SECOND STRIKE AIR CLEANER CALCULATOR

Introduction

Right up there with the big block / small block and carburetor size discussions are the quandaries about air cleaner selection. Does it look right? Will it fit under the hood? Does it do the job without choking my engine? Am I trying to shove a monster under the hood when a smaller unit will do the job?

The Second Strike Air Cleaner Calculator allows you to evaluate different air cleaner designs and will tell you how well each performs on your engine by calculating the pressure drop and horsepower loss over a range of engine speeds. You can then determine if this is acceptable for your circumstances. For a show car, originality and aesthetics may be more important than performance. For a car that sees the track from time to time, performance will be paramount. For performance applications, you should shoot for a pressure loss in the 0.5% to 1.0% range at the peak power rpm. Less is better.

The model is designed primarily to let you know if a filter works for your engine or not. It is not intended to yield precise three digit answers because a precise model would require more input (such as the number and depth of the pleats, flow bench airflow numbers for the material, volumetric efficiency curves and horsepower curves for the engine) than the average owner knows or would be willing to find out. And it really isn't necessary. When picking an air cleaner, it isn't important to know if the loss is 2 horsepower or 2.1. You really want to know if it is 2 (OK) or 10 (maybe) or 20 (not OK). The input has been simplified as much as possible to make the model usable by making a number of simplifying assumptions. The mathematical basis for the calculation is contained in the **Technical** section for those who are interested.

The model is for normally aspirated engines. It is not designed for blowers, turbos or nitrous. This model is for round and oval air cleaners with perimeter filter elements. It is not designed for filter elements in the lid.

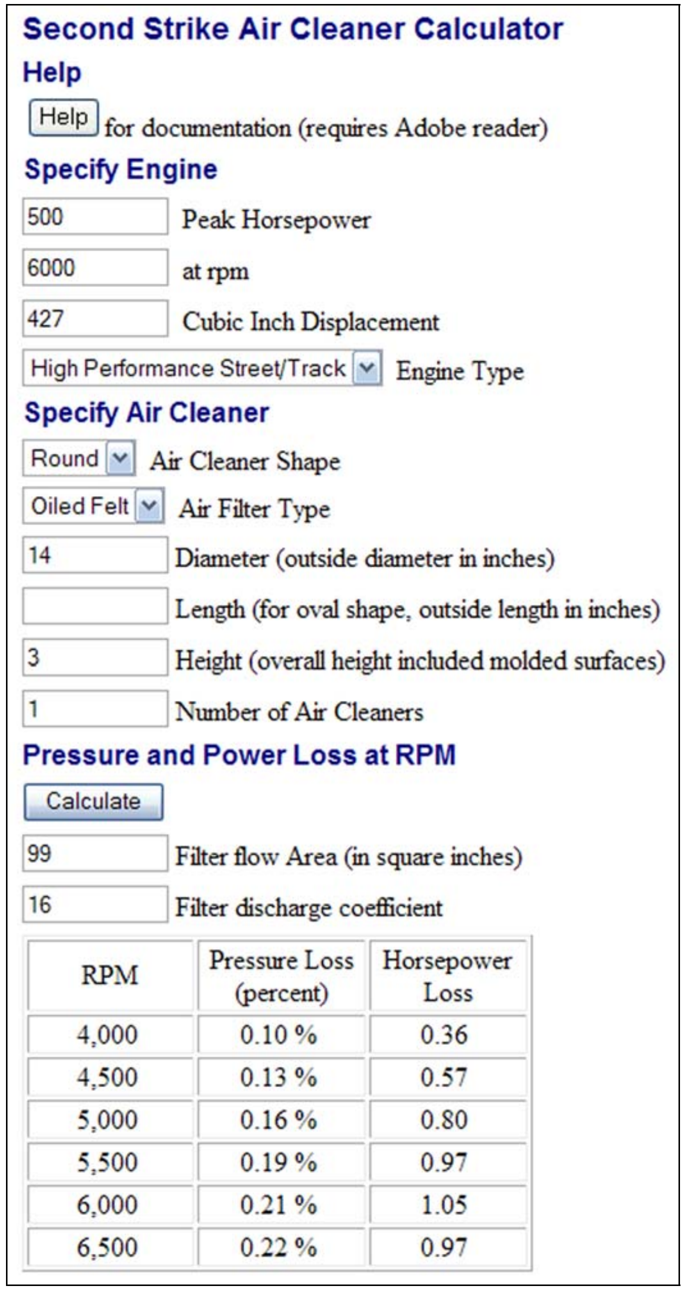
Input

Specify Engine

Peak Horsepower at rpm

Specify the peak horsepower and the rpm that the peak horsepower occurs. This should be the gross horsepower - dyno horsepower at the flywheel without installation losses (without air cleaner and accessories, with open headers).

If you have net installed horsepower (with air cleaner, accessories and road exhaust system installed), increase the net installed horsepower by 15%.



RPM	Pressure Loss (percent)	Horsepower Loss
4,000	0.10 %	0.36
4,500	0.13 %	0.57
5,000	0.16 %	0.80
5,500	0.19 %	0.97
6,000	0.21 %	1.05
6,500	0.22 %	0.97

The Air Cleaner Calculator is on www.SecondStrike.com.

If you have rear wheel horsepower, increase the rear wheel horsepower by 25%. This does not have to be exact. The horsepower is used to calculate the horsepower loss. The rpm is used to set the rpm range in the results.

Cubic Inch Displacement

Specify the actual cubic inches of the engine.

Engine Type

The engine type is used to approximate the volumetric efficiency (VE) curve. See the **Technical** section for details.

Specify Air Cleaner

Air Cleaner Shape

Two shapes are currently supported, round and oval. See **Specs** below for examples

Air Filter Type

Three types are currently supported.

Foam Standard type for the original Stelling & Hellings air cleaner. Foam is typically oiled and is washable and reusable. It is not a particularly good filter and is very restrictive.

Paper Standard for most original equipment and aftermarket air cleaners. Typically offers high filtration. Moderate restriction. Not washable or reusable. Inexpensive.

Oiled Felt Offered by K&N and others. Washable and reusable. Medium filtration. Low restriction. Pretty expensive.

Check the output section for the discharge coefficient of the filter element you selected. The pressure drop is directly related to the discharge coefficient. Lower is better.

Diameter

The outside diameter of the filter element for the round air cleaners. The outside width of the filter element for the oval air cleaners.

For stamped steel air cleaner housings, the diameter of the filter element is about the same as the housing. For cast aluminum housings, the filter element diameter, length, and height are approximately 0.3” less than the same dimensions for the housing. Input the filter element dimensions into the model.

Length

The overall outside length of the filter element. Specified for oval air cleaners only.

Height

The overall physical height of the filter element, including any molded surfaces.

Paper and oiled felt filter element typically have a built in molded rubber base and top. These moldings are typically 3/8” thick, so for paper and oiled felt 3/4” is automatically subtracted from the input physical height by the model to calculate the actual flow area.

Foam elements typically do not have the molded top and bottom and the model uses the full physical height to calculate the flow area.

Check the output section for the calculated flow area.

Number of Air Cleaners

Some engines have more than one air cleaner. A two 4-barrel setup might have one oval air cleaner or two small round air cleaners. A four 2-barrel Weber setup might have a single air cleaner, two air cleaners – one for each bank, four air cleaners – one for each carburetor, or even eight air cleaners – one for each stack. The flow area for each filter is multiplied by the number of air cleaners to get the filter flow area.

Results

Click on the calculate button to calculate the results for your input.

Filter Flow Area and Discharge Coefficient

Flow area and discharge coefficient are the two most important factors determining the pressure loss and horsepower loss.

The filter flow area is based on the dimensions, air cleaner shape, air filter type, and number of air cleaners. A higher flow area will reduce the flow speed and thereby reduce the pressure loss. When comparing two air cleaners, the one with the higher flow area will give better results, all else being equal.

The filter discharge coefficient is a measure of the flow efficiency of the filter element. The air filter type determines the discharge coefficient. All else being equal, the filter with the lower discharge coefficient will have a lower pressure loss and horsepower loss.

See the **Technical** section following for the flow area calculation and discharge coefficient technical definition.

Pressure Loss and Power Loss at RPM Table

The pressure loss is expressed as a percentage of atmospheric pressure. A one percent loss in pressure translates into a one percent loss in airflow, which translates into a one percent horsepower loss.

The horsepower loss is based on the estimated horsepower at the stated rpm and the calculated pressure loss. The power curve is approximated from the stated peak horsepower and rpm.

Results are shown from 2,000 rpm below the specified rpm to 500 rpm above.

Specs for Commonly Used Air Cleaners

Round

Stelling & Hellings

Air Cleaner Shape: Round
Housing diameter: 8 inches
Standard element:
  Foam 1.75 inches high

Ford Round 13" Air Cleaner

Ford Part No: M-9600-A302
Air Cleaner Shape: Round
Housing diameter: 13 inches
Standard element:
  Paper 2.75 inches high

Ford Round 14" Air Cleaner

Ford Part No: M-9600-P302
Air Cleaner Shape: Round
Housing diameter: 14 inches
Standard element:
  Paper 1.75 inches high
Available elements:
  Oiled felt 2.3 inches
  Oiled felt 3.1 inches high
  Oiled felt 4.0 inches high

Note: Photographs are approximately the same scale for comparison purposes.

Oval

Cobra Oval Air Cleaner

Ford Part No: M-9600-C302
Air Cleaner Shape: Oval
Hosing diameter: 10 inches
Housing length: 21 inches
Filter diameter: 9.5 inches
Filter length: 20.8 inches
Standard element:
  Paper 1.75 inches high
Available elements:
  Oiled felt 1.81 inches
  Oiled felt 3.00 inches high

Ford Oval Air Cleaner

Ford Part No: M-9600-R302
Air Cleaner Shape: Oval
Housing diameter: 8.375 inches
Housing length: 11.875 inches
Element diameter: 8.125 inches
Element length: 11.5 inches
Standard element:
  Oiled felt 2.5 inches high

Typical Air Filter Results

Case	Air Cleaner	Shape	Type	Dia.	Length	Height	Number	Flow Area	Pressure Loss	Power Loss
1	S&H	Round	Foam	8		1.75	1	44	9.3%	43.0
2	S&H	Round	Foam	8		1.75	2	88	2.3%	11.6
3	S&H	Round	Felt	8		2.4	1	41	1.2%	6.0
4	Ford	Round	Paper	13		2.75	1	82	0.90%	4.5
5	Ford	Round	Paper	14		1.75	1	44	3.1%	15.6
6	Ford	Round	Felt	14		2.30	1	68	0.44%	2.2
7	Ford	Round	Felt	14		3.00	1	99	0.21%	1.1
8	Ford	Round	Felt	14		4.00	1	143	0.10%	0.5
9	Cobra	Oval	Paper	9.5	20.8	1.75	1	52	2.2%	11.0
10	Cobra	Oval	Felt	9.5	20.8	1.81	1	56	0.66%	3.3
11	Cobra	Oval	Felt	9.5	20.8	3.00	1	118	0.15%	0.7
12	Ford	Oval	Felt	8.125	11.5	2.50	1	56	0.64%	3.2

Table 1: Typical Results

The results shown are for:

- 500 peak horsepower
- 6000 rpm
- 427 cubic inch displacement
- High performance street/track engine type

Pressure loss and horsepower loss are shown at 6000 rpm. Typical results are shown for a number of different elements in Table 1.

Cases 1, 2, and 3 are for the original Stelling & Hellings air cleaner. The small size allowed the air cleaner to fit in the “turkey pan” cold air box under the hood scoop. The small foam element (Case 1) has a whopping 9.3% pressure drop costing 43.0 horsepower. Dyno testing by Superformance owners shows that it may actually worse that this! Case 2 shows the addition of a second 4-barrel and the companion second air cleaner. The second air cleaner doubles the flow area and saves 31 horsepower. The second air cleaner is worth more horsepower than the second carburetor. It may be original, but even with two air cleaners; the Stelling & Hellings is unduly restrictive. It is recommended for show cars only. If you want to keep the turkey pan but are willing to deviate from originality, a 2.4 inch oiled felt element will help. It won’t improve the area (remember foam doesn’t have the top and bottom caps), but it will eliminate the restrictive foam element. The pressure loss is a bit high at 1.2%, but a whole lot better than 9.3%.

Case 4 is the 13” Ford unit with a paper element. The 13” diameter clears the larger distributors on small blocks and the tall 2.75” element flows better than the stock element on its 14” brother.

Cases 5, 6, 7, and 8 are for a 14 inch diameter round air cleaner. The standard 1.75 inch paper element is inadequate for 427 cubic inches. The use of a 2.33 inch oiled felt element is quite acceptable as is the 3 inch element. Going to a 4 inch oiled felt element provides no real advantage and will cause hood clearance problems even on a small block with a dual plane manifold.

Cases 9, 10, and 11 are for the Cobra oval air cleaner. The standard 1.75 inch paper element is inadequate for 427 cubic inches. The use of the 1.81 inch oiled felt element is adequate, even for an engine of this size. The 3 inch oiled felt element is a tight fit on a small block with a dual plane manifold. Use of the 3 inch element on a big block requires extensive modifications to the housing. It may not be worth it for the gain of a couple of horsepower.

Case 12 is for the Ford oval air cleaner favored by 460 big block owners. The shorter oval shape allows it to snug up into the hood scoop for hood clearance. With the standard 2.5 inch oiled felt element, it is quite adequate for a 427 CID engine. Even with the massive 625 horsepower 514, the pressure drop at the 6250 rpm horsepower peak is only 1.0% with a power loss of only 6.3, still quite acceptable.

Air Cleaner Shape Considerations

The Second Strike Air Cleaner Calculator calculates pressure drop across the filter element. However, the air cleaner housing is more than two slabs of metal holding the element on top of the carburetor as this modified NASCAR housing shows.

The Holley HP carburetor used in NASCAR is chokeless with no air horn. The smooth inlet shape begs for an equally aerodynamic air cleaner housing. NASCAR uses such a housing available from CV Products (CV1511).

The contoured shape has two purposes. It turns the air gently to head straight down into the chokeless HP carburetor. It also drops down 1.7" over the carburetor allowing the use of a tall filter element.

The domed top is contoured to match the base as can be seen from the domed shape and deeply recessed hold down nut.

The chokeless carburetor and aerodynamic case can save as much as 20 horsepower in installation losses.

The unit uses a 14 inch diameter element. With a 3 inch tall K&N element, it has 1 inch of hood clearance for a 351W with dual plane manifold.

Technical

Technical types will like this section. Others can use it as a non-addicting sleeping tonic on restless nights.

Horsepower Loss from Airflow Restriction

The pressure loss Δp from airflow passing through a restriction is directly related to the dynamic pressure, q, of the airflow.

$$\Delta p = Cd \times q$$

The discharge coefficient, Cd, is a measure of the efficiency of air flowing though an obstruction. The lower the Cd, the more efficiently the air moves through the obstruction.

The pressure loss is typically stated as a fraction of the atmospheric pressure, p.

$$\Delta p \,/\, p = Cd \times \frac{q}{p}$$

The term $\Delta p \,/\, p$ is a decimal fraction, i.e. 0.01 means a 1% pressure drop. In working with normally aspirated engines, a 1% pressure drop in the intake side will cause approximately a 1% loss in horsepower.

The dynamic pressure is defined as:

$$q = 1/2 \times \rho \times V^2$$

The term ρ or rho is the atmospheric density. V is the flow speed in ft/sec. The speed can be expressed in terms of SCFM, the airflow in standard cubic feet per minute.

$$V = \frac{SCFM}{60} \times \frac{144}{Area}$$

where the flow area is in sq. in.

For standard sea level atmospheric conditions:

p =	29.92	inches Hg
	406.8	inches H_2O
	14.70	lbf/sq.in.
	2,116	lbf/sq.ft.
$\rho =$	0.002378	

If we combine these equations and resolve the constants, then for standard atmospheric conditions:

$$\Delta p / p = Cd \times \left[\frac{SCFM}{Area \times 556} \right]^2 \qquad (1)$$

The SCFM can be expressed in terms of displacement (CID), engine speed (RPM) and volumetric efficiency (VE):

$$SCFM = \frac{CID \times RPM \times VE}{2 \times 1728}$$

In terms of displacement and engine speed:

$$\Delta p / p = Cd \times \left[\frac{CID \times RPM \times VE}{Area \times 1{,}921{,}000} \right]^2 \qquad (2)$$

Equations (1) and (2) apply to any device, air cleaner housing, air cleaner element, carburetor, intake manifold, cylinder head, inlet valve, as well as exhaust system components. The pressure loss, and subsequent horsepower loss, can be calculated once the flow area and the discharge coefficient are known.

Flow Area

Paper and Oiled Felt

Paper and oiled felt filter element typically have a built in molded rubber base and top. These moldings are typically 3/8" thick, so for paper and oiled felt 3/4" is subtracted from the input physical height by the model to calculate the actual flow area.

For round elements:

$$Area = \pi \times diameter \times (height - .75)$$

For oval elements:

$$Area = (\pi \times diameter + 2 \times (length - diameter)) \times (height - .75)$$

Foam

Foam elements typically do not have the molded top and bottom and the model uses the full physical height to calculate the flow area.

For round elements:

$$Area = \pi \times diameter \times height$$

For oval elements:

$$Area = (\pi \times diameter + 2 \times (length - diameter)) \times height$$

Discharge Coefficient

K&N supplies the following airflow's for their air cleaner element and competitive elements.

Element	SCFM
Foam	376
Paper	508
Oiled Felt	887

The stated pressure drop is 1.5" of H_2O. Hence

$$\Delta p / p = 1.5 / 407 = .00369 .$$

The test air cleaner element is round, 12 inches in diameter and 3.5 inches high. The flow area for paper and oiled felt is 104 sq. in. The flow area for the foam element is 132 sq. in.

Rearranging equation (1) to determine the discharge coefficient, we get:

$$Cd = \Delta p / p \times \left[\frac{Area \times 556}{SCFM} \right]^2$$

From this equation, the Cd for the air filter elements is calculated as:

Filter Type	Cd
Foam	140
Paper	47
Oiled Felt	16

This means that based on K&N data, paper is 3 times as restrictive as oiled felt and foam is 9 times as restrictive as oiled felt.

It should be noted that the discharge coefficient depends on a number of factors besides the class material, including filter design, number and depth of pleats, and composition of the material. A filter with more pleats or deeper pleats could have a lower discharge coefficient. Wix makes a NASCAR grade oiled felt air cleaner with less restriction (and less filtering) than the K&N element of the same size.

Using one discharge coefficient for each type of material is better than using one discharge coefficient for all types, but it is still an approximation. The discharge coefficients should only be taken as approximations only, not highly precise numbers. Since the pressure loss and the horsepower loss are directly related to the discharge coefficient, these results should only be taken as approximations as well.

The Second Strike Air Cleaner Calculator calculates the pressure drop and horsepower loss through the specified air filter element. Since the majority of the pressure drop and horsepower loss is in the filter element in a well designed air cleaner assembly, this is a reasonable approximation of the loss for the air cleaner assembly as well. However, it should be noted that some air cleaner housing designs are excellent and some are not so hot. Smooth large radius turns are good. Sharp corners are bad. Keep this in mind when choosing between two air cleaner assemblies.

Volumetric Efficiency

The airflow depends on the volumetric efficiency. Various Holley carburetor manuals suggest the volumetric efficiencies for various engine types shown in Table 2.

Engine Type	VE at Peak Torque	VE at Peak HP
Street Stock street engines.	0.75	0.70
High Performance Street Modified engine suitable for street driving. Upgraded heads, header, cam, intake, and carburetor. For 1970's vintage performance parts.	0.85	0.80
High Performance Street/Track Modified engine suitable for street and track driving. Upgraded heads, header, cam, intake, and carburetor. For modern performance parts.	0.90	0.85
Race Modified engine not suitable for street driving.	0.95	0.90
Ram Tuned Race Modified engine with intake and exhaust runner lengths ram tuned for peak power rpm.	1.00	0.95

Table 2: Assumed Volumetric Efficiency VE

The assumed volumetric efficiency curve is a second order polynomial through the specified points with the peak at the torque peak. The torque peak rpm is assumed to occur at 80% of the power peak rpm.

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This article was updated on February 20, 2006 to correct the height of the Ford oval air cleaner described in Case 12. It is 2.5” high, not 3.5” high.

This article was updated on November 16, 2007 to reflect a minor correction made to the volumetric efficiency calculation. The pressure losses and power losses in Typical Results were reduced about 12% as a result of this change.

This article was updated on January 23, 2012 to include the High Performance Street/Track classification and the Air Cleaner Shape Considerations section. The High Performance Street/Track classification is more representative of current modified engines and is used for all the examples.