The Rotax Decision

We Put To Rest The Age Old Question

Of Which Powerplant Is Best For Your Kitplane

by Mike Stratman

Reprinted from "Kitplanes" Magazine

***D**uring the onslaught of technical questions at Oshkosh '94, I noticed one of the more frequent inquiries had to do with which engine should I get for my kitplane? 503,582,618 or the Rotax 912. It seems that the comparisons have never been fully addressed for those looking to purchase kitplanes from manufactures offering both powerplants. As with any aircraft the advantages and drawbacks of any particular powerplant has everything to do with the demands the pilot will be placing on the aircraft. But in the case of two cycle versus 912 the comparisons also have a lot to do with the pilot himself. Pilots come in all types, rich, & poor, experienced & novice. Some people like to do their own maintenance and some people don't want anything to do with it. Choosing between the vastly different powerplants is more a question of personal preference than anything else. With this in mind let's explore what makes each type of powerplant unique. Through the use of some Microsoft Excel programs I found some of the comparisons proved to be quite interesting.*

***Weight to Horsepower Comparisons:** Never in the history of propeller driven aviation has a powerplant had the kind of weight to horsepower ratios as the Rotax line of two cycle engines. If you compare engine block only weights the liquid*

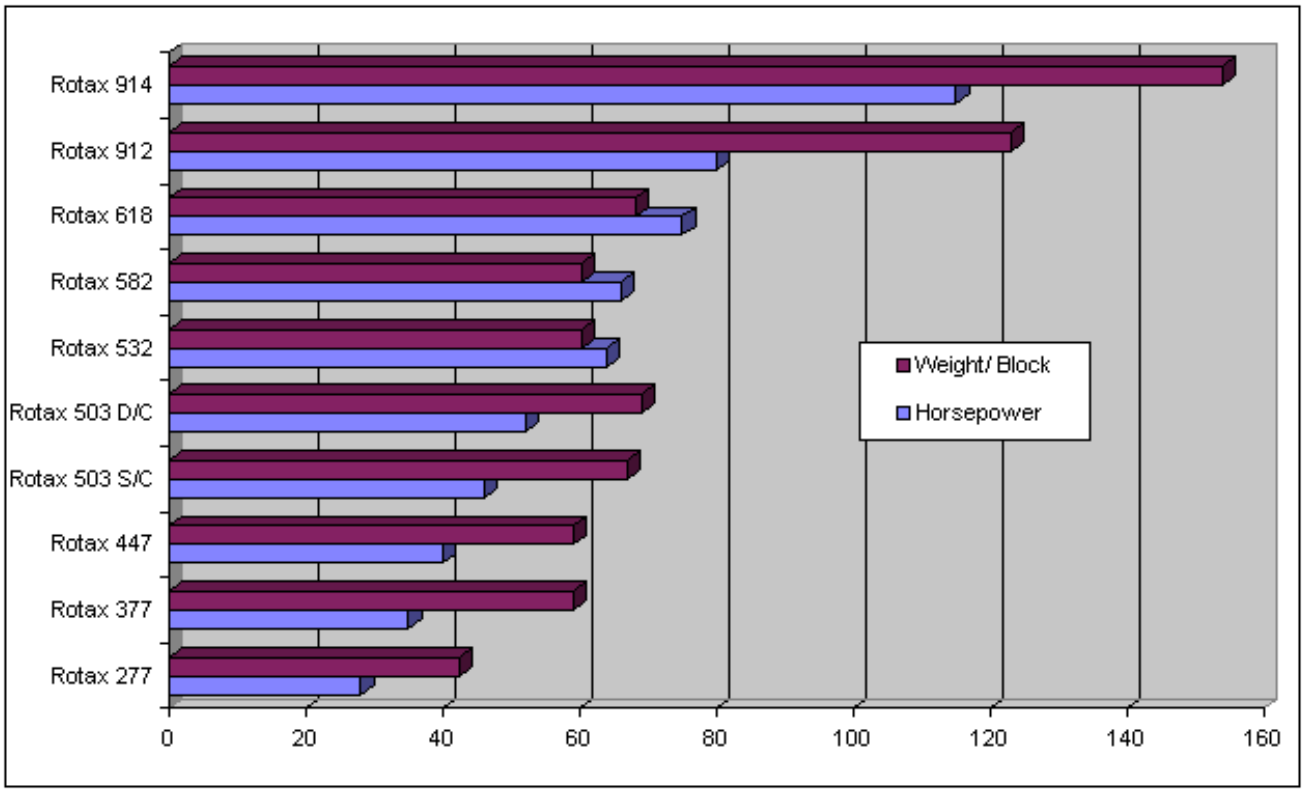

Figure # 1 - *Shown in Purple is the engine block weight versus the corresponding horsepower shown in light blue. Note the excellent ratios on the liquid cooled 532,582,618 motors. Better than 1:1.*

cooled motors exceed a 1 horsepower per pound ratio. See Figure # 1. For example a Rotax 618 engine block weights in at 68.3 and produces 75 horsepower or only 0.91 lbs. per horsepower. Of course the running weight of the powerplant is closer to 112 pounds with all the options such as electric start, intake silencer, etc. See Figure #2 Still not bad for an engine that will put the feet of two passengers over their heads during climbout on most installations. Interestingly enough the air cooled Rotax 503 D/C carries approximately the same installation weight as the Rotax 582-618 due to the lighter block weights of the liquid cooled engine. Of course the need for a radiator system consumes these savings.

In the case of the Rotax 912 the weight of 123 lbs. include the standard electric start and built-in gear box. Radiator systems are available from Rotax but are all most always waived by the manufactures for a custom unit that fits the design more closely. For this reason the chart comparisons are for Rotax 912-914 engines without radiators included. The Rotax 914 does include a complete exhaust system as part of the Turbocharger system at the listed 154 lbs., while the Rotax 912 is listed with no exhaust system (as supplied by Rotax). This is left to the builder to fabricate.

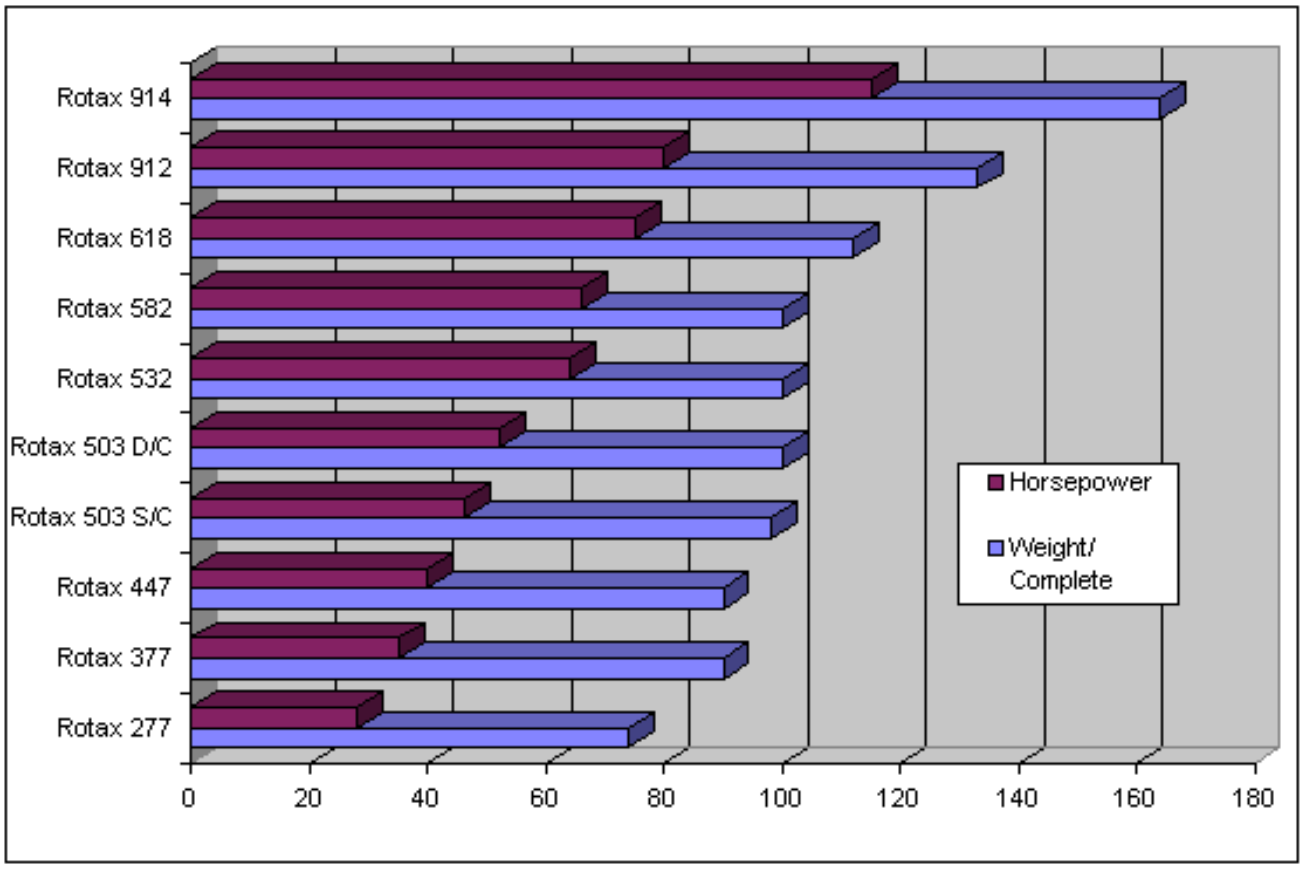

Figure # 2 - *Adding in the gearbox other options to equal the complete weight we can better see the finished performance package.*

Exhaust ports are equipped with weldable flanges already in place. Other parts including a main canister, flex ball joints, and cutable corner pieces are available from Rotax parts in either regular or stainless steel to assist in custom designs. Unfortunately these items tend to be a little pricey even by Rotax standards.

All Rotax two cycle engines come complete with a tuned exhaust system that is responsible for a large part of the engine's performance characteristics. Realizing this Rotax offers at least four different configurations to help the designer/builder fit a wide variety of installation situations. The 618 uses considerably larger diameter exhaust tubing and an oval shaped canister. I am told the oval shaped can is used to avoid what would be an incredibly large canister if left round as on other engines.

Remember that the two cycle powerplants can be equipped with a number of different options. To get a full understanding of the accessories available and the weight penalty each carries consult the following listing:

Accessories..... Weight/lbs.

Standard Exhaust System..... 10.8 lbs.
Model "B" Gear Box..... 9.9 lbs.
Model "C" Gearbox..... 17.6 lbs.
Model "E" Gearbox w/ starter..... 24.7 lbs.
Mag End Electric Starter..... 7.7 lbs.
Twin Radiator System..... 4.9 lbs.
Dual Intake Silencer..... 2.4 lbs.
Single Intake Silencer..... 1.4 lbs.
2.4 liter Oil Reservoir w/ sensor..... 1.3 lbs.
Dual Carbs w/ sockets..... 4.0 lbs.
Single Carb w/ socket..... 2.0 lbs.
Dual Air Filter 1.1 lbs.
Single Air Filter.... 0.6 lbs.
HAC Carb Retrofit 0.4 lbs.
Dual Fuel Pump... 0.3 lbs.
Single Fuel Pump 0.2 lbs.

Note the Model "E" gearbox includes the electric starter. This setup weights less, requires less length than a "C:" box and mag end starter. The price is also several hundred dollars less which has a lot to do with its immediate popularity. Of course, the in many cases the larger two cycle will out perform the heavier Rotax 912. In the case of the 75 hp 618 the scale shows it will pull within a few pounds of the 80 hp 912 and weights considerably less.

Fuel Consumption: *Examining the chart in Figure # 3 we see fuel consumption runs from just 1.7 gallons per hour on the 28 hp to a full 4 gallons per hour on the Rotax 912. Figures for fuel cost per hour are also shown with all engines using 92 octane unleaded auto gas, which is the factory recommendation for each motor. Cost per hour is figured at a national average of $1.70 per gallon for fuel. For two cycle engines the cost is about $20 per gallon for two cycle lubricant used at a 50 to 1 ratio or about 25 cents per gallon of fuel. This is reflected in the chart as $1.95 per gallon fuel for all two cycle engines.*

One thing that may not be obvious from the figures is that an overpowered aircraft will require much less time at full throttle setting to get around than a smaller engine package that has to be fire walled a good deal of the time and thus may even burn more fuel than the larger powerplant. The reliability factor also goes up dramatically with the oversized powerplant. A subject we will explore in depth a little later. In the same vane, dual carb engines will actually burn only

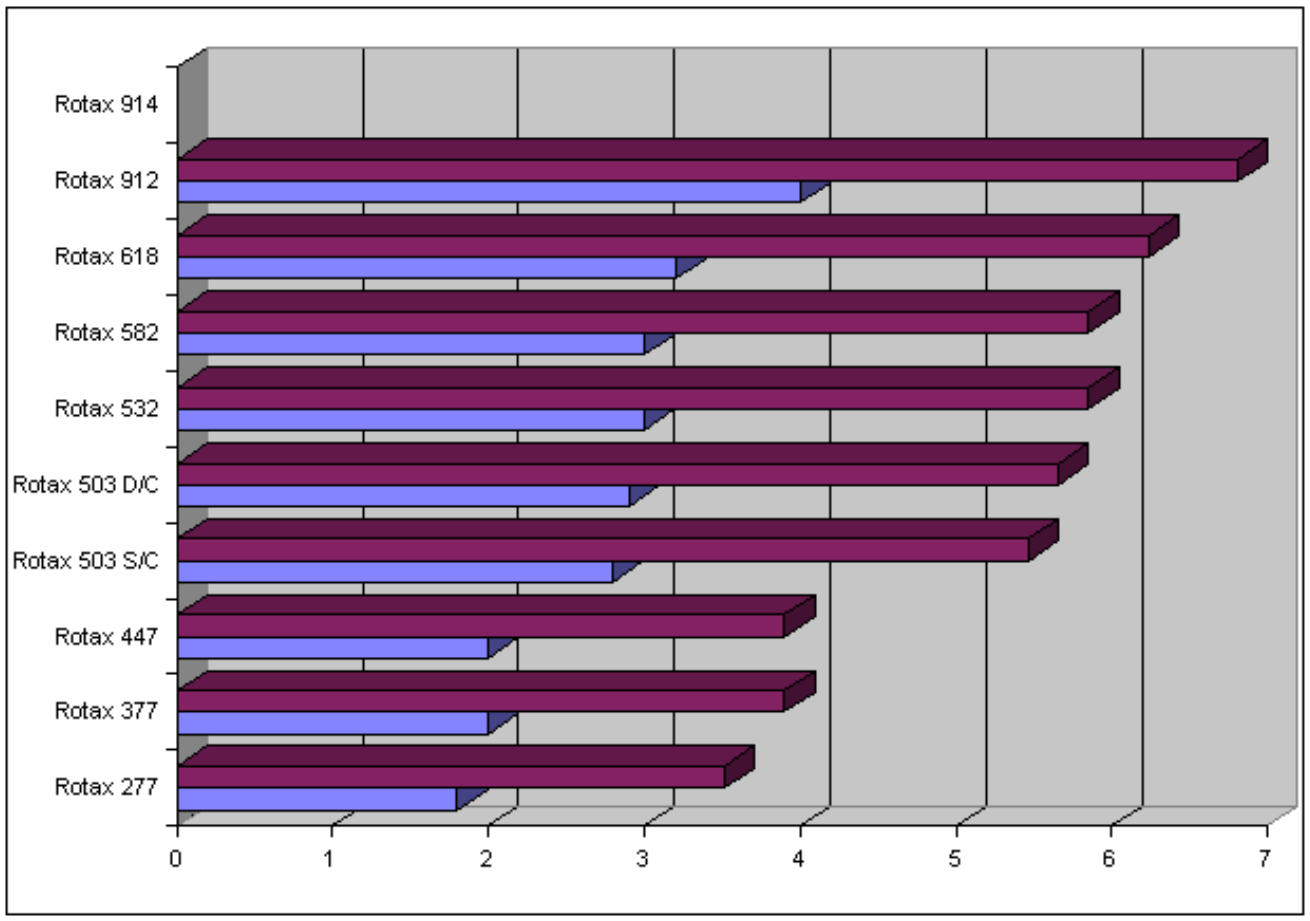

Figure # 3 - *Shown in Purple is the cost per hour in fuel to run each powerplant at 75% power or 5500 rpm. The Light Blue is the fuel consumption in gallons per hour.*

slightly more fuel than the same engine within a single carb installed. In-flight adjustable props will also cut down on fuel consumption as well keeping in mind the cruise speed and sleekness of the aircraft has a lot to do with this.

Retail Price vs. Horsepower: *If you are on a budget, then amount of "bang for your buck" is always something to look at. Again the two cycle engines are the clear winner in this department. Figure #4 shows graphic comparison of all powerplants where 1 horsepower is equal to $100. This is figured without gearbox or options, just with carb & exhaust only. At current retail prices nearly all the two cycles show a 2 to 1 ratio or about $50 per horsepower. Of course by the time you add an electric starter, gearbox, radiator system, etc. the $50 figure comes closer to $60-$65 range. Still very economical by aircraft standards.*

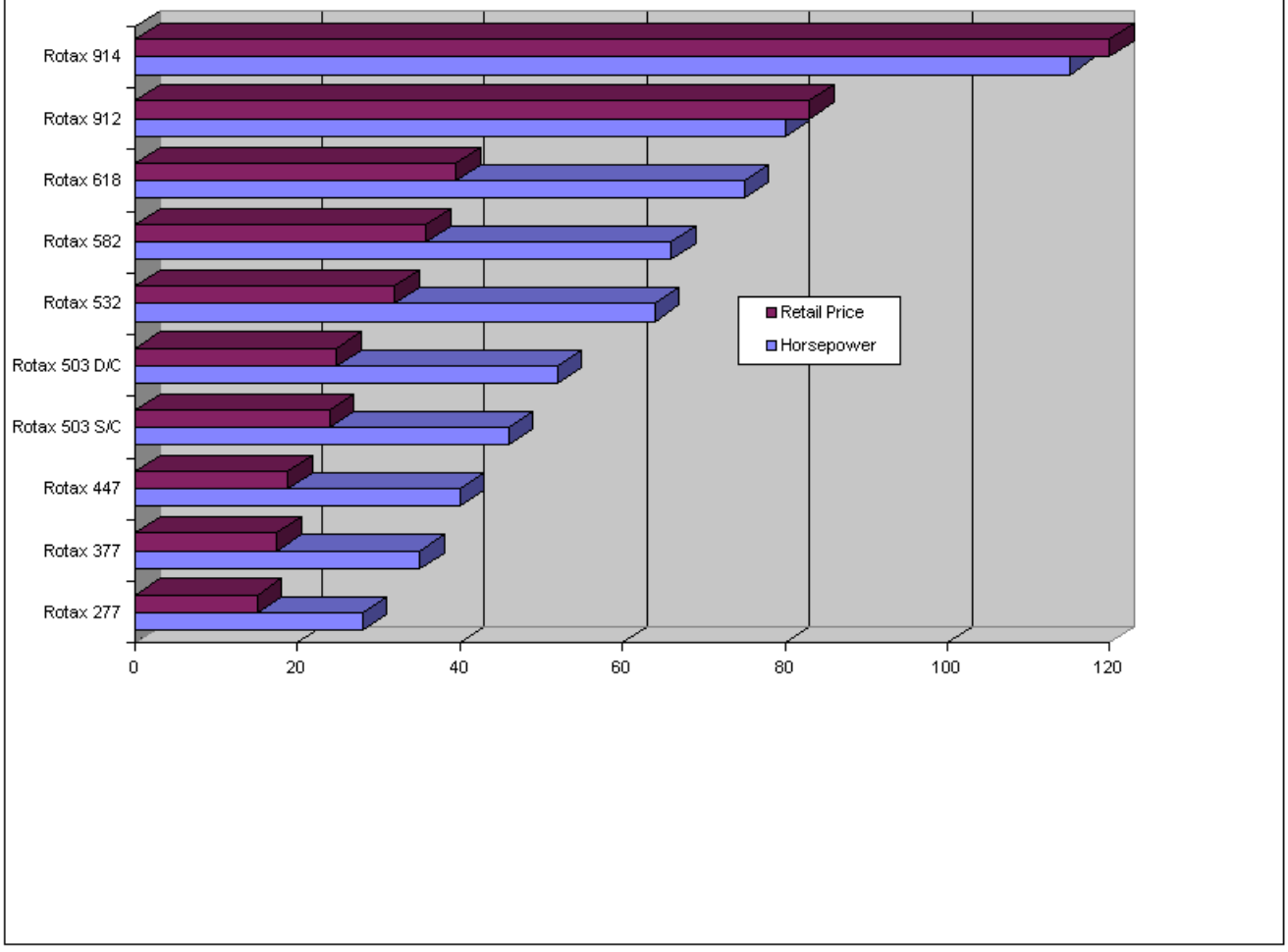

Figure # 4 - *"Bang for the Buck" is shown in this chart that illustrates the comparison if one horsepower = $100 of retail cost. Prices are for engine and gear box and may not include all options desired. Prices are current retail prices and are subject to change without notice.*

The Rotax 912 & 914 Turbo both come in just over $100 per horsepower. This figure includes both electric start and gear box and in the case of the 914 Turbo also includes a finished exhaust system with integrated turbocharger as well as a complete firewall motor mount. This motor mount is a chromoly welded steel four point mount that allows the entire package to be easily mounted directly to the firewall. Rubber mounts at the firewall provide for the vibration mounting. See Figure # 4. This item would cost you more than $1300 if purchased through Rotax parts. The addition of these two items to the 914 Turbo package gives the builder two less items to fabricate making the extra $4G a lot easier to swallow. More food for thought when comparing the actual costs of the two four cycle choices.

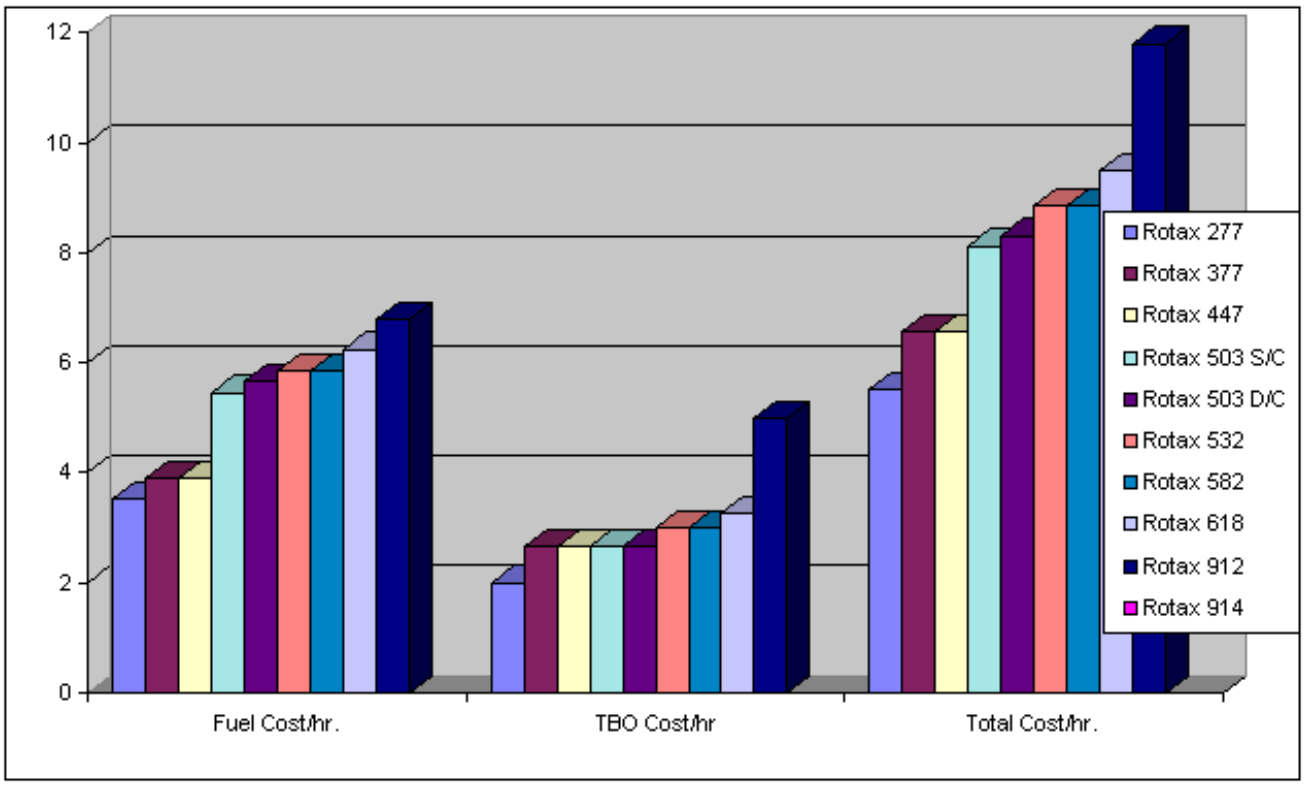

Figure # 5 - *Comparing the costs of operating gives us the total picture of what it costs to run each type of powerplant. Chart shows the Fuel Costs per Hour, Rebuild costs, and Total Operating Costs are shown in the final graph.*

Operating Costs: *Added to the fuel costs per hour are the repair/maintenance costs to equal the operating costs. See Figure #5 for graphic comparisons. Here is where the owners mechanical experience is the key element. With proper training and knowledge of two cycle theory there is little that most owners can't do with a reasonably small investment in tools. Rotax two cycle engines are not that complicated that the average owner can't do most of their own work. That is not to say that the everything is real obvious, make no mistake about it, you can get in way over your head real quick without the proper training. I have to admit that I thought I was a pretty fair mechanic up until my first experienced with a two cycle engine. Like most people, I simply couldn't believe that anything could be that touchy to certain things like ignition timing and fuel mixture. Believe it!, two cycle engines demand certain variables that must be very closely controlled. Here is where the proper training is essential. There is a lot of technical information available from Rotax as well as in the article series "The Proper Care & Feeding of the Rotax Motor" reprinted in the rear of the CPS Catalog. Understanding the theory outlined in here takes most of the mystery out of operating two cycle engines. Having on hand specialty tools worth about $200, they average owner can do most common maintenance for the price of the parts.*

Currently the TBO for all eight Rotax two cycle engines is listed at 300 hours. I feel this figure is real conservative. On one hand if the engine is in a helicopter application or something that runs a high percentage of full throttle operation, you might not reach 300 hours before TBO. On the other hand if you are over powered to start or run with the passenger empty a lot the same 300 hours are going to show a lot less wear. For example, a Rotax 582 complete overhaul including new factory crank and pistons costs around $700 in parts. Labor should run around $300 to $400 considering 8 hours at $40 to $50 per hour at a Rotax Service Center. Total overhaul bill: around $1000 or $3.33 per hour operating expense. If you do your own overhaul work the operating expense will be more like $2.35 per hour. See Figure # 5 for a comparison of operating costs. All figures shown include professional labor expenses.

The Rotax 912 & 914 Turbo is a different story. Anyone that tears into the guts of these motors

that is does hold an FAA A&P license is either real dumb or real brave! While not a certified motor, these motors are designed around the same kind of precision tolerances and special requirements as any Continental or Lycomming engine. I would not recommend tackling major repairs on these motors. See an experienced A & P for this kind of work. While the TBO on the 912 is currently listed at 1200 hours, you need to count on professional assistance when this time is reached. Cost estimates to remanufacture the 912 to new factory specs is approximately $4000 in parts alone. This includes new factory everything, crank, pistons, cylinders, heads, cam, lifters, oil pump, the works. Current 912's that have reached TBO have had many parts which were still within factory wear limits and even mic to new spec. Again, if you are not running certified your list of replacement parts is not a requirement. Rebuilding to new factory spec or to factory wear tolerances will greatly effect the end price. Labor will probably run right around $2000 in either case for a total bill of between $4500 to $6000. At the present time only a hand full of 912 have reached TBO. Hopefully as the number of overhauls increases the prices will begin to decrease with the demand. Figuring a "worst case" bill of $6G at TBO this calculates out to a $5 per hour operating cost. To rebuild to factory wear limits (approximately $4500) figure about $3.75 per hour. Figures for the 914 Turbo are not available as this time because it is not currently a production engine.

Reliability: *Here is while their is no substitute for spending the extra money. The Rotax 912 engine is fully certifiable. In certain parts of the world the 912 is sold under JAR 22 Certificate. The motor is essentially the same as the units sold here in the US as "experimental". The JAR 22 engines are dyno tested and fully documented on computerized equipment for a full three hours before leaving the factory. Every crank is also dimensional documented before assembly. An exhaustive and expensive procedure that adds over $1000 to the purchase price. The US or uncertified motor is dynoed for one hour at the factory. This of course eliminates any obvious production line problems and assures the user a "running" powerplant on delivery. As mentioned before, the kind of tolerances and precision engineering you expect from a Continental or Lycomming certified motor can be in the Rotax 912 & 914 Turbo. For a guy that does a lot of back country flying where an engine out has a big chance of becoming a real disaster, I would recommend the Rotax 912 & 914 engines.*

Reliability of the Rotax two cycle engines have come light years from the early 80's when an occasional engine out was just part of the game. I remember a time where guys where running MAC-101 chainsaw motors at 12,000 rpm! If everything was just right the plane would actually achieve takeoff and climbout at maybe 50' to 100' per minute. During such times the two cycle engine obviously built a reputation for less than 100% reliability.

The advent of dual ignition and liquid cooled motors have made great strides in the dependable factor. Over powered powerplants have also helped the reliability factor dramatically. The trend by designers is to use motors that provide climb rates in excess of 1200' per minute. With this kind of reserve power full throttle operation is the exception rather than the rule. Full power settings is where most of the heat and wear are generated in a two cycle and the closer the components are to the their limitations. This in itself has probably did more for reliability than any other factor.

Today's Rotax engines are a product of Austrian engineering that stress attention to detail and experience in dealing with design application situations. The people at Rotax realize that just producing a motor that <u>can</u> be used in for aircraft is not enough. They produce engines designed specifically <u>for</u> aircraft, which to a large degree is the reason for their dominate market share they estimate at over 85%.

	A	B	C	D	E	F	G	H	I	J	K	L
Engine Type	Fuel Consumption	Weight/ Complete	Max. RPM	Horsepower	Specific Fuel Consumption lbs/ hp/hour	TBO Rebuild Cost	Weight/ Block	Displacement	Retail Price	Fuel Cost/ hr.	TBO Cost/ hr	Total Cost/ hr.
Rotax 277	1.8	74	6400	28	0.7	600	42.5	268	14.99	3.51	2	5.51
Rotax 377	2	90	6250	35	0.85	800	59	368	17.5	3.9	2.66	6.56
Rotax 447	2	90	6250	40	0.9	800	59	436	18.84	3.9	2.66	6.56
Rotax 503 S/C	2.8	98	6250	46	0.5	800	67	496	23.92	5.46	2.66	8.12
Rotax 503 D/C	2.9	100	6600	52	0.55	800	69	496	24.78	5.65	2.66	8.31
Rotax 532	3	100	6600	64	0.71	900	60.4	537	32	5.85	3	8.85
Rotax 582	3	100	6600	66	0.062	900	60.4	580	35.82	5.85	3	8.85
Rotax 618	3.2	112	6600	75	0.65	975	68.3	613	39.52	6.24	3.25	9.49
Rotax 912	4	133	6000	80	0.45	6000	123	1211	82.99	6.8	5	11.8
Rotax 914		164	5800	115	0.41		154	1211	119.95			

Figure # 6 - *Shown in the table here is the information used to construct the Excel Charts shown in Figures 1-5. Most of this information is compiled directly from the Rotax Factory Specs.*

Legend for Figure #6

A. Fuel Consumption In Gallons Per Hour
B. Total Weight Complete With Gearbox, Radiator, Carb & Exhaust
C. Maximum Rpm
D. Peak Horsepower
E. Specific Fuel Consumption (Pounds Per Horsepower Per Hour)
F. Rebuild Costs At Overhaul
G. Weight For Engine Block Only
H. Displacement In Cubic Centimeters - Cc
I. Current Retail Price (Subject To Change Without Notice)
J. Fuel Costs Per Hour.....92 Octane Unleaded Pump Gas
(@$1.95 Per Hour W/Oil - Two Cycle)
(@$1.70 Per Hour - Four Cycle)
K. Total Costs For Overhaul At TBO
L. Total Operating Costs Per Hour Including Maintenance

Sourcing the Information: *If for any reason you wonder about the source of this information, Figure # 6 shows the Excel Worksheet that the charts were created from. If you disagree with the results, here is where data was created. Most of the figures are direct from the Rotax factory literature. Some of the information are based on average shop costs at CPS. All information has been reviewed and approved by the Rotax factory, which is my policy before publishing most any tech article.*

Conclusions: *Several things should control your choice of powerplants when purchasing a kitplane. The most important consideration is the pilot and what kind of flying he likes to do. Cross country trips over hostile terrain are best suited for the Rotax 912. Local and high perform flying are better suited for the larger liquid cooled two cycle motors.*

Operating costs are considerably less for the two cycle engines than the 912 - 914. As mentioned earlier, the owners ability to perform major repairs can reduce expenses even further while this is less likely with the more sophisticated 912 - 914. In either case, these powerplants are sold under the experimental or non-certified category allowing you to do your own repair and maintenance.

In the final analysis, the pilot and what kind of flying he likes to do has everything to do with choosing a powerplant. For the pilot who flies in hostile territory or flies cross country might do best with the Rotax 912. For the pilot with a big budget who really wants to "wring it out" with a lot of high performance or high altitude flight the soon to be released 115 hp Rotax 914 Turbo is an excellent choice. For the pilot who likes an aircraft that has loads of reserve power and doesn't cost a ton of money to operate the Rotax line of two cycle engines are real hard to beat.