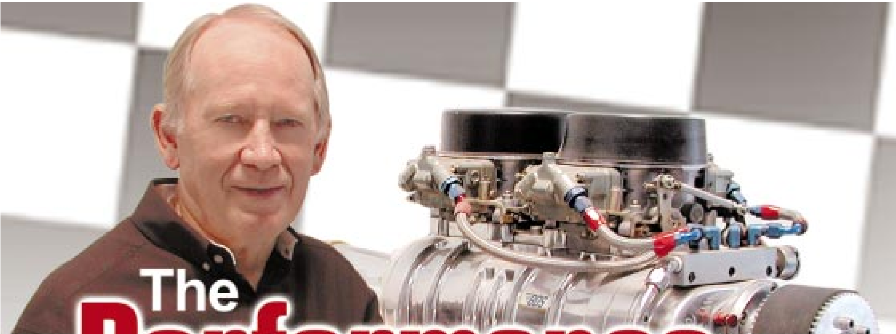

The Performance Professor

Jim McFarland

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The Manifold Parts of Automotive Induction Systems

Introduction

By one simplified definition, a typical automotive "induction system" is a network of passages connecting an engine's cylinders with a source of inlet air, attached to which is a metering device that regulates air or air/fuel mixtures. Such systems may include fuel injectors located downstream of the air inlet point or accommodate either carburetors or throttle body injection (TBI) units at a point servicing all passages to the engine's cylinders.

That's a functional definition. In a dynamic sense, an induction system includes a range of pressure conditions that can help an engine achieve torque (or volumetric efficiency) increases beyond that obtainable without the benefit of induction system "tuning." Several of these possibilities will be presented in the following discussion.

We'll wade through the "basics" section first, identifying fundamental components of an intake manifold, types of manifolds, the concept of cylinder-to-cylinder air (or air/fuel mixture) distribution, manifold "tuning" (in principle), carburetor systems, multiple carburetion and the benefits of throttle body and direct port fuel injection or multi-point FI. In the "advanced" segment, we'll get more into the essentials of manifold tuning, how volumetric efficiency (and torque) are influenced by manifold design, design components of intake manifolds, mixture motion (in the combustion space) as influenced by intake manifolds, the "reversion" phenomenon, and the concept of "variable" intake manifolds. Buckle up.

> An intake manifold plays a vital role in how each of an engine's cylinders receives air or air/fuel mixtures. Whether the design joins all cylinders to a common plenum (single plane) or divides cylinders in some fashion, there is a measure of "cross talk" that exists among connected cylinders, during a variety of engine operating conditions.

Basic Information

Fundamental components of an intake manifold

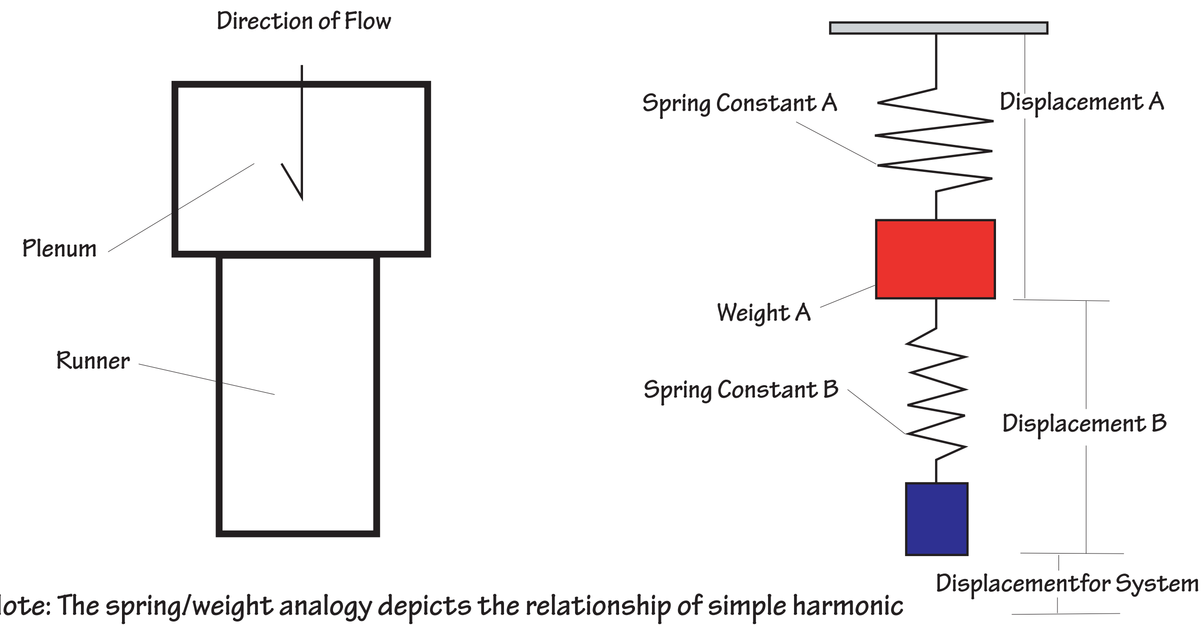
Since an intake manifold is a network of passages connecting a throttling device (air valve, throttle body or carburetor), you can view such passages as extensions of the inlet ports. In fact, that is exactly how they should be considered. If they are not, it's possible for each to become in conflict with the other, causing improper air (or air/fuel mixture) flow quantity and quality.

Generally, at or near the inlet manifold's point of air entry, there is a throttling device. These are located where the passages of the manifold (inlet port "extensions") meet in a common volume. That volume is often called a "plenum" and represents a region from which all manifold runners extend. Analogous to an exhaust system in which all tubes become joined in a single volume (collector), the plenum of an intake manifold is comparable to a header collector.

Types of Inlet Manifolds

If all of an engine's inlet ports are connected to a single plenum volume (chamber), the design is said to be a "single plane" arrangement. That means a single cavity is used to connect all inlet port passages (runners). If some of the runners connect to a cavity different from a second cavity connected to the remaining set of runners, the design may be called a "two plane" or "dual plane" design. Depending upon basic engine design (in-line, V-type, etc.), it's possible to connect cylin-

Schematic Illustration of Intake Manifold Plenum/Runner Arrangement and Spring/Weight Analogy Pertaining to Manifold Tuning and Resonance



Note: The spring/weight analogy depicts the relationship of simple harmonic motion resonant frequency patterns and how they compare to pressure excursions in an intake manifold arrangement of plenum and chamber. The plenum and runner(s) can exhibit individual resonance patterns but at some point will combine to form additive energy in aiding net volumetric efficiency. Specific wave motion in an intake manifold is not exactly displayed here, but the relationship of additive energy input to the system still holds.

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ders that alternate in the firing order. A typical instance is a V8 engine in which each successive cylinder is served by alternating intake manifold planes.

Here's an example. Suppose the firing order is 1-8-4-3-6-5-7-2. In this case, one plane of the manifold would be connected to (serve) cylinders 1, 4, 6 and 7 while the other would serve cylinders 8, 3, 5 and 2. In terms of crankshaft rotation and inlet impulses, successive cylinders would be provided mixtures every 180 degrees of rotation. This is the commonly known 180-degree manifold. A similar arrangement can be configured for other firing order and cylinder layouts.

Should the manifold design not include a plenum but provide singular paths into each inlet port, the type is called an "independent runner" or IR design.

This is a typical method for fuel injected engines intended for mid- to high-rpm use, such as narrow engine speed ranges associated with sprint car or high-speed-only applications. The ability to transition from low- to mid-rpm engine operation is foregone to benefit higher rpm and sustained speeds.

Cylinder-to-cylinder air (or air/fuel mixture) distribution

This is an important issue, as underscored in the interview with GM's Ken Sperry following the end of this lecture.

Today, bolstered by the rapidly emerging technology of Engine Cycle Analysis or ECA (to be discussed at length in a future n2performance.com lecture), the ability to examine and tune an engine "one cylinder at a time" is prevalent among many leading motorsports teams…including professional drag racing and NASCAR Winston Cup.

An intake manifold plays a vital role in how each of an engine's cylinders receives air or air/fuel mixtures. Whether the design joins all cylinders to a common plenum (single plane) or divides cylinders in some fashion, there is a measure of "cross talk" that exists among connected cylinders, during a variety of engine operating conditions.

Here's how that works. When an intake valve opens, there is a brief period of time when cylinder pressure is higher than pressure in the intake manifold. This causes an amount of combustion residue (exhaust gas) to be passed back into the manifold. Call it "reversion," "back flow" or by some other term, this reverse pressure "pulse" can affect primary inlet flow for another connected cylinder.

Depending upon engine speed, load and related factors, this reverse flow of exhaust gas can adversely affect other cylinders during their normal intake cycle. As a result, air/fuel ratios present in any given cylinder at any given time of engine operation can be a combination of fresh air/fuel mixtures or exhaust gas from a companion cylinder, connected via the intake manifold. Net cylinder-to-cylinder mixture distribution, as a result, can be affected by reversion and needs to be considered in the manifold's basic design.

The design or selection of an intake manifold, regardless of how fuel is introduced into the inlet path (carburetor, throttle body injection or multi-point fuel injection), should take into account the ability to treat each cylinder as an engine unto itself. More of this concept will be discussed in the future lecture on ECA, as promised. Optimizing individual cylinder spark timing will be included as a topic.

Inlet manifold "tuning" (in principle)

As a rule, every physical system has one or more "natural vibration" frequencies that are characteristic of the system and governed by the system. That's a technical definition of "resonance."

In practice, we could say the resonant frequency of a system is characterized by a maximum condition produced from a "normal" input. An organ pipe is a common example of how a resonant condition is displayed. Based upon the physical dimensions of an organ pipe, a flow of inlet air may produce a resonant tone or pitch. Changing the pipe's dimension, given the same amount of input air, could produce another resonant point or tone.

With regard to an engine's intake (or exhaust) system, it is possible to dimension a passage to accommodate specific cylinder displacements and engine speed so that a "resonant" condition helps produce an increase in total air flow (intake or exhaust). In it's simplest form, this amounts to "tuning" an inlet (or exhaust) passage. Physical dimensions of the passage are constructed to provide a resonant tuning point (particularly relative to rpm and valve timing) at which a "boost" in flow is produced. This results in an increase in cylinder filling (volumetric efficiency) and potential gains in torque.

Carburetor Systems

At best, carburetors are an economically driven compromise between efficient air/fuel mixture preparation/delivery and cost-to-manufacture. Utilizing a stream of essentially liquid fuel, forced into an air stream by atmospheric pressure acting on a lower inlet manifold pressure, carburetors do a poor job of atomizing fuel. Droplet sizes vary, sometimes extensively. Since droplet size relates to effective air/fuel ratios (large drops require more time to burn than smaller ones), the ability to approach uniform mixture ratios is difficult at best. Optimizing ignition spark timing for a "range" of air/fuel ratios is a compromise, resulting in less than maximum power and fuel efficiency. Exhaust emissions also tend to increase.

At the outset, designing or selecting an intake manifold with acceptable air distribution among cylinders is handicapped by the use of a poor "mixing valve."

It is still important to use a properly designed intake manifold and one specific to the intended application; else the problem of cylinder-to-cylinder mixture delivery will be compounded.

Use of multiple carburetors, aside from possible esthetic value and for outright racing applications, is generally an attempt to simply increase carburetor throat area exposed to the engine at wide open throttle. Most multiple-carburetor manifolds, especially those of decades ago when this practice was popular, did not contemplate specifically improved airflow. As such, they became "mounting pads" that facilitated the use of more than one carburetor.

Among the "tools" used in designing (or modifying) a carburetor intake manifold, the avoidance of sharp corners and edges is critical…as emphasized in the interview with Ken Sperry. These are areas where air tends to "turbulate" or form eddies, causing unsatisfactory air quality and potentially separated air/fuel mixtures. At best, mixture ratio range can be upset, leading to inordinately lean or rich mixtures in the combustion space.

Ideally, air and fuel should be homogenized from the time fuel enters the air stream, continuously blended into the engine's cylinders. But if fuel enters the air stream well ahead of the cylinders and is required to follow "disturbed" air along this path, chances are better than good mixture quality will be upset before it is subjected to combustion.

Throttle Body Fuel Injection (TBI)

If a conventional carburetor is believed to be an inefficient fuel-atomizing device, a throttle body injector is an attempt to improve upon this deficiency. Using a form of fuel injector, one or more device is placed in the equivalent of a conventional throttle body (a housing containing one more throttle blades, frequently fitted with various pressure or throttle position sensors).

Typically, nozzles are positioned above the throttle blades, pointed to provide atomized fuel into the air stream entering the intake manifold. Based upon a variety of sensed variables (engine speed, manifold pressure, etc.), an injector "on time" is determined by an on-board computer (electronic control unit or ECU). The length of time an injector is open ("on") equates to a pulse-width of control signal, thereby determining how much fuel is delivered to the engine.

Downstream, inside the intake manifold, an improperly designed plenum or runners can cause well-atomized fuel to re-collect or become dissimilar to the air/fuel ratios provided by the TBI unit. Therefore, TBI intake manifold design (or modification) should include consideration for an ability to properly transmit mixtures to the cylinders. Even though TBI units improve initial fuel atomization, downstream handling of mixtures is still critical to net combustion efficiency.

Multi-point Fuel Injection

As a rule, the further downstream in the inlet path fuel is introduced, the less chance of improper mixture delivery. While studies have shown a significant percentage of fuel is "atomized" in the combustion space after the inlet valve is closed, providing well-atomized fuel in advance of this event is beneficial.

The placement of a fuel injector in each manifold runner, near the inlet port, constitutes a multi-point system. While this method is superior to a TBI system, injector positioning or "targeting" (relative to the intake valve and cylinder bore) is critical to an efficient MPFI system. For example, there is evidence the current Chevrolet LS1 engine was primarily designed (from a power function standpoint) around specific injector targeting. Inlet ports and intake manifold were designed accordingly.

With recent and on-going advances in automotive micro-processors, the ability to sense and control specific engine operating parameters has made MPFI even more efficient. Driven somewhat by Federal exhaust emissions tandards, Corporate Average Fuel Economy (CAFÉ) requirements, and declining pump fuel quality, the domestic OEM have sought improved technology to update engine management controls and power levels. Multi-point Fuel Injection has become a cornerstone in that evolution. It also provides an opportunity to begin treating a multi-cylinder engine as a set of single-cylinder engines, optimizing power for each cylinder and netting higher overall power and efficiency. We'll discuss more of this subject in the Advanced Information section.

Advanced Information

Essentials of inlet manifold tuning

There is more than one school of thought on this subject. Two appear prevalent today. One holds that a plenum-runner manifold combines the effects of a quarter-wave organ pipe and a Helmholtz resonator and that each can operate either independently or in conjunction as a "system." The other contemplates so-called "wave motion" within the manifold, varying as a function of rpm, piston displacement and a host of related variables.

Helmholtz/quarter-wave organ pipe theory

In an ASME (American Society of Mechanical Engineers) paper published in the early 1970s, Peter C. Vorum revealed his Masters Thesis work combining the earlier resonant tuning characteristics found in electrical circuits with their acoustical counterparts in the internal combustion engine. Pete's formulas provided a mathematical means for configuring single and multiple degrees of freedom intake and exhaust systems, later incorporated in selected OEM manifold designs. His work has formed the basis for continued development of his "Short Pipe Tuning" methods.

Essentially, the Vorum method suggests the use of a quarter-wave organ pipe analogy for the plenum-runner (inlet port) portion of an intake system as a "fixed" set of computed dimensions that include the variables mechanical compression ratio, valve timing, rpm and piston displacement… among others.

Then he added the effects of cylinder volume, as it changes with piston movement (see accompanying illustration). Both the quarter-wave pipe and Helmholtz effects of piston motion can be used to "tune" the intake path, producing a desired 240-260 ft/sec mean flow velocity in the path at specific rpm associated with peak torque (volumetric efficiency).

Since the Helmholtz and quarter-wave effects can be isolated, one from the other, "single-" and "multiple-degree of freedom" systems can be designed. When combined, each can resonate at a different frequency but at some point, become mutually resonant and additive to the overall cylinder filling process (see accompanying illustration). While it is beyond the scope of this particular discussion to include finite details of the Vorum method, reference to ASME papers produced in the 1970s regarding "Short Pipe Intake Tuning" (by Peter C. Vorum) will provide additional explanation.

From a practical standpoint, this approach enables an engine builder or enthusiast to modify, evaluate or design an intake manifold targeted specifically to a piston displacement and rpm (or range) in which maximum torque is desired. Here's how that works.

Let's assume a piston displacement of 400 cu.in. That computes to an individual cylinder volume of 50 cu.in. Recognizing that an engine's intake and exhaust system can contribute separately to "net" torque, it follows that each system can produce its own torque peak. An intake manifold's path can be either tapered or of constant cross section area. If it is tapered, for purposes of the math involved, an "average" area can be computed by combining the inlet and outlet areas, into a single cross section value. If the runner is not tapered, the area chosen is the same throughout.

Vorum's method is actually rather complex and involves multiple variables, but a shortened version can lead to meaningful results, at least from the standpoints of the persons previously mentioned (builder, enthusiast, etc.). It goes as follows:

Cross section area = (cylinder volume x peak torque rpm)/88200.

By algebraic manipulation of these three variables, we can solve for any one if we know (or assume values for) the other two. For example, if we have an intake runner of known cross section area and want to determine the rpm at which a torque (volumetric efficiency) peak will occur, the equation becomes:

Peak torque rpm = (cross section area x 88200)/cylinder volume.

Correspondingly, if we'd like to determine a piston displacement for which an existing manifold exists (we already have an intake manifold we'd like to use), the equation can be transposed into,

Cylinder volume = (cross section area x 88200)/peak torque rpm.

In this latter case, if it turns out that the manifold in hand produces a torque peak on an engine larger than the one contemplated, the engine is said to be over-ported. If the engine size computed is smaller than the one on which we'd like to use the manifold, it could be considered under-ported.

Regardless of how this little equation is used, it's ability to "ballpark" basic dimensions of an intake manifold (and inlet port) is remarkable and a useful tool for basic manifold dimensioning where absolute refinement is not required.

Wave Motion Theory

The essence of this approach to intake manifold design or modification involves two fundamental types of pressure waves; compression and expansion. If we assume that any given passage contains a form of "gas particles," then this is the medium through which both compression and expansion waves travel. By assigning some "ambient" (existing) pressure level in a passage, compression waves are those moving at a higher-pressure value while expansion waves travel at a lower value.

Visualize a stream of water (a creek) passing from left to right. A stone is thrown into the stream. Waves traveling to the right at a rate greater than the stream's velocity are analogous to compression waves. Those traveling to the left and at a lower rate than stream velocity could be called expansion waves (also known as "suction" or "rarefaction" waves).

Due to pressure conditions created at each end of an engine's inlet path, both compression and expansion waves are developed. By proper dimensioning of the inlet path, it's possible to "time" these waves to be additive to net flow, at some specific engine speed. Precise computation of this information involves several variables, including valve timing, mechanical compression ratio, cylinder volume, gas temperatures, spark timing and rpm.

While prior art suggests this method falls short of accurate predictability for intake (or exhaust) path computations, there are current PC-based methods that yield more precise information. One of these is a software package from VP Engineering , available online at www.dynomation.com). Originally designed as a single-cylinder flow/tuning analysis tool, Dynomation is a powerful step in the direction of evaluating in-cylinder pressure conditions in a dynamic fashion quite similar to live Engine Cycle Analysis (ECA) methods. (ECA measures in-cylinder pressure as a function of crankshaft angle.)

Currently as a DOS program, a Windows version will be available this year. N2performance.com highly recommends this approach to intake (and exhaust) pressure analysis in the building, selection or modification of induction systems…for virtually any engine application.

Intake manifolds & Volumetric efficiency

In combination with cylinder head intake ports, inlet manifold runners comprise the total inlet path. If intake flow velocity patterns are a function of runner/port cross section area, then it is possible to configure them to optimize cylinder filling.

By one definition, volumetric efficiency is a quantitative comparison (typically expressed as a percentage) of physical cylinder volume to the volume of air entering the cylinder at any given rpm. For example, if an engine has a volumetric efficiency of 85% at 5000 rpm, it is said to be filling this portion of its volume at the indicated engine speed. With proper tuning, an intake manifold (certainly in conjunction with appropriate valve timing) can assist an engine in gaining v.e. levels well in excess of 100%, particularly at or near peak torque…, which also equates approximately to peak volumetric efficiency.

Tuning methods, sometimes termed "ramming," have been employed for many years in both stock and racing engines. Often characterized by long intake manifold runners, contemporary tuning techniques that embody multiple degrees of freedom (multiple torque or v.e. boosts) are allowing the design of manifolds that effectively broaden and flatten torque output curves. This is particularly valuable in small displacement engines where low- and mid-rpm torque is not a function of engine size. Even in artificially aspirated engines utilizing both turbo and traditional methods, intake manifold tuning can be successfully employed for additional gains in v.e.

"Mixture motion" and the intake manifold

The delivery of air or air/fuel mixtures can be significantly influenced by intake manifold design. Dating from the time of Sir Harry Ricardo and his highly advanced-for-the-times concepts of combustion techniques and explanations for such, mixture motion continues today in stock, modified and outright racing engines.

Movement of air/fuel charges in the combustion space following intake valve closing are particularly influenced by inlet path geometry, which, of course, include the intake manifold. Whether fuel is admitted by injector or carburetor, the ability to establish and maintain its suspension with air is critical to efficient combustion. It is important that the inlet manifold's runners and inlet ports be configured as extensions, one to the other.

Depending upon intake and exhaust valve location, (relative the cylinder bore), fuel injector targeting, type of combustion chamber (in the head) and spark plug proximity and aiming, the intake manifold runner can help produce the desired type and degree of mixture motion…or can detract from its production.

Even with some of the one-dimensional computer-aided software analysis processes being used by leading F1 teams and the OEM (both domestic and import), certain dynamic considerations are yet to be included in engine modeling techniques. But with emerging technologies in computational speed and capacity, refinements to current modeling methods are being made on a regular basis.

The complexity of turbulence modeling and that required for fluid dynamics modeling (further complicated by unsteady flow conditions in a running engine) places this type of design approach beyond the financial limits of most professional engine builders. But as with the emergence of most technologies for which commercial benefits can accrue, methods are becoming shortened and being produced on a more affordable level to include practice among others than the OEM and high-budget racing operations.

The "reversion" phenomenon

When an intake valve begins to open, at the start of each inlet stroke, cylinder pressure is typically higher than intake path pressure. Residual combustion materials briefly flow back into the inlet path, until the intake stroke has progressed to where cylinder pressure

Early-design high performance and racing intake manifolds provided for multiple carburetion with little emphasis on the need for improved manifold efficiency. Additional carburetor throats were the solution to higher rpm power.

equals inlet pressure. From this point into the remaining portion of the intake cycle, flow is toward the cylinder.

However, physical combustion residue (exhaust gas) that passes back into the inlet path is not combustible. It will either return to the cylinder being filled or shared with another cylinder's v.e. process following somewhere in the firing order. Especially in single-plane manifolds where internal "cross talk" exists among all cylinders, the degree of reversion will impact net combustion efficiency by the dilution of fresh air/fuel charges.

It is desirable to minimize reversion, unless its presence is used to diminish the tendency toward detonation. The net effect is reduced combustion temperature, which, from an emissions standpoint, reduces oxides of nitrogen (NOx). But if optimum power is sought, the reduction of combustion contamination is desirable.

Intake manifolds can be designed to help reduce reversion. Either by manifold-to-head port mismatch (intake manifold slightly smaller than inlet port) or the location of this mismatch in an area of low flow velocity, it's possible to cause reversion contamination reduction. Typically, such mismatches occur at the manifold-to-head gasket interface and should be located away from the short-path of flow into the intake port.

"Variable" intake manifolds

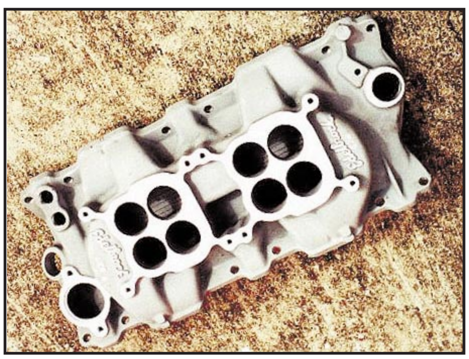
In 2-stroke-cycle engines, reed valves have provided a measure of variability in the inlet path, opening to increase "port size" as a function of air flow. Similar devices have been used in the exhaust path, again changing in size as flow rate increases.

The concept underlying these methods is to achieve and maintain the desired airflow rate (basically velocity related) over a wide range of engine speed. A corollary to this is the use of a variable torque output transmission that allows an engine to run a peak efficiency rpm. In either case, the intention is to allow (or cause) an engine to operate at inlet flow velocities associated with peak volumetric efficiency…or at least near that point for as much time as possible.

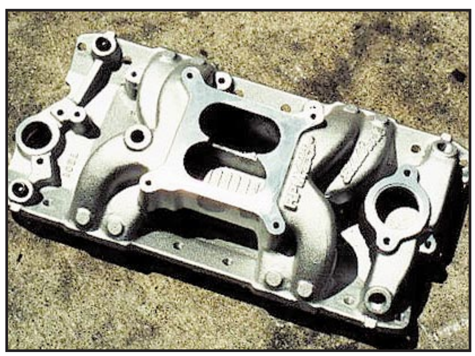
By the use of air- or electrically-operated valves, intake manifolds have been designed that utilized one set (usually small) of intake paths for low- and mid-rpm operation and a second set (larger in capacity) for higher engine speeds.

Return for a moment to the discussion about the Vorum concept in which a mean flow velocity (m.f.v.) of 240-260 ft/sec was proposed as the flow rate associated with peak volumetric efficiency or peak torque. A "variable" intake manifold using a set of small cross section runners will achieve this m.f.v. range at a lower rpm, while a set of larger runners will not reach this rate until a higher rpm is achieved. In theory, this arrangement will produce an intake torque curve with two peaks; one for the small, low rpm set and one for the larger, high rpm set. In practice, the result is a broader, flatter torque curve. Aside from improved driveability from a wider range of effective torque, combustion efficiency (mileage) also stands to benefit.

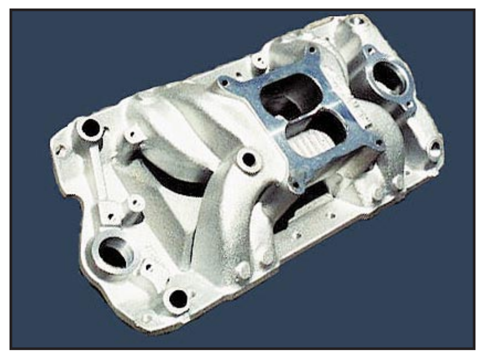
Both experimentally and in use, other methods have been and are being considered for production (and racing) vehicles. Regardless of the method employed, the objective is to achieve and maintain high levels of volumetric efficiency over a wide range of engine speed. The results are numerous, and virtually all of them are good.



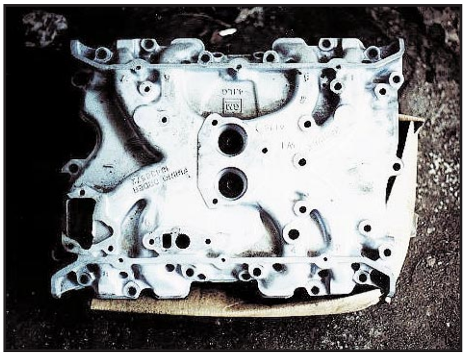
To simplify carburetor linkage assemblies while still providing additional carburetor throat area, in-line 4-bbl carburetors became a popular performance path. Such systems were also adopted as OEM options adding performance benefits beyond that obtainable with single 4V carburetion systems. Manifold design was limited to incorporating the 180-degree firing order pattern, as pioneered by Vic Edlebrock, Sr. in the 1940s.



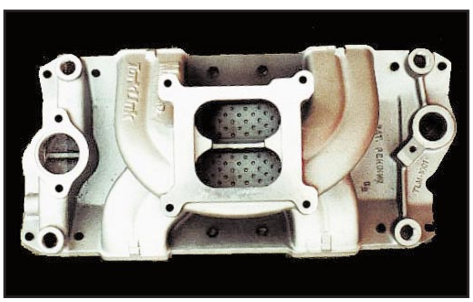
Today, intake manifold design sophistication relies less on multiple carburetors but more to the improvement of both airflow quantity and quality. Large 4V carburetors provide ample throat area, so refinement of manifold plenum chambers and runners enable a wide range of rpm in which power gains are obtainable.



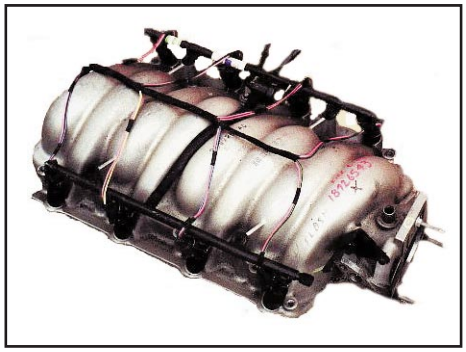
To further aid improved air/fuel mixture quality and condition, some inlet manifold incorporate an "air gap" feature. This approach provides air circulation between manifold runners and the valve lifter galley cover, typically subjected to elevated oil temperature from underside exposure to the lifter galley. Early use of this technique was limited to racing manifolds, now incorporated in high performance street designs like this Edelbrock version.



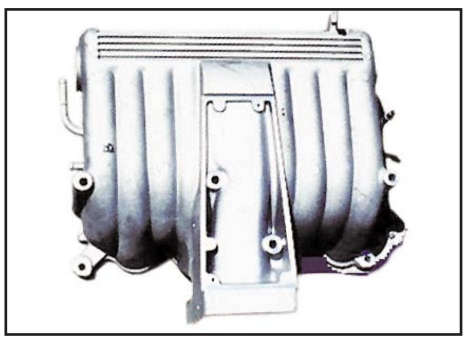
Due to low profile hood lines, some OEM intake manifolds were of single-plane design. Adding to the complexity of late-model intakes is the requirement for internally plumbed exhaust gas re-circulation (EGR) passages and exhaust crossover paths for additional carburetor (or TBI) heat. Manifolds of this type frequently compromise cylinder-to-cylinder mixture distribution in favor of packaging requirements.



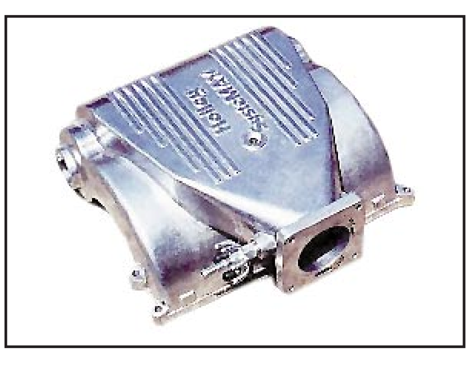
Combining features of a two-plane (two separate air cavities) and single-plane (runners extending into the plenum chambers), this H-Tech Engine Components "Tork-Link" design provides a wide-band range of torque. Initially intended for circle track engines requiring passing and off-the-corner torque, this manifold has found successful applications in an extensive variety of uses...including high performance street engines and others intended for low- and mid-rpm towing requirements. (Dimples in plenum floors aid mixture quality by improved homogeneity or mixing.)

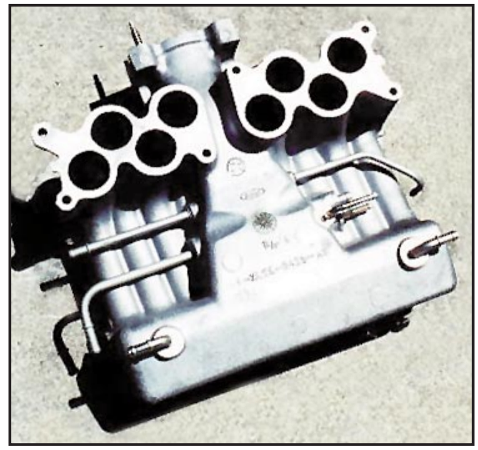


This so-called "folded hands" design is used on current Chevrolet LS1 (and LS1-type) engines. Fuel injector nozzle location is highly critical and formed the basis for much of the manifold (and cylinder head) design. Runners in this manifold are specifically intended as "extensions" of the cylinder head inlet ports. Long runners add to low- and mid-rpm torque output.

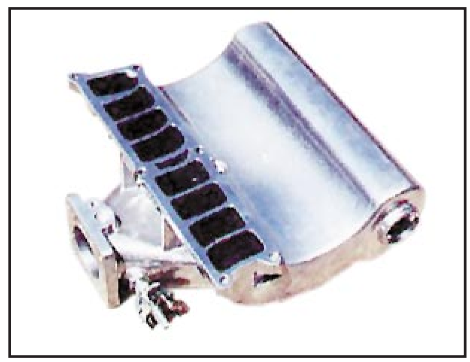


Stock FoMoCo manifold for 5.0L Ford V8 incorporates long individual runners, terminating in an intake manifold base providing paths to each cylinder head inlet port. "Plenum" function is provided by long flow path (volume) leading from throttle body mounting flange to entry of "air box" (additional plenum) to which all runners are connected.





Belly-side of Ford 5.0L manifold reveals shape of "air box" and throttle body path, tapering from TB flange into the box. Runner exit ports are staggered to allow alignment of cylinder head inlet ports; including bank-to-bank port stagger due to cylinder off-set (bank-to-bank).



Belly-side of Holley "SysteMAX" design reveals enlarged port runner cross section areas and aligned (although somewhat spread) inlet ports-to-manifold arrangement. Bank-to-bank off-set is compensated by spreading ports in manifold base, causing a measure of inclination of end ports to enable proper alignment between upper and lower parts of the manifold.

Holley's "SysteMAX" version of Ford's 5.0L V8 manifold shows enlargement of plenum path (from throttle body flange to runner-joined air box) and revised treatment of port runners.

Review Questions — True or False

1. Generally, intake manifolds that provide for multiple carburetors are intended primarily to increase net engine airflow, aside from any benefits derived from additional carburetor throat area.

2. A so-called 180-degree intake manifold provides successive air inlet pulses (intake strokes) to every other cylinder in the firing order.

3. Single-plane intake manifolds have port runners all of which (or most of which) extend from cylinder head inlet ports back to the manifold's plenum chamber (volume).

4. According to the interview with Ken Sperry, a carburetor intake manifold is much simpler to design than one for a TBI or MPFI system.

5. In the "Vorum" method of intake manifold tuning, the desired flow velocity should never be less than 300 ft/sec.

6. The "Wave Motion" theory of intake (or exhaust) manifold design or analysis contemplates similarities between acoustic waves and water waves.

7. Contemporary study of "mixture motion" has proven that induction systems have little or no effect on combustion efficiency.

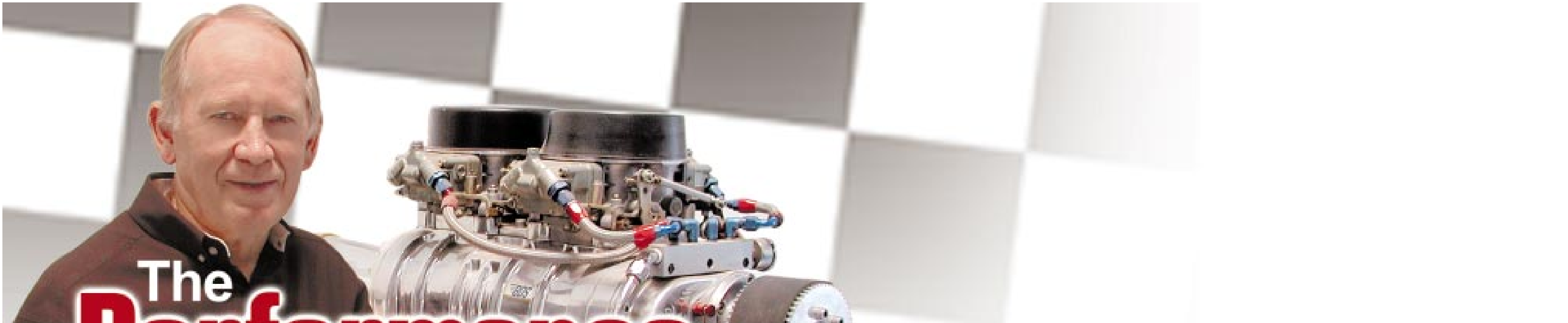
8. Reversion (or "back flow") is characterized by cylinder pressure higher than inlet pressure, at the time of intake valve opening.

9. In order to promote good power and optimize combustion efficiency, fuel injector "targeting" have proven to be important in MPFI manifold design.

10. Even with proper "tuning" techniques, it is never possible for a normally aspirated engine to achieve v.e. higher than 100%.

Answers

1. False 2. True 3. True 4. False 5. False 6. False 7. False 8. True 9. True 10. False



The Performance Professor

Jim McFarland

presented by N2PERFORMANCE.COM
The High Performance Authority

"Performance Professor" Interview - with industry notables

Ken Sperry - General Motors

Since 1975, Ken Sperry has been responsible for the air flow development of all engines released from the General Motors Powertrain Technology (Warren, MI, East) and the training of all air flow technicians currently working in the air flow facility. This includes, but is not exclusive to, airflow bench design and construction, tumble meter (mixture motion) design and construction, development and documentation tests and process procedures, reverse engineering to CAD systems, interfacing with engineering analyses, CFD work, combustion analysis and air flow COE. In the process of performing his work at GM, every cylinder head, inlet and exhaust manifold design released at the Warren East facility has been redesigned, with four US Letters of Patent awarded to the technicians on the projects. Two of these Patents, for intake and exhaust ports, were issued to Ken (via GM) in 1984 and 1986.

Personally, I have known Ken since the late 1970s. Beyond his activities internal to GM, he has participated in numerous projects that have extensively broadened his experience and value to motorsports. These include assembly and testing of race engines for Can-Am, NASCAR and the Indy 500. Since 1972, equipment from Sperry Fuel Controls has set more than 100 world or national records Among other current activities, Ken lectures on various air flow topics that include a course of study he helped develop for the SuperFlow Corporation.

Points he raises in the accompanying Performance Professor interview are worth noting and remembering to apply.

How would you describe the primary functions of an automotive induction system?

"The primary function of the inlet on power is to evenly distribute the air (and fuel) to the ports, with a minimum restriction to the air flow. After that, you want to optimize the manifold's tuning characteristics for the engine's particular application. For O.E.M. engines, we need to be concerned about induction system noise, often a function of manifold geometry and its relationship to the throttling mechanism."

From a performance standpoint, what areas of an induction system do you consider the most important?

"The primary factor of importance is cylinder-to-cylinder distribution, particularly when the system utilizes a carburetor. The next would be minimizing airflow losses, both for carburetor and fuel injector systems. The last factor would be tuning of the manifold (geometrical considerations)."

In your experience, what guidelines do you follow when selecting an induction system?

"This depends upon whether the system will use a carburetor or is a fuel injection system design. For F.I., I use the largest runners I can package without creating unnecessary flow losses during runner turns (directional changes). Large runners will need to be long for proper tuning, sometimes resulting in packaging difficulties…like a Crower system on a big-block Chevy. If I need to create more low-end torque, I make the runners longer, unless there's a packaging (hood clearance, etc.) problem if I do.

"For carburetor systems, I keep the runners short and as centralized under the carburetor as possible. Cylinder-to-cylinder mixture distribution is critical with carburetor systems. We once had half our engine dynos running mixture distribution tests, and now we have none, because of all the F.I. system work."

When it comes to modifying an induction system, what

areas do you typically avoid changing?

"On F.I. systems, I modify everything. But I have a fuel flow bench to measure the results of changes. On carburetor systems, I know how sensitive they are to mixture fixes (distribution corrections) and would only modify these type manifolds if I had an engine dyno with at least EGT (exhaust gas temperature) readouts or a wide-range O2 (oxygen) sensor. Actually, I prefer the O2 sensor approach. It's possible to improve air flow a ton and lose power by improper changes to mixture distribution (cylinder-to-cylinder)."

From a pure power standpoint, which method of fuel preparation to you feel is best; carburetion, TBI or MPFI…and why?

"OK. This is fuel (type) dependent. With gasoline, you want to introduce the fuel as far from the valve (inlet) as possible, as with the old F1 engines. Not a lot of latent heat is in gasoline, so you need time to completely vaporize the fuel (prior to combustion).

"For methanol, inject the fuel as close to the vale as possible since there's plenty (by comparison) of latent heat and time to transfer, but there's a lot of fuel which displaces air.

"For nitromethane, inject close to the valve. In these cases, you don't need to be concerned about playing with air density because you're injecting an oxygen carrying fuel."

What do you recommend NOT modifying in an induction system?

"Don't create any sharp corners or edges where there weren't any, particularly with carburetor systems. Several things can result from this, and they're pretty much all bad."

How do you view the relationship between cylinder heads and induction systems?

"The inlet manifold and the port are two sides of the same coin and should be developed as a 'system,' not separately, whenever possible."

Do you value the role of airflow benches in either evaluating or modifying an induction system?

"The engine is an air pump. The more air it pumps, the more power it makes. The airflow bench cannot evaluate the gains in manifold tuning length or fix (correct) mixture problems on carburetor manifolds. But it is useful to optimize the flow on all manifold designs, before mixture work begins.

"On F.I. engines, get the best air flow possible, modify the stacks to tune for correct intake path length, and you're done…except adjusting for proper fuel flow rate."

What do you foresee in the future of automotive induction systems, based on your many of development work at GM?

"Intake manifolds are going to be plastic (or derivatives thereof), of short runner lengths, large runners for wide power bands and with nozzle valve injectors located close to the valves…largely for emissions reduction purposes."