



Automotive Mechanical Engineering

Powertrain Design and Efficiency

Cylinder Head Analysis

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Abstract

This assignment is a focus at the limit of understanding and acknowledgment around engine components, and how they function via analytical techniques.

The assignment period is good chance for group students to work and share their ideas around the flow bench test, which will speak about next, what the cylinder head consists of, which components work together for one goal to produce power of movement. It is interesting assignment to watch how the flow bench machine works technically, how the student manage this test without teacher to guide them, how the parameters affect the functionality of the cylinder head, how to demonstrate topic specific management needs to provide good solutions by the principles of engineering.

Also the interpretation of automotive problems around the cylinder head design, for example, the bore and stroke are different shapes every time in the engine designs.

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Introduction

Fuel consumption, Engine Torque and power output are most deeply affected by piston crown design, combustion chamber what looks like an engine compression ratio.

In addition, there are important effective components such as exhaust and inlet valves what their size and numbers will be fitted in the engine, what the sparking plugs are location what the degree and timing to work, many things.

The aim of a good design for the combustion chamber, Is to improve the emptying and filling of the cylinder with burnt charge and new fresh unburnt charge continuously over the vehicle engine is functioning speed level rate.

Moreover to make the condition of the fuel and air inside the cylinder are mixed completely, the results excited to approach into the high level of turbulent, the charge will be burning in the shortest period of time possible.

So the most important device for engineers and designers to improve must be careful of the facts participate cross inducting the amount of charge into inside the cylinder, the purpose is to remove and mix the correct amount of air and fuel nearly, and burn together smoothly and quickly, and to eject out the burnt exhaust gases. The understanding how the parameters will affect when the engineers designing a combustion chamber, that will be looking at fuel efficiency, Emissions, power and the reliability, that help in the future when start manufacturing.

(Heisler, 2001)



Figure (1)

(Ehab, 2018)



Figure (2)

(godfreyracingengines.com, 2018)

Cylinder Head Design

“Good cylinder design is one of the most important features of good engine design. Not only do the cylinders constitute a large fraction of the engine cost, weight 925per cent is an average figure), and bulk, but they also exert a major influence on engine performance, reliability, durability, and maintenance.”

(Taylor, 1985)

Definition Flow bench

Flow bench or airflow bench, is equipment used for measuring the airflow capacities of cylinder heads that are requested to do so. It is preferable in this generation to who want to increase the function and performance of the engine's combustion, which is consist of inlet manifolds, valve profiles, intercoolers, ports, air cleaners, exhaust systems, two-stroke porting, throttle bodies etc. Generally, the list of components is endless to be tested.

(Dtec.net.au, 2018)

Goal of airflow

Is when the airflow under controlled conditions allows the testers and students to study airflow specifications and characteristics such as turbulence, tumble, velocity, swirl, distribution, basically the quality of the airflow not much important but the quantity results you count.

(Dtec.net.au, 2018)

Equipment and tools

Basic tools

1. Hammers and spanners.



Figure (3)

(Locksmiths of Ealing.CO.UK, 2018)

Spanners, metric socket, wrench set, angle gauge, hammer and torque wrench are important and needed to fit and tighten the bolts as typical specification.

2. G Clamp



Figure (4)

(Lawson H.I.S. Ltd, 2018)

G Clamp

This is a tool used for clamping two surface with each other and make it as one component, to avoid any sort of movements or leaks. It is made of cast iron or steel and usually the small top edge is flat and the bottom part is consist of large screw threaded moving up and down through hole as letter C or G. The purpose is between two edges you can manage to clamp and items between two edges, in the perpendicular direction as normal.

This tool is preferable for multipurpose such as wooding working and metalworking in the workshops and test labs.

2. Dial Gauge



Figure (5)

(PINSADDY.COM, 2018)

In this case, of flow bench test must use two TDI or Dial gauge used to move the valve up or down with specific measurements.

Combustion chambers

It is the most important area inside the engine because the fuel and air are mixed together compressed and ignited inside the combustion chamber.

The traditional design is the valve on the top of the cylinder head and the ignition by the side of the top of the piston.

TDC which the piston at the top dead centre the position of the chamber will be smallest wide dimension, this moment air and fuel mixture will be unstable case and easy to be ignited, the most preferable chamber design is called (breathes) it is efficient and active of general air flow everywhere in the engine.

Sorts of combustion chambers

1. Hemispherical combustion chamber.

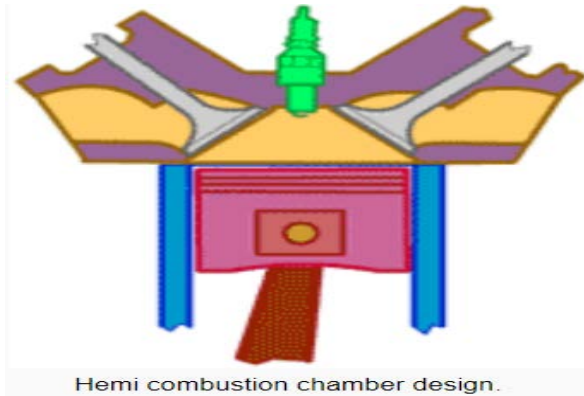


Figure (6) (Second Chance Garage.com, 2018)

This design is a bit weak for gaining efficiency, this type look like sphere throw into the cylinder head bottom.

The valves are located outside the bore area with proportional angle to the centre of the crankshaft, to improve this location allows to gain massive of airflow, just when the valve moves away from the wall to avoid from making any turbulence.

(Second Chance Garage.com, 2018)

Wedge shaped chambers

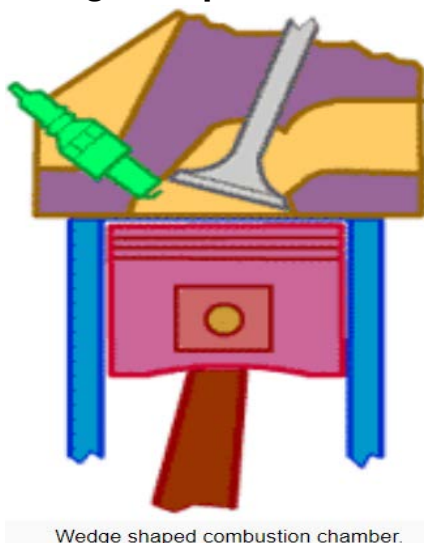


Figure (7) (Second Chance Garage.com, 2018)

The shape of inlet port between the valve and piston, and behind the valve, directs inlet air flow into a swirl. On the compression stroke, air-fuel mixture is moved from the centre to the wide edge of the combustion chamber increasing kinetic energy, adding to power output when the mixture is burnt.

Bathtub shaped combustion chamber

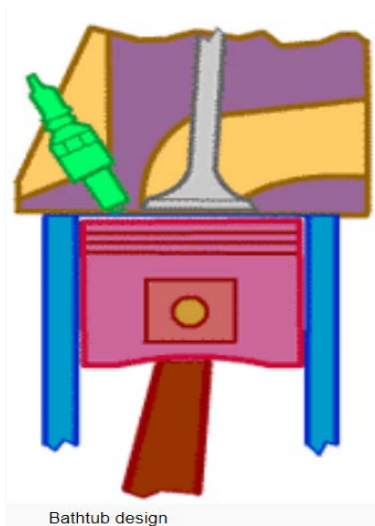


Figure (8)

(Second Chance Garage.com, 2018)

This design uses 2 combustion chambers next to each other and careful positioning of spark plug to develop high power output by improving burning. However, the valves are close to each other so are not so good at dissipating heat and volumetric efficiency is limited and this style would not work well as high compression engine with high octane fuel.

Bowl in piston

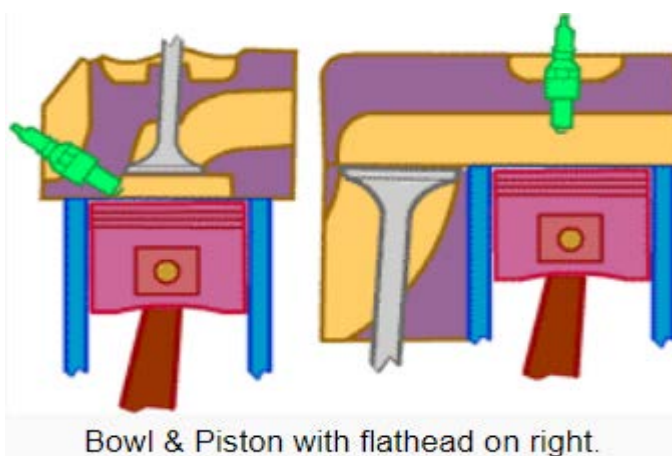


Figure (9)

(Second Chance Garage.com, 2018)

This design has been used for motor cycles and early cars such as Model T Ford. It works well to create turbulent flows for good air/fuel mixture, as the piston is shaped to have squish happen around its edge, but as a noisy engine it is not considered as good as other types.

Typical modification to create good cylinder head.

You can make modification to the engine cylinder head, but it depends on what sort of car engine, for example, for normal car road, race car or commercial vehicle.

If you look at the main body of cylinder head it consist of:

Valves, springs, camshaft, exhaust ports, inlet ports and spark plugs.

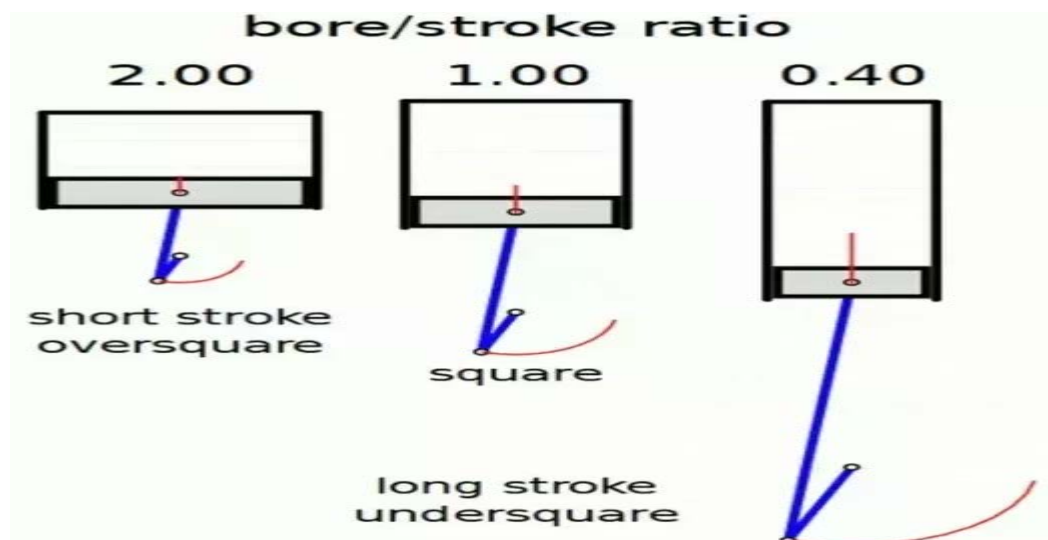


Figure (10)

(quora.com, 2018)

More air and more fuel produces high power. This is the simple equation for cylinder design, so $\text{force} = \text{pressure} \times \text{area}$. Plenty of area with high-pressure fuel and air mixture, will be producing extra power such as in commercial vehicle, which is the cylinder head on it is bigger than the small road car, also is different with race car.

The capacity of the cylinder is a secret word to create a good cylinder head; the first question is how the size and capacity of the cylinder head must be designed.

(Heisler, 2001)

Methodology

1. fit the cylinder head into the flow bench test block, by using bolts, nuts and plates also use two or three G Clamps to make the cylinder head fitted properly as one component. To avoid any sort of leaks between the flow bench machine board and cylinder head use some blue tech, it looks like gum to stop any sort of air leak during the test functioning.
2. Push the valves in an increment based on refraction of head diameter, so is important to measure the valve head diameter and stem of the cylinder head before you start your test.
3. Fit the flow bench component such as dial gauge by use G Clamps and some bolts with nuts.
4. It is important to start in below position range otherwise the machine does not get cooling to it is motors.
5. If you struggle to get the 25 inches which is the typical number of flow pressure on red scale, you can move to the next range. to get right percentage on the blue scale, if not there is two buttons can adjusted on the scale metal, by moving up and down.
6. Red scale measures pressure drop cross the cylinder head, and blue scale measures the flow.
7. Make sure, before you start work, blue scale reading is zero.
8. At test number 1 and 2 the arrow must be below 150/cfm, test 3, 4, 5, 6, 7, 8 must be above 150/ cfm.

Efficiency of Flow bench machine

this machine can both suck air through intake valves, and blow air out through the exhaust.

There is two switches on right of the blue scale, two controls Exhaust is up and inlet is down, there is also two positions below 150 cfm(cubic feet per minute), and above 150cfm.

Flow Bench operation

1. Before you start make sure the valve is fully closed, check the bolts and nuts are tightened properly.
2. Start wind half turn on the TD1 one and TDI 2, the same value on both, moreover repeat it for example 1.39 for range 1 and 2.77 for range 2, etc....
3. Switch on the electric motor and adjust the red scale until you approach 25 inches by turning the Black circular key.
4. Read the airflow on the blue scale as a percentage of figures up the blue scale is in percentage, with specific rang table, it is located beside the blue scale.
5. This table for six ranges so your flow percent must match the level in this table. it dependent of which range you are in.
6. adapt at range one by turning the arrow to right side intake, and pull out the black circular key and put in correct position, and you can use the same technique at the exhaust position.
7. Record the flow number when you see the flow is going up on blue scale as percentage.
8. switch of the machine and change the range position from number one into number two, Repeat this step for 8 times with different ranges.

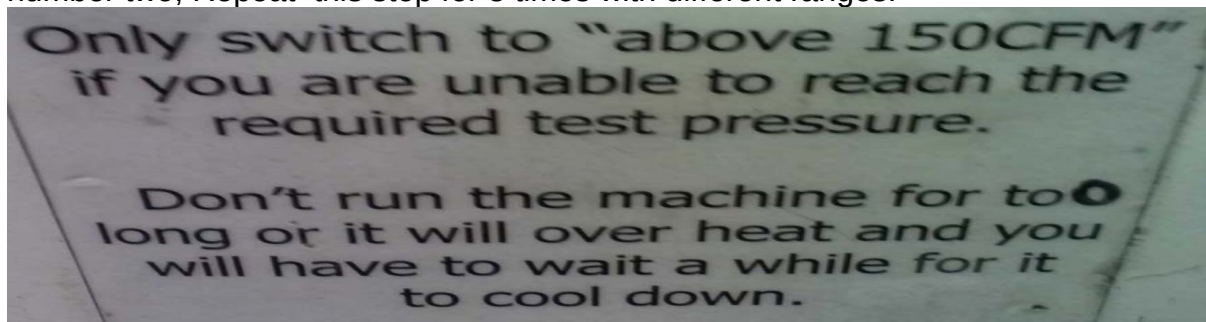


Figure (11) (Ehab, 2018)
showing important instruction to avoid overheat pump temperature.

Ford Test setup results

Super Flow SF300/600 Test Data table

Date:	23/12/2017
Test Description	Flow Bench
Head Description	Ford 1.6 Petrol
Port Number	1
Test Operator	All Group

Figure (12)

	Valve Head Diameter, DH(mm)	Valve Stem Diameter, Ds(mm)	Valve Head Diameter, Dh(in)	Valve Stem Diameter, Ds(in)	Effective Valve Area(in ²): $0.785(DH^2Ds^2)$
Intake	30.04	5.94	1.185	0.256	1.05 in ²
Exhaust	24.13	5.97	0.95	0.243	0.66 in ²

Figure (13)

Valve Lift/ diameter (L/D)	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
A. Intake Valve Lift(mm)	1.502	3.00	4.5	6.0	7.51	9.01	10.51	12.01
B. Exhaust, Valve Lift(mm)	1.20	2.41	3.61	4.82	6.03	7.23	8.44	9.65

Figure (14)

Range	1	2	3	4	5	6
E. Intake	34.98	70.98	147.764	292.984	440.536	592.54
F. Exhaust	41.34	78.652	159	314.82	465.552	603.352

Figure (15)

Test one

Ford Intake Valve Test Results

1.Test number	1	2	3	4	5	6	7	8
2.Test Pressure	25	25	25	25	25	25	25	25
3.Valve Lift(B)	1.502	3.00	4.5	6.0	7.51	9.01	10.51	12.01
4.Flow Range(1-6)	2	3	3	3	4	4	4	4
5. Flow scale (%)	56.5	56.7	81	95	48	48.5	49	49.5
6.Flow scale(5/100)	0.565	0.567	0.81	0.95	0.48	0.485	0.49	0.495
7.Raw Test Flow cfm(6Xf)	40.10	83.78	119.68	140.37	140.63	142.09	143.56	145.02
8.Leakage(Flow scale% when Valve are shut)	0	0	0	0	0	0	0	0
9.Test cfm(7.8)	40.10	83.78	119.68	140.37	140.63	142.09	143.65	145.02
10.Test cfm/sqinch(9/Effective Area	38.11	79.79	113.98	133.68	133.93	135.32	136.88	138.11
11.Potential Flow (p30-31of Manual)	25.3	47.3	65.7	80.2	91.1	98.2	101.5	101.1
12.%Potential Flow (10/11)	1.50	1.69	1.73	1.67	1.47	1.37	1.35	1.37

Figure (16)

Ford Exhaust Valve Test Results

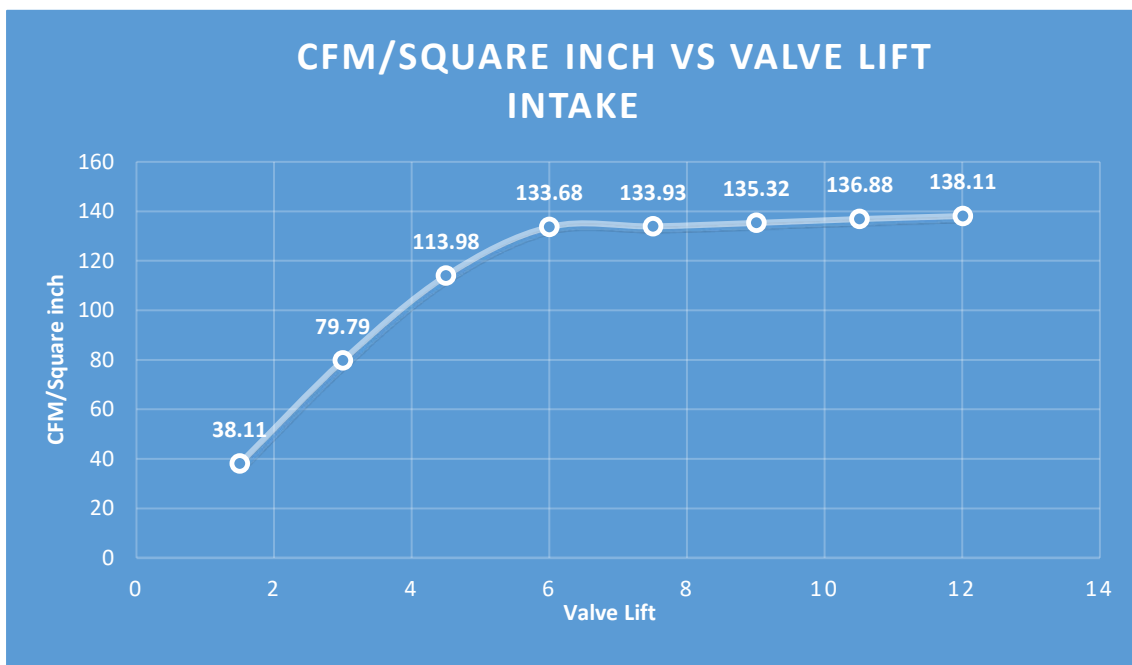
1.Test number	1	2	3	4	5	6	7	8
2.Test Pressure	25	25	25	25	25	25	25	25
3.Valve Lift(B)	1.20	2.40	3.61	4.82	6.03	7.23	8.44	9.65
4.Flow Range(1-6)	1	2	2	3	3	3	3	3
5. Flow scale (%)	66	60.5	84.5	53.0	57.0	60.5	62.5	64.5
6.Flow scale(5/100)	0.66	0.60	0.845	0.53	0.57	0.60	0.62	0.64
7.Raw Test Flow cfm(6Xf)	27.28	47.58	66.46	84.27	90.63	95.4	98.58	101.76
8.Leakage(Flow scale% when Valve are shut)	0	0	0	0	0	0	0	0
9.Test cfm(7-8)	27.28	47.58	66.46	84.27	90.63	95.4	98.58	101.76
10.Test cfm/sqinch(9/Effective Area	41.3	72.09	100.67	127.67	137.31	144.55	149.33	154.11
11.Potential Flow (p30-31of Manual)	25.3	47.3	65.7	80.2	91.1	98.2	101.5	101.1
12.%Potential Flow (10/11)	1.67	1.52	1.53	1.59	150	1.47	1.47	1.52

Figure (17)

Ford Intake comparison

CFM/Square inch	Valve Lift
38.11	1.50
79.79	3
113.98	4.5
133.68	6
133.93	7.51
135.32	9.01
136.88	10.51
138.11	12.01

Figure(18)



Figure(19)

As the chart display the value of L/D when the flow rate drops of at 6 valve lift and 133.68 cfm/Sqinch, the CFM dropped at test number 6 which CFM/square inch is $133.68 - 3.68 = 130$ so the tuning potential in intake is 130.

Ford Exhaust Comparison

CFM/Square inch	Valve Lift
41.3	1.2
72.09	2.4
100.67	3.61
127.67	4.82
137.31	6.03
144.55	7.23
149.33	8.44
154.11	9.65

Figure (20)

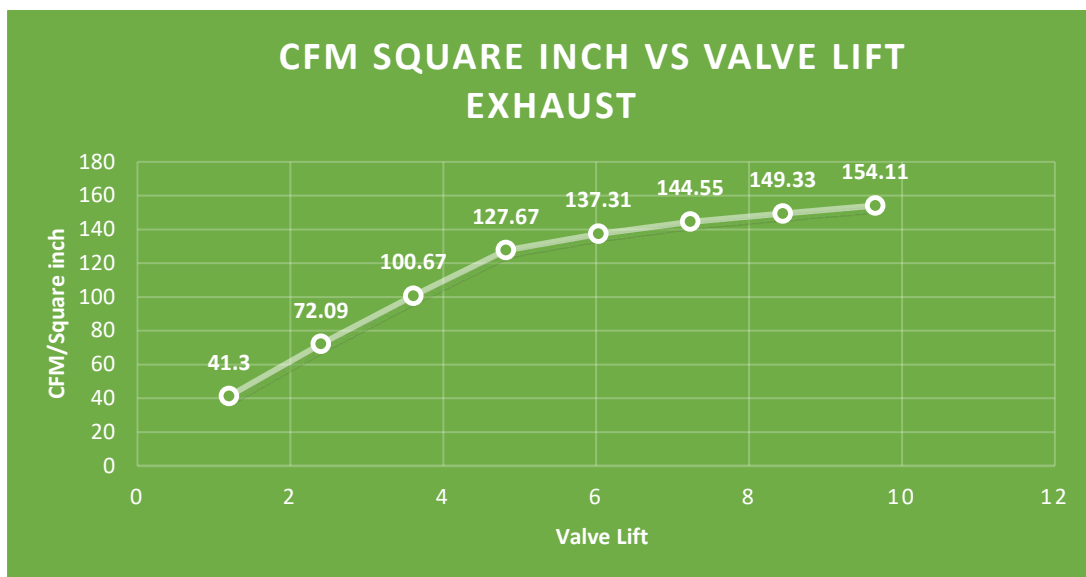


Figure (21)

As the figure show the CFM drop off at test 6 valve lift and cfm/square inch is $137.31 - 4.51 = 132.8$ so the tuning potential exhaust is 132.8/Square inch

Test two for Rover Cylinder head

Date:	23/01/2018
Test Description	Flow Bench
Head Description	Rover 1.6 Petrol
Port Number	2
Test Operator	All group

Figure (22)

	Valve Head Diameter, DH(mm)	Valve Stem Diameter, Ds(mm)	Valve Head Diameter, Dh(in)	Valve Stem Diameter, Ds(in)	Effective Valve Area(in ²): $0.785(DH^2Ds^2)$
Intake	27.7	6.45	1.083	0.26	0.87 in ²
Exhaust	24	6.08	0.90	0.25	0.65 in ²

Figure (23)

Valve Lift/ diameter (L/D)	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
A. Intake Valve Lift(mm)	1.39	2.77	4.16	5.54	6.93	8.31	9.69	11.08
B. Exhaust, Valve Lift(mm)	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6

Figure (24)

Range	1	2	3	4	5	6
E. Intake	34.98	70.98	147.764	292.984	440.536	592.54
F. Exhaust	41.34	78.652	159	314.82	465.552	603.352

Figure (25)

Rover Intake Valve Test Results

1.Test number	1	2	3	4	5	6	7	8
2.Test Pressure	25	25	25	25	25	25	25	25
3.Valve Lift(B)	1.39	2.77	4.16	5.54	6.93	8.31	9.69	11.08
4.Flow Range(1-6)	1	2	3	3	3	3	4	4
5. Flow scale (%)	93.5	89	61	74.8	84.1	90	45.5	47
6.Flow scale(5/100)	0.935	0.89	0.61	0.748	0.841	0.90	0.455	0.47
7.Raw Test Flow cfm(6XF)	32.71	63.17	90.14	110.53	124.27	132.99	133.31	137.70
8.Leakage(Flow scale% when Valve are shut)	0	0	0	0	0	0	0	0
9.Test cfm(7-8)	32.71	63.17	90.14	110.53	124.27	132.99	133.31	137.70
10.Test cfm/Sqinch(9/Effective Area	37.56	72.66	103.66	127.00	142.88	152.88	153.22	158.22
11.Potential Flow (p30-31of Manual)	25.3	47.3	65.7	80.2	91.1	98.2	101.5	101.1
12.%Potential Flow (10/11)	1.49	1.54	1.58	1.58	1.57	1.56	1.50	1.56

Figure (26)

Rover Exhaust Valve Test Results

1.Test number	1	2	3	4	5	6	7	8
2.Test Pressure	25	25	25	25	25	25	25	25
3.Valve Lift(B)	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6
4.Flow Range(1-6)	1	1	2	2	2	3	3	3
5. Flow scale (%)	50	96.5	74	88	96	57	61.5	65
6.Flow scale(5/100)	0.5	0.965	0.74	0.88	0.96	0.57	0.615	0.65
7.Raw Test Flow cfm(6XF)	20.67	39.89	58.2	69.21	75.51	90.63	97.79	103.35
8.Leakage(Flow scale% when Valve are shut)	0	0	0	0	0	0	0	0
9.Test cfm(7.8)	20.67	39.89	58.2	69.21	75.51	90.63	97.79	103.35
10.Test cfm/sqinch(9/Effective Area)	31.8	61.37	89.54	106.48	116.17	139.43	150.45	159
11.Potential Flow (p30-31of Manual)	25.3	47.3	65.7	80.2	91.1	98.2	101.5	101.1
12.%Potential Flow (10/11)	1.26	1.29	1.36	1.44	1.46	1.23	1.82	1.92

Figure (27)

Rover Cylinder Head Comparison Intake

CFM/Square inch	Valve lift
37.56	1.39
72.66	2.77
103.66	4.16
127	5.54
142.88	6.93
152.88	8.31
153.22	9.69
158.22	11.08

Figure (28)

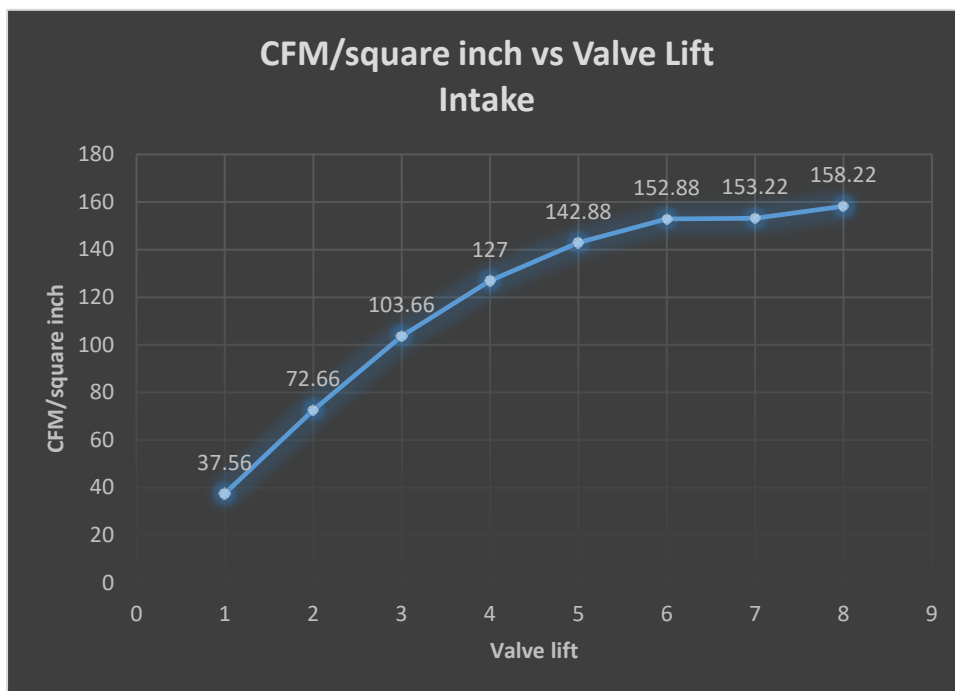


Figure (29)

As the curve shows the flow rate starts to drop off at test valve lift 6 the CFM drop off at $152.88/\text{cfm} - 4.51 = 148.37$ so the tuning potential exhaust is 148.37

Rover Exhaust Comparison

CFM/Square inch	Valve Lift
31.8	1.2
61.37	2.4
89.54	3.6
106.48	4.8
116.17	6
139.43	7.2
150.45	8.4
159	9.6

Figure (30)

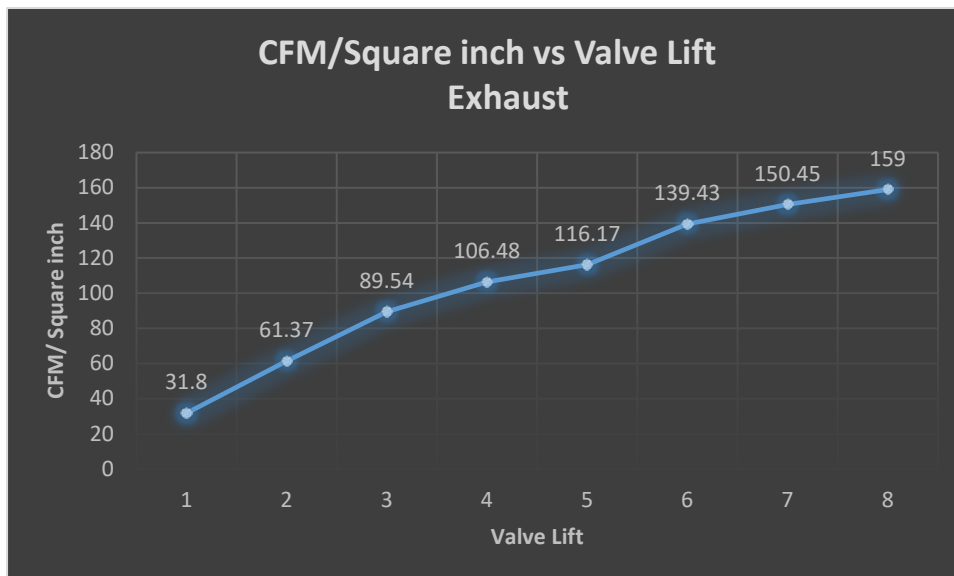


Figure (31)

As the chart showing the L/D which is the flow rate 6 start to drops off CFM at 139.43/cfm – 4.51 = 134.92 so the tuning potential is 134.92.

Ford Intake Values vs Rover Intake Values

CFM	Valve Lift	CFM	Valve Lift
38.11	1.5	37.56	1.39
79.79	3	72.66	2.77
113.98	4.5	103.66	4.16
133.68	6	127	5.54
133.93	7.51	142.88	6.93
135.32	9.01	152.88	8.31
136.88	10.51	153.22	9.69
138.11	12.01	158.22	11.08

Figure (32)

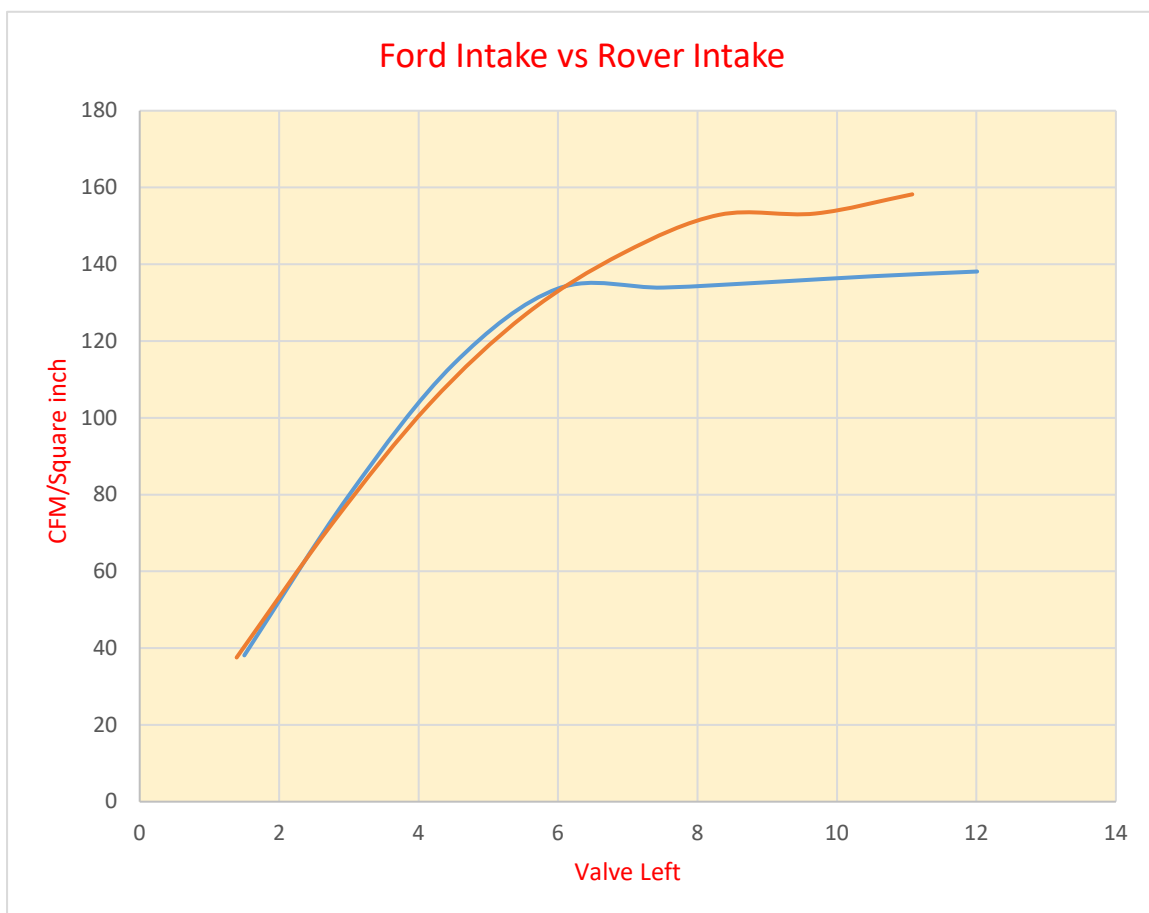


Figure (33)

The chart showing two curves which are for Ford intake and Rover intake, they are grown gradually and dropped off at 6.

Ford Exhaust Value vs Rover Exhaust Values

CFM	Valve Lift	CFM	Valve Lift
41.3	1.2	31.8	1.2
72.09	2.4	61.37	2.4
100.67	3.61	89.54	3.6
127.67	4.82	106.48	4.8
137.31	6.03	116.17	6
144.55	7.23	139.43	7.2
149.33	8.44	150.43	8.4
154.11	9.65	159	9.6

Figure (34)

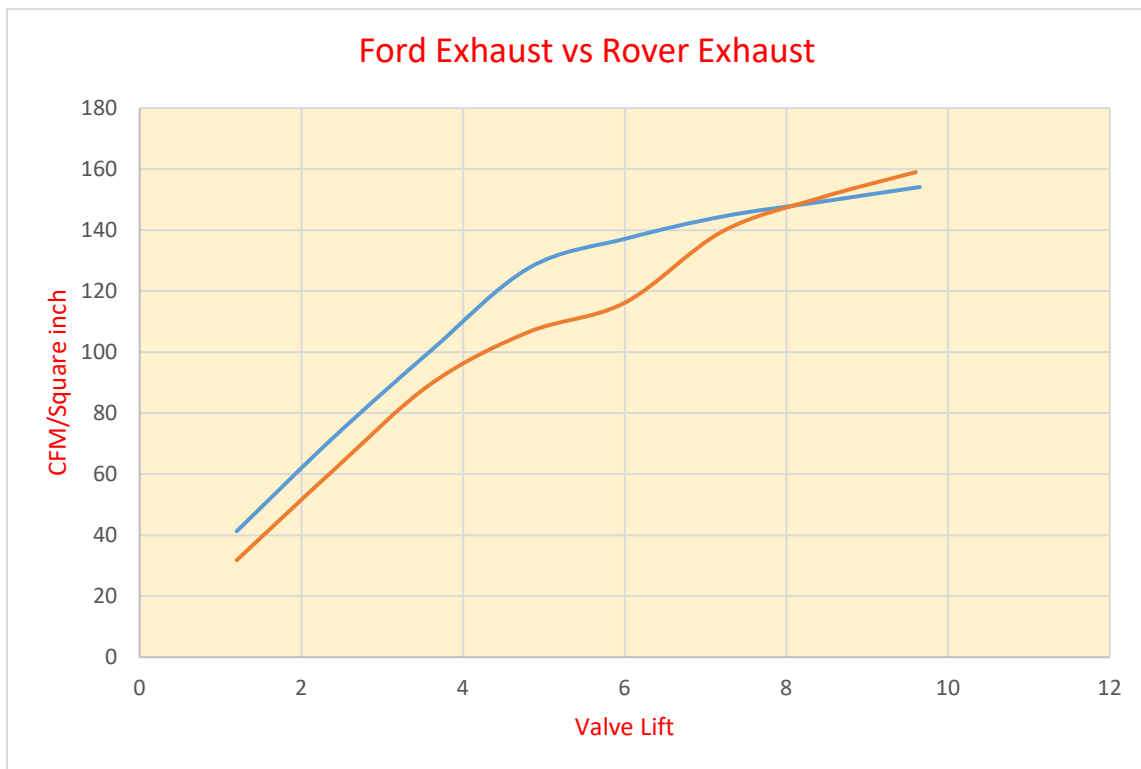


Figure (35)

the figure show the ford intake curve comparisons with Rover exhaust curve, the point to drops off at test number sex.

Definition of tuning potential

it basically is calculation operation between the value of CM/Square inch when the flow bench drops off , take this value away from corresponding value for super flow manual and the result will be the tuning potential.

(Superflow Corporation, 2017)

Recommendations for improvements

the selection for design cylinder head is it hard, some modifiers looking at the big size of valves, does not mean always cylinder head is better.

but this not true in this generation, they looking for extra authority and more power if it is in a good way correctly, focus at port size along and valve flow numbers to create appropriate decision.

The recommendations for improvement is to look at torque you need it on the street. good intake velocity comparing with how limit of scavenging exhaust gases properly, it is not always big valve and huge port to approach there, also you need good design camshaft profile, working harmony with cylinder head, finally nice and high performance with good flow through the power of momentum and good overlap.

(Exxon Mobil Corporation, 2005-2017)

Discussion

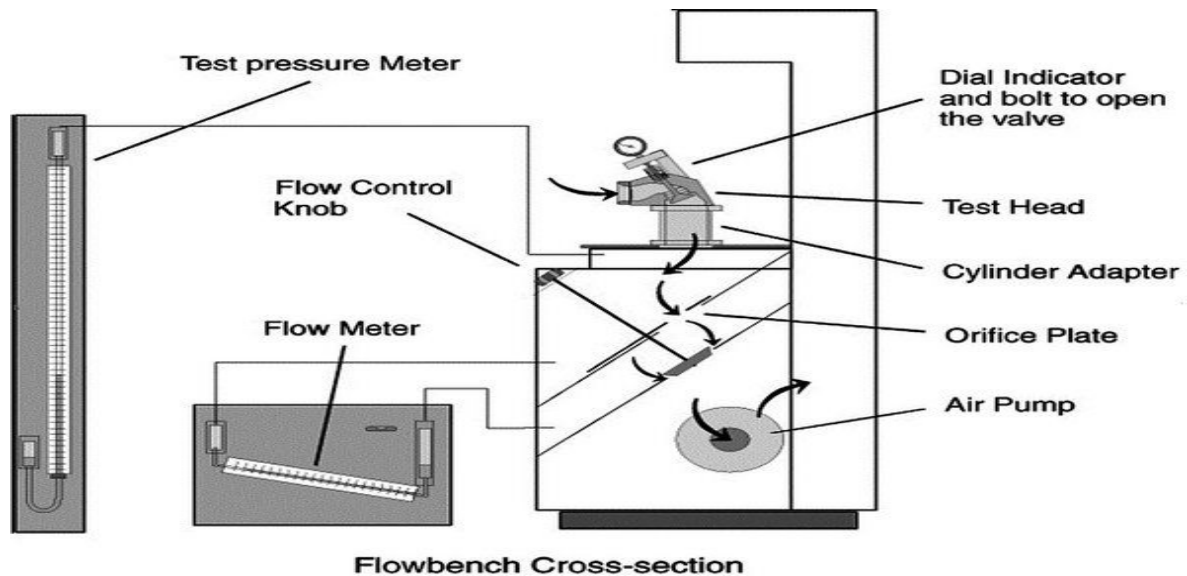


Figure (36)

(CHEVYDIY.com, 2018)

The flow bench measures flow resistance by using a vacuum pump to make pressure differences in compartments inside the machine. When the machine is set-up, there are three restrictions to airflow: valve, orifice and flow control knob. Pressure drops are measured either side of the valve and orifice plate. All readings must be equivalent to each other so the test pressure meter has to have the same reading for each measurement – this is often 25" of water.

Starting from the smallest possible, an orifice size must be selected to allow enough airflow between the plate and flow control knob to give a reading on the flow meter. This reading is a value for how much air passes through the machine. If the orifice is too big then the pressure will equalize on both sides and no reading is possible. If the hole is too small, the limits of the flow meter will be exceeded as the pressure is too high, or not enough flow will be able to pass by the valve, so in this case a reading is not possible either. Choosing the right orifice to allow the flow meter to produce readings in the high resolution area is ideal.

The flow bench is used to measure how flow rate through a cylinder head increases with valve lift. After a change to port dimensions or adding a trumpet to the inlet, measurements can be retaken to see improvements. The aim of these tests is to increase flow to as high as possible. However, a downside to this is the inlet air has to swirl/tumble as it reaches the cylinder. Changing port dimensions for optimised air flow for the inlet must be done carefully to maintain air turbulence, allowing good fuel air mixture for combustion even at low revs.

(Superflow Corporation, 2017)

Conclusion

By all means it is more interesting to work on flow bench test, the test tech how the student rely on themselves, using different tools and equipment, also learn how to fit important components such as cylinder head, and turning the cylinder head on both sides intake (inlet) and Exhaust two times, how to record and calculate the precise data, it is a lot of advantages and benefits it will be gained after finish flow bench test.



Figure (37)

Flow bench test

(Ehab, 2018)

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