HOUSING MODS & PREP

In classes such as the old Champion Spark Plug Challenge, rules covering engine modifications are very restrictive. However, even with restrictions, rotary engines produce impressive performance as demonstrated by Jim Downing winning the series championship in 1981.

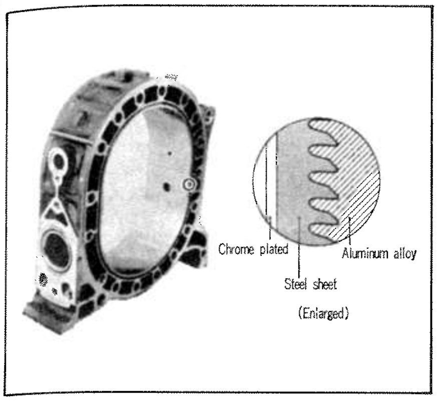
ROTOR & SIDE HOUSINGS

As Mazda once so aptly pointed out, a rotary engine doesn't go "boing, boing, boing" because it doesn't have any pistons. Consequently, cylinder walls are nowhere to be found, either. But just as a rotor is the rotary engine's equivalent of a reciprocating engine's piston, the inside surface of the rotor housing is roughly the equivalent of a cylinder wall. However, unlike a cylinder, the rotor housing surface cannot be refinished once it's worn or damaged. The finish itself is a chrome plating applied over a machined steel liner cast into the aluminum housing. Once the chrome is scored or otherwise damaged, the housing must be replaced.

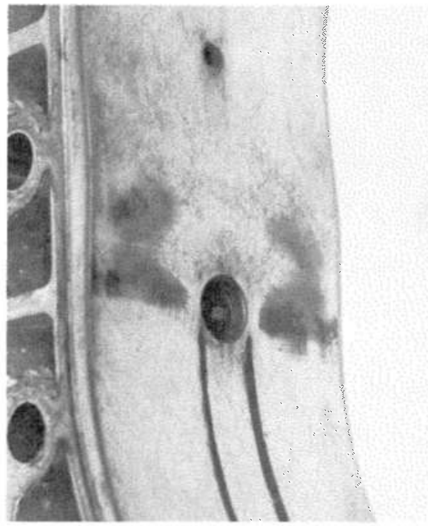
Rotor-Housing Machining—The only noteworthy machining operations that you should (or can) perform on a rotor housing are those that improve heat transfer or increase the flow capacity of the port or ports. Singular and plural are used in the previous sentence because a standard engine has only its exhaust port located in the rotor housing. The intake port is in the side housing. However, the rotor housings of peripheral-port (race only) engines include both intake and exhaust ports.

Side-Housing Machining—Side housings, which are cast iron, are also somewhat analogous to cylinder walls. The apex-seal ends, side seals and oil seals all contact the side-housing surface much like piston rings operate against a cylinder's surface. Like rotor housings, side housings are generally replaced when their original surfaces are worn, scored or warped. Warpage in excess of 0.04mm (0.0016 in.) or stepped wear in the side-seal or oil-seal areas are the culprits most commonly responsible for sending a side housing to the great iron recycler in the sky.

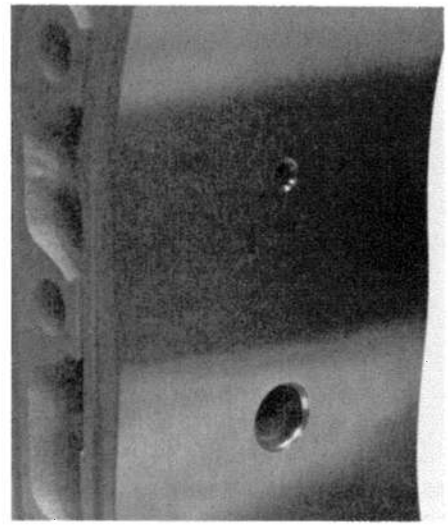
It is possible to have a side-housing surface reground and finished to acceptable standards, but such operations call for a large blanchard grinder and a highly experienced operator. In addition to being flat, the surface must not taper across



Since 1974, Mazda rotor housings have made use of the Sheetmetal Insert Process (SIP). In this process, the aluminum housing is die cast around a steel insert. Jagged teeth on back side of insert makes for a better steel/aluminum bond. Drawing courtesy Mazda.



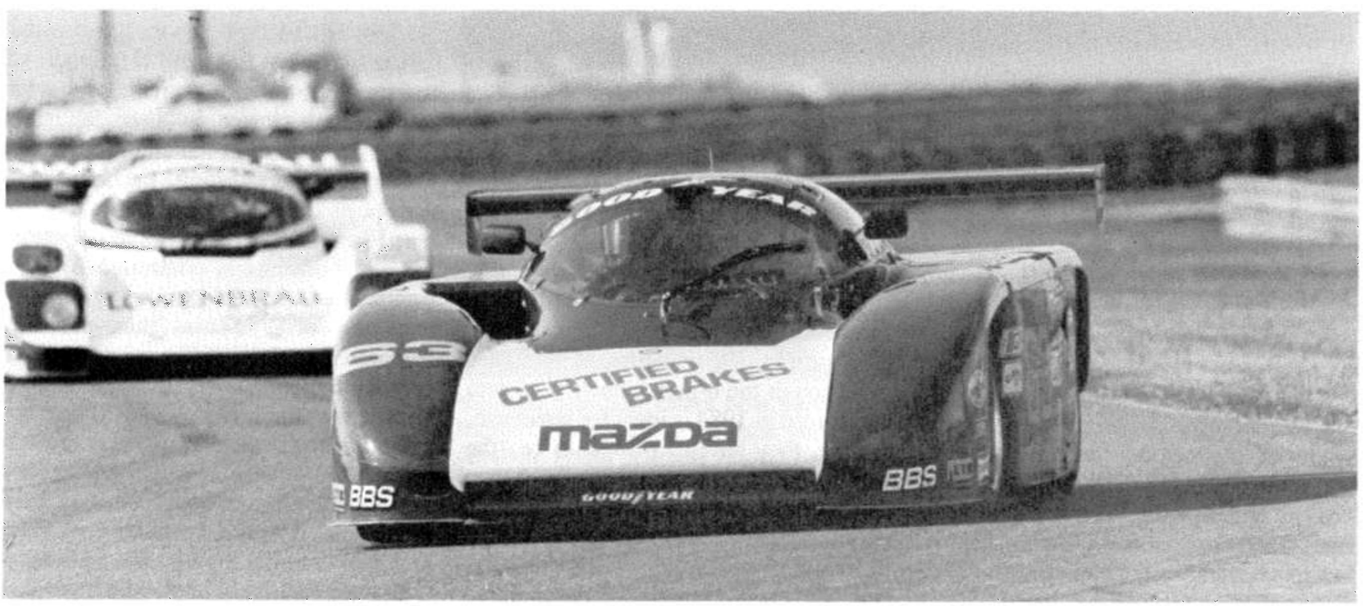
Rotor housing is still usable (barely), but with chrome surface plating worn away below sparkplug hole, not for long.



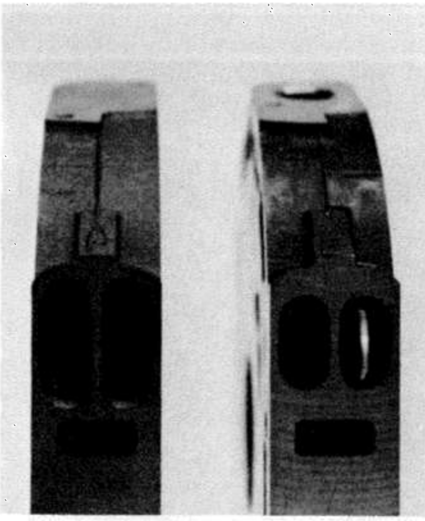
When brand new, rotor-housing interior surface has a satin finish. Various surface finishes have been used over the years.

its entire face. After grinding, the surface is too rough to come face to face with a seal, so it must be *lapped* to achieve the desired finish. Typically, it's less expensive to purchase a new side housing, unless a lot of time and effort has been invested in the existing one.

When purchasing new side housings, it should be noted that versions used in 1974—75 and in 1976 rotary truck engines had the least restrictive stock ports. 1976 and later passenger-car side housings—except 6-port versions—have noticeably smaller intake ports. However, this difference is of interest only if the housings are not to be reworked. All stock side-housing intake ports



In unrestricted classes such as IMSA's Camel Lights, there are no limits on engine alterations. Engines installed in Camel Lights race cars are allowed to make use of special competition rotor housings with peripheral intake ports.



All side ports are not created equal. At left is an intermediate housing with larger ports found in 1974—75 passenger car and 1976 rotary truck engines. Obviously, less grinding is required during porting if large-port housing is used.

If air pump is removed as part of high-performance rework, air passages in 1975 and earlier rotor housings must be plugged. Photo courtesy Racing Beat.

can be enlarged to the same dimensions.

The same dimensional considerations hold true for rotor housings; 1974 and '75 housings have the largest stock ports. If you are going to rework the exhaust port, the stock dimensions are of no consequence. If the air pump is removed from the engine as part of a high-performance program, the air passages in 1975 and earlier rotor housings must be blocked.

Either Racing Beat aluminum blocking nozzles may be installed or the top 1/4 in. of the stock nozzles can be cut off and welded shut. Closing the passages in '76 and later housings is more involved. For street applications, Racing Beat's headers have an extension on the header flange that closes off the air passages. This arrangement is not recommended for race engines. Instead, their openings should be closed with fabricated plugs to enhance exhaust flow.

Side housings produced for 1979 and later-model RX-7's feature *gas nitriding*—a surface-hardening process that improves durability. You can identify these housings by their dull gray finish. Earlier housings were painted black on unmachined surfaces. If the housings are to be ported, use gas-nitrided versions.

Although the 6-port induction system introduced in 1984 is ideal for street use, to date, they haven't proven to be "the way to go" for racing. With the 6-port configuration, an extra port is included in each end (side) housing while a conventional center housing is retained. As is the case with a standard 4-port engine, the center ports are fed by the primary side of the carburetor. At increased throttle openings, the secondaries open and a full air/fuel charge is also delivered through the ports in the end housings.

With a 6-port system, the four standard ports function in a traditional manner. Flow through the auxiliary ports in the end housings is controlled by two rotary valves that are actuated by exhaust back pressure. When this pressure reaches a predetermined level—which corresponds to a relatively heavy engine load such as wide-open-throttle acceleration—the valves open to permit air to flow through the auxiliary ports. This rather ingenious design produces a very broad torque curve with strong low-speed torque and top-end horsepower.

For street-driving applications, 6-port engines can be effectively ported to produce additional power.

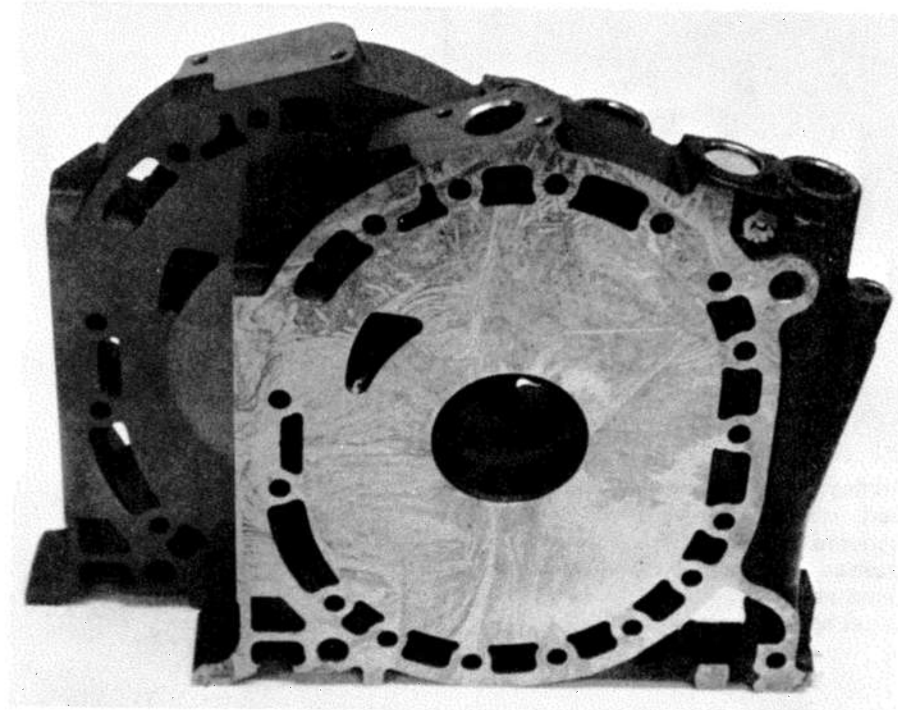
CONVENTIONAL PORTS

A bit of grinding in the right places will significantly improve airflow of a standard side intake port. Just as importantly, a reworked port also offers a longer intake event; as the triangular port opening in the face of the side housing is extended back toward the water jacket, intake-port opening occurs sooner. As the roof is raised and extended toward the center, port closing comes later. The net effect is analogous to that of a high-performance camshaft—intake duration is lengthened as is intake/exhaust *overlap*. Overlap is the time during which both intake and exhaust ports are uncovered.

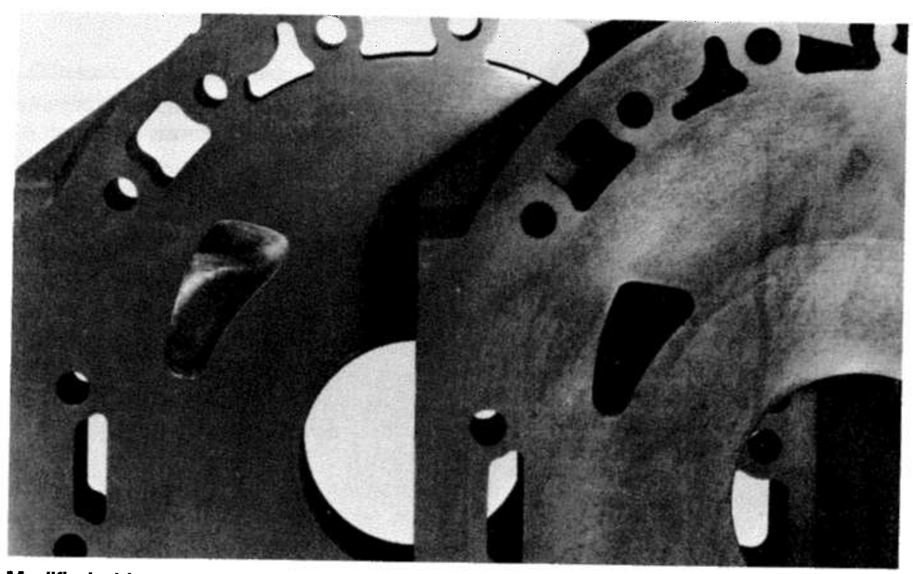
Due to the arc described by the rotor, lowering the *floor*—the side toward the shaft center—of a stock side port has no affect on port timing. Typical street porting, therefore, involves grinding the outer wall of the intake opening *back*—toward the water jacket—a maximum of 1.5mm (0.060 in.) for earlier opening, and raising the roof and reshaping the inside wall for later closing. But there are limits on how much you can cut back the outer wall. If it is ground too far, the leading edge of the side seal or corner seal will drop into the opening, thereby eliminating all performance, high, low or otherwise.

The top side of the port opening controls closing timing, with the innermost radius being closed last. As the roof of the opening is raised, it must also angle inward a little more. This shape is designed to provide a smooth scizzor-like action as the side seal crosses the port opening. Without proper reshaping, the seal would chop the port closed abruptly, rather than "squeezing" it closed in a controlled fashion.

While street porting represents a significant power increase, the affect is minimal if the exhaust system has not been modified as described in Chapter 2. For maximum return on your investment in street porting, a high-performance intake system should also be added. In effect, a ported engine not fitted with the requisite intake and exhaust systems is like a 3-in.-diameter fire hose supplied by a standard household faucet and capped with a garden watering nozzle. The flow capacity of the hose is of virtually no consequence because it is restricted at both inlet and outlet.

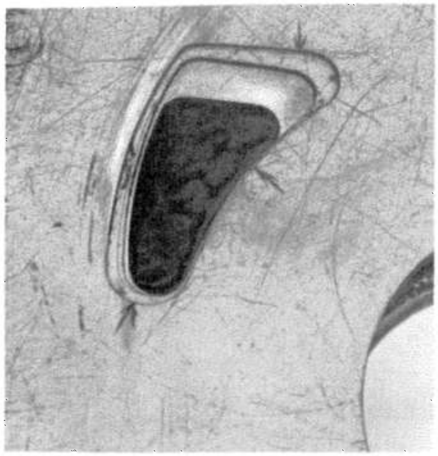


1979 and later side housings are gas nitrided for better durability. Finish is dull gray.



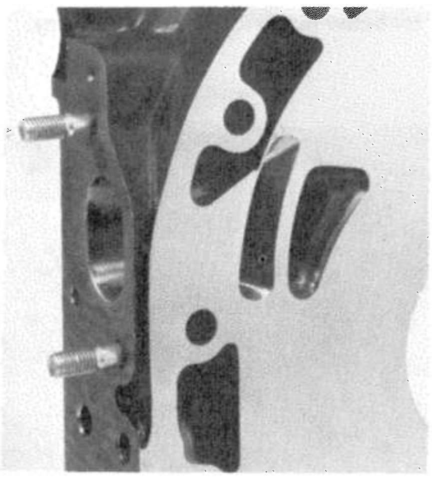
Modified side port offers best performance potential for street engine. In addition to improved airflow characteristics, mild porting alters port timing and provides longer intake duration. Photo courtesy Racing Beat.

Bridge Porting—There are limits to how much a stock port can be opened up. Ideally, the outer port wall would be brought back to the water-jacket area. The problem is if you do this, there would be nothing left to support the corner and side seals. Consequently, for race applications where stock com-



Porting templates illustrate extent to which port shapes are changed for high-performance operation. Due to path traveled by rotor, left port-wall position determines opening timing. Rounded apex at upper right controls closing.

Variation on a theme; Racing Beat converts standard 13B rotor housings into a peripheral-port configuration by literally screwing a port sleeve into a drilled-and-tapped hole in housing.



Thin lip of material left between two port openings forms bridge that provides a path for seals to travel across. Without bridge, they couldn't get to other side. Photo courtesy Racing Beat.

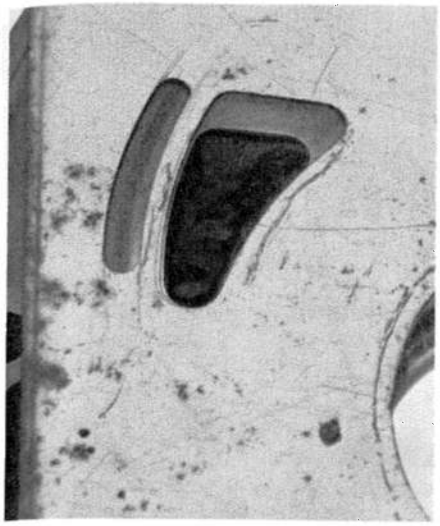
ponents must be used, a narrow strip of material—a bridge—is left when the port is opened. The bridge supports the seals and also divides the reworked *bridge port*. While the split port opening isn't as efficient as a single open port, there's no alternative when a stock induction configuration must be retained. Unrestricted race engines utilize peripheral intake ports that have a greater airflow capacity and wider port-timing latitude.

Compared to a stock-type port, a bridge port adds 100—150° of timing to the intake event. In essence, it allows the port to remain open all the time, just as on peripheral-port engines. Rather than the port being closed, as the corner of the apex seal passes it, the incoming mixture is diverted to either the preceding or following working chamber depending upon seal position.

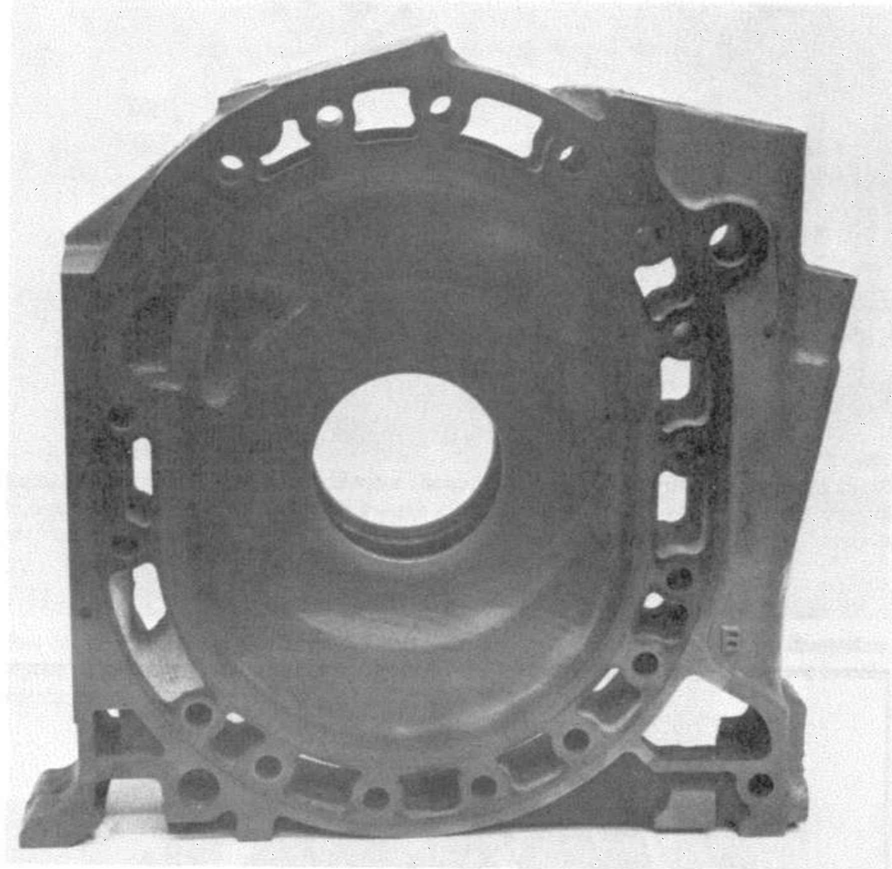
With the amount of timing increase provided, even the mildest bridge port is not suitable for street applications. It's designed to increase high-rpm power—with horsepower peaking as high as 9000 rpm—and too much low-speed torque and driveability is sacrificed for street use.

Racing Beat makes another excellent point regarding the foolishness of building a bridge-ported engine for the street: Just about any exhaust system that is quiet enough for street use is so restrictive that exhaust-gas recirculation into the intake port will be excessive. Exhaust gasses don't burn very well, so with a street exhaust system, a bridge-ported engine may actually produce less horsepower in the usable range than its stock counterpart.

As might be expected, all bridge ports are not created equal. The original bridge ports were very small and did not require any rework of the rotor housing. But over the years, some rather bizarre shapes have been utilized in the quest for greater horsepower. As the ports were made continually larger, they reached a point



Back in the early days, Rick Engman used this template to scribe area that would be cut away to form a bridge port. However, port shape changed rapidly.



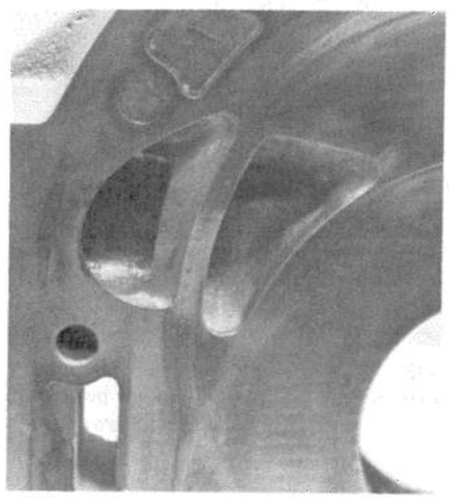
Otherwise innocent looking side housing contains one of the most radical bridge ports in existence. Rick Engman fashioned port for GTU competition.

where material was being removed back in proximity of the red inner seal between housing face and cooling jacket. Obviously, the port can't protrude into the water jacket, but on the more radical bridge port design, it gets close.

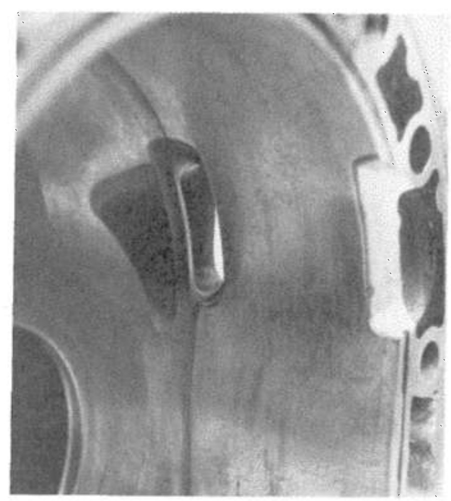
With these types of ports, it's necessary to relieve the rotor housing in the adjacent area so that it does not block the port. RTV is then used in place of the stock water jacket seals in the port area. With that area of the engine being relatively cool, there isn't an overabundance of expansion and contraction, so leakage is a surprisingly rare problem so long as a flexible sealant is used.

PERIPHERAL INTAKE PORTS

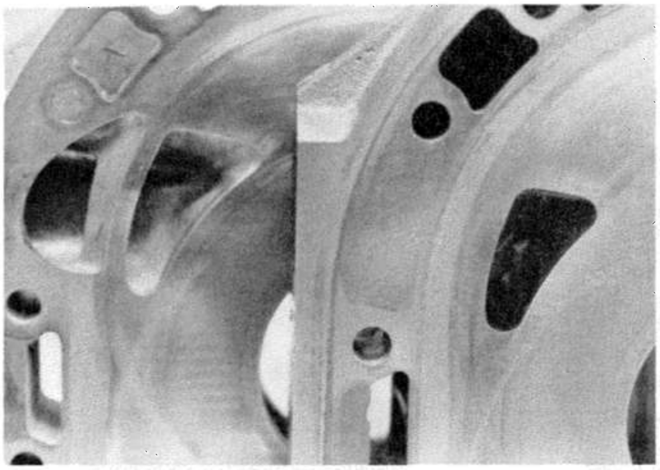
In prepping a peripheral-port engine for competition use, comparatively little intake-port rework is called for; certainly a lot less than is required to create a bridge port. Mazda peripheral-port rotor housings—which contain both an intake and an exhaust port—are intended strictly for racing. Consequently, port timing and volume are consistent with the demands of high-horsepower, high-rpm applications. Racing Beat also makes a perpheral-port rotor. It's less costly than Mazda's—but it's not legal in all racing organizations.



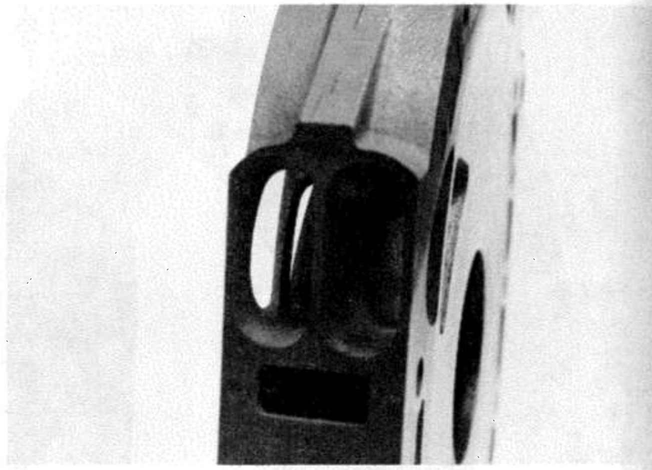
As can be seen, outside wall of port encroaches into area normally occupied by red rubber inner seal that contains coolant flowing through water jacket.



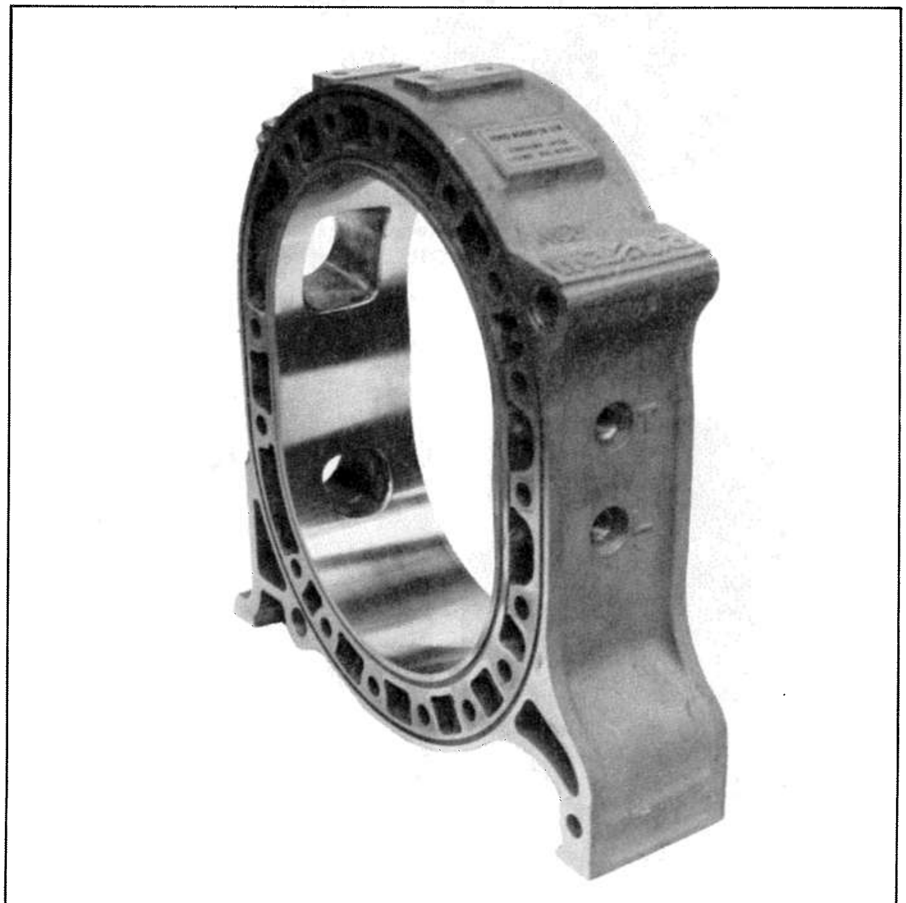
To accommodate radical bridge port, water jacket must be plugged in port area. RTV is used to seal area. Note that rotor housing has also been modified.



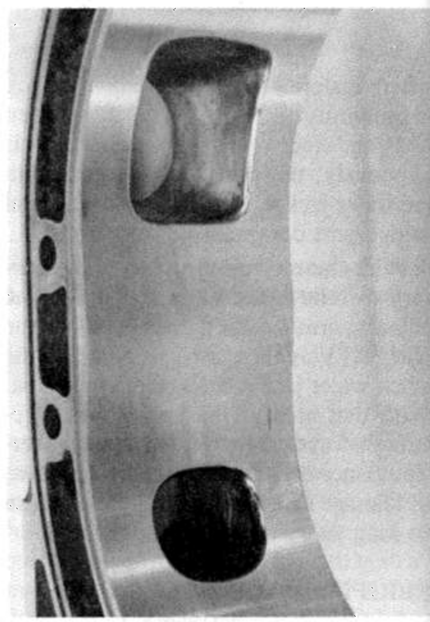
Stock port (right) illustrates just how far Engman went in developing his "monster" bridge port (left). While not applicable to street engines, it certainly did the job in IMSA competition.



Intake manifold's eye view of a bridge port: Air tends to move in a straight line and, therefore, favors the main port. Significant flow on other side of bridge occurs only after capacity of main port is exceeded.

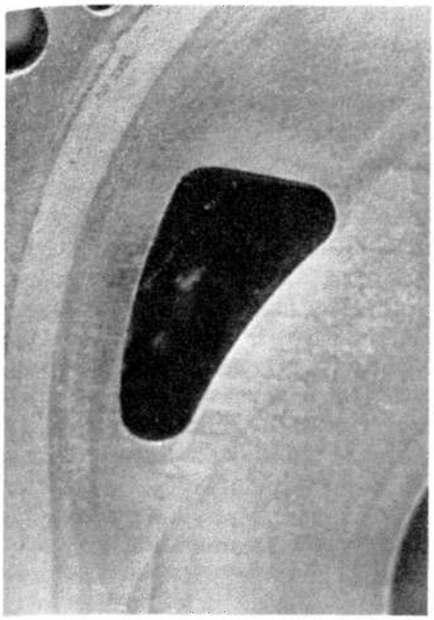


Rotor housings with peripheral intake ports are found only in race engines. Port timing is too radical for an engine with an exhaust system that includes a muffler of any consequence.

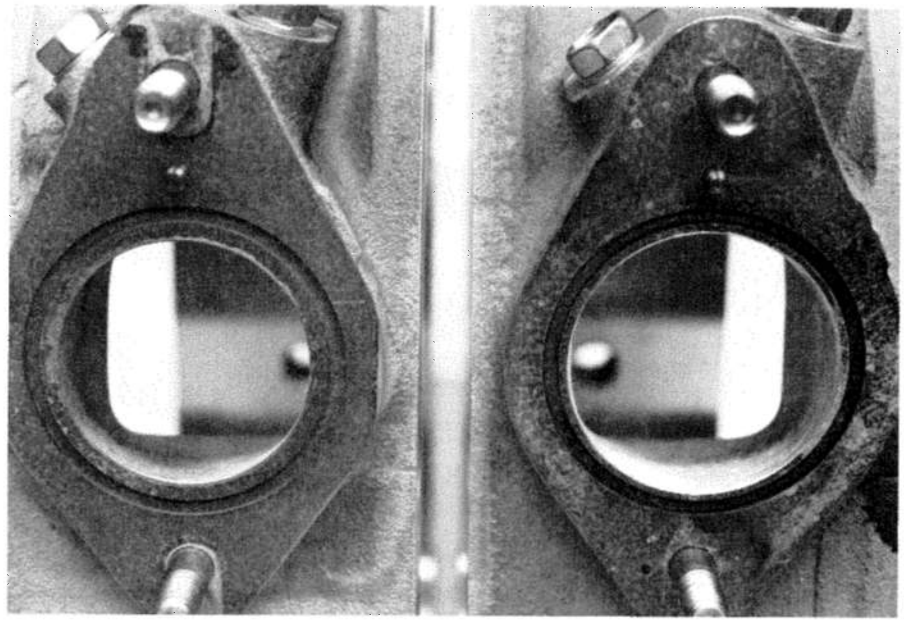


Although manifold side of peripheral intake port is changed very little, inside opening is usually enlarged considerably.

Even though the peripheral-port rotor housings are special castings, they are used in conjunction with standard side housings. If your brain is still in gear, you should now be struck with a lightening bolt of apprehension. Standard side housings contain intake ports, so what becomes of them when peripheral intake ports enter the picture? Unlike the mouth



When using rotor housings with peripheral intake ports, standard intake ports in side housings must be plugged.

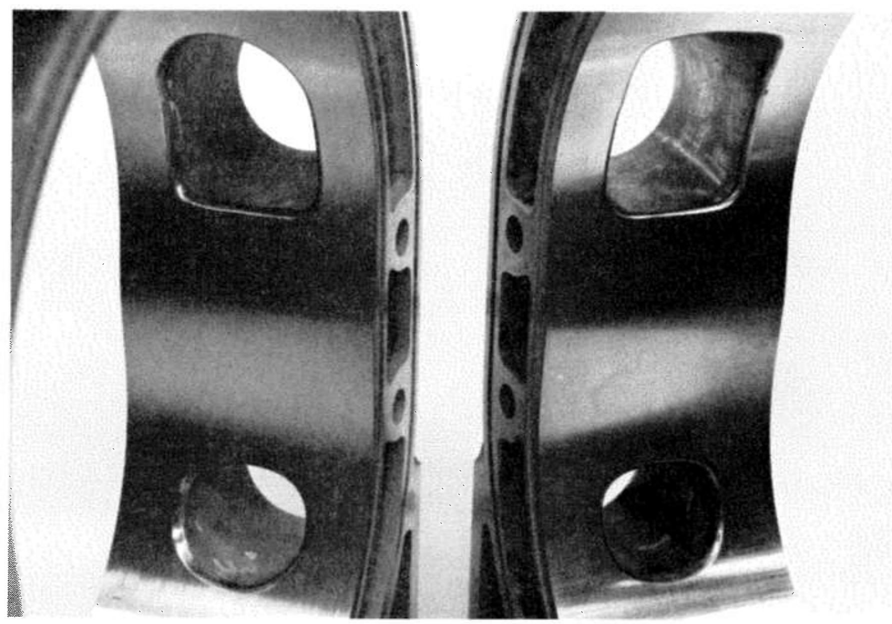


View of unmodified peripheral intake port (left) and race-ready version (right) illustrates degree to which manifold side of port is altered. Notice that lip inside seal groove is only slightly thinner.

of an overbearing mother-in-law, they do not remain open, but are plugged with a good grade of dense epoxy. Mazda offers a material called *Threebond* which is of sufficient density. Plastic Steel is also suitable; it is heavy enough and contains a sufficient amount of metal that its coefficient of expansion is reasonably close to that of the cast-iron side housing.

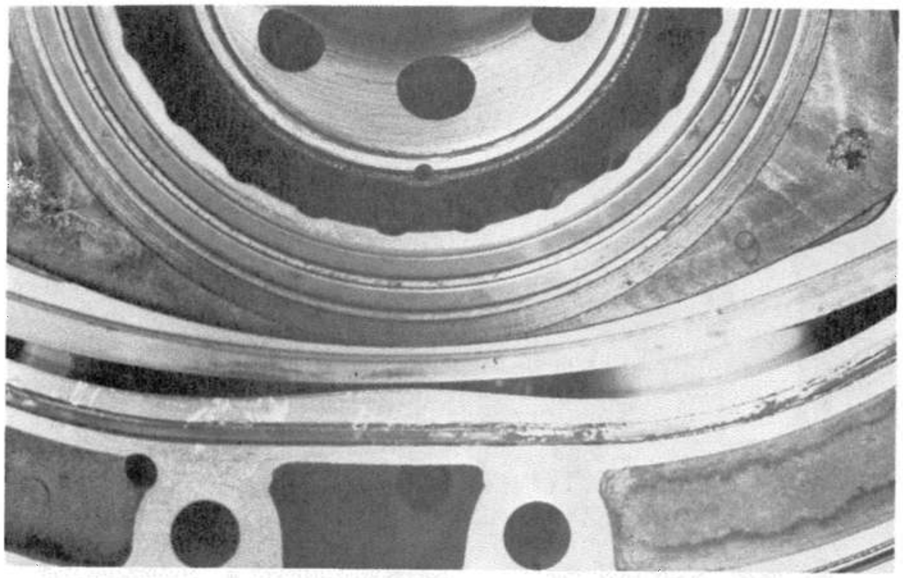
When plugging a side port, one end of the port is sealed and the filling material poured in from the other. One of the problems with the lighter epoxies is that they won't flow all the way down into the port.

Rather than completely filling the opening on the face side of the port, a 1/16-in. relief should remain. This small pocket provides a space for blowby gasses that leak past the side and corner seals. As the rotor spins, the port is still uncovered even though it's plugged, but now it allows the blowby gasses to be purged out of the relief and into the working chamber that is on the intake cycle. In essence, the relief in the side intake-port plug becomes a temporary holding area for blowby gasses that would otherwise be forced into the crankcase.

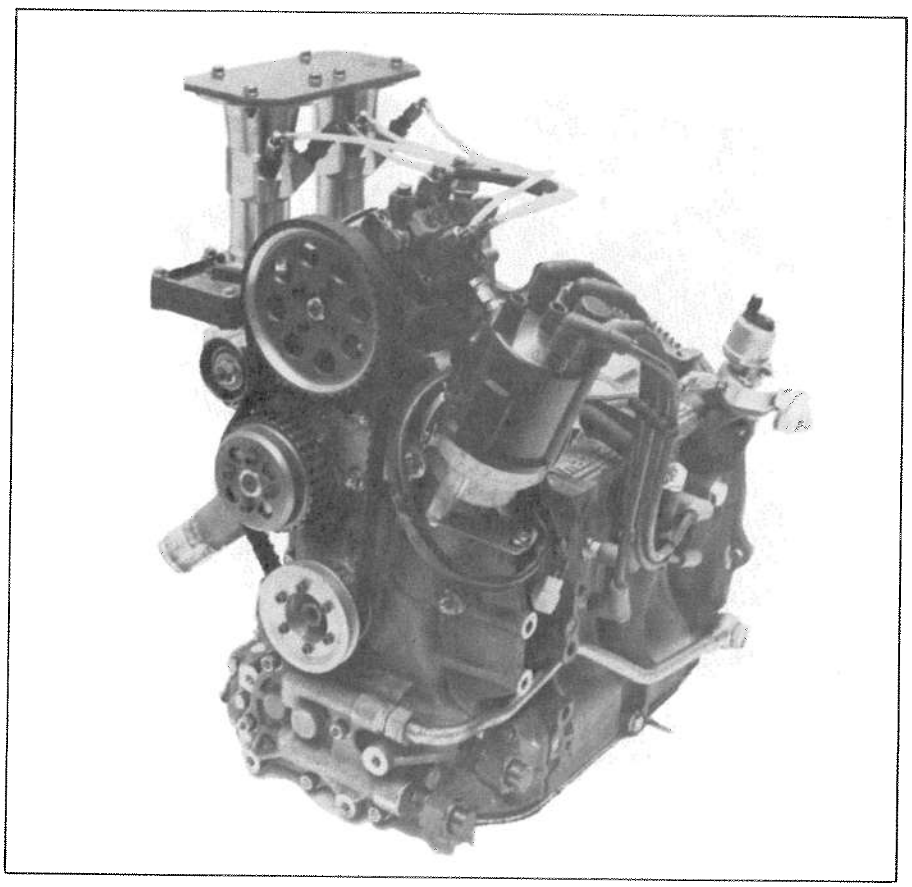


As supplied, peripheral intake port is a D-shape. It is retained for some applications and converted to a rectangular shape for others. Port shape influences rpm at which peak horsepower occurs.

Port Rework—Peripheral intake-port size and shape are partially dependent upon the type of racing for which the engine is being prepared. In the housings destined for a Downing Camel Lights powerplant, the port floors are not lowered; the roofs are occasionally recontoured. For a 24-hour race, where rpm will not exceed 8500 rpm, Engman either retains the original D-port contour, or just raises the curved outer edges of the



Look closely at opening between rotor and rotor housing. Pieces of paper protruding through peripheral ports illustrate that both ports are open simultaneously for a rather long period of time.



In conjunction with port rework, intake-stack length must be altered so that peak horsepower is reached at a usable rpm level. This 13B Camel Lights engine is tuned to produce maximum horsepower just below 9000 rpm.

D, transforming the opening into a rectangular window, but retaining the D-port timing. There's no need to significantly alter timing for a "24-hour engine" because stock timing concentrates horsepower in the desired range.

As opposed to making the top of the port opening flat, Engman humps it slightly so that it doesn't close abruptly. He states, "Almost everybody does a straight top and, after a period of time, you'll see a wear pattern right at the top edge along the sides. This is where the apex seal jumps across the opening. I don't feel that's particularly good, so I curve the top slightly—maybe five degrees down on either side."

On a sprint engine—one that's used in shorter races and run at higher rpm—Engman raises the top several millimeters but still curves it slightly. Additionally, the round opening that leads to the intake manifold is opened up, as is the inside diameter of the manifold runners.

Manifold Porting—The concept involved in porting a manifold is not to simply grind large passages, but to enlarge them uniformly so that the diameter remains relatively consistent over the full length of the runner. To assist in this operation, Engman has fabricated a round plug of the appropriate diameter, or approximately 1/2-in., and affixed it to a peg. By shining a light from one side and viewing from the other, he can determine precisely where the port-wall material must be removed. The plug is worked all the way through the manifold with the walls being ground where indicated.

Typically, manifold runners measure 48mm (1.89 in.) at the carburetor or fuel-injection junction and 43mm (1.69 in.) at the rotor-housing end. Obviously, if a Weber with 51mm throttle bores is installed, the carburetor end of the manifold must be enlarged to 51mm. Engman allows the runners to taper to 45mm, then flares them slightly, to no more than 46mm, as they reach the rotor-housing junction. This slight venturi affect makes for smoother flow through the manifold.

With a large carburetor or fuel injection, the standard D-port or small window port will put peak torque in the 7800—8000-rpm range. If a restricted carburetor is required, it makes no sense to run the big port/runner combinations. The carburetor will cancel its affect. When the inner port roof is raised and large manifold runners are used, peak torque peak is in the 8500—8700-rpm range.

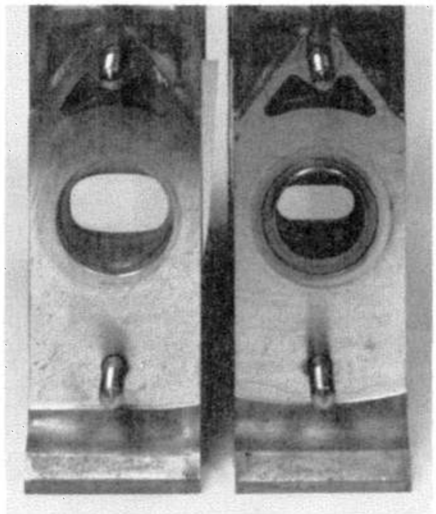
While the port-volume increase is helpful in producing higher horsepower figures, the attendant 8500—8700-rpm torque peak is somewhat high. But by lengthening the intake tract, the torque peak can be dropped to provide more usable power. According to Engman, "With a 12A engine which you might run at 9400 rpm, the 8700-rpm torque peak is just about right because horsepower will probably peak right at 9400—9500 rpm."

On the other hand, with a 13B engine running with an imposed 9000-rpm redline—as in Camel Lights racing—an 8700-rpm torque peak means that a good deal of horsepower will not be utilized. Consequently, torque peak must be lowered so that peak horsepower is reached at or slightly below 9000 rpm. This is achieved by fashioning longer stacks for the fuel injection or inserting spacers between the intake manifold and block.

EXHAUST PORTING

With exhaust gasses exiting through a peripheral rather than side port, modification techniques are rather straightforward. For street applications, the port as viewed from the inside of the housing should be cleaned up and widened slightly. As opposed to moving the side walls back any great distance, it's best to simply square up the rather generous radii of the stock opening. In straightening the side walls, the port will be widened slightly. A small radius will then have to be cut in each corner so there will be a smooth transition between the vertical and horizontal walls.

For normally-aspirated engines, a slight raising of the port roof is also recommended. This will lengthen exhaust-port timing slightly, adding to peak horsepower without seriously affecting idle quality. However, in turbocharged engines, the port roof should not be touched. This is because an increase in overlap is detrimental to performance. Some of the pressurized intake charge will blow by into the exhaust.

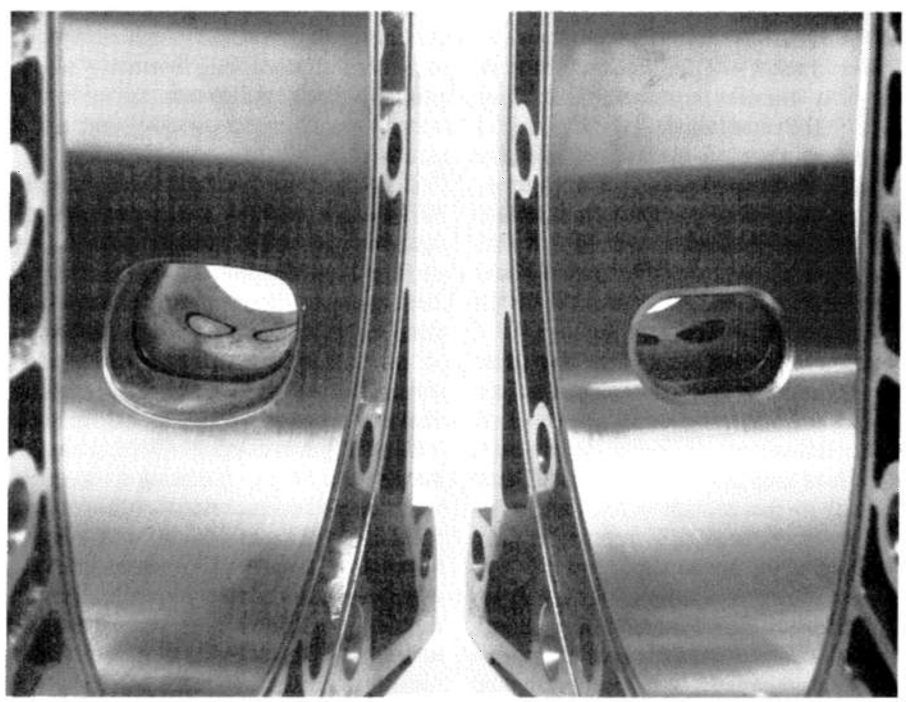


Modified exhaust port at left obviously offers a considerable flow improvement over stock port, right. This type of port requires a low-restriction exhaust system to be truly effective at increasing horsepower. Photo courtesy Racing Beat.

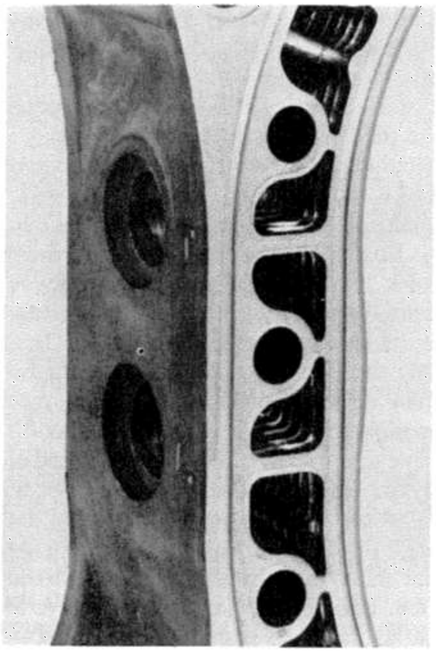
If the vertical port dimension is increased, it should be done by lowering the floor instead of raising the roof.

On the header side of the exhaust port, the steel ring that is pressed in place should be retained. If removed, the port will then be too large for a street engine; it may even be too large for a race engine. As Engman points out, "The ring is there for a reason—it serves to insulate the aluminum housing from exhaust gasses. It's at the outer surface so it transfers heat into the header (or reactor) area rather than into the water jacket. The race (peripheral-port) rotor housings don't have the rings, but if I could get some of the proper size and shape, I'd use them. In the giant bridge-port engine that I did for GTU, I left the ring in and just worked the inner port around it. That worked fine. I don't think exhaust ports have to be as large as some people think—especially in a street engine."

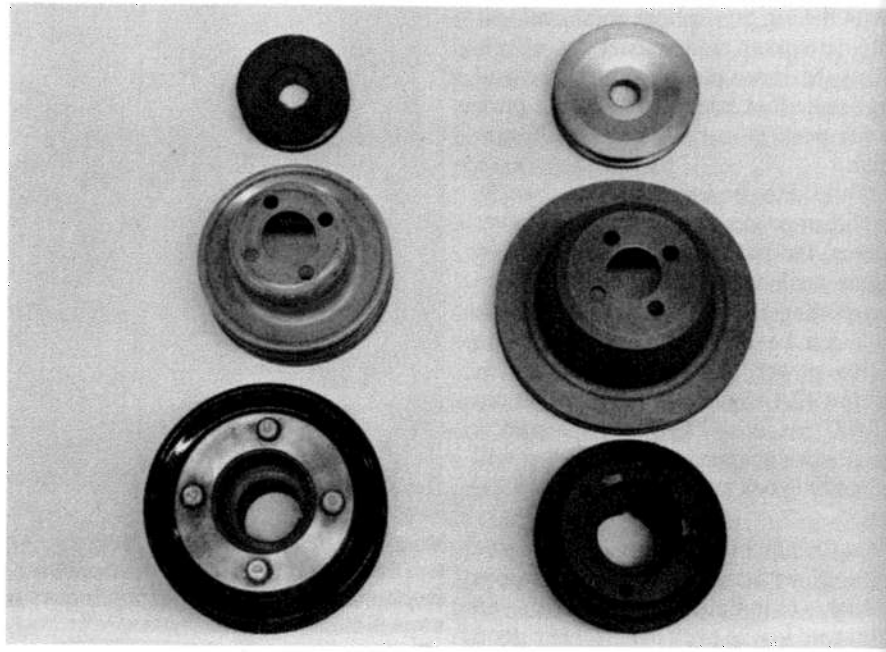
On peripheral-port housings that are specifically designed for racing, Engman does relatively little grinding. He cleans the port up a bit and squares the sides, but doesn't do anything to change the timing much.



Stock exhaust port (right) is considerably smaller than street-ported version (left). Street exhaust ports are surprisingly similar to those found in race engines. Photo courtesy Racing Beat.



Grooving water jacket in area around sparkplugs increases cooling. This is hottest area of the rotor housing as it is adjacent to the combustion chamber. Photo courtesy Racing Beat.



One means of avoiding water-pump cavitation is to replace stock pulleys with ones of different sizes. Reducing size of eccentric-shaft pulley and/or increasing size of water-pump pulley slows pump. Same relationship applies to the alternator.

COOLING-SYSTEM MODIFICATIONS

Water Jacket—To improve combustion-heat transfer to coolant flowing through the rotor housing, cut a series of grooves in the water-jacket walls in the vicinity of the sparkplugs—where combustion temperatures are hottest. This modification is needed only in extreme cases and many race engines maintain acceptable coolant temperatures with untouched water jackets.

Essentially, the grooving operation transforms a flat surface into one that has a series of fins similar to the exterior of an air-cooled engine. The resulting increase in surface area allows for increased heat transfer to the coolant where it can be rejected by the cooling system rather than building up in the housing.

Water Pump & Pulleys—Whether or not the water-jacket modification is performed, chances are a stock water-pump/pulley arrangement is inappropriate for competition. The biggest drawback is stock water pumps are designed to operate at relatively low engine speeds. As a result, the standard impeller will *cavitate*—churn coolant rather than push it through the cooling system—when spun by stock pulleys at racing rpm, thereby reducing cooling-system efficiency.

According to Racing Beat, a stock 1973 water pump—which should be used on all 1973 and earlier high-performance Mazda rotaries—with standard pulleys should not be run continuously at an engine speed of 7600 rpm or more; '74 and later water pumps should not be spun continuously at or above an engine speed of 6300 rpm.

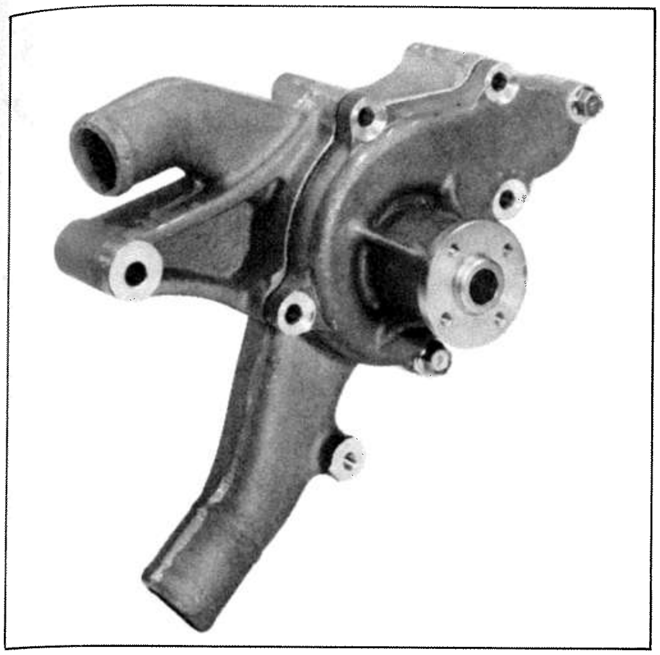
Rick Engman concurs with this noting that on the dyno, cavitation of a stock water pump becomes noticeable between 5500 and 6000 rpm. The water hoses are the clue to what's going on inside the water pump. When the impeller starts to cavitate, the hoses jump around due to turbulence caused by cavitation and the resulting aerated coolant.

Racing Beat, Mazmart and Mazda offer a number of pulley combinations that will slow water-pump speed sufficiently to avoid cavitation. While these special pulleys are absolutely essential in a full-on race engine, they are generally not required for street use. However, Mazda street-performance enthusiasts that have run special pulleys—as a safeguard against overheating the engine in the event of a prolonged stoplight Grand Prix—report no adverse affects at lower engine speeds.

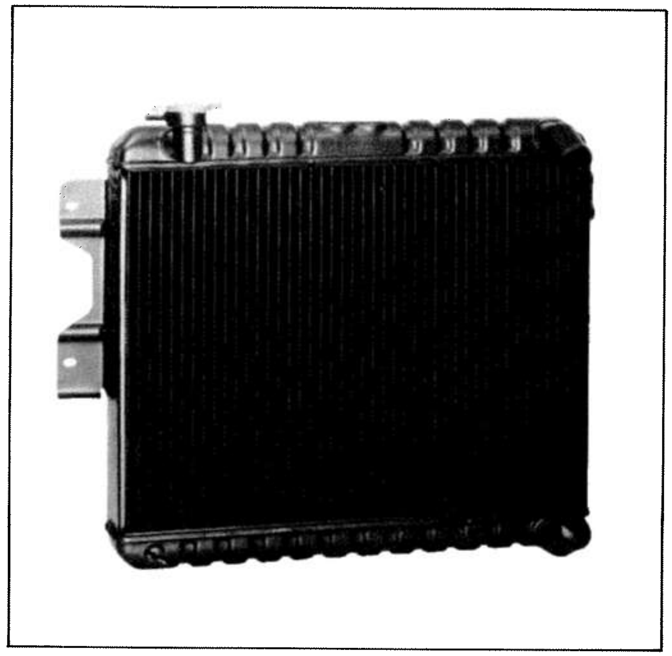
Racing Beat's two-sheave main and alternator pulleys slow pulley speeds *and* give two-belt reliability. These pulleys are suitable for street use in '74 and later engines with or without air-conditioning compressors.

In some cases, street engines are fitted with the older fan-mounting arrangement. In this case the fan is driven directly by the crankshaft rather than by the water-pump pulley. With this arrangement, water-pump speed can be reduced without affecting fan speed.

While on the subject of pulleys, any engine that's to be revved at the high end of its rpm range for any length of time should also have an alternator fitted with



Mazda's competition aluminum water pump weighs a scant 5 lb compared to 14 lb for stock cast-iron version. However, those are nine of the most expensive pounds you're likely to find. Photo courtesy Racing Beat.



Factory competition aluminum radiator offers considerably greater cooling capacity than stock model. It's approximately 22-1/8-in. wide, 19-1/2-in. high and 2-1/2-in. thick. Photo courtesy Racing Beat.

a large-diameter pulley to slow its speed. With the stock pulley ratio, the alternator is *overdriven* by approximately 33%—if the engine is turning 6000 rpm, the alternator is spinning at 8000 rpm.

Mazda offers an oversized aluminum alternator pulley that reduces the overdrive ratio, thus reducing pulley speed. For most high-performance engines, alternator output at idle is not a factor. And the alternator reaches maximum output at approximately 3500 rpm, so there's no need to spin it any faster. Otherwise, power is lost and the alternator is overworked.

It should be noted when changing pulley sizes—which requires different-length fan belts—the resulting drive ratios may not be compatible with certain driving environments. As an example, if the water pump is slowed significantly on a car equipped with air conditioning that is driven in traffic in hotter climates, some overheating may result. A large-capacity radiator, such as the Mazda competition aluminum radiator that is properly shrouded to force air through the radiator rather than around it, is essential to the longevity of any high-performance rotary—especially one that is saddled with an air conditioner. The need for increased radiator capacity is greater when an engine is subjected to a wide variety of operating conditions.

Depending on where you live and your regard for the speed limit, special-ratio pulleys may or may not be of interest. A short burst of high (engine) speed operation can generally be tolerated with no ill effects on the engine. But for sustained high-speed operation, special pulleys are essential to reduce water-pump speeds to levels that will avoid cavitation.

Water Pump—The stock Mazda water pump contains a provision for a thermostat that incorporates a bypass. When the engine is started cold, the bypass allows a slight amount of coolant to circulate until the thermostat opens. This system should be maintained for street driving; only a Mazda thermostat should be used.

A non-bypassing thermostat will result in extremely high coolant temperature. However, when a stock cast-iron-pump housing is used on a race engine, the thermostat should be removed and the internal passage that is fed by the thermostat bypass must be plugged. This may be accomplished by tapping the hole with a 1/2-in. pipe tap and installing an appropriately sized plug. Mazda offers a competition cast-iron water-pump housing that incorporates this modification.

Another option is the Mazda aluminum race pump and housing. The aluminum pump is fairly expensive, is 9-lb lighter than its cast-iron counterpart, has no thermostat and requires that the alternator be repositioned to the right side of the engine. Mazda also suggests that a special alternator brace be used with this pump.