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REF: Engine Mechanicals - Sub-04R

Air Pressure and Vacuum at Different Elevations

Absolute, Relative and Gauge Pressures

Air pressure is caused by the weight of air above an area pressing on surfaces below. It is measured in two ways: absolute barometric pressure and relative barometric pressure. Pressure on Earth varies with the altitude of the surface; so air pressure on mountains is usually lower than air pressure at sea level. Pressure varies smoothly from the Earth's surface to the top of the mesosphere. Although the pressure changes with the weather, NASA has averaged the conditions for all parts of the earth year-round. As altitude increases, atmospheric pressure decreases. One can calculate the atmospheric pressure at a given altitude. Temperature and humidity also affect the atmospheric pressure, and it is necessary to know these to compute an accurate figure. [1)]

Absolute (barometric) pressure is a comparison of how much pressure is exerted by the atmosphere compared to a perfect vacuum, a space where there are no gases at all. A perfect vacuum is defined as absolute zero in the absolute pressure scale. The air pressure in a vacuum would be zero, since there are no gases to exert pressure on objects. Absolute barometric pressure is used primarily in scientific studies and industrial applications requiring precise data. It is used mainly to measure pressures for aircraft’s, etc. At this scale, there is no molecular movement present at any point in the system and no pressure is exerted on the surface of the container. Therefore, pressure cannot be lower than absolute zero; there is no negative absolute pressure. Absolute pressure implies that the pressure measured will be the same no matter what the surrounding atmospheric conditions are.
Units for absolute pressure are sometimes suffixed with the letter “a”; for example, “kPaa” for absolute pressure in kiloPascal or “psia” for absolute pressure in pounds per square inch. [2) 3)]

Relative (barometric) pressure is the atmospheric pressure corrected to sea-level conditions for comparison. It is a measurement of how much pressure an air column would exert at sea level. To determine corrected barometric pressure, an absolute air pressure measurement is taken, along with an altitude measurement. The relative air pressure of that column is the amount of air pressure it would exert at sea level, if it remained at a constant pressure all the way down. It is sometimes called relative pressure because it reports pressures relative to sea level. [4)]

Air pressure at sea level (considered one atmosphere) is equivalent to 760 mm Hg, 29.9212 inches

Hg, or 14.696 psi.
Numbers are generally rounded to 14.70 PSI.

Gauge Pressure is the measure of pressure relative to the ambient atmospheric pressure (or measured against the zero of atmospheric pressure). It is the difference between absolute pressure and the atmospheric pressure. Therefore, a zero value on the gauge pressure scale means that the absolute pressure of the system is equal to the absolute pressure exerted by the surrounding atmosphere. A gauge is the instrument used in measuring pressure. A gauge always needs a reference point since the reading is made with a deflection in the gauge caused by a difference in pressure. Usually, a gauge is vented, meaning it uses the pressure of the air as reference. This is why it is called gauge pressure. [5)]
Since gauge pressure is measured relative to the ambient pressure, changes in the weather result in different readings on the gauge pressure. A lower atmospheric pressure would make your tires have higher gauge pressure, whereas they would actually have the same absolute pressure. A positive gauge pressure refers to a pressure measurement that is greater than the ambient pressure. A negative gauge pressure refers to pressure lower than the ambient pressure, and is sometimes called “vacuum pressure.”
Gauge pressure units sometimes use the letter “g” as a suffix, such as “kPag” or “psig.” Some gauges are sealed so that the reference pressure may be a value other than the ambient air pressure. The reference pressure may even be the standard atmospheric pressure (1 atmosphere) which represents the pressure at sea level at standard temperature. Sealed gauges would allow one to measure the pressure independent of the current actual condition of the environment and may be used to show absolute pressure.

Absolute Pressure vs Gauge Pressure
Absolute pressure cannot be lower than absolute zero as that is its zero point. On the other hand, gauge pressure uses atmospheric pressure as its zero point. Even with varying atmospheric pressure, absolute pressure is always definite. Meanwhile, due to varying atmospheric pressure, the measurement of gauge pressure is not precise. Absolute pressure units are sometimes suffixed with the letter “a” whereas units for gauge pressure use “g” as a suffix. [6)]

Measuring Engine Crankcase Vacuum

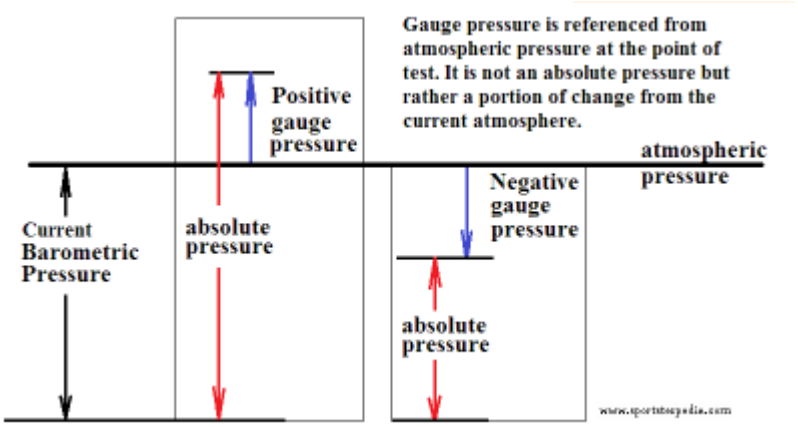
Engine vacuum is simply air pressure lower than (and is based on comparison with) atmospheric pressure.
It is usually measured as Gauge Pressure.
It varies with altitude just as atmospheric (barometric) pressure does.
As altitude increases, vacuum decreases by about 1“ Hg for every 1000 feet above sea level.

These figures are all over the internet and actual vacuum is a large concern for CNC users for holding down the work piece with a set amount of vacuum.
This is also important to vacuum pump users in internal combustion engines trying to obtain a certain residual vacuum in the crankcase.
And so, operating at higher elevations sometimes requires higher rated vacuum pumps to attain the same vacuum you would at lower elevations.
And likewise, operation at higher elevations affects the air/fuel mixture in the combustion chambers since

air is less dense.

However, it doesn't appear that elevation has much to do with the amount of vacuum created in the crankcase.
A 12” pressure drop will still be a 12“ pressure drop no matter if it drops from 50 or 5000 feet above sea level.
The important number is the pressure swing. The more vacuum that is created, the farther away from atmosphere it becomes.
The positive makeup pressure on downstroke normally brings vacuum back to near atmosphere.
But an increase in vacuum lowers scavenging ability for the oil pump.

Gauge pressure is a measurement taken from the current atmospheric pressure level (depending on current elevation above sea level).
When taking a vacuum measurement, you are measuring how much the air is lower than the current atmospheric pressure at your location (elevation wise).



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Example of crankcase pressure testing results from different elevations.
Results below are both at 1000 RPM at operating temperature and the test point in each motor was the timing hole plug.
From testing in these Sportsterpedia articles;

- Slack tube testing on a 1998 1250S model, (elevation app 630 feet);
  - 1250cc
  - The crankcase pressure had a mean vacuum of 21” of water column.
  - At 630 feet above sea level, ambient atmosphere is applying app. 29.24“ Hg of force (397.52” WC or 14.36 PSIA).
    (both outside in and inside out of a parked engine)
  - Vacuum at idle created by the pistons lowered ambient atmosphere inside by 21“ WC.
  - So the mean pressure against the gaskets and seals at 1000 RPM (breather valves closed) was 376.21” WC (27.67“ Hg or 13.59 PSIA).
  - The crankcase cycled from a mean pressure of 13.59 PSIA (idle) to near 14.39 PSIA (5000 RPM) - (range 0.8 PSIA).
- Testing with a Slack Tube (Manometer) by bustert, (elevation app 12.8 feet);
  - The crankcase pressure had a mean vacuum of 30” of water column.
  - At 12.8 feet above sea level, ambient atmosphere is applying app. 29.91“ Hg of force

(406.63” WC or 14.69 PSIA).
(both outside in and inside out of a parked engine)
- Vacuum at idle created by the pistons lowered ambient atmosphere inside by 30“ WC.
- So the mean pressure against the gaskets and seals at 1000 RPM (breather valves closed) was 376.63” WC (27.70) Hg or 13.60 PSIA)
- The crankcase cycled from a mean pressure of 13.60 PSIA (idle) to near 14.63 PSIA (5000 RPM) - (range 1.03 PSIA).

The Effect of Atmospheric Pressure on Vacuum Level

The chart below shows working vacuum loss at higher altitudes.

Vacuum Gauge Reading When Read at Altitudes [8]					
Altitude Above Sea Level (feet)	Altitude Above Sea Level (meters)	Atmospheric Pressure (psi)	Maximum Vacuum Level Attainable (inches Hg)	Vacuum Level Loss at Altitude	Maximum Vacuum Level Possible at this Altitude
0	0	14.70	29.921	–	–
1000	305	14.16	28.9	3.4%	96.6%
2000	610	13.66	27.8	7.1%	92.9%
3000	914	13.16	26.8	10.4%	89.6%
4000	1219	12.68	25.8	13.8%	86.2%
5000	1524	12.22	24.9	16.8%	83.2%
6000	1829	11.77	24.0	19.8%	80.2%
7000	2134	11.33	23.1	22.8%	77.2%
8000	2438	10.91	22.2	25.9%	74.1%
9000	2743	10.50	21.4	28.6%	71.4%
10,000	3048	10.10	20.6	31.3%	68.7%
11,000	3353	9.71	19.8	33.9%	66.1%
12,000	3658	9.34	19.0	36.5%	63.5%
13,000	3962	8.97	18.3	39.0%	61.0%
14,000	4267	8.62	17.5	41.4%	58.6%
15,000	4752	8.28	16.9	43.6%	56.4%

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[1] [2] [4]
https://sciencing.com/absolute-vs-relative-barometric-pressure-13425786.html
[3] [5] [6]
https://theydiffer.com/difference-between-absolute-pressure-and-gauge-pressure/
[7]
drawing by Hippysmack, referenced from https://sciencestruck.com/absolute-vs-gauge-pressure

8)

referenced from ASE Systems
https://www.asesystems.com/vacuum-lifters/the-effect-of-atmospheric-pressure-on-vacuum-level/