IND

EXHAUST SYSTEMS

By Don Francisco

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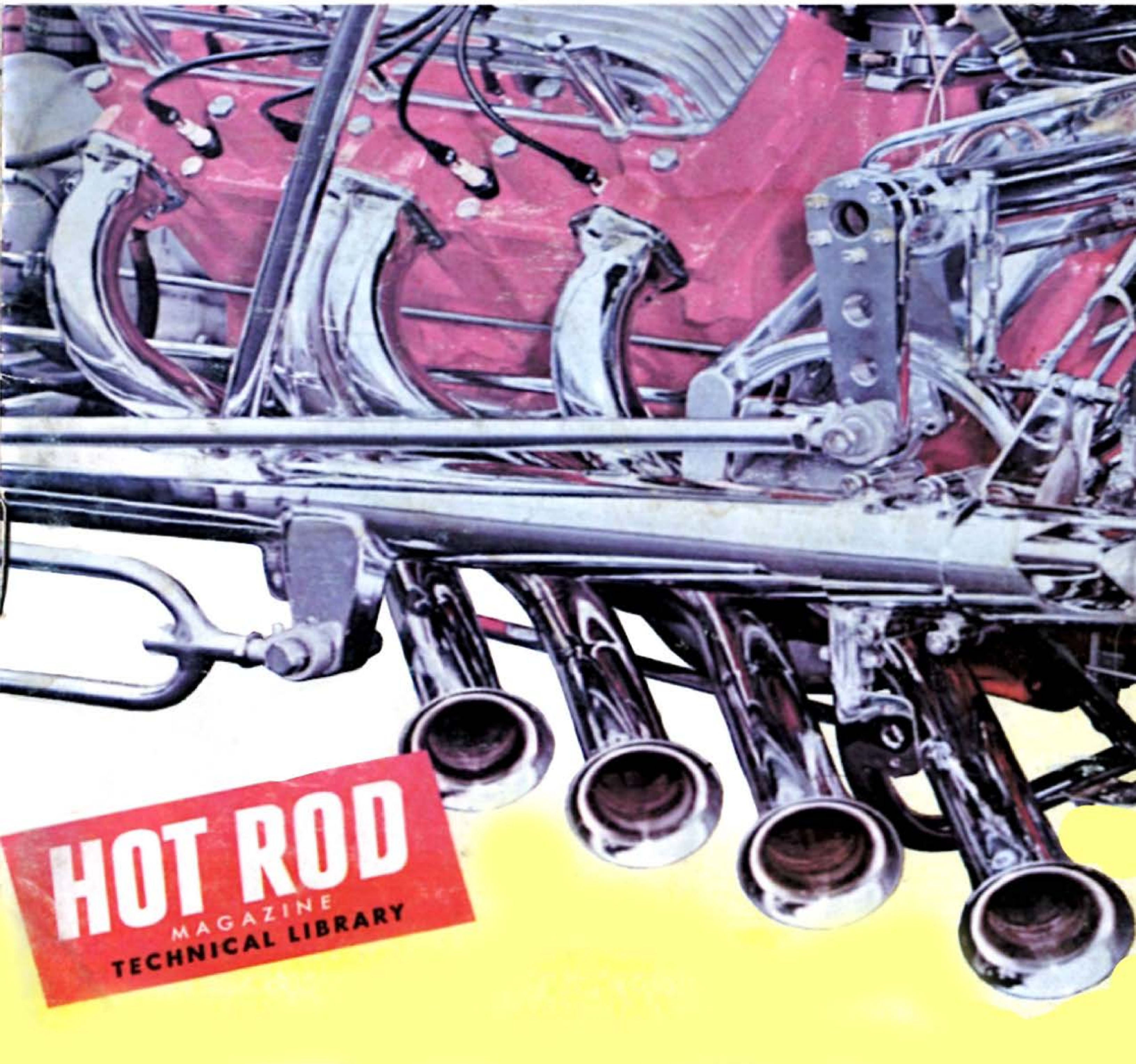

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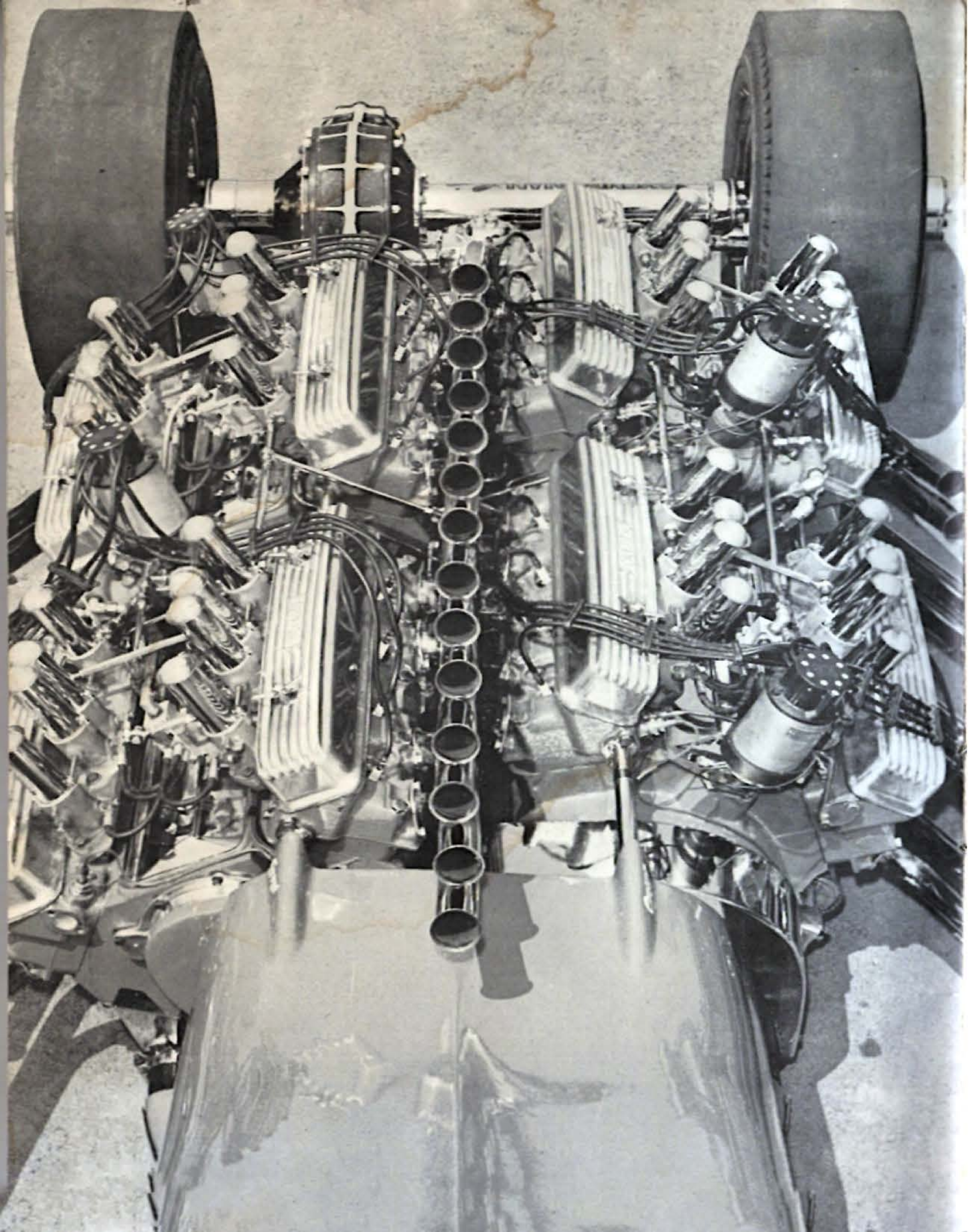

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by DON FRANCISCO

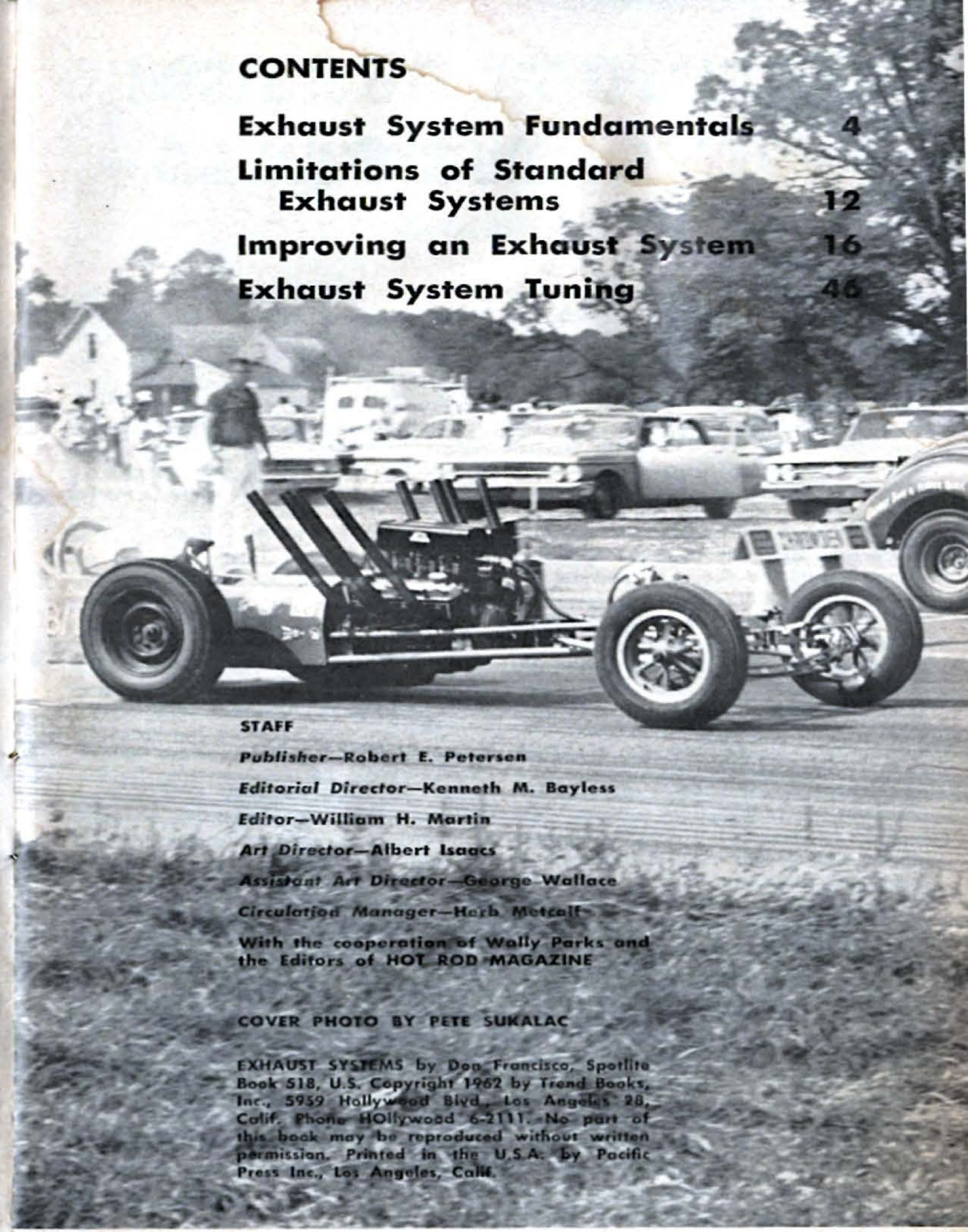
INTRODUCTION

The man who designed the first internal combustion engine must have had some medical training or perhaps it was only through coincidence that he designed the engine to operate on the same principle the human body uses. A person inhales air, the ingredients in the air the body requires are extracted, and the waste material is exhaled. An engine inducts air, with which a fuel of some sort has been mixed, the energy in the air-fuel mixture is extracted in the engine's cylinders, and the waste products are exhausted.

Just as a person who is working hard requires more air than one who is relaxing, an engine that is working hard requires more air and fuel than one that is idling. The more air and fuel an engine inducts, the more waste products, or "exhaust gases," it must exhaust. The high temperature of these gases, the noise they make when they are released to the atmosphere, and the lethal effect they have on human beings require the exhaust system for an automobile engine to have much longer passages, as measured from the cylinders to the atmosphere, than those for the induction system. These passages subdue the gases so they leave the exhaust system with a quiet hiss rather than a loud bang and at a point where they cannot contaminate the air breathed by the automobile's occupants but they present a resistance to the flow of gases that causes a pressure to build up in the exhaust system. This is "back pressure."

The effect of back pressure is to reduce the amount of air-fuel mixture an engine's cylinders can induct on each of their intake strokes. This prevents the engine from developing the maximum horsepower of which it would otherwise be capable. The stock exhaust systems on most modern automobiles and the back pressure they create are entirely satisfactory for the type of use for which the cars and their engines were designed but when a car's performance is to be improved by reworking its engine with the standard methods of boring, stroking, adding carburetion, etc., the exhaust system must also be reworked so it can handle the larger volume of exhaust gases that will result from the greater quantity of air and fuel the engine will induct. If the exhaust gases cannot get out of the cylinders, air and fuel cannot get in.

There are as many types of exhaust systems as there are uses for which an automobile can be built. Even the simplest of them consists of considerably more than just a few pieces of steel tubing and none of them can be better than its least efficient component. ■



CONTENTS

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EXHAUST SYSTEM FUNDAMENTALS

EXHAUST systems for all internal combustion engines are similar in that they begin in their engine's combustion chambers and end at the point where the exhaust gases are released to the atmosphere but this doesn't mean that all exhaust systems are alike. They can vary in the many details involved between the combustion chamber and the exhaust port in the cylinder head or block, in the number of cylinders that are connected together, in the way the gases from the cylinders are collected, in the way and to the extent the exhaust noise is silenced, and in the distance from the engine's exhaust ports to the atmosphere.

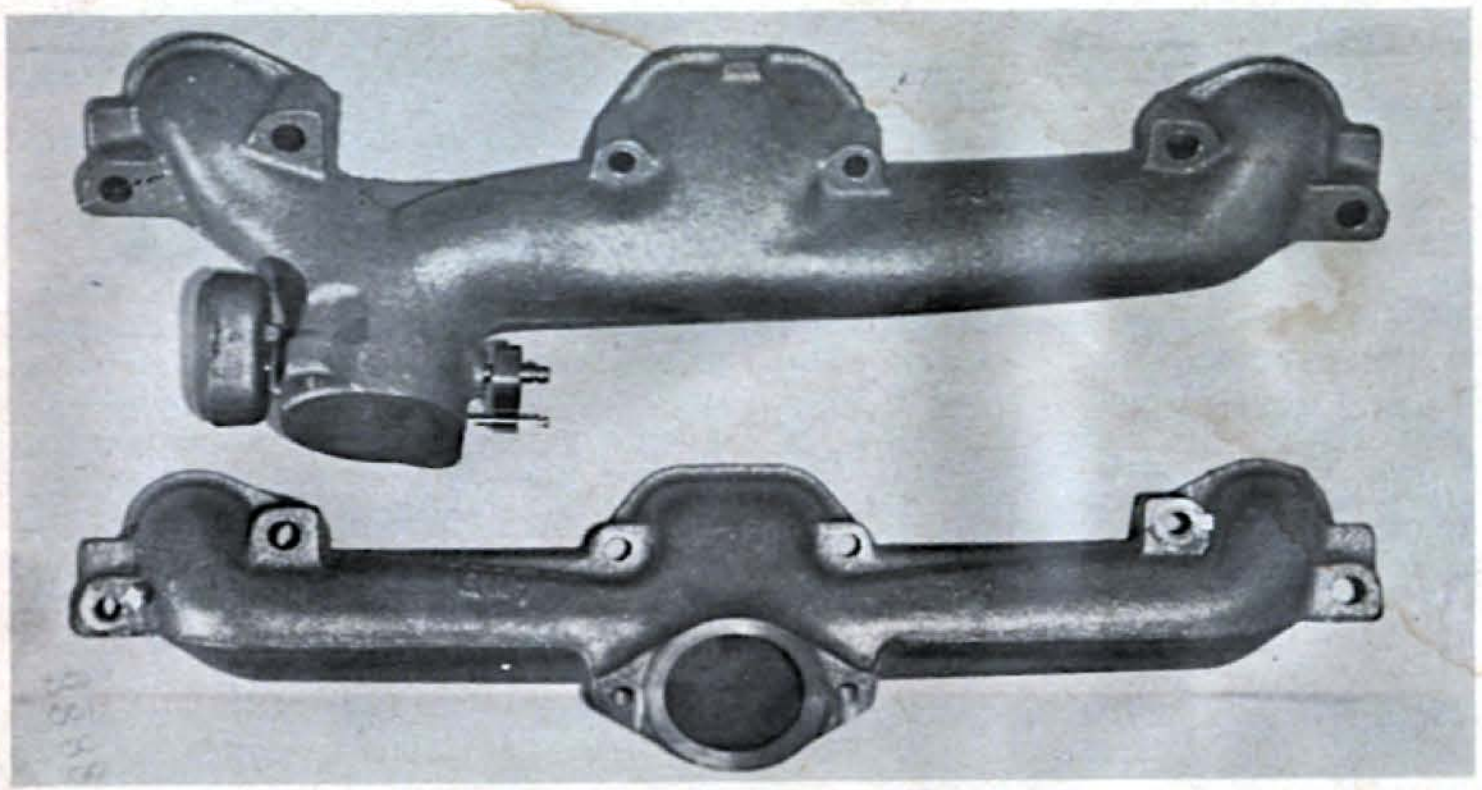
The things that happen in an engine's cylinders determine how much work the engine can do and work is a factor in the amount of horsepower the engine can develop. Air and fuel that are mixed in the carburetor flow into the cylinders on intake strokes, the mixture is compressed by the following compression strokes, is ignited at the end of the compression strokes, and then expands and exerts force against the piston heads. As the combustion pressure moves the pistons down the cylinders, piston movement is transmitted to the crankshaft by the connecting rods. This rotates the crankshaft, movement of the crankshaft is transmitted to the car's drive wheels, and the car moves. Near the ends of the power strokes the exhaust valves open to allow the products of combustion to escape from the cylinders. Now the exhaust system begins to work.

The exhaust valve is opened before the piston reaches the bottom of the cylinder on its power stroke. Pressure in the cylinder is usually fairly high at this time but the valve must be opened before the exhaust stroke actually begins to give the exhaust gases enough time to flow out of the cylinder before the next intake stroke. Some combustion pressure is lost by opening the valve before the piston reaches the end of its stroke but this is unimportant as far as the loss of force against the piston head and the resultant effect on horsepower are concerned because the angle the connecting rod forms with the crankshaft's throw when the piston is near the bottom of the cylinder is such that the piston is no longer contributing appreciably to the crankshaft's rotation.

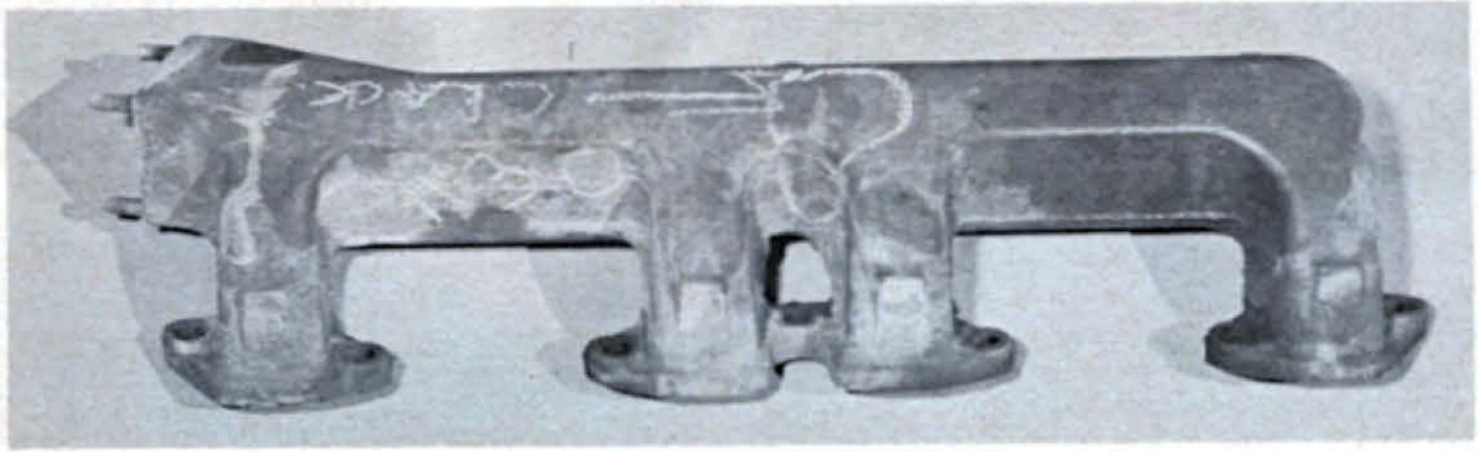
Opening the valve against the pressure in the cylinder places greater loads on the valve's actuating mechanism and the camshaft but, on the beneficial side, it allows the pressure to start the exhaust gases moving through the exhaust system. By the time the piston starts up the cylinder on its exhaust stroke the pressure is greatly reduced. Under ideal conditions it would be at atmospheric pressure or less. The lower it is as the piston moves through its exhaust stroke the lower will be the crankshaft effort required to move the piston. Any reduction in crankshaft effort for this or any other internal engine function is automatically added to the crankshaft's torque output and, consequently, to the engine's horsepower.

It isn't possible for the piston to force all the exhaust gases out of the cylinder. The reason for this, which has to do with engine design, is that movement of the piston on its exhaust stroke does not reduce the combined volume of the cylinder and its combustion chamber to zero. The combustion chamber is still filled with exhaust gases when the piston is at top center in the cylinder at the end of its stroke.

The exhaust valve is closing during the last part of the exhaust stroke. As its head moves closer to its seat in the cylinder head or block the resistance to flow past it becomes greater. This can cause the pressure of the gases still in the cylinder to rise as the piston nears the end of its stroke. Also, the back pressure built up in the exhaust system can raise the pressure of the gases. The higher back



Typical of the low-efficiency manifolds for late model engines are these for Pontiac.



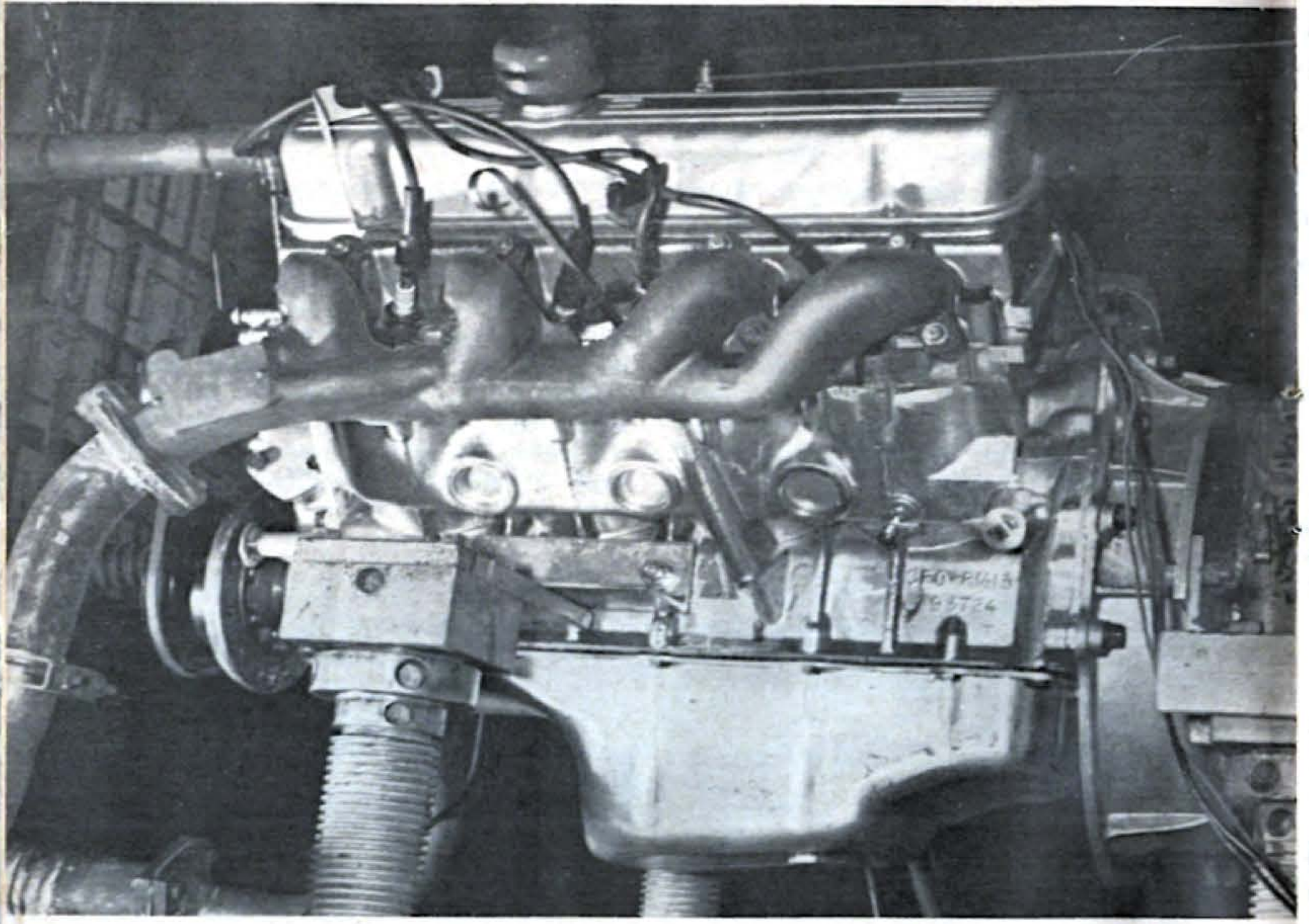
This exhaust manifold for Ford OHV engine is loaded with undesirable design features.

pressure becomes, the greater will be the pressure of the gases remaining in the cylinder when the valve closes. These are "residual gases," or "clearance gases."

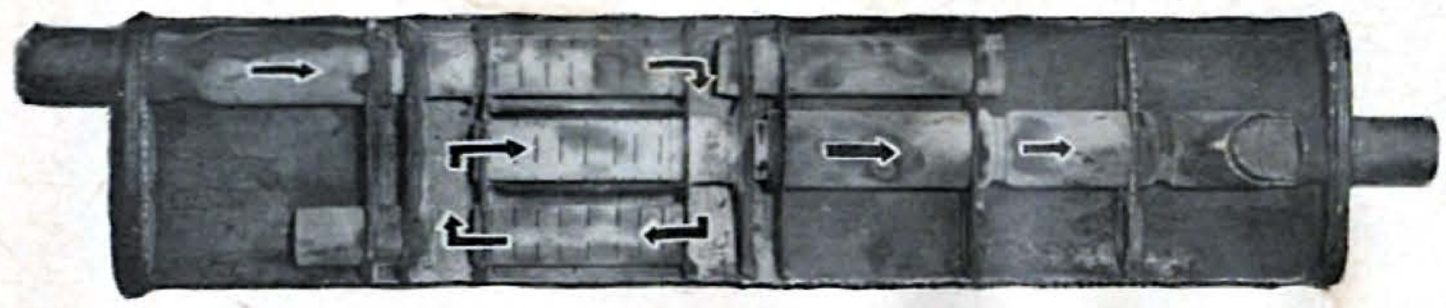
After the exhaust gases flow past the exhaust valve head they enter the "valve port," which is the port that surrounds the valve stem and its guide in the cylinder head or block. The valve seat, on which the valve head rests when the valve is closed, is formed on the valve port's end. The port's other end joins the "exhaust passage," through which the exhaust flows to escape from the engine. The opening that forms the atmospheric end of the exhaust passage is the "exhaust port."

During the comparatively short trip from the cylinder to the exhaust port the gases from each cylinder flow through the only portions of the system that are separated from each other. Exceptions to this are the "siamese" passages in some engines in which valve ports for adjacent cylinders connect to a common passage. The trend in modern engines is away from siamese passages to individual passages and ports for all cylinders.

After leaving the ports the gases flow



Design of the manifold on this GM aluminum V8, reversed for dyno, is above average.



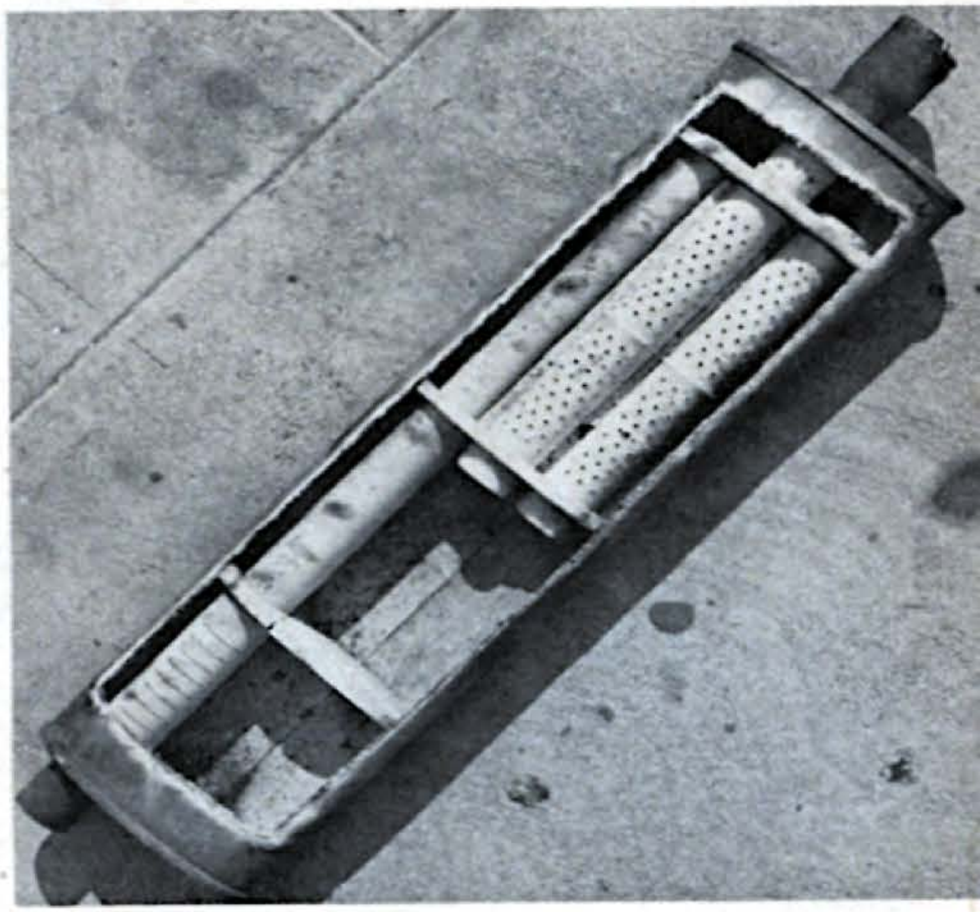
Arrows indicate the path of the exhaust gases that pass through this late-type muffler.

into a "manifold" that bolts to the cylinder head or block. The number of cylinders a manifold serves depends on the number of cylinders in the engine and the engine's configuration. V8's have a manifold for each cylinder bank, which means that each manifold accommodates four cylinders.

Exhaust manifold design varies from engine to engine, primarily because of the engine's location in relation to frame and chassis members, but all manifolds serve the same purpose. Branches from the engine's ports are joined together in some manner to form a common passage that has an outlet and a flange to which an exhaust pipe can be bolted. This pipe is the exhaust system's "headpipe." Headpipes are made in a variety of shapes and from tubing of different sizes to suit specific installations. Exhaust gases that pass through the manifold enter the headpipe and flow to the "muffler."

A muffler is a device that has the sole purpose of taking the noise out of the exhaust gases. The thing about the gases that causes the loud sound when they are released to the atmosphere is their high pressure. A muffler reduces

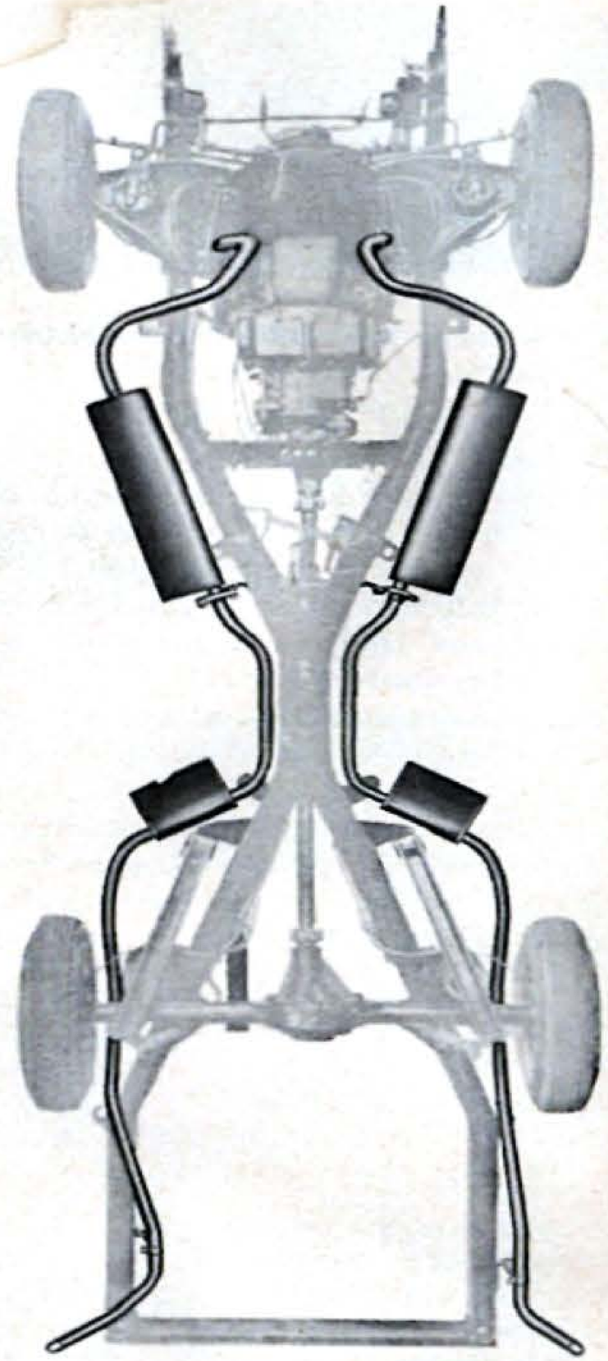
The design of the passages and chambers in a muffler of this type is important to the degree to which the muffler will silence the exhaust gases that flow through it.



this pressure by allowing the gases to expand and to lose some of their heat. The gases contract as their temperature drops. This helps reduce their pressure. The heat is transferred to the muffler's shell and then to the air that surrounds the muffler.

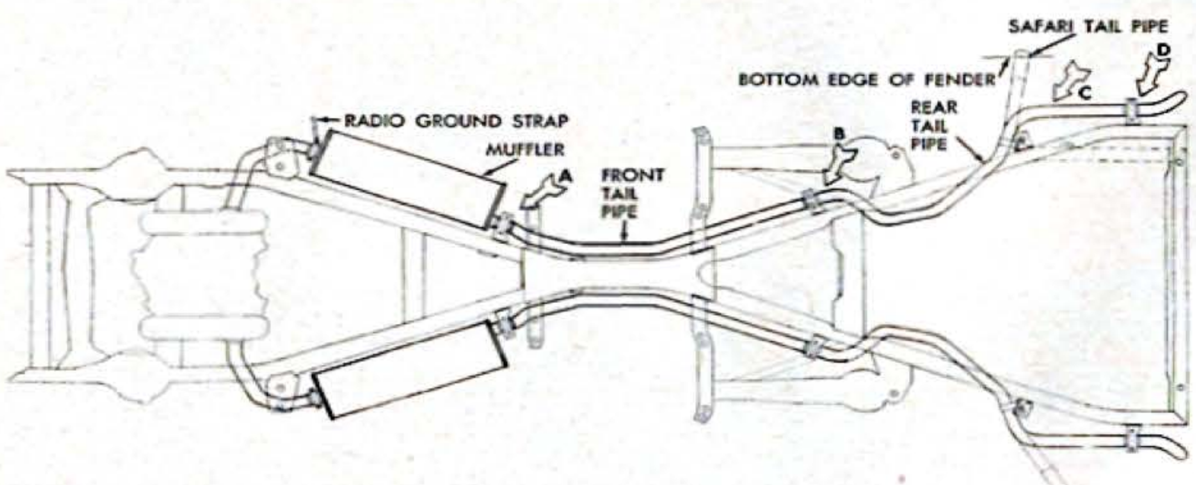
Muffler design is quite complex. Each engine and installation has its own problems that must be taken into consideration. One thing common to all mufflers is that exhaust gases must not pass through them so quickly that they don't get a chance to lose enough of their heat. The length of time the gases are in a muffler at any specific engine speed is controlled with the muffler's length. The longer the muffler, the longer the time that will be required for the gases to pass through it.

Years ago, when cars had lots of open space in their frames, finding room for a fairly long muffler wasn't any problem. But now that open space under cars has been drastically reduced because of styling requirements and, in many cars, by elimination of the frame,



Standard dual exhaust system for Chevy V8 has four mufflers, is shaped to match frame. Short mufflers are "resonators."

Dual system for Pontiac has only two mufflers. Arrows indicate system's supports.



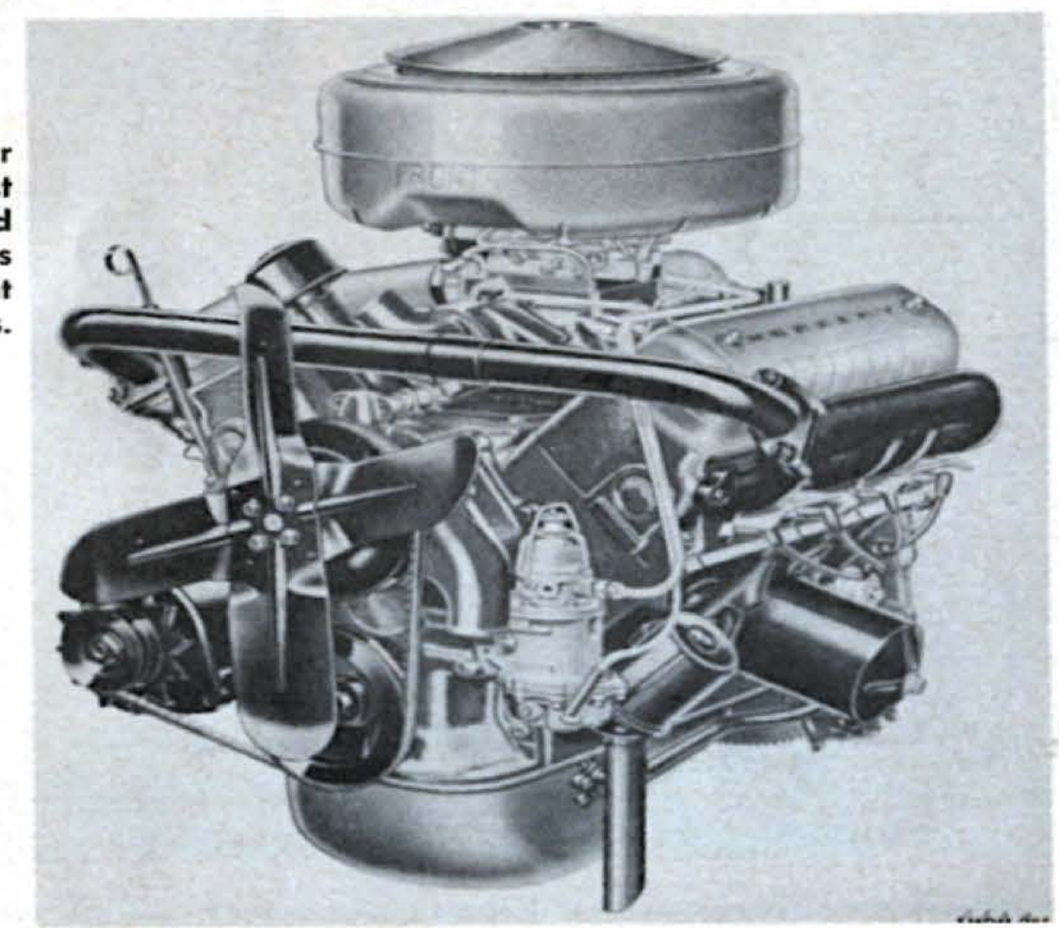
finding enough space for a muffler has become a problem and mufflers must, of necessity, be short. Compensation for the shorter length is made by fitting a muffler's interior with a series of passages through which the gases must flow. The gases enter the muffler at one end, pass back and forth through various tubes and chambers, and leave it at the other end. The design of the pipes and chambers differs widely between muffler makes and for different engines.

After passing through the muffler the gases enter the "tailpipe" for the rest of the trip to the rear of the car where they are released to the atmosphere. Tailpipes can be made of tubing smaller in diameter than that used for headpipes because the comparatively cool gases that enter them have considerably less volume than the hot gases that pass through headpipes. Because of the many obstructions between the muffler and the rear of the car, tailpipes usually consist of a series of bends. Some tailpipes are made in two sections to simplify their installation.

A few years ago there was a strong trend among automobile manufacturers to equip most cars fitted with V8 engines with dual exhaust systems. A dual system consists of a manifold, headpipe, muffler, and tailpipe assembly for each of the engine's cylinder banks. Its purpose is to increase an engine's exhaust system capacity and thereby improve the engine's horsepower output by reducing back pressure.

A dual system is used in place of the standard system that consists of a manifold, headpipe, muffler, and tailpipe assembly for one cylinder bank and a manifold and "crossover pipe" for the other bank. The crossover pipe connects the manifold for the bank that doesn't have a muffler to the headpipe for the other bank. With this type of system the exhaust from both cylinder banks flows through the same headpipe, muffler, and

The cross-over pipe for the single exhaust systems on the first Ford product OHV engines connected the front ends of the manifolds.

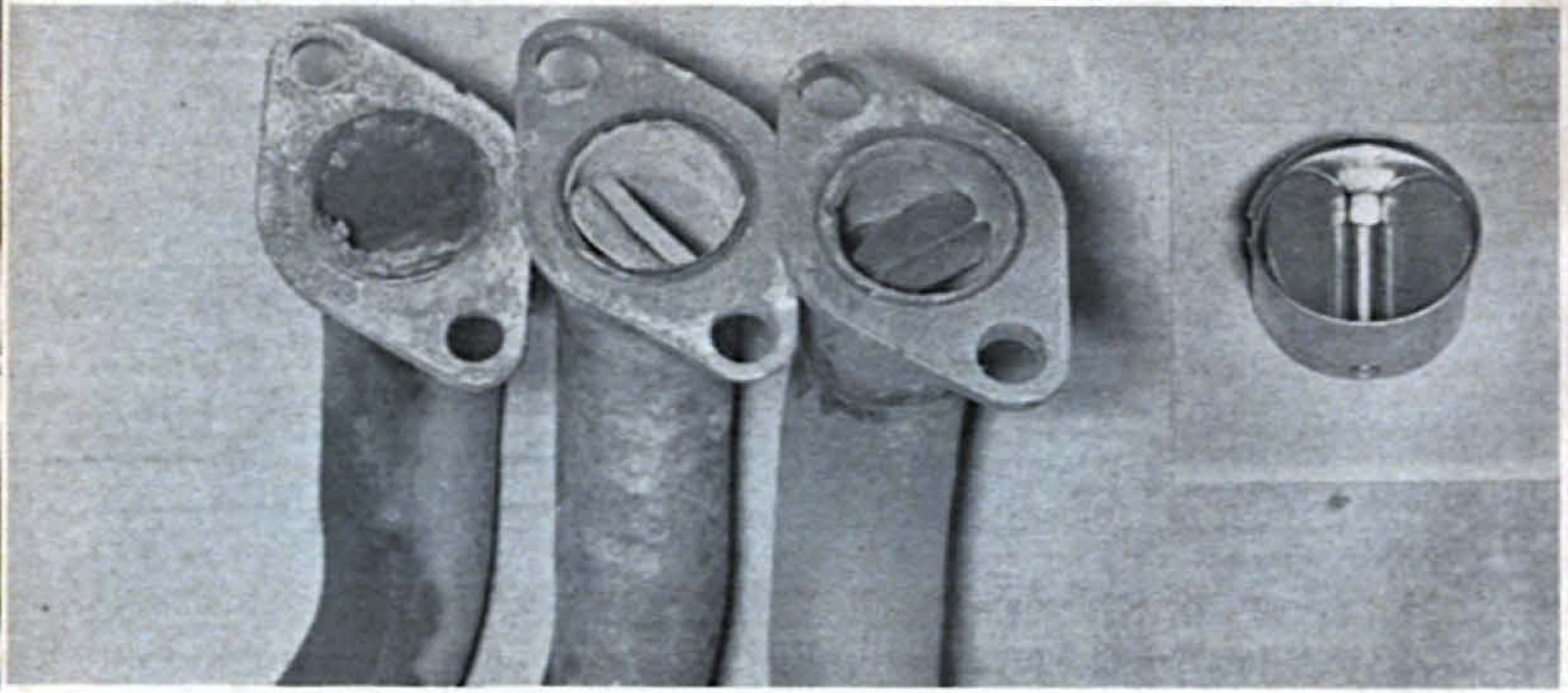


tailpipe assembly. For some engines the crossover pipe connects the front ends of the manifolds. This makes it necessary for exhaust from one bank to flow through the manifold for the other bank to reach the headpipe.

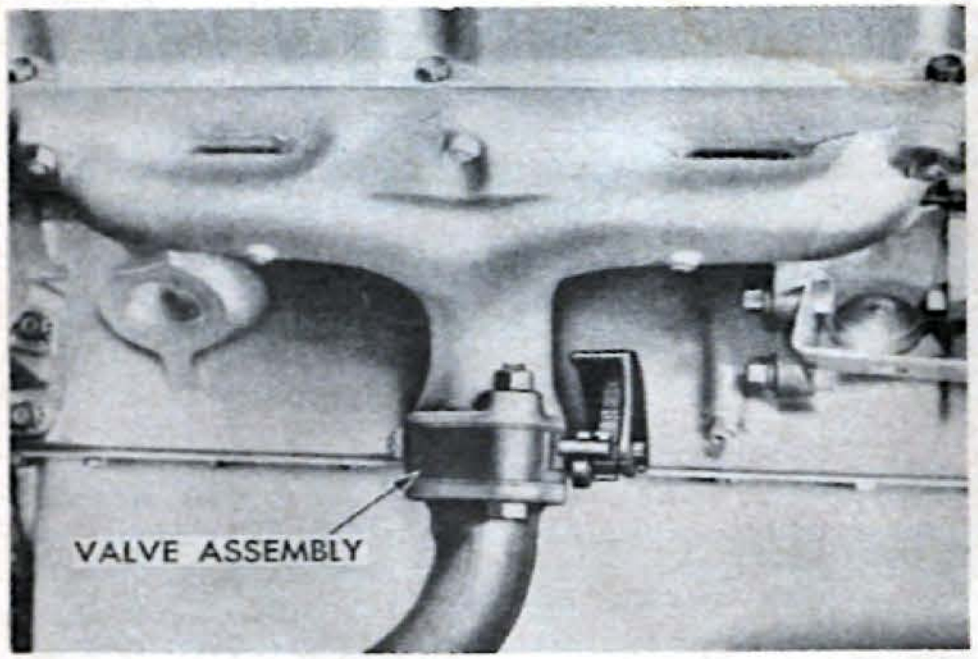
Factory dual exhaust systems do the job they are supposed to do but they create a reliability problem. Flow through one of them is restricted when the engine is cold and at slow driving speeds by the intake manifold heater valve. The purpose of such valves is to restrict the flow of exhaust gases from the manifold on one of the cylinder banks so they will be forced through passages in the cylinder head and intake manifold, through a chamber that surrounds a portion of the intake manifold passage through which fuel and air mixture delivered by the carburetor must travel to reach the cylinders, and then through the other cylinder head to its manifold.

Heat imparted to the intake manifold by the exhaust gases heats the fresh mixture flowing to the cylinders. This causes more of the fuel in the mixture to be vaporized. The result is improved throttle response at normal driving speeds. However, restricting the flow of exhaust gases to one of the mufflers in this manner allows the muffler to run so cold that the water vapor created in the cylinders by combustion of the air-fuel mixture condenses on its inner surfaces. Highly corrosive acids formed when the exhaust gases mix with this water can quickly destroy a muffler. The other muffler, which is being used all the time, has a much longer life because it becomes hot enough to prevent the water vapor from condensing. The vapor continues through it with the exhaust gases without causing any harm.

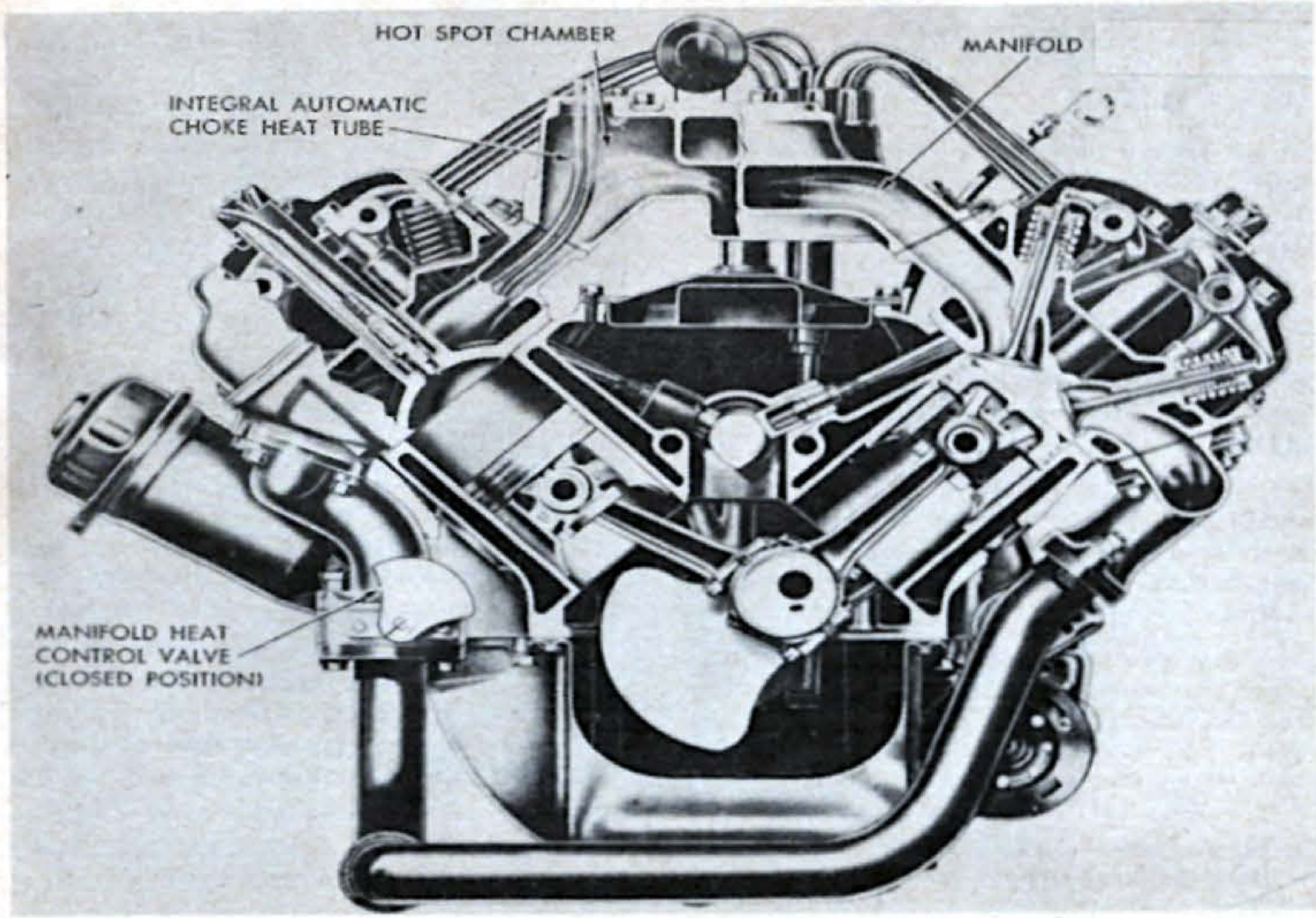
The obvious solution to the cold muffler problem is to eliminate the second muffler. In addition to its cost and short life, a third factor against the second muffler is that few drivers drive their car hard enough to require the extra exhaust capacity it affords. After considering the problems involved with dual exhaust systems and the lack of need for them, automobile manufacturers have returned to the single system for most of their models. ■



A new flathead Ford manifold heater valve and three that froze in different positions.



This '52 Chrysler V8 intake manifold heater valve is of the butterfly type. It has its own housing that bolts between the exhaust manifold and the headpipe.



Evident in this view of a Chrysler are its cross-over pipe and manifold heat passage.

LIMITATIONS OF STANDARD EXHAUST SYSTEMS

ENGINEERS in automobile factories have a rough job. They must not only design the many parts that are finally combined to make an automobile so the parts will do the jobs they must do and have adequate service lives but also so the manufacturing and material costs for the parts will be as low as possible. The cost factor is usually responsible for a very strict guard against any tendency to over-design. In other words, parts are designed to just do the job they are supposed to do, with a reasonable safety factor. Engineering for greater strength or service could add to the car's total cost.

Exhaust systems engineered to these standards are satisfactory on stock engines as long as the engines are used for the type of service for which they were built. Some of the systems are capable of permitting an engine to develop its maximum horsepower output but most of them are not. An exhaust system limits an engine's power output by creating too much back pressure.

Back pressure is the result of the inability of exhaust gases to flow out of a cylinder and through the exhaust system to the atmosphere as rapidly as the piston moves up the cylinder on its exhaust stroke to force the gases out of the cylinder. If the gases cannot flow as fast as the piston is moving them, the piston raises their pressure by compressing them in the same manner it compresses a charge of fresh mixture. The extent of this compression, which determines the pressure in the cylinder when the intake valve opens, depends on the extent to which the exhaust system restricts the flow of gases through it. The greater the restriction, the greater the amount of compression and the higher the pressure.

Because an exhaust system's capacity doesn't change but the quantity of exhaust gases created by an engine becomes greater as throttle opening and crankshaft speed increase, back pressure is a problem only at comparatively high crankshaft speeds. At normal driving speeds the system will have ample capacity for the quantity of gases it must handle but when maximum horsepower is required from the engine it may not be up to the job and back pressure will be excessive.

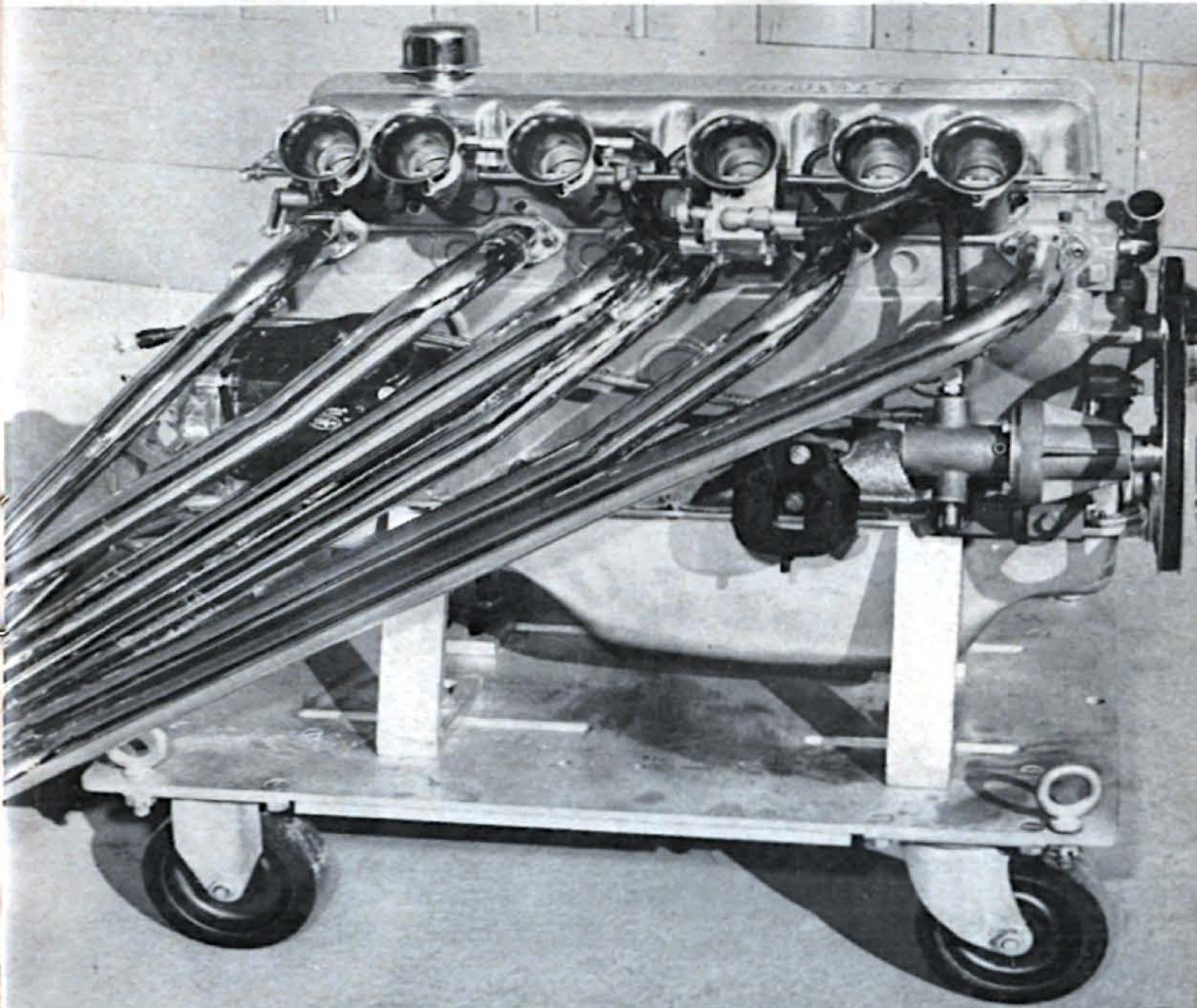
The way back pressure restricts power output is by limiting the weight of the air-fuel charges the engine's cylinders induct on each intake stroke. Actually, back pressure reduces the volume of the fresh charges rather than their weight but their weight is the factor that determines the charges' effect on power output. When all other conditions that have to do with the charges are equal, their weight will become greater as their volume increases.

A flow of fresh mixture into the cylinders of a naturally-aspirated engine, which is an engine that isn't fitted with a supercharger, depends on the difference between the pressure in the cylinders during intake strokes and the pressure of the air surrounding the engine. This difference is a "pressure differential." It is the result of a piston's increasing the combined volume of its cylinder and the cylinder's induction system by moving down the cylinder. When a piston moves in this manner the gases in the cylinder and its induction system expand to maintain the same pressure at all points. When the gases expand, their pressure drops.

In contrast to the steadily dropping pressure in the cylinder, the pressure of the air surrounding the engine is, as far as this explanation is concerned, remaining at a constant value. This pressure is "atmospheric pressure."

Atmospheric pressure is created by the weight of the blanket of air that surrounds the earth. It varies with the thickness of the blanket and the air's temperature. Its standard pressure, measured at sea level when the temperature of the air is 62 degrees Fahrenheit, is 14.7 pounds per square inch. As the altitude at which the measure-

The best way to eliminate standard exhaust system limitations is with individual pipes.



ment is taken is increased above sea level, the pressure becomes less, and as the distance below sea level becomes greater, the pressure increases. As the temperature of the air rises above 62 degrees, the pressure becomes less, and as the temperature drops below 62 degrees, the pressure increases.

When a piston is moving down its cylinder on an intake stroke the head of the cylinder's intake valve is off its seat. This places the cylinder in communication with the air around the engine by means of the passages in its induction system. As movement of the piston reduces the pressure in the cylinder and induction system, atmospheric pressure forces air through the induction system and into the cylinder in an effort to equalize the pressures. As the air passes through the carburetor the correct quantity of fuel is mixed with it to form the air-fuel mixture.

Theoretically, exhaust gases should flow through an exhaust system fast enough to allow the pressure of the residual gases in a cylinder to be at atmospheric pressure when the intake valve opens. Then, if the pressure in the cylinder's induction system is also at atmospheric, which it can very possibly be, fresh mixture will start to flow into the cylinder the instant the piston starts its intake stroke. But if the pressure of the residual gases is higher than atmospheric and the pressure in the induction system is atmospheric, residual gases will flow out of the cylinder and into the induction system when the intake valve opens. This flow continues until downward movement of the piston on its intake stroke lowers the pressure in the cylinder to a value lower than that in the induction system. Fresh mixture then forces the residual gases back into the cylinder where they mix with the mixture and become part of the inducted charge.

From the foregoing it is apparent that residual gases limit an engine's power output in two ways. Gases of any pressure displace a certain volume in the cylinder that otherwise would be filled with fresh mixture. Gases under pressure higher than atmospheric delay the flow of fresh mixture into the cylinder by the length of time it takes them to enter the induction system and then reenter the cylinder.

For the maximum volume of mixture to flow into the cylinder during the intake stroke the pressure differential must be as high as possible when the intake valve opens, with cylinder pressure low, and as low as possible when the valve closes. The theory is for pressure in the cylinder to be the same as atmospheric pressure when the valve closes.

Residual gases raise the temperature of the fresh mixture but authorities say that the effect of this temperature change on power output can be disregarded because the transfer of heat doesn't take place until after the intake valve has closed. If the mixture's temperature were raised before the mixture entered the cylinder or before the intake valve closed it would be expanded and the weight of the inducted charge would be reduced. This would cause a reduction in power output.

As stated previously, an exhaust system can't be any better than its least efficient portion. The portion this may be depends on the particular system. It may be the combustion chamber, it may have to do with the valve or the way the valve is actuated, it may be the passages between the valve and the manifold, it may be the manifold, or it may be the muffler or its pipes. A system can be well balanced from one end to the other but have too small a flow capacity for the engine on which it is used.

It's possible but not practical for manufacturers of automobiles that have modern large-displacement V8 engines to equip them with single exhaust systems that would handle the same volume of exhaust gases as a dual system.

One manufacturer has estimated that pipes in a single system that would have this ability would have to be 2½ to 3 inches in diameter. In view of this it's safe to assume that any standard single exhaust system on a modern V8 will be inadequate at high engine speeds.

Components of standard exhaust systems that are usually the least efficient and the major causes of back pressure in a stock engine are manifolds and mufflers. Manifolds seldom have the flow capacity to handle the volume of gases that must flow through them at high engine speeds and usually their design is such that flow from certain cylinders can interfere with flow from others.

Manifold deficiencies are generally attributed to lack of space in the engine compartment. In modern automobile design, styling and chassis considerations determine where the engine can be placed. If the engine is a V8 it is almost invariably dropped into a hole formed by front suspension brackets, air ducts, the steering column and its shaft, the power brake mechanism, the car's heater, etc. This would be fine if the engine didn't require exhaust manifolds because there is seldom room for them. Usually, the only manifolds that can be used must have small passages, short-radius turns and bends, and branches from the individual cylinders that are too short to keep one cylinder from interfering with another. The manifolds are compact, they clear all the interference points in the engine compartment, and usually they look nice but they are bottlenecks in the exhaust system.

The terrific growth in engine displacement that has occurred in automobile engines during the past few years has made things rough for muffler engineers. The larger an engine's displacement becomes, the more difficult it is to silence its exhaust. Also, the changes in chassis design that have limited the space in which mufflers can be installed have compounded the problem. The result is that muffler design has become almost a science. Each engine and chassis combination presents its own combination of silencing and installation problems.

Years ago mufflers were cylindrical in shape and the exhaust gases traveled straight through them. Openings in the wall of their inner pipe allowed the gases to pass through the pipe and into surrounding chambers when pressure of the gases was high. When the pressure dropped, the gases would flow back into the pipe. This action continued as long as the engine was running and affected each charge of exhaust gas as it made its way through the muffler.

The action of exhaust gases in modern mufflers is similar to that of the early straight-through types in that it passes in and out of openings in the passages through the mufflers and into chambers of different sizes and shapes but it differs in that the direction of the flow changes a number of times to give a back and forth route that lengthens the distance the gases must flow. The shapes of the openings in the inner pipes and the shapes and locations of the chambers through which the gases pass and into which they expand are important to a muffler's silencing ability.

The intake manifold heater valve that all exhaust systems have can have a serious effect on back pressure. These valves are designed to close at low engine speeds when their effect on engine performance is unimportant and to open at high engine speeds when the full capacity of the exhaust system is required; however, it's not unusual for them to become rusty or corroded and fail to open properly. When a valve of this type doesn't open as it should the performance of at least half the engine's cylinders will be seriously affected. It will be impossible to extract anywhere near maximum performance from the engine. ■

IMPROVING AN EXHAUST SYSTEM

ONE OF the very first things that must be done when modifications are to be made to an engine to enable it to develop greater torque and horsepower outputs and to run at higher crankshaft speeds is increase the capacity of its exhaust system. It stands to reason that an exhaust system that isn't capable of handling the volume of exhaust gases created by a stock engine will be even more inadequate on a reworked engine.

Just as engines are reworked to different degrees for various types of use, exhaust systems are reworked in different manners for various applications and to comply with rules for specific competition classes. The various modifications possible will be listed in their logical order. They can be used in the combinations that will best serve the requirements of different engines.

EXHAUST VALVE

The exhaust valve plays an important part in the exhaust system. Its features and the things concerned with it that affect the flow of exhaust gases out of the cylinder are the diameter of its head, the head's shape, the angle of the head's face, the clearance in the combustion chamber around the head when the head is off its seat, the distance the head is lifted off its seat, and its opening and closing pattern and duration.

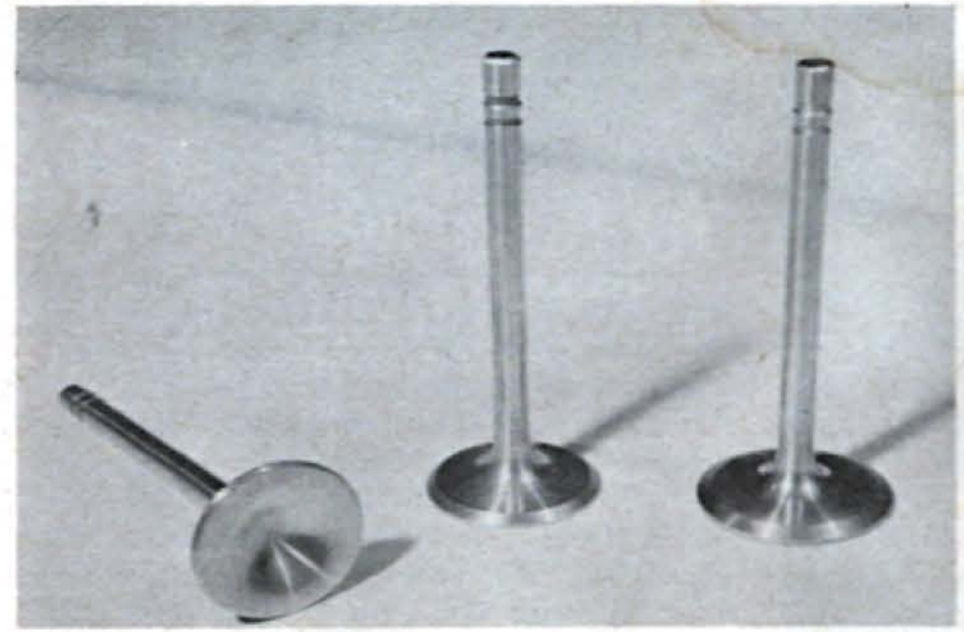
The diameter of the valve's head determines the diameter of the opening in the combustion chamber through which exhaust gases can flow to leave the cylinder. If the head is too small, the opening will be too small and the flow of gases will be restricted.

Exhaust valves in all modern automobile engines have heads smaller than those on intake valves. There are two reasons for this. One is that exhaust gases are forcibly ejected from the cylinder by their own pressure and movement of the piston whereas induction of fresh mixture depends on the relatively weak force of atmospheric pressure. Therefore, it is reasoned that exhaust valves don't have to be as large as intake valves. The second reason is that there is still combustion pressure in the cylinders when the exhaust valves open. This pressure can be quite high, depending on the valve timing. Because the pressure is acting against the valve's head, force much greater than that that would have to be exerted merely to overcome the pressure of the valve's spring is required from the camshaft and the rest of the valve's actuating mechanism to move the valve off its seat. The larger the head, the greater the total pressure on it and the more apt the valve's mechanism is to be noisy and to suffer from wear. But from the hot rodder's point of view, the additional force required by valve actuating mechanism to open larger valves against the pressure in the cylinder is secondary to the better performance the valves provide.

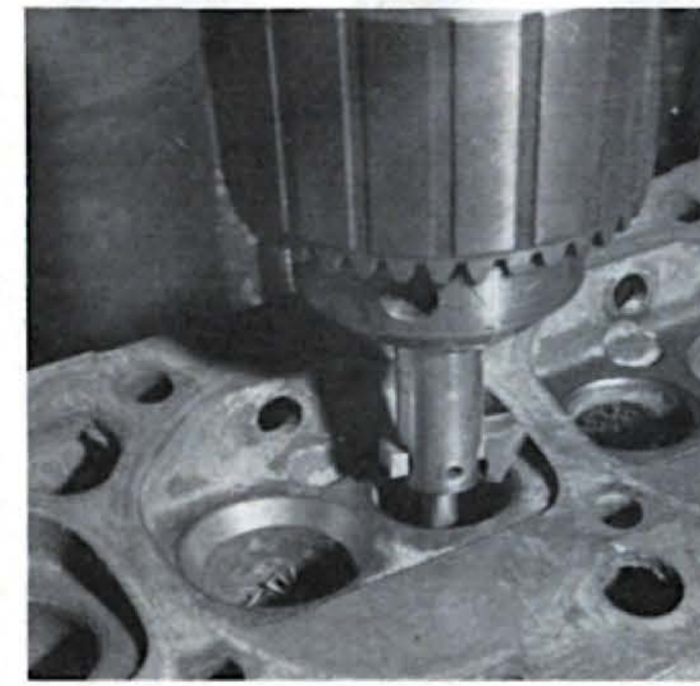
After an engine has been reworked by normal hot rodding procedures, especially if its displacement has been increased by boring and stroking, an exhaust valve that was just the right size for the engine in its stock form cannot help but be too small. The obvious solution is to install a larger valve. In most engines a valve with a head approximately ⅛-inch larger than standard can be installed without difficulty.

The factor that usually determines the maximum possible diameter of the valves that can be installed in an engine is the clearance between the standard valves. There must be at least .035-inch between the heads of the valves for each cylinder when they are cold to prevent their touching when they are at their normal operating temperatures.

Special offset valve guides that permit the installation of valves considerably larger than those that would be possible with standard guides are now available for some engines. The principle on which these guides work is that of increasing the distance between the centers of the bores in the guides for a cylinder's intake and exhaust valves.

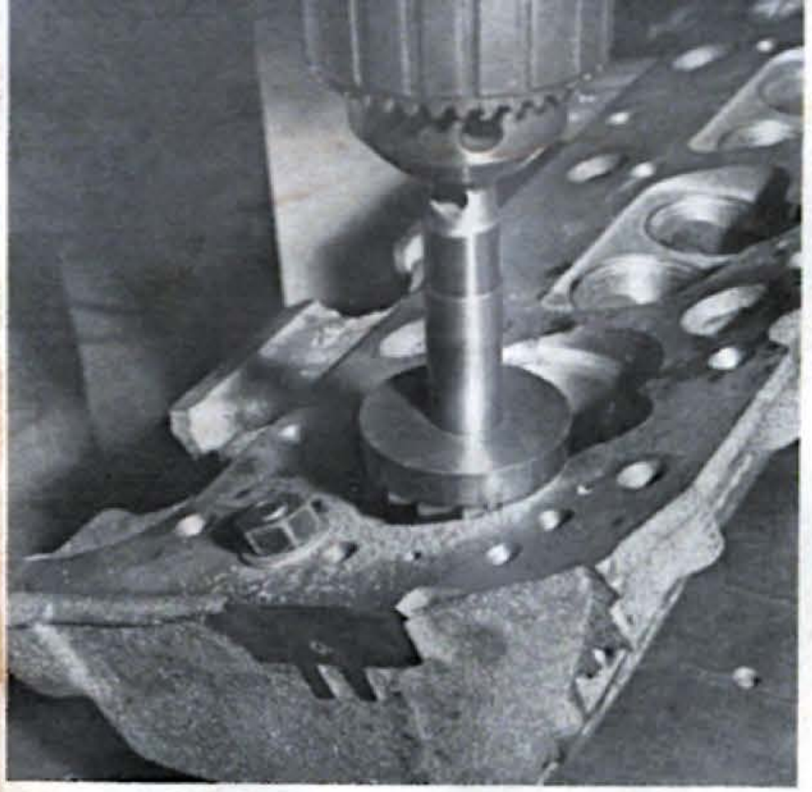


Special oversize valves, similar to these intake and exhaust types, are available for all V8 engines.



ABOVE—A cutter of this type can be used to enlarge the upper ends of valve ports for oversize valves.

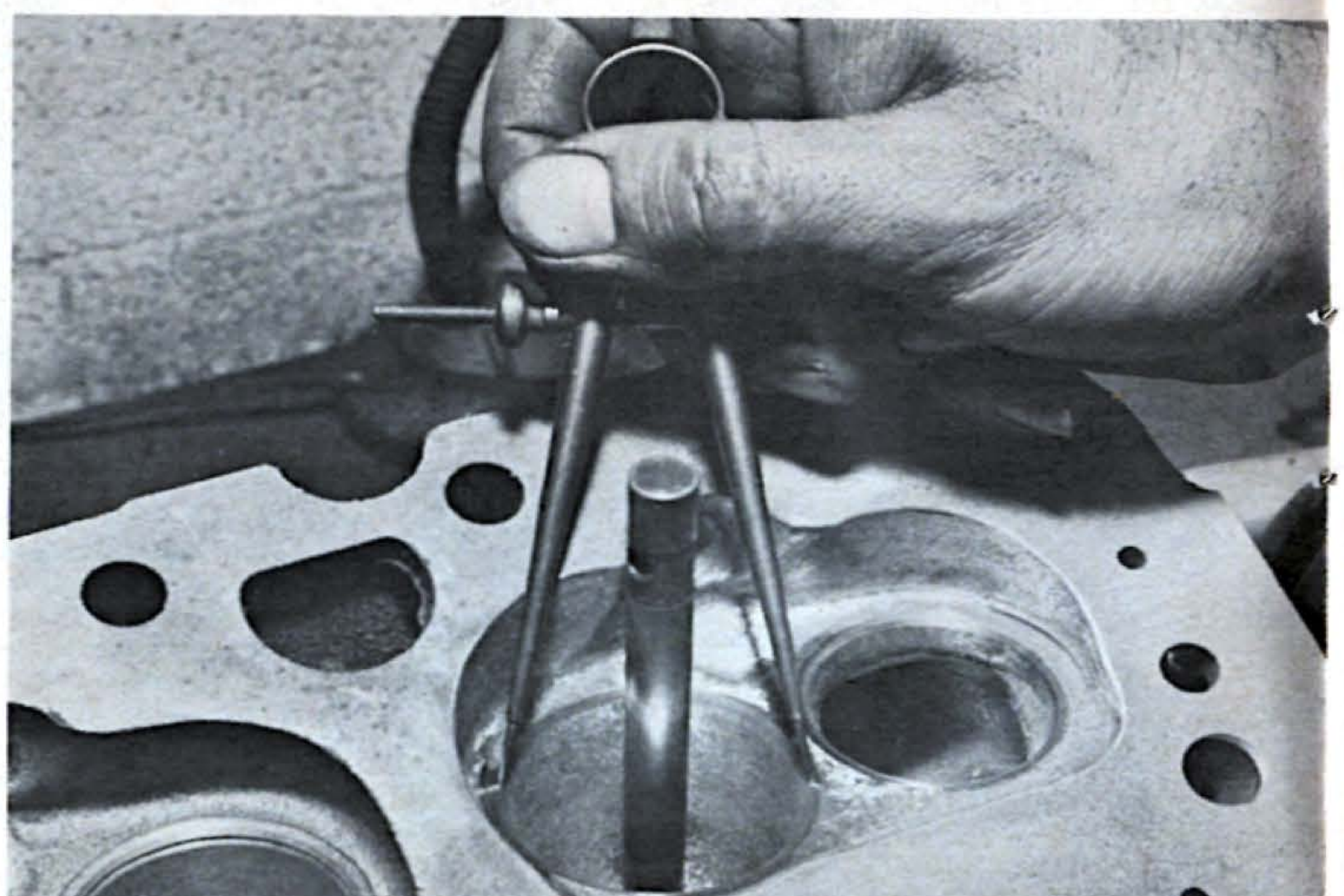
LEFT—After their upper ends have been enlarged, the rest of the valve ports are enlarged with a grinder.



Enlarging combustion chambers around big valves is easy with this special cutter.

This increases the distance between the valves' heads by the same amount. However, the head of a valve installed in an offset guide can be enlarged twice the amount the guide's bore is offset and still have its original clearance from the other valve.

Usually, the amount of exhaust gases that will flow past a valve's head can be increased by reshaping the head. Valve head contour influences the way the gases will flow out of the cylinders; however, the best contour is not always the one that would appear to be best for the job. The head should direct the gases into the valve's port so they will flow through the port in the best possible manner. A tulip-shaped head, which means one that has large fillets between its underside and the stem, may be better than one that has a flat underside.



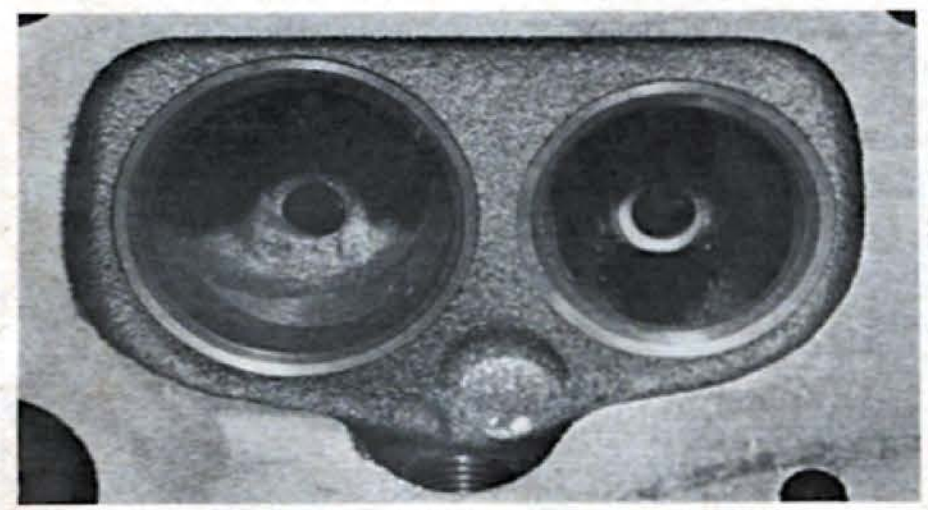
Valve seat diameters to match the new valve heads are easily established with dividers.

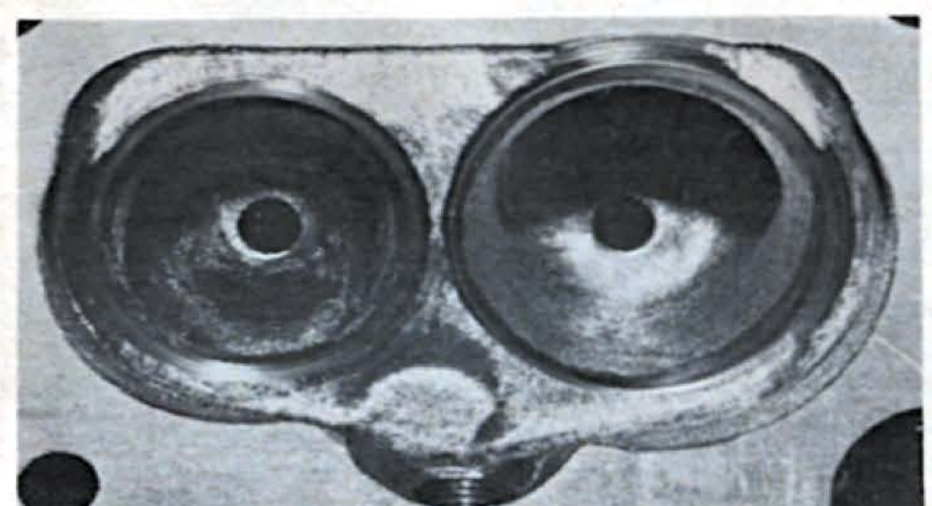
Heads of stock valves can usually be made thinner. The best way to do this is by removing material from the top surface of the heads. This reduces a head's "margin," which is the thickness of the material between the top of the head and the upper edge of the head's face. The margin on stock valves is fairly thick to provide plenty of material for grinding new faces during valve reconditioning jobs and to give the heads adequate body to help them resist the high temperatures and pressures to which they are subjected. Exhaust valves in a reworked engine don't need more than a minimum margin because they are expendable, so to speak and, if necessary, can be replaced at fairly frequent intervals. Actually, the life of a valve in a reworked engine is long enough because the mileage such an engine gets is small compared to that accumulated by one for normal use.

Making valve heads thinner reduces the valves' weight a slight amount. This could be beneficial at high crankshaft speeds by allowing the valves to function at a few more rpms without floating.

It's common practice to polish both the top and bottom surfaces of valve heads. This is a good idea as the resistance of a polished surface to the flow of gases over it is undoubtedly less than the resistance presented by a rough surface.

The angle of the face on a valve's head and the corresponding angle of the seat in the cylinder head or block on which the head rests when the valve is closed has an influence on the area between the face and the seat through which gases can flow when the valve is open. The smaller the angle, which is





Above is a standard combustion chamber in a 283 Chevy head. Below is another chamber in the same head that has been fitted with oversize valves and enlarged for the valves.

the angle the face describes with the upper surface of the valve's head, the greater the area. This is the reason 30 degree faces are used on the intake valves for many engines. However, a greater angle, such as 45 degrees, makes the valve self-centering in the seat and gives it a wedging action that helps it seal better. Sealing is important with exhaust valves because they operate at much higher temperatures than intakes. In view of this and the fact that there is ample force available to move the exhaust gases out of the cylinder, 45 degree faces are used on exhaust valves for most high-performance engines.

Something that must be checked closely when oversize valves are to be installed is the clearance that will be between the valve heads when they are off their seats and the walls of the combustion chambers in the cylinder or cylinder head. For an ideal condition this clearance will be great enough to provide an area between a valve and the wall at least equal to that between the fully-opened valve and its seat in the head or block. In most engines it is difficult, if not impossible, to provide the ideal area but the area must be as large as practicable. Less area than that necessary creates a "shrouding" effect that limits the quantity of exhaust gases that can flow between the wall and the valve.

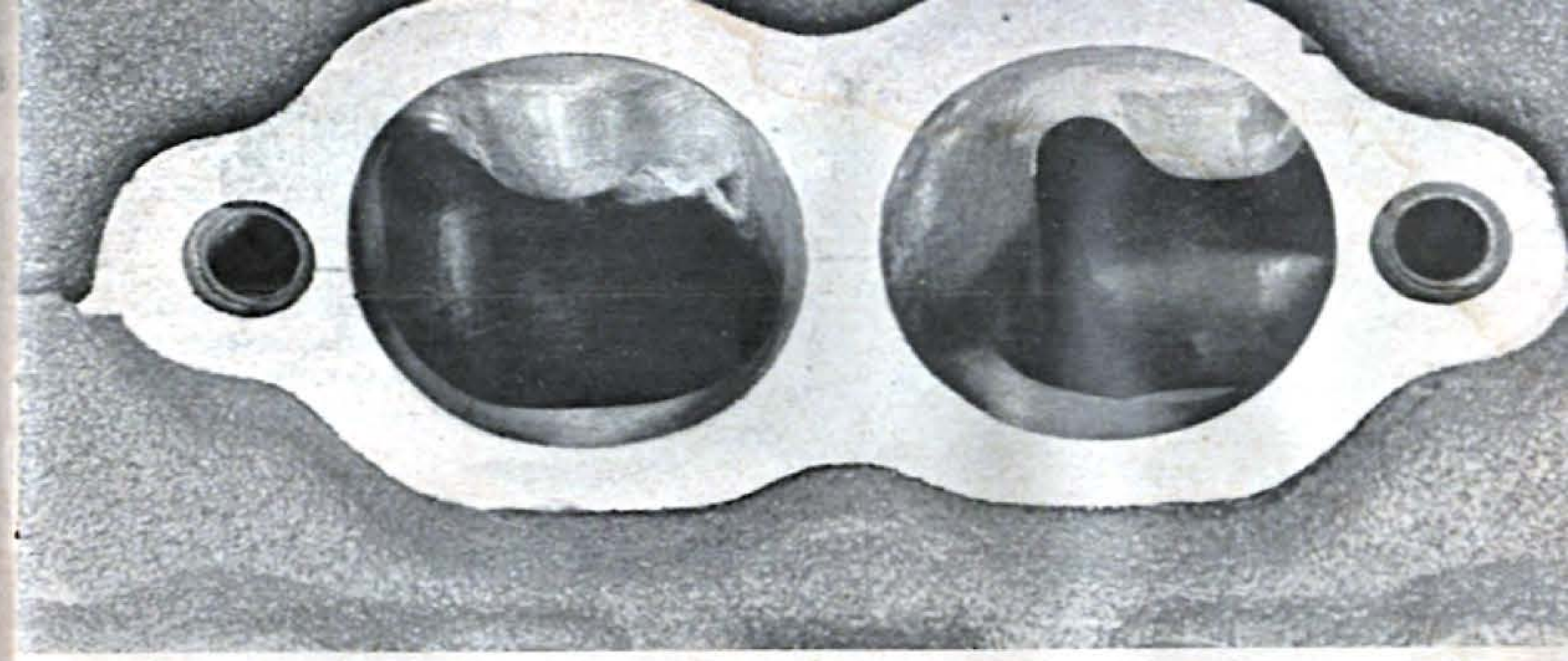
The only method a rodder has of increasing the area around a valve is by enlarging the combustion chamber. This can be done by grinding material from the chamber's wall with small grinding wheels rotated by a portable grinder or flexible shaft. Care must be taken when doing this to prevent making the wall so thin that it will crack or break under combustion pressure.

It's not impossible that in some engines the shrouding effect, even after the combustion chambers had been enlarged, wouldn't allow exhaust gas flow out of the cylinders to be greater than that past standard valves or valves only slightly larger. It would be foolish to install oversize valves in such an engine because of their additional weight and greater resistance to being lifted off their seat. So, rather than forging blindly ahead and installing oversize valves just because they're big, first make a few measurements in the combustion chamber to determine whether the additional valve head area is actually going to be an asset to the engine's breathing ability.

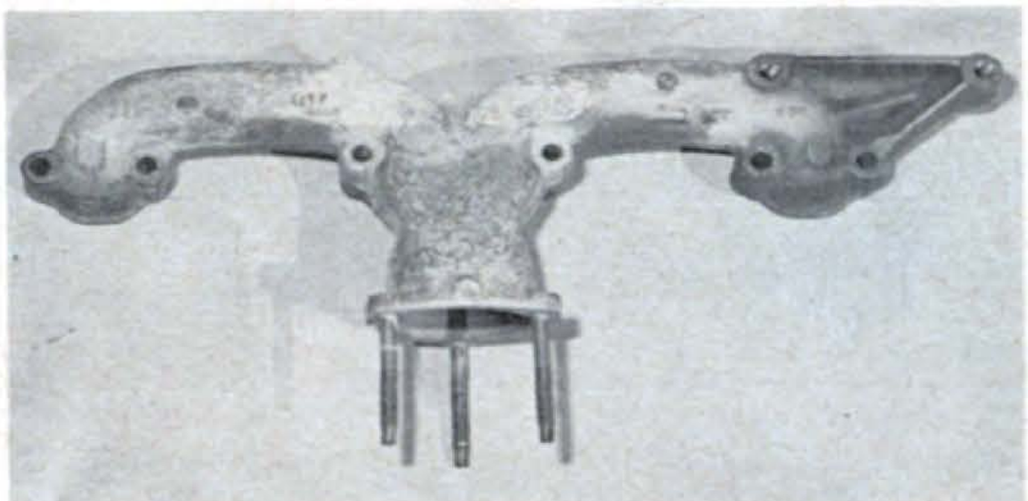
Regardless of the diameter of a valve's head, the area between it and its seat in the head or block through which exhaust gases can flow is dependent on the distance the valve is moved away from the seat. The greater this distance, up to the point where the area equals the area of the valve port, the greater the quantity of gases that can flow from the cylinder. The maximum distance a valve is moved away from its seat is its "lift."

Maximum area is obtained between a valve head and its seat when the lift

A gasket and a scriber are used to mark an exhaust port as a guide for enlarging.



These Chevy exhaust ports, rectangular in stock form, were made round for headers.

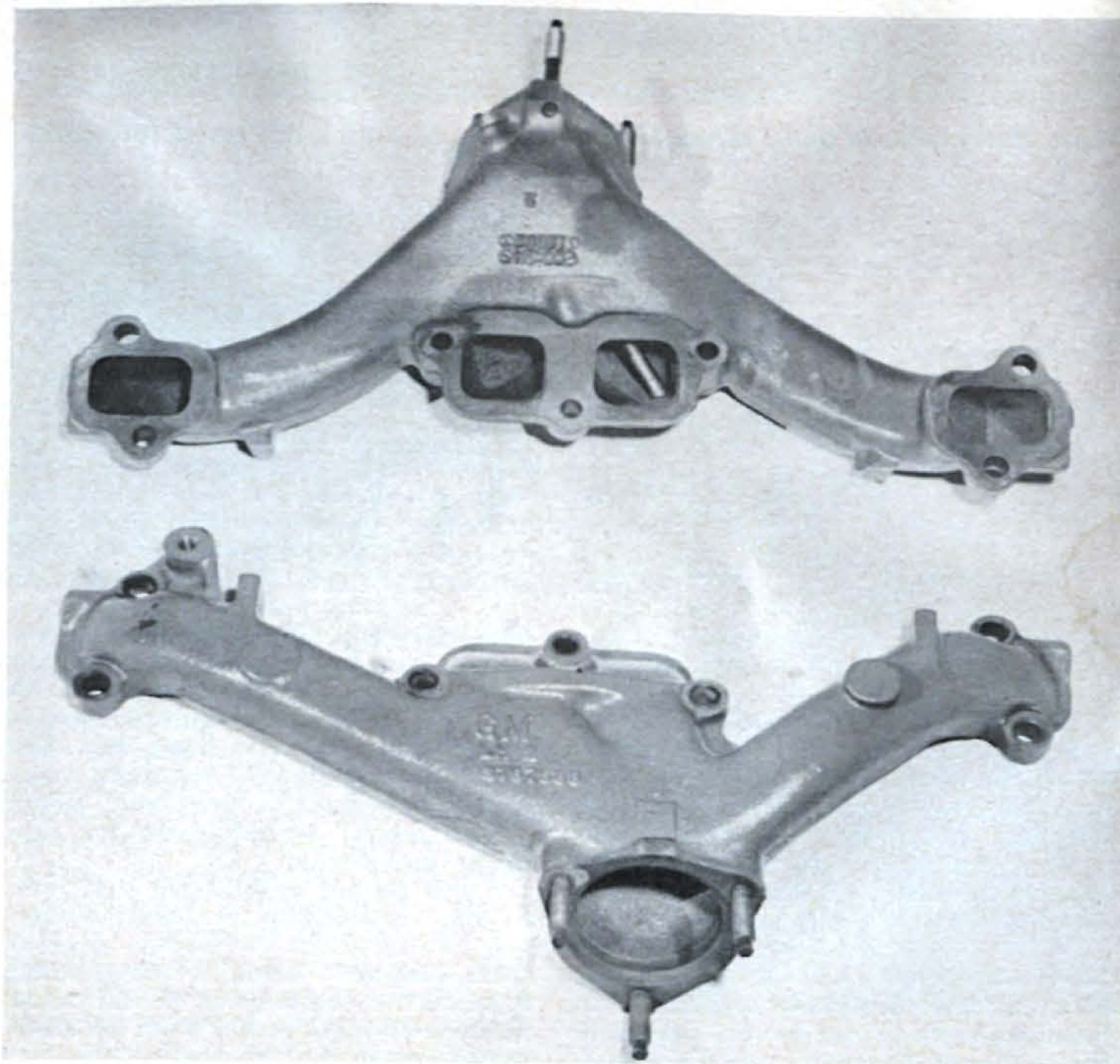


This "ram's horn" manifold, for a Corvette, is of better design than most stock types.

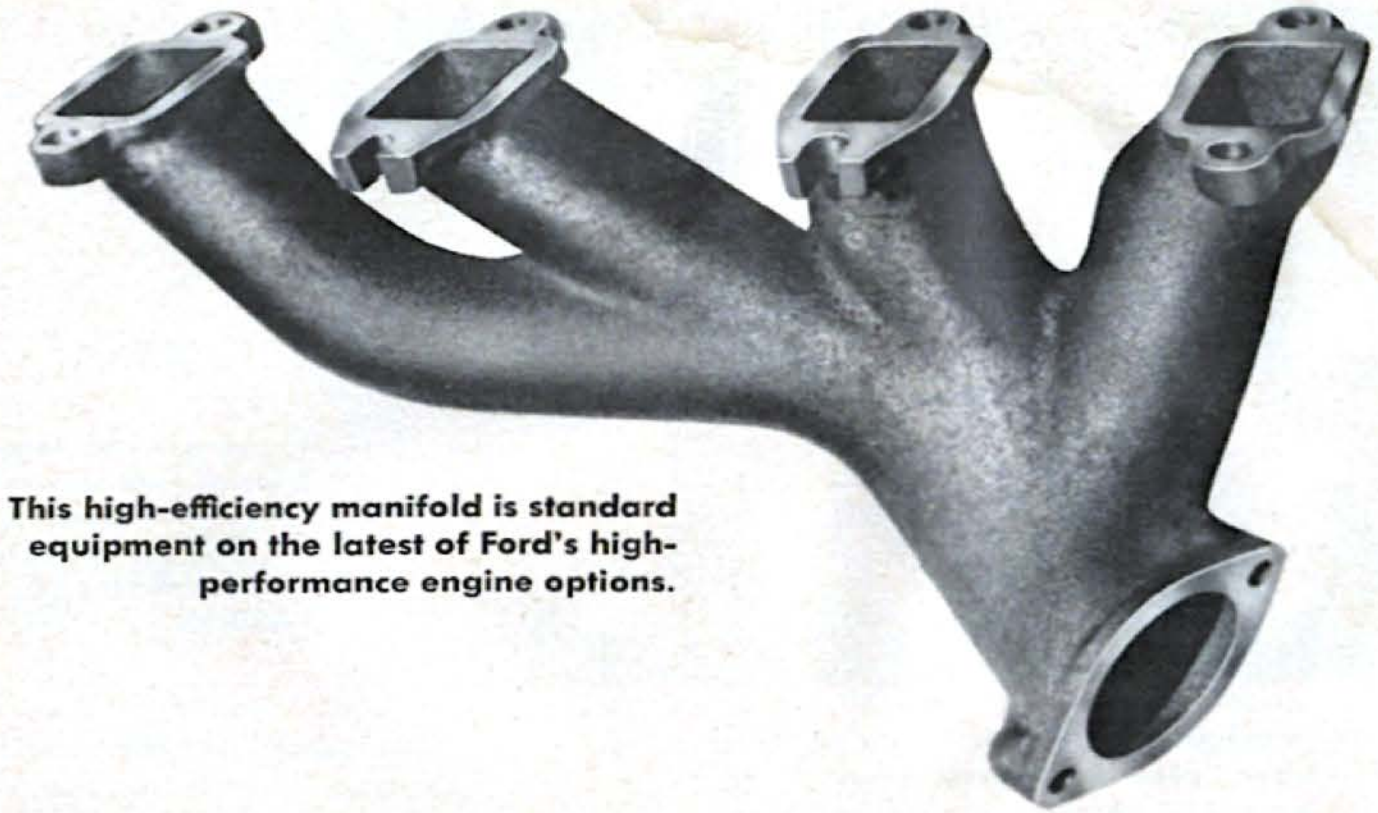
equals approximately one-fourth of the head's diameter. This means that the minimum lift for a valve that has a head 1.5-inch in diameter would be ⅜-inch. However, better flow will result if the lift is made greater than this because flow through the valve port becomes easier as the lift becomes greater. In other words, moving the valve head farther from the seat after the lift equal to one-quarter of the head's diameter has been reached will allow greater quantities of exhaust gases to flow from the cylinder. Unfortunately, there are factors that limit the amount a valve can be lifted. Among these are clearance in the combustion chamber for the valve's head, limitations in the amount a valve's spring can be compressed, cam and lifter design, forces created in the valve's actuating mechanism, an increased tendency to float, etc. Lifts provided by many reground cams range between 7/16-inch and ½-inch. These should be adequate for practically any engine.

Valve timing is the term that refers to the relationship of valve opening and closing times in relation to crankshaft position. Actually, valve timing is related to the location of the pistons in the cylinders rather than to crankshaft position but because piston locations are difficult to determine and the pistons must follow a definite move-

Another manifold of ram's horn design is this one from a racing kit for a 312-inch Ford.



These manifolds were standard equipment on Chevy's 409 when introduced in '61.



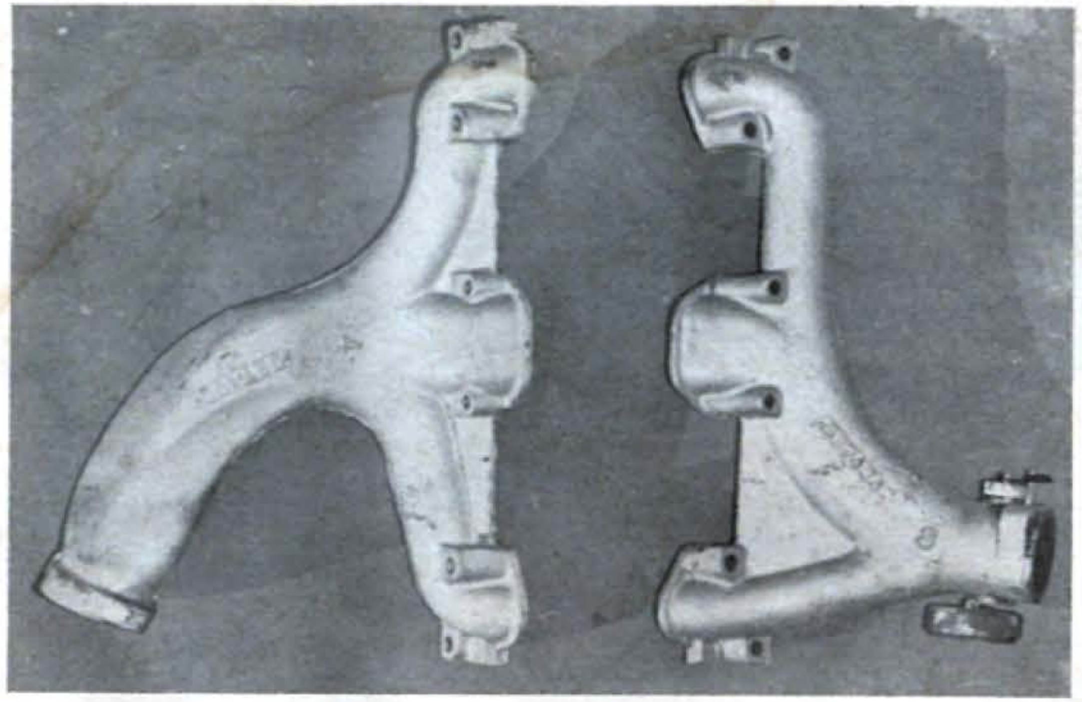
This high-efficiency manifold is standard equipment on the latest of Ford's high-performance engine options.

ment pattern as the shaft rotates, it has become common practice to use crankshaft position. Shaft position is easily determined with a degree wheel of some sort. After the wheel has been mounted on one of the shaft's ends and adjusted correctly in relation to piston position, crankshaft rotation is measured in degrees.

Valve timing figures supplied for either standard or special camshafts are of little, if any, value for determining the performance camshafts will provide. The only practical value they have is for determining whether the camshaft, as it is installed, opens the valves and allows them to close as the man who designed the shaft's cams says it should. For any other purpose the figures can be misleading because they give no indication of the action imparted to a valve between the time it leaves its seat and then contacts the seat again as it closes. The valves may open and close slowly or quickly.

The thing about valve action that is important, and about which timing figures can be deceiving, is the total opening area provided by a valve from the time its head leaves the seat to open until it contacts the seat again to close. This area is measured by plotting on graph paper the amount the valve moves per degree of crankshaft rotation. Two valves that have exactly the same timing can have altogether different opening areas simply because they open and close at different rates. The one that opens and closes at the higher rate will have the greater area, if its lift is equal to that of the other valve.

Although a piston doesn't start its exhaust stroke until it has reached the bottom of its cylinder on its power stroke, the exhaust valve is opened several crankshaft degrees before this, as explained in a previous chapter. This gives the pressure in the cylinder a chance to drop and the exhaust gases the opportunity to start moving through the exhaust system before the exhaust stroke starts. One authority has stated that the exhaust valve should be open an amount equal to fifty percent of its lift when the piston reaches bottom center on its power stroke.



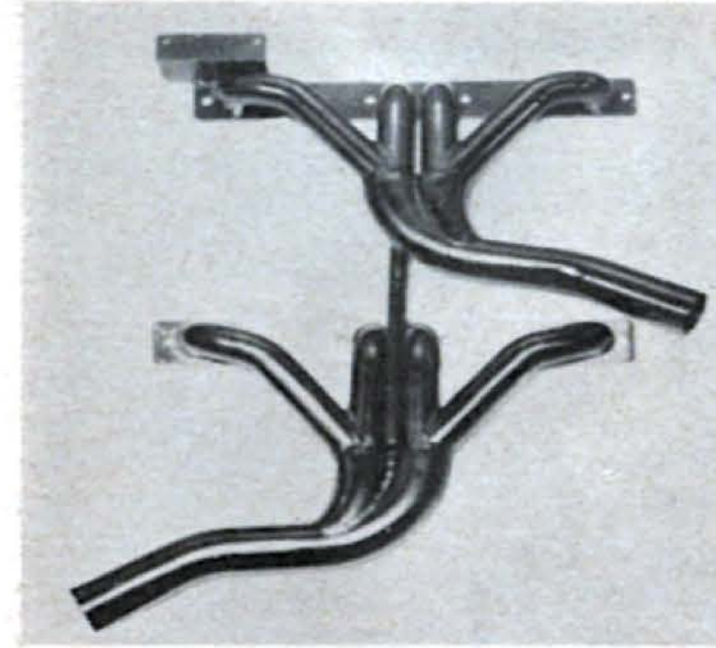
These are the second best of two special types of heavy duty manifolds for high-performance Pontiacs.

The exhaust valve is usually held open until after the piston reaches the end of its exhaust stroke. The purpose of closing the valve late in this manner is simply to allow it to be open when the piston reaches the end of the stroke. The previously quoted authority states that at the end of the stroke the valve should be five percent open. This and the previous figure are, however, merely approximations. The many variables involved in engine and exhaust system design prevent the possibility of cut and dried formulas for valve action when ultimate performance is the goal.

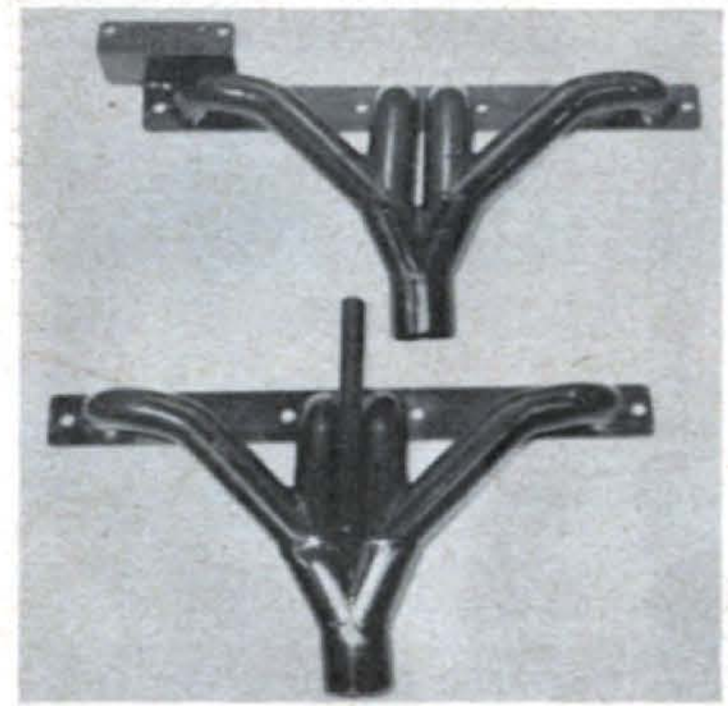
The ideal valve timing for any engine is such that the maximum possible quantity of exhaust gases can flow out of the cylinder on exhaust strokes and the maximum possible quantity of fresh air-fuel mixture can flow into the cylinder on intake strokes and be trapped in the cylinder when the intake valve closes. This is a very difficult condition to attain. One of the problems involved is that conditions in a cylinder vary so much at different crankshaft speeds; however, a rodder is usually concerned with maximum power output, which automatically means high crankshaft speeds. To gain this type of performance he must make sacrifices at low crankshaft speeds. To him, these sacrifices are usually of minor importance.

The exhaust valve port must be as large as possible if the maximum quantity of exhaust gases is to flow through it. It should be enlarged by removing material from its walls with grinding stones or suitable reamers. As the port's diameter can't be any larger than the inner diameter of its valve seat, it makes sense for the seat to be as large as it can within the limitations imposed by the valve head. The

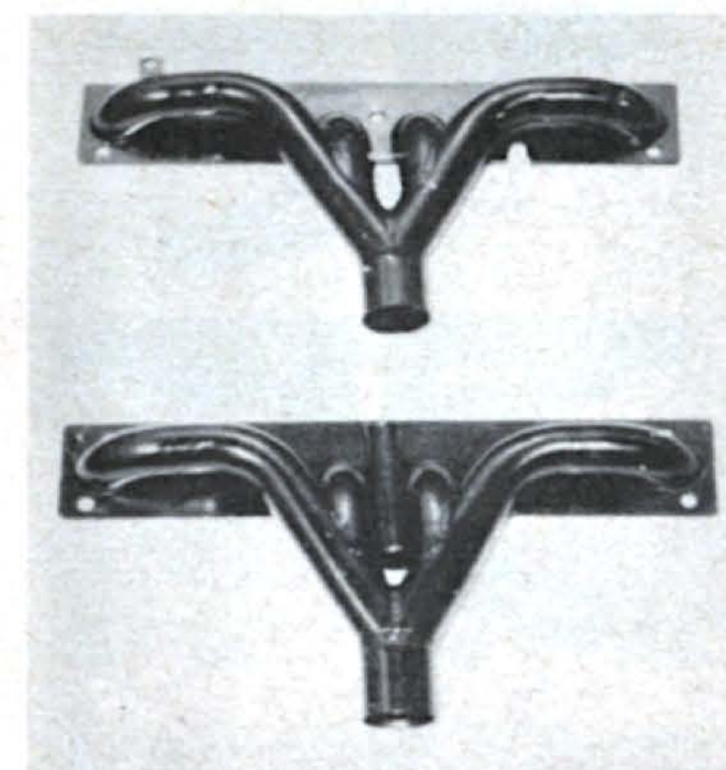
The best of Pontiac's heavy-duty manifolds are cast-iron headers, with dual outlets.



Hedman "Hedders" are made in Los Angeles. These are for '55-'57 Chevys.



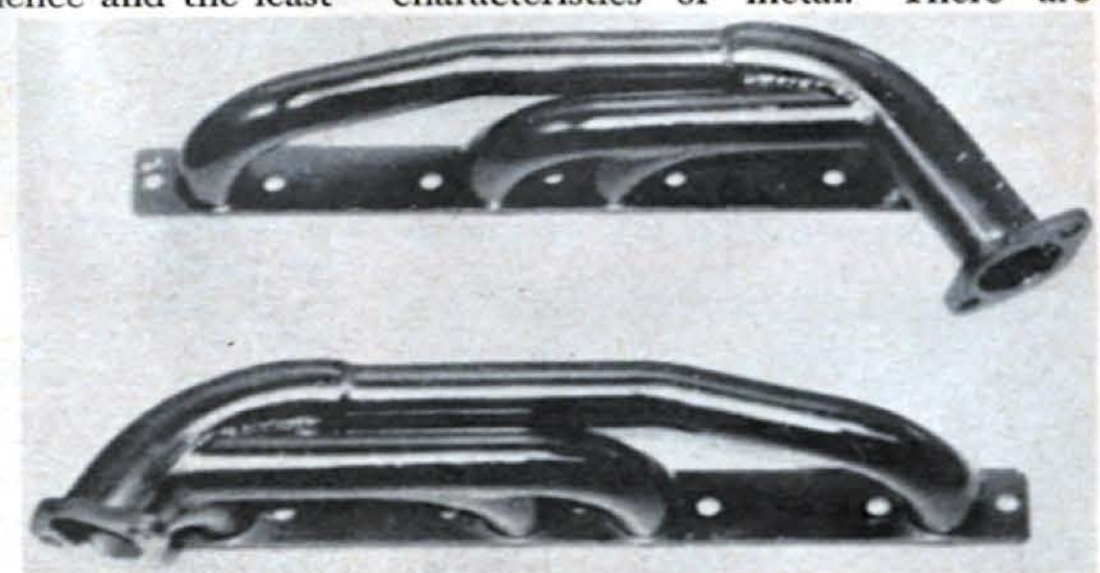
All Hedders are steel tubing welded to a steel plate. These fit '58-'61 283 Chevy.



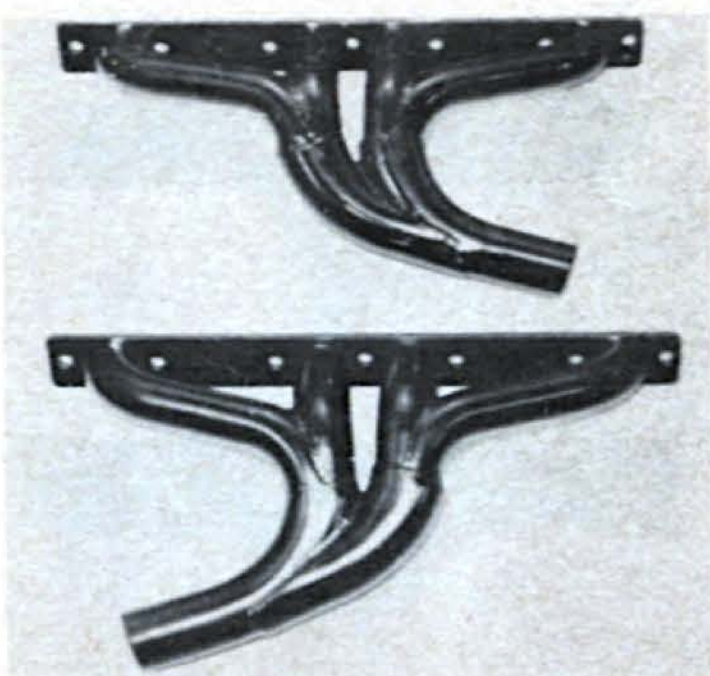
Hedman Hedders have proven to be a definite exhaust system improvement. These are 348 Chevy.

seat's outer diameter should be just a few thousandths of an inch smaller than the valve's head and the seat should be as narrow as practicable for satisfactory heat transfer from the valve's head to it and for adequate service life. Exhaust seats 1/16-inch to 3/32-inch wide fulfill these requirements for practically any engine.

The contour of the port should be such that the gases flowing through it will be directed into the exhaust passage to which it is connected with a minimum of turbulence and the least possible restriction. It isn't usually possible to change the contour much from what it was originally because the amount of material that can be removed from the port's walls is limited by the walls' thickness. However, the walls are thick enough to permit the removal of irregularities and roughness created during the process of casting the head or block. It is possible to fill depressions or sharp corners with a paste material of some type that hardens into a product that has the characteristics of metal. There are



This set of Hedders is for 292 and 312 cubic inch engines in '55 and '56 Ford passenger cars.



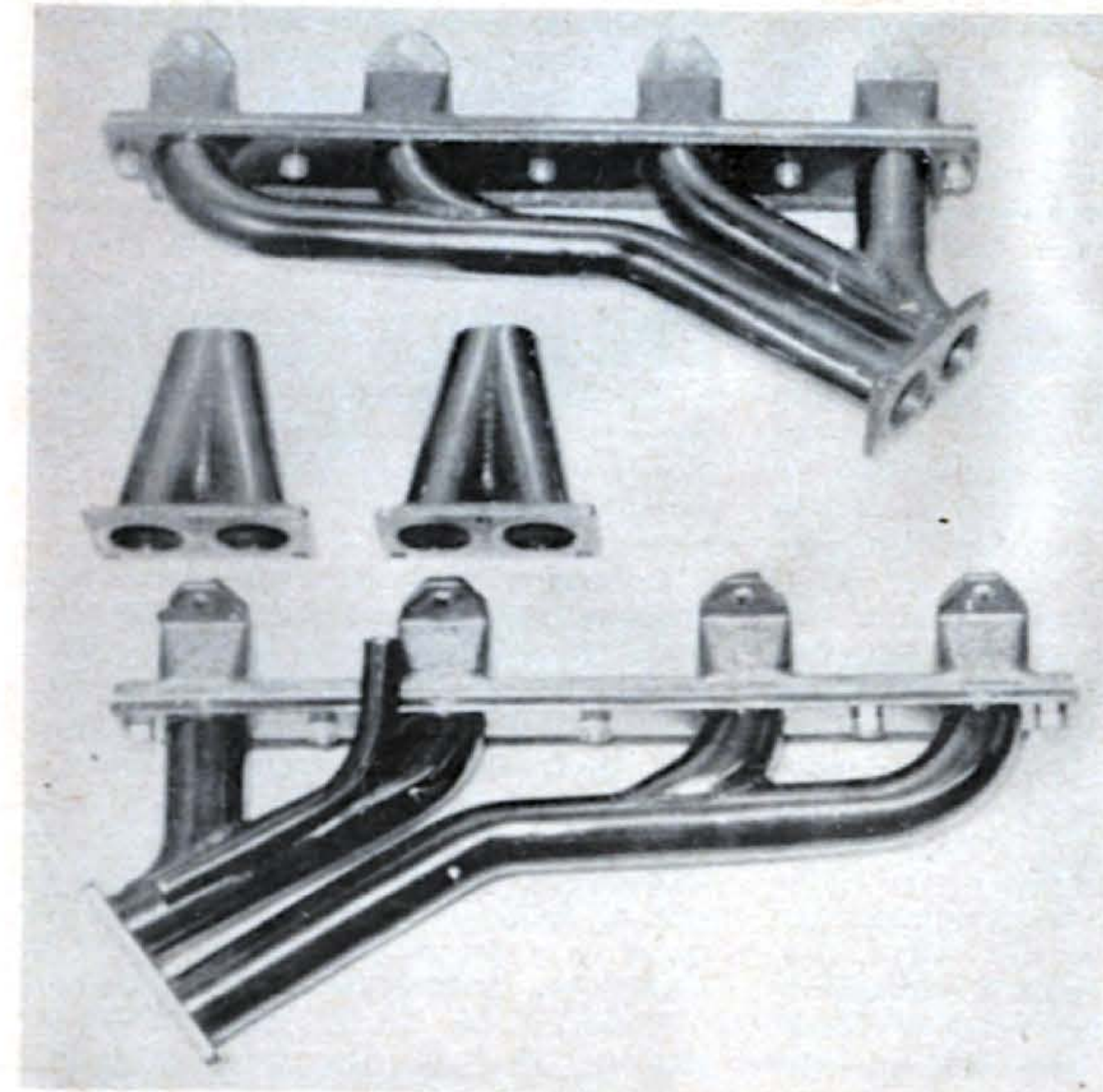
Hedders for '55-'57 T-Birds are quite different than for same year passenger cars.

several of these materials available. After they have hardened they can be ground or otherwise machined the same as the metal to which they adhere.

Surfaces of valve ports, and the exhaust passages to which they connect, needn't be polished to a high gloss but they should be smooth to the touch. Smoothness is essential to minimum resistance to the gases that pass over the surfaces.

For some engines it is advisable to shorten or reduce the outer diameter of the portion of the valve guide exposed in the port. The purpose of either of these modifications is to reduce to the practical minimum the restriction the guides form to the flow of gases.

Guides for exhaust valves serve at



For 332-inch and larger Ford engines Hedders are made in two pieces that bolt together. They can be used with either two or four pipes.

least three purposes. One of these is to hold the valves in correct alignment with their seats. Another is to conduct heat the valves' heads transfer to their stems to the cylinder head or block. The third is to shield at least a portion of the stem from the hot exhaust gases flowing through the valve port when the valve is open.

As far as a fellow who is planning to modify the guides to reduce their effect as a restriction is concerned a guide's most important duties are to hold its valve in alignment with the seat and to protect a part of the stem from exhaust gases. Unless the guides extend a considerable distance into the ports it would probably be a good idea to leave them at their standard length and to concentrate on reducing their outer diameter.

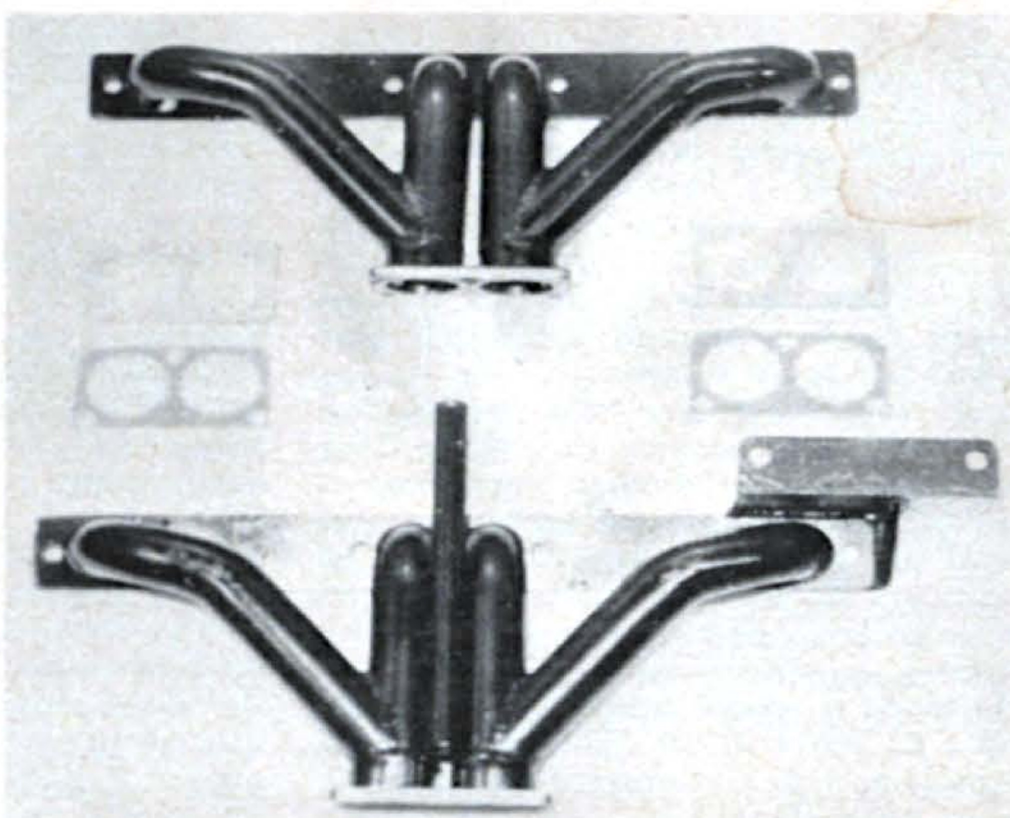
Methods used to rework guides will depend on the type of guides involved. Those that are removable can be driven out of the head or block and be replaced with new ones that have been reworked in the desired manner. Guides that have been removed from a head for any purpose shouldn't be re-used. Also, new valve seats must be ground after new guides have been installed. The slightest change in the relationship between the center of a seat and its guide will prevent the valve installed in the guide from contacting the seat squarely.

The integral guides used in most modern engines are a part of the cylinder head and, therefore, cannot be removed. The best way to modify such guides is with special cutters that can be piloted in the guides' bores. This will guarantee that the machined surfaces will be concentric with the bores.

Whenever valve guides are shortened by removing material from their end nearest the valve head the surface of their end around the bore should be at an exact right angle to the bore. The only reason for this is to provide an accurate aligning surface for the pilots used with some types of valve seat grinders. As the surface on these pilots that seats in the upper end of the guide is tapered, a pilot seated in a guide that didn't have an end perpendicular to its bore could be forced to one side or the other. This would prevent the pilot's upper end from being concentric with the bore. The seat ground with a grinder mounted on the pilot could not possibly be concentric with the bore, as it must be if the guide's valve is to seat correctly on it.

It's important that the exhaust passage, which connects the valve port with the exhaust port at the manifold flange on the cylinder head or block, be large enough to pass the quantity of exhaust gases that will be able to flow from the cylinder past the reworked valve and through the enlarged valve port. It's standard practice to enlarge these passages and their ports to the size of the openings in standard manifold gaskets. While this is being done, irregularities that might restrict the flow of gases are removed and the passages are recontoured where necessary and possible to give them the best flow characteristics. All the passages and ports should have the same cross-sectional areas and contours.

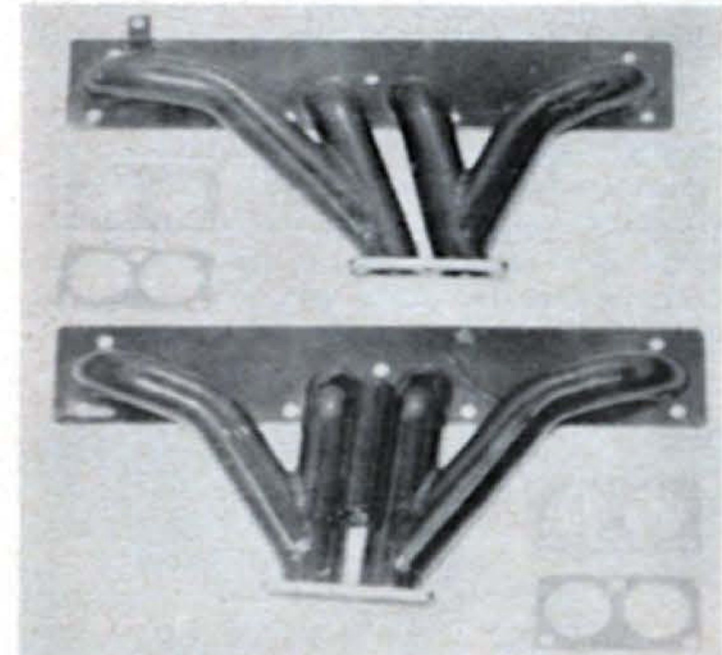
Enlarging and otherwise reworking exhaust passages isn't easy. The big problem, if one has the necessary tools to enable him to do the job, is that the passage walls aren't very thick and their thickness usually varies at different points. This makes it easy to grind holes through the walls and into the water jacket. At best, the result of such an accident would be the price of a repair job, which could be expensive, and possibly the head or cylinder block would have to be replaced. Perhaps the best thing for



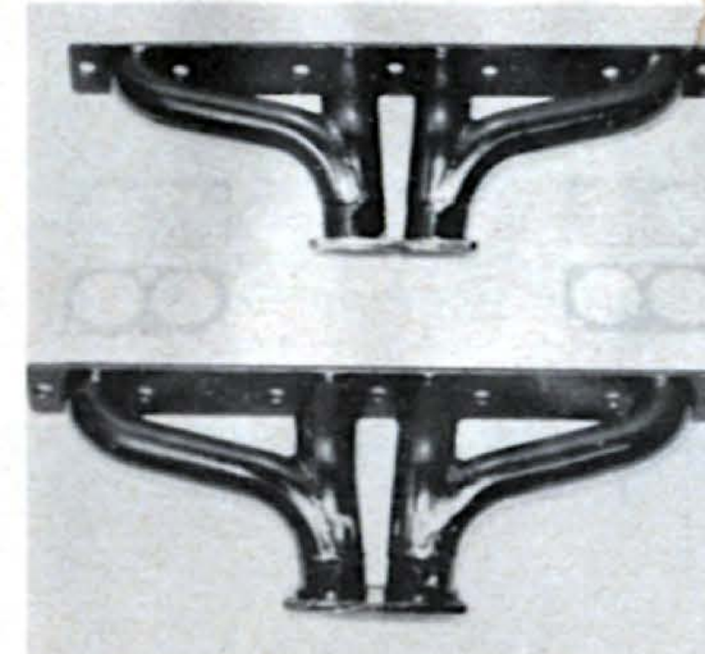
All Hedders for racing engines are designed for two exhaust pipes for each cylinder bank. These are for Corvette.

the average rodder to do is to have his porting done by an expert who has the necessary experience and tools for the job. This will definitely cost the rodder more than if he were able to do the job himself but it will be less expensive than if a hole or two were ground through a passage wall and more than likely the finished job will be much closer to the desired result.

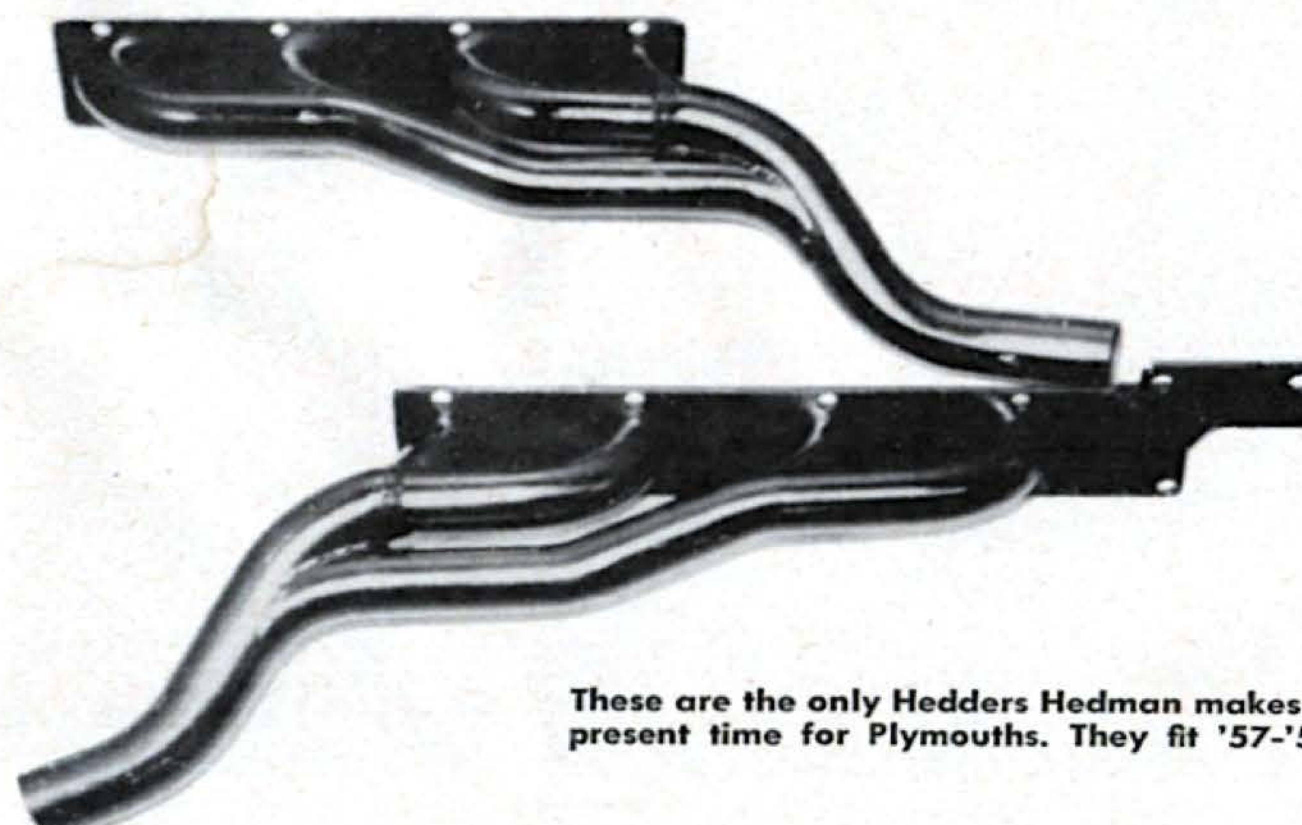
Exhaust gases that leave the ports in the head or block must flow smoothly into the manifold, headers, or indi-



Supplied with racing Hedders are flanges for pipes. These are for 348-409 Chevy.



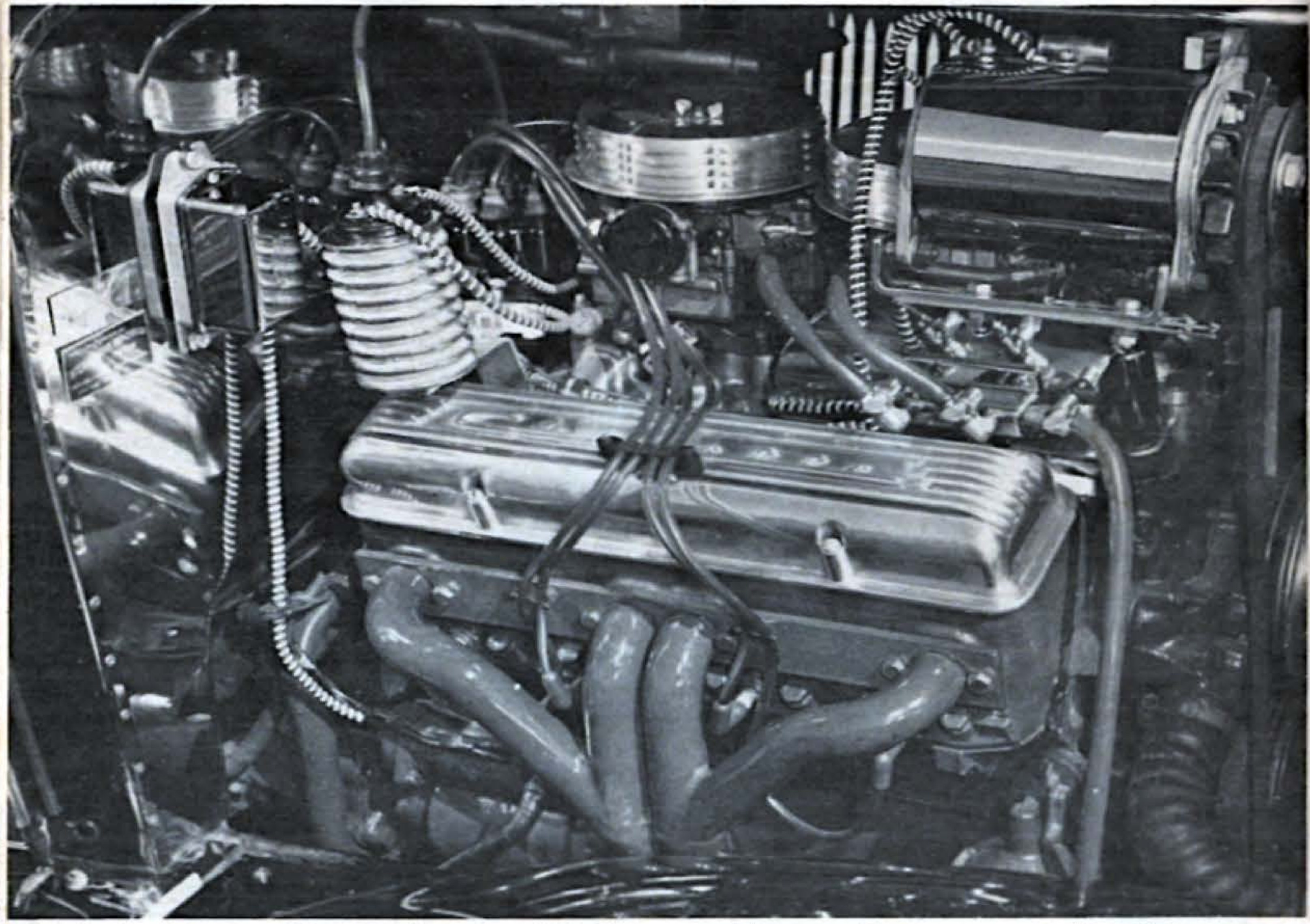
Racing Hedders for 292 & 312-inch Ford engines are similar to other racing types.



These are the only Hedders Hedman makes at present time for Plymouths. They fit '57-'59.

vidual pipes that form the next portion of the exhaust system. Because the manifold or other member is a separate part that is machined or fabricated individually, the odds in favor of its ports and passages being out of alignment with those in the engine are quite high. This means that care must be taken when installing the manifold or other member to align its ports so they don't overlap those in the engine. Overlapping at this point reduces the cross-sectional area of the passage at the joint and can create turbulence in the exhaust gases. Turbulence is a swirling action. It can reduce the exhaust system's flow capacity.

Ports in standard exhaust manifolds are made larger than those in the engine to reduce the possibility of their overlapping the ports they serve. This is the manufacturer's way of compensating for variations in port alignment that can result from mass production techniques. When an engine is being reworked the ports should be aligned more accurately. However, it is still a good idea to make the ports in the manifold or other member slightly larger than those in the engine to compensate for the different expansion characteristics of the parts involved. Ports that might be in perfect alignment when the parts are cold could be out of alignment when the engine is



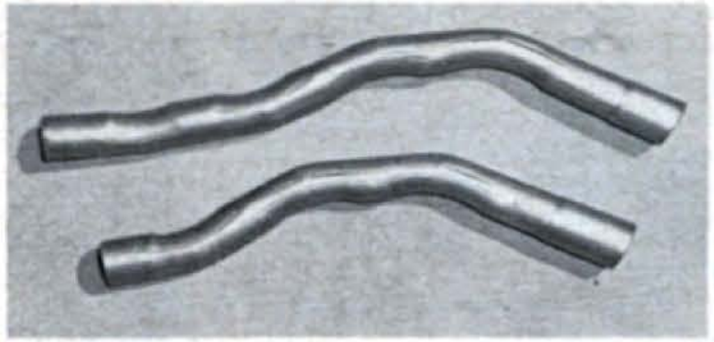
The headers on this 283 Chevy in a '31 Chevy combine good appearance with efficiency.

at its operating temperature. The result of having the ports in the manifold or other member slightly larger than those in the engine is that the passages get larger rather than smaller at the joints. As long as the change in area isn't too great it won't have any bad effect on exhaust flow.

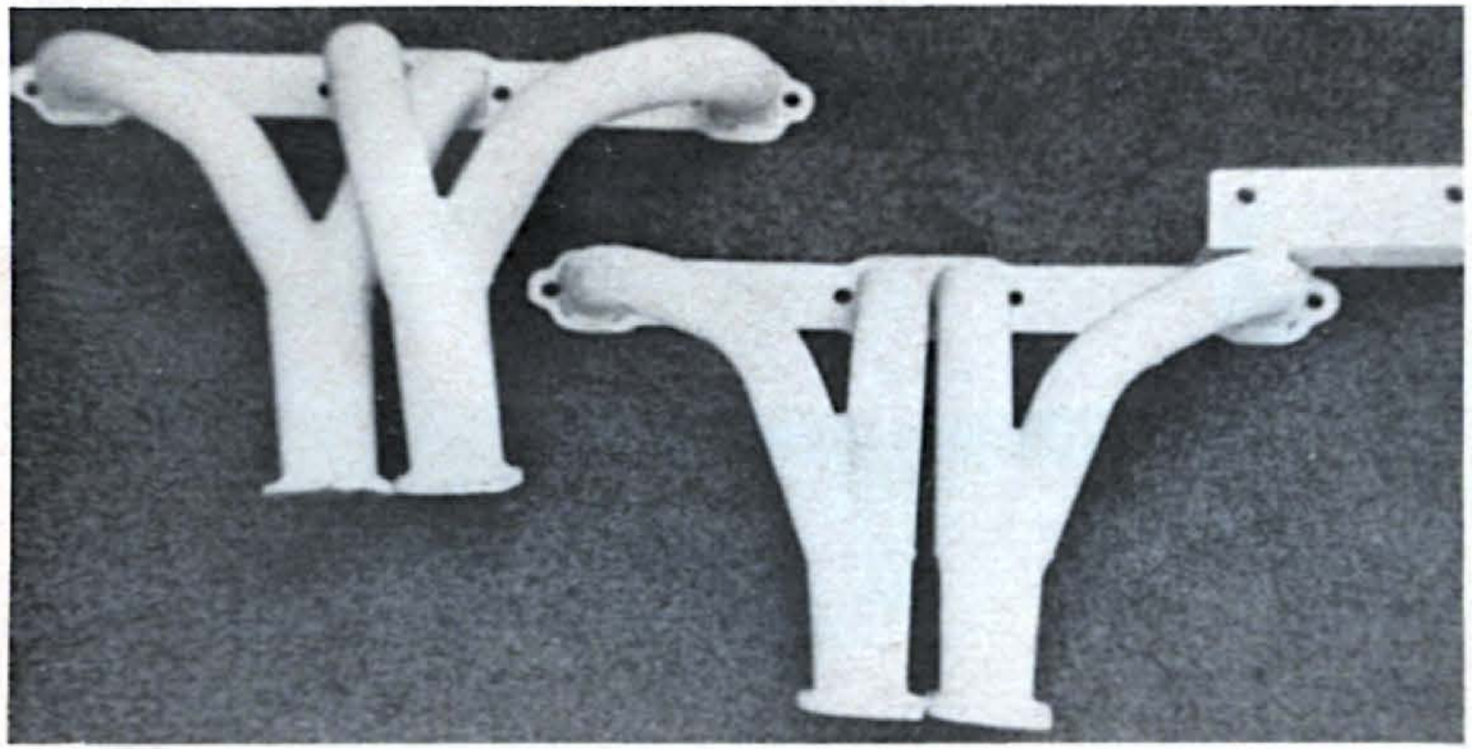
The design of the exhaust system between the cylinder heads or block and the atmosphere will depend on many factors. One of these is the type of vehicle the engine is in, another is the rules under which the car will run if it is a competition car, and another is the acceptable noise level. The system can consist of stock parts, headers and dual pipes, headers and lakes pipes and plugs, headers and straight pipes, individual pipes for each cylinder, etc.

Actually, the determining factor for any type of exhaust system is the way the engine is to be used, not what was done to the engine. Theoretically, one system is as good as another up to the point where the quantity of exhaust gases discharged by the engine starts to exceed the system's flow capacity. If an engine was reworked to improve a car's acceleration and general liveliness for everyday driving and was seldom, if ever, required to run with full-throttle, a good standard dual system could be adequate. There are many engines of this type in use every day by drivers who never exceed the speed limit but who want better performance in the speed range in which they drive.

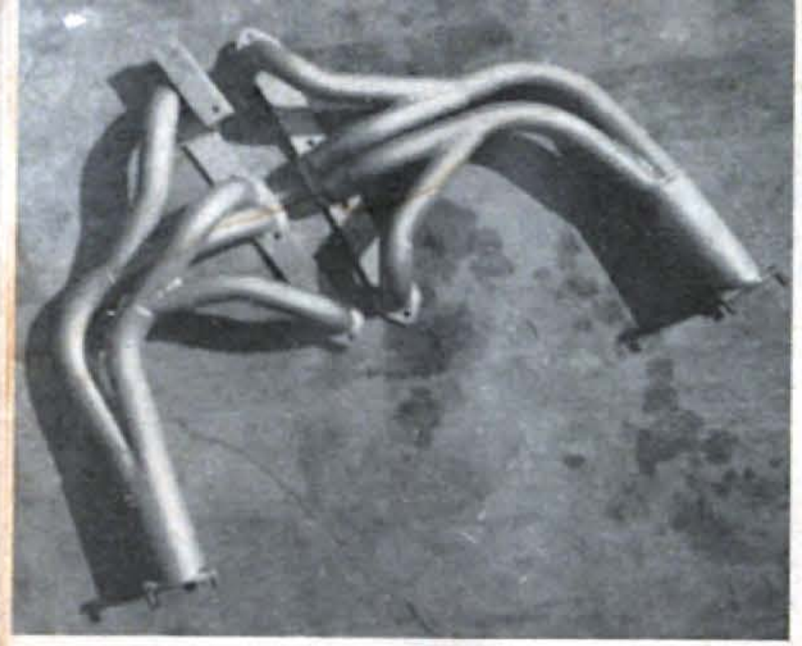
When maximum power with wide-open throttle and high crankshaft speeds become important, everything possible, within limitations imposed by



Some Hedman Hedders require extension pipes to enable them to be connected to a car's mufflers. These are for Chevy.



Racing headers by Horse Power Eng. for 283 Chevy have pipes arranged for firing order.

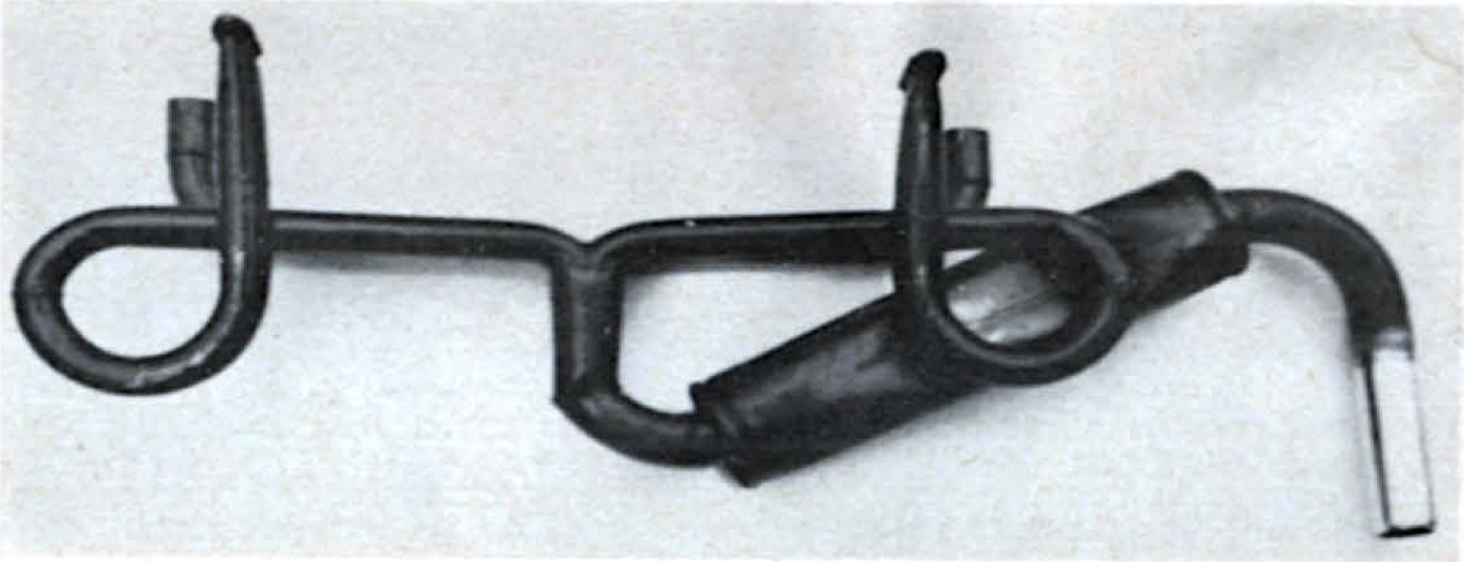


Corvette racing headers by Jerry Jardine empty into large single collector pipes.

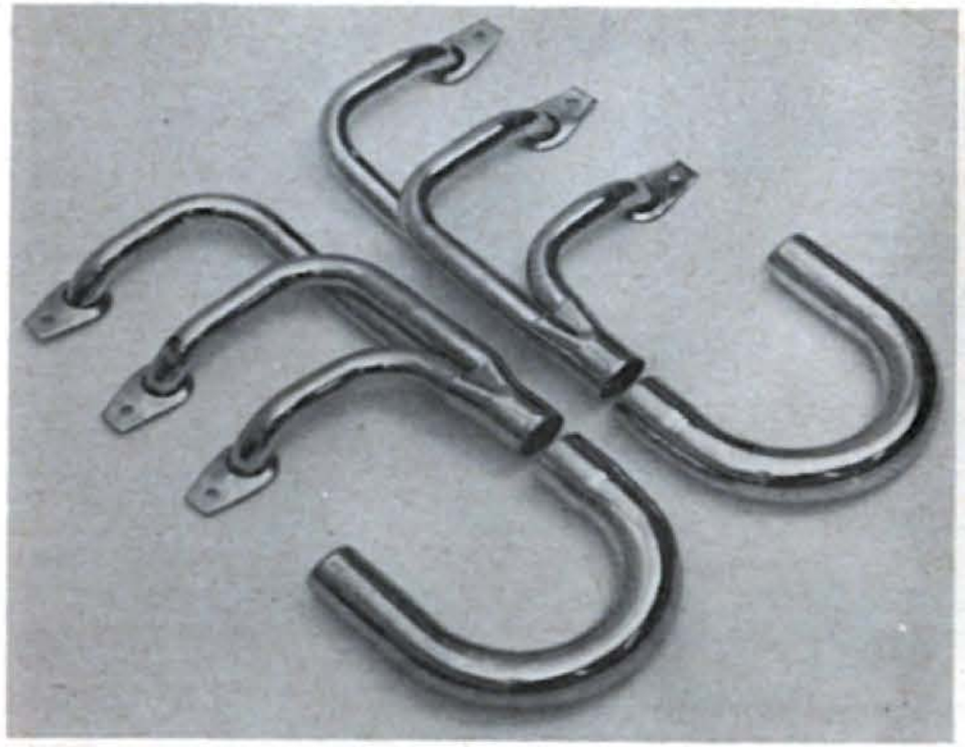
the vehicle and the way it will be used, must be done to reduce back pressure to the minimum. For a passenger car this would mean special manifolds or headers of some type, elimination of the intake manifold heater valve, and dual low-restriction mufflers.

The dictionary definition for the word manifold as the word applies to mechanical subjects is "a pipe fitting with several lateral outlets, for connecting one pipe with others." An exhaust manifold for an automobile engine is nothing more than a large cast-iron fitting that has several inlets and one outlet. The special "headers" that are used in place of standard manifolds when greater exhaust system efficiency is required are also manifolds. Most headers are fabricated from steel tubing simply because this is the simplest method of making them, but those supplied by some automobile manufacturers for their high-performance optional engines are cast-iron.

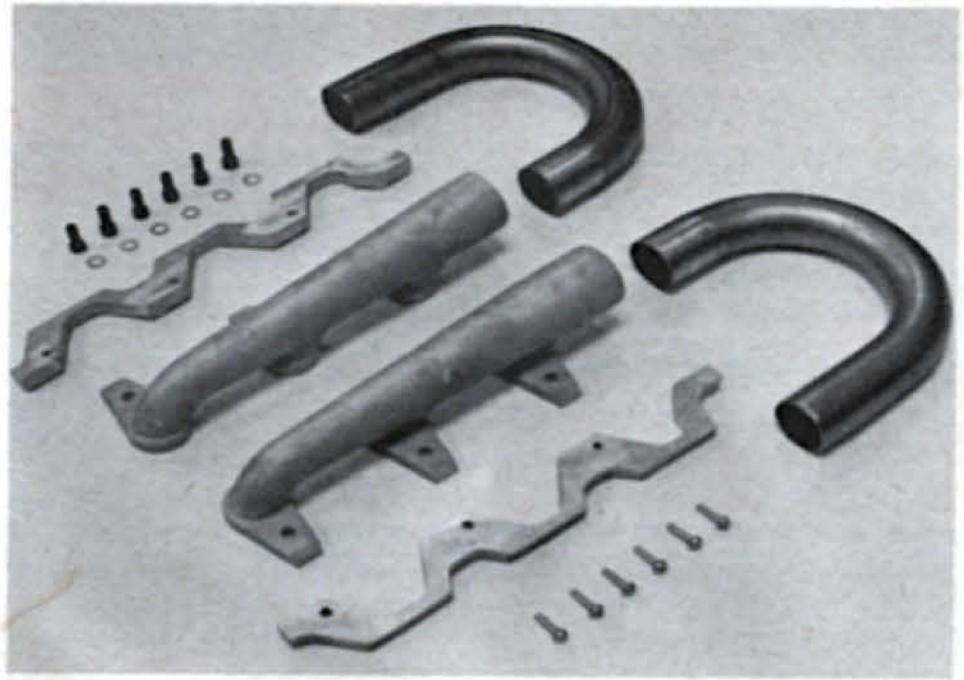
Headers differ from standard manifolds by being designed to permit maximum flow of exhaust gases from an engine's cylinders. They do this by having passages that have cross-sectional areas throughout their length at least as great as the areas of the passages they serve, by having large radius bends to reduce the restrictions caused by the bends to the practical minimum, and by having branches long enough and isolated from each other in such a manner that the pressure of the gases in one cannot influence flow through another. The inside diameter of tubing used for headers must be uniform throughout the entire length of each branch. A reduction in the diameter for any reason



Each cylinder in a Porsche has a pipe of equal length with this Horse Power Eng. setup.



Runyon headers for Corvair can be used for either street or competition. Curved pipes adapt mufflers.

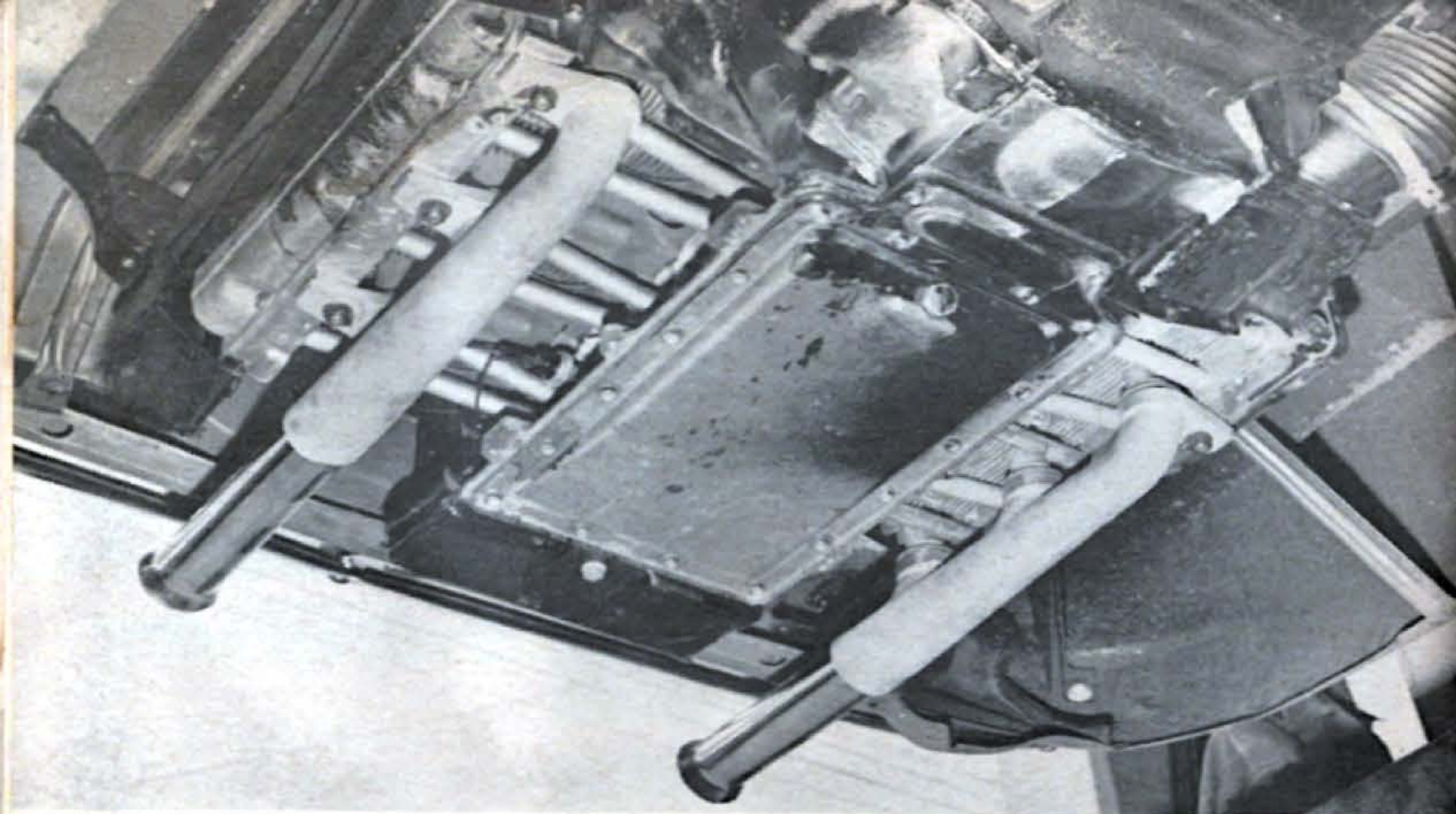


Eelco cast-aluminum headers for Corvair. These, too, can be used for either street or competition.

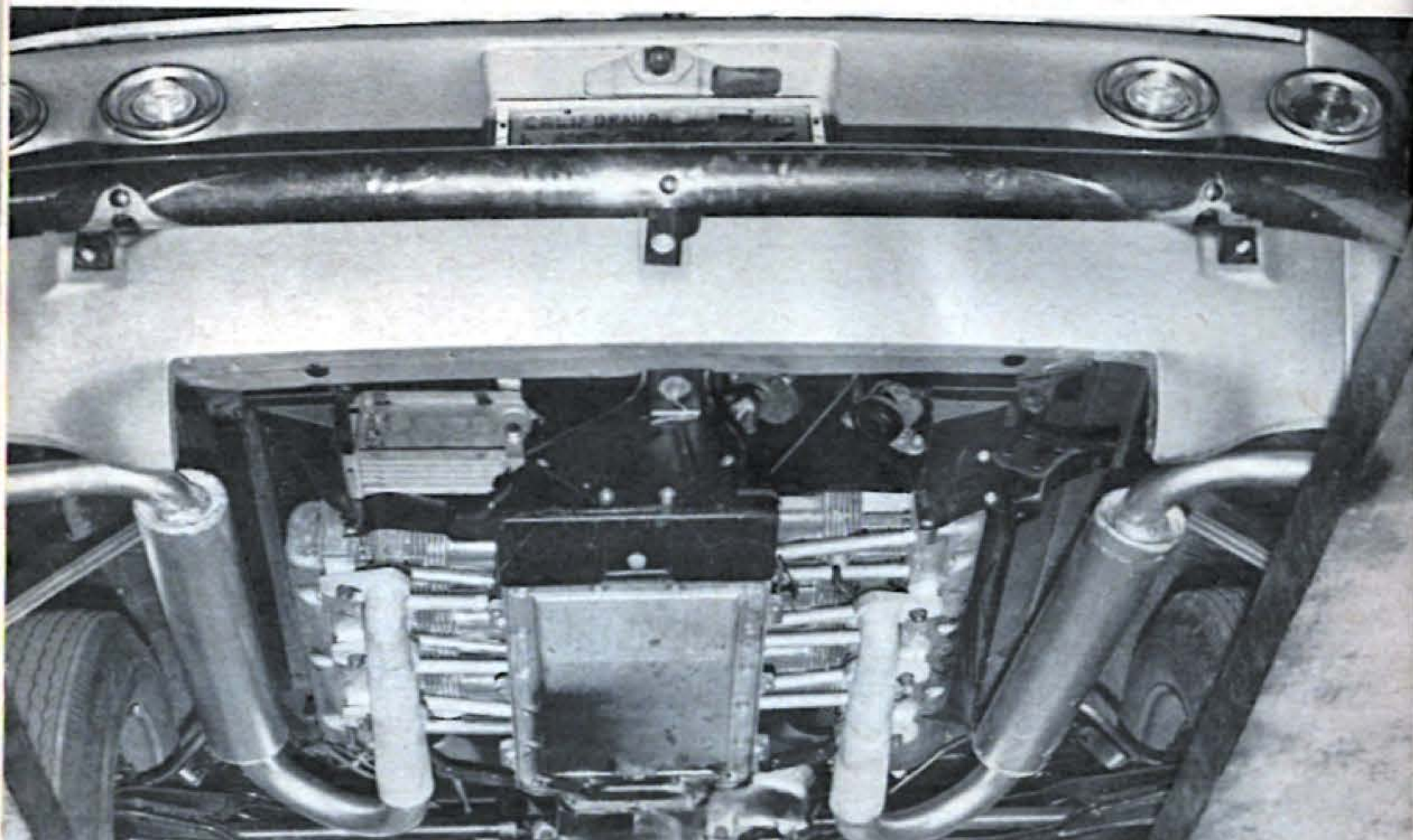
will create a restriction to the flow of gases.

Cylinder heads for many engines have rectangular exhaust ports. Ports in headers that bolt to these heads must also be rectangular; however, when port ends of header branches are changed from round to rectangular the cross-sectional area of the branches must be equal or larger than the area of their rectangular ends. Sometimes rectangular ports are reshaped to make them round when the heads are ported. The inside diameter of header branches for round ports must not be smaller than the ports' diameter.

The standard practice now for header construction is to weld the pipes that are the header's branches to a steel plate that has openings that correspond with the engine's exhaust ports and holes that align with the engine's capscrew holes. Individual flanges were used on some of the first



Eelco Corvair headers fitted with short extensions for drag strip or other competition.



For street use, Corvair headers are reversed on the engine and connected to mufflers.

headers that were made for rods but it was found that the pipes that formed the header branches would become distorted by the heat of the exhaust gases and make it difficult to reinstall the headers after they had been removed. The problem was in aligning the capscrew holes in the flanges with the holes in the block or head.

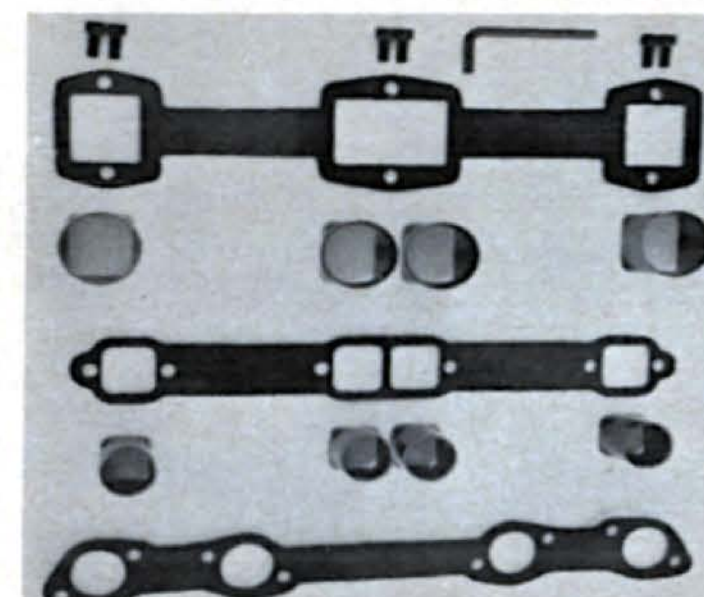
Sometimes it is difficult to bolt headers made of tubing that has the required diameter to the heads because the capscrew holes for the standard manifolds are too close to the ports. Port ends of the manifold branches interfere with the capscrews that must hold the headers in place. A possible solution to this, where space will permit, is to use adapter flanges of the type that have become popular for all-out competition engines. These are usually approximately 1-inch thick. They are secured to the heads with the standard capscrew holes and capscrews that are recessed below their outer surface. This leaves a flat surface to which the flanges for headers or individual pipes can be bolted by means of threaded holes in the flanges.

The bends in header branches are important because the restriction a bend creates to flow through it becomes greater as its radius becomes smaller. Also, the restriction becomes greater as the number of degrees described by the bend becomes greater. As far as headers for passenger cars are concerned, header manufacturers are faced with many of the same problems that cause the engineers who design standard exhaust manifolds to make the manifolds small and with short-radius bends. If the header manufacturer can solve the problem in some manner that lets him make the bends larger and more sweeping, it will be possible for the headers to be an improvement.

Because each exhaust valve in an eight-cylinder engine is open for considerably more than 180 degrees of crankshaft rotation, and one of the cylinders fires every 90 degrees of rotation, at least three exhaust valves are open to some degree at all times. If two or more of these cylinders empty into the same exhaust manifold it's possible for one of them to begin its intake strokes with a greater quantity of residual gases than the other. What happens is that the cylinder that fires first is well on its way toward the completion of its exhaust stroke when the exhaust valve for the other cylinder opens and its exhaust gases, which are still at combustion pressure, flow into the manifold. The pressure of these gases raises the pressure in the manifold to a value much higher than that in the first cylinder and forces exhaust gases back into the first cylinder where they are trapped when its exhaust valve closes.

The only way to prevent gases that are leaving one cylinder from flowing into another is by separating the cylinders with manifold or header branches of such length that pressure from one

Flanges such as these are available to fellow who can make his own headers.

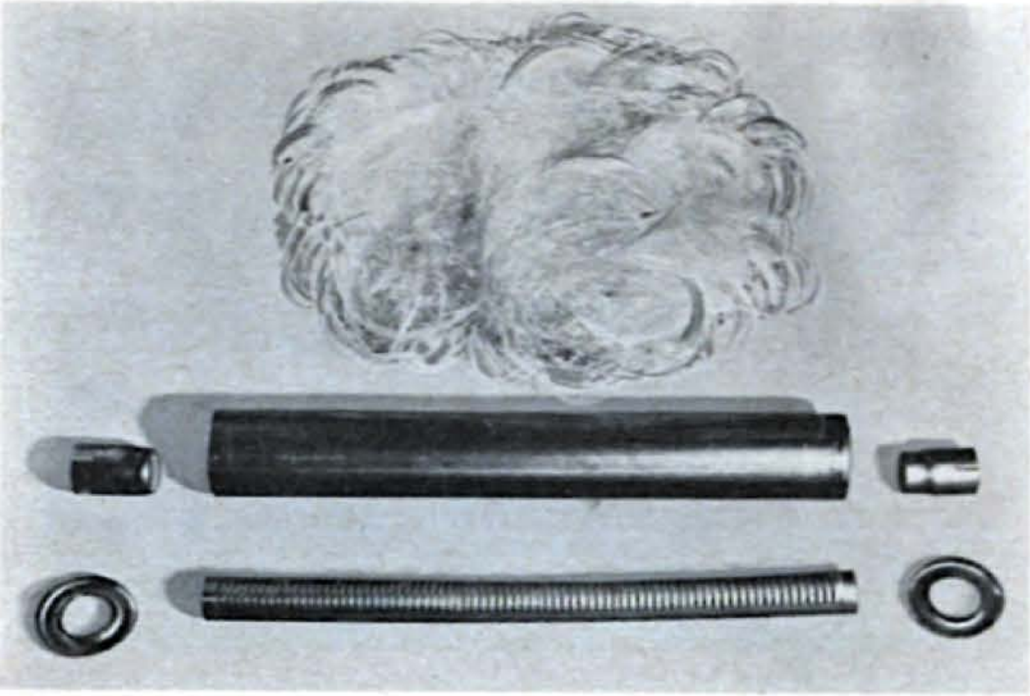


cannot affect the flow of gases from another in which the exhaust valve is open at the same time. Perhaps the most satisfactory way of doing this is by dividing the branches so that only cylinders in which the valves are not open at the same time are connected together.

For modern V8 engines the method of dividing the cylinders of each bank as much as practicable is by splitting one of the headers so the front two cylinders are together and the rear two are together and splitting the other so the first and third cylinders are together and the second and fourth cylinders are together. The reason for splitting one header for the 1-3, 2-4 cylinders is that two adjacent cylinders in its bank fire consecutively. In some engines this is the left bank and in others it is the right bank. For maximum effect each bank should have two exhaust pipes, one for each pair of cylinders; however, by making each of the branches long enough it is possible to separate the cylinders with enough passage volume to prevent one cylinder's causing any difficulty with another.

After considering the many factors involved it becomes apparent that efficient headers must have branches of adequate diameter, bends of large radiuses, and branches that provide enough separation between the cylinders to prevent exhaust from one cylinder from flowing into another. For a competition car, in which there aren't any obstructions around the headers, these requirements aren't difficult to fulfill; however, for headers to be used in a passenger car the story may be different. As a consequence, headers for passenger cars are not to be accepted as being terrific improvements over stock manifolds just because they are headers. Those manufactured by established companies and specialty shops that have proved their products through use can be relied upon to do what is claimed for them but those from other sources should not be accepted until they have been proved to be better than the manifolds they replace.

An intake manifold heater valve could possibly be used with headers but the restriction the valve would create would destroy the headers' efficiency. The purpose of headers is to allow exhaust gases to flow out of an



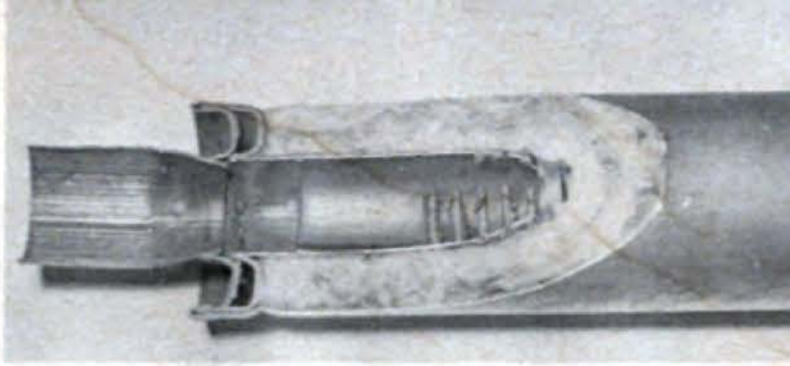
These are the ingredients used to manufacture a typical glass-packed muffler.

engine as freely as possible; stuffing a cork in the end of one of them wouldn't make much sense. Such a valve is out of place in any special exhaust system, even if standard manifolds are used. The length of time required for an engine that requires a special exhaust system to warm up to operating temperature is unimportant and its air-fuel mixtures will be rich enough to allow it to run smoothly at low speeds. A heater valve is almost a necessity for engines to be used for normal driving in cold climates but an exhaust system that has one of them cannot be considered a high-performance system.

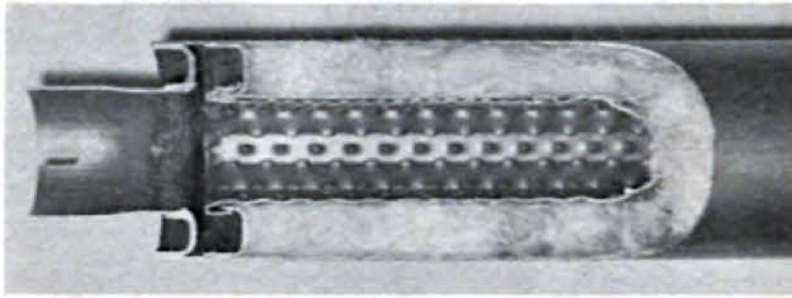
Most headers made to be used in passenger cars are designed for standard headpipes. Sometimes the flanges on the manifold ends of the pipes have to be replaced with lengths of tubing that will slip over the headers' outlets. The pipes usually have ample flow capacity but whatever their capacity their resistance will be less than that of the muffler that will be connected to them.

Unless a car that has a V8 engine was factory-equipped with a dual exhaust system, standard headpipes for both its cylinder banks may not be available. If the car is one of those that is popular among performance-minded drivers, there undoubtedly will be a special headpipe for its non-standard side available for it from shops that specialize in muffler work. These shops will also have tailpipes and the other parts necessary for installing dual mufflers.

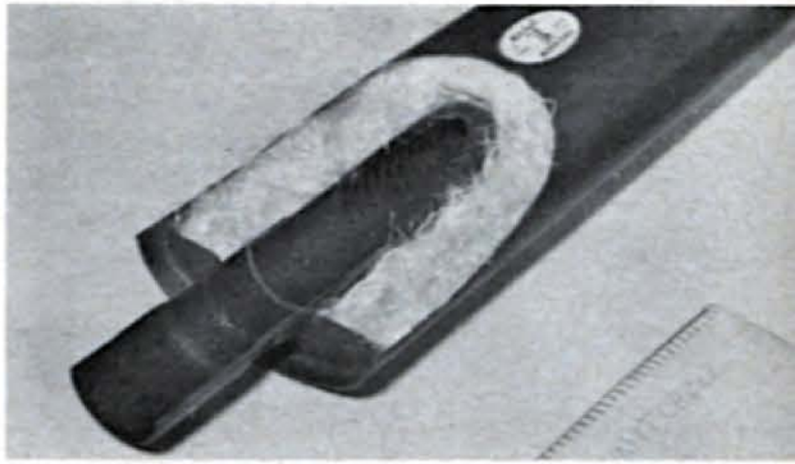
Standard mufflers for passenger cars vary as much in performance as they do in appearance. Their primary consideration is that they make the exhaust whisper-quiet. The amount of back pressure they create is secondary; however, muffler engineering has advanced tremendously in recent years. Some of the latest mufflers are remarkably efficient, possibly even more



Visible in this cutaway display muffler are the innards of an Advance glass-pack.

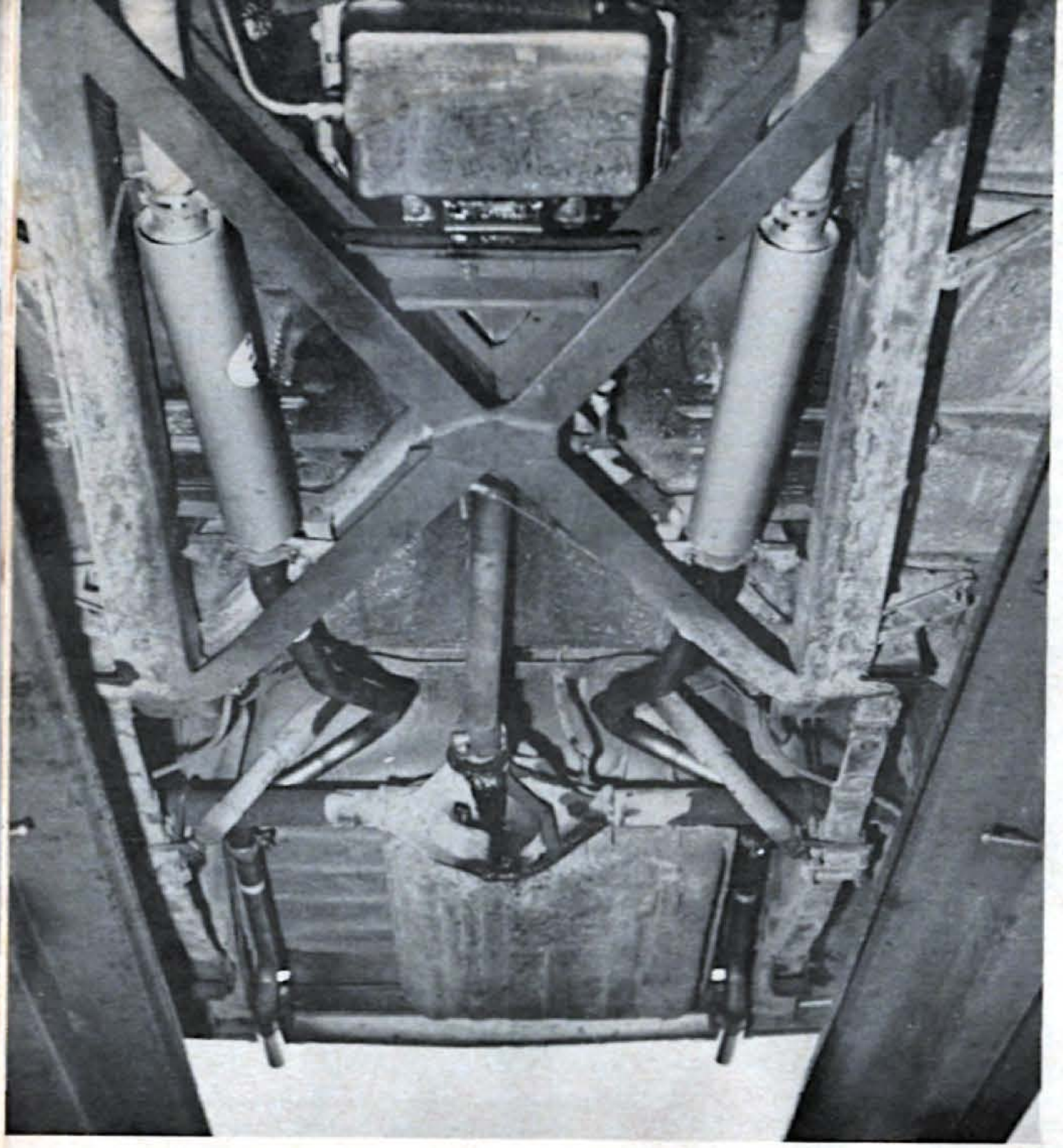


This is a Douglass glass-pack. Note how the centerpipes in the mufflers differ.



Mitchell glass-packed mufflers are manufactured with both round and oval shells.

This glass-pack is the product of Sonny's Muffler Shop. Glass-packs are durable.



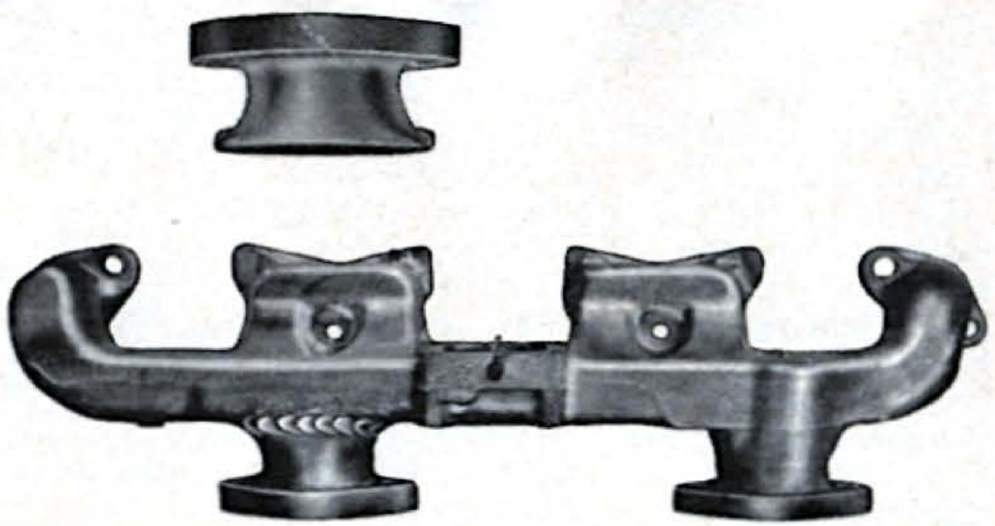
so than some of the special types manufactured for special installations.

Unfortunately for rodders, mufflers are not rated as to their efficiency. A letter or number stamped in its shell that would identify a muffler as to the degree of back pressure it created when it was used to silence a certain number of cylinders and a certain number of cubic inches of displacement would solve all a rodder's problems. But this is something that will never be done. Therefore, the only safe thing to do is to consider all stock mufflers as being the same as far as their back pressure characteristics are concerned. The only alternative to this would be to try each of the mufflers individually in a specific installation and give it a performance rating according to actual car performance. This, of course, is much too involved.

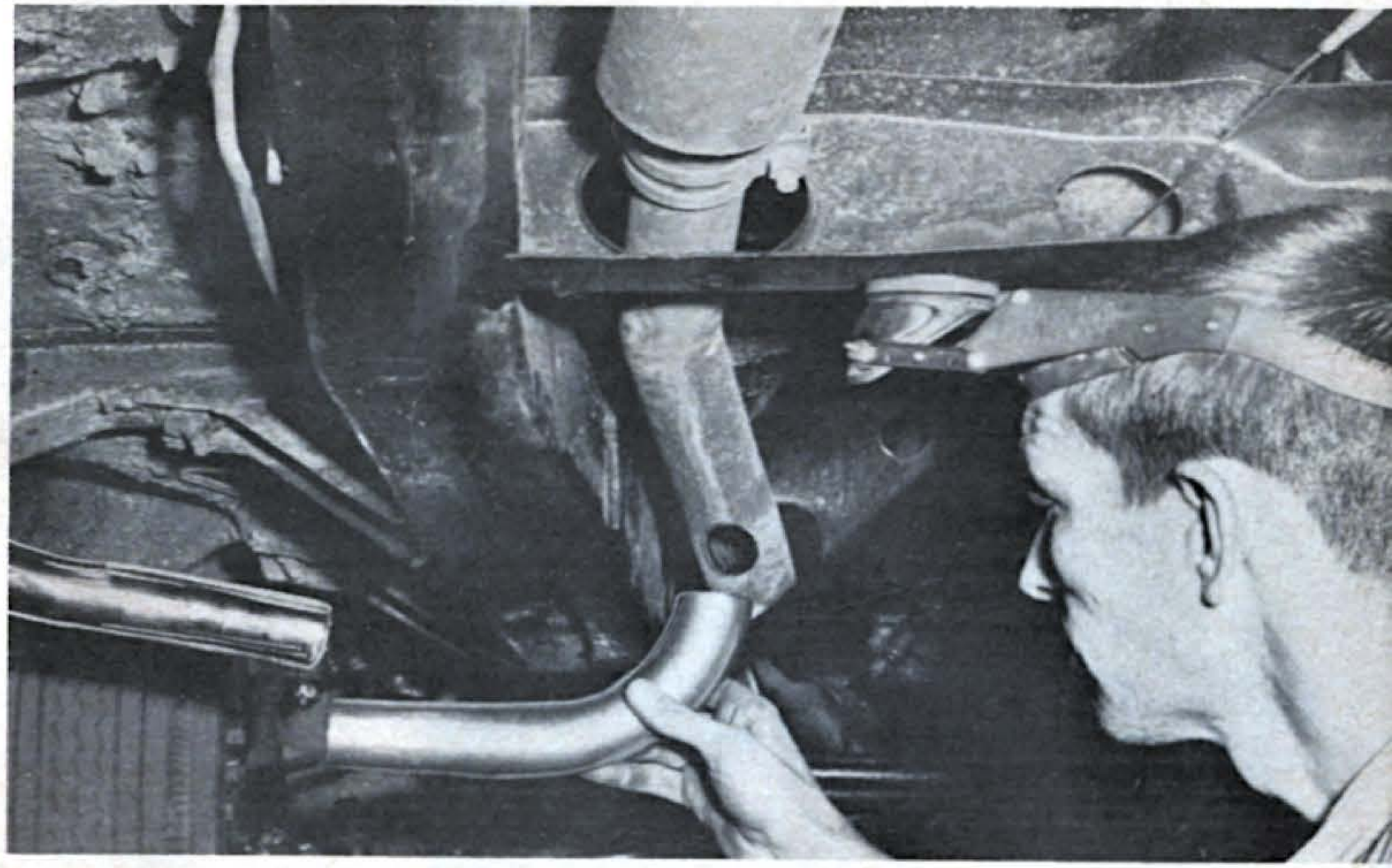
Something to remember about stock mufflers is that many cars have only one of them to handle the engine's entire displacement. If the exhaust system capacity is doubled by installing another muffler of the same type, the system could be fairly efficient.

The most popular of the special mufflers now being manufactured by companies that specialize in high-performance exhaust systems are of the "glass packed" type. These are straight-through mufflers, which means that exhaust gases travel straight through them. Their outer shell is usually 4-inch diameter steel tubing and the inner pipe, through which the exhaust gases flow, is approximately 1⅞-inch in diameter. The walls of the inner pipe are perforated with many openings through which the gases passing through the muffler can expand into the

The longest glass-packs hat could be fitted into the openings in its frame were used on this T-Bird.



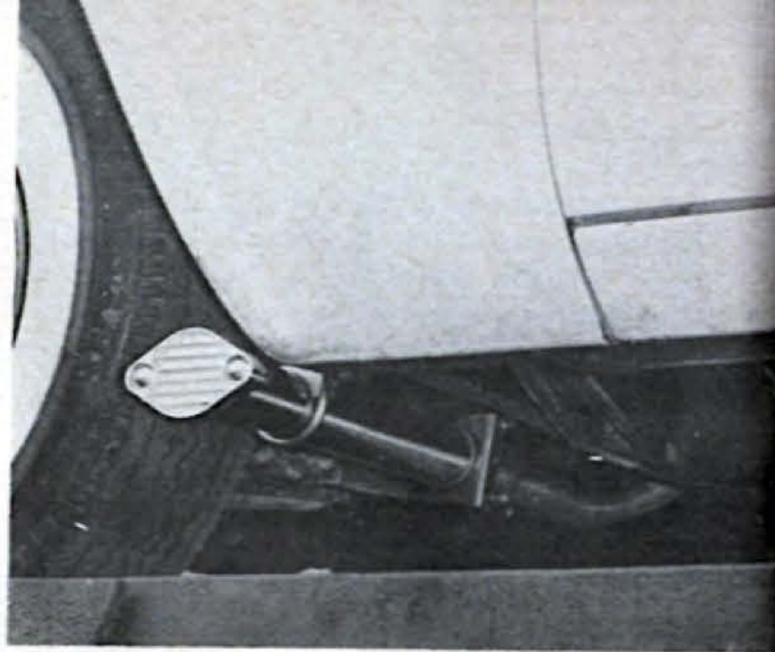
Dual pipes can be fitted to a six-in-a-row engine by welding a fitting like this to its manifold.



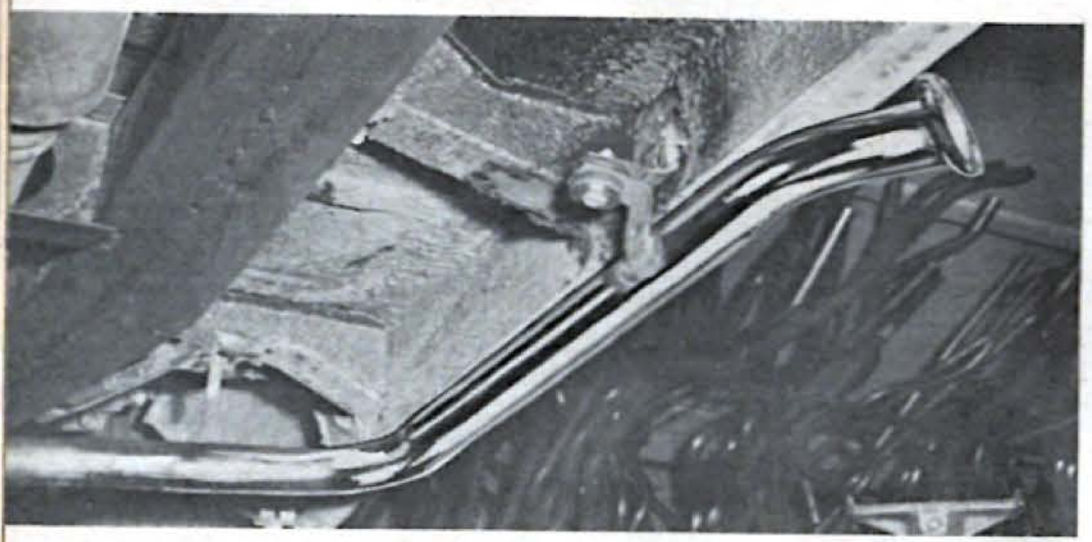
Lakes pipes welded over openings in headpipes are a simple competition exhaust setup.

chamber surrounding the pipe and then flow back into the pipe as the pressure in the system changes. These openings vary in shape and size for mufflers of different makes.

The space between the inner pipe and the shell is packed with glass fibers. The packing must be done carefully so the glass will be packed to the correct density. Incorrect packing can change the tone of the exhaust that leaves the muffler. Exhaust from a straight-through muffler that does not have any packing has a hollow, tinny sound and exhaust from one in which the packing is too tight or solid has the loud, individual explosion sound very similar to the noise the

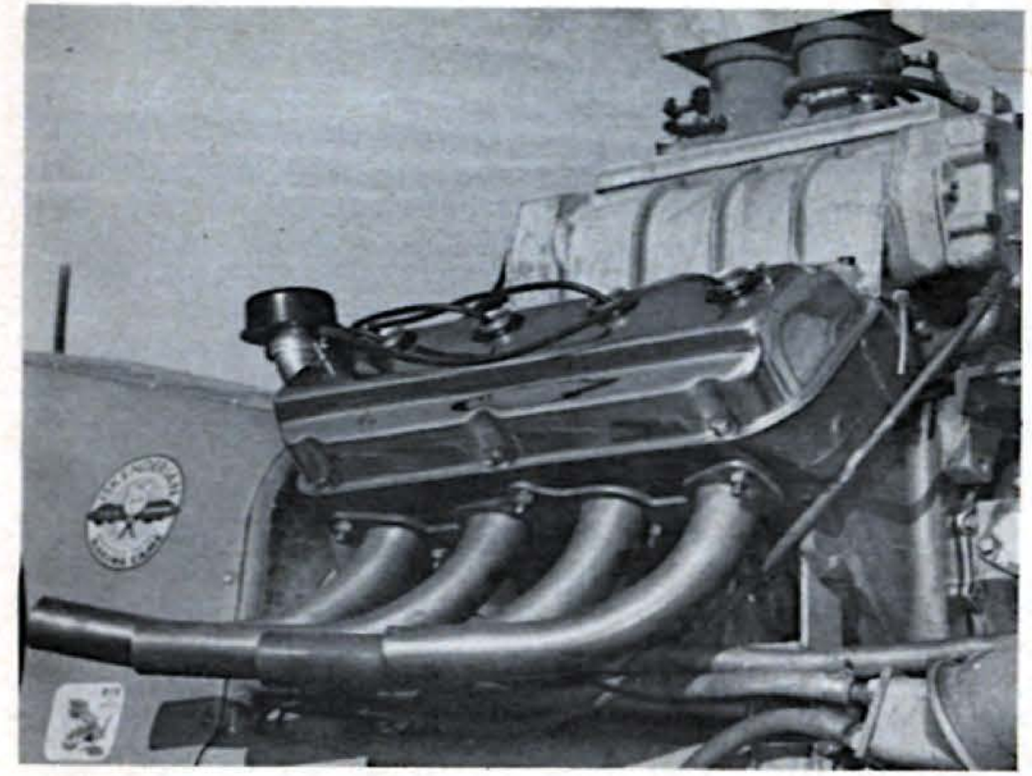


For normal driving, the atmospheric ends of lakes pipes must be closed with caps.



Some lakes pipes are for decoration as well as efficiency. The longer ones are more decorative.

Simplest of competition exhaust systems are the short individual pipes, as these on a 283 Chevy.



Curved individual pipes can be as efficient as straight ones if the curves do not have too short a radius.

system would make if the muffler were replaced with a length of steel tubing the same diameter as the headpipe or tailpipe.

The purpose of the glass fiber, which is heat-resistant, is to dampen the vibrations the gases create in themselves by their sudden expansion as they enter the chamber formed by the muffler. The greater the extent to which the vibrations can be dampened and the individual pressure impulses from the cylinders blended together to form a steady flow of gases at a constant pressure, the less objectionable the sound waves created by the release of the gases will be to the human ear.

Glass-packed mufflers manufactured by different companies vary in their construction details, such as the diameter of their shell, material used for the shell, diameter of their centerpipe, shape of the openings in the centerpipe, and the method of attaching their end covers, but all the companies make them in several lengths for different installations. Connecting the mufflers to headpipes and tailpipes of different makes of cars is simplified by welding nipples of the correct diameter and lengths to the ends of their centerpipes at the required angles.

The silencing effect a glass-packed muffler has on the exhaust gases flowing through it depends on the muffler's length: the longer the muffler, the quieter the exhaust system. It was their range of sound that made the original packed-type mufflers popular when they first became available. This was many years ago when the flathead Ford V8 was the hottest thing on the road and all automobiles had a single exhaust system as standard equipment. The single systems were changed to dual systems with special headpipes and tailpipes for the non-standard side and packed mufflers were used to give the exhaust the desired "tone," which became a polite term for noise. The tone was regulated from a pleasant purr, possible with the longer mufflers, to a nerve-jarring rap with the shorter ones.

It was the noisier of the packed mufflers that eventually became responsible for the rather strict legislation concerning automobile exhaust noise that has been enacted by most states. This legislation and the eagerness with which it is enforced by city, county, and state law enforcement agents has made loud exhaust systems almost a thing of the past. However, the good side of packed mufflers, which is their low back pressure characteristic, has kept the longer, quieter mufflers popular for replacements in both single and dual standard systems and for special dual installations.

After the exhaust gases leave the muffler they must follow a more or less winding route through the tailpipe to reach the atmosphere. The purpose of the tailpipe is to conduct the gases to the rear of the car where there will be smaller chance of their making their way into the passenger compartment. Tailpipes must be as crooked as they are to clear all the obstructions along their route. They would present less resistance to the flow of gases through them if they were straight but straight tailpipes aren't practical for standard automobiles. Fortunately, standard tailpipes have capacities equal to that of the rest of the system in which they are used.

Regardless of how easy it is for exhaust gases to flow through an exhaust system that has mufflers and tailpipes, there is more resistance to the flow through such a system than there would be if the gases could escape to the atmosphere before they reached the mufflers. A method of converting a system so that the gases don't have to pass through the mufflers is with lakes pipes and plugs.

Lakes pipes consist of short lengths of steel tubing the same diameter as the headpipes welded to the headpipes at points as close as practicable to the exhaust manifold or header outlets. An opening that will have the same shape as the connection between the two pipes is cut in the headpipe before the lakes pipe is welded to it. The atmospheric end of each lakes pipe is fitted with a cap of some sort that can be easily installed or removed. With the cap removed, exhaust gases can flow through the lakes pipes as well as through the mufflers. As the gases will take the path to the atmosphere that presents the least resistance, most of them will flow through the lakes pipes. This eliminates the back pressure normally created in the exhaust system by the mufflers and tailpipes but the noise created by the unmuffled exhaust gases is so great that the lakes pipes can be used only where there aren't any restrictions against exhaust noise. They must be plugged when the car is driven on public streets and highways.

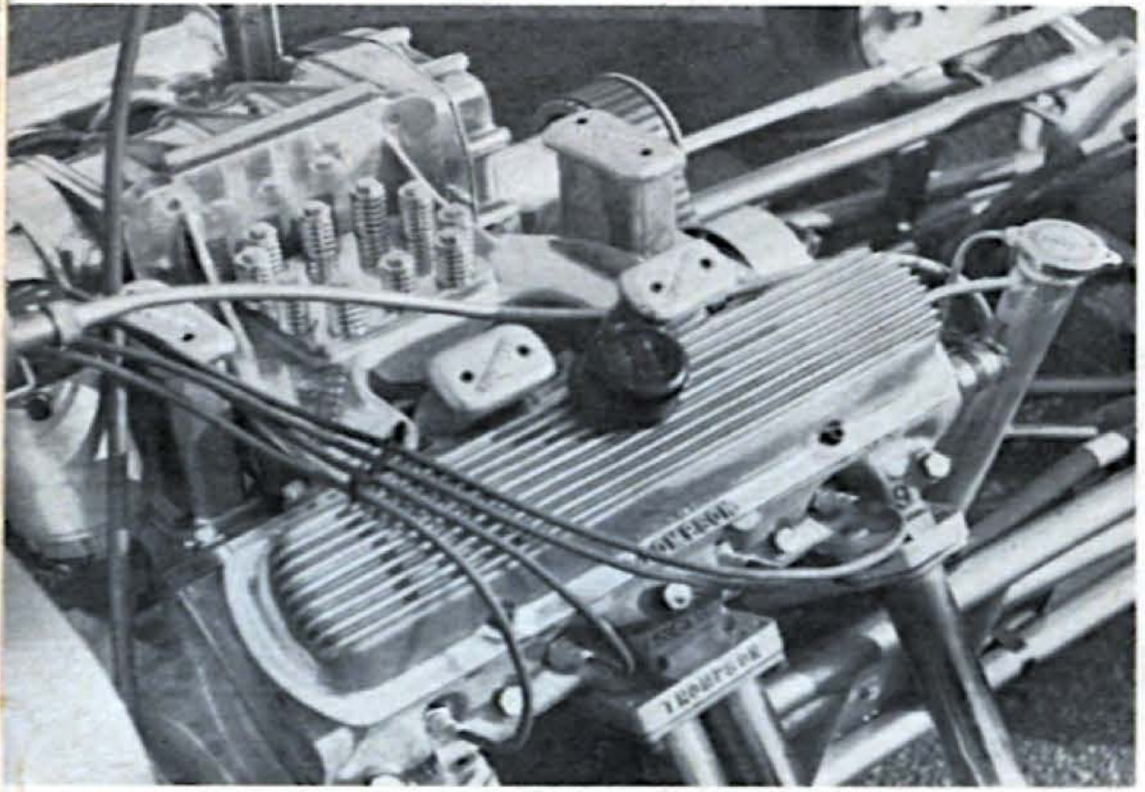
Lakes pipes can be used with standard exhaust manifolds but they can't reduce back pressure the manifolds may cause. They have an effect only on the part of the system between the point where they connect to the headpipes and the atmospheric ends of the tailpipes. The efficiency of the system when the pipes are open will be greatest when they are used with headers.

Most lakes pipes are installed at a right angle to their headpipe and with their atmospheric end even with the side of the car. Aiming the pipes in this manner causes the exhaust gases to be directed out and away from the car; also, the ends of the pipes and their plugs are readily accessible and clearly visible.

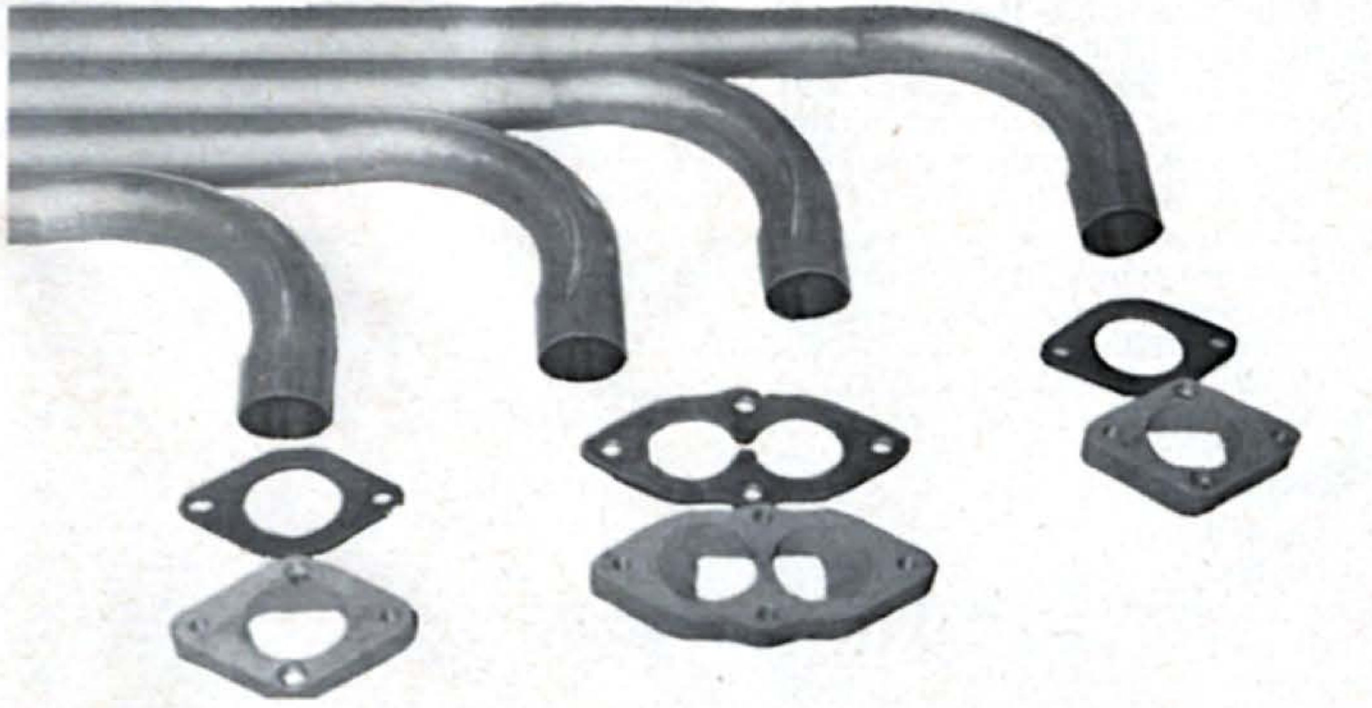
For some persons the fact that their car has lakes pipes is more important than the effect the open pipes have on the car's performance. For these persons the pipes are a prestige factor that suggests greater things under the hood and wondrous deeds on the drag strip or through the measured mile.

Cars that will be used only for some type of competition, which means that they will never be driven on public streets nor highways, may not be required to have headpipes, mufflers, and tailpipes but they may not be allowed to have an individual pipe for each cylinder. The obvious answer to such rules is an exhaust system that consists of efficient headers and low-restriction pipes between the headers and the atmosphere.

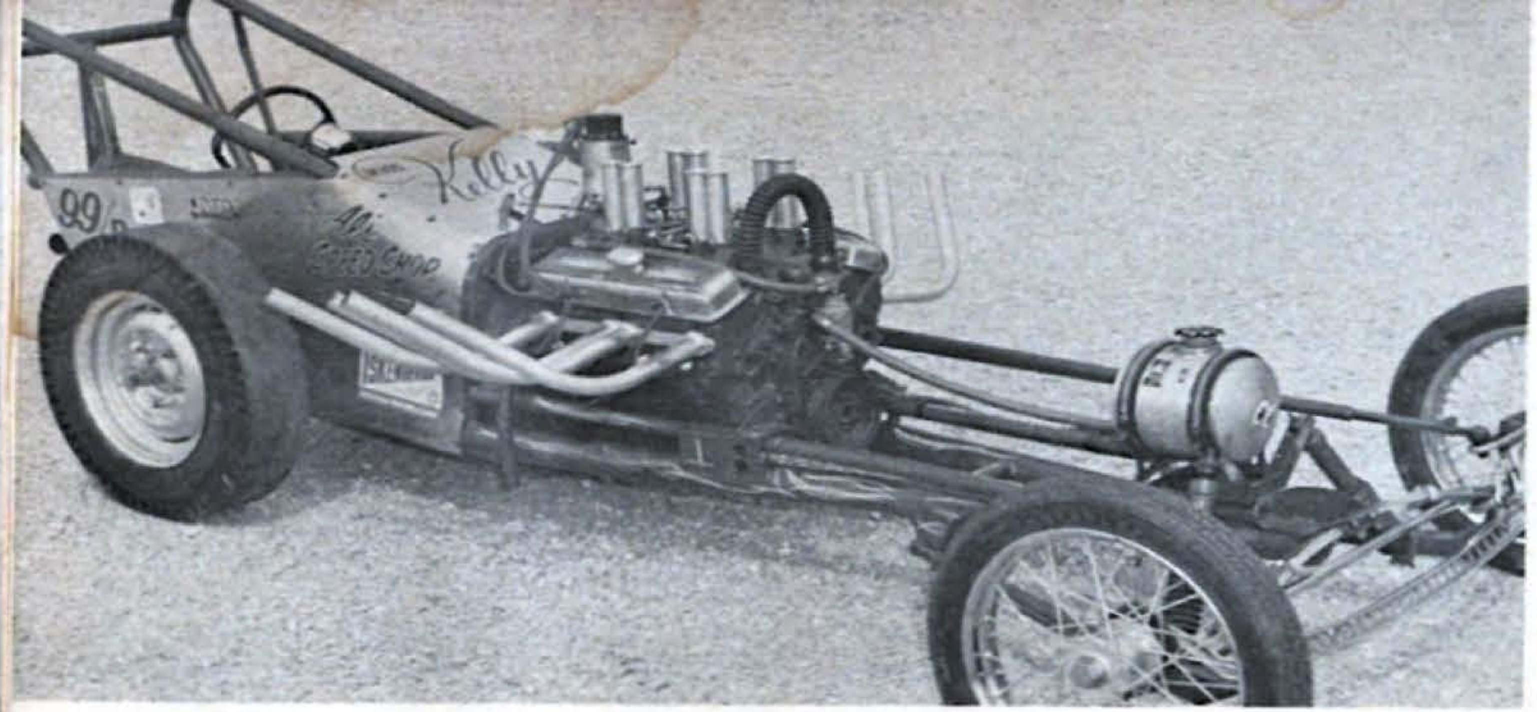
Pipes for a system of this type must conform with the rules but for most installations they should be as straight and as short as possible. The rules may require that the pipes extend to a certain point, such as behind the front



Individual pipes on this Tempest four were fitted to the cylinder heads with adaptor plates.



This Chassis Research kit includes adaptor flanges, pipe flanges, and pipes.



This Chevy's individual pipes are on the long side. Most rodders try different lengths.

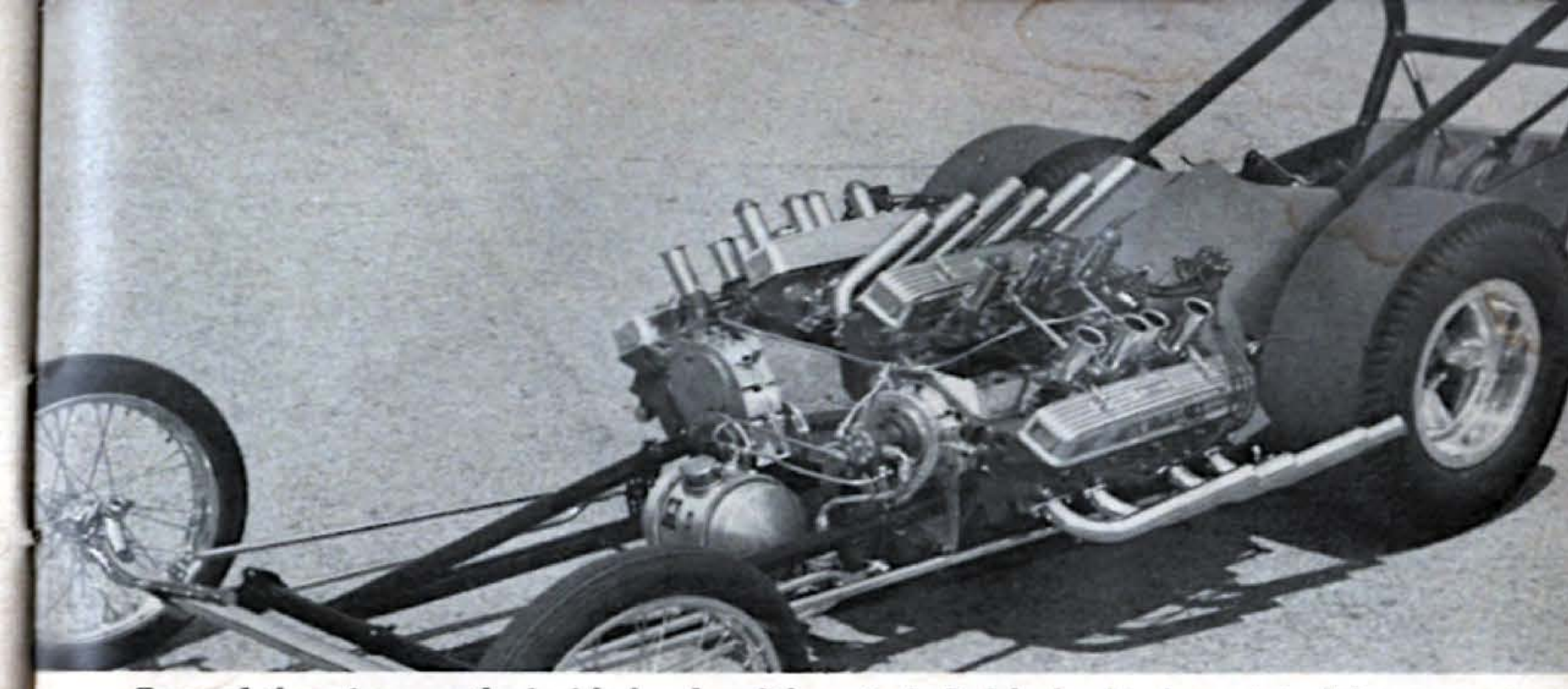
door, and their open ends point in a specified direction. The simplest method of complying with such rules is usually the best. The pipes used should have the same inside diameter as the header outlets and bends in them should be kept at a minimum. Bends that are necessary should be made as long and as sweeping as possible.

For competition classes that permit them there seems to be little doubt that an individual pipe for each cylinder is the best. Tubing of the same diameter is used for all the pipes and when possible the pipes are made the same lengths and given the same contours. This is an ideal setup when each cylinder has its own exhaust port and still the best when the two middle cylinders in each bank are served by a siamese port. The pipes can be attached to a common plate in the same manner as header pipes or, if the capscrew holes are arranged correctly in the engine, each pipe can have its own flange.

In stock-bodied cars it is usually necessary to direct individual pipes downward and toward the rear of the car. Occasionally they are run straight out from the engine through openings in the fenders or straight up through the hood but most fellows are reluctant to cut holes in fenders or a hood for this purpose. They can be connected with suitable brackets and braces to prevent their vibrating excessively and breaking off the flange at their cylinder head end.

Exhaust system design freedom is greatest in cars built for all-out performance. The simplest of these are dragsters. The average dragster's engine is completely free of body panels of any sort that might interfere with its exhaust system. The pipes can be aimed any direction considered best and can be long or short. The noise from such a system can crack eardrums but the cars wouldn't be half as much fun if their exhaust were quiet.

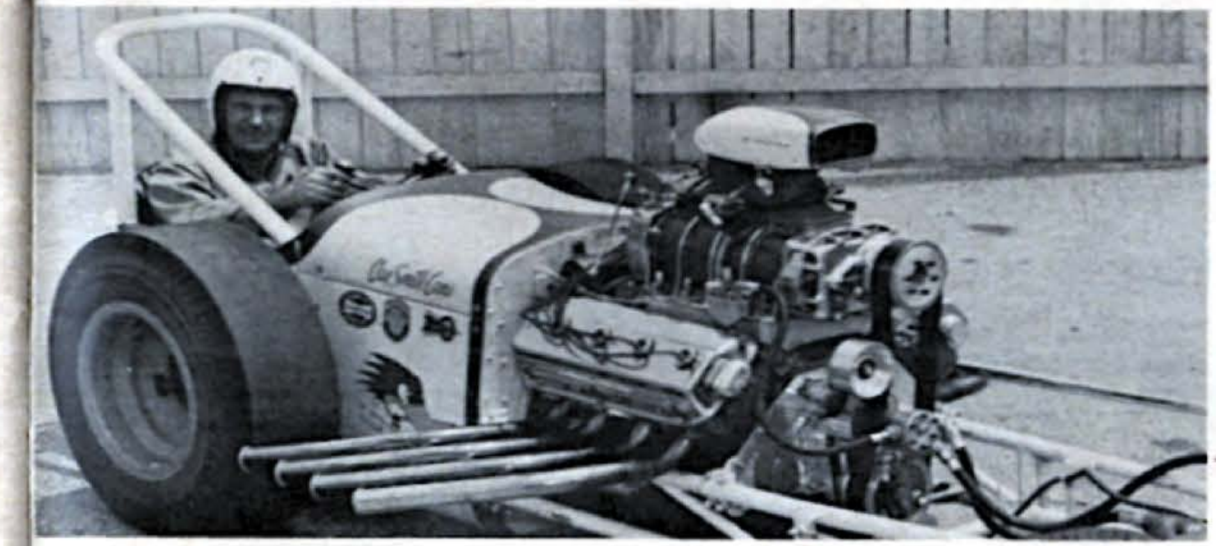
The adaptor flanges described in the section on headers were designed specifically for individual pipes. After the exhaust ports and passages have been enlarged to normal porting standards pipes that have areas equal to that of the ports are usually so large that there isn't room between them and the capscrew holes for the installation of capscrews to secure their flanges to the engine. The adaptors are a cure for this condition by providing new capscrew holes that are far enough



Two of the pipes on the inside banks of these twin Buicks had to be pointed downward.

apart to give ample capscrew head clearance.

The adaptors have the secondary advantage of simplifying pipe and port alignment. They can be bolted to the head or block, without the pipes, and then their openings can be aligned perfectly with the engine's ports. After this has been done they can be removed from the engine and be bolted to their respective pipes. This will enable the openings in the pipes and their flanges to be aligned with the openings in the adaptors. It isn't necessary to make the ports in the adaptors or the pipes bolted to them larger than the engine's ports to compensate for port mis-alignment due to block expansion. As there isn't any connection between the adaptors or between the pipes there isn't anything to cause them to move in relation to the engine's ports. Any difference that may exist in the sizes of the ports in the various members must be such that the ports become larger in the direction of exhaust gas flow. This will prevent the possibility of any overlapping of the various members that might create a resistance to the flow of exhaust gases or cause turbulence in them. ■



Pipes on the Chrisman-Cannon dragster's Chrysler are fairly long to clear the tires and are aimed downward.

EXHAUST SYSTEM TUNING

A SUBJECT that usually pops up sooner or later when high-performance engines are being discussed is exhaust system tuning. This is something that is shrouded with a cloak of mystery almost as impenetrable as the one that surrounds witchcraft. It has been credited with effectiveness second only to that of the H bomb.

The theory of exhaust tuning is to use the flow of gases through an engine's exhaust system to cause the pressure in the engine's cylinders to be lower than atmospheric pressure when the intake valves open. The lower the pressure in a cylinder when its intake valve opens, the sooner fresh mixture will start to flow into it and the greater will be the weight of the charge in it when the valve closes.

Exhaust system tuning requires a combination of ideal conditions in a cylinder and its exhaust and induction systems. The crankshaft speed range over which this combination of conditions is effective is extremely narrow, and it is said that the exhaust system required for it can cause power losses at other crankshaft speeds that are considerably greater than the increase gained at the favorable speed.

The induction system becomes involved in exhaust tuning because the pressure in it when the intake valve opens is important. To prevent pressures from different cylinders from affecting each other it is necessary that each cylinder have its own induction system.

For the magic of exhaust tuning to be possible, both of a cylinder's valves must be open at the same time so the low pressure in the exhaust system can act on the mixture in the induction system. This doesn't pose any problem as having the valves open together is nothing more than valve overlap, which is common with the valve timing provided by most camshafts; however, for exhaust tuning the amount of overlap would probably have to be greater than the amount ordinarily used. Each cylinder must have its own exhaust pipe so exhaust pressures from one cylinder can't influence the pressure in another pipe and its cylinder. The volume of the exhaust system, as determined by the length and cross-sectional areas of its passages and pipe, must be correct. Exhaust system volume is the heart of exhaust tuning.

One of the more predominant of the theories often given as a reason for valve overlap, and which is closely related to the theory of exhaust tuning, is that holding the exhaust valve open after the piston begins its intake stroke allows inertia created in the exhaust gases flowing out of the cylinder past the valve to continue to cause gases to flow from the cylinder although the force of the piston against the gases has ceased. This is said to increase the quantity of gases that leave the cylinder over that possible if the valve closed as the piston reached the end of the stroke. Movement of the gases as they are propelled by inertia supposedly creates a low pressure in the cylinder, which is the purpose of exhaust tuning. Because the intake valve is partially open, this low pressure causes fresh mixture to start flowing into the cylinder although the piston hasn't moved far enough to become effective on its intake stroke. This fresh mixture supposedly displaces exhaust gases, causing a greater quantity of the gases to be forced out of the cylinder.

The effectiveness of valve overlap for the purpose of starting fresh mixture flowing into a cylinder would depend on the amount the valves were open and the period of time they were open together. The amount the valves would be open would be determined by the action imparted to them by the camshaft but at most it could be only a slight amount, a matter of only a few thousandths of an inch. Valves usually open quite slowly the first few degrees of crankshaft rotation and then at a more rapid rate. This action is reversed when they close. The length of time they would be open together would be determined by crankshaft speed.

As an example, the period of time valves that have an overlap of 60 degrees are open at the same time in an engine running at 5000 crankshaft rpm is approximately 1/500th of a second. To get an idea of just how short this time is, watch the shutter of a high-speed camera as it opens and closes. And, most competition engines turn considerably faster than 5000 rpm, which makes the time even shorter. At slower crankshaft speeds, when the intake valve doesn't have to open early, the exhaust valve doesn't have to close late, and the effects of overlap are a detriment to engine performance, the length of time the valves are open together is longer. This is when exhaust tuning might become practical but the application wouldn't be any good for an automobile engine.

The real reason for valve overlap has to do with the period of time each of the valves is open for its respective stroke and the slow rates at which the valves open and close. The fact that the intake valve starts to open before the piston finishes its exhaust stroke and the exhaust valve closes after the piston starts its intake stroke is simply because the valves can't be opened and closed instantaneously.

At low crankshaft speeds, when the periods during which the valves are open for each stroke are comparatively long because the crankshaft is making fewer revolutions each minute, opening the intake valve just as the piston started its intake stroke would probably allow ample time for enough fresh mixture to flow into the cylinder while the piston completed its stroke, and the maximum quantity of exhaust gases would probably be forced out of the cylinder if the exhaust valve closed as the piston finished its exhaust stroke. But at higher crankshaft speeds, when the time during which fresh mixture can flow into the cylinder and exhaust gases can flow out of it may be only a half or a third of the time allowed at the lower speed, the intake valve must start to open earlier in relation to piston position so it will be open enough when the piston starts its intake stroke to allow fresh mixture to begin flowing into the cylinder without delay. Closing the exhaust valve after the piston has completed the exhaust stroke causes it to be open a slight amount when the piston reaches the top of the cylinder at the end of the stroke. This allows exhaust gases to flow out of the cylinder during the stroke's full duration.

The theory that a steady low pressure is created in an exhaust system by exhaust gas inertia is shot down by one of the world's greatest authorities on the internal combustion engine by his statement to the effect that the pressure of the exhaust gases that flow from a cylinder and through its exhaust pipe alternates continually between magnitudes slightly above and slightly below atmospheric pressure. The actual pressures are said to depend on the length of the pipe. If the pressure is lower than the pressure in the induction system when the intake valve opens, fresh mixture will begin immediately to flow into the cylinder; if it is higher than the pressure in the induction system, exhaust gases will flow past the intake valve and into the induction system. Pressure in the induction system when the intake valve opens depends on the system's length and volume but in a naturally-aspirated engine that has a system common to automobile engines it cannot be higher than atmospheric pressure.

The alternately high and low pressure conditions in an exhaust system make a high pressure in a cylinder when the intake valve opens just as possible as a low pressure but, according to the exhaust tuning theory, a low pressure period can be obtained at the crankshaft speed where it would be most helpful by correctly adjusting the volume of the cylinder's exhaust system. This is done by finding the correct combination of exhaust pipe length and diameter .Also, as the magnitude of the pressure is dependent on exhaust pipe length, using the correct length of pipe will guarantee the lowest pressure. Doing these things shouldn't be any more difficult than balancing a bowling ball on the end of a pencil.

The same authority referred to before also states that when the pressure in the exhaust system and the cylinder is lower than that in the induction system in engines in which the intake and exhaust valves are close together, as they are in most automotive engines, fresh mixture rather than exhaust gases will flow past the exhaust valve and into the exhaust system. In other words, fresh mixture will be lost by being carried into the exhaust system but the quantity of residual gases remaining in the cylinder when the exhaust valve closes will not be affected to any appreciable extent. However, on the credit side, flow of fresh mixture into the cylinder will have been started.

As far as the average rodder is concerned, the possibility of obtaining any benefit from exhaust tuning is remote almost to the point of being impossible. If a fellow has an engine dynamometer and lots of money, time, and patience he might eventually improve an engine's performance in a certain speed range with a special exhaust system. But the result that might be gained doesn't seem to balance the effort. ■

Right: Huth Tube Bender. Photo Courtesy Huth Manufacturing Co.