Rotapower® Engine Overview

FREEDOM MOTORS

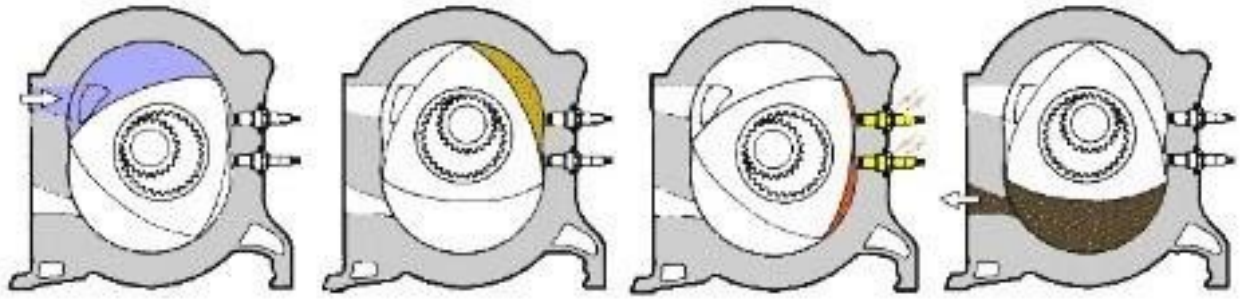
Engineering Presentation

Experience the Power of Freedom

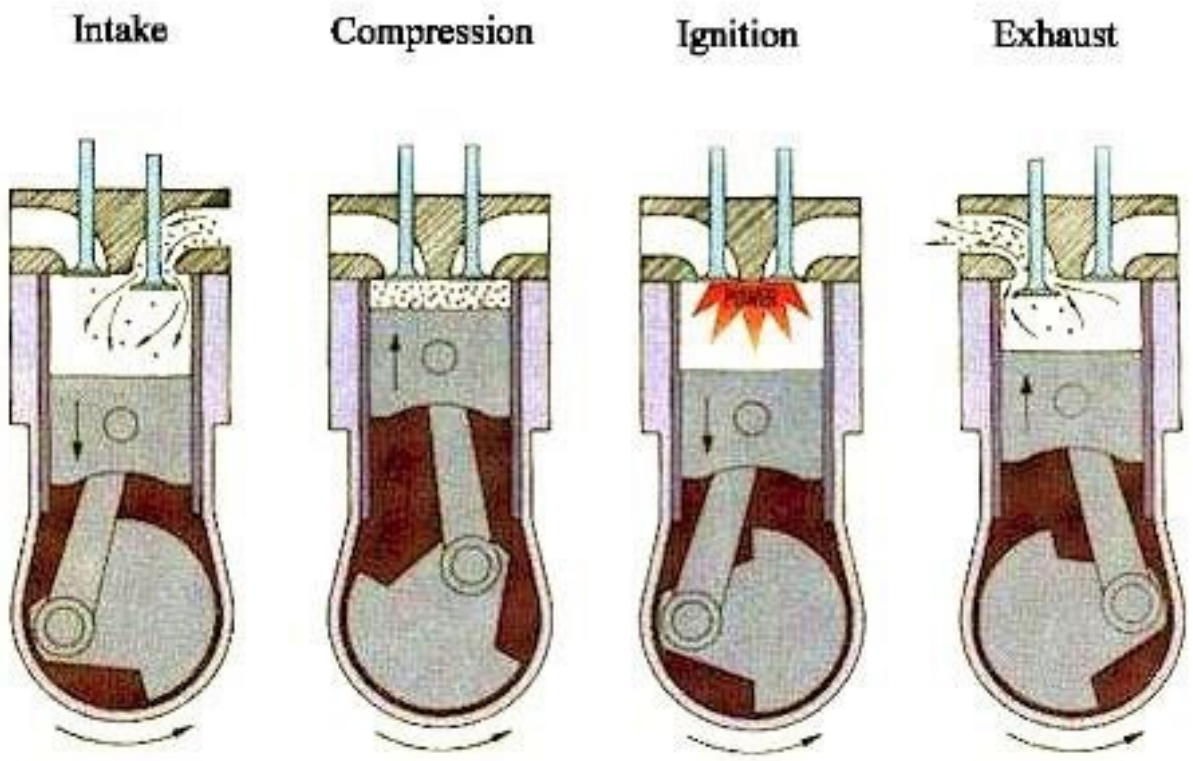
410 Gateway Plaza, Suite G, Dixon CA 95620

Rotary verses Piston - Engine Cycles

Rotary

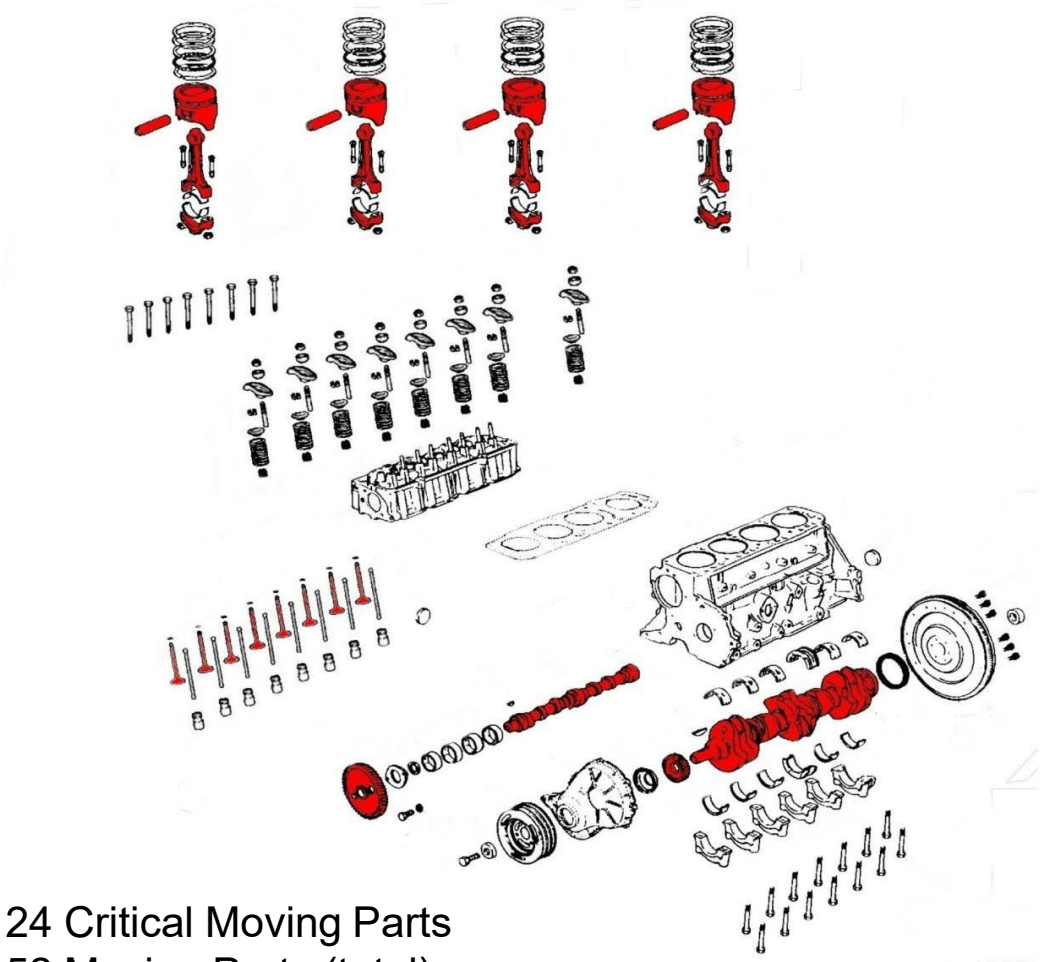


Piston



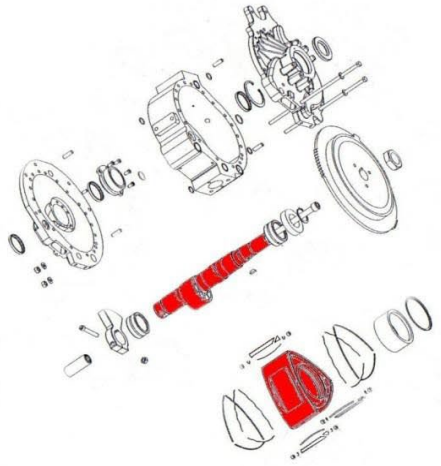
Engine Comparison

Four-cylinder, 4-stroke Piston Engine



24 Critical Moving Parts
52 Moving Parts (total)

One-rotor, 4-stroke Rotapower ® Rotary Engine



2 Critical and only moving Parts

Note: A 4-stroke piston engine requires 3 cylinders in order to match the instantaneous output torque of a single-rotor Rotapower engine.

Key Attributes of a Rotary Engine

- Perfect radial balance
- Low torsional vibration (2-rotor = 6-cylinder piston)
- High power for weight and size
- Very reliable
  - Ingersoll-Rand
  - Mazda
  - Outboard Marine Corporation (OMC)

Rotapower ® Engine Development

- FM has acquired the entire rotary engine technology assets from:
  - Outboard Marine Corporation (OMC)
  - Infinite Engine Company (IEC)
- Has acquired significant rotary engine assets from:
  - Curtiss Wright Corporation
  - Rotary Engine Technologies, Inc.
  - Savkel Ltd (Syvaro)
  - General Motors
- Expended approximately $65 million developing new and improved versions of these engines
  - New 27cc and 150cc series engines
  - Improved 530cc and 650cc series engines

Oil-cooled versus Charge-cooled Rotor

- Oil-cooled rotor rotary engines:
  - Mazda (Automotive)
  - NSU (Automotive)
  - Ingersoll-Rand (Industrial)
- Charge-cooled rotor rotary engines:
  - Infinite Engine Company (Acquired by Freedom Motors)
  - Fichtel-Sachs (No longer in manufacturing space)
  - Norton (Primarily in motorcycle space)
  - OMC (Acquired by Freedom Motors)
  - Freedom Motors

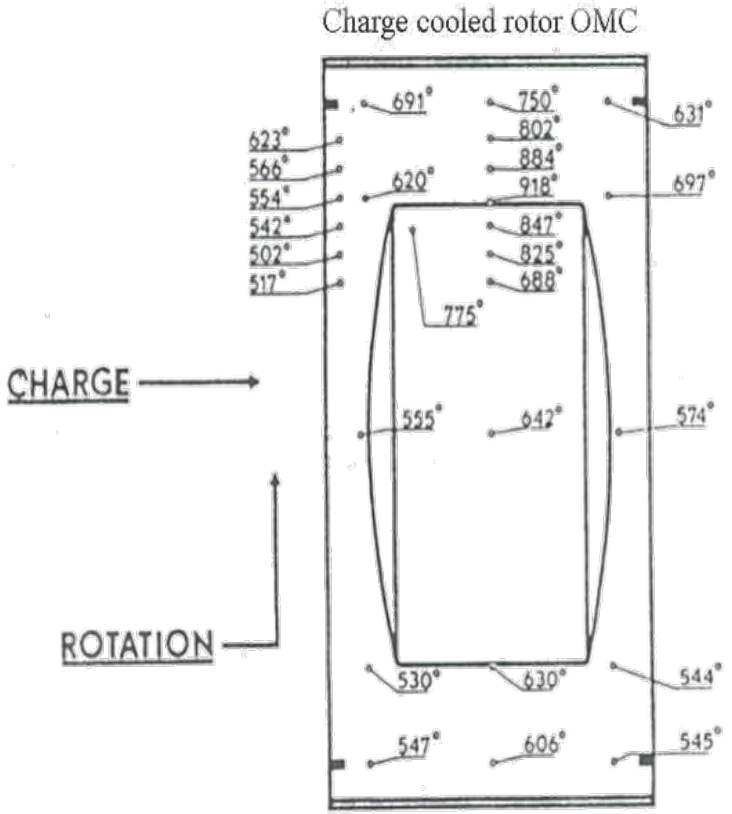
Advantages of a Charge-cooled Rotor

- 15% improvement in specific fuel consumption (SFC)
  - 10% oil cooling related loses
  - 5% uses roller bearings
- Hot rotor surfaces (725° F vs. 377° F) prevents combustion quenching
  - Allows efficient combustion at lambda = 1.25
  - Absence of valves tolerate lambda = 1.25
  - Summation of all toxic emissions is lowered by 99%

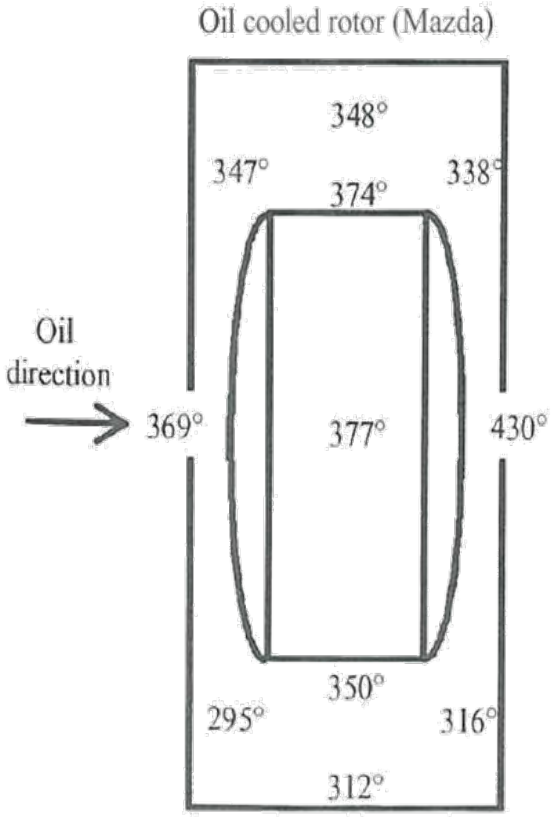
Rotapower® Patented Improvements

- Freedom Motors incorporated patented improvements into its designs:
  - Parallel cooling for rotor (Patent #5413877)
  - Unique oil injection lubrication system (Patent #6325603)
  - Complimentary cooling towers (Patent #6164942)
  - Six patents in process for submission
- Cooling approach eliminated end-loading the roller bearing and side-thrust on the rotor
- Lubrication patent placed lubricating oil precisely where it was needed

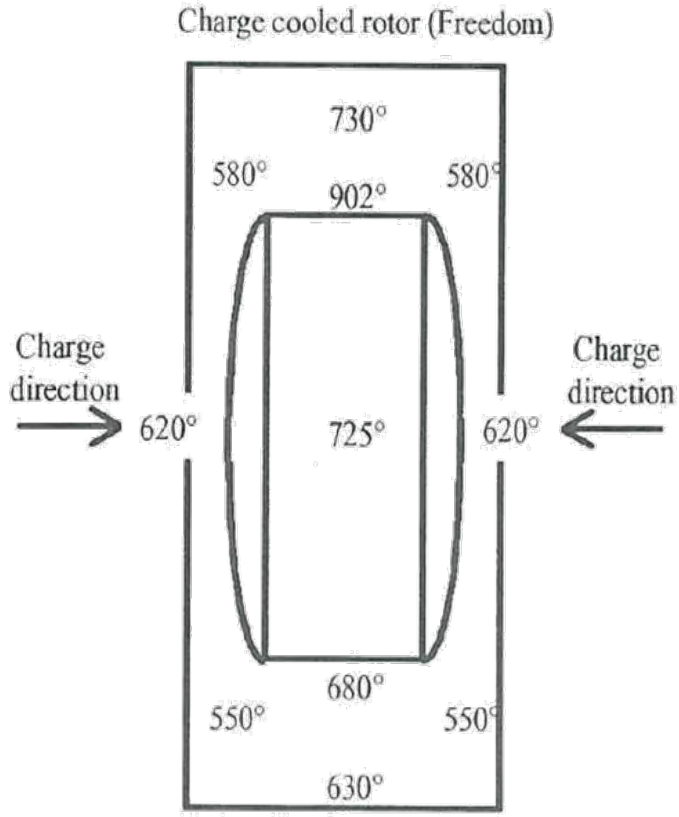
Rotor Surface Temperatures



Source: Outboard Marine Corp.



Source: "Rotary Engine", by Kenchi Yamamoto



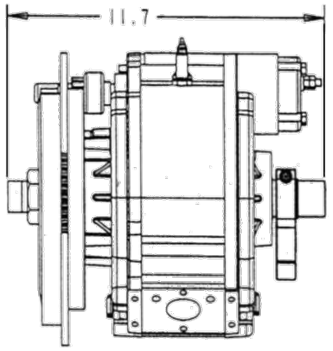
Source: Rotapower Dyno Testing
Dual Plug Configuration

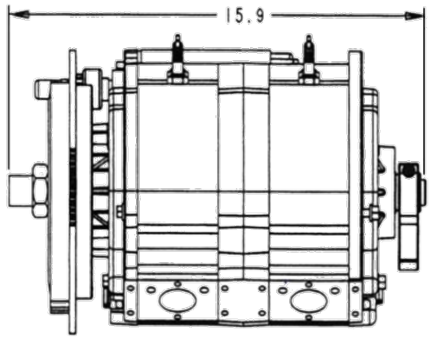
OMC **Mazda** **Freedom**

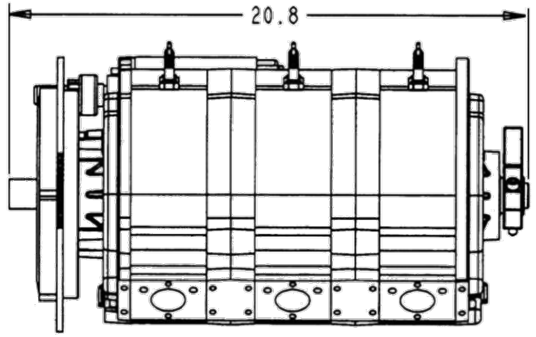
Additional Improvements

(Proprietory Trade Secrets)

- 20,000-hour life seals
- Proprietary rotor housing grind finish that eliminates need to lap housing
- Lower cost plasma coatings for rotor housing
- Modular design allowing for simple implementation of multiple engine configurations from 1 to 9 rotors



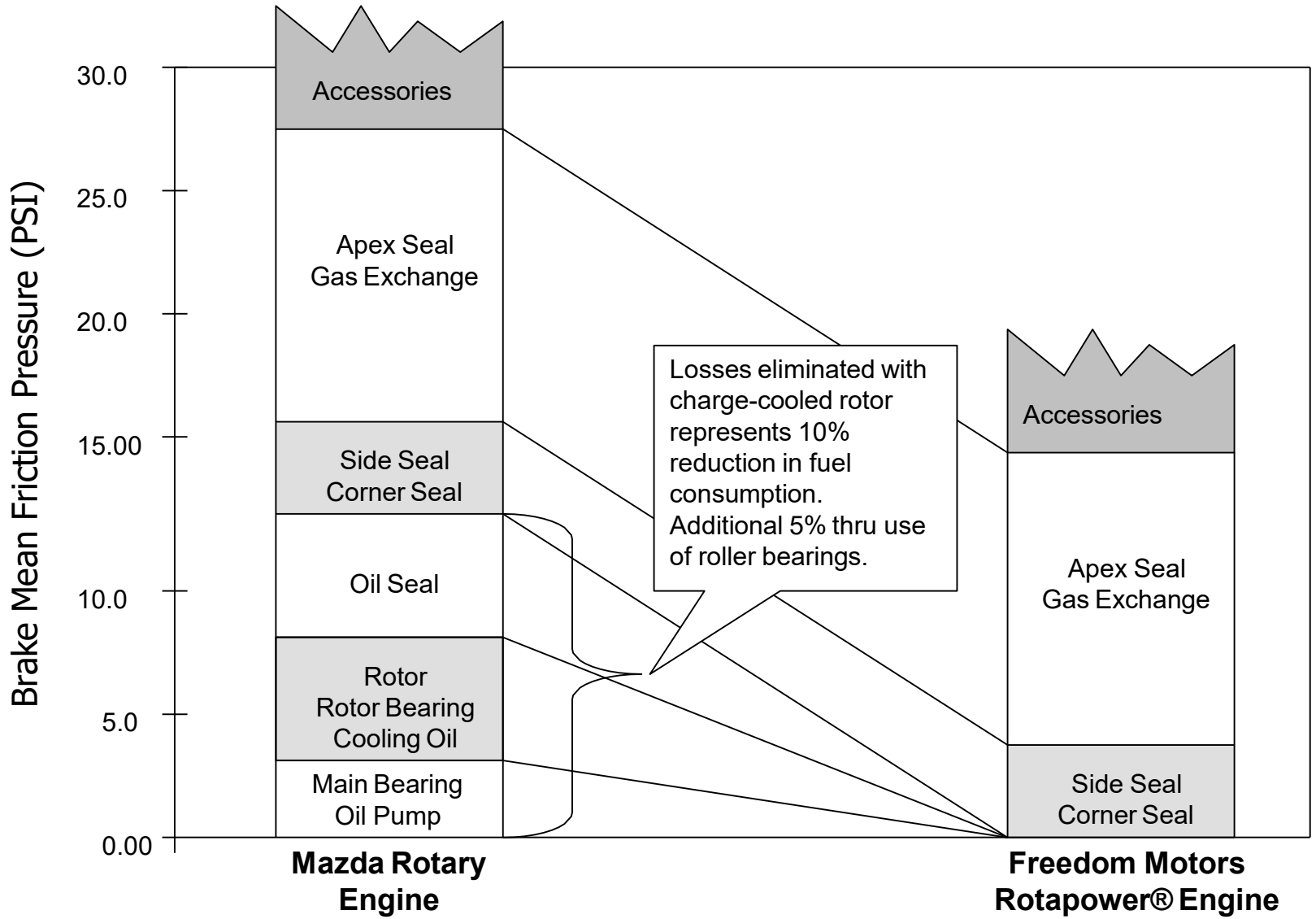




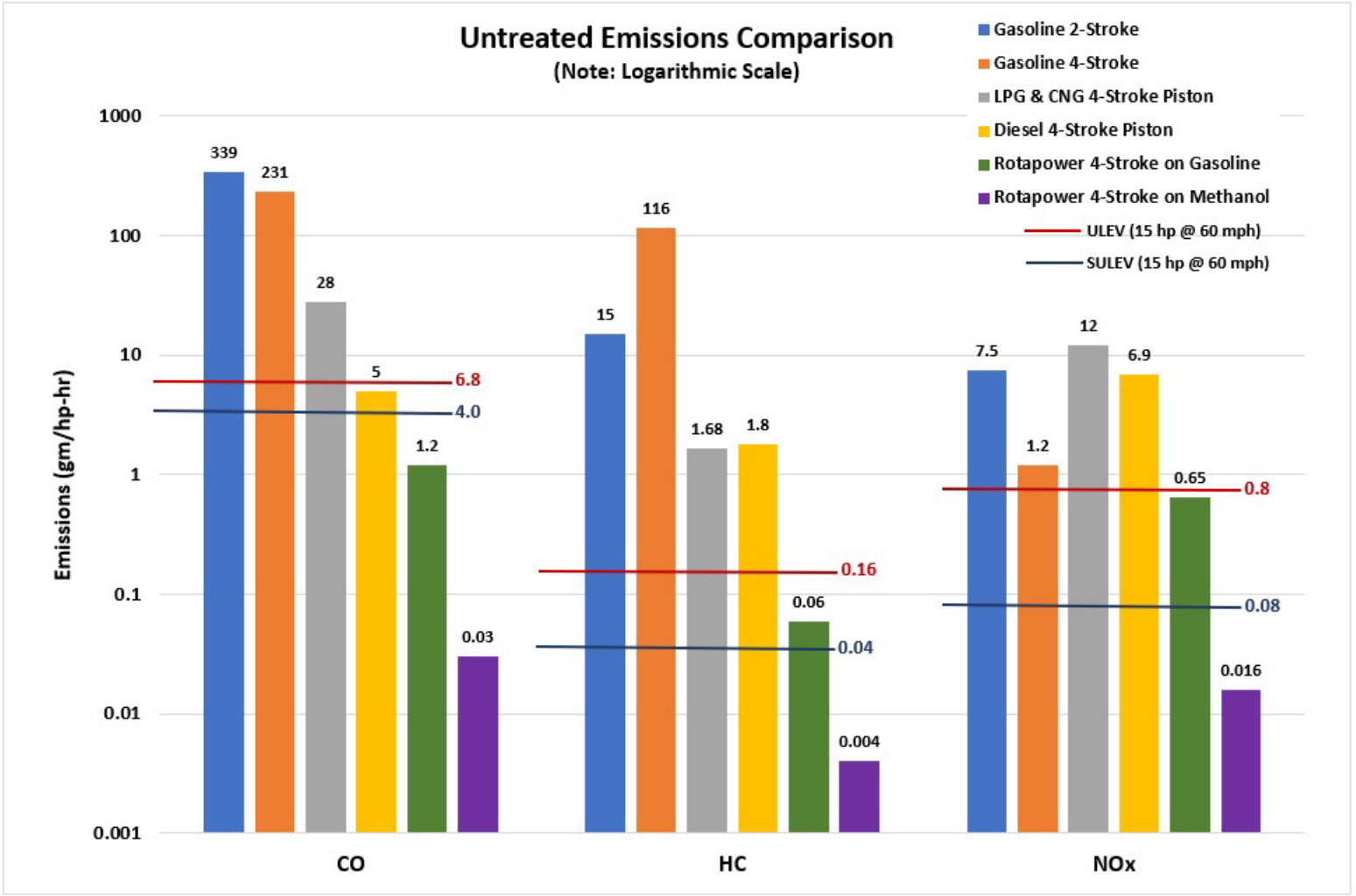
Specific Advantages of the Rotapower® Engine

- Patented rotor design eliminates major weakness of all other charge-cooled rotor rotary engines:
  - Patented rotor cooling
  - No bearing end loading
  - No rotor side thrust
  - 20,000+ hour seal life
  - Patented cooling towers increase cooling
  - Patented lubrication system
  - Modular design (530cc series) allows broad range of power alternatives

Comparison of Friction Loss Between Mazda 500cc and Freedom Motors 530cc Single Rotor Engines



Untreated Emissions Comparison



Piston engine data from EPA report No. NR-0106
Rotapower engine data verified by California Air Resource Board (CARB) and Dr. Andrew Burke of the Institute of Transportation Studies (ITS), University of California, Davis

Basic Rotapower® engines

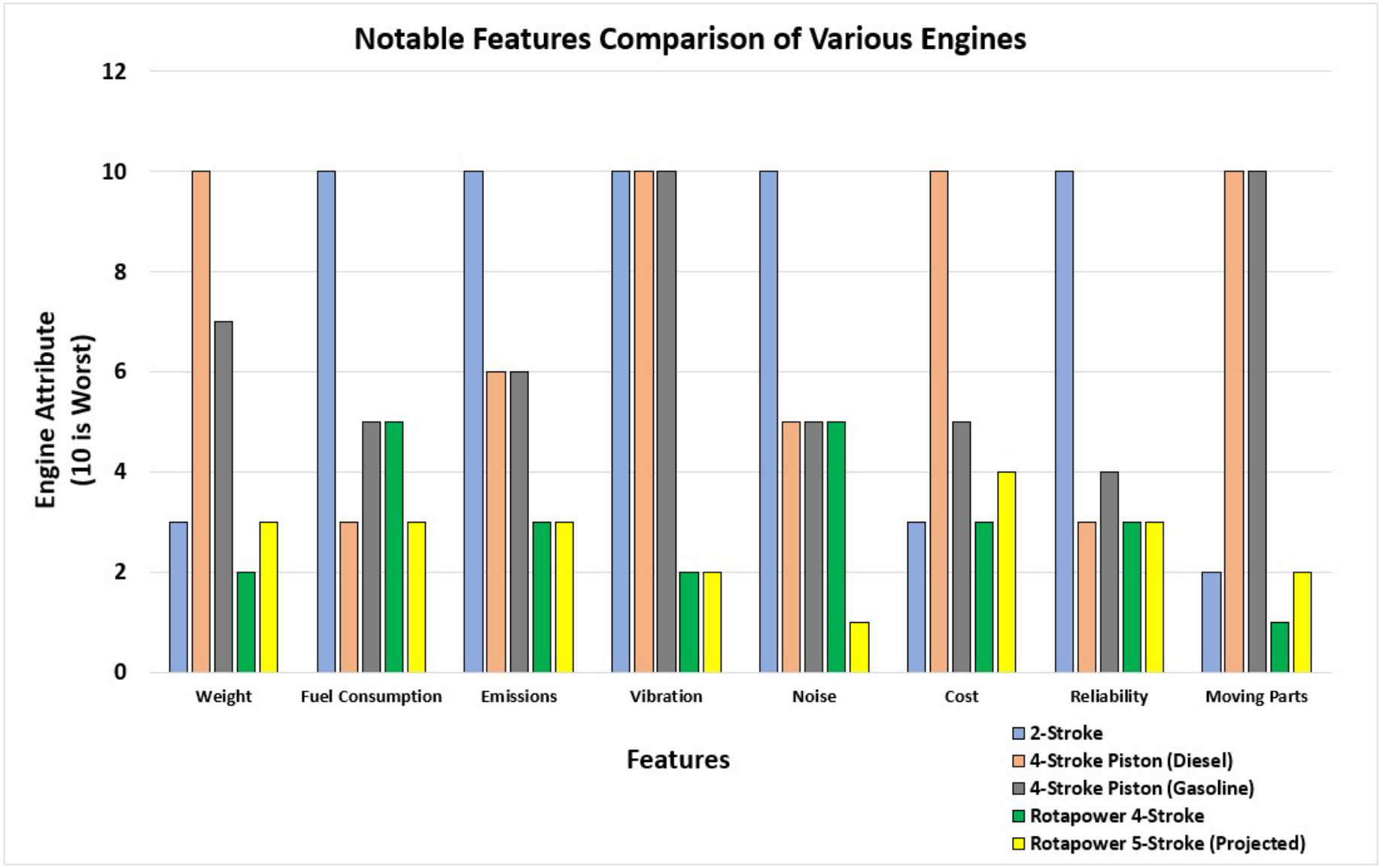
(Developed or in development)

Applications and Horsepower Range of the Rotapower® Engines			
Max Horsepower	Displacement	Configuration	Potential Applications
2.5 - 7.6	27cc	Single	Lawnmower, leaf blower, hand-held powertools, trimmers, tuk-tuk, motor scooter, portable generators. Recreational uses like power surfboards.
4 - 10	40cc	Single	
7.5 - 15	75cc	2-Rotors	
20 - 35	150	Single	Hybrid cars, gen-sets, motorcycles, snowmobiles, all terrain vehicles, jet skis, and jet boats. Any high performance use where light weight and small size is important.
28 - 45	200cc	Single	
40 - 70	300cc	2-Rotors	
50 - 125	530cc	Single	
100 - 250	1060cc	2-Rotors	
150 - 375	1590cc	3-Rotors	Boats, industrial engines, large gen-sets, or any applications that is space limited, weight sensitive or reuires multi-fuel capability.
200 - 500	2120cc	4-Rotors	
270 - 625	3180cc	6-Rotors	
65 - 150	650cc	Single	
130 - 300	1300cc	2-Rotors	

Note: The power output depends on fuel choice and operating RPM

Developed **In Consideration** **In Development**

Engine Comparison



Ideal Applications for Rotapower® Engine

- The charge-cooled rotor rotary engine is ideal for a series or Plug-in Hybrid Electric Vehicle (PHEV) or a Range Extender and a portable fast DC EV charger
- Other applications:
  - Recreational – Snowmobiles, ATVs, PWC
  - Utility vehicles – Motorcycles, motor scooters, etc
  - Portable power – Pumps, generators, etc
  - Boats
- Narrower RPM band maximizes power and minimizes emissions

Specific Fuel Consumption

Engine Type	Specific Fuel Consumption	
	LB per hp-hr	Grams per kw-hr
2-Stroke recreational piston engine	.65	395
4-Stroke commercial piston engine	.45	274
Mazda rotary engine	.52	316
OMC rotary engine	.6	365
Rotapower® rotary – carbureted	.43	262
Rotapower® rotary – direct fuel injection	.4	243
Rotapower® rotary – compound version[1]	.31	188

[1]Projected SFC based on NASA report

Maximum engine efficiency as a function of power fraction (P/Pmax)

Data compiled by Dr. Andrew Burke[1] from the Institute of Transportation Studies (ITS), University of California, Davis.

Maximum engine efficiency as a funtion of power fraction (P/Pmax)[1] Engine Efficiency (%)					
Power Fraction P/Pmax	Freedom Rotary[2] (non-compound)	Standard Saturn Gasoline Engine	Honda Insight Lean-Burn Engine	Audi Turbocharged Diesel Engine	Freedom Compound Rotary[3] (Projected)
0.2	23.0	28.6	37.7	38.5	31.4
0.3	29.0	32.1	37.7	39.7	39.4
0.4	31.9	32.7	37.2	39.7	43.4
0.5	31.9	32.7	36.3	38.5	43.4
0.6	30.7	30.0	35.3	37.0	41.8
0.7	29.2	26.7	33.1	35.4	39.7
0.8	29.0	26.0	28.5	31.2	39.4
1	25.7	25.3	27.0	27.8	35.0

[1]From "Hybrid Vehicles with Batteries and Ultracapacitors in China" Andy Burke, ITS, UC Davis, 2005. (Dr. Burke is recognized as a world expert on Hybrid automobiles)

[2]SFC = .4 lbs/hp-hr.

[3]The Compound Rotary Engine is projected by NASA to be able to achieve a SFC of < .3 lbs/hp-hr.

Column added by FM using a SFC of .31 lbs / hp-hr

Engines for hand held power tools…

		Displacement	HP	Weight	Volume	Emissions	Critical Parts
Piston Engine		100cc	2.8	28 lbs.	1.5ft^3	Meets emissions standards for California without catalytic converter	32
Rotapower Engine		27cc	2.8	4 lbs	.2 FT^3	Emissions far below California emissions standards without catalytic converter	2

Example Rotapower® Engine – size/weight Comparison

	Freedom Motors Rotapower®	Briggs & Stratton
Horsepower	18.5	16
Weight	18 lbs	90 lbs
Volume	0.75 cu ft	6 cu ft
Displacement	300cc (Equivalent)	530cc

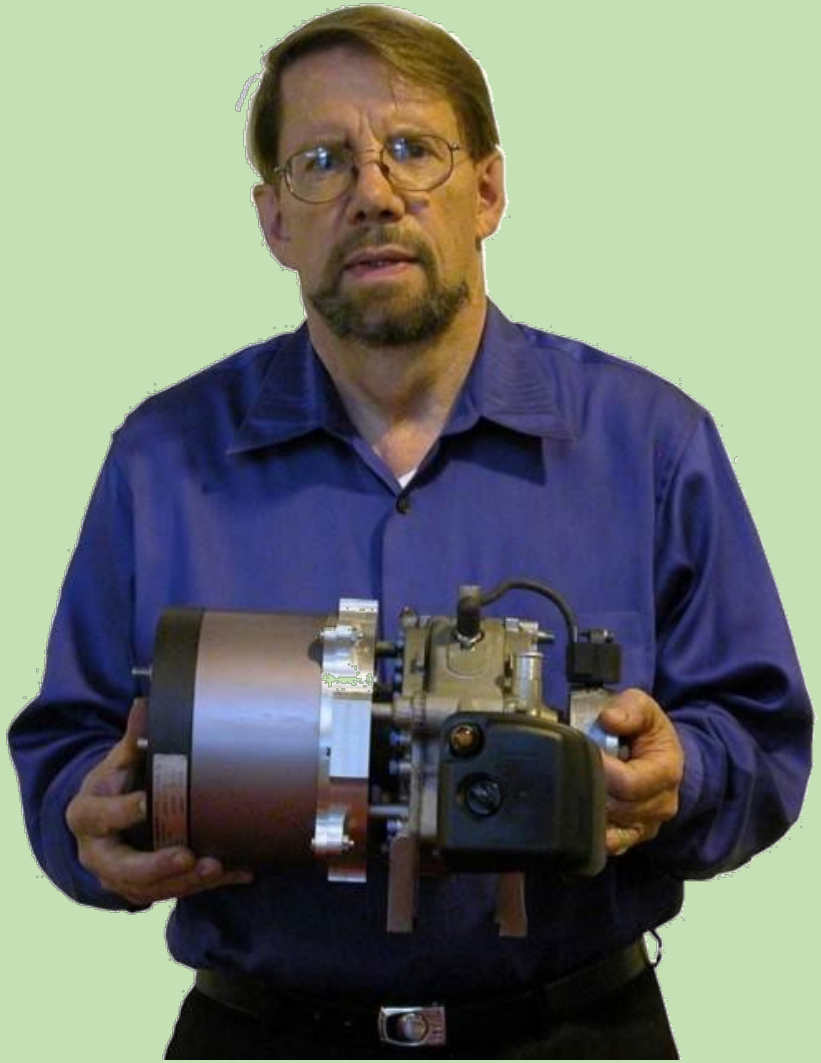
Briggs & Stratton Vanguard

Freedom Motors Rotapower 150

Freedom Motors Rotapac™ Generator

For application in a plug-in hybrid vehicle (PHEV) or a Range Exender

- Enhanced performance
- Based on Rotapower 150cc rotary engine
- 25 KW of power (Alcohol or Gasoline/water)
- < 1 cu ft
- < 40 lbs

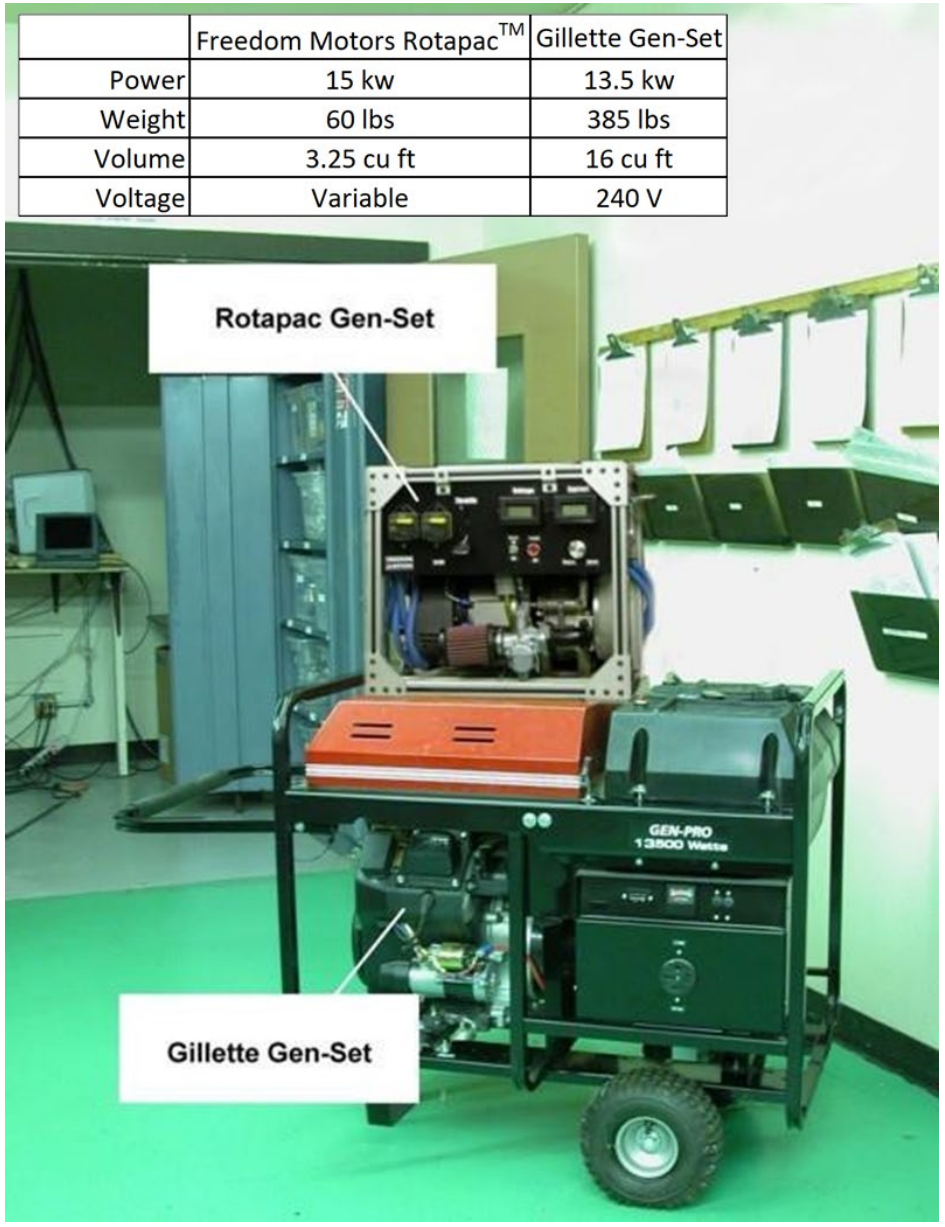


Freedom Motors Rotapac™ Generator

Rotapac™ Generator

In the Range Extender application the cooling system is not required and the size and weight of the Rotapac™ can be reduced by at least 20%.

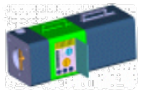
	Freedom Motors Rotapac™	Gillette Gen-Set
Power	15 kw	13.5 kw
Weight	60 lbs	385 lbs
Volume	3.25 cu ft	16 cu ft
Voltage	Variable	240 V



Military Electric Power*

One Lightweight (*Single Soldier Carry*) System with the Functionality of 6 Current Generators

Portable Power System

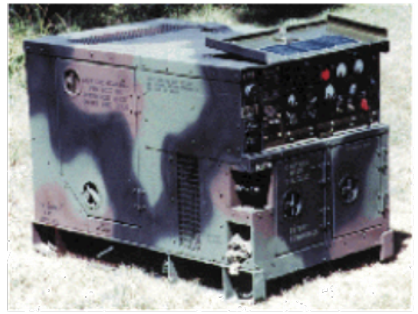


Multiple Power Levels
2 kW to 5 kW

Multiple Frequencies
DC, 56/60 Hz, 400 Hz

Light Weight
30-40 lbs

Equivalent Functionality

2 kW	3 kW	5 kW
6525 fielded systems	22085 fielded systems	18508 fielded systems
		
DC 138 lbs	50/60 Hz 325 lbs	120, 120/240 1 ϕ, 120/208 3 ϕ 50/60 Hz 888 lbs (Goal 665 lbs)
50/60 Hz 158 lbs	400 Hz 325 lbs	120, 120/240 1 ϕ, 120/208 3 ϕ 400 Hz 911 lbs (Goal 665 lbs)

*Pratt & Whitney Rocketdyne and MI/FM Collaboration, Glenn Havskjold, 4 Nov 2005

Engine Costs

Cost of Goods

- 27cc priced out for every component
  if made in India or China = $30/unit (similar to 2-stroke engine)
- 530cc OMC cost in 1973 = $110
  - Production level = 15,000 units
  - $753 per unit
    (using inflation factor of 3.93%/year)
  - $934 per unit with fuel injection and improved bearings
  - 530cc Rotapower engine cost of goods = $1,025* with outsourced and inhouse, if produced in the USA.

*Our business plan uses a cost of goods inefficiencies at 20% higher than that projected from OMC's experience to address uncertainties during production startup. This premium is progressively reduced by production year five. In year five the cost of goods is projected at $571.

Reliability & Durability

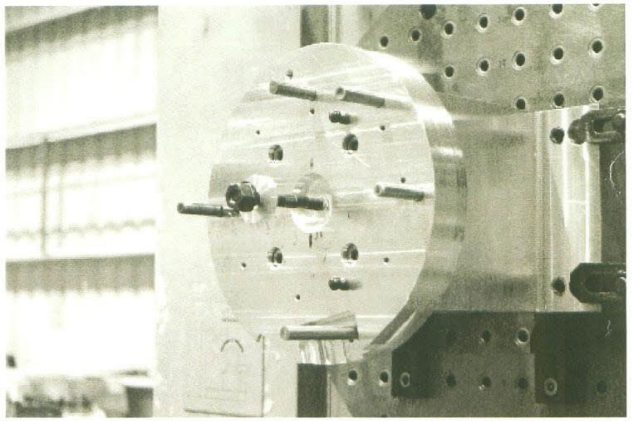
- Ingersoll-Rand – Average lifetime was 34,000 hours
- Mazda rotary – Repeatedly won Daytona 24-hour race
- OMC accumulated 5 million working hours on snowmobile engines (530cc)
- GRI established in report GRI-87/0050 that rotary engine is only IC engine capable of 20,000 hours between overhauls
- Freedom Motors completed most demanding FAA test of 150 hours at maximum power

Manufacturing Startup

- Present casting molds are for low volume production
- OEM and EPA require engines produced with final molds and materials (lost foam, permanent tooling, etc)
  - Better mechanical and thermal properties
  - More accurate dimensions (less machining)
  - Higher production rate
  - Less inspection require
- Have molds and castings produced
- Begin machining, assembly, inspection and testing in US
- Produce 300-to-1,000 engines prior to full-up production

Comprehensive Manufacturing Plan

Manufacturing PLAN



Rotary Beta II Engine
Manufacturing Plan

SM-ALC/TIMM
5225 Bailey Loop Building 243D
McClellan AFB, CA 95652-2510

Moller International
1222 Research Park Drive
Davis, CA 95616

July 1998

EXECUTIVE SUMMARY

NATIONAL CENTER FOR MANUFACTURING SCIENCES, INC.
AND
MANUFACTURING AND SERVICES DIVISION
TECHNOLOGY AND INDUSTRIAL SUPPORT DIVISION

This project follows a proud history of successful DOD and private sector experiments. Programs such as the Automatic Program Tool (APT) software language, development program, participated in by the Air Force and MIT. This program resulted in the first computer language used to program industrial Numerical Control (N/C) milling, drilling and lath machines. The use of APT latter lead to the modern CAD systems used to build the casting tooling for or current project.

The project's goal "to improve the manufacturability of a prototype rotary engine" has been successful and fully satisfied. TIM, the prime contractor, has worked closely with, Moller International, the subcontractor on this project. Moller had developed a prototype rotary engine, and was building test models from solid blocks of aluminum. TIM redesigned the engine producing an all aluminum cast engine. TIM then cast and manufactured components to build three single rotor, one double rotor or one triple rotor engine. The main goal "to improve the manufacturability of the engine" was fully realized. This important benefit will result in a cost-effective engine that now can be mass-produced and compete on the open market. The cast engine design resulted in extra benefits also, a lighter more portable engine with a better power to weight ration.

It is expected that the results of this project will have impacts on both the military and civilian sectors and how they chose to power portable generators, industrial pumps and an array of other devices and vehicles. This project has resulted in the development of a cost effective, light, high power to weight ratio, smooth, quiet, rotary engine. The engine not only has military, industrial and agricultural applications but is also designed for marine use, in jet boats.

This program proves again, that tremendous benefits can result from the combined cooperation of public enterprise and the DOD community.

Information Transfer Samples

- Types of data available for transfer are:
  - Source data sheet
  - Native ProE CAD files of individual parts
  - Fabrication Process Sheet
  - Engine Component Inspection Sheet
  - Trochoid Generation spreadsheet
  - Desired Surface Finish Measurements
  - Vendor specifications sheets for “Off-the-Shelf” components
  - Assembly instructions, drawings and procedures
  - Technician’s engine build sheets
  - Dynometer engine test reports

Structure & Materials

- Six primary components:
  - End housings (2) – high silicon aluminum
  - Rotor housing – high heat transfer aluminum
  - Crankshaft – alloy steel
  - Rotor – nodular iron
  - Stationary gear – alloy steel

Production Equipment Required

- Computer Numerically Controlled (CNC) Machining centers
- Custom built side-seal slotters
- Plasma spray system (for rotor housings)
- Automatic Lathe
- Broach machine (for gears)
- Lapping machine (for end housings)
- Grinder, mill, band saw, press, and other common machine tools
- Heat treatment ovens
- Inspection equipment

Assembly process

- Entire OMC assembly line was 15 meters long
  - Six parts assembled with 19 bolts
    - 4 for stationary gear
    - 15 for housing assembly
  - No special tools required for assembly
  - Simple fixtures speed assembly

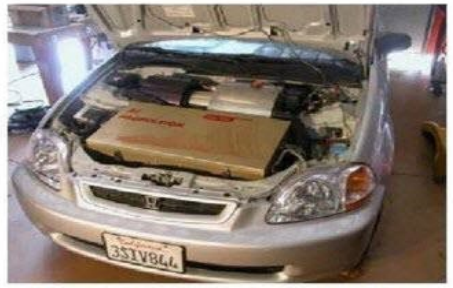
Testing the Assembled Engine

- Leak-down test provides reliable final inspection check
- Dyno test unnecessary if ignition and fuel systems can be tested

OEM Requirements

- Must meet EPA requirements for automotive applications
- Carbureted and fuel injected models (depending on application)
- Specify engine mounting and output shaft configurations
- Company/OEM engineering interface required during startup

Applications Utilizing the Rotapower® Engine



Hybrid fuel-electric vehicle (530cc)

All Terrain Vehicle - ATV (530cc)

Mini Jet Boat (1060cc)

Trimmer (27cc)

Snowmobile (530cc)

Jetski (1590cc)

Portable Gen-Set (150cc)

Aviation - Related Applications

Aerobot®

Skycar®

Scooter
(150cc)