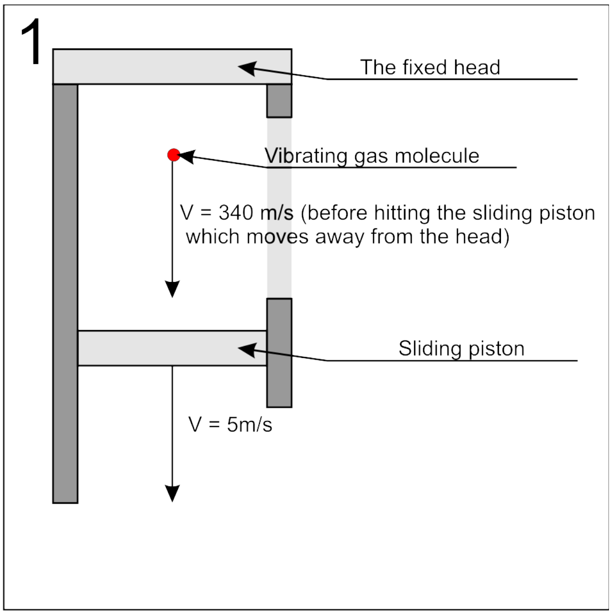
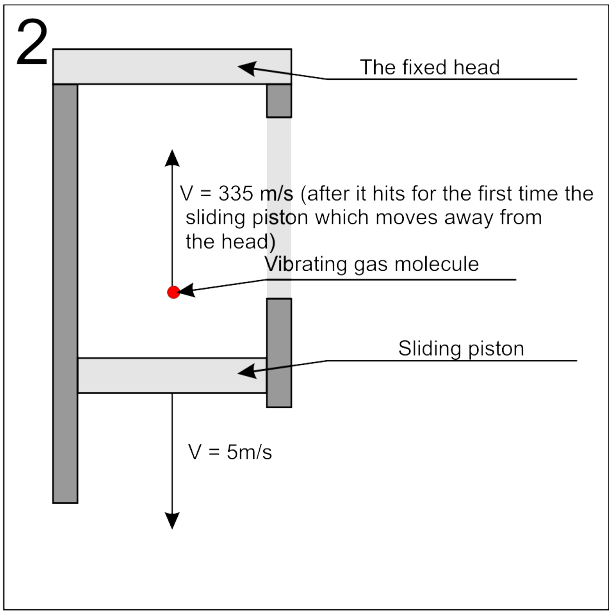
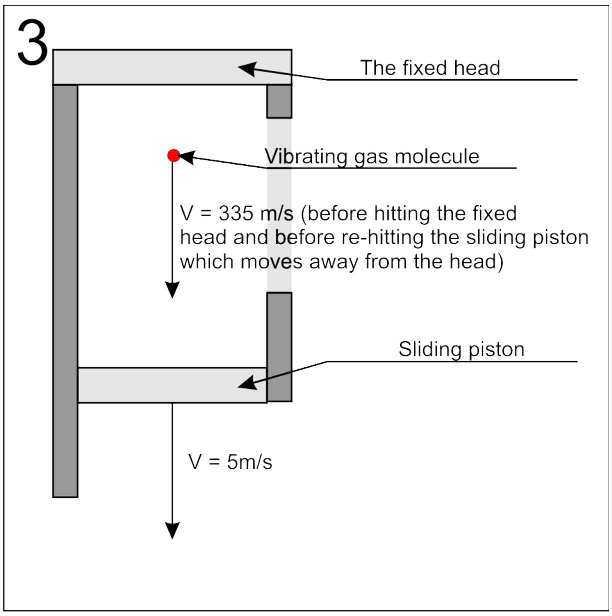
The thermodynamic theory of the variable speed of gas molecules (supplemented).

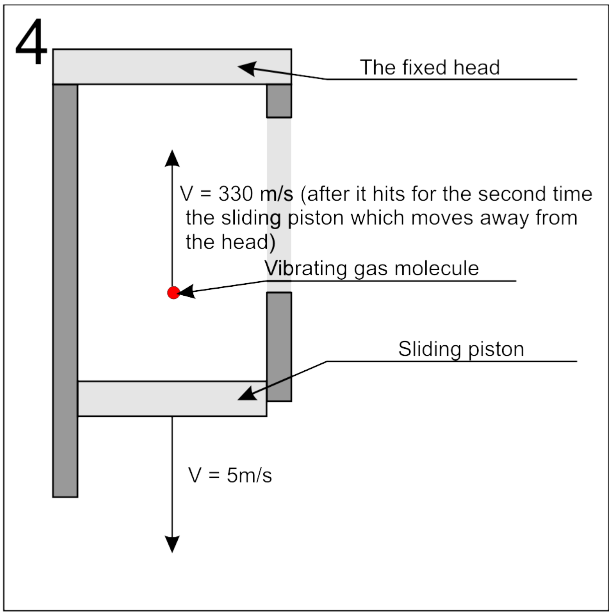
The goal of the thermodynamic theory of the variable speed of gas molecules is to illustrate the ‘mechanism’ that allows to understand and to explain the conversion of thermal energy into mechanical energy using the thermodynamic equipment, and allows to create a precise image of thermodynamic relationships.

The following figures illustrate how the gas molecules behave as exemplified by a piston engine in the expansion phase as the piston ‘escaping’ towards the fixed head, vibrating gas molecules decelerate which results in cooling the gas, while in the energy balance, the thermal energy (vibrating molecules) is converted into the mechanical energy which is then transmitted by the sliding piston and the connecting rod onto the shaft of the engine.

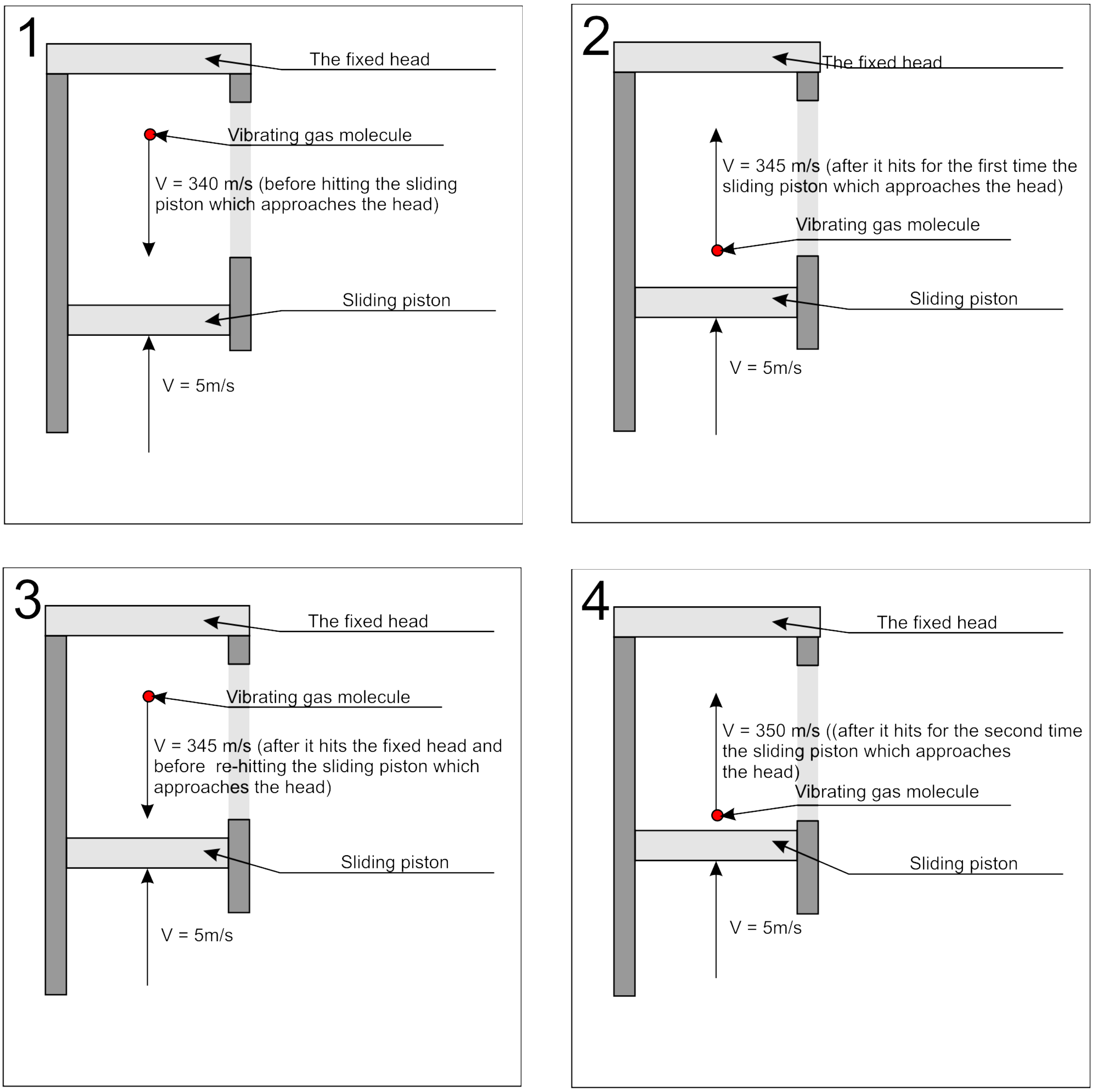








The following figures illustrate how the gas molecules behave as exemplified by a piston engine in the compression phase as the piston approaches the fixed head, vibrating gas molecules accelerate which results in heating the gas, while in the energy balance, the mechanical energy which is then transmitted from the shaft of the engine by the connecting rod on the sliding piston, is converted into the thermal energy (vibrating gas molecules).



The following is an example calculation of the increase of temperatures (the speed of gas molecules vibration) for reciprocating piston engines where the following parameters were applied:

1. Piston stroke = 100 mm
2. The length of the connecting rod = 125 mm
3. Rotational speed = 1.200 revs/minute
4. Compression ratios = 1:11, 1:21, 1:41
5. Pressure at BDC = 1 bar.
6. Gas molecules vibration velocity at BDC = 340 m/s

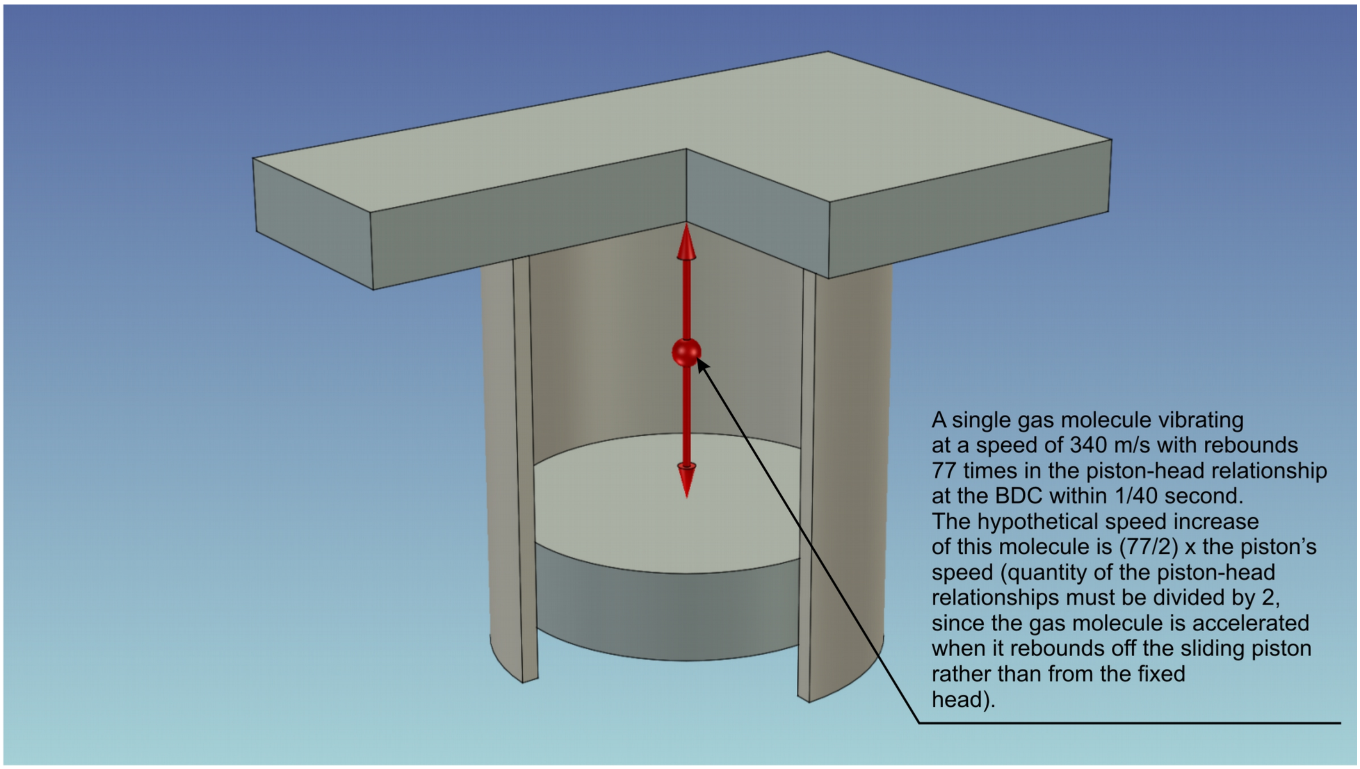
In order to fully illustrate how the gas molecules behave, a single gas molecule has been adopted. The molecule only moves vertically up and down (in reality, in the engine cylinder there is a huge amount of gas molecules that vibrate in all possible directions, but the example for a single molecule of gas presented here will allow to demonstrate logically and in a simple way that this theory is correct).

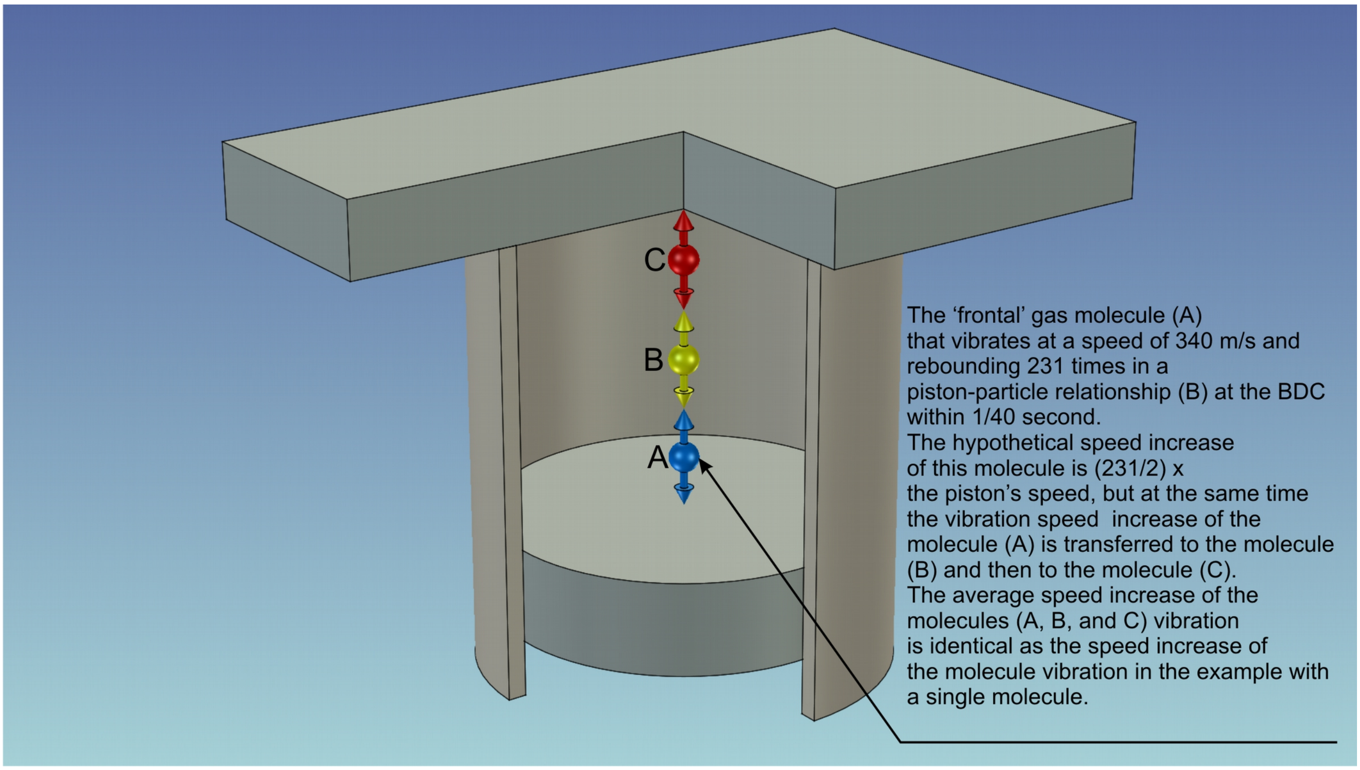
At the rotational speed of 1,200 revs/minute, rotational speed of 20 revs/second is obtained. With this rotational speed, during one second the piston travels the BDC-TDC-BDC distance 20 times, i.e. 20 x 200 mm, i.e. the average speed of the piston is 4m/s.

In this case, a single compression stroke lasts 1/40 second, and during that time, the hypothetical vibrating gas molecule will travel a distance of 8.5 m at a speed of 340m/s. This allows to calculate that with the compression ratio of 1:11 and the piston stroke of 100 mm, the distance of the bottom of the piston from the head at BDC is 110 mm, and this in turn allows to calculate that with the piston's position at BDC, within 1/40 second the hypothetical gas molecule is able to travel the piston-head distance about 77 times, and each time the molecule hits the moving bottom of the piston, the piston's speed is different. The difference is the piston's speed it moves at any given time. This is the increase in speed in compression stroke and the loss of speed in expansion stroke. For the piston's TDC, within 1/40 second, the gas molecule vibrating at a speed of 340 m/s is able to travel a distance of 10 mm (piston- head distance at the piston's TDC) 850 times. In order to calculate the speed increase of the 'hypothetical' gas molecule during the compression stroke relatively accurately, I used the example using a spreadsheet, where I made measurements every 5º of the crankshaft's rotation from the piston's BDC to TDC. In this example, in measurement points, a variable piston-head distance is taken into account as well as the increasing speed of molecules vibration as the piston approaches the head. Of course, the example below is a schematic description of this theory and it does not include, for example, losses of the thermal energy (molecules vibration) that is radiated to: the walls of the cylinder sleeve, piston head and the head with the valves. In order to understand this theory it is very important to assume that the theoretical assumption, which analyses how the gas molecules behave as a single molecule moving vertically up and down, correctly reflects the increase in speed of the gas molecules vibration as a result of the piston moving towards the head. In order to become certain that this assumption is correct, please imagine that in the example shown, the piston head's surface area is 100 cm^2, which is equivalent to 1,000 cm^3 of the cylinder capacity and 1,100 cm^3 of cylinder volume at the piston's BDC. The quantity of the gas molecules in this volume at a pressure of 1 bar is about $3x10^{22}$, while the distance between the vibrating the gas molecules is about $2,1x10^{-7}$ m. Please imagine that the gas molecules are perfectly arranged and 'rebound' from each other only in a vertical relationship, and at the same time the 'frontal' molecules at the top rebound off the head, while the 'frontal' molecules at the bottom rebound off the piston's head. In this relationship, for the actual dimensions the 'frontal' molecules that rebound off the piston's head within 1/40 second for the speed of the molecules vibration 340 m/s, will rebound off the piston and another 'layer' of molecules approximately 40,476,190 times and as the piston moves towards the head, they will be accelerated for the value of speed of the piston and the increase of this energy will be 'evenly' transferred (through the energy of their vibrations) to all the molecules contained inside of the cylinder. Thus, the assumption that the cylinder contains a single hypothetical molecule moving only vertically up and down, fully reflects how the gas molecules behave in terms of changes in the speed of their vibrations (increase or decrease), depending on whether we are dealing with compression or expansion. It should be emphasized here that by analogy to compression stroke, the reverse process occurs during the power (expansion) stroke when the piston moving away from the head converts the gas molecules vibrations energy into mechanical energy, which is then transferred to the motor shaft.

If you doubt whether the example with a single hypothetical molecule above is correct, imagine that the engine presented here is placed in a chamber where perfect vacuum prevails and only one gas molecule is placed inside the cylinder. A single molecule rebounds vertically from the piston head, which is perfectly flat and perfectly levelled and from the inner surface of the head, which is perfectly flat and perfectly levelled. At the same time, the following figures show that of molecule vibrations speed increase for a single and for more molecules considered is identical.

What is essential to properly understand this theory is to analyse these examples with the assumption that we are dealing with a perfectly airtight system and perfect thermal insulation, where we assume ideal ‘resilience’ of the piston head and the cylinder head.





The following table shows an example of the speed increase of the gas molecules vibration during the compression stroke of the piston engine with a compression ratio of 1:11

Angle	The piston speed m/s	Compression ratio 1;11	The piston-head distance mm	The molecules vibrations speed m/s SI engine compression ratio of 1:11
DMP	0	1	110	340
5	0,164564303	1,0010399965	109,885719234	340,176799409
10	0,4945393574	1,0041783943	109,5422891247	340,710049884
15	0,8270211255	1,0094709584	108,9679688986	341,6079131499
20	1,1635700042	1,0170124533	108,1599341735	342,8839450664
25	1,5055735044	1,0269394504	107,1143970177	344,5573797992
30	1,8541641134	1,0394344119	105,8267830501	346,6535263611
35	2,2101255667	1,0547312144	104,2919736287	349,2042840066
40	2,5737864565	1,0731223425	102,5046219228	352,2487851277
45	2,9449021627	1,0949680636	100,4595509765	355,8341772051
50	3,3225288789	1,1207080025	98,152239255	360,0165594625
55	3,7048969844	1,1508756778	95,579394127	364,8620957807
60	4,0892948965	1,1861167492	92,7396060044	370,4483339082
65	4,4719782656	1,2272119906	89,6340655422	376,8657728761
70	4,8481220564	1,2751063497	86,2673141141	384,2197364951
75	5,211833592	1,3309459353	82,6479852308	392,6326311709
80	5,5562419965	1,3961254045	78,7894838443	402,2466905468
85	5,8736730602	1,472349066	74,7105442192	413,2273357977
90	6,1559086941	1,5617101024	70,4356076261	425,7673047041
95	6,3945182616	1,666793698	65,9949699445	440,091717144
100	6,5812375682	1,7908115261	61,4246660777	456,4642349373
105	6,7083629142	1,9377769013	56,7660807206	475,1944130113
110	6,7691245522	2,112731521	52,0652997816	496,6461750138
115	6,7580069954	2,3220350456	47,3722393681	521,2469806179
120	6,6709920437	2,5737251763	42,7396060044	549,4964941123
125	6,5057119381	2,8779424957	38,2217504919	581,9720575428
130	6,2615119759	3,2473783492	33,8734782864	619,3253653546
135	5,9394318171	3,6976190838	29,7488728579	662,2593073594
140	5,5421211556	4,2470751225	25,9001776109	711,4642643053
145	5,073708112	4,9158124221	22,3767691998	767,4772470253
150	4,5396382006	5,7219419188	19,2242426716	830,4054055587
155	3,9464990749	6,6732921076	16,4836183141	899,4384672858
160	3,3018425555	7,7515708392	14,1906720949	972,1046531824
165	2,6140115883	8,8886114423	12,3753862697	1043,4013286589
170	1,8919763226	9,9443893264	11,0615138235	1105,3682654638
175	1,145180734	10,7147211653	10,2662494248	1148,1813704512
GMP	0,3833991717	11	10	1163,4665019251

As shown in the table above, at the piston’s BDC, the speed of the hypothetical gas molecule vibration is 340 m/s, while in the subsequent measurement points, as a result of piston’s speed, this speed increases to be as high as 1163 m/s at the piston’s TDC. (It should be noted here that in the above table, at the piston’s BDC, in the ‘piston’s speed’ column, ‘0’ value is shown, while at the piston’s TDC, in the ‘piston’s speed’ column, a value greater than ‘0’ is shown, since the value at the BDC is an initial value, while the value at the TDC is an average speed the piston travels the distance from the ‘175^{o}’measuring point to the piston’s TDC).

The following table shows an example of the speed increase of the gas molecules vibration during the compression stroke of the piston engine with a compression ratio of 1:21

Angle	The piston speed m/s	Compression ratio 1;21	The piston-head distance mm	The molecules vibrations speed m/s CI engine compression ratio of 1:21
DMP	0	1	105	340
5	0,164564303	1,0010895741	104,885719234	340,1852276016
10	0,4945393574	1,0043782366	104,5422891247	340,7439959761
15	0,8270211255	1,0099264332	103,9679688986	341,6851328034
20	1,1635700042	1,0178370202	103,1599341735	343,0233144074
25	1,5055735044	1,0282585323	102,1143970177	344,7794018495
30	1,8541641134	1,0413899643	100,8267830501	346,9809139882
35	2,2101255667	1,0574872889	99,2919736287	349,6626492602
40	2,5737864565	1,0768720285	97,5046219228	352,8674723769
45	2,9449021627	1,0999423203	95,4595509765	356,6472880594
50	3,3225288789	1,127187074	93,152239255	361,0642321648
55	3,7048969844	1,1592040443	90,579394127	366,1921222308
60	4,0892948965	1,1967229485	87,7396060044	372,1182261116
65	4,4719782656	1,2406351902	84,6340655422	378,945430976
70	4,8481220564	1,2920323644	81,2673141141	386,7949279404
75	5,211833592	1,3522565935	77,6479852308	395,8095730111
80	5,5562419965	1,4229669938	73,7894838443	406,1581464573
85	5,8736730602	1,5062283787	69,7105442192	418,0408148269
90	6,1559086941	1,6046309312	65,4356076261	431,6962085915
95	6,3945182616	1,7214534263	60,9949699445	447,4106720353
100	6,5812375682	1,8608882834	56,4246660777	465,5304312346
105	6,7083629142	2,0283552191	51,7660807206	486,4776733287
110	6,7691245522	2,2309429768	47,0652997816	510,7718453051
115	6,7580069954	2,4780375445	42,3722393681	539,0578547686
120	6,6709920437	2,7822230043	37,7396060044	572,1432214079
125	6,5057119381	3,1605799949	33,2217504919	611,0463551762
130	6,2615119759	3,636555283	28,8734782864	657,0573666677
135	5,9394318171	4,2426174559	24,7488728579	711,8094031945
140	5,5421211556	5,0238807514	20,9001776109	777,3480200856
145	5,073708112	6,0425501883	17,3767691998	856,1576802938
150	4,5396382006	7,3817638256	14,2242426716	951,0330231072
155	3,9464990749	9,1434595899	11,4836183141	1064,5174753367
160	3,3018425555	11,4246269386	9,1906720949	1197,3087062201
165	2,6140115883	14,2365424888	7,3753862697	1344,6540413191
170	1,8919763226	17,322405435	6,0615138235	1490,3852848758
175	1,145180734	19,9382884345	5,2662494248	1602,9179681669
GMP	0,3833991717	21	5	1645,5955668735

As shown in the table above, at the piston's BDC, the speed of the hypothetical gas molecule vibration is 340 m/s, while in the subsequent measurement points, as a result of piston's speed, this speed increases to be as high as 1,645 m/s at the piston's TDC. (It should be noted here that in the above table, at the piston's BDC, in the 'piston's speed' column, '0' value is shown, while at the piston's TDC, in the 'piston's speed' column, a value greater than '0' is shown, since the value at the BDC is an initial value, while the value at the TDC is an average speed the piston travels the distance from the '175º'measuring point to the piston's TDC).

The following table shows an example of the speed increase of the gas molecules vibration during the compression stroke of the hypothetical piston engine with a compression ratio of 1:41

Angle	The piston speed m/s	Compression ratio 1;41	The piston-head distance mm	The molecules vibrations speed m/s The hypothetical engine compression ratio of 1:41
DMP	0	1	102,5	340
5	0,164564303	1,0011161788	102,385719234	340,1897503906
10	0,4945393574	1,0044855018	102,0422891247	340,7622160035
15	0,8270211255	1,0101710038	101,4679688986	341,7265924222
20	1,1635700042	1,0182800222	100,6599341735	343,0981756417
25	1,5055735044	1,0289677303	99,6143970177	344,8987280792
30	1,8541641134	1,0424423216	98,3267830501	347,1569958976
35	2,2101255667	1,0589721044	96,7919736287	349,9093926512
40	2,5737864565	1,0788948782	95,0046219228	353,2008701458
45	2,9449021627	1,1026301109	92,9595509765	357,0860052941
50	3,3225288789	1,1306946286	90,652239255	361,6303427112
55	3,7048969844	1,1637228096	88,079394127	366,912048351
60	4,0892948965	1,2024926534	85,2396060044	373,0239517593
65	4,4719782656	1,2479596538	82,1340655422	380,0760863878
70	4,8481220564	1,3013011952	78,7673141141	388,1988827596
75	5,211833592	1,3639753572	75,1479852308	397,5472333809
80	5,5562419965	1,4377997213	71,2894838443	408,305738482
85	5,8736730602	1,5250583252	67,2105442192	420,6955686434
90	6,1559086941	1,6286487708	62,9356076261	434,9835603606
95	6,3945182616	1,7522874206	58,4949699445	451,4944192504
100	6,5812375682	1,9007999021	53,9246660777	470,6272840434
105	6,7083629142	2,080538953	49,2660807206	492,8784692607
110	6,7691245522	2,2999957479	44,5652997816	518,8730628672
115	6,7580069954	2,5707108912	39,8722393681	549,409379231
120	6,6709920437	2,9086590806	35,2396060044	585,5223286809
125	6,5057119381	3,3363984265	30,7217504919	628,5749744124
130	6,2615119759	3,8864801558	26,3734782864	680,3924681197
135	5,9394318171	4,6069749535	22,2488728579	743,4597184356
140	5,5421211556	5,5705984022	18,4001776109	821,2130408528
145	5,073708112	6,8899368286	14,8767691998	918,4609344164
150	4,5396382006	8,7425689548	11,7242426716	1041,9432156168
155	3,9464990749	11,4096566012	8,9836183141	1200,8755553535
160	3,3018425555	15,3198361159	6,6906720949	1406,6503284416
165	2,6140115883	21,0239751948	4,8753862697	1668,5241842727
170	1,8919763226	28,7798967183	3,5615138235	1976,290496622
175	1,145180734	37,053780863	2,7662494248	2260,3707135433
GMP	0,3833991717	41	2,5	2380,7351940176

As shown in the table above, at the piston’s BDC, the speed of the hypothetical gas molecule vibration is 340 m/s, while in the subsequent measurement points, as a result of piston’s speed, this speed increases to be as high as 2,380 m/s at the piston’s TDC. (It should be noted here that in the above table, at the piston’s BDC, in the ‘piston’s speed’ column, ‘0’ value is shown, while at the piston’s TDC, in the ‘piston’s speed’ column, a value greater than ‘0’ is shown, since the value at the BDC is an initial value, while the value at the TDC is an average speed the piston travels the distance from the ‘175º’measuring point to the piston’s TDC).

The calculations in the above columns were made in the following manner:

Example for the line from the point of measuring 15º:
V = Molecule speed from the preceding line (10º)
L = Piston-head distance from the line 15º.
V2 = The average piston's speed from positions for measuring points 10º -15º.
T = (For the engine's rotational speed of 1,200 revs / minute it was calculated that) the period the piston travels between the adjacent measuring points lasts 1/1440 second.

The molecule vibration speed (in the line 15 º) is calculated as follows:
((((V/(L/1000))*T)/2)*V2)+V

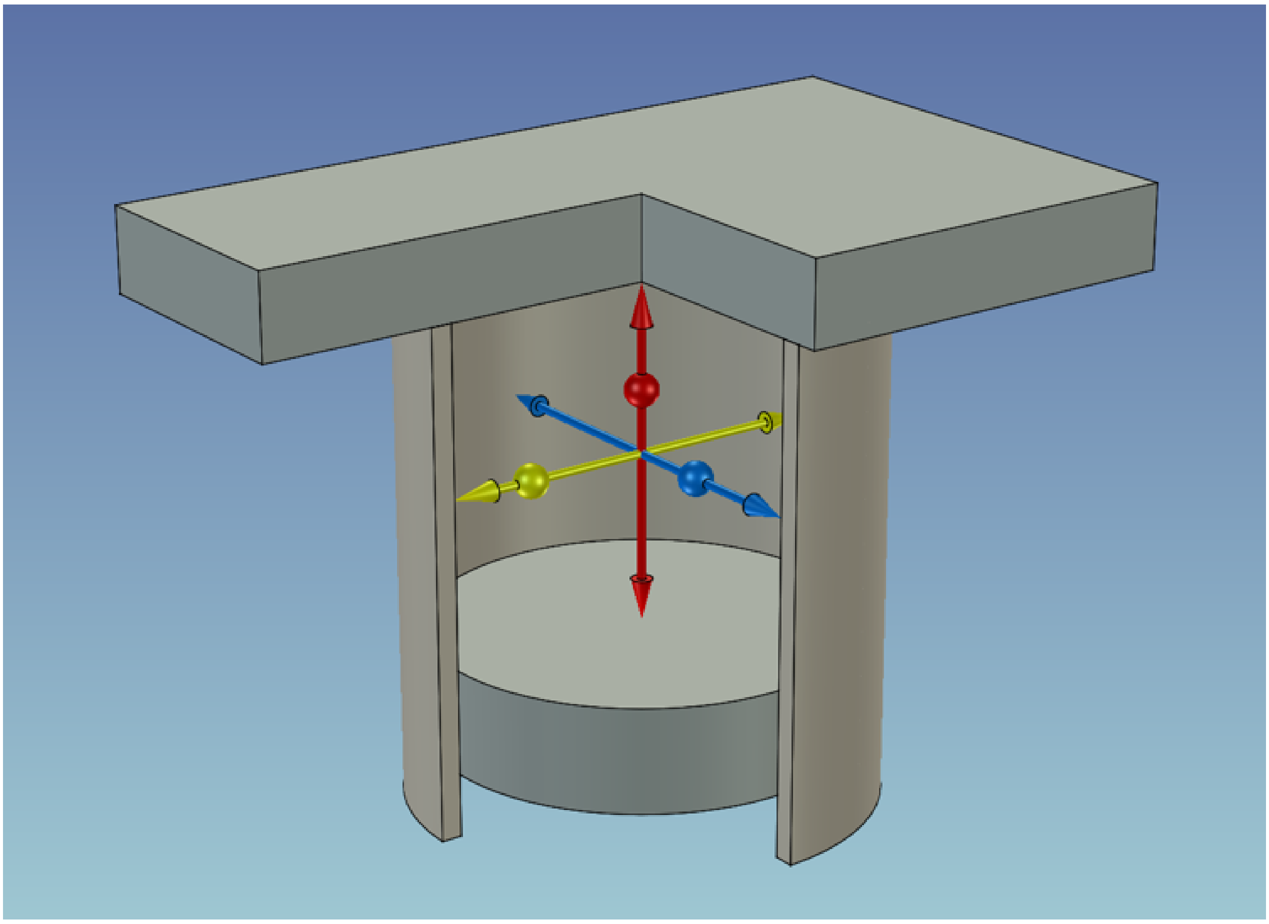
If we now assume that the engine we discuss is perfectly tight and its thermal insulation is perfect and at the piston's BDC pressure of 1 bar prevails inside the cylinder, then using the example of the first engine with compression ratio of 1:11, the gases having been maximum compressed, 11 times greater gas molecules 'density' is obtained and if you hypothetically assume that the these gas molecules do not increase their speed, with the same speed at the BDC and the TDC which is equal to 340 m/s, then at the piston's TDC, gas molecules will bump on o the piston's head 11 times more frequently within the same unit time producing 11 times greater increase in pressure. On the other hand, if we take into account that as a result of the piston movement, in this example, gas molecules are accelerated 3.42 times, then will the speed of the gas molecules in the cylinder in reality increase 3.42 times? Well, no. As I said earlier, in reality, in the engine cylinder there is a huge amount of gas molecules vibrating in all possible directions, so what you should take into account is the behaviour of the gas molecules that vibrate in different directions rather than only in vertical, up and down, relationship. To do this, imagine that our hypothetical example of molecules movement is presented in the 3D example, which takes into account the main motion vectors of gas molecules in the following directions: vertical, in the 'X' plane, horizontal, in the 'Y' plane, and horizontal, in the 'Z' plane (see figure below). This example shows that statistically, only 1/3 of gas molecules will be governed by the principle of speed change of gas molecules resulting from the piston's movement (those that interact in a vertical relationship), while 2/3 of gas molecules, which interact in a horizontal relationship, will statistically not be governed by the principle of speed change. Therefore, in order to properly calculate the average speed of gas molecules using the example of the engine with compression ratio of 1:11, the following formula should be used:
(340m/s + 340m/s + (340m/s * 3,42)) / 3
which produces the result of approximately 614 m/s
whereas to determine the value of the pressure increase, the following formula should be used (including E=mv2) for the piston's TDC: 11 * $(614\text{m/s} / 340\text{m/sec})^2$, i.e. approximately - 35.9 bar.

Using the example of the engine with compression ratio of 1:21, the following formula should be used:
(340m/s + 340m/s + (340m/s * 4,84)) / 3
which produces the result of approximately 775 m/s
whereas to determine the value of the pressure increase, the following formula should be used (including E=mv2) for the piston's TDC: 21 * $(775\text{m/s} / 340\text{m/sec})^2$, i.e. approximately - 109 bar.

Using the example of the hypothetical engine with compression ratio of 1:41, the following formula should be used:
(340m/s + 340m/s + (340m/s * 7)) / 3
which produces the result of approximately 1.020 m/s
whereas to determine the value of the pressure increase, the following formula should be used (including E=mv2) for the piston's TDC: 41 * $(1.020\text{m/s} / 340\text{m/sec})^2$, i.e. approximately - 369 bar.

Of course, what we analyse here is a perfectly airtight system with perfect thermal insulation. In fact, the large amount of thermal energy of this gas (energy of vibrating molecules), is (excluding the piston rings blowby) transferred to the walls of the cylinder sleeve, to the piston head and the cylinder head (especially at the engine's low rotational speeds), which results in significantly cooling down the gas, whose molecules will not reach the level of 'high-energy' (not to be confused with high energies of molecules obtained in particle accelerators) that using the example of starting the engine with the compression ratio of 1:11, produce dozen of bars of pressure at the TDC with relatively low temperature.

Please pay attention to the fact that in a hypothetical perfectly airtight piston system with perfect thermal insulation, the increase of the molecule vibration speed is not affected by the engine rotational speed. What does affect it is the compression ratio applied. In contrast, please analyse for example the identical piston system with twice as much rotational speed (2400 revs/minute). Although in this case, the average piston speed is twice as big i.e. it is 8 m/s, the compression stroke is half as short and lasts 1/80 second, which all in all allows to calculate that the speed increase of vibrating gas molecules for the speed of 1200 revs/minute and for the speed of 2400 revs/minute is identical.



To illustrate the above theory, a piston engine was used as an example, but to revolutionise the way it is used and direct conversion of heat (gas molecules vibrating energy) into mechanical work, gas turbine according to patent application No. P-410894 can be used. I am the author of this turbine application. It may be operated in a wide range of different types of power supply (all fuel that generates heat) and it may also convert the gas heat (e.g. air heat) into mechanical energy without any combustion.