40,000 mile Endurance Test: Mazda RX-2

BY DON SHERMAN

By now, everyone knows how a Wankel engine works, the remaining question is how long it will live

• Skeptics of the world relent. There exists an alternative to the piston engine and it's complete with fail-safe reliability. The evidence is so convincing that car designers the world over are stumbling all over one another in a Mad Hatter scramble to negotiate rights, develop hardware, and tool up for their future power source—the Wankel.

The vanguard of this automotive revolution, the biggest since interchangeable parts, lies at the doorstep of Toyo Kogyo. That Hiroshima, Japan firm already offers the world Mazda automobiles with a taste of tomorrow awaiting each twist of the ignition key. Although it missed distinction as the Adam of Wankel engine production, Mazda holds the unassailable honor of marketing the very first fully developed rotary-engined car. That means a foolproof automobile for an inept public conditioned to the paper clip reliability of piston-engined sedans. And Mazda delivers more than the promise you won't have to replace the engine with each oil change. Its rotary-engined cars have the additional incentives of hushed good manners matched to an unprecedented level of performance for a car that size. The *Car and Driver* Super Coupe trials (December, 1971) proved that fact. The Mazda RX-2 was not the all-conquering champion of the contest but it was the fastest, and easily earned the distinction as a red-blooded alternative to insipid transportation.

The RX-2 is, first of all, small enough to manage without a chauffeur's license. Its overall length is only an inch longer than a VW Super Beetle but Mazda packs enough full-bodied virtuosity in that span to make a Gemini capsule designer uncomfortable. With its 70 cu.in. 2-rotor engine there's 130 net horsepower on tap to unequivocally humiliate the socks off a host of sports cars as well as legions of economy sedans.

But it's the interior environment that makes the Mazda RX-2 a unique experience. Sound levels under all conditions are worlds below the gamut of small, cheap cars. At idle, the engine's presence is less noticeable than that in a Mercedes-Benz 450 SLC, and during full throttle acceleration to 70, the RX-2 is quieter than a Jaguar XJ6.

As expected; for the distinction of owning a Wankel-powered coupe you'll pay a premium price. The Mazda RX-2 starts at $3195 and its smaller sibling, the RX-3, has a base price of $2995 in a land of $1980 Pintos and $2060 Vegas. But Mazda's rapid rise to the fifth largest U.S. auto importer even prior to nationwide expansion shows that there is a solid market for a first rate car of compact dimensions—in spite of the price.

Still, the rotary engine presents an unknown quantity. Performance testing has precisely ranked the Mazda RX-2 against its rivals and the finely detailed interior is readily accessible to every critical eye. The price tag requires no profound insights before one can weigh it properly on the purchasing balances. What remains is a question every discriminating buyer must answer in his mind before he invests in a Mazda: Is the engine durable, at least in comparison to present piston powerplants?

To answer that query in no uncertain terms, *Car and Driver* undertook the most extensive and lengthy test in its history. Before we could speak with assurance of the Mazda's durability our test heaped such abuse on the RX-2 as countless flat-out laps at Bridgehampton, thousands of miles over the pockmarked streets of Manhattan, the cold of one New York winter—all negotiated by every type of driver from meek mannered secretaries to nervy streetracers. And as a capper, there was a high speed trip spanning America. In all, over 40,000 miles and 15 months of high intensity testing. At the end there was a complete tear-down of the engine. It's the only sure way to accurately predict the life span that Mazda has designed into its rotary powerplant.

During the test, we had the opportunity to observe direct operating expenses for a diversity of situations. Mazdas have been notoriously substandard (in comparison with economy cars) in terms of fuel consumption and our tests confirmed that fact. During winter, primarily city driving, mileage dropped to an average 14.2 miles-per-gallon over a 2000 mile stretch. At the other end of the spectrum, our Mazda RX-2 achieved its best economy during a 2000 mile trip of largely Interstate driving. The speed never exceeded the posted limits and the 17.8 mpg fuel economy was the best average we ever obtained for extended distances. Between those limits, typical mixed city/highway driving yielded mileage predominantly in the 16 to 17 mpg range. There is one compensation for the Mazda's thirst—the very low octane requirement (83), which guarantees that Mazda rotaries will happily digest the cheapest grade of Econotane you'll ever encounter in this country.

A primary cause of low fuel economy is the Mazda engine's wanton lust for high rpm. The horsepower curve is soft at the low end but rapidly bulges as the speed goes up. That curve is still pointing skyward at 7000 rpm so the only cause for the next gear is a prudent observation of the redline. The engine's gentle moan does intensify at high rpm but not to the extent that even Wally Cox would be scared into another gear. So virtually everyone exercises the Mazda's penchant for high engine speeds at the expense of fuel economy.

In addition, the Mazda rotary engine consumes oil—by design. A metering pump is charged with the task of delivering small amounts of oil to the carburetor for lubrication of the engine's sliding seal faces. The quantity delivered depends upon rpm *and* the load applied to the engine. We found the engine could consume a quart in 450 miles of hard city driving and go as many as 2000 miles on a quart during interstate travel. In spite of this perpetual replenishing, Mazda recommends a change every 4000 miles and 8000 miles between oil filters.

Spark plugs also need attention at regular intervals. Mazda suggests replacement every 12,000 miles but we found that a high speed misfire would generally develop within 7000 miles.

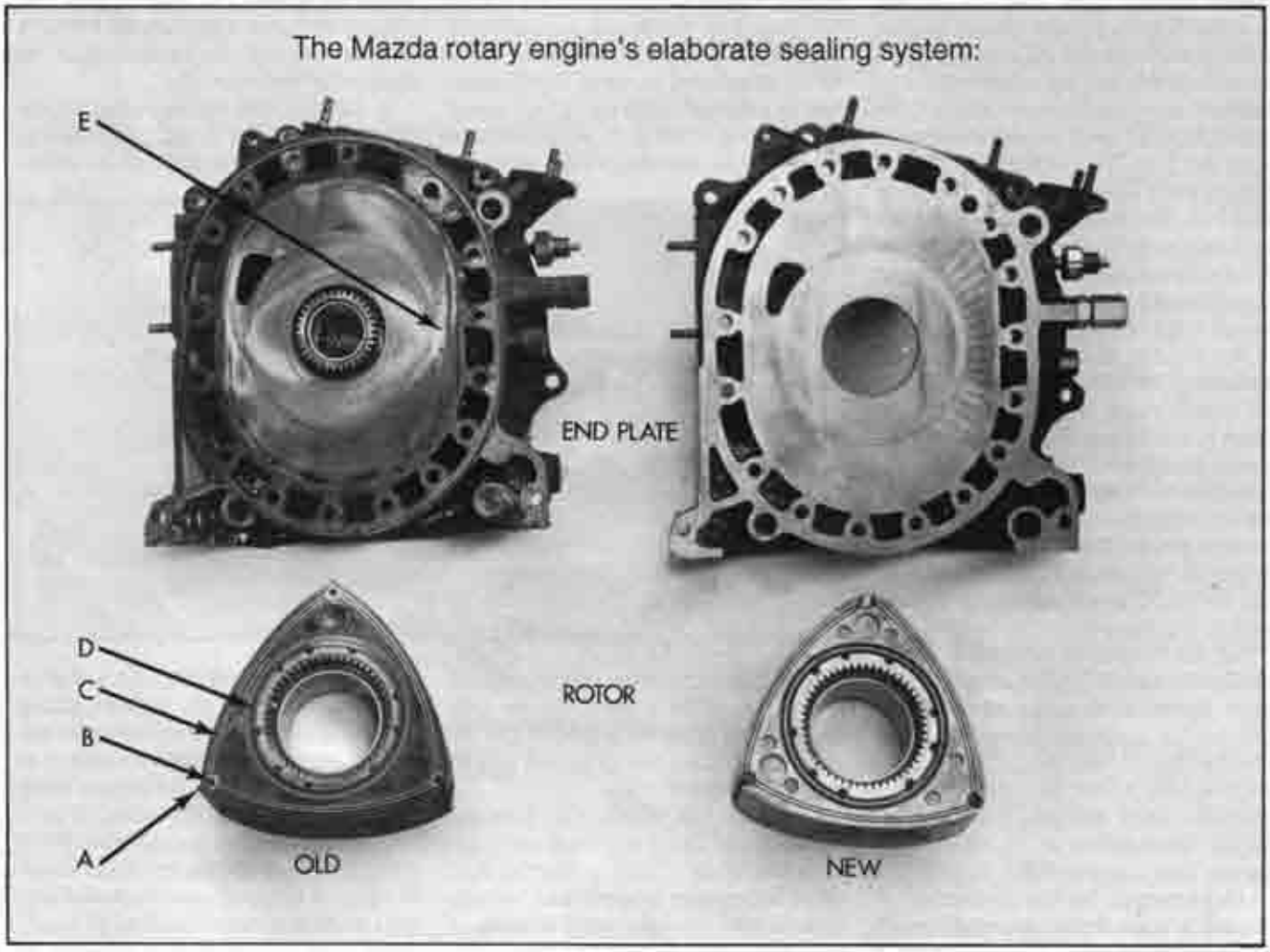
PHOTOGRAPHY: RICHARD GEORGE

This severely cripples the Mazda's acceleration but we found no loss in fuel economy with plugs left in for as long as 15,000 miles. Virtually every high performance engine of old has insisted on fresh spark plugs for that razor sharp edge and the Mazda is an inheritor of that bygone era's requirement. In the case of a rotary engine, spark plug electrode erosion is rapid because the plug fires once for every crankshaft revolution. In piston engines there is only one spark every two revolutions, with a blast of cool air in between. Those who want every last surge of performance from their Mazda must insist on a fresh set of plugs at frequent intervals.

Surprisingly enough, there's very little else that demands periodic attention. Mazda rotary engines have the world's most comprehensive and complicated emissions system but ours received not so much as a screwdriver's twist of adjustment during our 40,000 miles of experience. And when the RX-2 rolled across the doorsill of the Mazda Motors of America center near Los Angeles, the California Air Resources Board would have been well satisfied. In idle testing procedures used at the roadside to pinpoint gross polluters, our Mazda generated only 1.6% CO and 100 parts per million unburned hydrocarbons. That's about one half and one third respectively of the limits specified by the very stringent California law.

No engine of the future can be considered in the running if it is unmanageable from an emissions standpoint. Mazda has licked the current requirements with a thermal reactor fed by exhaust gases from the engine along with fresh air from an auxiliary air pump. During certain modes of operation the exhaust gases and fresh air mix to continue burning in this "oven" outside the engine. A central electronic brain, similar to the Bosch fuel injection control box, monitors and governs the emissions system with the help of an immense network of sensors and servovalves. It's much too complicated for the home mechanic but every Mazda dealer must own the diagnostic equipment to oversee it all. For that, no Mazda owner should lose the friendship of his service manager.

Aside from the engine, there were some minor breakdowns of the car during its *C/D* trial by fire. A balky clutch master cylinder expired after 16,000 miles. The replacement part of a new design gave no further trouble, however. In addition, the clutch began slipping badly at 40,000 miles and a final inspection showed the disc to be worn out. Within the realm of clutches, it did not die young. By comparison, the transmission synchronizers suffered infantile paralysis. A fast upshift to second had oc-



A. apex seal
B. corner seal
C. double side seals
D. oil seal

E. The engine's only wear point, excluding the replaceable seals: at the minor axis of the rotor's epitrochodial dance across the cast iron end plate. The combination of the corner seal's abrasion and combustion temperatures eventually erodes a ridge in the end plate's surface. The corresponding new part shows finger-like traces of induction hardening in the same area.

casionally produced a painful grunch from the very beginning. And after 40,000 miles, one had to pause for two heartbeats before engaging second or third gear. Mazda admits to some complaints from owners on downshifting which it has traced to poorly seated synchronizer rings. Our problem seems more extensive and since it worsened with mileage, the synchro rings had likely worn to the point of ineffectiveness.

The original equipment Bridgestone tires lasted for 21,800 miles but their lives were likely shortened by skidpad and racetrack testing at the onset. Still, frequent tire rotation is necessary because the Mazda's MacPherson strut front suspension forces the tires to run at large camber angles, which quickly wears down the inside tread ribs. And the problem was complicated by a toe-in setting that frequently drifted due to the Baja-type punishment of New York streets. The front brake pads lasted 39,800 miles and the rear linings were less than half worn out at that point. All four shock absorbers went the distance and there was no deterioration of the ride at the end. As for the interior, not even a light bulb failed within the grueling 40,000 miles. All upholstery and trim stood the test of time and the carpeting wore well—but repeatedly bunched up underfoot because of poor attachment hardware.

In all, the car proved as durable as anything you can buy today. With the exception of the failed synchronizers, every component successfully endured the rigors of automotive No Man's Land—Manhattan—as well as a team of sadistic test drivers. But to examine the critical internal workings of the Wankel engine, we returned the RX-2 specimen to its origin, Mazda Motors of America, for the final dissection.

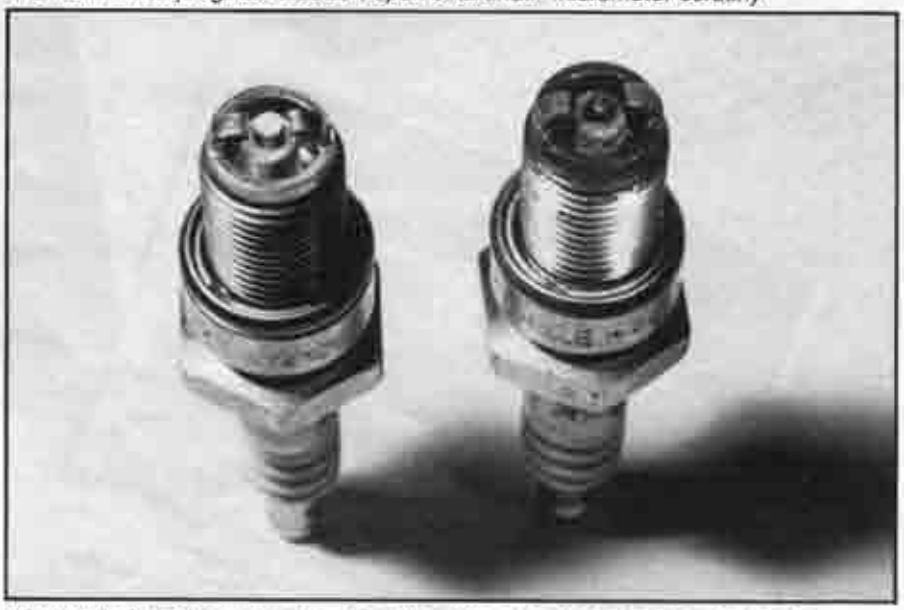
The thermal reactor was the first major component stripped from the engine once it had been pulled from the car. It's a heavy, $300 stainless steel pod that showed a light brown lining of lead deposits but no signs of deterioration. Mazda recommends lead free gasoline when possible, but a good deal of leaded gas passed through the *Car and Driver* RX-2 with no bad side effects.

The remaining externals were quite conventional in nature and prosaic in comparison to the mysteries that lurked inside. After the 4-barrel carburetor, intake manifold, air pump, air conditioning compressor, water pump, distributors, alternator, and miscellaneous emission components were stripped away, the en-

(Continued on page 104)

Inside the futuristic Wankel chambers: light carbon deposits and normal seal wear

An aluminum-impregnated carbon apex seal under micrometer scrutiny



After 15,000 miles: severe erosion of the twin ground and center electrodes

40,000 MILE ENDURANCE TEST

(Continued from page 39)

gine seemed to shrivel before our eyes. Suddenly, there was nothing left but an aluminum and iron hatbox bolted to the engine stand . . . 130 horsepower from about one cubic foot of metal castings.

Finally the last bolts were removed and the Mazda rotary's internal organs were laid out for the world to see. Two triangular rotors and a stubby eccentric shaft are the only moving parts. The block itself is a sandwich assemblage of three cast iron end plates and two aluminum rotor housings. Every component was visually compared with a new part from the shelf prior to measurement.

Crepehangers will be saddened to hear there was nothing out of the ordinary at all inside the Mazda engine. The rotors' faces were coated with a thin skin of carbon deposits, just as one finds at the top of pistons in reciprocating engines. The tip seals had polished the chrome plated rotor housings to a mirror finish but we found no nicks, scratches or chatter marks. Each of the three end plates had telltale stain marks that gave some idea of the localized high temperatures and the strange hula-hoop motion of the rotor. The eccentric shaft was virtually indistinguishable from its corresponding new part. Every seal was intact and in its proper location still prepared for a full day's work.

After a thorough cleaning, the analytic eye, this time complemented with a revealing micrometer, again passed over every critical component. Normal service manual procedures were followed to eke out any traces of wear or distortion that might indicate an impending failure of the guinea pig engine. The results: noticeable wear in only two locations. The apex seals and end plates exhibited the only traces of wear in excess of *new* component dimensional tolerances.

At the minor axis or the "neck" of the hourglass-shaped rotor housing, the rotor halts its sliding translation and sort of pivots on its heel for a short period. When this occurs, one corner seal is very close to the spark plug which is the hottest part of the engine. The combination of that steel corner seal pirouetting on the hot end plate causes a concentrated wear point. After 40,000 miles there was a noticeable ridge or step in each of the four end plate surfaces. Precise measurements with a dial indicator showed the maximum wear to be .020 millimeters, while the replacement limit is .10 millimeters. If the wear is excessive at this point, eventually there would

be a loss of compression pressure and power. Assuming a linear wear rate, the end plates would have to be replaced after 200,000 miles in our engine.

But the ultimate Achilles heel of Mazda's engine is at the apex seals. There are six in each engine, one to seal the three tips on each rotor. The seals are made of carbon and aluminum and look like a machined piece of pencil lead. Small leaf springs behind each seal hold them against the walls for starting, but only until gas pressure on the back surface rises to force the apex seals outward. When new, the apex seals are 10 millimeters tall but naturally sliding and sealing action against the rotor housing causes this height to wear down—how quickly this wear occurs, or how well they do their job of sealing has generally been thought of as any Wankel engine's most crucial aspect.

Our measurements revealed that about 10% of the height had been worn off each apex seal. The recommended replacement limit is 8.0 millimeters or a 20% loss of height. The most worn seal measured 8.765 millemeters and with a linear wear rate, it would have reached replacement limits at about 66,000 miles. Mazda technical experts report seals worn as far as 7.0 millimeters that still effectively sealed the engine. In fact, they claim the seal must wear to a 6.0 millimeter height before there is a dramatic loss in compression, power and fuel economy. Given that premise, the engine would last from 100,000 to 130,000 miles with no major repairs.

If you consider the role of the apex seals as valves and piston rings, even the most conservative estimate of a 66,000 mile engine life is impressive. Loss of compression from leaking valves in a piston engine is usually well underway by that point. And whenever the Mazda rotary's seals are deemed in need of replacement, the job is comparable to a valve and ring repair in conventional engines. Mazda manuals specify a flat rate of 13.6 hours to replace seals in comparison to 9.2 hours to grind the valves and install new rings in a Vega 4-cylinder engine.

Mazda rotary engines are as durable as a Chevy Six and at least two generations more advanced. Moreover, with advantages to be gained from a compact size, no reciprocating imbalance, and an attractive emissions potential, the Wankel is undoubtedly tomorrow's engine. Except that Mazda has it today. •