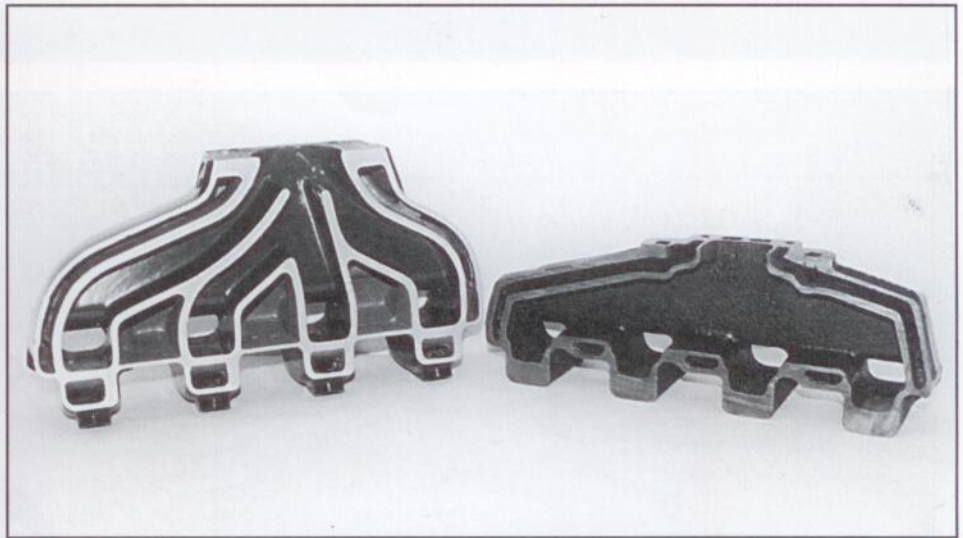


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EXHAUST SYSTEMS



On the right is a cutaway of the Mercruiser exhaust manifold that has been used on all big-block Chevrolets since 1982. It is simply an open chamber that exhaust gases enter into and exit out of the top. On the left is a high performance exhaust manifold; notice how an attempt has been made to separate the exhaust pulses from each cylinder. The exit flange sits much higher than on the stock manifold to extend each exhaust port to be as long as possible. The high performance manifold will increase the performance of any engine when used in place of the stock manifold.

Although exhaust systems is not the largest chapter in this book, it is probably the most important. The biggest roadblock to improving performance with a marine engine is in the exhaust. Because a correctly designed exhaust system can produce such dramatic increases in horsepower on a V8 engine, there has been a great deal of research, testing and development in this area. Automobile race engines have benefited tremendously from this research. When modifying an automobile, individual tube exhaust headers are relatively inexpensive and the very first thing done to increase performance.

THE DIFFERENCE BETWEEN HEADERS AND EXHAUST MANIFOLDS

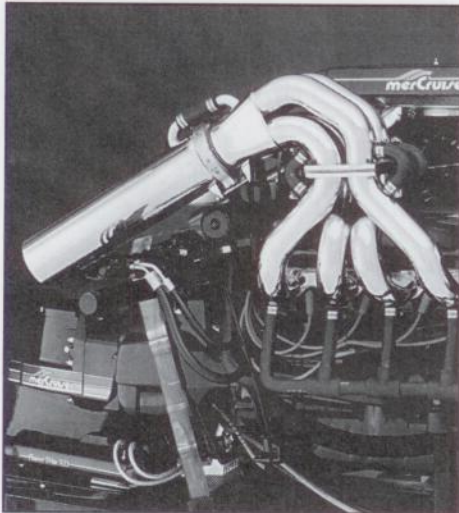
Many people confuse exhaust headers with exhaust manifolds, and think they are the same thing, which is not true. Headers are made from two sets of four individual tubes at least 1 3/4" in diameter, each at least 24"

long (preferably 30–35" long) connected to an exhaust collector at least 3" in diameter and an absolute minimum of 6" long (preferably as long as possible) with one set bolted to each side of a V8 engine.

An exhaust manifold is usually a cast piece where all the exhaust is discharged into one common chamber. Although some manifold manufacturers may make an attempt to separate each exhaust port within the manifold, and market it as an exhaust header, no respectable exhaust system engineer would consider it a header if the individual runners are not at least 24" long and connected to a collector at least 6" long. Certainly, very short tubular exhaust systems belong in the manifold category if the pipes are less than 24" long.

Exhaust Scavenging

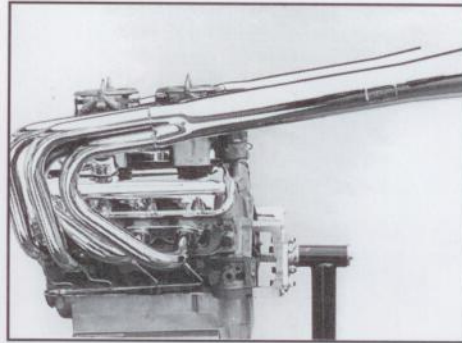
The operating differences between exhaust manifolds and headers is quite simple in practice but to explain it in a book is quite difficult. An exhaust header, with its individual tubes and collectors, can create a very



This exhaust system would definitely be considered an exhaust header. The primary pipes are long enough to create the effects of exhaust scavenging. This header would make more horsepower than any exhaust manifold or tubular exhaust manifold.

powerful exhaust system phenomenon known as *exhaust scavenging*. As exhaust moves down the exhaust tube the inertia of the speeding exhaust gases leaves a vacuum behind it. This inertia induced vacuum can be used to pull the fresh air/fuel mixture into the combustion chamber when the intake valve starts to open (remember the intake valve and exhaust valve are open at the same time during valve overlap). This inertia can also leave a vacuum in the exhaust tube after the exhaust valve closes. When the exhaust valve reopens again the next exhaust pulse enters into this vacuum increasing the exhaust flow. But, and this is a big BUT, this inertia can only be utilized if the individual exhaust tubes are long enough and of the correct diameter. If the exhaust simply exits to an open chamber all inertia is lost and no scavenging effect will take place.

The positive effects of exhaust system scavenging should not be dismissed easily as some aftermarket exhaust manifold manufacturers will

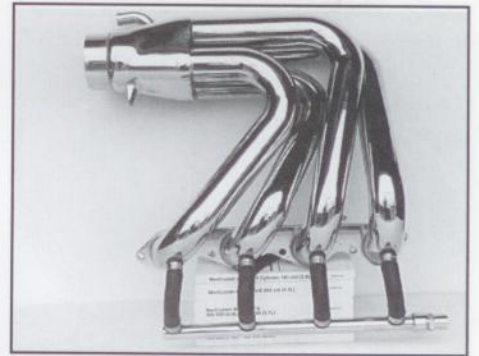


These headers are manufactured by Hooker Headers. They are typical of the header designs used on Jet Boats in the 1970s and 1980s. This is a single wall, water-injected header that discharges over the transom of a low profile boat. This is a perfect example of using long primary pipes and long collectors for maximizing the effects of exhaust scavenging for horsepower gains from the exhaust system.

try to do. There are definite and provable scientific principles as to why headers work better than exhaust manifolds.

SINGLE-WALL, WATER-INJECTED HEADERS

The most economical headers to build are water-injected headers. These single-wall headers have water injected directly into the exhaust tube two to three inches downstream from the exhaust port exit. The water mixes with the exhaust inside the pipe and is carried out by exhaust pulses. The disadvantage to this type of header is that it allows water to enter the engine's cylinders at low speeds, particularly with engines that have a camshaft with a large amount of valve overlap. These types of headers have been used successfully on jet boats with stock Chevrolet engines for years, because stock engines have camshafts with very wide lobe separation angles (the wider the lobe separation angle is the smaller the amount of valve overlap).



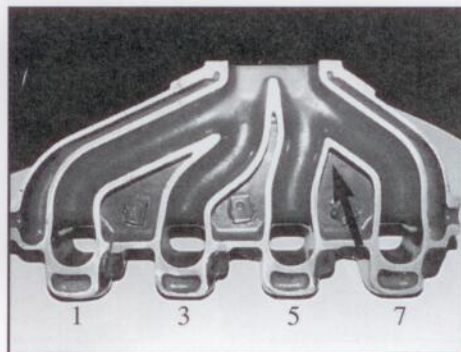
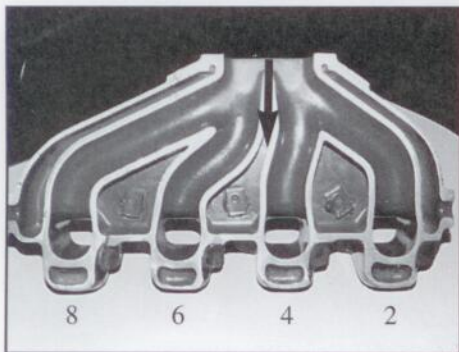
This is a custom built double-wall header built by CMI for a 40-ft. offshore race boat being built at Hallett Custom Boats in California. CMI builds custom headers to match any marine application.

Header Specifications for Single-Wall, Water-Injected Big-Block Headers

Because water is injected directly into the header tube with this style header, exhaust gas velocities are effected in a negative and somewhat unpredictable way. These headers will usually work more efficiently with tube diameters about an 1/8" to a 1/4" larger in diameter than double-wall headers. The tube lengths should be the same at 30" to 35" long. The collector diameter should also be slightly larger at 3 1/2 to 4" in diameter. The collector length should be at least 12" long.

DOUBLE-WALL, WATER-JACKETED HEADERS

The double-walled header has a water jacket surrounding both the primary tube and the collector the full length of the header. The cooling water is discharged into the exhaust gases at the end of the collector. Because of the elaborate construction of this style header, it is expensive; however, if maximum performance is to be achieved from a marine engine, this design is almost mandatory.



The big-block Chevrolet has a firing order of 1-8-4-3-6-5-7-2. This means that in each exhaust manifold, we will have two cylinders that will fire in succession. Cylinders 8 & 4 on the starboard side manifold and cylinders 5 & 7 on the port side manifold. In the photos above, we can see the starboard manifold (left) has a divider (arrow) that separates the exhaust pulses from cylinders 8 & 4. This divider keeps the exhaust gases of the number 4 cylinder from entering the number 8 cylinder when the number 8 exhaust valve is still open. The port manifold (right) actually groups cylinders 5 & 7 together. Without a divider between these two cylinders (arrow), the exhaust gases from the number 7 cylinder will enter the number 5 cylinder when the number 5 exhaust valve is still open. This is not what we want. Using this style manifold on both sides of a V8 engine is not very efficient.

Header Specifications For Double-Wall, Water-Jacketed, Big-Block Headers

Primary Tubes—Primary tube diameters should be 1 3/4" to 1 7/8" in diameter for a relatively low performance big-block 454 cid running under 5000 rpm and 2" in diameter for most average to high horsepower 454 cid and 502 cid big blocks running up to 6000 rpm. Only very powerful big block engines over 502 cubic inches and running higher than 6000 rpm can use a 2 1/8" diameter header tube. Primary header tube lengths should be between 30" and 35" long to be ideal. A longer primary header tube will increase low end power slightly while a shorter primary header tube will increase top end power slightly (realistically, the differences will be almost immeasurable if the primary tube lengths are within 30" to 35" for any big block). All eight primary header tube lengths should be as equal to each other as is practical but very little is to be gained and cost could be increased

considerably from the effort of equalizing them all to the exact same length. Ideal collector diameter is 3" to 3 1/2" in diameter, 3" for most engines and 3 1/2" for very high horsepower engines.

Collector Length—One of the most important dimensions, and one of the easiest to correct, is collector length. Quite simply, it should be as long as possible. For a marine engine running less than 7000 rpm the longer the collector is the more performance the engine will make. Collector lengths as long as 35" will show a power increase on all marine engines.

EXHAUST MANIFOLDS

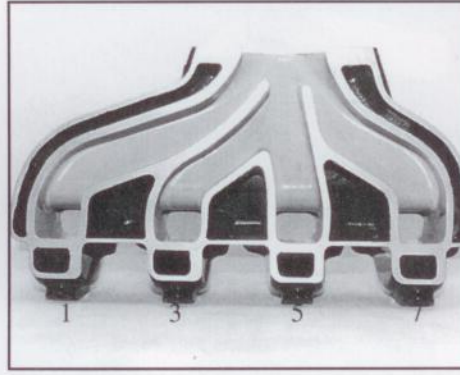
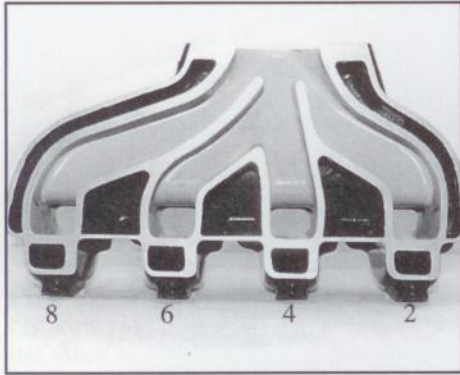
The main reason high performance exhaust manifolds are so popular on marine engines is because they cost less to manufacture and are more durable. Headers must be made of stainless steel to prevent corrosion, and they are very time-consuming to manufacture, so they are more expensive. Also, the different expansion and contraction rates of double wall stainless steel headers

creates cracks and fatigue, drastically shortening their usable life span over exhaust manifolds.

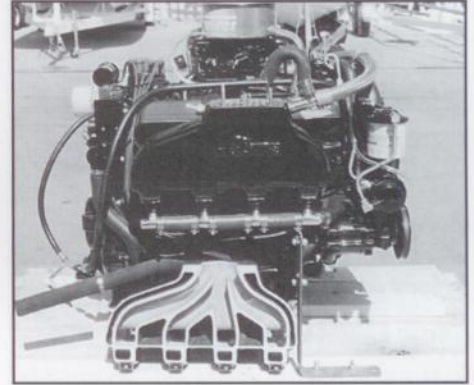
A high performance aftermarket exhaust manifold can deliver a performance increase over a stock OEM exhaust manifold. If properly designed it can do this in two ways: by separating exhaust pulses and by lowering back pressure.

Separating Exhaust Pulses

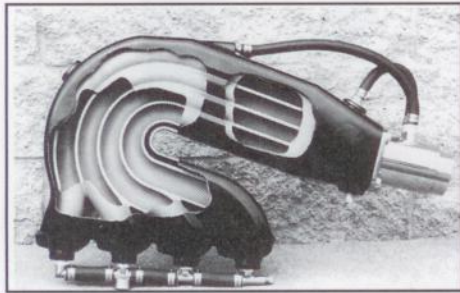
All V8 engines have a firing order that fires two cylinders within 90 degrees of each other on the same bank of cylinders. With a firing order of 1-8-4-3-6-5-7-2 we have #8 and #4 firing on the port side of the engine within 90 degrees of crankshaft rotation of each other and on the starboard side we have #5 and #7 firing within 90 degrees of crankshaft rotation of each other. Of course, this also means that the exhaust gases for these cylinders immediately discharges into the exhaust manifold one after the other. It is at this point, when the two cylinders fill the manifold in immediate succession, that the exhaust manifold becomes overwhelmed with exhaust gases, creating excessive back pressure. In fact these two cylinders on each bank, firing in succession, not only creates excessive back pressure in the manifold but all the way down the exhaust pipe. Excessive back pressure from an overwhelmed exhaust system will not only keep spent gases from leaving the cylinder head exhaust port but in certain ports, exhaust gases from adjacent cylinders may find their way back in. The solution is to isolate each exhaust gas pulse as much as possible for as long as possible in the exhaust manifold. There are aftermarket manifold manufacturers



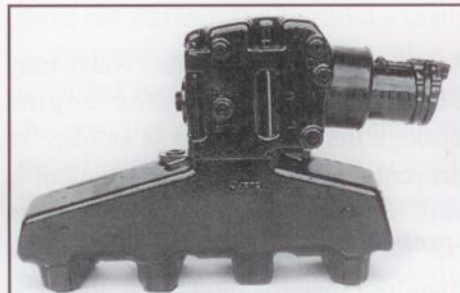
At first glance it appears this Gil manifold is no different than any other, but upon closer inspection, this manifold is much more suited to be run on either side of the engine. In the photo at left, we can see that when used as the starboard manifold, cylinders 4 and 8 are separated quite nicely with a divider. In the right photo, we can see that when used as the port manifold, cylinders 5 and 7 are also separated quite nicely with a divider. This is a well-engineered exhaust manifold.



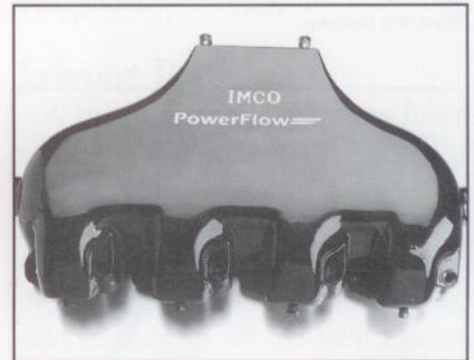
This Gil manifold is used by the Mercruiser High Performance Division on the 500 hp engines. This 500 hp is going to be installed in a boat at Hallett Custom Boats.



Arguably the finest exhaust manifold made is this one from Keith Eickert Power Products in Palm Coast, Florida. This is the only cast aluminum exhaust manifold that could be considered a true header. The runners are computer designed for uniform cross sections and are all 32" in length. The price is comparable to standard exhaust manifolds and the performance will rival double wall stainless steel headers.



This is the standard cast iron Mercruiser exhaust manifold. It is easily the best manifold available for an engine that is used and kept in salt water. Even when flushing an aluminum manifold on a regular basis cast iron manifolds last much longer in salt water. Although it flows better than any other cast iron manifold it still creates a considerable amount of back pressure.



The IMCO Powerflow high performance aluminum exhaust manifold has a much larger internal volume for a reduction in backpressure. The IMCO manifold is also anodized inside and powder coated outside for protection from corrosion.

that go to great lengths to isolate each exhaust pulse the full length of the manifold and there are some that barely address the problem at all.

Choosing a high performance manifold that isolates each runner is the key to building horsepower with the exhaust system.

Divided Exhaust Manifolds

Because the starboard side of the engine fires cylinders 4&8 in succession, there is a cylinder (#6) separating the two. Dividing this

manifold into two different sections by grouping cylinders #2 and #4 in the front half of the manifold, and #6 and #8 into the back half of the manifold with a divider, works relatively well in isolating cylinders #4 and #8.

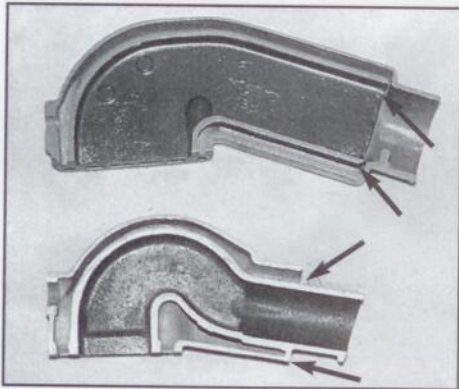
On the port side of the engine, we have a problem. The cylinders that fire in succession, 5&7, are next to each other. Dividing the port manifold into a front half and a back half groups cylinders 1&3 together (which is okay) but also groups cylinders

5&7 together (definitely not okay). This is exactly what we are trying to prevent. The correct way to build the port side manifold is to isolate the exhaust gases from cylinders 5&7 all the way to the manifold exit. This can not be done with a simple divider in the middle of the manifold.

Lowering Back Pressure

Lowering back pressure in the exhaust manifold is a combination of isolating the exhaust pulses as discussed in the previous paragraph and simply making the exhaust system larger. Large passages in the exhaust manifolds, a large exit hole out of the manifold, a large exhaust

EXHAUST SYSTEMS



These two elbows show where the water discharges out of the back of the elbow and into the exhaust stream. This photograph also shows the differences between exhaust elbows. The top elbow will flow more exhaust than the bottom.



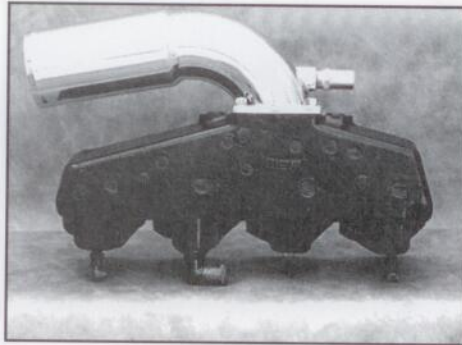
This is a good example of a free flowing exhaust from the manifold outlet to the exhaust tips. Courtesy IMCO.

pipe and large radius curves in the pipe wherever the exhaust gases have to change direction are the secrets to lowering backpressure.

EXHAUST ELBOWS AND PIPES

When the exhaust exits the exhaust manifold it must make a turn to flow towards the transom of the boat. This is accomplished by an exhaust elbow. At the end of the elbow, the water that has been cooling the exhaust manifold and elbow is mixed with the exhaust gases and swept out of the exhaust system and discharged overboard.

On engines with hot camshafts that have a large amount of intake/exhaust

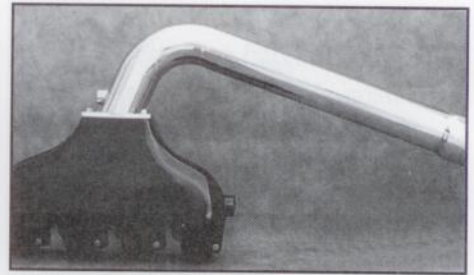


IMCO makes high performance stainless steel exhaust elbows that bolt to the stock cast iron Mercruiser exhaust manifolds. They have a large diameter pipe with a gentle radius for an increase in performance. This is a good way to improve the performance of a marine engine that needs a cast iron exhaust manifold for corrosion protection in salt water. Courtesy IMCO.

valve overlap some of this water may be sucked back into the engine through the exhaust port at an idle. To prevent this from happening, a double wall stainless steel exhaust pipe can be purchased from aftermarket manifold manufacturers to replace the elbow. This pipe will discharge the water into the exhaust gases farther down stream from the exhaust manifold opening. The longer this pipe is (the farther downstream the water discharge point is from the exhaust ports on the engine) the less chance of water being sucked back up into the engine. The downside to running the discharge point all the way to the transom is that exhaust system noise is increased considerably.

THROUGH-THE-PROP EXHAUST

Through-the-prop exhaust systems are used on most modern stern drives. The exhaust pipes connect to a Y pipe at the rear of the engine and the exhaust pulses travel through the transom and into the outdrive by



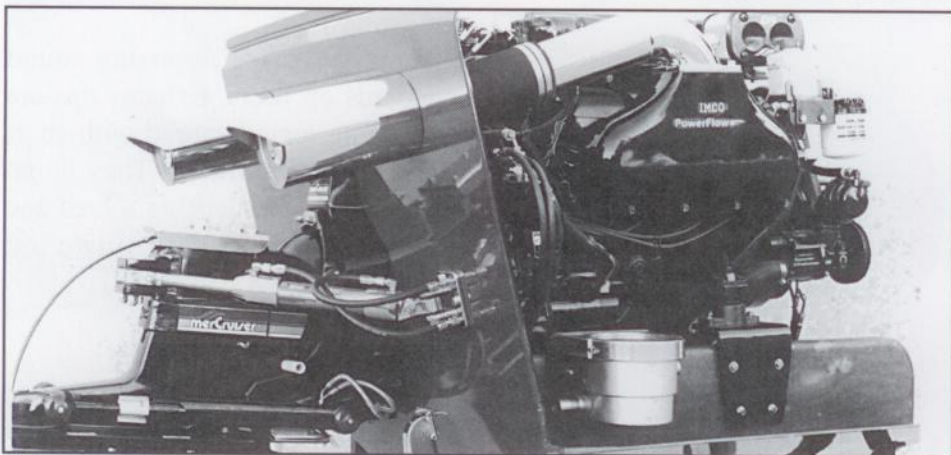
This stainless steel elbow has the water jacket running back three feet from the manifold where it discharges the water into the exhaust gases. If a camshaft is being used with lots of overlap this is sometimes necessary to keep water from being sucked back into the manifold and the engines cylinders at an idle. Courtesy IMCO.



When the exhaust leaves the exhaust manifolds it enters into this Y pipe that connects to the outdrive transom plate. From there it enters the outdrive through a flexible rubber bellow and is discharged through the center of the prop. When the prop spins, the water is not only pushed back but also slightly outward from the center. This creates a void directly behind the prop, which is perfect area to release the exhaust gases.

means of a rubber exhaust bellow. They enter into an exhaust cavity ahead of the prop in the lower gearcase and are pulled out of the stern drive by a vacuum created in the middle of the spinning prop. There are two advantages to this system.

The exhaust is literally being pulled out of the engine and the exhaust is being discharged underwater creating a very quiet boating experience. Stern drive manufacturers have claimed for years that through-the-prop exhaust



This is the IMCO through-the-transom exhaust system. The exhaust tips have mufflers inside that reduce exhaust noise.

systems actually improve horsepower. I believe it will only increase horsepower on small four and six cylinder engines that do not have large volumes of exhaust gases. Although some big blocks do come with through-the-prop exhaust, changing over to through the transom exhaust will usually make more power.

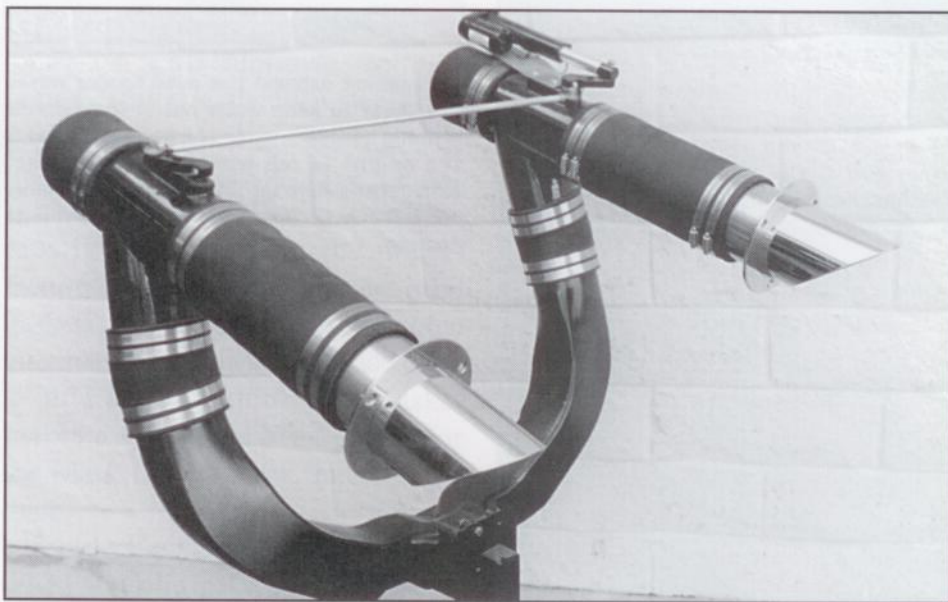
THROUGH-THE-TRANSOM EXHAUST

Most high performance marine engines will need a straight shot out of the boat with their exhaust. This is called *through-the-transom* exhaust; some low-profile boats will have an exposed engine with the exhaust system curving up and over the transom called *over-the-transom* exhaust; these can be included in this category also. A through-the-transom exhaust has an exhaust tip installed into the transom. The exhaust pipe will be fitted to within 3" to 4" of the exhaust tip with a flexible rubber exhaust hose connecting the two.

COMBINATION THROUGH-THE-TRANSOM / THROUGH-THE-PROP EXHAUST

This is a relatively new exhaust

system that is quite interesting. The exhaust Y pipe is retained on the stern drive but through-the-transom exhaust is also utilized. A butterfly valve is installed into the system, and when the position of the valve is changed, the exhaust gases can be directed to flow only through the prop, creating a very quiet engine. When additional power is needed changing the valve position allows the exhaust gases to



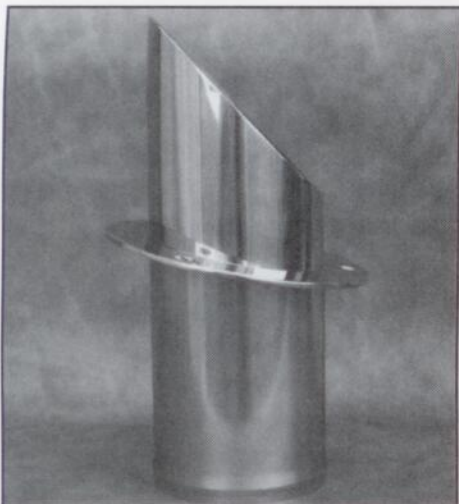
This is becoming a very popular exhaust system for family boating. With a flick of the switch the system changes from routing all of the exhaust out through the prop to routing it through the both the prop and the transom. You could call it a triple exhaust system. When the exhaust is routed only through the prop the boat is very quiet. When the triple exhaust is activated backpressure in the exhaust system is dropped to zero for a horsepower increase at high rpm. Mercruiser calls their system Silent Choice, this is an IMCO system called Sound Advantage.

exit through both the prop and the transom. The valve is actuated by either an electric motor or an air-operated cylinder by a switch on the dash. This system is becoming very popular with high performance boaters, because it offers the best of both worlds at the flick of a switch. I must say, however, that as neat as this system is, on every boat I have ever tested, only engines above 350 horsepower have shown any actual improvement in performance when the system was activated.

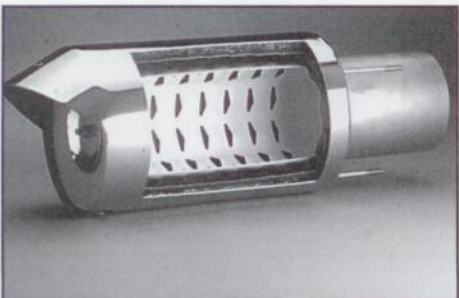
Exhaust Tips

A through-the-transom exhaust system uses exhaust tips in the transom of the boat.

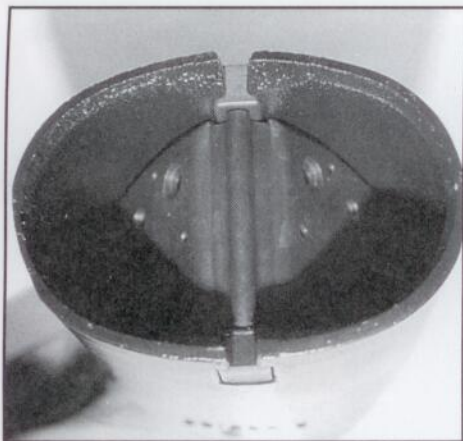
Because of the differences in transom angles and exhaust pipes on the various boats being manufactured seldom does an off the shelf exhaust tip fit, so most exhaust tips are custom made.



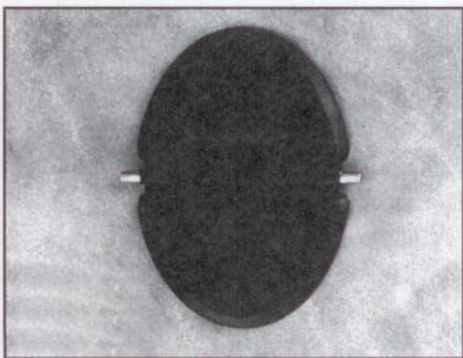
A stainless steel exhaust tip carries the exhaust gases through the transom. Different transom angles and exhaust pipes may mean custom built exhaust tips for your boat. IMCO Products in San Dimas, California, can make any exhaust tip you need on a custom basis.



Mufflers are required more and more on the lakes these days. Some day you may show up at your favorite lake and they will say no more through-the-transom exhaust without mufflers! Exhaust tips with mufflers may be in your future.



Mercuriser engines with through-the-prop exhaust have flapper valves in the Y pipe to keep water from coming back into the exhaust when the boat slows down. If you hear a tapping noise in your engine compartment, that is probably your flapper valves, that means they are OK.



Aftermarket exhaust tips need flapper valves like these to keep water out of the exhaust system. Flappers wear out frequently and if the engine is run without water the hot exhaust will burn up the flappers in no time. They should be inspected every time you go boating.

Many lakes are imposing sound standards on boats. Exhaust tips are now being manufactured with short marine mufflers inside. They do an adequate job of silencing a boat and generally do not cut down on horsepower much at all.

Flapper Valves

Marine engines should be equipped with flapper valves to keep water from entering the exhaust from outside the boat. Modern stern drives with through-the-prop exhaust will have factory-installed flapper valves. Engines with through-the-transom exhaust should have flapper valves installed in the exhaust tips. Flapper valves should be checked frequently. If the engine is ever run without water for any period of time these rubber coated valves can become damaged from the lack of coolant. Damaged or missing flapper valves will allow water to enter the engine, particularly when the throttle is pulled back very quickly and water rushes up to the back of the boat (sometimes called "following seas"). So much water can enter the engine through the exhaust that the piston could actually hydraulic and bend the connecting rods.