CHRYSLER'S TURBINE FOR TODAY!

by Karl Ludvigsen

A radical Chrysler development has tamed the turbine. Against the Wankel engine and this kind of competition it's no longer a question of which will win, but how long the ninety-nine year-old piston engine will last!

Always a pioneer in the use of gas turbines in automobiles, Chrysler recently unveiled a brand-new pinwheel powerplant that's closer than ever to the production line. It's a completely new unit with an important new feature that makes major inroads on three chronic turbine ailments: poor fuel economy, delay in acceleration, and lack of engine braking. It's called a "variable second-stage nozzle mechanism," and in general it is to the turbine what the invention of the throttle or the positively-operated intake valve was to the piston engine! Before we examine the latest engine and take a ride in a turbine Plymouth, let's look back at the origins of this exciting program.

IMPETUS: GEORGE HUEBNER

Behind all Chrysler's turbine work stands the figure of George J. Huebner, Jr. — executive engineer in charge of research. Now in his thirtieth year with Chrysler, Huebner speaks quietly but with authority and precision on research, and with enthusiasm on turbines. His thatch of gray hair is a recent arrival, spreading from the temples during the last five years when he's been most embroiled with the job of making the turbine perform!

Before the war, George Huebner made a brief survey of gas turbines for cars, but concluded then that neither materials nor techniques were sufficiently advanced to make research worthwhile. The war changed that, of course, and in 1945 Chrysler began laying out experimental automotive turbine designs. All of them included a heat exchanger, to return some of the heat energy of the exhaust to the compressor cycle, to bring the turbine's fuel consumption into the automotive area.

EARLY AIRCRAFT DESIGN

None of these early engines were built, for the Navy found out about Huebner's designs and contracted with Chrysler, in late 1945, for the development of an aircraft turboprop engine that would match the part-load economy of a piston engine — then an unheard-of requirement, since all earlier aircraft turbines had been most economical at peak power only. Specifically the Navy wanted a 1000-horsepower turbine with a b.s.f.c. (brake specific fuel consumption) of 0.52 pounds per horsepower-hour at 70-percent power. The design was completed in 1947 and the engine first ran in May of 1948, reaching its design goals soon thereafter. Budget restrictions forced the Navy to drop the project before the engine could be flown, but after this design success, George Huebner said, "from then on we were sold on turbines right to the hilt."

The heat exchanger used in the aircraft turbine was a conventional radiator-type unit known in turbine talk as a "recuperator". It returned a maximum of 70 percent of the exhaust heat to the engine cycle, which was adequate for limited conditions but not for the wide range of an automotive powerplant, which spends most of its life working at about a quarter of its capacity. Huebner's group set a new efficiency goal of 85 percent, which no conventional recuperator could meet. As Huebner said then, "Such a heat exchanger would easily have filled a house trailer or certainly would have occupied all the passenger compartment except — possibly — the driver's seat. A completely radical approach became necessary." It was found in the device turbine men call a "regenerator."

WHAT'S A REGENERATOR?

A conventional heat exchanger, like a car radiator, separates the hot and cold fluids or gases with a metal wall, through which heat must travel. This places a strict limit on the amount of heat that can be exchanged efficiently with an ordinary "recuperator." Is there another way to do it? Yes. Instead of boiling it in a pot on the stove (analogous to the "recuperator") water could be heated by warming a poker in the oven, then plunging it into the liquid. The same metal surface is involved in the transfer; heat doesn't have to flow through metal from one surface to another. Handled properly, it's a more efficient heat exchange system, termed "regeneration."

In terms of hardware, a regenerator revolves a metal mesh or matrix through ducts that carry the gases that must exchange heat. Naturally these ducts must be sealed off as completely as possible from each other, since any substantial crossover will defeat the purpose of the regenerator. In the turbine, heat is to flow from (*Continued overleaf*)

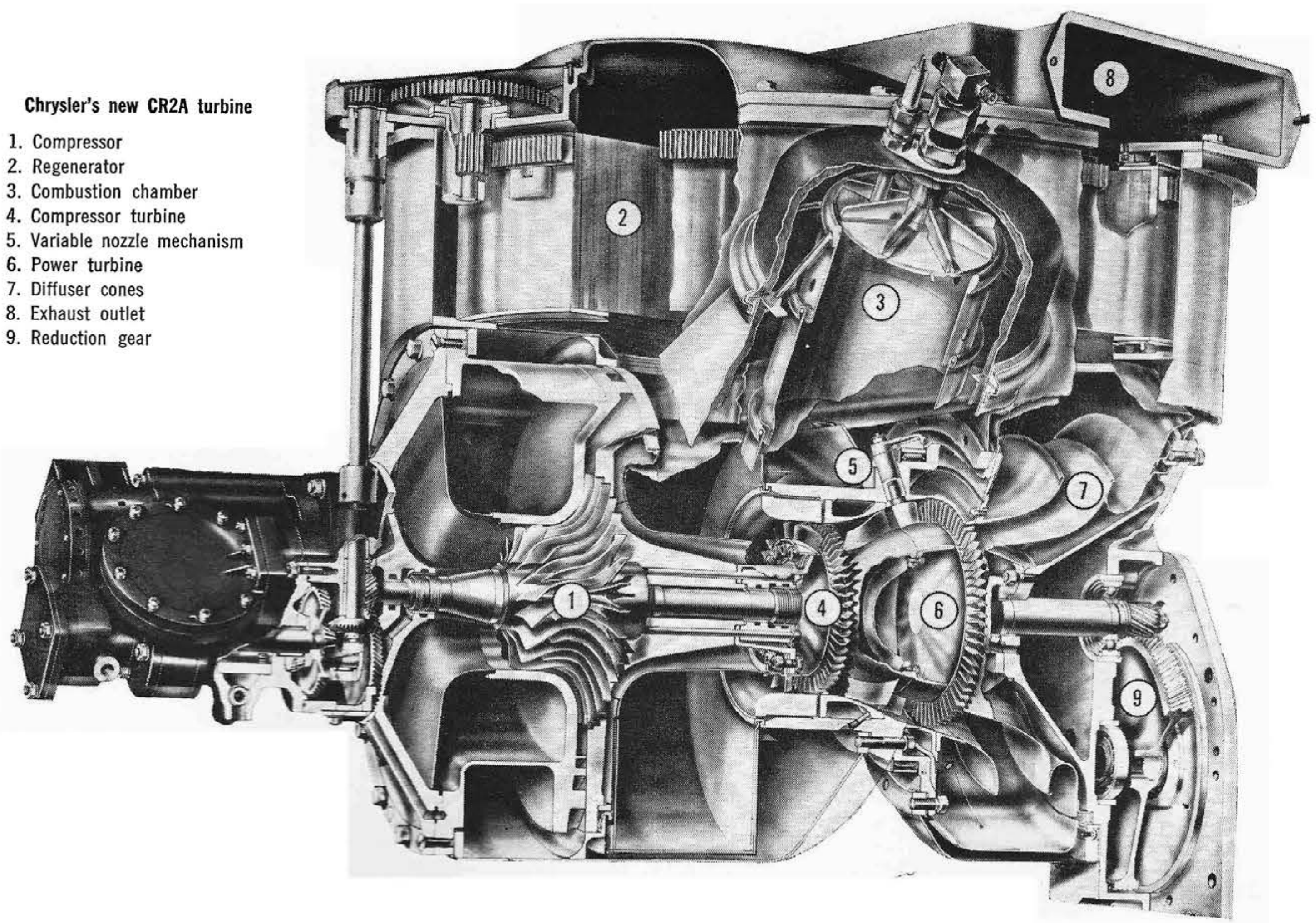
Steam car enthusiasts, take heart! With its welded steel case, the new turbine has a boiler-room look. Two big cylindrical air cleaners sit horizontally just behind the mildly restyled grille.

George J. Huebner, Jr. probably has more mileage behind the wheels of turbine-powered cars than any other American engineer. Modified dashboard of experimental Plymouth X7 is visible here.

Assembly above is early variable-nozzle ring, placed between compressor and power turbines and marked by key 5 below. On this display unit the vanes or "nozzles" are actuated by turning the control ring — and thus the vane levers — by moving the white knob at the top.

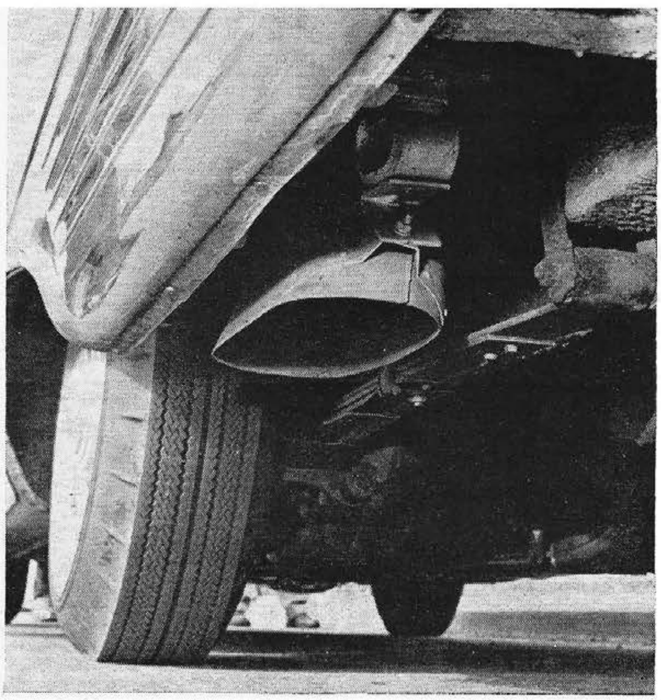
Chrysler's new CR2A turbine

1. Compressor
2. Regenerator
3. Combustion chamber
4. Compressor turbine
5. Variable nozzle mechanism
6. Power turbine
7. Diffuser cones
8. Exhaust outlet
9. Reduction gear



the hot (about 1250°) but low-pressure exhaust gases to the cooler (about 350°) but high-pressure air being pumped to the burner by the compressor. A regenerator's rotating matrix can be either drum-shaped or disc-shaped. G.M. eventually chose the drum for the Firebird turbines (two, one on each side) while Chrysler chose the disc, as did Ford, experimentally.

During the early fifties George Huebner was primarily concerned with Chrysler's gigantic Redstone missile production program, but his staff was able to make steady progress toward its first regenerative turbine. They managed to meet and exceed by one percent their 85 percent efficiency goal for the regenerator, and the installation in a 1954 Plymouth Belvedere sport coupe was successful enough to warrant a public announcement on March 25, 1954. Designed to give 100 bhp, this first engine actually produced 120 and yielded fuel economy comparable with contemporary piston engines – quoted as "between 15 and 20 mpg." It was a sensational announcement that, to many, made turbines seem



Nice detail engineering throughout Plymouth X7 includes twin exhaust ducts aimed downward behind rear wheels. The chassis is conventional.

much closer to production than was actually the case. Basic obstacles of design, materials and fabrication still stood in the way.

FURTHER FORWARD STEPS

Transferred to a 1955 Plymouth sedan, this engine continued to yield vital research data in spite of being, according to Huebner, "a rather primitive design for its state of development." Huebner was able to get back from missiles to turbines in late 1955, a time he regards as the real beginning of Chrysler's serious research on the automotive turbine. Early next year Huebner rode as copilot in a New York to Los Angeles endurance run in a 1956 Plymouth powered by this "primitive" turbine. Failures were non-critical: overheated reduction gear bearing, and cracked intake casing. The principle was proved; it was time to build a new turbine.

1957 and 1958 went by in the design, construction and development of a bigger engine that received major publicity in January, 1959 when it made an economy run from Detroit to Woodbridge, New Jersey and back. Encased in a '59 Plymouth, it returned 19.39 mpg on the way out, at a 38.3 mph average, and 17.17 mpg at 51.65 mph on the way back. It performed impartially on diesel oil, jet fuel and both white and leaded gasoline. Shaft output was 225 bhp, exactly the same as the G.M.-Allison GMT-305 turbine being publicized in 1959, though the Chrysler unit ran at a lower temperature (1600° against 1650°) and got fractionally better specific fuel economy (0.54 pounds/bhp-hour against 0.55). It almost smacked of 1951, when Chrysler picked Cadillac's dimensions for its new V8 – then got 20 extra horses out of it!

CRACKING THE ALLOY PROBLEM

By 1959 Huebner and his men were well along on two new high-temperature alloys that would reduce the turbine's appetite for rare and expensive elements. One was suited to low-stressed but hot parts, like the combustion chamber liner; the other was tremendously promising for turbine wheels and blades. What's it composed of? "Over 85 percent iron," Huebner says, "no cobalt, a reasonably low amount of nickel (as a matter of fact, I probably have enough nickels in my pocket for several passenger cars) and just a pinch of this and that. The 'this and that' is readily available under normal conditions and even fairly available in wartime." It's much less brittle than the more usual cobalt alloys, as easy to weld and easier to cast, making it possible to cast turbine blades integral with their wheels.

This alloy isn't the end of the line, either. "We're working on a combination now that will allow us to use temperatures of 2100° F.," Huebner says, "which will give us 40 percent more power and 25 percent better economy."

The 225-horse turbine was a development workhorse for other techniques. One turbine drawback had always been the leisurely rate of acceleration of the compressor section – the single-shaft assembly of centrifugal compressor, burner and axial turbine that produces hot gas to drive the axial power turbine. It's also called the gas generator or "gasifier", a G.M. term. The turbine doesn't deliver solid power until the gasifier is near peak rpm, which is usually 20-30,000 rpm higher than idle! Chrysler's first turbine took 7-8 seconds to accelerate from idle to peak, introducing a serious control lag.

One way to minimize the delay is to reduce the rotating inertia of the gasifier section as much as possible. Keep the shafts light and impeller and turbine diameters small. To reduce gasifier turbine size, Chrysler engineers made it do more work by hiking gas speeds across the blades into the transonic region – at and above the speed of sound. By this means, and by the first experimental application of the variable-nozzle principle, the gasifier acceleration time was cut to only three seconds.

THE LATEST TURBINE

All these experimental advances were incorporated in the design of Huebner's third car turbine, a smaller engine that was intended to be as near a production unit as possible. It's the engine in experimental Plymouth X7, known as model CR2A.

Chrysler's design goals for the CR2A compare interestingly with the performance actually achieved. This tabulation tells the story:

	PROJECTED	ACTUAL
Output	140 bhp	140 bhp
Specific fuel consumption	0.46 lb/bhp-hr	0.51 lb/bhp-hr
Turbine inlet temperature	1600°	1700°
Compressor air flow	2.0 lb/sec	2.2 lb/sec
Pressure ratio	4.30 to one	4.25 to one
Compressor efficiency	80%	80%
Compressor turbine efficiency	87%	87%
Power turbine efficiency	84%	84%
Burner efficiency	95%	95%
Regenerator effectiveness	92%	90%
Regenerator leakage	3.9%	4%

You'll note that the actual fuel consumption isn't quite as good as projected, mainly because the regenerator wasn't as effective in the engine as component tests had indicated. It had also become possible to use (*Continued on page 87*)

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a higher peak temperature than had been thought likely when the CR2A was planned. The fuel economy achieved is still better than any competitive turbine engine can claim today, and as good as most piston engines over most of the operating range.

Regenerator design will still progress in search of that 92 percent effectiveness. The CR2A's regenerator disc is 21 inches across and 4½ inches thick, compared to 18 x 3½ inches for the original Chrysler regenerator, and 22 x 3 inches for an experimental Ford disc. On the Chrysler engine it rotates at about 17 rpm at peak gasifier revs which, you'll appreciate, involves a lot of reduction from 44,610 rpm! Its matrix is made of type 430 stainless steel, wound around a central core, and its through-passages are given the most miniscule aerodynamic study to reduce pressure loss to a minimum.

Originally the areas of the disc exposed to the hot/cold gases were proportioned 70/30, like most regenerators, but on the CR2A the ratio is 60/40. The 4 percent leakage shown on the tabulation is hard to reduce, since a certain amount of carry-over loss through the matrix passages is inevitable. Seals themselves present no problems. "As an example," George Huebner says, "we have a seal material that shows so little change after 1000 hours that we stopped running endurance tests with it. Perhaps in the next 1000 hours of running something startling may happen to it, but we doubt it."

REDUCTION OF INERTIA

More progress was made in reducing the inertia of the gasifier section, to cut down turbine acceleration time. Transonic blade design allowed the use of a compressor turbine wheel only 6¾ inches in diameter, while the centrifugal compressor wheel is 7⅛ inches across. The latter is now made of aluminum, though experiments are being made with magnesium, and with cutting away of the wheel surface to leave no more metal near the rim than is absolutely necessary. At peak gasifier rpm, the tip speeds of compressor and turbine respectively are 1390 and 1315 feet per second—both well above the speed of sound of about 1100 fps. Result: total acceleration time cut to 1½ seconds! It's still not so quick as a piston engine, but it's very, very close.

Detail development has thus been fruitful in regeneration and inertia reduction, but the big story in the CR2A is the perfection of the variable power turbine nozzle. Between the compressor turbine and power turbine—in any g.t. engine—there's a ring of stationary vanes that form "nozzles" that direct the hot gases at the power turbine blades at an angle that's optimum for engine performance. These nozzles could only be set in one position, which would be just right for one turbine operating speed but would be a compromise for all other conditions. This is

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okay for an aircraft turbine, with its very limited design speed range, but it hampered the creation of a versatile, wide-range automotive turbine.

ACCOMPLISHING THE IMPOSSIBLE

Could these nozzle vanes be made movable? Could Chrysler engineers "switch the pitch" to improve performance? These vanes work at temperatures between 1200 and 1700° F. No lubrication could be applied anywhere near them. Separating the vanes from their carrying rings introduced new problems of compatible expansion and contraction without binding. Any leakage meant reduced efficiency and added problems. Somehow they did it.

Only 23 vanes are used, quite a lot less than in a stationary nozzle ring. Each one pivots on a shaft that runs radially outward to a square end, to which a small lever is fitted. A round ball tip on this lever is engaged by a slot in a ring which runs around the whole nozzle assembly, picking up the levers from all the other vanes. Movement of this roller-bearinged ring thus moves the levers and swings the nozzle vanes back and fourth. It's mechanically simple but the metallurgy must be murder.

Early variable nozzles had only 80° of movement, which still opened new design vistas. An extreme, nearly-closed nozzle could be formed for maximum economy. A normal position could be assumed for best power. An open, straight-through nozzle was available for fastest gasifier acceleration. Manually operated, the variable nozzle contributed greatly to the fine fuel economy obtained in Huebner's 1959 demonstration run.

The CR2A, though, has a full 100° of movement which allows actual reversal of the nozzle angle to produce positive engine braking! The gas turbine has always been conspicuous for the absence of this useful characteristic; Chrysler has been able to design it in with the most fundamental possible technique — no extra ducts, dump valves, or reverse-direction clutches. The CR2A's nozzle control system has understandably not been described in any detail by Chrysler, but it's apparently sensitive both to throttle position and to gasifier rpm. Movement of the control ring is effected by a hydraulic cylinder, through a control system that draws from automatic transmission technique, "only simpler," Huebner hastens to add.

As the power curve shows, peak output appears at 4570 rpm and a maximum of 5360 shaft rpm are allowed. These correspond to 39,000 and 45,730 power turbine rpm, and to turbine tip speeds of 1255 and 1470 feet per second respectively, on the 7⅜-inch turbine wheel. The CR2A weighs 450 pounds, complete with all accessories and ready to install. Huebner's staff is now working on a dieting program, with light alloys, that will probably bring the figure down to 300 pounds. Maximum dimensions are 36 inches long, 35 wide (at the top only) and 27 high.

The CR2A is now installed in a 2½-ton Dodge truck and in a 1960 Plymouth four-door sedan named "X7" since it's the seventh such turbine car Chrysler has built and run. The center of its grille has been blanked out by a fiberglass nosepiece, to symbolize the turbine's independence of radiators, and it sports a handsome red stripe down its centerline. Lifting the hood reveals a shape that will delight steam car enthusiasts. The CR2A's simple, round outline looks like nothing more than a steamer's boiler! It's a valid comparison, too, for the turbine shares the steamer's impressive torque at zero shaft speed. Ahead of the engine is a wide case enclosing two big cylindrical Purolator air filters, with paper elements. A turbine's filtering needs aren't as demanding as those of a piston engine, so it's not difficult to provide the large volume of air it requires.

EXCITING SIGHTS AND SOUNDS

Let's climb aboard Plymouth X7 and go for a drive with George Huebner. He faces a restyled dash panel with four round dials. The two on the left offer no surprises, with info on generator charge, fuel level and car speed, but the two on the right are reserved for the space age motorist. One indicates engine oil pressure and the temperature at the power turbine nozzle — a range of 0-2000° F. is provided. The other shows gasifier speed in terms of percent of peak power rpm — 39,000 rpm in this case, as you'll recall. This relieves the pilot of the confusion of interpreting these astronomical rev numbers and gives him only the information he needs. Below the left-hand dial are four buttons to control the three-speed automatic gearbox used in X7. It's one of Chrysler's regular three-speeders, but without a torque converter or neutral position, neither being needed or desired by a turbine.

When Mr. Huebner inserts his key in the ignition and twists it to the right, 12 volt current courses through an Eemco starter-generator that's able to turn the gasifier up to 20,000 rpm if necessary. This time it isn't, for as the starter's whine cascades higher and higher it is joined by a deep rumbling sound that indicates the burner is lit. This voice of combustion is so muted that it's very similar, in volume and tone, to the sound of the Corvair's gas-fired heater. The starting sequence will have taken about eight seconds. If he desired, Mr. Huebner could now let the gasifier idle at its usual 40 percent of peak, or about 15,000 rpm. If he's out to impress you, which is more likely, he'll step right down and wheel X7 away at maximum power, for the gas turbine requires absolutely no warmup.

As this unique car swings into action, you begin to hear the fantastic automotive sounds of tomorrow. The main sound is the high whine of the gasifier section, steady at its peak controlled rpm at full throttle, or fluctuating up and down as throttle and power demands vary. Beneath this overlay you hear the deep whine of the power turbine section, steadily rising and falling as car speed varies and the gearbox shifts. Backed by the rumbling bass of the burner, these high notes weave and interlace a magnificent musical tapestry of the sound of the space age.

George Huebner is quick to point out that the high whining sounds of the CR2A engine are produced by the hand-machined gear trains and would be vastly reduced in a quantity-produced turbine. In the case of the gasifier it's the helical and bevel gearing to the accessories and regenerator; in the power section it's the reduction gear, which had a particularly loud period on X7 at about 30 mph. Even so, we found these sounds far more stimulating than disturbing.

DRIVES AND PERFORMS NORMALLY

The reduction in response time means that this turbine car can be driven just like any automatic-transmission vehicle. "I don't even think about it any more," Huebner said as he maneuvered X7 through the downtown traffic of Washington, D. C., where Chrysler was showing the CR2A to the military. He uses a two-foot technique, braking with his left in the automatic-box manner, and doesn't hesitate to apply the brake to build gasifier rpm for a quick takeoff from a standstill or down a turnpike entry.

How's performance? X7 moves out about like a normal Plymouth at first, then steps forward like a powerpack job as speed mounts. This pioneering installation was made without sufficient time to adjust the transmission's shift speeds just right, so to avoid roughness the turbine was restricted to 92½ percent of its power peak speed. "It's too bad," Huebner said, "because it really gives you a kick in the back at the top end. Peak speed would give us another 25 horsepower."

Does the variable nozzle really produce engine braking? Yes, indeed. The intention with X7 was to provide braking that would be familiar to most passengers, rather than violent. Just enough vane movement is allowed to reproduce the deceleration of an automatic-box car in high gear, as we confirmed when riding in an ordinary Plymouth after X7. It's not arresting but it's far better than the headlong free-wheeling you get on a closed throttle in all other turbine cars. If more braking is desired, as might be applied through a four-wheel-drive layout, the vane movement can be increased.

PRICE STILL THE PROBLEM

Chrysler's CR2A turbine now performs fully as well as a piston engine, with far greater smoothness, less weight, and greater simplicity. We asked George Huebner if the latter fact meant it could compete with the piston engine on a price basis too. "Right from the start we realized that the turbine could never match the price of the reciprocating engine unless it was mass-produced in the same large quantities. For this reason we've concentrated on developing it for passenger car use. We haven't calculated cost figures on this new engine yet — and it's not possible to say anything definite until we've actually done so — but we believe that this turbine would cost no more than our present passenger-car engines, if it were completely tooled and produced in the same large numbers."

For these reasons, as many observers have noted, turbines aren't likely to be offered for sale in cars until they're tooled for very large quantities. Rover might confound this, by selling a small-production turbine car at relatively high cost, but it's not likely that Chrysler will take that tack. It's a shame that this is the case, because we find it hard to imagine a more exciting sports car than one using this CR2A turbine. —K.E.L.