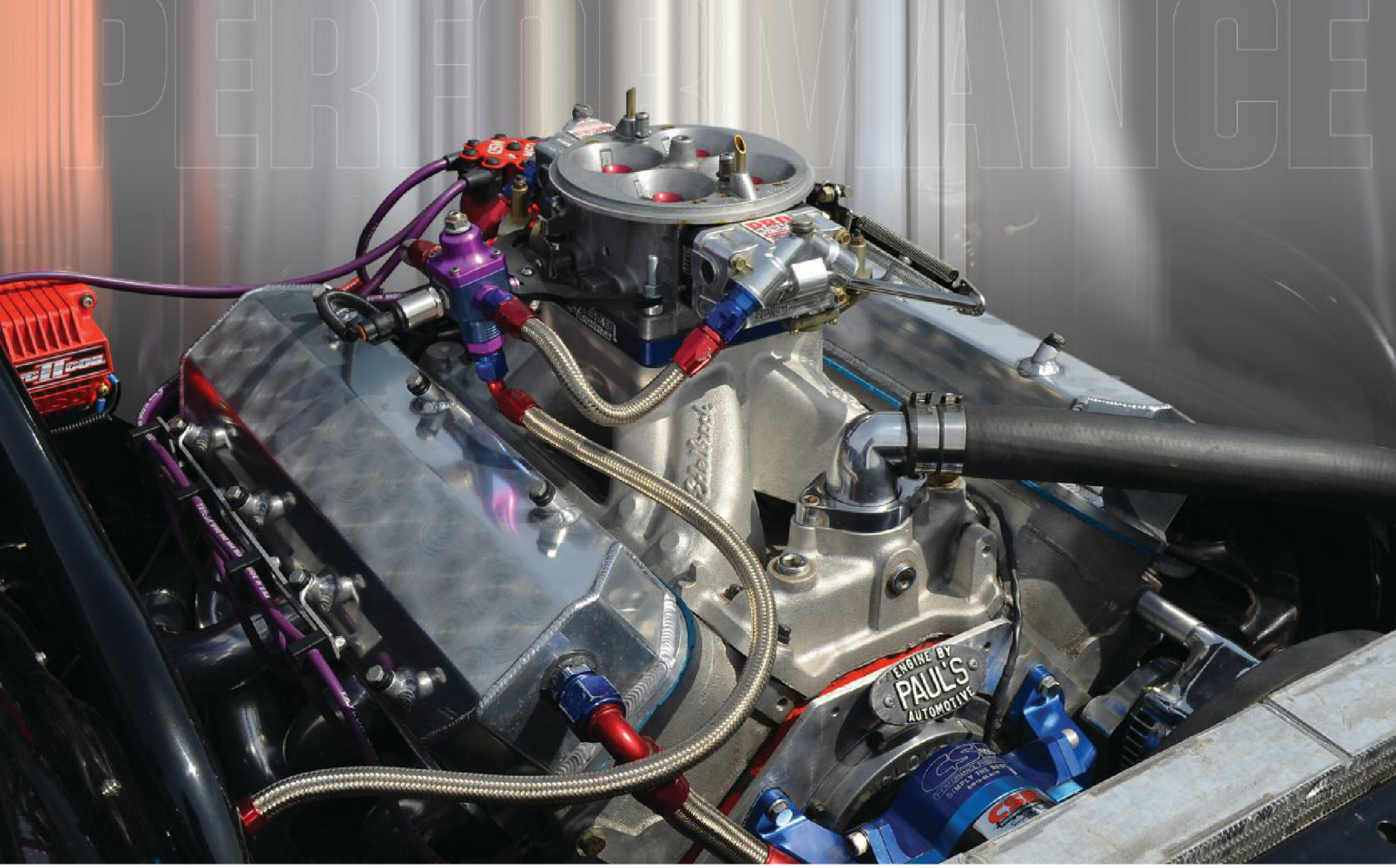


INTAKE MANIFOLDS MATCHED TO HIGHER PERFORMANCE ENGINE

Manufacturers continue to report incremental—but significant—gains that lead to major improvements in race intake manifold design.

By John F. Katz

BIGGER and hungrier emerged as two significant trends when we covered cylinder heads for race engines earlier this year. Feeding those heads, we reasoned, must require better-flowing intake manifolds. So we spoke to manifold manufacturers—and learned that bigger is only part of the story.

"Greater performance levels require induction systems that breathe more efficiently," stressed Kevin Feeney of Racing Head Service (RHS) and Fuel Air Spark Technology (FAST), Memphis, Tennessee. "As cylinder head technology evolves, it provides new opportunities to create intake designs that complement the complete induction system." But more so than larger, the design goal is "more efficient. Factors including enhanced airflow efficiency, out-of-the-box performance, and flexibility in engine combinations are pushing developments in all segments of racing."

"We most certainly keep track of cylinder head trends," reported Adam Layman of Holley Performance Products, Bowling Green, Kentucky. "Hardcore racing innovation is trickling down to the sportsman level, and even to street performance, at

Many factors influence the design process of intake manifolds. One contact reported advances in both upstream and downstream components, in manufacturing and production technology, and in design materials as well as tools—all small gains leading to major improvements. Photo courtesy of Holley Performance Products.

a faster rate than ever before. The trend toward larger ports, larger valves, and decreased valve angles, combined with the latest advances in valvetrain design, has greatly broadened the usable power band for performance engine builds.

> "Manifold design should optimize not only horsepower, but torque as well."

Add to this the growing popularity of all forms of power-adders, and it becomes apparent that there are countless market segments in need of specialized intake manifolds." Which has to be good news for anyone who makes or sells them.

"Cylinder head designs are advancing at a much faster pace today," confirmed Brad Cauzillo of Kinsler Fuel Injection, Troy, Michigan. "This keeps us continuously developing new programs for ports and runners."

And, agreed Tim R. Torrecarion of Air Flow Research (AFR) in Valencia, California, "as cylinder head technology advances, other components must advance as well. Increasing the potential airflow and performance of the cylinder head requires modifications to the intake tract and exhaust."

"We've seen and participated in this trend," added Smitty Smith of Edelbrock, Torrance, California. "Larger engine displacements, hydraulic roller cams, and EFI all like larger intake tracts—especially larger displacements and EFI."

"With the common availability of high-flowing cylinder heads," noted Andrew Starr of Hilborn Fuel Injection, Aliso Viejo, California, "the intake manifold becomes the most significant restriction in the intake tract."

Here is how today's race manifold manufacturers are meeting that challenge.

OEM Influence

To some extent, aftermarket manifolds have improved because the latest OE manifolds are so good. "The OEMs have implemented new technology and better manufacturing," said Torrecarion, "increasing performance from the factory and pushing the design window for the

COMPONENTS

When choosing an intake manifold for a particular application, one contact emphasized how the runner cross sectional area and engine displacement are directly related to each other, and runner length is directly related to rpm. He explained, "The velocity of the air/fuel mixture in the intake runner is determined by the volume flow demand of the cylinder divided by the cross sectional area of the runner. It turns out that all well-running engines end up with about the same speed of the air/fuel mixture in the manifold," regardless of engine type.

aftermarket. Customers who spend their hard-earned money on aftermarket parts rightly expect a significant and verifiable increase in performance."

"We see incremental drivers on all sides," added Feeney. "Advances in both upstream and downstream components, in manufacturing and production technology, and in design materials as well as tools. No single factor stands out, but rather small gains and opportunities that stack up to produce major improvements."

Smith observed how "new software and new tooling techniques help us to develop better manifolds. We use both Siemens NX (Unigraphics) and PRO-E advanced surfacing tools. Not only does this help smooth out the rate of change of curvature in the port walls, but by the very nature of the design process we can quickly try different parameters for each feature, and then judge how even a small change affects the rest of the design."

And sometimes, the answer is, well, bigger. "Our Super Victor II manifolds are substantially larger than their predecessors," Smith continued, "to take advantage of larger engine displacements. Most importantly, we were able to take advantage of new foundry techniques and more intricate tooling to package the larger runners and not lose carb signal. Since the Super Victor II's are out-of-the-box ready, with clean plenums and large port exits (our small block PN 2892 is machine-profiled to fit a 1206 gasket), they represent a great value to engine builders and customers who would otherwise need to port a manifold to get the same level of performance."

And while on the subject of bigger parts, let's not forgot that weight is always a consideration. "In some of the dirt-track classes," Smith noted, "they use our two-piece manifolds and CNC both the inside and then the outside for weight reduction. We displayed one of these manifolds at last year's PRI Show after it had been ported by Marty Zimmerman; he had removed seven pounds of aluminum from it!"

Lighter & Cooler

Still, it would be difficult to machine any aluminum manifold until it weighed as little as a composite unit straight out of the mold. When the OEMs introduced plastic-composite intake manifolds several years ago, most aftermarket manufacturers were discouraged from following by the significant tooling and startup costs involved. "But seeing that this was the future of manifold design," said Torrecarion, "AFR invested considerable time and resources to develop our Titon composite manifolds. Now, we've seen increased attention to the use of composite materials. Heat is the enemy of horsepower, and from Cometic gaskets to composite manifolds, racers and manufacturers alike are looking for ways to reduce intake temperatures. Reducing the heat soak allows cooler, denser air to fill the cylinders. That was just one of our goals when we released our Titon line." AFR's Titon manifolds incorporate another popular feature in that they are

modular, "so racers can quickly and easily interchange the runners, permitting some tuning to accommodate changes in conditions and/or engine setup."

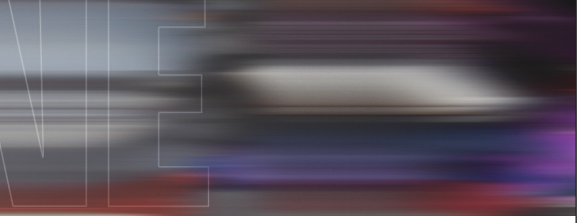
Another OEM innovation—now universal on showroom vehicles—is electronic fuel injection (EFI), which Layman said "opened the door for innovative thinking regarding intake manifold design. At one end of the spectrum, the ability to introduce fuel into the runner, rather than through the plenum, presents opportunities in designing manifolds for applications where space in the vehicle is limited. At the other end, we are now able to create all-out racing manifolds for optimal airflow, plenum volume, effective runner length, and so on, without constraining ourselves to a carburetor mounting pad."

A more challenging development at the OE level was presented by the GM LS series of engines. "Because these engines are so much more efficient than the first-generation Chevrolet small blocks," Layman continued, "with significantly lower brake specific fuel consumption, small differences in cylinder-to-cylinder fuel distribution through the manifold can significantly affect the air-fuel ratio in individual cylinders. Small nuances masked by the relative inefficiency of the first-gen small block become very obvious on an LS platform. It took a significant amount of R&D to engineer our manifolds to work well on LS engines with carburetors or throttle-body fuel injection."

RHS and FAST recently completed co-development of manifolds and EFI for the GM LT1 engine platform. "We looked at the cylinder heads and intake as a single cohesive system, rather than individual components," said Feeney. "As with any modern engine platform, the manufacturer has done a great job of making these engines efficient straight from the factory. Our job is to find areas of compromise that we can exploit for additional performance."

Custom Fabrication

As mentioned earlier, the explosive proliferation of cylinder heads has also



spurred demand for custom-engineered intakes. "Some engine builders are having custom heads manufactured just for them," said Cauzillo, "and at Kinsler we specialize in providing custom manifolds for these heads, no matter how unusual they are. We design all of our castings to allow great flexibility in machining custom details, so they are cost effective for most special heads. And our five-axis machining centers give us the ability to produce completely unique manifolds from aluminum billet. Of course, every customer's design is kept confidential. And we are doing more of these all the time."

> "There are countless market segments in need of specialized intake manifolds."

According to Cauzillo, the IR (Individual Runner) configuration allows for design flexibility, making it relatively easy "to change runner lengths and throttle diameters. We make small block Chevrolet manifolds with throttles from 2.0 to 3.0 inches, in 1/16-inch increments. This flexibility, combined with engine management systems that can provide fueling for individual cylinders, results in significant torque and power gains."

Still, the GM LS engines used in the IMSA Prototype series presented a particular challenge. "In addition to making good horsepower, with a broad torque range, these manifolds had to be very light," Cauzillo continued. "They also required a uniquely smooth, low-drag throttle tip-in for excellent drivability. But we achieved this using a 3:1 progressive throttle linkage and a ball-bearing throttle shaft in a billet aluminum manifold."

Hilborn Fuel Injection custom-engineers IR manifolds for cylinder head manufacturer and engine builder Mast Motorsports of Nacogdoches, Texas. "We are also developing a manifold for a custom head designed by the School of Automotive Machinists (SAM) in Houston," said Starr, "where they've programmed

their own ports into a CNC machine. When we receive a new head from a customer, not only are the ports larger, but they can be in different locations, or they can be tipped, or modified in some other way according to whatever is the newest design theory. Our three-piece intakes allow rapid design and prototyping for these unique applications—in most cases without requiring an entirely new casting. This allows our customers to put their one-off heads into service immediately, without the cost of tooling a casting or completely CNC machining a new manifold for (at most) a handful of heads."

Hilborn's three-piece configuration (two banks of throttle bodies, plus the base plate or valley cover) "allows us to easily adapt not only to new head designs," Starr explained, "but also to unique deck heights and other custom criteria." And for any engine, "IR manifolds have established themselves as a way to reach an engine's maximum potential in any racing class." Perhaps that is why "there are more people making IR manifolds today than ever before, and we're all competing for a slice of a very small market. New product is essential to capturing this business," he added.

That said, the custom trend applies to conventional manifolds as well. "The outlaw classes and street racers are demanding bigger and more exotic, but still stock-appearing, cylinder heads," said Mike Weinle of Weinle Motorsports, Cleves, Ohio, "and these heads require custom-made, sheet-metal intakes, with two or three injectors per cylinder. Currently, our best-selling custom intakes are for the new 123-mm/5-inch throttle bodies." These are two-piece manifolds with the top of the plenum bolted on.

"There are so many small cylinder head manufacturing shops that now provide their own customized cylinder heads with unique intake manifold hole assembly locations and port geometries for specific performance requirements," observed Keino Williams from Williams Engineering, Cincinnati, Ohio. "It can become a serious engineering challenge for a manifold manufacturer to develop and track the highly customized cylinder head configurations."

> "Increasing the potential airflow and performance of the cylinder head requires modifications to the intake tract and exhaust."

To address this issue, Williams Engineering has "developed modular billet induction systems and applications to be integrated with these custom engines," Williams explained. "Many of our induction system products are not your typical OEM stock dimension-driven products.

Intake manifolds are continually being refined and improved by manufacturers who use new software and new tooling techniques. For example, the team at Edelbrock uses both Siemens NX (Unigraphics) and PRO-E advanced surfacing tools. Not only does this help smooth out the rate of change of curvature in the port walls, explained a representative, but the design process allows them to try different parameters for each feature, and then judge how even a small change affects the rest of the design.

"With increased availability and affordability of engineering tools for 3D (CAD/CAM/CAE) modeling, simulations and applications to designers, engineers and manufacturers, this has enabled race engine builders and teams to develop custom engine blocks, cylinder heads and manifolds more efficiently than ever before," he added.

Williams Engineering's products "are pushing the performance envelope by the engineering methods used to design, analyze and manufacture them," Williams said. "Through our engineering and manufacturing solutions for our products, we have virtually eliminated and/or minimized any human hand made errors or weld distortions associated with fabricated sheet metal and/or cast manifold in the attempt to produce optimal performance output."

Williams Engineering's top tier level product application is its billet runner sets—a typical set comes in eight, six and four depending on the engine configuration—offered for various engine types. "An engine builder or manifold fabricator would build and weld the remaining portions of the manifold to complete their induction system," Williams said. "The correct terminology for this type of manifold is a billet runner intake manifold only. Optional EFI or nitrous ports and bosses, large inlet radii and other flow enhancement assembly features can be integrated with any runner configuration. These manifolds are typically all welded together by a manifold fabricator, engine builder or end user to complete the product."

Specialty Items

The market, we also discovered, is ripe for innovation. Dart of Troy, Michigan, makes a dual-plane, single-four-barrel manifold for the GM 8.1. "It was the last iteration of the big block," said Dick Maskin, "a fuel-injected 496 that came in a lot of trucks. When it was discontinued about five years ago, we created an industrial version to help replace some of the parts that were no longer available from GM. And one of the parts we made was a manifold that

would accept a distributor—so you could take all the electronics off of that engine and put [them] on 4150 carburetor or throttle body. And we sell hundreds of them, because a lot of people don't want electronic fuel injection."

New from Indy Cylinder Head of Indianapolis, Indiana, is the Mod Man manifold, which uses a two-piece modular approach to provide "a universal manifold for all of the Chrysler and AMC V8s," said Russ Flagle. The bottom (spider) portion of the manifold is a casting for a specific engine. It's a single-plane design with ample space under the plenum. "Think short tunnel ram," said Flagle. Various billet top plates can be bolted on to accept a single four-barrel, two four-barrels, three two-barrels, or even a supercharger. "All the tops are interchangeable, so we only have to make four of them," Flagle explained. "It's a very cost-effective way to offer a manifold for all of these engines. It allows us to offer a two-four, a three-two, and a blower manifold for an AMC 401, none of which existed before, because the market wasn't big enough." Other specific castings are available for the Chrysler 5.7 Hemi; 6.1 Hemi; 426 Hemi; 400/440 big block; and 318/340/360 small block, with a single casting fitting both the LA and Magnum. Optional on all of these are injector holes and fuel rails for EFI.

Flagle added, "We've refined some of our port designs. We sell a lot of manifolds for Nostalgia Super Stock. And our Predator engine has gained ground in Top Dragster and with anyone who wants to go fast." The Predator, for those not yet acquainted with it, is a 655-cubic-inch, 1400-horsepower "no-compromise" power plant engineered from the ground up by Indy Cylinder Head around the stock 4.800-inch-centerline 426 Hemi block. All other parts are unique, which, of course, includes the tunnel-ram-style intake manifold.

Works In Progress

Looking to the future, Layman sees the greatest opportunities for further development in "off-road, road racing, autocross and drift. These segments have

been growing by leaps and bounds, and require a different approach from drag racing applications"—while "a high level of competition" drives the search for "any competitive advantage." Meanwhile, drag racing, too, "will continue to need bigger and better manifolds to keep up with expanding cubic inches and rising deck heights. Drag racers will also require additional application-specific solutions for boost, nitrous and EFI." He noted that Holley has some new products in the works to fit the needs of various types of racers, but wasn't ready to share details.

As an alternative to using fuel injection, Dart offers its dual-plane, single-four-barrel manifold for the GM 8.1, which was the last iteration of the big block. When the GM 8.1 was discontinued several years ago, Dart created an industrial version to help replace some of the parts that were no longer available from GM. One of those parts was a manifold that would accept a distributor, allowing the racer to remove the electronics from that engine and put on a 4150 carburetor or throttle body.

AFR has adopted "some new methodologies, regarding plenum and runner orientation, to better equalize airflow to all cylinders for a more consistent air/fuel ratio and power output," said Torrecarion. Some of these new features will be incorporated into the new big block Ford manifold that AFR expects to launch later this year.

Smith shared an interesting problem that Edelbrock is currently working on. "We offer a full line of XT EFI manifolds, and our big block Chevy rectangle-port is an outstanding piece. It idles great and is capable of making over

700 horsepower, with a fantastic torque curve. The oval port-version, which is very similar in design, had a misfire in number 7 at idle that we just couldn't get rid of. It wouldn't do it on all engines, but it was present on the popular 502/502 combination. We tried different throttle body positions, different plenum shapes, and different runner entries, but nothing entirely eliminated the problem. We even enlisted the help of the graduate program at Clemson University, who ran a full in-cylinder pressure analysis that showed the misfire as it was occurring. Bleeding external air directly into the runner band-aided the problem, but we still haven't found a complete solution."

Smart Choices

All of which brings us to the very practical question of choosing the right intake manifold for a particular application. "When choosing an intake manifold," Smith noted, "runner cross sectional area and engine displacement are directly related to each other, and runner length is directly related to rpm. The velocity of the air/fuel mixture in the intake runner is determined by the volume flow demand of the cylinder divided by the cross-sectional area of the runner. It turns out that all well-running engines end up with about the same speed of the air/fuel mixture in the manifold—it doesn't matter if it's a Briggs motor in a Junior Dragster or a Pat Musi 903."

Torrecarion also pointed to the need to match a new manifold "to your build and expected usage. A good place to start is by noting the operating range specified by the manufacturer." AFR, Torrecarion noted, offers both single- and dual-plane manifolds, with either 4150- or 4500-style mounting flanges, for operating speeds ranging from 1500 to 8500 rpm.

In every case, Cauzillo added, "properly sizing the throttle diameter and runner length is critical to performance. Manifold design should optimize not only horsepower, but torque as well. Using a very large-diameter throttle to make maximum peak horsepower is often not the way to win races."

What matters most, according to

Bill Mitchell of Bill Mitchell Products in Ronkonkoma, New York, is results. "A flow bench only tells you that you may or may not have gained any flow—but it's horsepower that matters, and horsepower is not always a result of airflow. We build more than 2000 engines every year, and test every one on the dyno, which gives us the chance to fine tune, fine tune, and fine tune again. When you start with a clean sheet of paper, test every day, and make small adjustments every day, then keeping up is never a challenge. The only challenge is keeping the parts on the shelves.

"Stan Ray and Sons, also known as Ohio Crankshaft, built a 632-cubic-inch, big block Chevy with our BMP aluminum block, heads and manifold with 10.1 compression and a .621-inch hydraulic roller cam," he added. "It runs on pump gas and makes 865 horsepower. But that wasn't enough, so they also built a 582 cid big block—again using our block, heads and single-carb manifold—that makes 1100 horsepower. These results are easy with our components."

> "As cylinder head technology evolves, it provides new opportunities to create intake designs that complement the complete induction system."

Mitchell cautioned buyers to "beware of cheap knock-offs that may look the same but can't duplicate the results you get with the original. We've tested R&D (Rip-off & Duplicate) versions of our own products a number of times, and found their performance down by as much as 40 horsepower. As the old saying goes, 'you get what you pay for.'"

So it's up to the industry's true professionals to guide customers to quality intake manifolds that will feed their own race engine's particular hunger. PRI