What Is a Flowbench?

By Bobby Markiewicz

Building race engines at the entry level really isn't that difficult; with the right tools and knowledge, it's a piece of cake! Many manufacturers can help you get set up to blueprint a 4-cycle engine, but beyond the entry level, when trying to pull the last 5% of power from the engine, things become more difficult. Looking on the internet or in your favorite technical magazine you can find many engine building tips that can help you build power, but you won't find tips on pulling the last 5% in those sources. The last ounce of power that can be pulled from an engine is kept very close to the pros' chests.

What gives the pros the ability to find that last little bit of power? Years of experience, networks of engine builders, and the right development equipment and methods. The reason the hard to find horsepower is kept so quiet is because of the time and efforts the engine builders have invested into developing something that, once figured out, can probably be explained in five minutes. So it becomes easy to see why engine building is very much a black art.

In the past sophisticated testing equipment was something that could be afforded by very few outside of the top builders. With electronics coming down in cost and there being such a high demand for performance engine parts, things are slowly becoming more affordable. The two most important development tools for an engine builder are a dyno and a flowbench. With a dyno you can figure out what works and what doesn't work to make horsepower by trial and error. With a flowbench, you really don't know if what you have done has increased power until you run it at the track or on the dyno. Put both the flowbench and dyno together and you can easily find trends and have an efficient recipe for pulling power out of whatever engine you work on.

Superflow™ is the industrial standard in the performance industry when in comes to flow benches. This SF600 model is one of the more common benches for automotive use and though it will work for our smaller applications most would consider it an over kill. Picture courtesy of Superflow ™.

In the next couple of issues we are going to concentrate on what a flowbench is, how to build one, and how it can be used to develop power. This month we will talk about the different types of benches and how they are constructed. Next month we will use Performance Trends EZ Flow System to construct an affordable, professional level, electronic flowbench.

Let's first talk about what a flow bench is and what it is intended to accomplish. We have all heard of an engine referred to as an air pump, which in most respects is true. Although we don't spend thousands of dollars hopping up our air compressors to produce more air output, we probably could use many of the same methods as we do on our engines to increase its flow. This is because the engine's output is relative to the energy that we put into it. Because the ratio of fuel to air should always stay relatively stable, increasing the amount of air going into the engine also increases the amount of fuel going into the engine. The added fuel that mixes with the air has more energy potential and increases the power output that we see at the crank. It is easy to see that by increasing the breathing of an engine (air intake), we also increase the power.

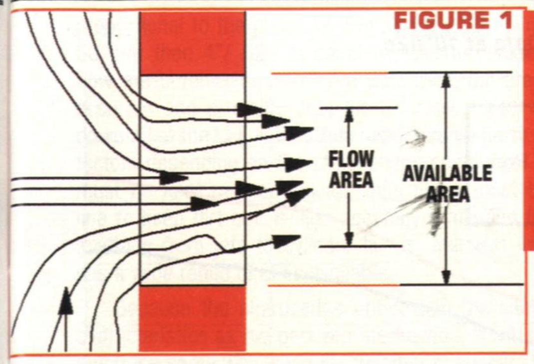
Things like velocity probes and other devices can be used with the bench. This means that not only can you measure the airflow inside the ports, but you can also start to understand it. When you start to understand and visualize airflow making power will become much easier to you. Picture courtesy of Superflow ™

Big cams, big carburetors, free flowing air cleaners, porting, and big valve heads are all examples of ways to increase the air intake of our engines. Though an engine is very dynamic in its running state, static testing of components to see how much volume flow they produce has been a means used to judge and increase horsepower output for over 50 years. Some things are easy to test to see how well they flow in comparison to other similar parts. An air cleaner, for example, can easily be tested to see if it flows better than the next by simply putting it on the flow bench and measuring its flow. A head, on the other hand, is more complicated because it needs to be flowed at various valve lifts in order to get the whole story. Regardless, any one component can be compared against similar parts to determine which one flows better, and in turn, should produce better power.

Smaller benches like this SF60 are designed specifically for what we do. It is more compact but will still give accurate results for most of your small engine flowing needs. Picture courtesy of Superflow ™

There are a couple different ways to flow components and measure the amount of air volume they can pass through them at a given pressure. This given pressure, normally called the test pressure, is a measure of the pressure used to flow the component. This test pressure should be kept consistent and recorded when flowing components. Let's say you put a carburetor on a flow bench and find 35 cfm of air flowing through it. This value, without knowing what pressure it was flowed at is just an irrelevant number. On the other hand, 35 cfm at 10"/H20 test pressure is a value that can be repeated and used for comparison by you and others. The 10"/ H20 means that the carburetor had 10" of water (see side bar) vacuum pulling air through it. If it was flowed at 20"/ H20 then it would have had twice the force pulling air through the carburetor naturally making the value go up. Figure 3 (page 28), may help you better understand what this test pressure is referencing and why it is important. Always make sure that when you are talking about flow related to engine parts that you reference the test pressure for the previous mentioned reasons.

FIGURE 1



The flow area of a sharp edge orifice is reduced because of the contraction of the air flow path around the sharp edge of the inlet. As you can see here with this generic illustration the available flow area is much smaller than the actual orifice size because of the separation the air experiences from the wall. This also makes it easy to see how even the slightest chamfering or rounding of the corner at the entry can change the available flow area, and improve the flow coefficient of the orifice, by getting the air to follow the wall closer.

Most heads are flowed at 10"or 28"/ H20. I think a lot of people flow heads at the 10"/ H20 because it is much easier to achieve than the high flow ranges. The bench's pressure source must be much stronger to achieve 28"/ H20 for a given valve lift. Back in the pioneering days Smokey Yunick found that 28"/ H20 was a good number for flowing heads. His findings showed that by flowing at values much less than this, slight changes in port designs weren't always noticed on the bench. Something to keep in the back of your mind is that 28"/ H20 is very close to 1 psi pressure, so it is not a lot, but it does result in very high volume flows of the test piece.

Now that we have established the test pressure, we must now have a way to measure what is flowing through the component. There are a couple different ways to do this, but most benches are designed off of the same principle. By measuring the pressure differential across an orifice of some type, flow can be calculated. Pressure differential is simply the difference in pressure from one side of our measuring device to the other. The simplest and most commonly used measuring device for benches is the sharp edge orifice. It is simply a skinny plate placed in line

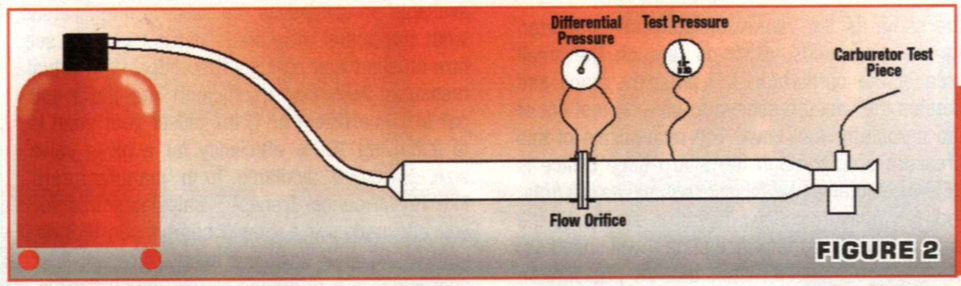


FIGURE 2

Flow benches can be as simple as a vacuum source, some tubing, a measurement orifice, some pressure gauges, and a test piece. By measuring the pressure drop across the measurement orifice we can compare flow between two test pieces and see which one is better. Remember, this is only true if the test pressure is kept the same between the two tests. Though this is very simplified, it is still the basis behind most flow benches.

with the flow with no chamfering or rounding of the hole, just a hole with sharp edges as machined.

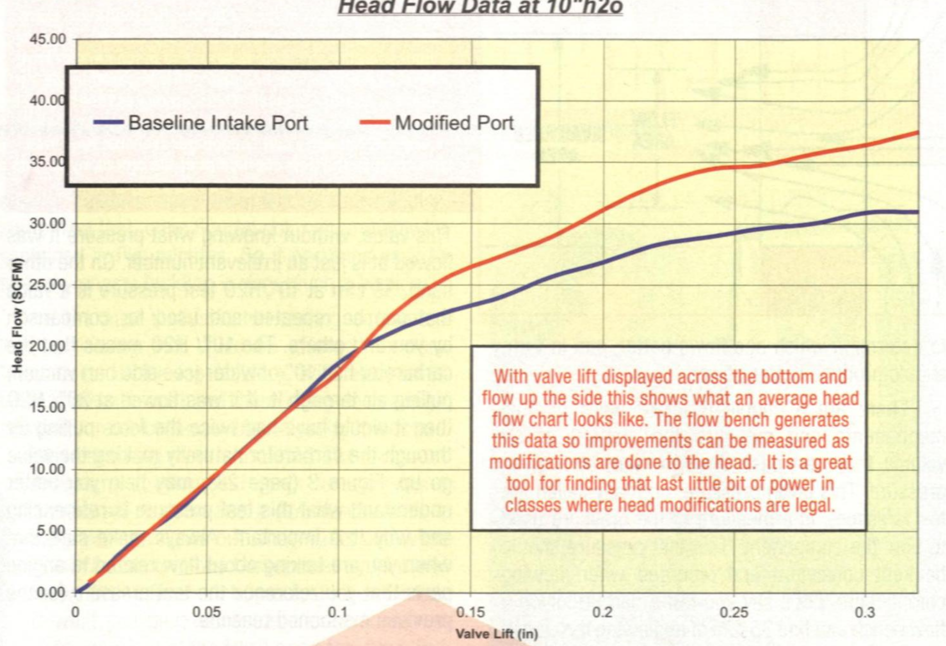
Figure 2 (page 27) shows how a simple set up would measure flow. The measuring orifice plate hole size must be sized for what it is you are measuring, but for the most part one size will flow a wide range of values. For instance, a one inch hole in a plate can be used to flow about 50 cfm at 10"/ H2O. This means that by having a vacuum source on one side of the system, an orifice plate in the middle, your desired component on the other side, and a way to measure the pressure differential and test pressure, you have created a flow bench. You may think that this is too simple, but actually, it is very similar to how most benches are designed. By adjusting your test pressure (vacuum if checking intake flow, pressure if working on exhaust flow) to your desired value, 10"/ H20 in this case, and then measuring the difference in pressure from one side of the orifice to the other, you can calculate the flow.

How does the orifice plate measure flow? It is relatively simple. Energy must be changed to get the air to flow through the orifice plate hole size you have selected. Air velocity is proportional to area which means that if you double the area of a pipe (not diameter) you have reduced the velocity in half. On the other hand, if you have reduced the size of the area that the air must flow through, you have increased the velocity. This increase in air speed is accompanied by a decrease in pressure because the kinetic energy increased causing the pressure energy to decrease. This is much the same as the venturi inside your carburetor. As the air speeds up to go through the small area of the carburetor, the pressure drops and creates the vacuum needed to pull the fuel out of the carburetor fuel bowl. The relationship of this pressure drop through the sharp edge orifice is VERY predictable and this is what makes it a great tool for measuring flow. To put it simply, as the air flows through the orifice plate it will speed up. This change is speed means that the pressure on one side of the plate is going to be different than the other because of this change in energy. By measuring this pressure difference we now also have a reference to flow.

Unfortunately the sharp edge orifice doesn't have a linear relationship of flow to pressure drop. The sharp edge orifice has a flow coefficient of about 61%. This means that for what could theoretically flow through a 1" hole at a given pressure drop, only 61% of it actually will. This has to do with the contraction of air as it enters the hole. See figure 1 (page 27) for a good visual explanation. Understanding flow coefficient isn't that important for the creation of the flow bench. However, this is a good example because it is also used in the development of heads. By knowing what should theoretically flow through the area available on a head as the valve is lifted versus what the actual measured flow is, you can see how efficient your port is. (Theoretical flow/actual measured flow=flow coefficient) The closer you get to a coefficient of 1, the closer your head is to achieving 100% efficiency for a given valve size. Software available from manufacturers like Performance Trends™ calculates this for you and makes it a simple comparison tool on your report after flowing a head. To recap, flow coefficient is a reference to how much flow is going though a given area compared to how much could theoretically flow through it. Fifty percent means that only half the air could make it through due to some type of restriction. In reference to the sharp edge orifice, 61% of what could flow through it does because of the contraction of air at the sharp entry.

There are flow-measuring devices that do have a linear pressure differential versus flow. The type most commonly used in what we do is called a laminar flow element (LFE). It works in the same manner as the sharp edge orifice where flow is calculated by measuring the pressure differential from one end to the other. The positive benefit with the LFE is that flow is

FIGURE 3



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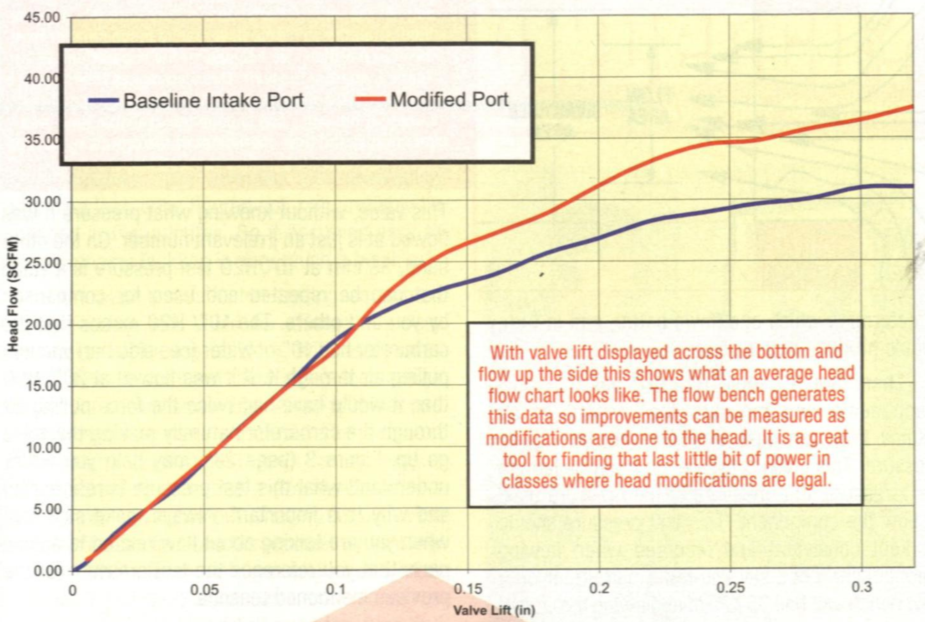

With valve lift displayed across the bottom and flow up the side this shows what an average head flow chart looks like. The flow bench generates this data so improvements can be measured as modifications are done to the head. It is a great tool for finding that last little bit of power in classes where head modifications are legal.

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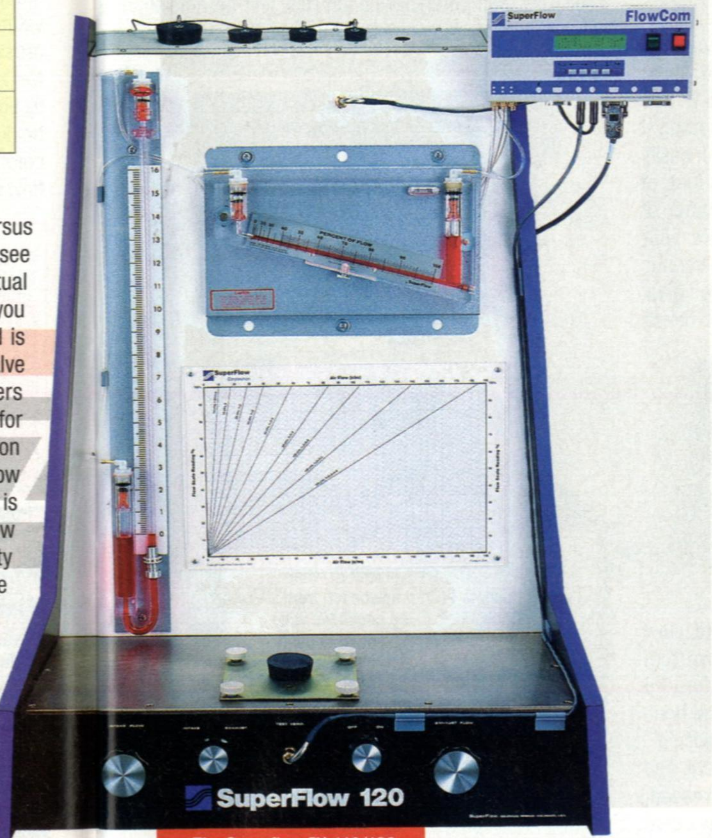
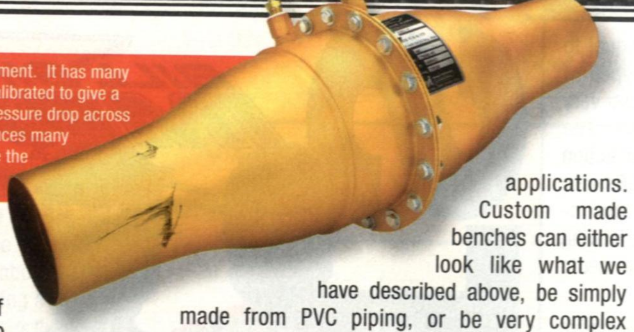
Because the sharp edge orifice has the same relative characteristics as the part you are flowing, it will respond in much the same way when the weather changes. This means that it doesn't require correction factors. Because we are measuring volume flow and not mass flow, the results at the different conditions should prove to be the same. Superflow™, the authority in flowbenches and probably the closest thing the engine industry has as an industrial standard, has found this theory to be true and doesn't recommend correction factors for most orifice-based benches. The exception would be if the measuring orifice were in an area that ran at a different temperature than the measured piece, at which case the bench should have temperature correction added to it.



The Superflow ™ 110/120 benches are sized physically smaller than the full size stand alone bench but are still capable of flowing automotive heads along with any of your small engine needs. As flow benches increase in size, so do their flow capabilities and their price. Superflow™ benches displayed here range from about $2500 to $11,000 depending on the size and options. Picture courtesy of Superflow ™

The vacuum source for the bench is normally the more expensive part of the bench. To get high flow, multi-stage vacuum motors or high-pressure blowers are needed. They can get very pricey depending on what is needed to achieve the flow level desired. Obviously, a car head flowing 300 cfm is going to require a higher power source than flowing



This is an example of an Laminar Flow Element. It has many small tubes running through it that are calibrated to give a linear relationship between air flow and pressure drop across the devise. Merriam™ instrument produces many different sizes for applications that require the highest measurement accuracy.

50 cfm through a small engine head. The benefit of having too much blower is that you can test at any pressure desired, where if the blower is undersized 10"/ H20 may be as much as you can get at high flow numbers. Some big shop benches use roots style car blowers (6-71) powered by electric motors to get the desired flow. Next month, when we do our build up we will use a simple shopvac as our pressure source. It may seem unprofessional, but it has the advantages of being relatively powerful, bi-directional (can do intake and exhaust), and inexpensive, not to mention readily available! If the bench is built in a upgradeable manner, then the pressure source can always be upgraded to fit your growing needs, with very little changes to the bench itself.

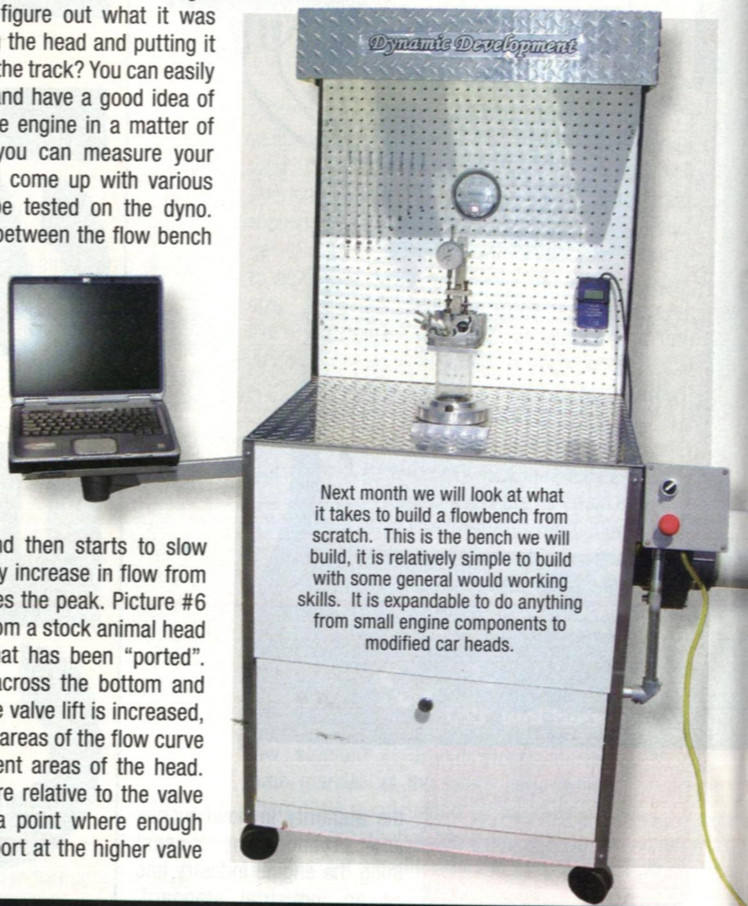
What does a flowbench look like? There are many different benches around, but the most common benches are the Superflow™ benches in their distinguished blue color. Their SF60 is small enough to take to the track in a trailer, while their SF1010 is big enough to take up a good portion of your shop. The SF60 is designed for what we do; and as many will tell you, works very well. The bigger benches are more designed for automotive applications but will also work for most karting applications. Custom made benches can either look like what we have described above, be simply made from PVC piping, or be very complex expensive benches made for doing particular tasks.

Now the important part, what good is it to the engine builder? How about knowing what air filter flows the best without having to go though extensive power testing? Or, which out of your six Animal carburetors flows that couple tenths more cfm? Most importantly, it is a head porter's number one tool. How else can you do slight changes to a head and figure out what it was worth without assembling the head and putting it on the dyno or taking it to the track? You can easily make a change, flow it, and have a good idea of how it will respond on the engine in a matter of minutes. Good or bad, you can measure your changes to the head and come up with various versions that can then be tested on the dyno. Over time, a relationship between the flow bench and the dyno can be established so you can accurately predict power improvements from flow improvements.

A head is flowed at various valve lifts to produce a curve that looks a lot like a power output curve. The flow goes up relatively fast and then starts to slow down and doesn't have any increase in flow from the valve lift once it reaches the peak. Picture #6 shows how a flow curve from a stock animal head looks compared to one that has been "ported". The graph has valve lift across the bottom and flow up the left side. As the valve lift is increased, the flow goes up. Different areas of the flow curve are more related to different areas of the head. Low to mid lift flow is more relative to the valve and seat geometry, until a point where enough flow is going through the port at the higher valve lifts to cause the port itself to become restrictive. As you can see, by flowing the head through the entire lift curve, or at very minimum to maximum valve lift of your particular cam, you can see how different areas of the head can respond to changes made to it.

Things like air cleaners, exhausts, and carburetors all normally only require one flow point. Just make sure to always use the same test pressure when you measure them. This will ensure that they can be compared against each other, whether it is done today or next year.

In the near future we will look at using Performance Trends™ EZ Flow system to create a flow bench from scratch. Though it may not be as refined as a Superflow bench but it will be a legit, full size, computerized bench that will be able to generate the data needed to make horsepower. Stay tuned. NKN



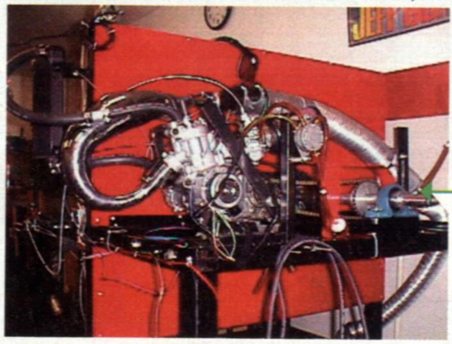
Next month we will look at what it takes to build a flowbench from scratch. This is the bench we will build, it is relatively simple to build with some general would working skills. It is expandable to do anything from small engine components to modified car heads.

TOOL OF THE MONTH

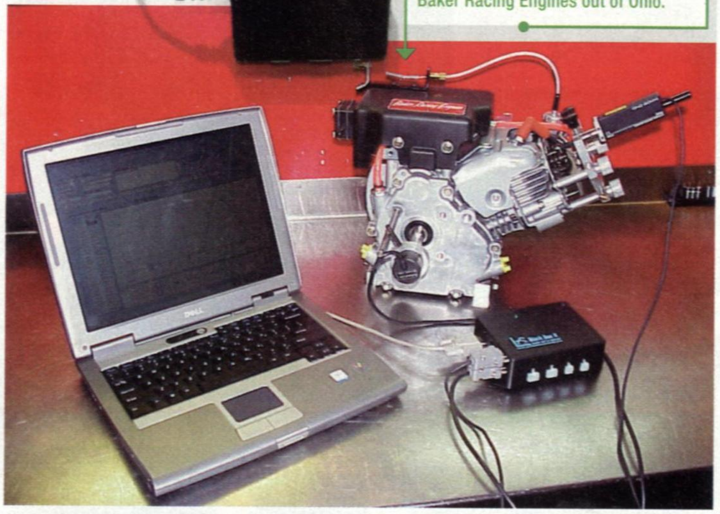
By Bob Markiewicz

Performance Trends™ Black Box

These days advancements in electronic technologies are growing at an exponential rate and we find ourselves in a "keep up or fall behind" society. Racing is no different. Striving to be the best means taking advantage of all of the technologies available so we can maximize our competitive edge. Electronics have helped to advance karting and in modern era of computer and video games, I bet that many younger racers are just as drawn to the cool data acquisitions mounted onto the steering wheel as they are to what engine type they are running. Part of the fun in karting is the fact that while our vehicles are smaller and cheaper than full-size cars, many of the same technologies exist. Unfortunately, it seems that we don't always take advantage of all of the technologies available to us. Some companies are in existence just to help make the engine builders' and racers' job easier. It is up to us to use the equipment to its full potential to become faster at the track or make more power on the dyno. It seems that if we don't keep up with what is available today, we will just be further behind on what is available to us tomorrow.



The most common application for the Black Box is the dyno configuration. The Black Box records the amount of time it takes to accelerate a flywheel with a known inertia and then uses simple physics to accurately calculate the HP output from the test engine. It is about as cheap and accurate as a functional dyno can get.



Profiling cams isn't a fun job by any means. The Black Box may not make it your favorite job in the shop but it can make it more enjoyable. With an encoder connected to the crank and an indicator measuring the cam lift at either the valve or tappet and then by rotating the crank a profile is generated for analysis in a matter of seconds. This set-up was courtesy of Baker Racing Engines out of Ohio.

Performance Trends™ is a company that is committed to bringing the latest software and hardware technologies specifically to the racer to help advance racing at an affordable level. Although engine analysis software programs have been available for a long time, accurate and affordable options were far from the reach of the average kart racer. Performance Trends ™ engine analysis software and electronics have changed this by giving engine builders and racers options that only the "big boys" could play with in the past.

A good example of this is their Black Box, which is a data acquisition system that is used for various types of engine development. It can be set up for dyno, flow, and cam measurement. In its dyno configuration, which is probably the most widely used dyno hardware and software in the industry, it brings accuracy and affordability to the average kart shop. Most of the builders I know utilize Performance Trends™ dyno system and are very happy with it. It uses a rotating wheel of a known inertia connected to the engine to measure horsepower. By knowing the inertia of the wheel and the amount of time it takes to accelerate it to a given engine speed, simple physics allow horsepower to be calculated. The data that the Black Box records while doing a dyno pull is then sent to a computer and their software configures it for easy analysis. This means that by having a relatively simple dyno stand with a known rotating mass for the engine to spin and Performance Trends™ Black Box you have just created an "inertia" dyno that is a great development tool. By adding different channels to the Black Box you can easily measure temperatures, A/F ratios, pressures, and other information you might feel is important. This not only allows you to look at horsepower results, but also see where your horsepower is coming from. The dyno can also be instrumented with a weather station that can take into account the current conditions and correct for them. An inertia dyno is not a new concept, but putting the electronics and comprehensive software together at an affordable price makes it now easily accessible.

Performance Trends™ has made their Black Box so it can be configured in different ways from the factory to fit specific jobs. Another great function of the black box is the cam measurement feature. By using an encoder that measures up to 10,000 pulses per revolution connected to the crank along with an electronic indicator to measure the valve or cam displacement to .00004 inches, the Black Box can accurately profile a camshaft. By simply turning the engine over by hand with these two things installed, you can generate the data for their Cam Analyzer software. This software allows you to look at and compare cam profiles in not only the normal way of lift vs. degrees, but also things like acceleration, velocity, jerk and area. Reports can be generated in both numerical and graphical form and be custom tailored to your liking. This allows you to create printouts for development or customers to show just what is important in an easy to read format. They even have a feature that generates cam cards. Anybody who has had to profile a camshaft by hand can understand the importance of this tool. Instead of turning the cam a couple degrees at a time and manually entering the valve lift data, with a couple minutes of set up and about 15 seconds to rotate the engine over, more accurate data is efficiently created. You can then decide what type of data you want to analyze from the information gathered. The data is also put into a comprehensive database so it can be easily retrieved and used for comparisons at a later date.

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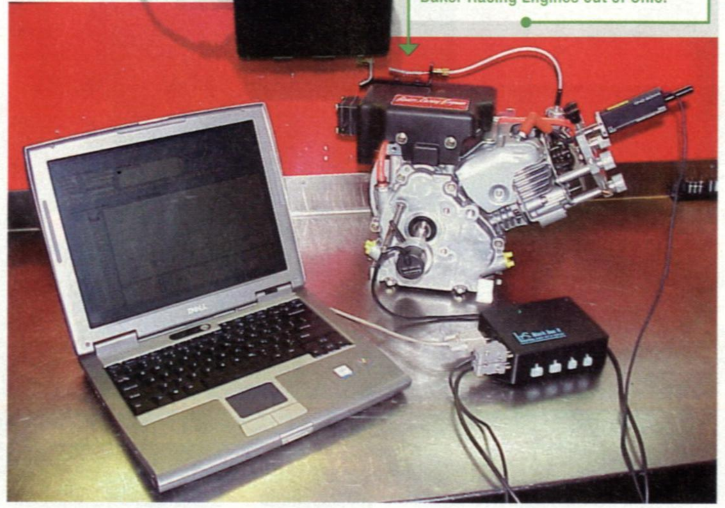

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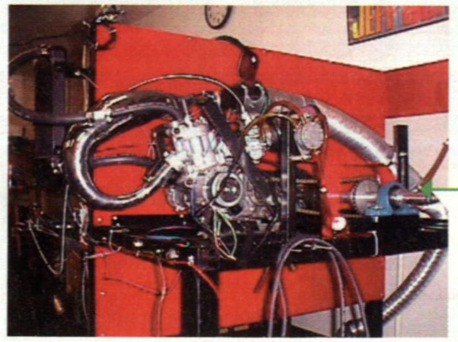

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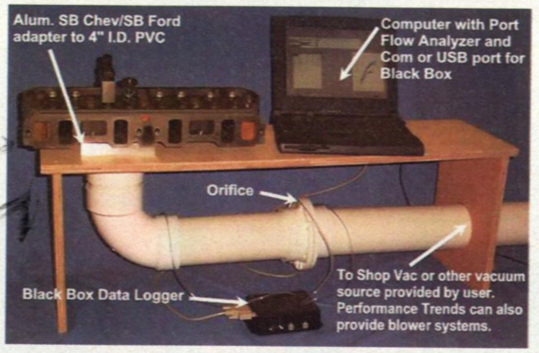
Performance Trends™ is a company that is committed to bringing the latest software and hardware technologies specifically to the racer to help advance racing at an affordable level. Although engine analysis software programs have been available for a long time, accurate and affordable options were far from the reach of the average kart racer. Performance Trends ™ engine analysis software and electronics have changed this by giving engine builders and racers options that only the "big boys" could play with in the past.

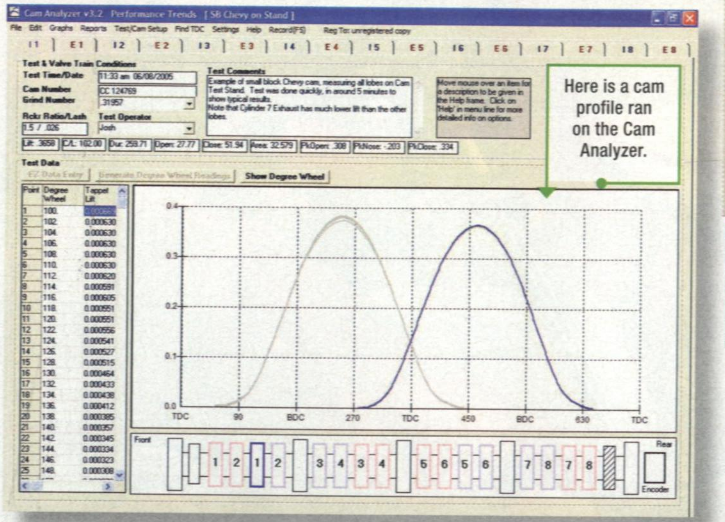
A good example of this is their Black Box, which is a data acquisition system that is used for various types of engine development. It can be set up for dyno, flow, and cam measurement. In its dyno configuration, which is probably the most widely used dyno hardware and software in the industry, it brings accuracy and affordability to the average kart shop. Most of the builders I know utilize Performance Trends™ dyno system and are very happy with it. It uses a rotating wheel of a known inertia connected to the engine to measure horsepower. By knowing the inertia of the wheel and the amount of time it takes to accelerate it to a given engine speed, simple physics allow horsepower to be calculated. The data that the Black Box records while doing a dyno pull is then sent to a computer and their software configures it for easy analysis. This means that by having a relatively simple dyno stand with a known rotating mass for the engine to spin and Performance Trends™ Black Box you have just created an "inertia" dyno that is a great development tool. By adding different channels to the Black Box you can easily measure temperatures, A/F ratios, pressures, and other information you might feel is important. This not only allows you to look at horsepower results, but also see where your horsepower is coming from. The dyno can also be instrumented with a weather station that can take into account the current conditions and correct for them. An inertia dyno is not a new concept, but putting the electronics and comprehensive software together at an affordable price makes it now easily accessible.

Performance Trends™ has made their Black Box so it can be configured in different ways from the factory to fit specific jobs. Another great function of the black box is the cam measurement feature. By using an encoder that measures up to 10,000 pulses per revolution connected to the crank along with an electronic indicator to measure the valve or cam displacement to .00004 inches, the Black Box can accurately profile a camshaft. By simply turning the engine over by hand with these two things installed, you can generate the data for their Cam Analyzer software. This software allows you to look at and compare cam profiles in not only the normal way of lift vs. degrees, but also things like acceleration, velocity, jerk and area. Reports can be generated in both numerical and graphical form and be custom tailored to your liking. This allows you to create printouts for development or customers to show just what is important in an easy to read format. They even have a feature that generates cam cards. Anybody who has had to profile a camshaft by hand can understand the importance of this tool. Instead of turning the cam a couple degrees at a time and manually entering the valve lift data, with a couple minutes of set up and about 15 seconds to rotate the engine over, more accurate data is efficiently created. You can then decide what type of data you want to analyze from the information gathered. The data is also put into a comprehensive database so it can be easily retrieved and used for comparisons at a later date.

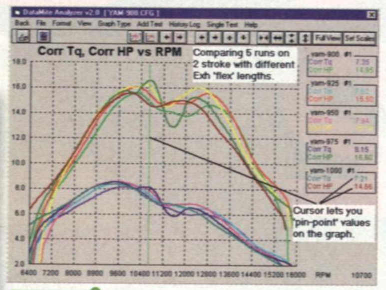


This picture courtesy of Performance Trends™ is an example of a flow bench that is easily constructed from PVC. Simple yet effective at measuring head flow.

One of my favorite tools that Performance Trends™ offers is their flow bench support equipment. The black box can be configured to work as a foundation for a stand alone flow bench or be integrated into most existing benches. Flowing heads is much like measuring cams; though the data is great fun to analyze, getting the data is not nearly as exciting as say a dyno pull. Because analyzing and comparing data is the fun part, the faster and easier the data can be generated, the better. When the Black Box is configured to measure flow, it is fitted with transducers that replace the normal water filled manometers commonly used on the flow benches. By fitting the Black Box with transducers it can measure flow and once again communicate the data to a software program for comparisons. Flowing heads can be taken to the next level, with things like port velocity mapping and their swirl meter attachment, which are all read by the black box and analyzed by the Port Flow Analyzer program. The program is so powerful it can even take things like cam data into consideration and show you your flow area and flow potential relative to the cam you are running. Things like flow coefficients, mass flow, swirl, tumble, velocities, stability, intake to exhaust percentages and others can all be compared with the Port Flow Analyzer program. The best part about the Black Box flow feature is that the bench to generate all this data can be home built as we will show you in the upcoming months.



Here is a cam profile ran on the Cam Analyzer.



This chart shows the graphical print out of the Performance Trend ™ dyno software. The data is put into a format where it can be compared against other tests for easy analysis.

A good feature about Performance Trends™ programs is that most of them use a similar format, so once you have mastered one you can very easily learn the others. Check out www. performancetrends.com for more information on what they offer. As you start to search their site you will start to realize how the different aspects of what they offer work together to create a complete technology based package. Their Engine Analysis software can take data from their flow and cam measurement tools which ultimately can be tested on their dyno system. Their little electronic Black Box allows us to use today's technologies to generate the data needed to look at with comprehensive software packages. The days of having to be an electronics guru to design and utilize electronic engine development tools are over. Performance Trends ™ is an example of a company who has done the hard part so you can concentrate on what's important, making horsepower and winning races. NKN