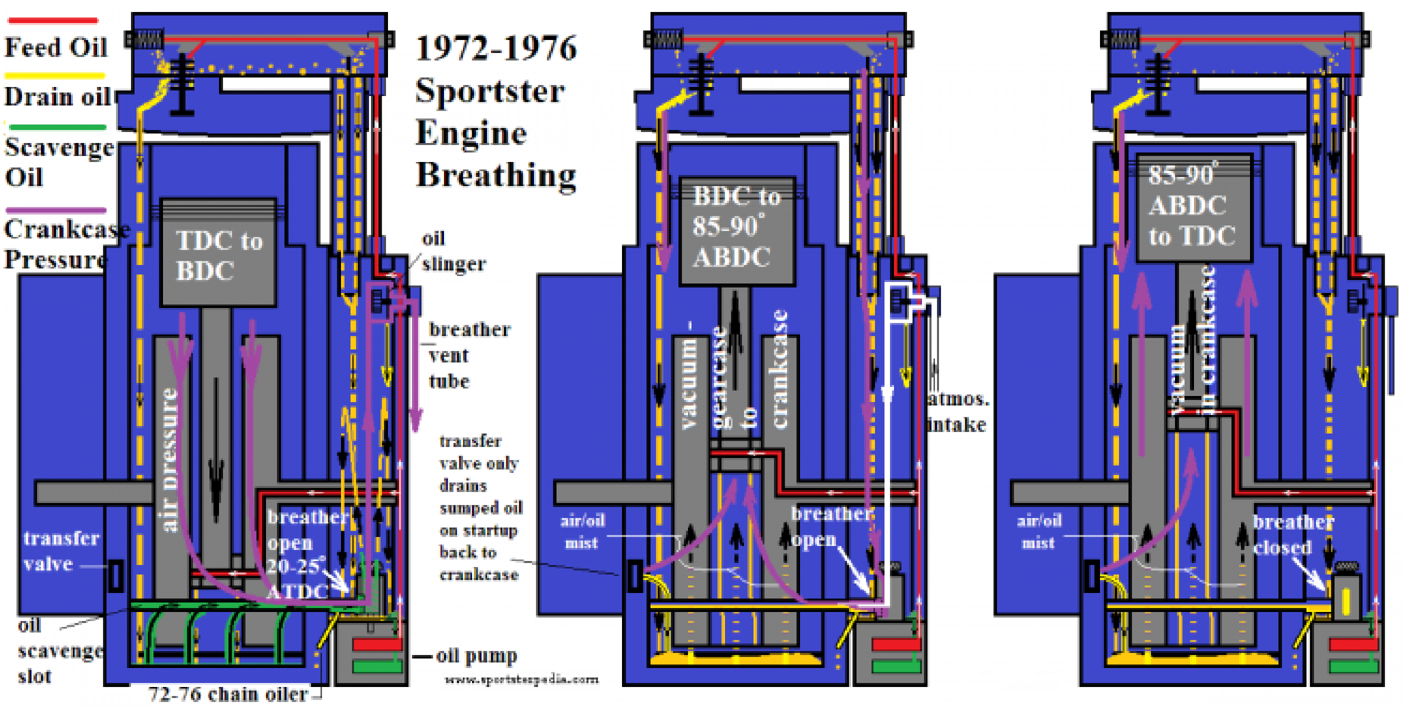
Engine Breathing Cycle: A mixture of crankcase air and oil mist is produced on each piston down stroke.
Upstroke pulls this mixture up into suspension but in tiny particles to mix with the air moving around and thrown here to there for lubrication.
The oil is separated from the air by way of collision. Everything the air/oil mix touches on the way to the vent separates some oil from the air.

1977-up engines scavenge oil from down low in the crankcase and breath up higher through holes in the cam wall.
On piston downstroke, drain oil is pushed into the oil galley and crankcase air pressure is pushed into the gearcase and the breather valve is pushed open.
The air/ oil mist is slung around in the gearcase where it bounces on cam gears, case walls, etc.
Remaining air / oil mist flows toward the vent.
On 1977-E1984 engines, oil gets spun out of suspension by the oil slinger on the generator drive gear and crankcase exhaust air is then sent out the breather vent.
On L84-85 engines, the slinger washer was removed and a breather baffle tube was installed in the cover to separate oil.
Oil hits the breather baffler tube then the back side of the breather valve to separate from the air and drains back into the gearcase.
The breather valve then closes at piston (BDC), creating vacuum in the crankcase as the piston rises and the cycle repeats.
There were several changes made of the valve itself, but they operate on the same principle as a one way breather valve.

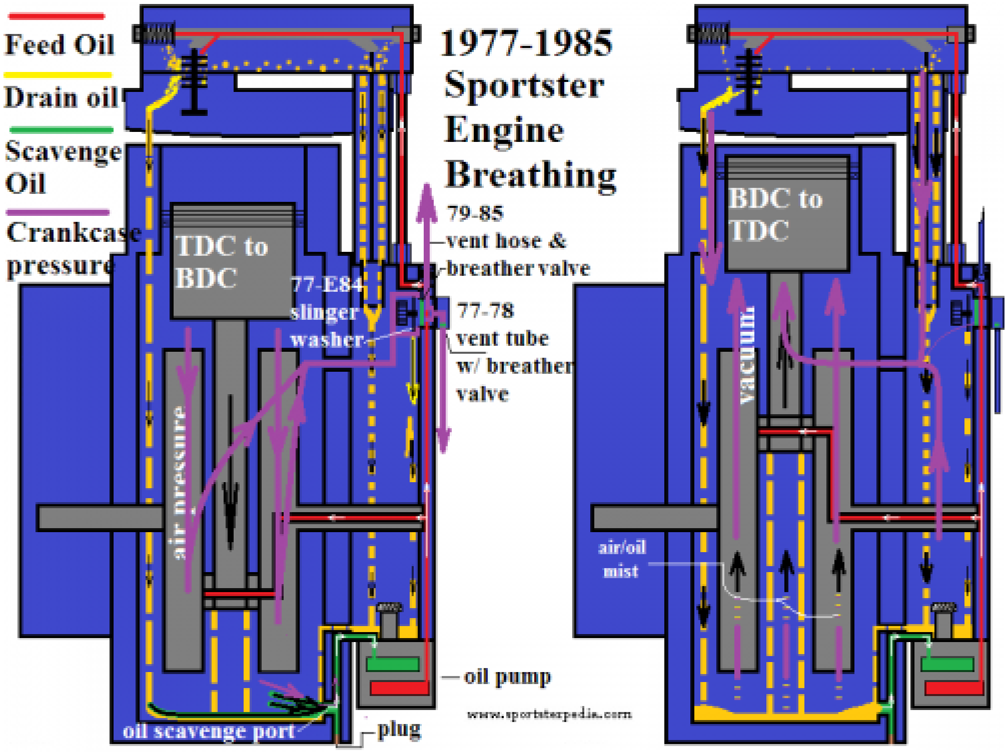
OEM oil paths and engine breathing drawings


Feed Oil
Drain oil
Scavenge Oil
Crankcase Pressure
1957-1971 Sportster Engine Breathing
TDC to BDC
air pressure
oil slinger
breather vent tube
breather open 20-25° ATDC
transfer valve
oil scavenge slot
72-76 chain oiler
oil pump
www.sportsterpedia.com
transfer valve only drains sumped oil on startup back to crankcase
BDC to TDC
air/oil mist
breather closed

4)


Feed Oil
Drain oil
Scavenge Oil
Crankcase Pressure
1972-1976 Sportster Engine Breathing
TDC to BDC
air pressure
oil slinger
breather vent tube
breather open 20-25° ATDC
transfer valve
oil scavenge slot
72-76 chain oiler
oil pump
www.sportsterpedia.com
transfer valve only drains sumped oil on startup back to crankcase
BDC to 85-90° ABDC
vacuum - gearcase to crankcase
air/oil mist
breather open
atmos. intake
85-90° ABDC to TDC
vacuum in crankcase
air/oil mist
breather closed

5)



6)

Engine Breather Valves

Sub Documents

- Breather Valves (1957-Up) (list of breather valve changes)
- Timing the 57-76 Breather Valve
- Further Study of the Timed Breather Valve
- Oil Drainback and Supplemental Air Intake from Breather Valves
- Dissecting the 77-78 Breather (foo-foo) Valve (24634-77)
- Further Study of the 79-E82 Reed Valve
- XR-750 8-Ball Breather Valve
- Breather Venting / Relocation (list of breathing mods and aftermarket breathers for 1977-up engines)
- Wet Sumping
- Why Oil Pukes Out the Breather

Symptoms of Breather Valve Problems

The most notable signs of breather valve problems include weeping / leaking gaskets or blown gaskets / seals.
1977-E1982 breather valves can get drudged in old thickened oil and not open/close properly.
L1982-up rubber umbrella(s) get hard and if they don't flex well enough, they'll allow the engine to fully

inhaler and exhale on every stroke uncontrolled.
Stopped up breather valves won't allow the engine to breath well and can create excess vacuum and implode gaskets.
Or it contributes to too high of oil density and slings excess oil out. Other factors are involved so results will vary.
However, a slight amount of oil in mist form coming out the vent/air cleaner is totally normal and does not quantify as puking oil.

Wetsumping can be a result of poor engine breathing but not always.
Blowing oil out after extended shutdown periods is a condition of bad oil pump sealing, bad check valve or regulator (if equipped) sealing.
Blowing oil out the vent/air cleaner during riding first looks to the oil tank being overfilled.
If the engine is not at operating temp before checking the oil level, you'll end up adding too much oil to the system.
Blowing oil out the vent/aircleaner during high sustained RPM may be high crankcase pressure or poor oil scavenging.
Also see the full article on wetsumping in the sub documents above.

Crankcase Pressure

Sub Documents

- Example of Air Pulses Using a 1000cc Motor
- Affects of the 45° Rod / Piston Arrangement
- Differential Pressure
- Air Pressure and Vacuum at Different Elevations
- Blowby and Ring Seal
- Liquid Drag vs Fluid Drag
- Further Study of Internal Engine Pressure
- Oil Tank Pressure
- Vacuum Pump for Reducing Crankcase Pressure
- See also in the Sportsterpedia:
    - Transfer Valve

In the crankcase air system

Crankcase air pressure is mainly generated by the up and down movement of the pistons.
Additional air pressure is created by blowby from the combustion chambers past the rings and into the crankcase.
Additional air can be created by other small air intake areas as well as from gasket leaks.
Crankcase pressure also initiates the splash and mist process (the movement of the pistons and flywheels splash oil around in the engine).
The piston motions create a pulsating blast of air pressure (push pull condition as each piston rises and

falls).

The pressure in the crankcase is not from oil pump pressure

Static oil pump pressure has already been dissipated by the time it reaches the crankcase.
(although it takes static oil pressure to get the oil from the pump to the crankcase)

Crankcase (CC) pressure will have an average and constant change in velocity.
Gravity oil (from the drain ports in the heads) returns to the crankcase.
Gravity oil (from the pushrod tubes) returns to the gearcase. Oil in the crankcase adds resistance to the air pressure generated (raising the pressure).

Role of the breather valve

CC pressure both pushes to and sucks from the breather valve.
The breather valve allows for controlled air pressure to both leave and enter the engine to obtain what is referred to as a "slight running vacuum" in the crankcase.
If the breather valve isn't there;
The pressure generated from upstroke and downstroke would both push all the under piston air volume out of the engine and back into the engine.
(including any oil that was suspended with it. Also that would create thicker oil suspension and more oil blowing out of the engine but not returning.
The volume between positive and negative pressure decreases as RPM goes up.
The speed of the breather valve action is important as it has to keep up with RPM changes.

See also, Example of Air Pulses Using a 1000cc Motor, in the sub documents at the top of this page.

Affects of the 45° Rod / Piston Arrangement

Since Sportster piston movement is not equalized, we get the potato, potato sound we all love but the equilibrium in the crankcase is off by design.
This constant push / pull from offset pistons contributes to an imbalance of pressure that needs to controlled.

See, Affects of the 45° Rod / Piston Arrangement, in the sub documents at the top of this page for more information.

Differential Pressure (vacuum and air pressure)

Vacuum and (positive) air pressure are the terms that describe the amount of molecules of a gas in a given unit of space. [7]
More molecules inside the engine than outside = inside air pressure.
Less molecules inside the engine than outside = inside is vacuum pressure.

57-76 engines are subject to the most volume of vacuum in the crankcase, rocker box, oil tank and primary compartments.
77-85 engines are subject to the same volume of vacuum in the gearcase, rocker box, oil tank, gearcase and primary compartments.

Oil scavenging:
Positive crankcase air pressure aids scavenging. It pushes the oil to the oil pump.
Negative (vacuum) pressure makes the pump's job harder. High vacuum makes the downstroke push to scavenge less powerful.
The oil pump wants to receive more oil, high vacuum slows down the delivery of oil to the oil pump.

Ring seal and pumping loss:
Too much positive pressure is harder on the pistons on downstroke since they are having to expel that air pressure on the way down.
High positive air pressure in the crankcase is said to rob horsepower.
So it is good to have a slight vacuum in the crankcase when the downstroke begins.
A vacuum condition when downstroke begins lessens the restriction on the descending pistons and doesn't lower overall horsepower.

In most engines negative crankcase pressure allows less ring pressure and the combination of both means more hp. [8)]
Over the years folks have used exhaust system energy to pull pressure from the case for this reason.
Guys have won championships with an engine that had an electric vacuum pump to reduce (positive) crankcase air pressure.
Crankcase pressure in these engines fluctuate wildly from positive to negative. [9)]
However, high vacuum can have a dramatic affect on scavenging.

See, Differential Pressure, in the sub documents at the top of this page for more information.

Symptoms of High Crankcase Pressure

Picture a balloon inside the engine being blown up.
It puts internal pressure against the weakest structural points (gaskets and seals).

Symptoms include: [10)]
Sweating oil from the cylinder base gaskets and rocker boxes.
As well as the push rod tubes and lifter blocs on the other side.

Blowby

Normal blowby:
In the absence of any blow-by getting past the rings, the crankcase alternates from atmospheric (pistons down) to a vacuum (pistons up). [11)]
But in the real world, a little gets past the rings, so there's a net outflow equal to that.
Conventional rings have a ring gap and the combustion pressure is very great. [12)]
So you can bet some of this tremendous pressure is entering into your crankcase instead of 100% of it

exiting your exhaust pipes.

Excess blowby:
The ringlands on the pistons 'should be' sealing but sometimes are not.
You can end up with 'out of round' or scratched cylinders from different conditions.
Imperfections in ring seal increase the amount of air from the combustion chambers getting into the crankcase.

See, Blowby and Ring Seal, in the sub documents at the top of this page for more information.

What causes extra air in the crankcase?

Ring seal, as mentioned, is not as good on higher RPM even on a healthy engine.
Gasket / air leaks can introduce more air in the crankcase.
They allow more air into the engine that add to the positive and take away some of the negative (vacuum).
So the introduction of air leaks into the crankcase lowers the RPM at which pressure changes affect the system.
Worn / stiff breather valves will allow more or less air at atmosphere into the crankcase.
This changes the average vacuum and contributes to higher positive pressure on downstroke.
The timing of the breather valve opening and closing can also bring in air to the crankcase during upstroke.
The faster it closes, the more vacuum is kept in the crankcase on upstroke.
The slower it closes, the less that vacuum can be contained in the crankcase.

Why is the ratio of positive and negative pressure important?

It takes a balance of the two to run a Sportster engine.

Piston upstroke creates negative pressure and suction of oil from the sump.
It pulls oil up in the form of oil mist to be tossed around on the moving metal parts.
So it is important for lubrication and it keeps down aeration in the oil.
But without the reciprocating piston downstroke, there wouldn't be a lot of force to help splash it around other than the spinning wheels.
The upstroke pulls oil into suspension (air/oil mist) so the downstroke can help blow the mist around working in conjunction with flywheel and cam rotation.
Negative pressure is also important for ring seal as it allows the rings to seat better on high RPM.
Too much negative pressure is detrimental to oil scavenging as it allows thicker oil to be pulled up into suspension.
The thicker oil separates slower and can wrap around the flywheels (instead of moving toward the scavenge port in the sump).
The bulk of gravity oil on the sump floor is heavier than the moving air.
But the spinning action of the flywheels can pull that oil up to be slung around the wheels creating more drag as it does.
So it's important to get the excess oil in the bottom out of the engine as fast as possible to keep down

flywheel drag.
That's where the positive pressure comes in.

Positive pressure is important for oil scavenging as it works in conjunction with splash lubrication as well as the suction of the oil pump.
The positive pressure generated by the downstroke pushes oil toward the scavenge pump to be sucked vertically into the oil passage to the pump.
So there is a balance of positive and negative pressure that has to be maintained for overall engine operation.

The role of positive and negative pressure can be confusing.
Even though there is a positive 'push' on internal pressure through piston downstroke, the overall internal pressure is still negative.
It's just less negative than it was before the downstroke until high RPM changes that.
This creates a pulsing effect on oil in the sump which helps shift the oil toward the scavenge port.
Even though there is normal blowby throughout the RPM range, the vacuum created buffers that.

Crankcase Pressure Testing

Sub Documents

- Dyno testing using the timing plug location for an additional crankcase vent by aswracing
- Breather System Air Volume Test by DK Custom
- Testing with a Slack Tube (Manometer) by bustert
- Building Your Own Slack Tube
- Using / Diagnosing with a Slack Tube (Manometer)
- Slack tube testing on a 1998 1250S model
- Breather Catch Can Test For Oil Leaks Out the Vent

Crankcase pressure can be tested to see what the pressure is doing, when it does it and the affects of changes to the breathing system.
Testing can also be done to determine pressure issues before they become a big problem as well as diagnosing that there is one.

57-76 engines:
Vacuum in 57-76 engines should be checked to make sure it's not creating too much especially if oil leaks / weeps keep happening.
If everything is percolating nicely, a test then is a good base line. Oil leaks can easily be a result of too much vacuum.
And that depends on gasket / seal conditions and limits. The head drains are also possible vacuum routes, thus rocker boxes and down.
How many have had reoccurring pushrod tube leaks? Surely the 3rd or 4th set of seals were installed correctly.
Too much vacuum can implode the tube seals. Testing the amount of vacuum at that point may reveal

too much.
What can you do if you have too much vacuum in 76< engines?
Check for the breather gear out of time or gasket / seal leaks.
Seal leaks on downstroke lower mean pressure and allow more vacuum to generate on upstroke.
Other things to consider are a plugged / kinked vent tube or breather vent mods that could have raised vacuum.

In the sub documents above are some examples of different testing that was done on Evos. Below are some noted results of that testing.
Each of the tests above do basically support each other given the different variables.
But the results have to be taken in context as each have different criteria for testing.

- **Testing from DK Custom**:
  - The criteria for their testing was to see how much air was passed out the breather vents (outside the engine) at idle, under a load, at cruising speeds and on throttle let-off' for different model engines. They sell modified breather venting configurations and was doing some R&D presumably in the interest of same.
  - Their testing supports bustert's slack tube testing as normally at most of the RPM range, there is more vacuum than positive pressure. And it's the positive pressure that leaves the engine. Therefore, their results for the Sportster are equaled out more. Even though there is normal blowby throughout the RPM range, the vacuum created buffers that.
  - In example, 15“ of vacuum at idle that all of a sudden is hit by 5” of positive pressure rolling the throttle still yields 10“ of vacuum at the time. So there would be no air moving into the balloon or container at that point. In theory and during that transition from 15” to 10“ vacuum, more oil is pushed toward the scavenge hole in the sump, the pump gets a fatter supply of oil to send to the tank, pressure goes up in the air space in the tank due to the restriction size of the vent.

- **Testing from bustert**:
  - This was a test of the differential pressure changes (inside the engine) through the RPM range up to 6000 RPM.
  - You may have read and heard from many sources that the Sportster requires a 'slight vacuum'. But the slack tube testing puts a visual to the process showing that the 'slight vacuum' is not really a stagnant number but a constantly moving range.

- **Testing from aswracing**:
  - Dyno testing was with the normal head breather vents in place (with and without the timing hole plug removed) to see if either would show increased HP over the other.
    The dyno sheets show the affects (HP changes) between the stock setup and with addition of air induced into the engine through the RPM range.
    However, it does not show internal pressures during the testing.
  - The testing revealed a dip in performance starting around 5700 RPM which coincides with bustert's slack tube testing showing positive and negative pressure equaling out up in that range. But the Dyno test is a load test as where the slack tube was done with no load on the engine… more variables.

What does all this mean?

The testing shows that there is more potential for crankcase pressure problems in the high RPM range.

There will be a normal amount of air passing the rings by design.
As the rings heat up and expand, there will be less air passed by them until you run up past the 5000 RPM range.
Then, questionable ring seal comes into play to pass more air through the rings which creates more positive pressure in the crankcase.
So normal blowby increases with engine speed.
Couple that with the increasing speed of the pistons which helps to equalize positive and negative pressure during operation.
As engine speed increases, there is not as much time to build vacuum on upstroke or positive pressure on downstroke due to the faster changing piston positions.
Just as you can inhale air slowly and fill up your lungs but faster breathing will not allow you to fill them due to the faster time that you exhale.
This would make for a shorter range of (both vacuum and positive) pressure that would be able to build in the crankcase.
So the internal pressure is more stable until extra air (or blowby) is induced into the crankcase.

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[1], [2]
mrmom9r of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/122424-breather-diagrams/page4?t=1204854&page=4

[3]
aswracing of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-motor-top-end/135598-crankcase-pressure?t=1468237

[4], [5], [6]
drawing by Hippysmack

[7]
Dr Dick of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/122424-breather-diagrams/page4?t=1204854&page=4

[8], [9]
maru of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-engine-conversions/38153-xr750-883-series-race-engine-venting-etc/page8?t=75740&highlight=reed+valve&page=8

[10]
Jorgen of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-engine-conversions/38153-xr750-883-series-race-engine-venting-etc/page9?t=75740&highlight=reed+valve&page=9

[11]
aswracing of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-motor-top-end/10013-blowby-article/page2?t=15705&page=2

12) Deimus of the XLFORUM https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-bottom-end/35356-install-new-crankcase-vent-04/page3?t=67658&page=3

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