Turbo compound Wankel rotary engine.
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TURBO COMPOUNDING THE WANKEL ROTARY

A turbo-compound engine collects all of the exhaust gasses and passes them through a turbine, with all of the power generated going back into the crankshaft and ultimately to the propeller thereby recovering some of the waste heat in the exhaust. This waste energy varies from 40% to 60% of the total energy contained in the fuel (depending on engine configuration. Obviously there is considerable potential for enhancing efficiency if this energy can be captured in a practical manner.
Ref (1).

Besides the economic advantage of turbo compounding an engine there are other consideration.

Turbo compounding promises to add considerable range and endurance. this provides real safety enhancements in allowing flexible flight planning (To include weather avoidance and the ability to plan to bypass airfields with less than optimum navaides).

Having the range to turn back has saved my life more than once when on a long cross country's over remote areas of Canada, Alaska and Baja. A high performance airplane with a small thin wing has a limited volume for fuel. Such air cooled piston engine airplanes may need to stop every 400 or 500 miles for fuel and the pilot often has little flexibility in preflight planning or in making changes while enroute.

Turbo compounding also improves the power to weight ratio of an

engine by roughly 15%. Ref (1).

Allison built a V12 turbo compound engine during World War II in an attempt to recover some of the waste energy. Ref (2) It was identified as the V1710-E22. Work began in 1944 and continued until 1946. It was sponsored by the US government but canceled with the advent of the turbo jet engine. Apparently it was the first turbo-compound engine. The V1710-E22 had a military rating of 2320 hp, and a War Emergency Rating with water/alcohol injection of 3090 hp. With a compression ratio of 6:1 it achieved a 19% improvement in the BSFC. It never flew. The normal supercharged Allison V12 generated 2000 take off HP and 2500 HP War Emergency Rating.

The most widely used turbo-compound engine was a version of the air-cooled, 18-cylinder, two-row radial Curtiss Wright R3350-TC. Ref (1) This engine was used in many airliners and several military aircraft. Thousands were built. The R3350TC had three turbines, each fed by 6 cylinders, that were geared to the crankshaft. The turbo-compounded version produced 3500 hp and weighed 3440 lb resulting in a power to weight ratio of over unity. The BSFC was as low as .37 at sea level and .33 at 30,000 feet with a compression ratio of 7.2:1. The normal supercharged version produced 2700 hp and weighed 2850 lbs.

The worlds record prior to the Rutan Voyager for un-refueled distance was held by a P2V powered by an R3350 TC that flew from Australia to Ohio. Super G Lockheed Constellation with this engine were able to fly non-stop LA to London over the pole in the 1950's. Ref (1a)

The Achilles heel of this engine proved over time to be the failure of the exhaust valves when the exhaust gas pressure was 25% higher than the intake pressure. Much of the development effort was expending on improvements in exhaust valve durability. Ref (1)

Another prototype turbo-compound engine is the Napier Nomad, which was built in England. It was a 12-cylinder, horizontally opposed, liquid

cooled,
valve-less, 2-stroke Diesel engine with a 3-stage turbine. It reached flight test but not production. BSFC was .345 (shaft HP) at 11,000 feet and a compression ratio of 8.25. Ref (3)

NACA sponsored several reports on turbo compound engines. One of which used a dynamometer tests to gather data. Ref (4) This test program indicated a BSFC of .323 at 10,000 feet. 14% better than a normal engine at 10,000 feet and 21% better at 30,000 feet.

NASA also did a study of several configurations of the turbo compound Wankel rotary engine Ref (5)

The Wankel rotary engine is a very mechanically robust engine that tolerates high boost pressures. There are no cyclical reversing stresses in the three major moving parts of a two rotor rotary engine that so often lead to fatigue failure in the light weight piston engine. Consequently the power to weight ratio of the current Mazda RX8 Wankel rotary engine is comparable to an air cooled aircraft engine at 240 HP and 190 pounds less the weight of the required PSRU.

The compression ratio is inherently low limited to about 10:1 due the necessity of locating the rotating combustion chamber in the rotor. The combustion chamber surface to volume ratio is high reducing the basic efficiency of combustion but adding to the ability of the engine to survive high power to displacement ratios with out thermal fatigue failure of the combustion chamber inner surface.

The Wankel rotary has no poppet exhaust valves. "Piston" porting is done by the rotor as it orbits inside the rotor housing. The Wankel rotary has approximately three times the net available kinetic energy in the exhaust as compared to a piston engine. Two thirds of the total kinetic energy in the exhaust of a piston engine is dissipated by the exhaust valves. Ref (1)

The high level of kinetic energy in the Mazda Wankel rotary engine

exhaust has been known for 30 years. Anybody that has been present at race where a Mazda Wankel rotary powered race car operated without a muffler can appreciate the tremendous kinetic energy in the exhaust. There is always as much or more potential HP in the exhaust as there is available from the output shaft. (Ref 6) The more you boost it the more HP is available to boost it. This is an exponential effect so the real HP limit is detonation, durability and structural strength of the core engine. Turbocharged Mazda 2.6 liter two rotor engines have been boosted to 800 HP for racing purposes using alcohol and nitrous oxide. Ref.(7) The Wankel rotary appears to be an ideal gas generator for a turbine engine.

BUILDING A TURBO COMPOUND WANKEL ROTARY ENGINE.

I had an idea on how to implement a turbo compound arrangement using a ball traction drive gear box from a Paxton Centrifugal supercharger. The HP, gear reduction and RPM is about right for installing a turbine and feeding the power back into the engine instead of discarding it as waste heat. Hopefully we will obtain 20% to 25% more shaft power with no additional fuel and no additional load on the engine cooling system.

My concept for the rotary turbo compound would use a stock Mazda turbocharger radial inflow turbine feeding power into the eccentric shaft and a centrifugal blower using modern aerodynamic designs for both.

We will start with a turbine reduction gear ratio and boost level that optimizes the torque feed back to what the engine will tolerate without detonating at sea level and at an e-shaft RPM of 7500. That e-shaft RPM assumes a PSRU with a 2.85:1 reduction ratio and a maximum prop RPM of 2630. RPM red line on the stock Mazda RX8 Wankel engine is 9,000 RPM. The historical evidence suggests we will eventually obtain more than a 20% efficiency improvement in BSFC, power and about a 15% improvement in power to weight ratio with a turbo compound rotary.

I decided not to use a Paxton Centrifugal supercharger.
I decided to design a traction reduction drive using rollers and not balls. We are now machining the traction drive RPM reduction device to

extract
the excess HP from a stock turbocharger. Input speed RPM can be up to 100,000 RPM and output RPM will be one tenth of that. The power from the traction drive output shaft will be transfered to the e-shaft of the rotary by a V-Ribbed belt to absorb the torsional vibrations from the rotary engine. We hope to recover at least 50 HP from the waste heat in the rotary exhaust improving the BSFC from the current .47 to .38 at cruise altitude. The range of any airplane using this engine will increase by 15% to 20%. We hope to test the engine soon on a dyno to gather the data.

Ref(1) 1954 SAE Transactions. Development of the R3350 Turbo Compound Engine. F.J. Wiegand and W.R. Eichberg
Volume 62 page 265

Ref 1a. "Lockheed Constellation" by Stringfellow & Bowers Motorbooks ISBN 0-87938-379

Ref (2) Vee's For Victory by Daniel D. Whitney. Schiffer Military History 1998 ISBN 0-7643-0561-1

Ref (3) book "A history of Aircraft Piston Engines" by Herchel Smith Sunflower University Press Corrected edition 1986 ISBN 0-89745-079-5

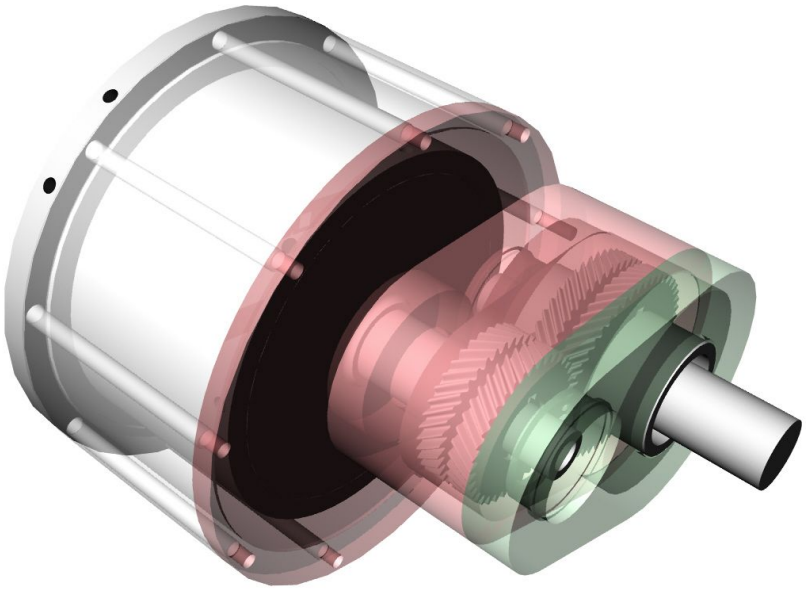
Ref (4) NACA REPORT No. 822 1944
CALCULATIONS OF ECONOMY OF 18-CYLINDER RADIAL AIRCRAFT ENGINE WITH EXHAUST-GAS TURBINE GEARED TO THE CRANKSHAFT
By RICHARD W. HANNUM and RICARD H. ZIMMERMAN

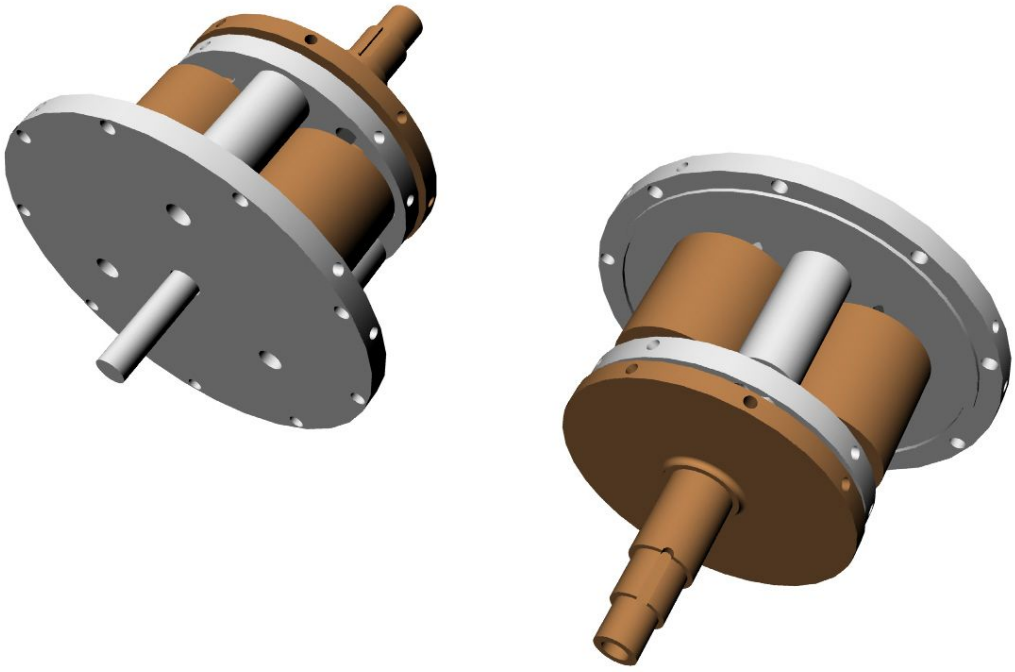
Ref(5) Stratified Charge Rotary Engine Critical Technology Enablement Volume II NASA Contractor Report 189106
C.E. Irion and R.E. Mount
Rotary Power International, Inc.
Wood-Ridge, New Jersey

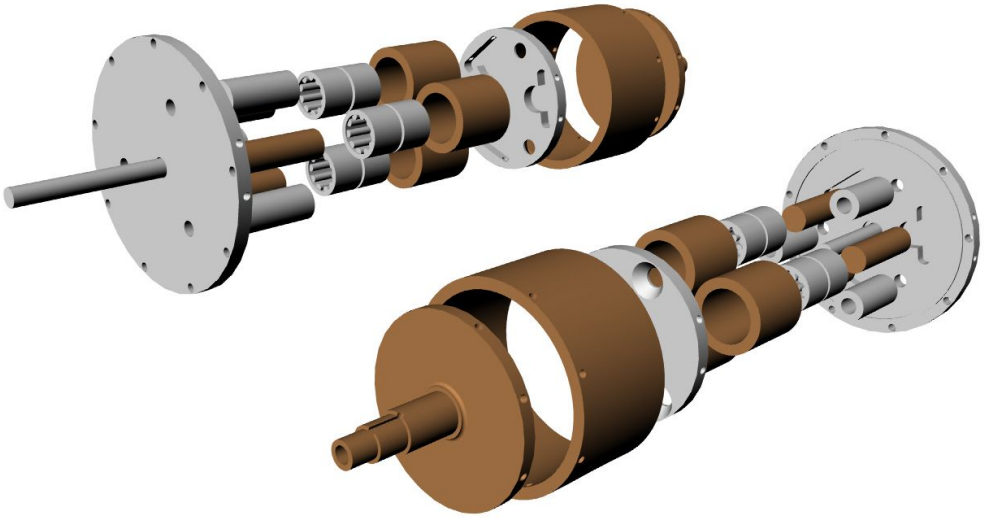
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Sunstrand Aerospace

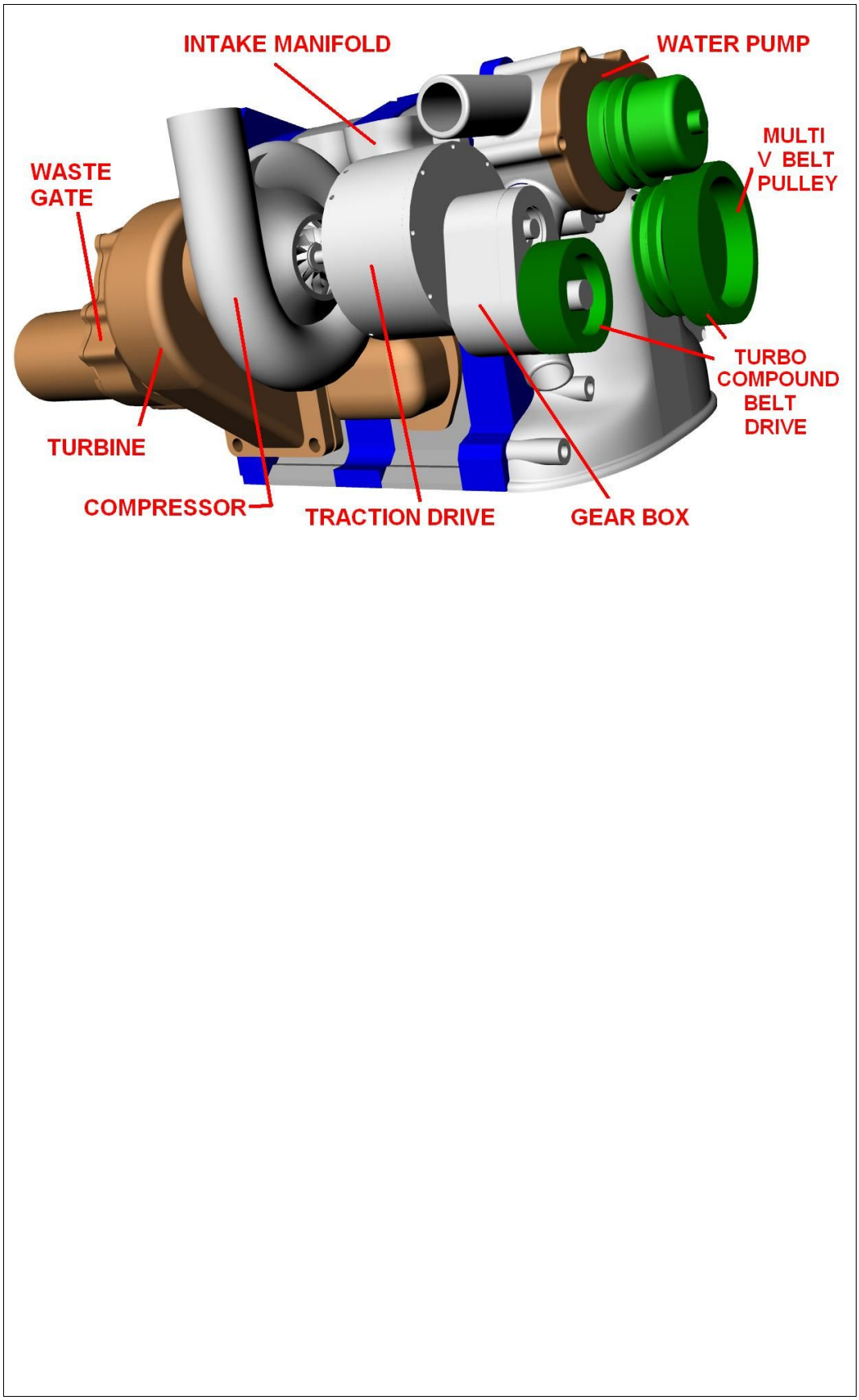
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Ref (7) Turbo & Hi-tech Performance magazine. July 1997
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INTAKE MANIFOLD
WATER PUMP
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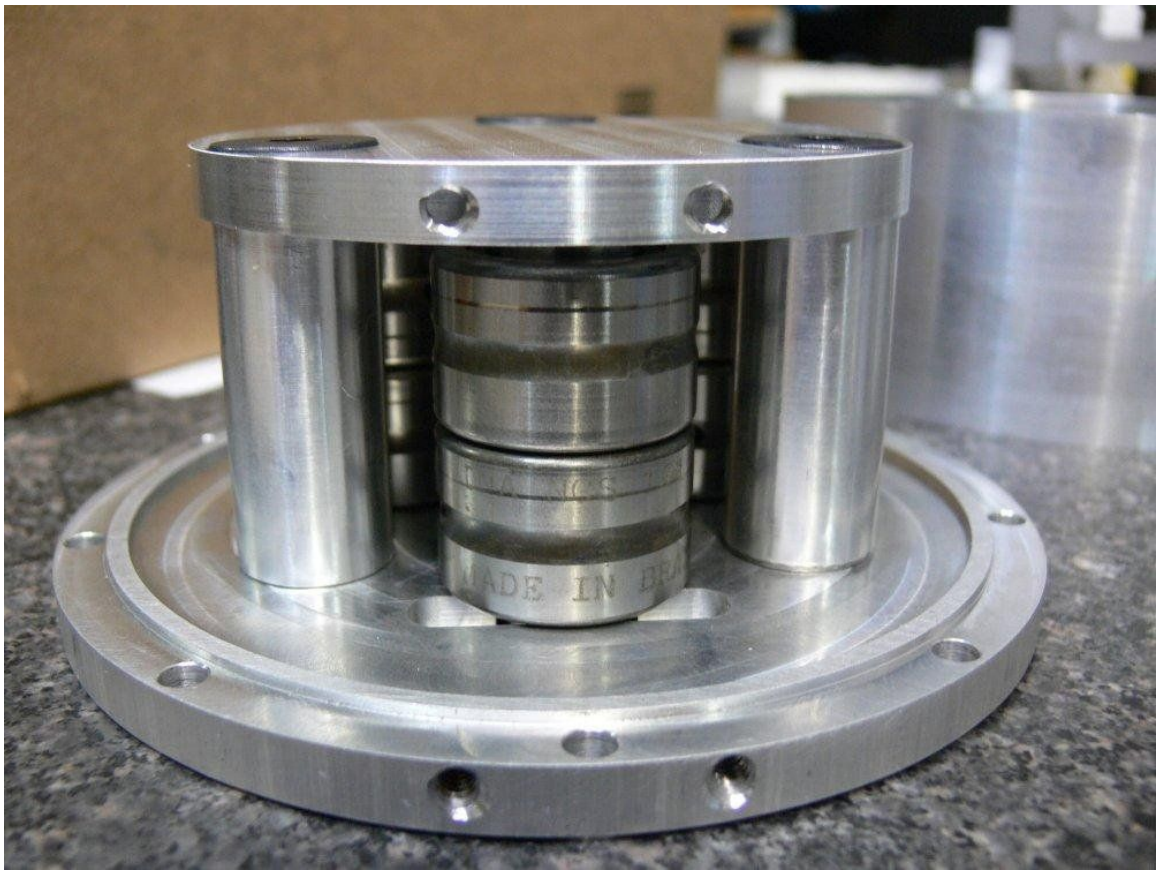

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