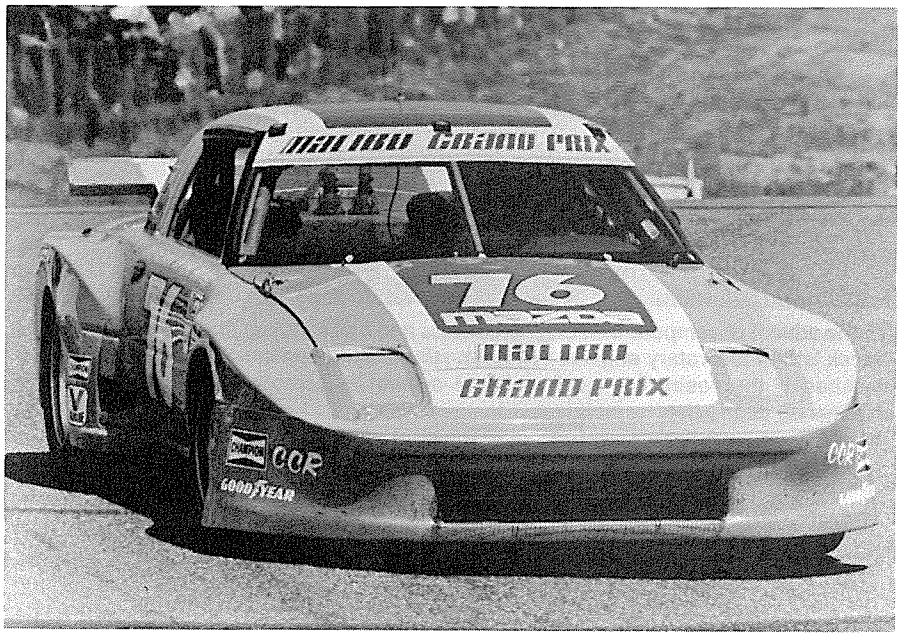
EXHAUST

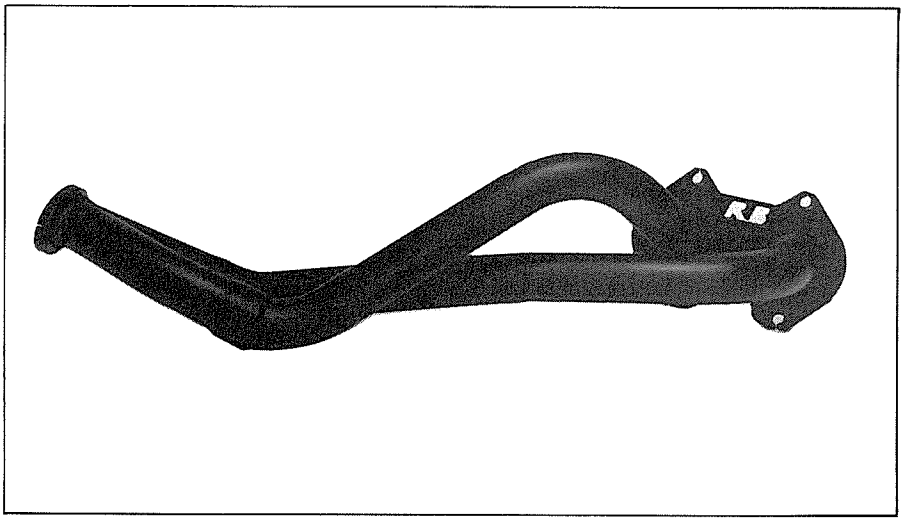


For street *and* racing, rotary-engine exhaust noise is always a problem. Unless you enjoy collecting traffic citations, a racing-type exhaust system, such as the one used on this championship GTU racer, shouldn't even be considered for use on a street car. An interesting aside, this car, designed by David Downing, has won four GTU championships—1982 with Jim Downing at the wheel, 1984 and 1985 with Jack Baldwin and 1986 with Tom Kendall.

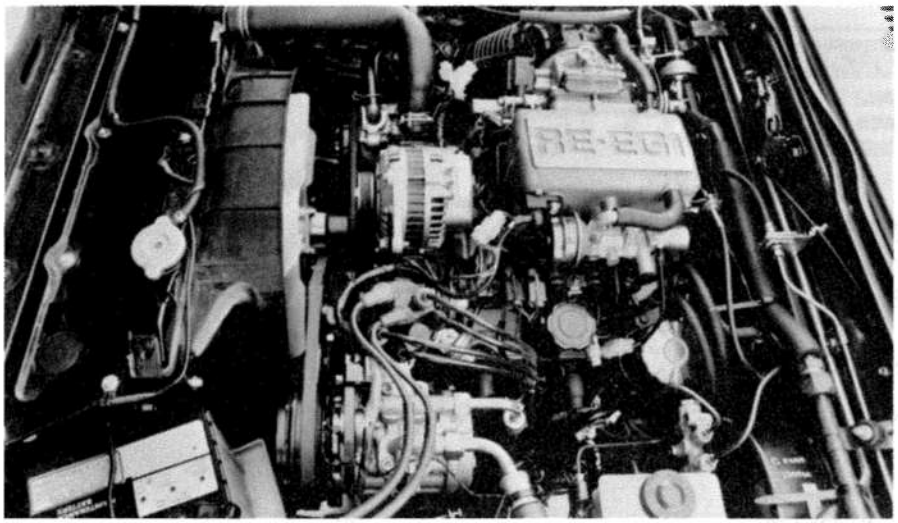
It's only logical when delving into the innermost secrets of an internal-combustion engine that the explanation should follow the same event sequence as that of its subject—intake, compression, power, exhaust. So why on earth, you are no doubt wondering, does Chapter 2 deal with the exhaust rather than intake cycle?

No, you guessed wrong. The author hasn't developed a terminal case of brain fade. Exhausting spent gasses may be the last cycle of the combustion process, but when dealing with a rotary engine, it is of paramount importance.

Restrictions in the exhaust system will choke the life out of the healthiest rotary powerplant. In fact, the need for a free-flowing exhaust becomes increasingly more critical with every power-raising modification. Consequently, when modifying a Mazda rotary engine, the exhaust



Racing Beat's streetable header/collector fits 1981—85 RX-7s and considerably reduces exhaust-system back pressure. Models are available for either 12A or 13B. Photo courtesy Racing Beat.



With the advent of computerized engine controls and fuel injection, the horsepower level of stock late-model rotary engines has been raised. But even more horsepower can be unleashed if the restrictive stock exhaust system is scrapped in favor of a high-performance alternative.

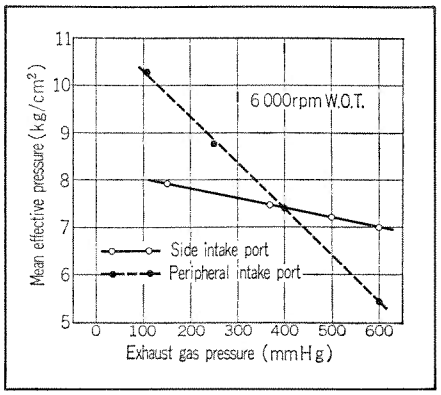
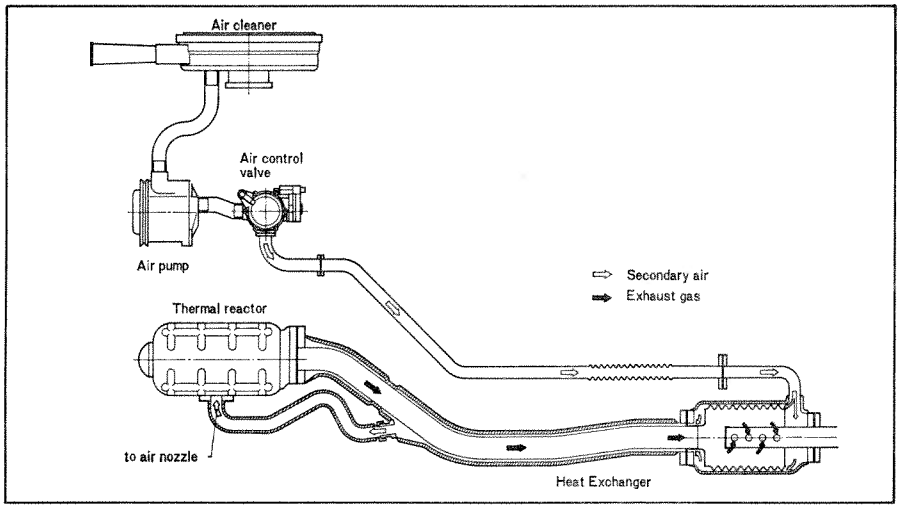


Chart shows effect of back pressure on engine performance—measured as mean effective pressure. Note that peripheral-port engines produce considerably more power when exhaust back pressure is low, but as back pressure increases, output drops below that of a side-port engine. Extended overlap of peripheral-port design is largely responsible for severe power drop in the face of a highly restrictive exhaust. Even the best streetable exhaust system is too restrictive for a peripheral-port engine. Chart courtesy Mazda.

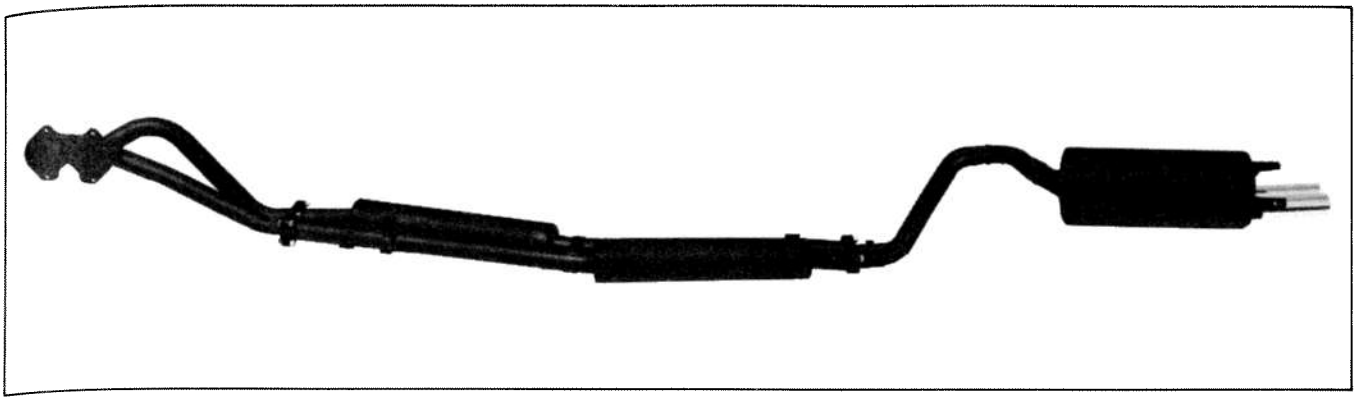


Air and exhaust-gas flow through thermal reactor and heat exchanger. Drawing courtesy Mazda.

system is the place to *start*, not end. So, there is some logic at work here after all.

Intake-Charge Dilution—A restrictive exhaust system has a detrimental effect on the performance of any type of internal-combustion engine. But with a rotary powerplant it is especially harmful because the incoming charge can be diluted by the gasses from two exhaust cycles rather than one. Internal combustion is internal combustion irrespective of whether the engine involved is of the reciprocating or rotary persuasion. But the rotary is unique because its combustion chambers move. As the rotor spins through its assigned route, it pulls the intake charge in, compresses the fresh mixture while moving it over to the sparkplugs, then delivers the spent gasses to the exhaust port.

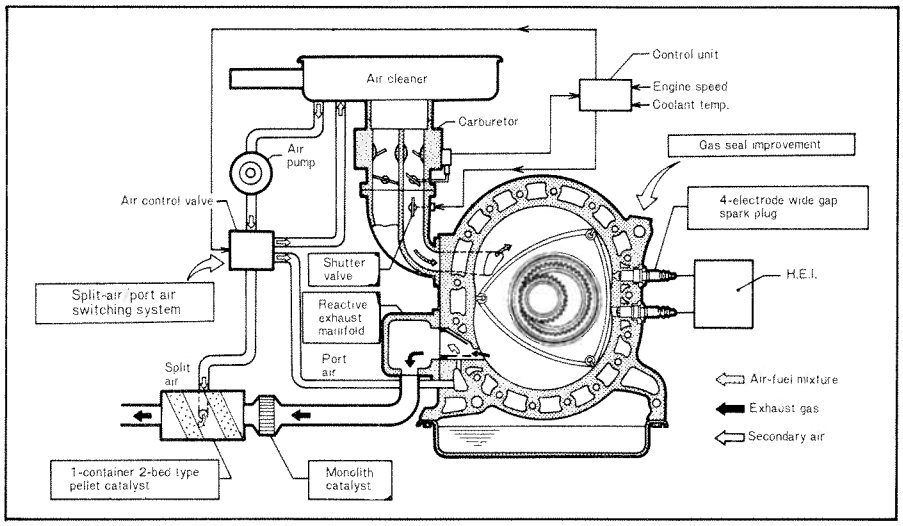
The gasses in one chamber are not completely eliminated before gasses from the succeeding chamber are brought to the exhaust port. And during the time the rotor apex is across the port, the high-pressure exhaust gas from the following chamber can travel into the leading chamber and up to the intake port. This double dose of exhaust gas is obviously detrimental to the power-producing capabilities of the intake mixture, but the situation is made worse because the gasses in the second chamber are at maximum pressure when the apex clears the exhaust port.



One exhaust-system design will not meet the requirements of all engines. Racing Beat system is designed for street-ported engines and includes a header, two presilencers and a muffler. Not that the two primary pipes are not joined until the muffler entrance.

Consequently, if flow through the exhaust system is impeded to a significant degree, it's far more serious than it would be with a reciprocating engine, where the gasses remaining in the combustion chamber are simply residual and relatively benign. In a rotary, a restrictive exhaust system results in both residual and high-pressure exhaust gas—from the following chamber— interfering with the intake system.

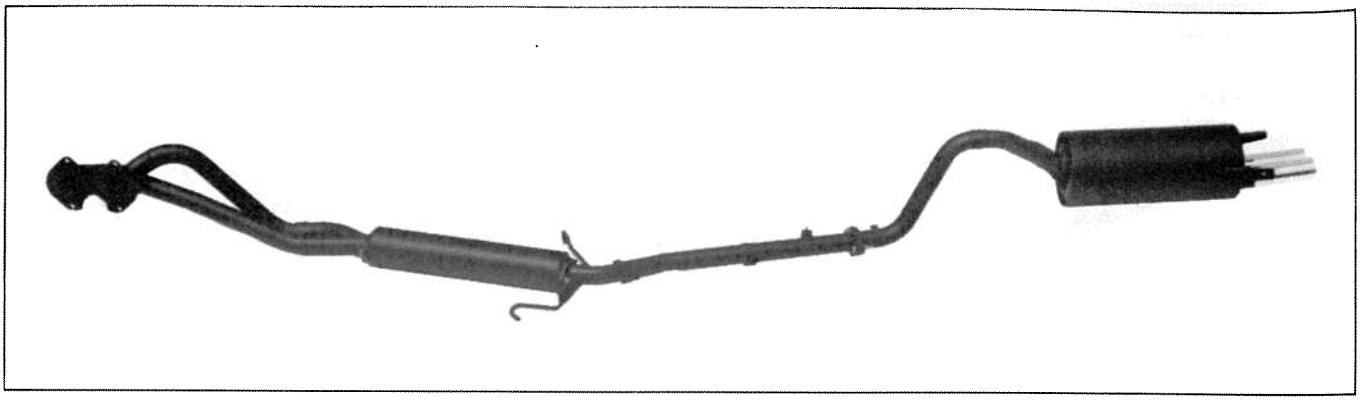
The situation is roughly analogous to a two-cylinder, four-cycle reciprocating engine with both cylinders served by a single exhaust port. If cylinder number-1 were in its *overlap period*—where both intake and exhaust valves are open—and the exhaust valve of cylinder number-2 opened, its high-pressure exhaust gas could enter cylinder number-1—because of the single exhaust port—and play havoc with the incoming air/fuel mixture. Naturally, a highly restrictive exhaust system would aggravate the situation—just as it does in a rotary. As exhaust back-pressure increases, a greater percentage of the high-pressure exhaust—from the following chamber—is channeled into the chamber receiving a fresh intake charge. That results in a decrease in intake-charge volume and a corresponding drop in power output.



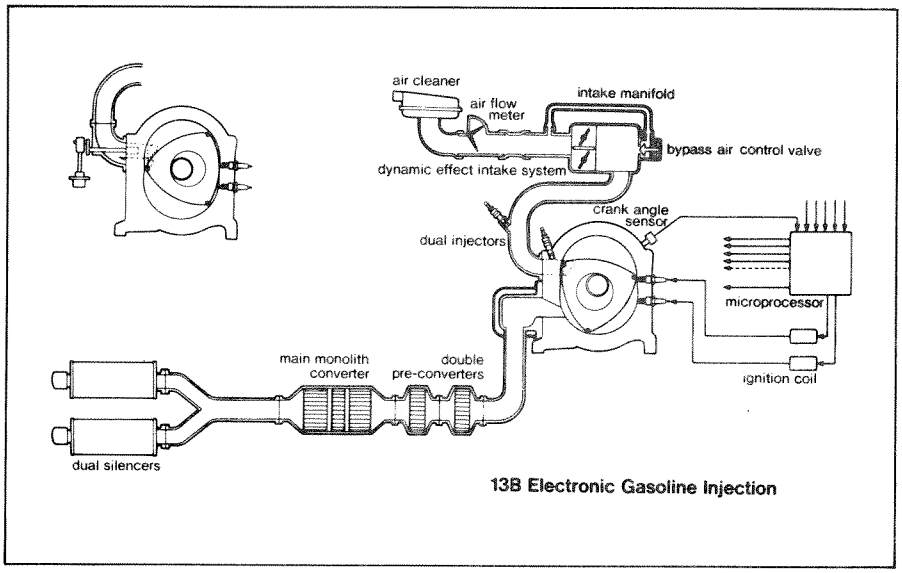
Air and exhaust gas-flow through catalytic-converter-equipped exhaust system. Drawing courtesy Mazda.

Power losses caused by restrictive exhaust systems aren't as great in reciprocating engines because each cylinder has its own exhaust port. And high-performance and race engines are fitted with headers that keep the exhaust pipes from each cylinder separated for some distance. In instances where exhaust tracts from adjacent cylinders can't be completely isolated—as in engines utilizing Siamesed exhaust ports—power output is less than optimum.

With stock-type reciprocating engines where the exhaust manifolds are essentially a single collecting chamber, valve opening and closing times can be easily altered to minimize the negative impact of exhaust dilution. With a rotary engine, intake- and exhaust-port opening and closing timing is determined by port



Exhaust system is designed for unported engines and includes a header that joins the two primary pipes at the presilencer. Only slightly louder than stock system, it increases power by over 20%. Photo courtesy Racing Beat.



13B Electronic Gasoline Injection

As schematic shows, 1986—87 RX-7 has dual outlets, not dual exhausts. Although it is a considerable improvement over previous stock systems because of increased capacity through the use of two mufflers, it is more restrictive than a header system.

size and position. Due to the rotor-housing configuration, there isn't as much latitude with intake and exhaust opening and closing times as there is with camshaft-controlled valve timing. There are also constraints on the degree to which ports can be enlarged. And, of course, performance compromises must also be considered.

Delaying exhaust-port closing improves wide-open-throttle performance, especially at engine speeds in the higher ranges. But the later port closing increases overlap—where both intake and exhaust ports are open—reducing efficiency under light loads and decreasing idle quality.

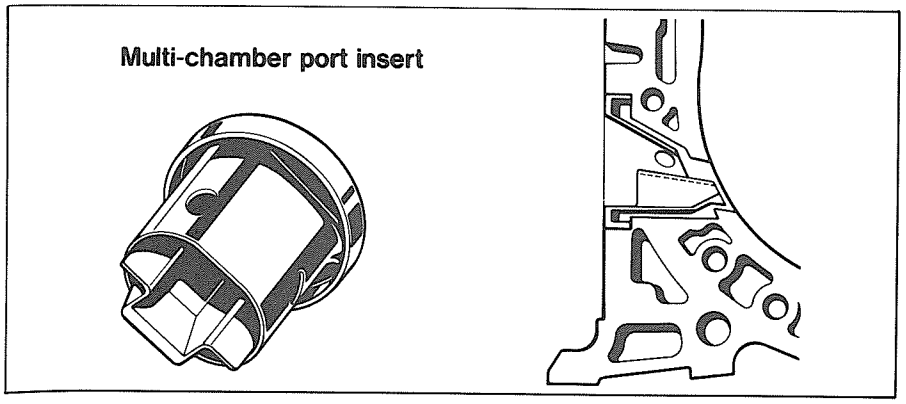
Porting a rotary engine is therefore analogous to changing camshaft timing in a reciprocating engine. Most rotary-engine porting jobs incorporate port-timing alterations in addition to improving flow capacity. And just as a "radical" camshaft is inappropriate in an engine used for street driving and autocrossing, excessive rework of the ports in a rotary engine intended for similar applications is equally inappropriate. The most logical starting point for improving exhaust-system efficiency is with the exhaust header.

EXHAUST SYSTEM

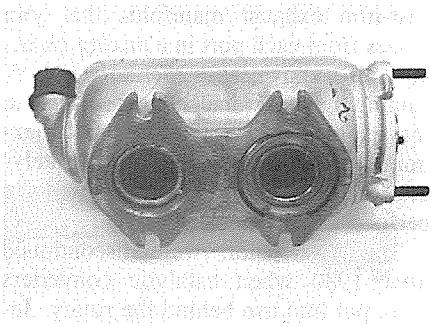
With a reciprocating engine, the standard approach to eliminating restrictions in the exhaust tract is to remove the original-equipment exhaust manifold/muffler assembly and replace it with a set of tubular headers and a free-flowing muffler. This technique is equally effective when applied to a rotary engine, but it becomes a bit more involved, especially with street-driven vehicles. When the rotor spins past the exhaust port, it signals an all-out assault of heat and noise; special measures are required to deal with the onslaught.

At full throttle, rotary exhaust-gas temperatures (EGT) are *extremely* high—possibly reaching 1600—1800F. Compare this to an EGT of 1150—1400F for the typical reciprocating engine operating at wide open throttle.

In order to withstand a rotary's fiery breath, header tubing must be either extra heavy-wall mild steel or stainless steel. Stainless offers an attractive appearance, but it is expensive and difficult to weld. Consequently, mild steel is usually the material of choice with most manufacturers offering headers for Mazda 12A and 13B engines. In addition to keeping



Multi-chamber port insert is included in 1986—87 13B engine as a means of reducing sharpness of the exhaust note. Insert is not used on turbocharged engines.



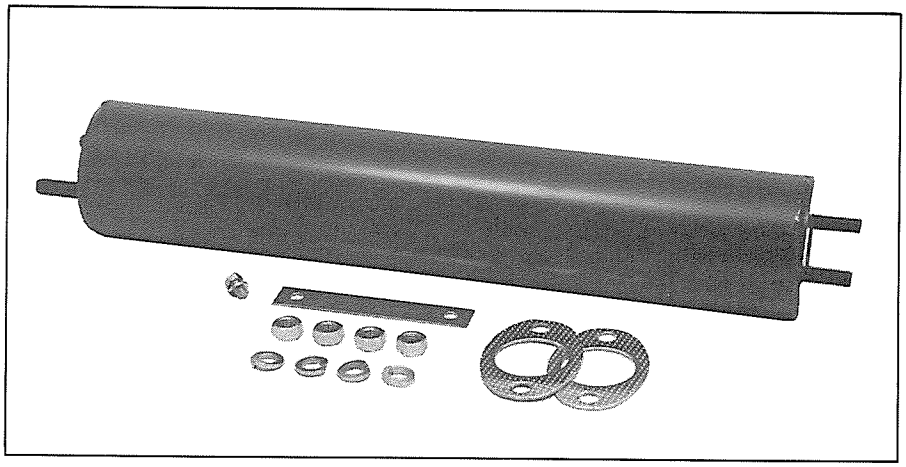
While thermal reactor may do great things for noise and emissions control, it puts a severe kink in the horsepower curve. It also imposes quite a weight penalty.

down costs, heavy-wall mild-steel tubing also reduces the exhaust-noise level. And when dealing with a rotary engine, *anything* that reduces noise without impeding exhaust flow is extremely valuable.

The high intensity of a rotary engine's exhaust sound is due primarily to the sudden uncovering of the wide-open exhaust port. Whereas a reciprocating engine has a comparatively slow-moving poppet valve to run interference, when a rotor spins past an exhaust port, the sound waves are presented with an immediate, unrestricted path to the world outside. As you may guess, conventional two-stroke engines experience a similar noise problem. A high noise level is the price that must be paid for a highly efficient exhaust port.

Considering the fact that headers for a Mazda rotary engine should be fabricated of minimum 0.120-in.-wall tubing—headers for reciprocating engines typically sport 0.049—0.062-in.-wall tubing—do-it-yourself header building is practical only if you have access to good tube-bending equipment. The more sensible approach is to purchase a finished header or header kit from a Mazda parts specialist such as Racing Beat, Rotary Engineering or Mazmart.

As applied to Mazda rotary engines, several exhaust-header options exist. Research devoted to maximizing the performance of the championship Mazda RS, GTU and Camel Light race cars campaigned by the Downing/Atlanta



Presilencer is essentially a small, straight-through muffler that helps control exhaust noise emitted by a rotary engine. Straight-through design offers minimal flow disruption, yet drops noise level sufficiently that the main muffler can reduce it to tolerable levels without being overly restrictive. Photo courtesy Racing Beat.

race team and others has demonstrated the critical nature of primary tube length when working with a stock- or street-ported engine. The distance between the exhaust ports and collector influences the engine speed at which maximum torque and, consequently, maximum power occurs. While the effects of altering pipe length by a few inches are not dramatic for optimum performance, the exhaust system should be tuned to the engine's operating range.

However, it isn't necessary to work with infinitely variable exhaust-system lengths. In practical applications, stock or mildly ported rotary engines respond best to an exhaust system that has the longest possible primary length. Unfortunately, the exhaust system that produces the most power always seems to be the noisiest, so the "best" system may not be practical in some applications. Any header system, even those with two relatively short pipes joining in a collector, will lead to increased exhaust noise. As might be expected, it is the separation of exhaust pulses that contributes to the power increase produced by the header—more power, more noise.

Stock Mazda exhaust systems utilize

cast-iron exhaust manifolds that join pulses from each port in a *mixing chamber,* also known as a *thermal reactor.* Joining the two exhaust tracts as close to the engine as possible provides maximum noise reduction. Unfortunately, this practice isn't necessarily good for performance.

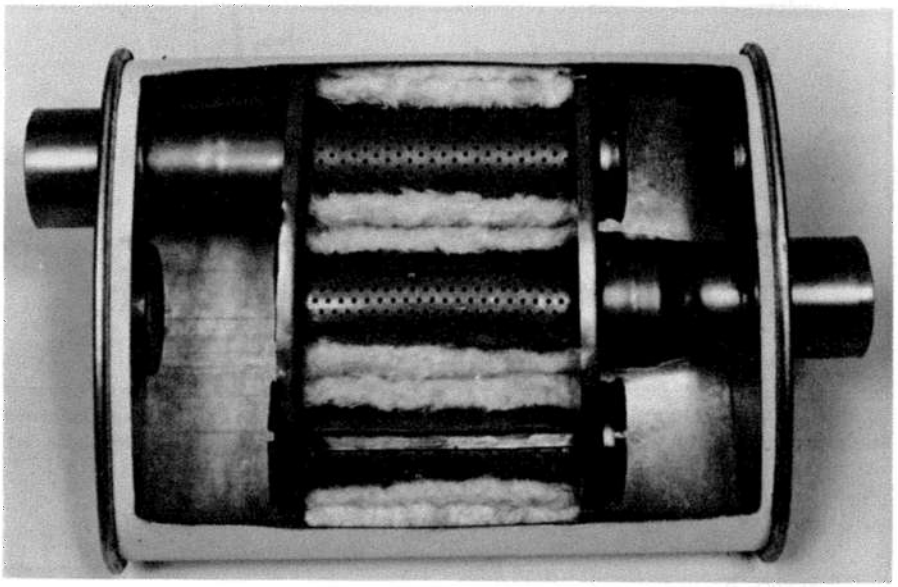
Thermal reactors were discontinued after 1980 when catalytic converters were put into use behind the rotary. Instead, a high-nickle-content cast-iron exhaust manifold is used.

Mufflers, Reactors, Manifolds & Converters—Except for '75 and earlier rotaries, downstream from the stock reactor or manifold is either a heat exchanger or catalytic converter and muffler. An air pump is used to inject fresh air into the exhaust port as a means of continuing the *oxidation*—burning—of the residual hydrocarbons in the exhaust. The oxidation process takes place in the thermal reactor, which is essentialy a "furnace."

1971—75 models have a reactor and small muffler ahead of the main muffler; 1976—80 models have a thermal reactor, head pipe, heat exchanger and muffler; '81 to current models are equipped with an exhaust manifold, *monolithic* converter, catalytic converter and muffler. 1984—87 models use two monolithic converters.

Monolithic or pre-converters have a one-piece egg-crate construction that *lights off* unburned fuel before it reaches the main converter, where additional air is added to complete the burning. Monolithic converters are expecially useful in cold starts where they speed *light-off* of the main converter for reduced emissions.

Unfortunately, because of the noise and heat that the exhaust system must handle, components are rather expensive. Beginning with the 1981 model year, RX-7s were equipped with catalytic converters rather than thermal reactors. With the restrictive nature of the converter, it was possible to utilize a relatively free-flowing muffler. At first glance, it would seem that installation of 1981 or later RX-7 mufflers, on early rotary-engined Mazdas would be a low-cost "speed secret." It is in some instances, but if a 1981 or later muffler is used in conjunction with a header, the resulting exhaust noise will certainly invoke the unbridled wrath of the local constabulary.



Sonic Turbo marketed by the makers of Cyclone and Blackjack headers employs typical "turbo muffler" cross-flow construction, but also includes pyrex packing to control noise. Even though it's one of the best low-restriction mufflers available, the extremely hot breath of a rotary will cause rapid degradation.

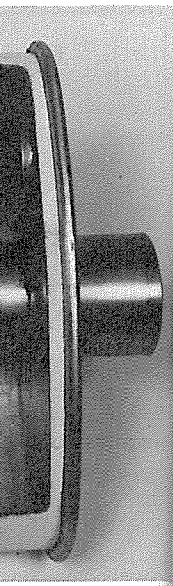
Second to the 1981 and later stock mufflers, the 1979—80 mufflers are least restrictive. However, they are only marginally better than any of the other stock rotary mufflers except for the ones used on RX-3s, which are the most restrictive. While a noticeable performance improvement with acceptable noise level could be derived from installation of an RX-7 muffler on an RX-3, a complete high-performance exhaust system is required to produce a significant power increase.

There are very few mufflers capable of coping with the fire found in a rotary-engine's exhaust system; a standard low-restriction glasspack or *turbo* muffler will be fried like a sausage cooked with a blow torch after a few hours on the job. To date, the only mufflers found to be satisfactory are the Prima Flow muffler from Racing Beat and Mazmart or those produced by Mazda. When an engine is fitted with a header, the Prima Flow muffler is typically used in conjunction with a "Power-Pulse" presilencer.

Rotary Engineering has devised an exhaust system that incorporates a presilencer/collector assembly that bolts to the header. A second presilencer is bolted to the first, and a standard turbo muffler is then used downstream. Rotary Engineering claims that this mellow sounding system provides a significant power increase. And while it is a good compromise between noise, power and cost, other systems may be better suited for some applications.

Exhaust-System Design—Mazda 12A and 13B engines intended for highway and autocross applications should produce maximum torque at relatively low rpm. Consequently, maximum length is preferable. That means running two pipes—either 1-3/4 or 1-7/8-in. ID depending upon application—from the engine all the way to the rear bumper.

Ideally, the pipes should be collected at that point and connected to a megaphone. Such an arrangement will prove much too loud for street driving and may, in fact, be too loud for autocrossing. Both Racing Beat and Rotary Engineering offer exhaust systems that provide a good compromise between noise and power. Although these systems



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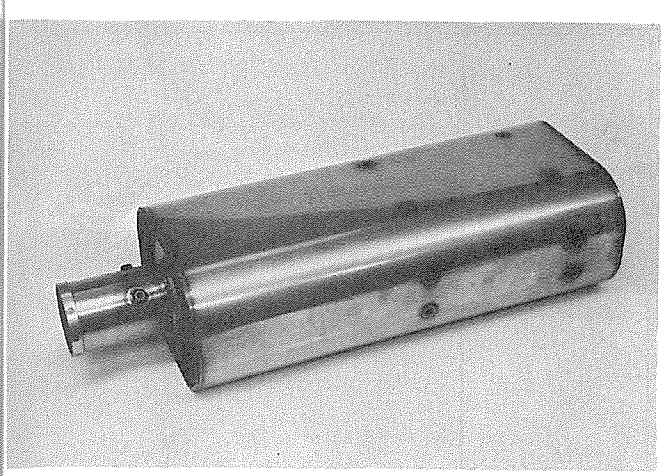
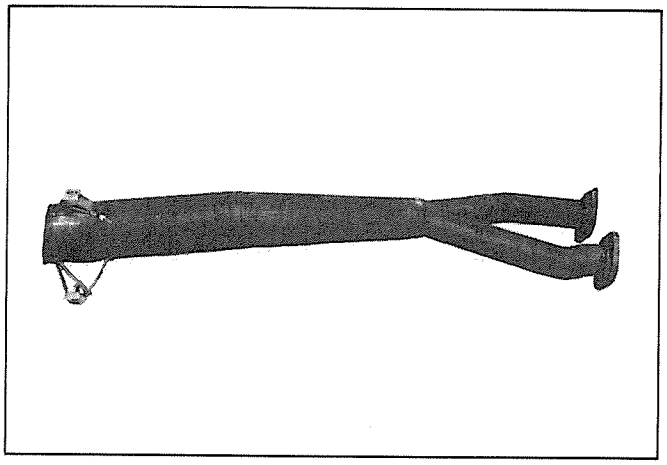


As population closes in around race tracks, complaints over noise increase in frequency and intensity. As a result, it's not unusual that race cars be required to run mufflers. This stainless-steel muffler was developed by Mazda and installed on the Downing/Atlanta Camel Lights GTP race car.



Race-car chassis design often limits exhaust-system design. This extremely short header/collector was necessitated when muffler had to be added to the already cramped Argo chassis.

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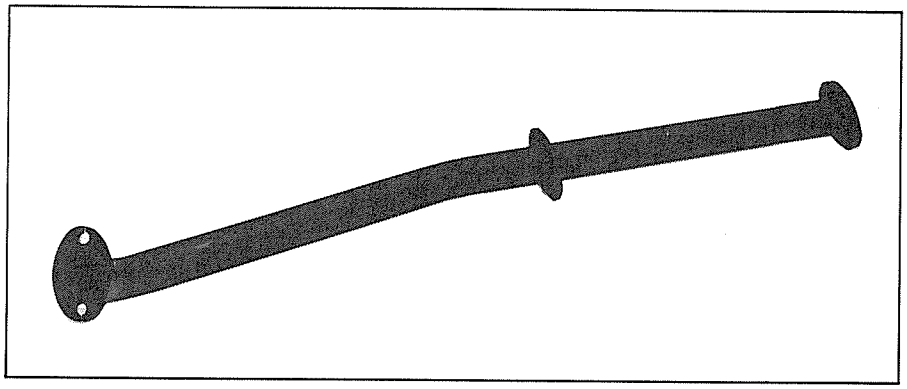
aren't particularly cheap, in the long run—considering fabrication costs and traffic citations—they may prove to be the most economical.

An example of an alternate approach is the system on Rick Engman's street RX-3. (Rick is the engine builder for the Downing/Atlanta team.) One Power-Pulse presilencer, one glasspack muffler and one Rotary Engineering high-temperature glasspack muffler are spliced into each primary pipe. In essence, six straight-through mufflers are incorporated to minimize flow restrictions. This system makes relatively few compromises that affect performance negatively. However, while it produces excellent power, it wasn't cheap and its noise level probably exceeds acceptable standards in some localities. Another drawback is that even though the glasspack muffler is at the rear of the system—farthest from the heat—it must be replaced periodically.

The least restrictive, streetable exhaust system from Racing Beat is the *Street Port* model. This system utilizes relatively long primary pipes, each of which incorporates a presilencer. The primaries are collected after the presilencers into a single pipe that leads to a Prima Flow muffler. The previously noted system from Rotary Engineering is also a good compromise for street applications.



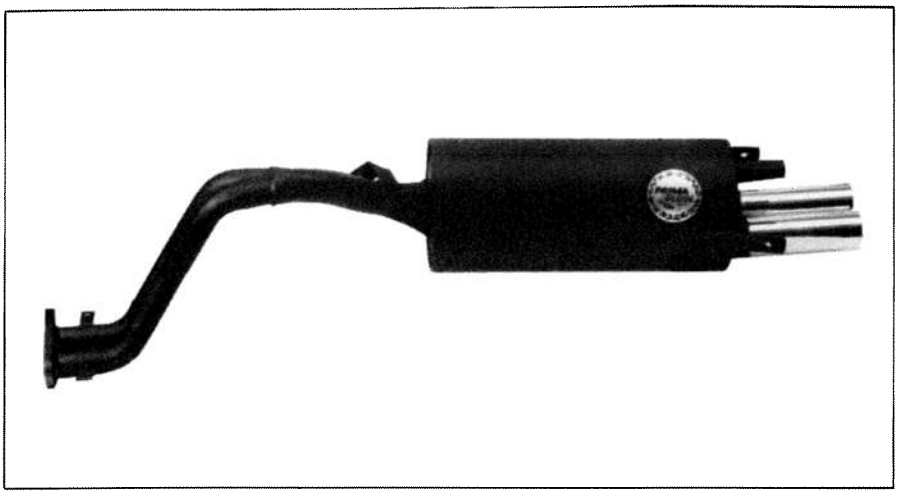
On '81 and later RX-7s, a substantial power increase can be realized by simply removing catalytic converter and replacing it with pipe made for that purpose. Of course, such replacements are not legal in some states. Photo courtesy Racing Beat.

Irrespective of the system chosen, whenever catalytic converters are removed from a 13B engine with six-port induction, a sensing tube must be added to transmit exhaust back pressure. This is required to open the auxiliary-port valves. Racing Beat offers an appropriate flange with gasket that bolts to a *Power-Pulse* presilencer for this purpose. Also, Racing Beat presilencers designed specifically for six-port engines incorporate a back-pressure sensing tube.

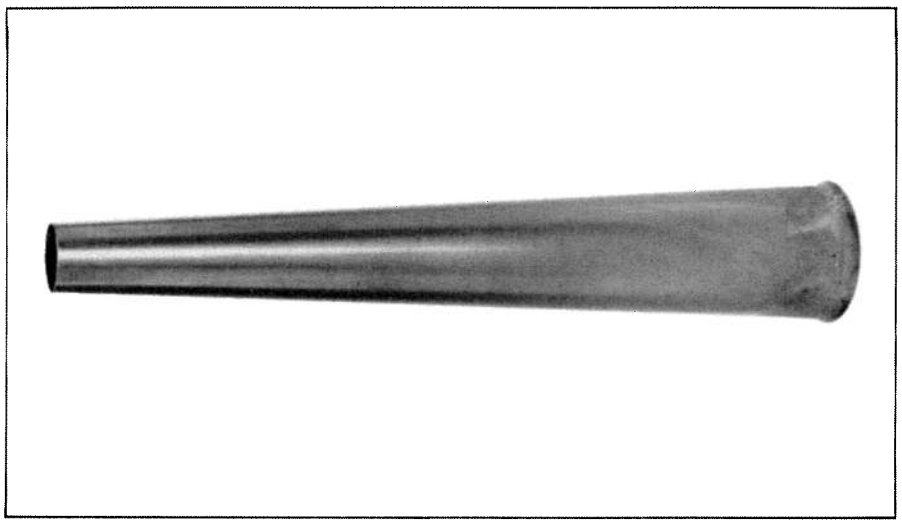
Rotary Engineering's and Racing Beat's headers for '84—85 13B six-port engines feature an oxygen-sensor fitting and back-pressure tube that bolts to the presilencer, replacing the catalytic converters.

Catalytic Converters—Although any high-performance exhaust system will give a power increase, some of this potential is lost with 1981 and later engines. The culprit? An ignominious device known as a *catalytic converter*. In order to take full advantage of any aftermarket exhaust system, the highly restrictive catalytic converter must be removed.

Catalytic-converter replacement pipes are available from several sources. Unfortunately, consigning the converter to the trash can is like sunbathing in the



The Prima Flow muffler is one of the few that can withstand the exhaust heat produced by a rotary engine. It is a direct replacement for the stock muffler and offers approximately a 5 HP increase while keeping exhaust noise at stock levels. Photo courtesy Racing Beat.



Exhaust system of a race-only vehicle should incorporate a megaphone after the two primary pipes join. Megaphone entrance diameter is 2 in. Photo courtesy Racing Beat.

nude—it's frowned upon in some states and localities, and downright illegal in others. Tampering with your car's exhaust system is likely to evoke the wrath of certain enforcement agencies, so check local regulations before modifying the exhaust system of any vehicle that will be driven on the street. And lest my name be added to the *Most Wanted* list of the latter-day Gestapo known as the California Air Resources Board (CARB), just about everything discussed in this chapter is "Legal in California only for racing vehicles which may never be used upon a highway."

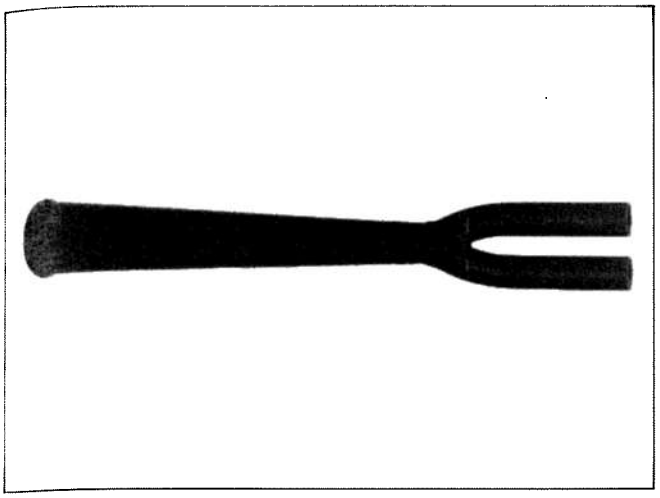
Header Design—Most race engines are of the peripheral-port or bridge-port persuasion. Both of these port configurations optimize power at rpm levels significantly higher than stock ports, hence header length must be adjusted accordingly.

Note that it isn't the port configuration itself that dictates header length, rather port configuration determines the engine speed at which peak power is produced. Header length is therefore *tuned* to maximize power at the rpm level at which the engine generates maximum power.

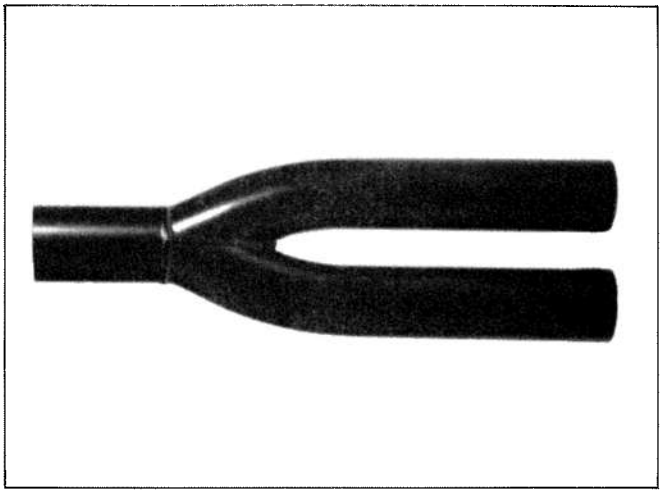
Peripheral-port engines call for primary tubes measuring 89—94-in. long with a 1-7/8-in. inside diameter (ID). By comparison, a "long" header system for a bridge-ported engine should incorporate primary tubes of the same diameter, but be 120—125-in. long. Neither the long nor the short systems show a significant power advantage with respect to one another. In fact, the Mazda/Argo race cars campaigned in IMSA Camel Lights road-racing competition must be fitted with short exhaust systems. Some chassis configuration don't allow for the installation of the preferred long exhaust tract.

Racing Beat's Jim Mederer says, "We've tried many different tuned exhaust lengths on engines. In general, for stock or "street-ported" engine, longer primaries are better. We have never found a point where power dropped as length was increased.

"For race engines (unmuffled or with Mazda's factory race muffler) there are certain specific tuned length "ranges" that should be used. Within this range, power peaks can be shifted slightly up or down in the rpm range. However, outside that range, normally *everything*



Racing Beat's collector/megaphone incorporates 2-in. inlet pipes and a 4-in. outlet diameter. The entire assembly is 35-in. long with the megaphone section measuring 24-in. long. Photo courtesy Racing Beat.



When fabricating exhaust-system components for a rotary, extra heavy-wall tubing must be used. Collector is fabricated from 0.120-in.-thick wall, 2-in.-OD steel tubing. By comparison, standard exhaust tubing has 0.049-in. wall thickness. Photo courtesy Racing Beat.

drops. I can't explain why because too many factors are involved, but that is the result."

While theoreticians go on ad nauseam about the optimum inside diameter of header tubes, availability makes their theories irrelevant. The only readily available stainless-steel tubes suitable for an exhaust system have 1-7/8, 2-, 2-1/8- and 2-1/4-in. IDs. That being the case, system length must be tuned to accommodate tube diameter; the larger the tube, the shorter it must be to be tuned to a particular rpm range.

Testing with the peripheral-port engines used in Camel Light competition has shown that a short header of 9—11 in.—measured from the header flange to the crotch of the collector—is most desirable with 1-7/8-in.-ID tubing. A shorter length such as 8 in. will not work as it creates severe fuel *stand-off*.

The collector itself should have a minimum 2-1/8—2-1/4-in. ID for most applications. Full-on race engines with either peripheral ports or bridge ports usually respond best to a minimum collector ID of 2-1/4—2-3/8 in. Ideally, the collected tubes should feed into a megaphone measuring 10—14 in. in length and 4 in. in diameter at the exit.

Porting, which is certainly an important part of improving exhaust efficiency, is covered in the chapter devoted to rotor-housing modifications.

On the rally circuit, the only thing more distinctive than the RX-7's ability to win is its exhaust sound. It's no wonder that (jealous) competitors talk badly about Mazdas. Richard Kelsey and codriver Chris Senske debuted their new car (1984) in impressive fashion; by beating their nearest competitor by 18 minutes.