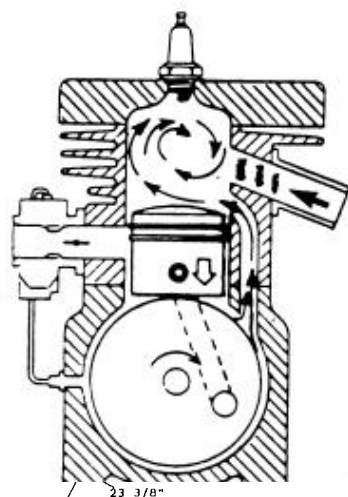


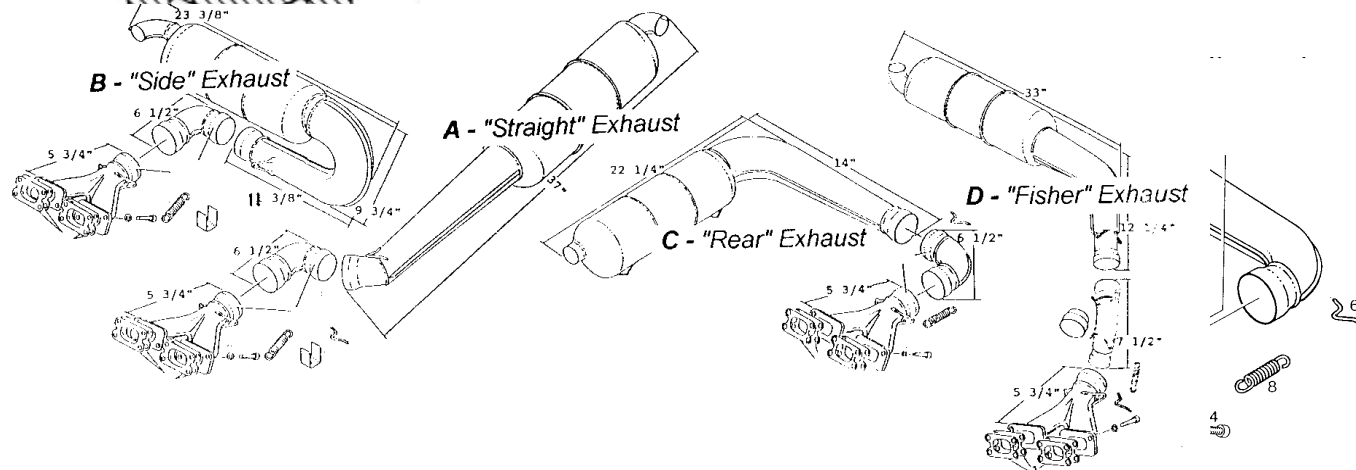
Part #48 Rotax Exhaust Alternatives 1

by Mike Stratman

The other day this guy calls me, says his Rotax 503 won't make more than 4500 rpm. The more I listened to this guy, the more convinced I was that his problem was not an engine problem. Come to find out, this bonehead used an exhaust pipe off a Honda dirt bike and custom welded his own exhaust system! Obviously he failed to understand that a tuned exhaust system on any two stroke engine is an important component in determining engine performance. While a four cycle engine has an exhaust valve and a piston stroke to control the exit of gases, a two stroke has neither. This month we'll take an in depth look at why a Rotax two stroke needs a tuned exhaust system, the different styles available and what they all have in common, how to select, mount, modify, maintain, and repair your exhaust system. For some reason a lot of the exhaust systems I see on planes are nothing short of hideous rust buckets. Guy's!, this has got to stop!! There are some new inexpensive treatments that can make what is usually the nastiest rustiest part of the plane look great. We'll detail all the popular options and what it takes to do the job right.



What The Exhaust Is Designed To Do: This is basic two stroke theory and one of those things like fuel mixture and ignition timing, that must be perfect. As already mentioned, four cycle engines have a dedicated exhaust stroke and exhaust valve that physically forces the expended gases out of the combustion chamber. By the time the exhaust valve closes the process is complete, making the actual design of the exhaust system of little importance to the engine's performance. Two stroke engines depend on a "timed echo" sent back from the exhaust canister to close an invisible exhaust valve long enough to maintain the incoming fuel in the chamber. Without this effect you can well image the top end performance and fuel consumption would be nothing short of pathetic. See illustration. Thus the length and taper of the exit cone is crucial. These designs are determined by extensive dyno testing by the Rotax factory under an actual prop load using variable length and shaped cones. The performance possibilities are endless and filled with compromises. This is why experimenting with non-aircraft engines and exhaust systems not designed especially for a prop load is a very poor gamble.



Exhaust System Designs: Rotax offers no less than four different configurations of exhaust systems for every model engine. On close inspection you will find regardless of the shape every unit measures measure the same distance from piston to canister. In the past Rotax offered two piece systems that consisted of only just manifold and muffler. See illustration.

These designs were plagued by premature cracking and weld splitting. After trying many different alloys, material thickness, etc. the factory concluded that a three piece with two ball joints was the only way to cure the problem. The second flex joint relieve enough of the vibration to make stress cracking much less common. While they are more complex and more of a hassle to mount, the extra flex joint opens up more options for positioning the system to fit a particular application.

Modifying a Stock Exhaust: Often times it is necessary to modify a stock exhaust to clear frame parts. This can be done by most any muffler shop keeping in mind an obvious rule to never change the distance from piston to canister. Premeasure this distance and plan your modification to preserve this. See illustration for a sample modification around an obstruction.

RPM Flat Spots: It is not uncommon for any two cycle engine to refuse to hold a particular rpm. Even the slightest change in throttle setting and the engine will increase from 500 to 1000 rpm. This situation can be extremely annoying especially if it occurs at cruise speeds. Holding a steady altitude requires constant throttle changes. You're either climbing or descending. This flat spot is a function of the exhaust design, the engine refusing to accept the exhaust timing at this point. Mid range jetting may move the flat spot slightly, but eliminating this situation can prove costly. Your options are a gear ratio change or try a different exhaust configuration. You may still have a flat spot but it will be at a different rpm and not effect your cruise rpm.

Dealing with the “Wha-Whas”: A situation can occur where a prop blade passing near the exhaust outlet sets up a slow pulsating vibration (hence the name “Wha-Wha’s”) that can be so severe as to shake the entire airframe. This is due to the pop of the exhaust outlet phasing with the passing prop blade. This usually happens with two blade props run at 2 to 1 reduction or a three blade prop on a 3 to 1 gear box. The fix is usually just change the gear box ratio or the number of blades. Most manufacturers and knowledgeable Homebuilders will avoid this combination.

Proper Exhaust Mounting Techniques: While Rotax offers a wide variety of exhaust configurations, they supply nothing for the actual mounting. This is left to the aircraft manufacture or Homebuilder. Be aware that when purchasing direct from a parts supplier, you will not be getting the brackets nor the hooks pre-welded as this is only done by the aircraft's manufacturer or left for the Homebuilder after the final positioning is confirmed. Don't just bracket the main canister to the airframe without rubber cushioning. Direct or "hard mounting" will transfer engine vibration to the airframe causing stress fractures and cracking. This must be avoided with a heat proof vibration mount. See illustration for two examples of no weld mounting systems.

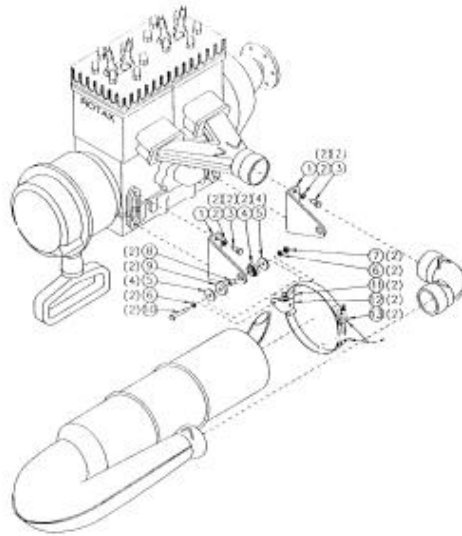
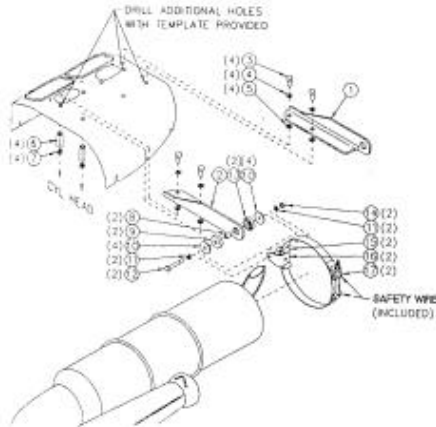
This system uses the head bolts to mount a pair of brackets, The male and female rubbers give the main canister a firm flexible mount.

This bolt-on system uses the side crankcase bosses not used on most aircraft installations to position this "side" exhaust system.

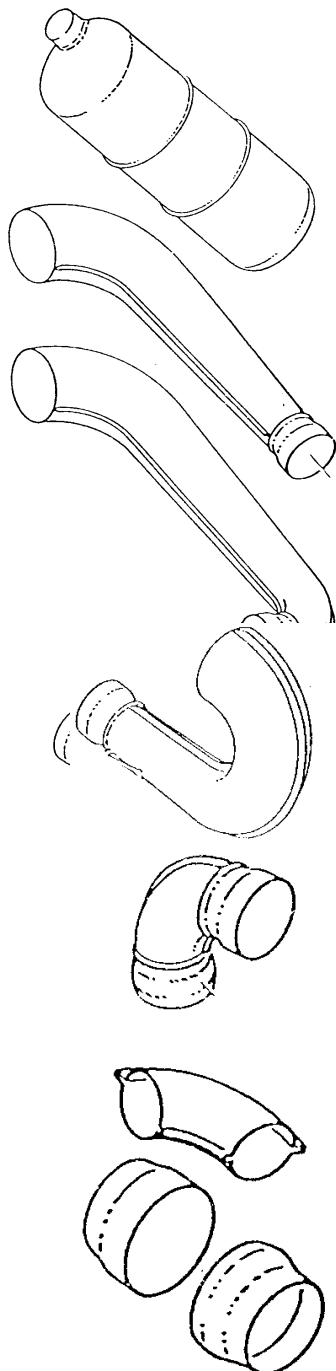
It is important to note that poorly mounted exhaust systems are a major source of prop strikes. It is not uncommon to hear that a

major exhaust component has been launched by a propeller. This is an extremely dangerous situation that can even cause the engine to be torn from it's mounting! Nothing to fool around with! Exhaust springs that are not safety wired are also a favor food for props.

Replacement Parts: in the past few years Rotax has really improved their selection of replacement parts. Realizing that these components are subject to stress, replacement of cones and ball joints makes more sense than trying to weld repair broken parts.



The following is a listing of replacement parts available from Rotax:



#973-175 Muffler is the one piece common on all Rotax 277-377-447-503-532-582 exhaust systems. Includes ready to weld flange on one end. No outlet in place. Measures 15" long x 5 5/8" round. Weight 5 lbs.

#973-546 Single 90 degree Cone w/o hooks slips onto and welds to #973-175 Muffler. Original part in #973-194 Muffler Assembly. Used on three piece muffler systems only. Hooks sold separately.

#973-540 Double 90 Cone w/ hooks slips onto and welds to #973-175 Muffler. Original part in #973-275 Muffler Assembly. Used on two piece muffler systems only. Hooks sold separately.

#973-544 180 degree Muffler Cone slips onto and welds to #973-175 Muffler. Original Part on #973-197 Muffler Assembly. Measures 10" long. Used on three piece muffler systems only. Hooks sold separately.

#973-542 180 degree Muffler Cone slips onto and welds to #973-175 Muffler. Original part on #973-198 Muffler Assembly. Measures 11 1/2" long. Used on two piece muffler systems only. Hooks sold separately.

#973-180 90 degree elbow w/o hooks. Used on all three piece muffler systems. Hooks sold separately.

#973-184 90 degree elbow w/ hooks installed. Used on all three piece muffler systems.

#879-920 90 degree exhaust outlet. Used on systems not fitted with After Muffler Kits.

Replacement Exhaust Joint Cones

Weld on replacement for Rotax factory exhaust system. Salvage an expensive exhaust component by replacing this inexpensive part. Not for use on Rotax 277 exhaust systems. Available in male and female configurations.

Male End...Part #878-660

Female End...Part #878-666

Exhaust Springs and Hooks: Most replacement parts do not come with the hooks welded in place for good reason. The hooks must be placed directly across from each other in the final installation. It is best to mark the spring position with chalk making sure a slight pre-stretch of (about 1/4" - 1/2") the exhaust spring. Rotax make two lengths (2-5/8" or 2-1/4") in cases you are off a little in one direction or another. If properly marked and all parts supplied, most any muffler shop can weld the hooks in place in a 10 to 20 minutes for \$20 or less. **Ball joints should always be coated with anti-seize to prevent freezing and galling of the metals.** This is one of most common omissions that causes problems down the road. Once everything is in place, secure all major parts including springs with safety wire. A bead of high heat silicone down the spine of exhaust springs will often times prevent the very ends of broken springs from becoming prop food.

Welding Techniques: If you are properly equipped you may want to do your own welding. The best choice is TIG welding (Tungsten Inert Gas), the gas helps eliminate impurities during the process for better results. TIG makes a clean, hard, low distortion weld that will be the stronger than any other method. Another good choice is a wire feed MIG (Metal Inert Gas) welding using shielded arc wire. Avoid flux core wire due to excessive splatter. You can also oxygen-acetylene weld with acceptable results. Special care must be taken to preheat and post heat the entire area to a cherry red. This will help relieve stress and minimize distortion. Do not use a regular arc welder even with a thin rod. This will likely burn through the material and/or harden the work area to the point where fracturing is a real possibility. Remember, most factory exhaust pipes are .040" wall thickness.

Exhaust System Maintenance: Take a walk down any flight line and you will probably find the exhaust system to be the most unsightly part of any aircraft installation. Due to large and constant changes in heat the metal of the exhaust system is difficult to keep from rusting. Most people depend on the factory black paint that all new system come with. This paint is just

a shipping rust inhibitor. I doubt seriously if it is even high heat paint. They are counting on the fact that hooks and brackets need to be welded before installation, so a finish coat would be disturbed anyway.

High heat paint is better than nothing but will burn off eventually leaving the bare metal to quickly rust especially in a humid or salt water environment. There are several options that can be done to a new exhaust system that can not only inhibit rust but actually make the exhaust system one of the more sanitary parts of the aircraft. Notice how I said new exhaust system. Some chemical treatments require the parts to be dipped in solution. If your exhaust is used and full of soot and oil, chances are you will be turned away by the vendor, so think carefully about your options before installing new equipment.

When preparing surfaces for any of the permanent coatings, try to use mild blasting techniques. Heavy blasting with sand can harden surfaces and promote cracking. Use glass beads or similar media for best results.

Black Satin: One of the simpler coatings that you can apply with a minimum of specialty tools, Black Satin is a ceramic reinforced coating. When properly applied it becomes one the most effective thermal barrier coatings available, increasing performance, while extending component life. Black Satin has been tested to over 2000 degrees Fahrenheit without lifting, cracking or flaking. Unlike header wraps, Black Satin does not hold potentially damaging heat around the part. Rather, the surface temperatures are actually reduced because an increased ability to dissipate heat, extending the life of the part. In addition, as Black Satin cures a very effective corrosion inhibiting film is formed that protects the part against oxidation and imparts excellent chemical resistance that further extends part life and enhances appearance.

To Apply: Bead blast part and wipe down with a clean cloth using acetone, lacquer thinner or similar materials. Handle by gripping areas that will not be coated or with clean cotton gloves, hooks etc., Simply spray Black Satin on using an airbrush, detail gun or other spray equipment that will allow the operator to control pressure and film thickness. Aerosol spray units are not recommended as they do not allow proper control. Do not brush the coating on. Allow to dry and then install. A coated part may be stored for extended periods without curing if protected against moisture or from coming in contact with any liquid chemical. Since Black Satin is cured through exhaust heat, no oven curing is required. Available in 4 oz. bottle, more than enough for a complete system, for about \$40. Refer to CPS Part #C515.

Cermakrome: One of the more popular kinds of coating on the market. This type of coating is a metallic ceramic and can be done by a novice with reasonably good results. Cermakrome is extremely popular on exhaust systems, the high luster finish provides a very attractive, durable surface. The high temperature characteristics of ceramics have been combined with metallic frits to create a coating that can withstand metal temperatures in excess of 1300 degrees Fahrenheit and provides 5000 hr. salt spray protection.

A unique coating that is based on a water/solvent system, while it requires careful attention to application procedures, Cermakrome is easily applied at home or shop. Cermakrome may be applied to a variety of surfaces and metals, such as: exhaust system components, brackets, valve covers, wheels, hinges, grilles, suspension parts or any metal part that can withstand the 500 degrees Fahrenheit cure temperatures. Must be oven cured. Cermakrome polishes to a high luster, stainless/chrome appearance that will not rust, especially effective as a hard protective coating for aluminum parts. Because water is the solvent, the baking process does not produce hazardous, smelly fumes, like many other coating products. All tools clean up with water.

To Apply: Bead blast part, degrease with acetone, lacquer thinner or similar material. Absolutely all moisture must be removed because Cermakrome is water soluble. Apply the coating using an airbrush or detail gun. Coating should go on in a very thin layer to avoid sags and runs. Dry coating with low temperature until coating changes to a dull gray/white appearance, then bake at 500F for one hour. The part should come out looking with much like unpolished stainless steel. Buff with steel wool (avoid Scotch Bright, it is not hard enough) to desired appearance. For brightest appearance polish after buffing.

Do to the need to bake the coating onto the parts, any part that will not fit in an open kitchen oven will not be practical to coat at home. Check first to see if your oven is big enough to fit your parts. Can be applied to virtually any metal part that can withstand the 500 degree Fahrenheit baking temperature. A variety of surface appearances are possible depending on how the cured coating is polished. Available in 6 oz. bottle, more than enough for a complete system, for about \$40. Refer to CPS Part #C513.

Full Chrome Plating: Once the only way to go to get that show quality look, chrome plating is getting more expensive all the time. That smooth mirror finish is the result of much surface preparation and finished buffing. Here are some things to consider about chrome plating:

1. **Exhaust parts must be new.** No soot or internal oil.
2. All hooks and brackets must be installed and prefitted to the aircraft.
3. Be confident your mounting system will be adequate. Chrome can not be easily repaired, rewelded, or replated.
4. Never chrome plate a two piece exhaust system.
5. The areas of greatest heat will turn blue.

Back in the 80's CPS did a lot of chrome plating for customers. A chrome plating shop was literally a stone's throw from our front door. Most of the employees rode to work on a whole fleet of Harleys that were just dripping with chrome. It was safe to say that their hogs looked a lot cleaner than their owners. The shop was nothing short of a complete dive. A real toxic waste dump. One day EPA inspectors discovered that the raised flooring that the dip tanks were resting on was about to give way. They also found certain chemicals that where being used when mixed would produce hydrogen cyanide. This is the same stuff the State of California still uses to greet inmates to the great beyond. Needless to say the entire neighborhood was evacuated until the place could be stabilized. The street was closed off for nearly 6 months while guys in white space suits cleaned up the mess.

Needless to say anyone still in the chrome plating business is being carefully watched by Hazmat inspectors. The increased costs of compliance has to be passed on in the price of the product.

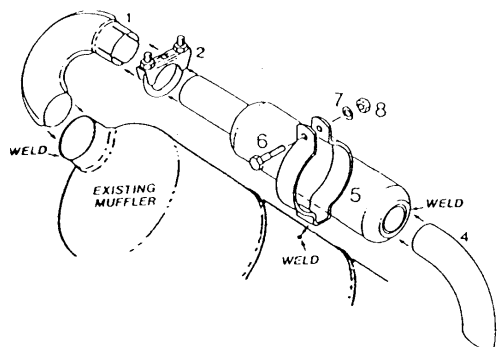
Aluminum Ceramic Coatings: Fast becoming the alternative to chrome plating, this process can be applied to both the inside and outside of the exhaust system. The inside surfaces are protected by combustion by-products, so this is not necessary. Available in just about any color imaginable, the finish is determined by the product used in the process. Air Born Coatings claims that finish will not stain or blue from heat, has a high abrasion resistance, and provides improved heat dissipation. They also offer a limited lifetime guarantee. Pricing looks to be quite reasonable at about \$100 depending on the service needed. The photo shown at the beginning of this month's article is not chrome, but rather a ceramic finish provided by Air Born Coatings. This process can be installed by Air Born coatings at either of two locations.

Airborn Coatings
5300 SW 23rd
Oklahoma City, OK 73128
Phone: 405-685-4433

Airborn Coatings
18 Emely Street
East Hartford, CT 06108
Phone: 203-528-8281

Fax: 405-685-4486

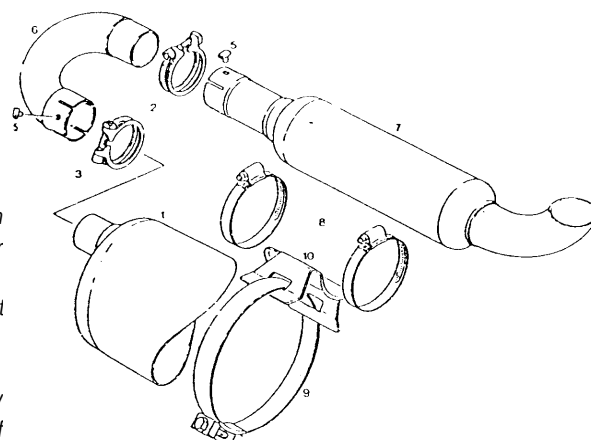
Fax: 203-528-0023



wise addition when outfitting a new Powerplant. The mini-canister is a straight through design so no changes in back pressure or jetting is needed. See illustration. Weight is 3.5 lbs. Refer to Part #12205 or AMKW. Cost is less than \$90.

A clamp-on after muffler unit is also available that is a straight bolt-on. The main canister must have a spigot outlet to accept the 180 pipe. This system weights in at 4 lbs. and relies on twice as many parts as the weld-on type. Refer to Part #12103 or AWKC. See illustration.

Summary: With a little advanced planning, the exhaust can be the most sanitary part of any Powerplant. There is really no reason for the exhaust to be the most unsightly rusted part of your aircraft. Next time you walk the flightline take an especially close look at the various exhaust installations. Chances are you will agree that there is usually always room for improvement.



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