THE DESIGNEE CORNER

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EXHAUST SYSTEMS PART I PLANNING YOUR EXHAUST SYSTEM

BASIC CONSIDERATIONS

An aircraft exhaust should be designed to carry the exhaust gases and heat away from the engine and to do it without burning up the airplane or asphyxiating the pilot. An equally commendable goal, in this age of environmental awareness, is to accomplish the aforementioned feat as quietly as possible. However, while you are contemplating the implications of all this, you should also be aware that there are many more factors to be considered in planning your exhaust system.

Where do you begin? If the engine you have was acquired with a serviceable exhaust system installed, study the installation to see how you can convert it to fit under the cowl of your airplane.

It might sound a bit fundamental but remember this: if you build and install the exhaust system first . . . your cowling must be made to fit around it. Naturally, if you already have a cowling then the exhaust system must be made to fit inside without touching any part of it. At any rate, don't be surprised to learn that a cowling you ordered won't fit around your exhaust system.

Sometimes, with just a little cutting and welding here and there, you can adapt a standard production type exhaust system to fit your airplane. If at all feasible, this should be your first choice. Such modifications are relatively easy to make and provide you with an economical and quick way to get airborne. A standard aircraft stainless steel exhaust system in good shape should never be discarded without due consideration. Most modifications will require wedge cuts at appropriate points and the addition of welded extension sections where needed.

All this is fine if you happen to chance onto a good used exhaust system, but some of the old patched-up exhaust installations one sees aren't fit to be in service in the first place. You probably wouldn't even allow some of those rigs on your plane.

If construction of an exhaust system is to be undertaken in its entirety, why not build and install exactly what you want. The problem, I suspect, is trying to determine what that "want" is, or what you think you want!

ROUTING AND EXITING THE EXHAUST

Many aircraft, we note, exit the exhausts coming out the bottom of the cowling. This is as true for those utilizing a single large exhaust pipe as it is for those having a two stack outlet. I have noticed, too, that the single stack outlets seem to be located more frequently on the lower right hand side. As a matter of fact, it would seem sensible not to outlet exhaust stacks on the left hand side (as viewed from the cockpit) at any point higher than the lower longerons. The propeller, due to its direction of rotation would tend to swirl the exhaust gases up toward the cockpit area. (VW engines would have opposite tendency.)

If cockpit vents are to be located near any exhaust outlet, try to determine if any fumes would find their way into the cockpit. Remember, it is possible for fumes to get in even though the cockpit or cabin is enclosed.

Do not overlook safety requirements in locating your exhaust outlets. The pipes should be long enough to clear the aircraft structure and not impose excessive heat on it. If necessary, protect the structure with metal and perhaps an underlying blanket of asbestos. Do not locate the exhausts ahead of the carburetor intake or ahead of the air inlet to the oil cooler. Naturally, you would not locate the gascolator fuel vents or overflow lines close to the hot stacks either.

Maybe the best reason to locate the exhaust pipes under the airplane is so you can't see those cherry red pipes with the flames leaping from them while flying at night.

BACK PRESSURE . . . AN EFFICIENCY CONSIDERATION

With the introduction of manifolds and longer exhaust pipes that have to be curved and intersected with each other in their route through the crowded engine compartment, we increase the risk of causing unwanted back pressure. Back pressure is a condition where greater than normal atmospheric pressure is created at the engine's exhaust ports. This excessive pressure (back pressure) may be attributed to the design and construction of the exhaust manifold or stacks. That is to say, the exhaust gases aren't scavenged as rapidly as they are expelled from the engine's exhausts ports. Things get crowded there and the pressures build up. This back pressure is often caused due to the pipes being too small in certain areas. Sometimes the intersection of two pipes causes turbulence because of a poor joint and very often because of a poorly designed or defective muffler. The causes can be many and cumulative.

Excessive back pressure affects the power output of the engine and the result is a loss in horsepower. The back pressure of a well designed system is quite low . . . usually less than 2% difference. If the bends in the exhaust system are quite sharp or if the pipes are too small

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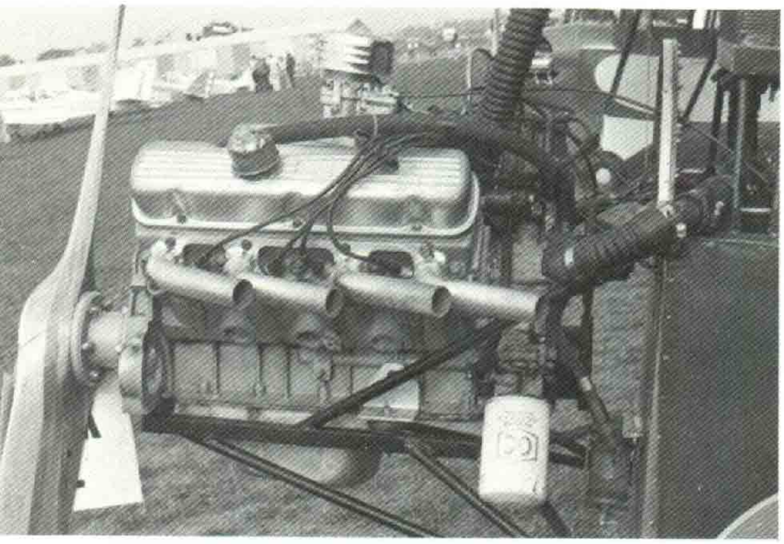

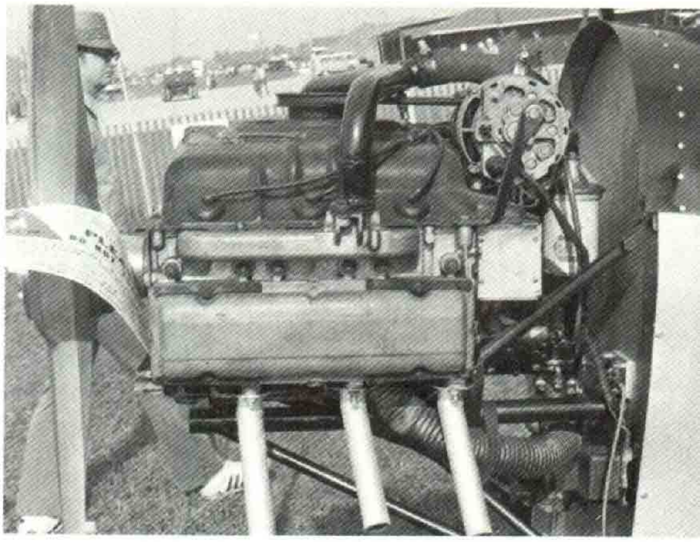

Photo No. 1 and 2
Examples of short stacks. Perhaps reminiscent of a bygone era.

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or are restricted, you can visualize how it would affect the thorough scavenging of the exhaust gases and tend to allow excessive pressure buildup at the exhaust port.

Most of us are not in a position to determine what effect the exhaust system will have on the power output of the engine as we do not have access to a dynamometer nor are we inclined to run torquemeter tests to obtain the required data. What to do then?

The best approach to planning and building an exhaust system is to pattern ours after a proven design. The results should be, in most cases reasonably effective.

EXHAUST SYSTEM CONFIGURATIONS

SHORT STACKS

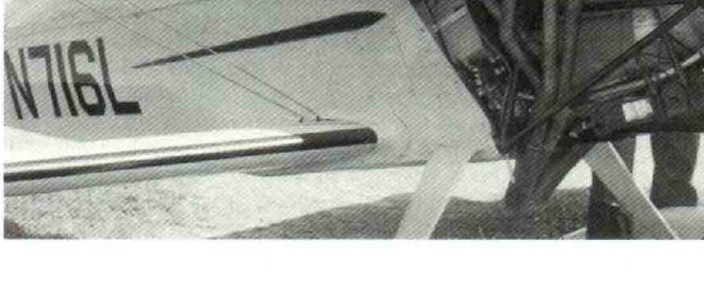
Well, how about the installation of short stacks to get rid of the exhaust gases safely and without unprogrammed pyrotechnic surprises?

Before I try to shoot that idea down as being unsuitable for the builder who will be completing his airplane during the next two or three years, it is only fair to admit to the advantages of the short stack installations. The term short stack applies to any installation that consists of comparatively short sections of individual exhaust pipes. (See photos 1 and 2) Ordinarily, the exhaust pipe that is bolted to each exhaust port is no longer than necessary for it to route the gases from the engine ports to the outside of the cowling. The Formula racers almost totally rely on this type of exhaust installation. If you examine photos of these fast little aircraft, you will see that the pipes are trimmed off even with cowl . . . no more, no less.

Can you imagine how noisy those engines are without the longer pipes and mufflers that most of us are accustomed to in the aircraft we fly? The perky bark of the engine might delight us at first, but not for long. In defense of short stack installations, though, it should be pointed out that they are economical . . . easy to fabricate and install . . . easy to maintain and to inspect, but perhaps even more important, they cause no significant back pressures. Furthermore, short stack installations help hold down exhaust valve temperatures to a minimum. All these things add up to greater available horsepower . . . and that is good performance wise.

For the average sportplane, unfortunately, the drawbacks to the short stack system are considerable. Who needs the noisy unrestrained staccato bark of a mighty four lunger engine on a long cross country hop? Noisy aircraft are no longer welcome at many airports. So, it is beginning to look as if the time has come to bury the short

Photo No. 3 and 4
Note the random directions worked into the exhaust pipes in order to obtain exactly the same length in each pipe. Greater efficiency is attributed to exhaust installations achieving a balanced or tuned exhaust. The four stacks from each bank of this powerful V-8 join into a common outlet of large diameter.



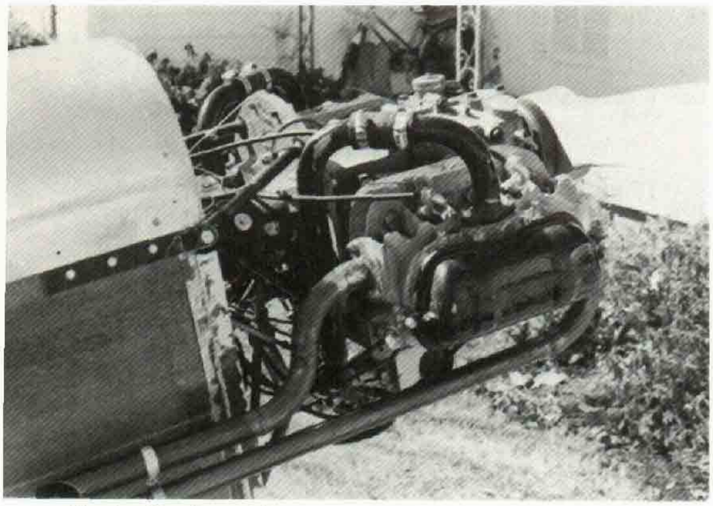
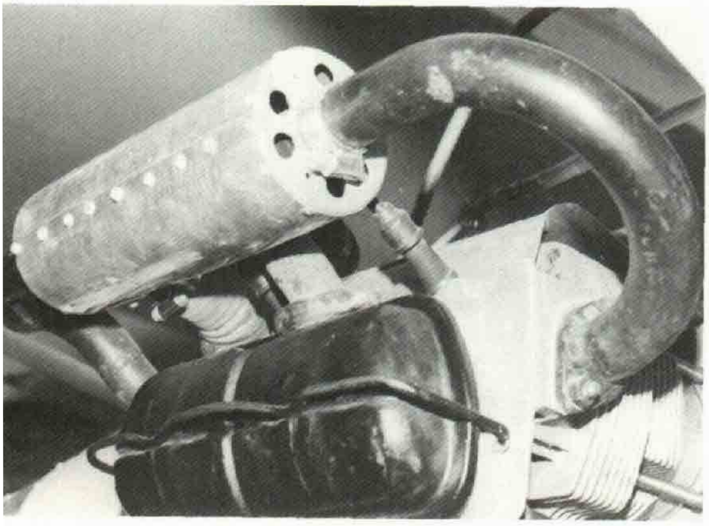


Photo No. 5 and 6
Although the chrome installation in Photo No. 6 doesn't look as sharp as the exhaust system in Photo No. 5, it may be the most efficient of the two. Note that the pipes in Photo No. 6 are of identical lengths . . . a difficult achievement in a VW installation.

stack installations along with the bones of the Dodo Bird. We must try to make our aircraft quieter for our own sake and not necessarily for the Johnny-come-lately environmentalist. As an added prod (incentive) . . . if we don't show concern for our own health, hearing, and well-being; "big brother" and his cronies, in one guise or another, will see to it that the job is done . . . their way.

If you were not moved by the preceding impassioned plea and still persist in your intention to build a short stack system . . . consider this too. Short pipes do not do a good job of conducting the exhaust gases away from the cockpit area. (Carbon monoxide in flight is nothing to joke about.) They also permit too rapid a temperature change at the exhaust ports whenever power is reduced suddenly. This can lead to warped valves and seats. And, there is more! Short stacks, being so short, leave no space for heat muffs or heat exchangers, and that can make it quite difficult to arrange for carburetor and cabin heat. So? With short stacks, if you don't lose your hearing . . . or get overcome by carbon monoxide fumes . . . or freeze to death, you may wind up in the poorhouse buying new valves. (Wow! Talk about overkill!)

Photo No. 7
This VW exhaust features a nice large radius which should improve scavenging and hold back pressures to a minimum.



EXHAUST MANIFOLDS

A system where the exhaust pipes on one side of the engine are joined together with a manifold, is a decided improvement over the short individual stack arrangement. Using a common manifold to gather the individual exhausts and then to direct the gases overboard through a single pipe provides a quieter running engine even when no muffler is installed. One important factor affecting the quietness of an engine is the length of the exhaust pipes. The longer they are, the quieter the engine. Often the manifold on each side of the engine is interconnected and only a single pipe exhausts the gases somewhere under the aircraft. Most often though, the homebuilder will use a separate exhaust pipe for each side of the engine.

Basic exhaust manifold sections may be purchased from any one of the few advertisers in *SPORT AVIATION* who handle complete inventories of materials for the homebuilder. These standard aircraft units were originally manufactured for some of the older aircraft models that were equipped with Continental and Lycoming engines. The prices are reasonable and sometimes less than if new raw materials were purchased to build up similar components. With two of these manifolds (to fit the type engine being used), and a few sections of exhaust pipe material, it is possible to custom build your own system.

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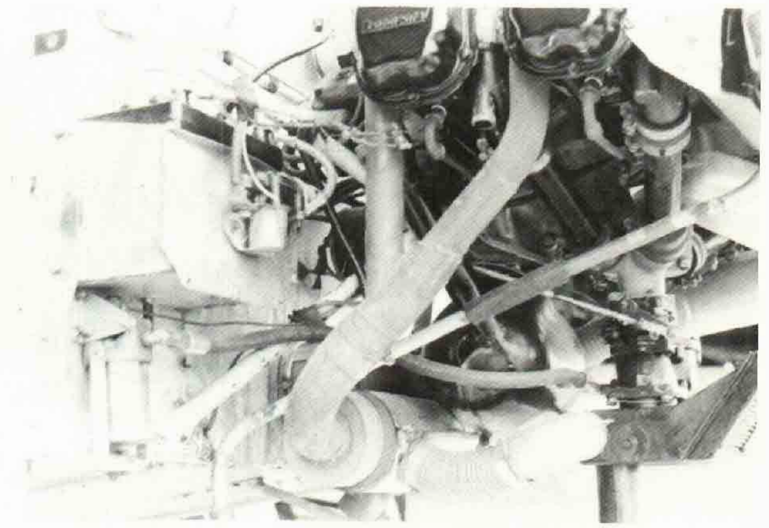
Photo No. 8
An excellent exhaust/muffler installation modified from a Continental ground power unit. Note where additional sections of pipe were welded in to permit the lowering of the muffler.



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CROSS-OVER SYSTEM

If you don't already have a clear-cut image of what a cross-over system is, try this explanation. A cross-over exhaust system is one where the front cylinder exhaust ports are joined together with a single exhaust pipe that routes the gases overboard through a single stack. The back cylinders are also interconnected in a similar manner and their exhaust gases are scavenged overboard through their own pipe. In other words, the right front cylinder's exhaust pipe crosses over to connect with the left front exhaust pipe. The rear cylinders are likewise connected by a cross-over pipe making the exhaust system look like spaghetti leaking out of the engine. As complex looking as it is, its proponents lay claim to increased efficiency through reduced back pressures. This, of course, would result in a better power output and increased rpms with the properly constructed cross-over system. The usual practice is to have both pipes crossing in front of the engine although there are cases where the builder takes the rear pipe around the rear of the engine. However, to do so may complicate the installation of heat muffs and mufflers. A cross-over system must be carefully planned to clear other vital components in the engine compartment. It should be compact enough to be easily cowled without any unusual bulges. One problem is that the long pipes will be conducting heat through a long route inside the engine compartment. Consideration must be given to assure that this does not cause problems. If the pipes come too close to the cowling they may burn through.

OUTLETS

Avoid excessive back pressures in the exhaust manifold by providing an easy out for the exhaust gases. Do not build in sharp angles or changes of direction or too small a discharge pipe in the outlet pipes.

Exhaust outlets should not be located so that the slipstream retards the exhaust gases as this has the same effect as an obstructed opening. Also, because of the high drag created, the exhaust pipes should not jut out into the slipstream at a 90^0 angle to the slipstream. It is better to exit the stacks at a swept angle. (See phots No. 1 and No. 4.) A reduction in drag is possible if you can arrange to have the tail pipes one behind the other . . . outside of the cowling. The outlet pipes can also be flattened somewhat in a vise to give an oval shape to reduce drag. Somewhere I heard that exhaust pipes should not be flattened to more than a 5:3 ratio. Seems reasonable enough, doesn't it?

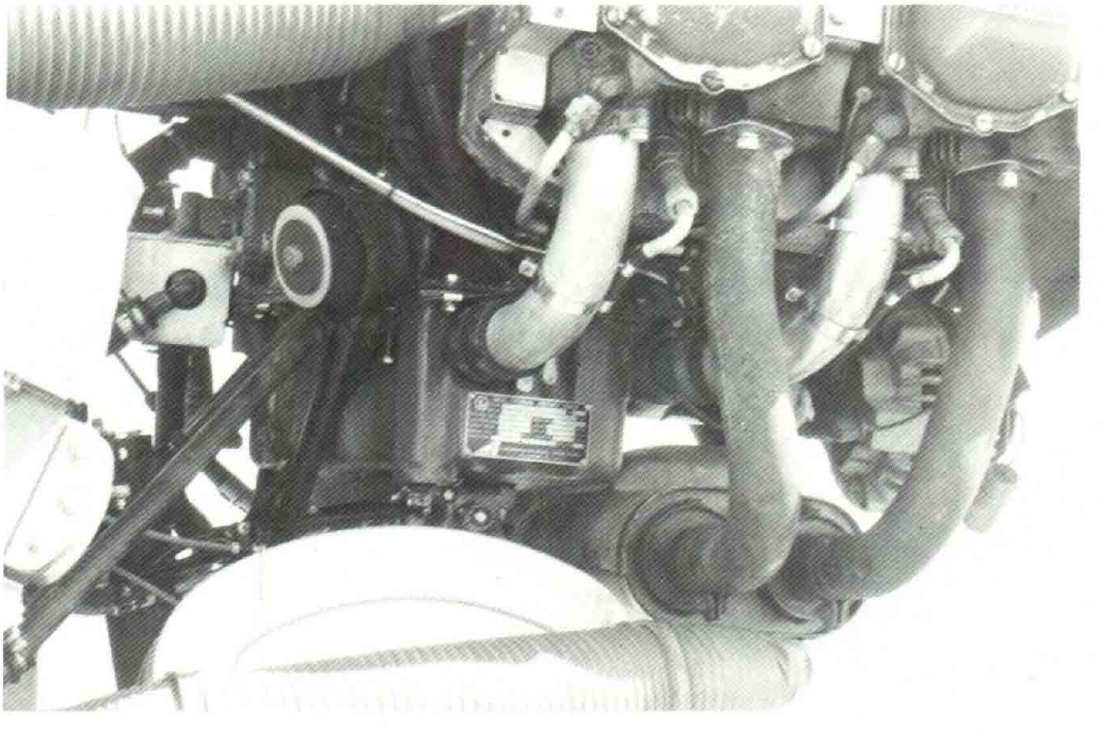
MUFFLERS

Straight stacks, even long ones will not reduce the noise of the engine significantly therefore, mufflers are required to do the job. Unfortunately, mufflers are fairly heavy. This could be bad news to the VW engine user and other small engine fans as weight is a critical consideration. In addition to the weight, is the very real possibility of increased back pressure in the exhaust system and the attendant erosion of available power. Still, a well-designed muffler has become essential and we had best start developing ways and means of reducing engine noise without reducing available power.

Our "hot rod" friends seem to be way ahead of the sportplane builders in this respect. The biggest difference between most hot rod installations (in addition to imaginative approaches) and the sportplane installations is, of course, weight . . . still, we can learn much by adapting some of the methods they use. It seems to me that aircraft exhaust systems have been patched onto aircraft engines with great indifference. There has been little new from the industry in the way of imaginative thinking or experimentation. Certainly, there is very little written about exhaust systems. Even the engine manufacturers seem to ignore exhaust requirements for their engines. When was the last time you saw a complete exhaust system or even a partial one illustrated or described in an engine overhaul manual?

Some builders have had excellent results with their exhaust installations but very few people ever hear about it. There is virtually no exchange of expertise in this area. Hopefully, we will get some useful feedback which we can pass on at a later date.

Photo No. 9
All exhaust pipes don't always head for the aft end. This Lycoming installation routes the pipes across the front of the engine, interconnecting the left and right cylinders.



EXHAUST SYSTEMS PART II — WELDMENTS

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ONCE YOU VISUALIZE the general arrangement for your exhaust system give some attention to the following design considerations:

1. Either the exhaust system must be made to fit your cowling or the cowling must be tailered to fit the exhaust installation. It all depends on which you prefer to acquire or build first.
2. The exhaust system should be constructed so that it will be easy to inspect and maintain without obstructing access to other engine components. Furthermore, the entire system must be adequately supported and free to expand and contract with operational temperature changes.

AUTOMOTIVE PIPES

The question most asked about exhausts is, "Say, what about using automotive pipes on my airplane?" (Nobody asks questions anymore that can be answered with a simple YES or NO.)

Well, I for one, am losing my long seated reluctance against the use of automotive pipes in sport aircraft. Automotive pipes when properly fabricated are every bit as effective as the stainless steel brand. They may not be as light or may not have as long an operational life, but, they should nevertheless, prove adequate under the conditions of use that we encounter in recreational flying.

Some builders are using the economical automotive pipes primarily because the source of supply is plentiful and curved sections (exactly as needed) can be obtained from practically any automotive supply shop. These steel pipes are very easy to weld and the finished product as a result looks very good.

There are drawbacks to using automotive pipes. Weight is one of them. In building a complex cross-over system the weight differential could be considerable as the automotive pipe walls are approximately .055" thick while the usual aircraft stainless steel pipes are made of .035" stock. This would make an automotive pipe installation almost twice as heavy.

For comparative purposes you can figure that a stainless short stack exhaust installation would weigh about 3 pounds. On the other hand, a simple stainless two manifold installation is not likely to weigh more than 8 pounds without a muffler and heat muffs. A complete stainless system with the works, muffler, heat muffs and braces, can be installed weighing somewhat less than 12 pounds depending considerably on its complexity. As these figures are for typical stainless systems, you can judge the weight of the equivalent automotive pipe system accordingly.

The ease with which automotive pipes can be welded seems to make it easier to overlook the handicap of their heavier weight. Still, make sure that you don't inadvertently use some pipes where the gauge is heavier than .055" wall thickness as it would become too ridiculous a price to pay in the form of a weight penalty.

After an automotive pipe system has been welded, the exhaust flanges should be checked for flatness to forestall leaks at the gaskets. If the flange isn't smooth and flat, correct the difficulty on a bench mounted disc sander or by careful hand-filing. Rubbing the flange over a piece of emery cloth backed by a smooth hard surface should give you more accurate results than by filing . . . provided the distortion isn't too severe.

The complete unit should then be completely sandblasted to remove the welding scale and rust. As soon as possible after the sandblasting the exhaust manifolds should be sprayed with a good grade of high temperature (1200°F) spray paint. It is available at most automotive shops and some discount stores. This protection will prolong the life of the automotive pipe exhaust system provided that you touch up the paint occasionally near the exhaust ports and any other place where it burns off. Some paints are much better than others but only personal experience can help here. When you realize that the exhaust gases at the ports come charging out at temperatures of between 1400°F and 1800°F, you can see that the 1200° paint is a bit shy of providing absolute protection. Some types of plating or porcelanizing would do much to extend

Those X-Rated Birds . . .
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One of the more unusual projects will come from the skilled hands of a homebuilder *par excellence*, C. M. "Marty" Lauridsen, QASAR manufacturing inspector at Los Angeles International Airport. What does a homebuilder do for an encore when he has built and rebuilt Pietenpols, Taylorcraft, Luscombes, Wacos, Piper J-3s, Sky Rangers, Aeroncas, Stinsons and a Citabria that he still flies? Why, build a real antique! He's undertaking the construction of the Wright EX, popularly known as the "Vin-Fiz." And he expects to fly this strut-and-wire open-fuselage Wright Brothers original, which was the first to fly across the United States.

Although all these planes may carry "experimental" tags, in many ways they and their pilots may be more airworthy than you might think. As Pacific-Asia's Murray remarked, "Once you build or rebuild an aircraft, you'd be surprised how acutely aware you become of the plane's capabilities and limitations. In a word, you become safe!" And then again, the homebuilder has had that GADO inspector at his elbow all the way.

the useful life of automotive pipes but such refinements are beyond the financial and geographic playgrounds within which most of us operate.

Automotive-type exhaust systems are certainly working out very well on VW powered aircraft and more builders seem to be installing them in larger engines. Only time will tell how long these installations will perform adequately under differing climatic conditions.

STAINLESS STEEL EXHAUSTS

The general acceptance of stainless steel systems speaks for itself. Stainless is, of course, a great material. It is very strong with a tensile strength of approximately 90,000 psi in its **annealed** condition and yet, it can be cut easily with tinsnips. It is quite ductile and can be bent and formed easily. In addition, it is nonmagnetic in the annealed state and very corrosion resistant. On the other hand, it is difficult to weld and tricky to drill holes into. In essence though, it is almost a perfect material for aircraft exhaust systems.

Stainless steel, type 321, is aircraft quality stainless that makes a good material for the construction of exhaust pipes and manifolds. I would suggest that the welded seam variety may be used as it is a good bit cheaper than the seamless variety and there is no visible seam which could conceivably cause hot spots in the exhaust pipes. The price difference per foot is significant. Stock aircraft pipe diameters are 1 1/2 and 1 3/4" OD with the wall thickness ranging from .035" to .049" for 4 cylinder engines. The tendency will be for the homebuilder to select the heavier gauge as it may be somewhat easier to weld successfully. If weight control is important, and it should be, be advised that the .035" thickness is proving quite adequate in certificated stainless steel exhaust installations.

Those of you who haunt the salvage yards in your search for aircraft project materials probably have already found some 1 3/4" stainless pipe at the salvage yard . . . or is it Inconel. Both look alike to me but Inconel is a nickel-chrominum-iron alloy while stainless is a chromium base alloy.

Inconel is also a corrosion resistant steel used in exhaust systems. However, most of us will probably have enough of a problem locating and working with stainless steel stock, much less something more exotic like Inconel. Futhermore, the welding of it does take a different type of welding rod than that for stainless. The point of all this is that you might accidentally acquire Inconel thinking you have the ordinary stainless steel.

BENDING EXHAUST PIPES

There is no use to try bending either the automotive pipes or the stainless steel exhaust pipes by heating them with a torch, or by any other home-devised scheme. Some builders might have access to a shop with a hydraulic tube bender machine that utilizes an I.D. mandrel and that's great. For the rest of us, though, to purchase the services of such a tube bender can be quite a pocketbook bender as it costs up to $15 per bend to have pipes custom bent. In most instances, it is much cheaper to buy a ready-made set of exhaust manifolds of aircraft quality than it is to obtain the raw material and pay for all the necessary bends.

HOW TO WELD STAINLESS

The stainless steel exhaust components may be welded with either an electric arc or an acetylene flame . . . of course, heliarc does the finest job.

Anyone using an electric arc welder should obtain flux coated rods to use in arc welding the stainless. This type of rod forms a gas surrounding the hot metal in the weld arc as the rod is being deposited.

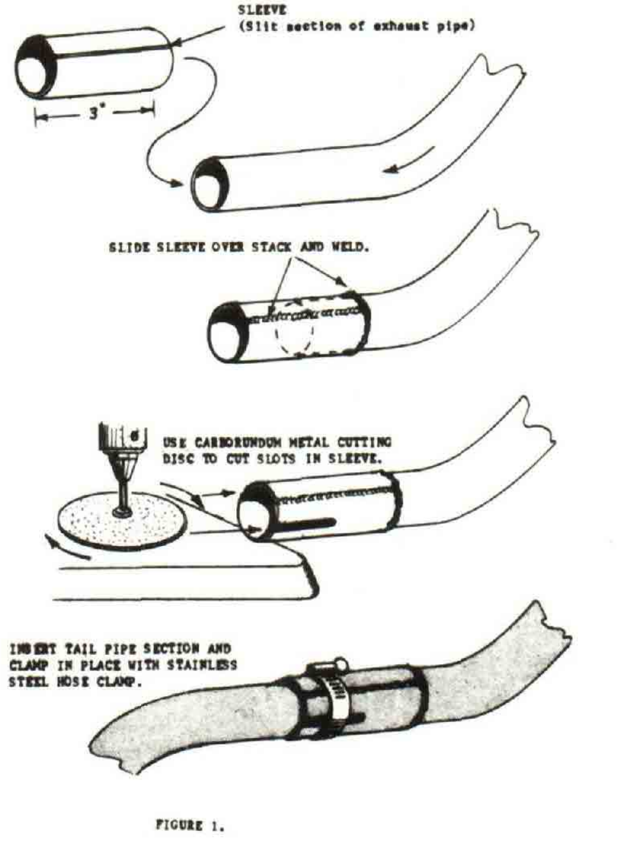

FIGURE 1.

CUSTOM MADE EXPANSION JOINT

I would assume that the majority of builders will have, at one time or another, tried their hand with oxyacetylene welding. However, welding mild steel or 4130 steel and welding stainless steel are two different ball games. If you have ever done any welding at all you should try welding stainless at least once.

Serviceable (maybe not pretty, but serviceable) welds can be made in stainless, believe it or not, by almost anyone who can use an oxyacetylene welder. It is not as difficult as welding aluminum nor as tricky. Nevertheless, do not start on your stacks and expect to produce nice looking beads if you have never tried welding stainless before. More usually, one's first results will probably look like a disorganized string of abandoned raisins. Don't despair. Once you have a better understanding of the characteristics and behavior of stainless during welding, you will be able to achieve acceptable results with a little practice.

Welding stainless requires a certain preparation of the work before you can start welding and it requires a certain technique during welding.

First, obtain some 1/16" stainless steel rod and a jar of Flux for welding 18-8 stainless. The numbers have reference to the chemical composition of the steel which is made up primarily of chromium, 18%; nickel, 8%; carbon, 10% and also silicon and manganese. The stainless melts at about 2500°F to 2679°F . . . about the same range as that for 4130 . . . yet there is something different about stainless steel.

Stainless dissipates heat only 40% as rapidly as 4130. This means that not as much heat is required to do the welding and it is necessary to use a smaller flame and tip than you would expect. Because the heat is not diffused by the surrounding metal there is a good chance that you

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might inadvertently burn a hole in the thin exhaust pipe material before your realize it. So, be warned . . . use a small tip, one that is about one size smaller than you would use in welding 4130.

Any metal containing a lot of chromium as does stainless steel, will immediately start to oxidize if heated with a flame. An excess mixture of oxygen worsens the process. To avoid oxidizing the metal it is advisable to use a neutral flame. Since many welding regulators will not hold a precise gas mix, it is better to adjust the torch so that a slight excess of acetylene is visible. A fine feather of acetylene should show about 1/16" around the inner flame cone. An unwanted change to an oxidizing flame can then be easily detected and readjusted. Here are your options based on improper flame adjustments:

1. Too much oxygen . . . Oxidizes the molten metal making the weld porous. Interferes with adhesion.
2. Too much acetylene . . . Reduces corrosion characteristics of the stainless and tends to make the weld brittle as the acetylene takes up the excess free carbon.

During the welding process the metal must be protected from the air otherwise oxygen and nitrogen in the atmosphere will combine with the hot metal and hinder proper adhesion of the weld. This protection can be obtained by using a flux especially compounded for welding stainless as the flux will dissolve the chromium oxide which forms on the molten metal. Flux, as used for welding stainless steel, is a white powder which is mixed with water or alcohol (depending on the type and the instructions) and mixed to a pastelike consistency. Flux should always be brushed on the underside of the joint and allowed to dry before the welding of stainless is started. It may also be applied to the welding rod. It is not essential to apply flux to the top side as the flame will protect it. Eliminating the flux on the top surface may also make it easier for you to see the color of the hot metal by eliminating, to a certain degree, the glare caused by melted flux.

Excessive heat and the inadvertent development of a large puddle could combine to generate oxidation to a point where even the flux cannot counteract the oxide. So while the primary purpose of the flux is to counteract the tendency for the stainless to oxidize during the heat of welding . . . its capability is limited.

WELDING PROCEDURE

To be able to weld a decent bead around an exhaust stack requires a good initial fit of the two parts. Try for a fit that permits the parts to meet within 1/16" of each other all the way around.

The two parts should be bright cleaned with emery cloth. Getting the edges and weld area clean is much more important when welding stainless than it is when joining mild steel or 4130.

Apply the welding flux to the freshly cleaned area and perhaps to the welding rod, too, if you are so inclined.

Jig up or clamp your work so that you can weld "downhill". This will permit the flux to dissolve and flow along with your weld affording greater protection against oxidation during the welding ritual.

The texts had me believing that the technique to use was the forehand method (figure 3) but this screw driver and hammer mechanic can't seem to do anything with that method except burn holes. I would suggest instead that the reverse technique might be the most successful for you. As a matter of fact, it is suggested that the torch be tilted more than the recommended 80^0 and pulled back slightly at frequent intervals to keep a close check on the degree of heat evident at the weld. Directing the flame back over the completed portion helps me keep from burning through unexpectedly. Thin wall pipes melt through pretty quickly so vigilance is in order. If you

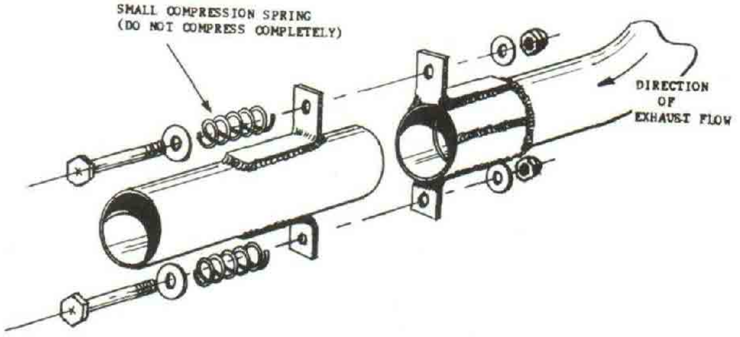

FIGURE 2.
EXHAUST SYSTEM EXPANSION JOINT
(ALTERNATE METHOD)

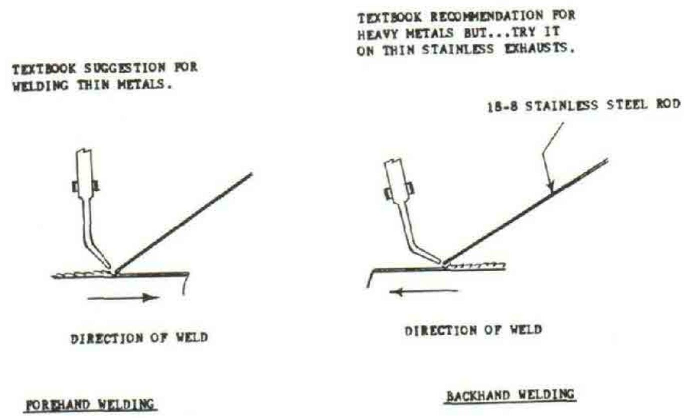

FIGURE 3.

would slip into the pipe being welded, a metal back-up (a smaller tube, a hunk of iron, or copper), it will serve as a leveler for the weld bead and aid in preventing welding sags on the underside of the weld. Although it will also act as sort of a heat sink, it should not interfere with obtaining good penetration as the exhaust pipe material is relatively thin.

To get started, begin by tacking the two parts together with very small tack welds in about 3 places around the pipes.

Check to see that the welding tip is in good condition and that the flame doesn't come out cockeyed or forked. It is hard enough to make an acceptable weld when everything is just right, anyway.

Use a somewhat smaller flame than you would for mild steel but one big enough to bring the metal up to welding temperatures without noticeable delay. Fill the joint completely and do not move on until the deposited filler from the rod diffuses. Once started, finish each bead without interruption. If for some reason you find it necessary to stop, reheat the entire weld area (within 2") to a red hot color before beginning to weld again.

When welding keep the rod within the limits of the flame envelope and allow it to melt and flow into the melting puddle. This is easy to say but somewhat harder to do because the stainless doesn't seem to form nice puddles that can be moved along as well as with 4130 steel.

The inner cone flame should be directed so that it just about touches the molten area. If you don't hold the flame until the edges of the added filler rod are feathered there will be a tendency for your weld bead to be piled high and you will have a narrow bead with poor penetration. Apply the rod sparingly.

While some sources say that it isn't necessary to anneal a weldment in stainless, the heat of welding does act to reduce the corrosion resistance in the weld area. This deficiency can be corrected by heating the weld area to 1900° to 2000°F (sort of a lemon color) and cooled rapidly. Actually, the thin walled pipes are cooled rapidly enough in still air.

There really is not much welding associated with constructing an exhaust system . . . perhaps 6 joints or so. This might raise the question of how big an effort should be made in learning to cope with the welding peculiarities of stainless . . . and that is worth considering.

But, since our movement is 50% educational, most of us are willing and determined enough to try to do everything ourselves, first.

HOW ABOUT USING A MILD STEEL WELDING ROD?

It is being done you know. The problem with using a mild steel rod for welding stainless is that it is not corrosion resistant and that is has a markedly different coefficient of expansion. Stainless conducts heat only 1/3 as quickly as ordinary steel while it will expand 1 1/2 times as much as 4130. This could ordinarily create some severe stresses in a weld. One thing that minimizes that condition in an exhaust pipe weld is the fact that the weld is continuous completely around the pipe. Another drawback is the ilaim that the mild steel weldment is not corrosion resistant as is the stainless. Funny thing though, it doesn't seem to be a serious matter in service and the welding of stainless with a mild steel rod does work nicely and the appearance of the weld is much more appealing to one's aesthetic senses.

CHECK YOUR WELDS

After all welding is completed, it is a good idea to check your seams for tiny holes and leaks that you may not have noticed. Do this by holding the torch inside the pipe and moving it around the weld area while you watch for sparks or signs of light around the welded bead on the outside. If this seems a bit crude to you, give it the Pressure Test. This will certainly show up all poor welds and fits. To make a pressure test, you will have to make and install plates with gaskets to block off all openings. Pressurize this sealed exhaust system with about 10 to 15 psi of air. Use a mixture of liquid detergent and water. (Two tablespoons to a cup of water.) Apply the liquid to all joints and watch for bubbles. If you don't see any . . . fine, otherwise back to the welding rig.

TECHNICAL ADVISORS FOR THIS MONTH

My thanks for much of the technical information, suggestions and support go to:

Bob Haley, EAA Designee No. 64, RR No. 5 E. Hampton, Conn. 06424

Terrance O'Neill, EAA 5572, 791 Livingston, Carlyle, Illinois 62231

FROM AN EARLY HOMEBUILT

A fine example of early homebuilt craftmanship was recently donated to the EAA Air Education Museum by Hans Dam, 5909 Oakwood Ave., Cincinnati, Ohio. Back in the early 1930's one of the leading designers of homebuilt airplanes was Robert Retz of Farmland, Indiana. The streamlined wheel covers shown in the accompanying photo are from his Retz R-8 biplane, a neat little craft powered with a converted Chevrolet engine. A photo of it appears in POPULAR AVIATION for June, 1934. Note the wire formers — they are made of coat hanger wire. The covering is doped fabric, in excellent condition — after 40 years!

Retz was later killed in a crash with a student in an American Eaglet but his work is recognized as outstanding in the pioneering days of homebuilding. Mr. Dam is compiling data for a biography of Retz and would appreciate hearing from anyone who has photos or other information.

(Photo by Lee Fray)

George Hardie, Aircraft & Display Research (left) and Bill Hodges, Assistant Museum Director, examine the Retz R-8 wheel covers.

EXHAUST SYSTEMS PART III — CONSTRUCTION PRACTICES

THE DESIGNEE CORNER

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A common problem encountered in adapting a stock exhaust system is the lack of clearance with the cowling or insufficient clearance at the firewall due to the use of a shorter engine mount. In spite of these minor difficulties, it is easier to modify a stock exhaust/muffler system than it is to build a new one from raw materials. Ordinarily, a simple modification has to be made to alter the direction of the pipes to the desired point or angle of exit (Fig. 1). Sometimes, it may be necessary to weld in short sections of pipe in order for the stacks to clear the cowling. More often, however, the modification may only consist of altering the location of the muffler. This can be accomplished by cutting a small wedge out of the pipe and rewelding that particular joint in its new deflected position.

In the example illustrated in Figure 2, the stock J-3 muffler was too close to the firewall and the builder had no space for the generator. By welding in the short exhaust pipe section, he was able to lower the muffler location. This had the additional advantage of permitting him to reduce the length of the tail pipe and to allow it to exit at a more favorable angle. The original shroud on the tail pipe was removed and a wrap-around muff installed on the muffler. The muffler in its new position, however, could add unwelcome heat to the oil if located too close to the oil tank. Should that happen, the oil tank must be shielded from the muffler with an asbestos backed metal baffle.

A typical installation as shown in Figure 2 with its comparatively heavy muffler at the end of a long exhaust pipe, exerts quite a load on the exhaust flanges and studs. An installation like that is prone to develop cracks and weld failures. It is a good idea to install a couple of small straps to help take up some of the weight and to dampen the vibration. One end of the support straps is ordinarily attached to some point on the engine so that the vibration is contained within the shock mount frequency of the engine. Admittedly, finding a place on the engine to secure one end of the strap or brace is not simple. On the other hand, if the straps were attached to some point on the engine mount or aircraft structure they might serve, instead, in aggravating the problem. A possible exception could be in installations of the type shown in Figure 3. Here the ball joint connection in the system is spring loaded and permits movement of the exhaust pipes without imposing stresses on the flanges and the welds. Ordinarily, bracing the exhaust tail pipes against the aircraft structure does not seem to be a practical solution unless that section of the exhaust system is free to move independently of the shock mounted engine. This means that to do this successfully it would probably be necessary to have both slip joints and ball joints in each tail pipe. Their location too, would be quite important.

Cross-over systems are particularly prone to developing cracks unless they are constructed with a similar degree of flexibility built-in.

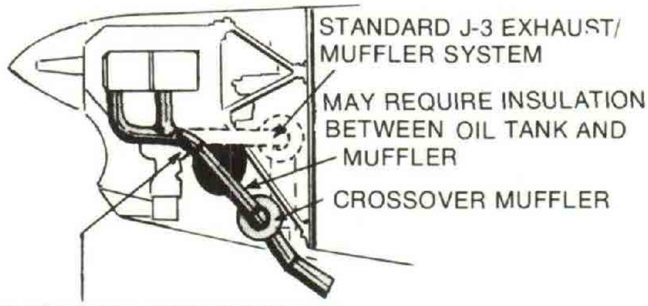


FIGURE 2.
TYPICAL MODIFICATION OF A STANDARD EXHAUST SYSTEM

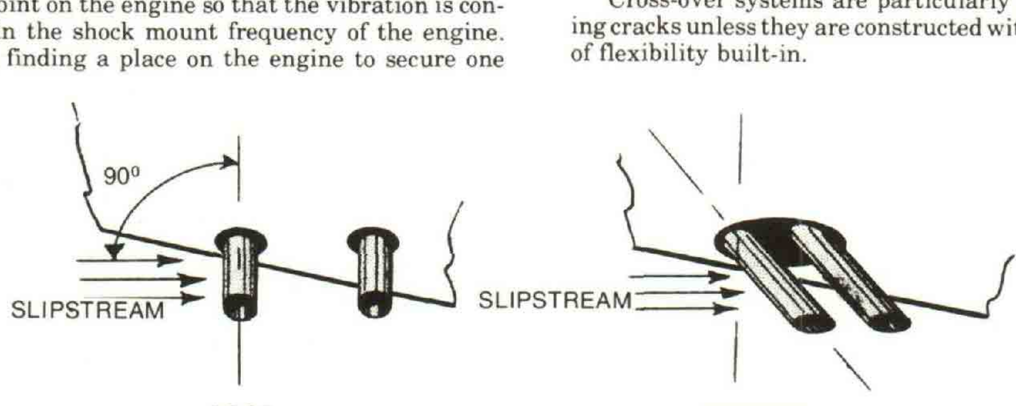


FIGURE 1.

EXHAUST OUTLETS CREATE LESS DRAG WHEN SWEPT

Before undertaking the modification of a stock system, you might first assure yourself that the unit is in good condition, otherwise there would be little purpose in going to that trouble and expense.

STOCK MANIFOLD COMPONENTS

If you cannot acquire a good complete stock system to adapt, you might consider building up an installation using a couple of standard exhaust manifold components as your second easiest option. There are still plenty of Luscombe, Aeronca, Cub, and T-Craft exhaust stacks and mufflers to be had at competitive prices. Stock manifold units make a good starting point as they can be cut, or simply added to, to form a complete custom-built installation. Using this method will give you the advantages of a new system with a minimum of work and welding. The flanges would have already been properly fitted and welded and you would need only to add to the downstream portions to fit your airplane. Be sure, though, that the manifold components you purchase will fit your model engine.

Some builders find it necessary to make their own exhaust flanges and to weld up the entire system from new materials but this is the hard way. I would suggest, instead, that short stacks or stub exhaust stacks may be purchased as a starting place simply because these short stacks already have flanges fitted and welded.

The next step is to decide whether you want to go to the trouble of laying out and making a welding jig, or whether you prefer to build the exhaust system on the engine. If you would rather make and use a welding jig, the layout position and spacing for the flanges can be taken from the engine manufacturer's specifications sheet for the make and model engine you have.

Some layout dimensions for exhaust flanges are also illustrated for a number of common engine types in EAA publications. For example, EAA Aircraft Manual on Engines, Volume 1, contains the layout for the Continental engines A50, A65, A75 and A80 (all identical) as well as the details specifications for the Lycoming 0-290-2B. So why not review your old EAA manuals to see what you have.

There is something to remember when laying out a jig. In viewing the spec. drawings, you will be looking down on the engine and flange layout. But, for the jig, the angles as shown for the flanges must be reversed as the exhaust pipes really come out of the bottom of the engine (drawing) . . . right?

When you work from a jig board (preferably a steel plate), bolt the exhaust flanges to the jig plate and begin to tack weld the stack sections together . . . occasionally removing your creation from the jig for trial fits on the engine.

There are many builders who will naturally use the engine as a jig for making their manifold sections. Although this is a common practice, the accepted rule is that the engine is used only to make the initial tack welding fit of the pipes. The main welding will be done somewhere else . . . in the clear . . You are aware, of course, that the flame from a welding torch can damage most any part of the engine or its accessories in a moment of distraction. It is good sense to caution yourself once in a while about safety precautions as it is so normal to become complacent and perhaps a bit careless.

By the way, during the construction of your exhaust system it is suggested that you do not mark on exhaust pipes with a lead pencil but rather use a felt pen. Lead pencil marks will be absorbed after the pipes get hot and cause a change in the metal, tending to soften it in the areas marked. This sort of thing might lead to cracks and failures. I understand that the use of zinc plated or galvanized tools could create the same effect wherever the plating of the tool is rubbed off onto the pipes. Although this appears to be a romote possibility, it does make a good conversation piece and is interesting enough to note.

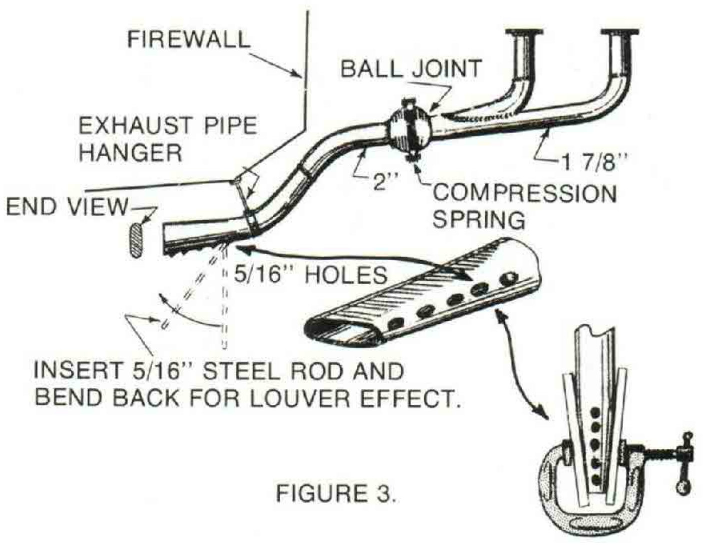
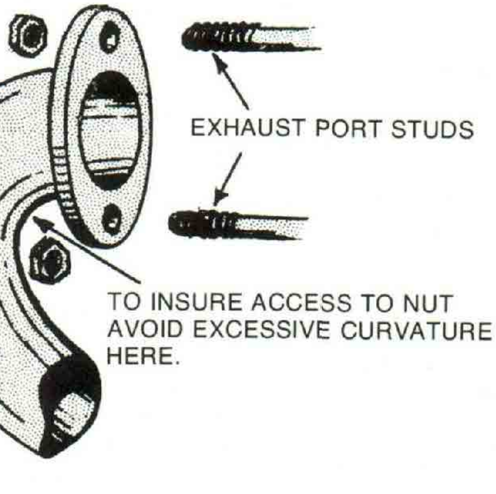


FIGURE 3.



VW ENGINES — FRONT EXHAUST PIPES
FIGURE 4.

A problem peculiar to the VW and similar engines is the need to curve the exhaust pipe rather sharply from its flange connection to provide safe clearance with the propeller. (Figure 4.) A sharp curve at this point may make it impossible to put a wrench on the nut for torquing it. The solution is to try to weld the exhaust pipes perpendicular to the flanges even if for but a short distance before the pipe curvature starts.

DRILLING HOLES IN STAINLESS STEEL

During the fabrication process you may want to drill some holes in the stainless pipes. If you don't use the right technique you could learn to your surprise that it is almost impossible to do. It may help to first grind the drill bit to a slightly flatter angle than a regular bit, although if you handle it right the ordinary bit will do the job. Make a very light punch mark. Do not try to get the drill bit to get started without the help of one . . . it may be useless effort. Use a slow speed for the bit, about half that you would use in drilling 4130 steel. Back up the work with a solid support while drilling. KEEP THE BIT CUTTING or else the steel will get so hard after the first few non-cutting revolutions of the bit that you will dull or burn the drill bit and get nowhere a-tall! The only recourse once you start the useless spinning, is to stop and to regrind the drill bit to a different angle, or maybe, to punch out a hold and file it to the size you want with a rat tail file. A file used to sharpen chain saw blades works nicely, too.

Figure 3 and the photo show how holes drilled in the end of exhaust pipes can be made to have a louver-type of effect. The hole sizes used for this type of effect appear to vary from 5/16" to 1/2" in most cases, dependent on the builders preference. In any case, a steel rod of the proper diameter is inserted and then swept backward toward the end of the pipe. This forces the metal outward to assume a nice louver-like appearance.

EXHAUST JET EFFECT

Getting rid of the exhaust gases represents a considerable waste of energy so it is not surprising that attempts are frequently made to utilize some of this energy. In its most elementary application, the exhaust pipe is constructed to provide a smooth unrestricted path for the exhaust gases with its outlet pointed downstream to the slipstream. This will definitely give a little jet thrust to your airplane, however, little that may be. A refinement of this jet reaction is possible by encircling the exhaust pipe with a shroud. A section of thin walled stainless steel about 3 or 4 inches in diameter may be used. The ends are flaired somewhat as shown in Figure 5. Stainless is very ductile and flairing should be rather easy to do. The idea behind this feature is to construct the shroud so as to cause the air to be accelerated past its opening using the principle of the venturi to increase both the velocity of the engine compartment air, and the exhaust gases leaving the stack.

This same "jet blast" system has been most effectively used for years by Ray Hegy in his famous little 65 hp red biplane El Chuparosa . . . one of the flyingest homebuilts in the country.

Such an augmented system serves a dual function in that the cooling air passing through the engine compartment is accelerated and therefore assists in reducing the overall cooling drag while, at the same time, taking advantage of the jet-like reaction of the exhaust gases.

You can increase the jet effect by constricting the exhaust tail pipe portion somewhat. You cannot, however, get something for nothing so if you squeeze the pipe down too much you may be creating excessive back pressures and will only be reducing the available power instead.

As we have previously suggested, an exhaust pipe can be squeezed to a fineness ratio of 5:3 with reasonable assurance that it will not cause adverse back pressure effects. In those installations where you plan to drill a series of holes in the side of the tail pipe, it may be possible to squeeze the pipes a bit flatter without a lost in efficiency. But then, this could make a good test program . . . something you could experiment with on your own aircraft.

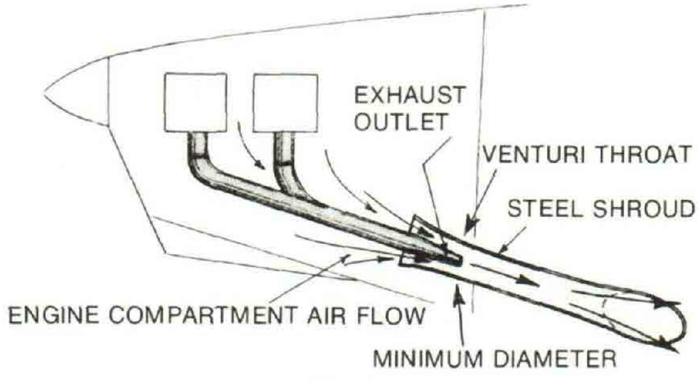
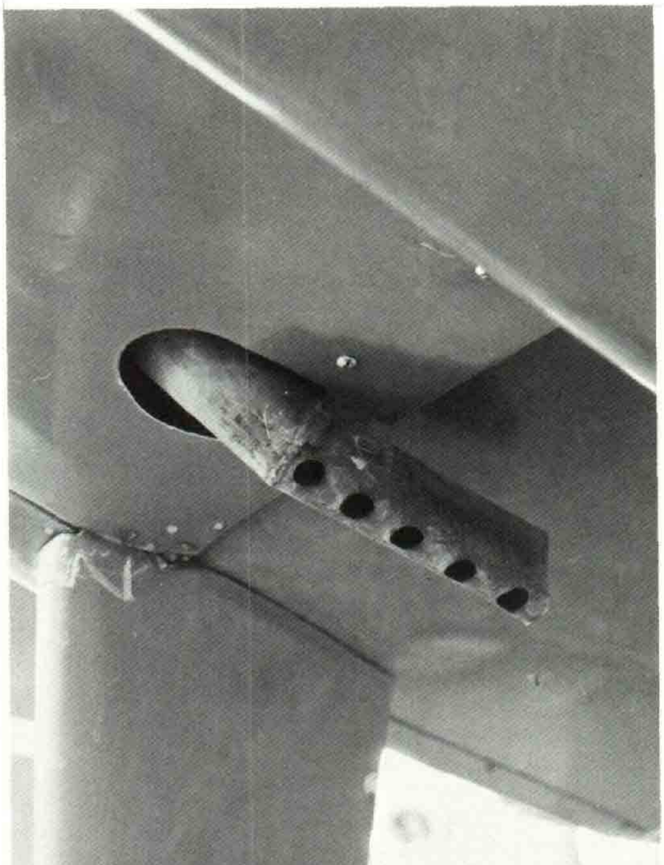


FIGURE 5.

EXHAUST JET/COOLING SYSTEM



(Photo by Noah McCullough)

For minimum drag exhaust pipes are swept and outlets are parallel to the slipstream.

TECHNICAL ADVISORS THIS MONTH —

My thanks to:
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EXHAUST SYSTEMS PART IV — MUFFLERS AND HEAT MUFFS

THE DESIGNEE CORNER

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The addition of a muffling system on an aircraft normally results in a loss of performance and an increase in cost and weight and maintenance. Consequently, I wasn't too surprised to find that only 1 out of 10 homebuilts in this area (Central Texas) has mufflers installed. It seems that many homebuilders subscribe subconsciously to the philosophy that anything not on the airplane will never break, slow you down, or cause you trouble.

Why then, should any builder even consider the difficult business of adding a muffler to a homebuilt? Mostly, I suppose, for his own sake. A quiet airplane will reduce the harmful effects its noise may have on one's hearing. A permanent degeneration of hearing can result from continued over exposure to certain ranges of sound. Somehow too, a quiet airplane seems to convey the impression that it is better built and safer.

Of course, another reason for considering the installation of mufflers stems from the growing pressures being manifest by both society and government against unnecessary noise. And amigos, what is music to your ears is nothing more than an annoying racket to the non-simpatico. Inevitably, governmental regulation soon follows each new public movement. Environmental and noise regulations have for some time now, been imposed on jet aircraft. Other regulations will affect all light aircraft under 12,500 lbs. manufactured in the standard category, including aerobatic aircraft and restricted aircraft. Although the amateur-built aircraft may not be specifically indentified in these regulations, it behooves the thinking builder to exercise some restraint in unleashing a noisy airplane on the public. I believe we should all try to muffle or at least subdue the sharp bark of our engines.

Unfortunately, any significant loss of available power in lightweight aircraft powered by a small engine is considered as unacceptable. This may be the reason you will only rarely find a muffler installation in a homebuilt powered by an engine of less than 65 hp. Mufflers are particularly rare in VW engine installations.

To muffle the engine noises caused by combustion and the turbulent gas flow you must somehow smooth out, or at least modify the normal exhaust pulsations. Longer pipes, do, of course, help a bit. Some builders also add unusual treatments to the ends of the exhaust pipes in order to effect some modification in the exhaust pulsations. One such variation is to flatten the last 6 to 8 inches of the tail pipe and to drill random holes in it. This type of tail pipe modification is standard in the VW powered Fournier. Walt Lane's Turner T-40 (*SPORT AVIATION*, Feb. 1974) uses a similar tail pipe treatment with the holes serving as louvers to help accelerate the flow of gases. Although these tail pipe designs do help alter the noise patterns, they are not true mufflers in the sense that the engine combustion noises are significantly suppressed or reduced. It is interesting to note that Walter Lane constructed his tail pipes so that they would both exit at the same point, and as close together as possible for improved sound modification. (See Photo)

MUFFLER CONSTRUCTION

The standard aircraft muffler consists of a tube of some finite length and diameter. It is usually a rather large stainless steel tube and may or may not have built-in internal baffles. The practice has long been to construct aircraft mufflers with baffles and with the inlet and outlet tubes often staggered. In some mufflers the exhaust gases are forced to change direction drastically in their pell mell trip to the free atmosphere.

To construct your own muffler with similar baffles built-in, is a chore of questionable value unless you have some relentless urge to experiment. The practical thing would be to omit the baffles completely as they usually are the first point of failure in the exhaust system. The occurrence of collapsed baffles in standard category aircraft often obstructs the flow of gases and has been known to cause serious loss of power or engine failures.

Mufflers are most effective when they are located as close to the exhaust outlet of the cylinder as is practical. The Cessna 150 is one example where this concept is effectively practiced. Its individual mufflers are hung on each side of the engine on short exhaust risers.

In some Piper models too, the crossover system mufflers are intergrated as far upstream as possible.

As for muffler size, the Cessna muffler is about 4" x 10" (it looks bigger with the shroud around it) and should be considered as the mimimum size for the muffling job on hand. With due regard for the extra weight and lack of space under the cowling, the builder should nevertheless, if he wants a quiet airplane, make his muffler or mufflers as large as possible.

Forget about internal baffles as their usefulness is questionable when everything is considered . . . instead make the diameter as large as possible. A good length of tail pipe downstream from the muffler will increase the effectiveness of the muffler noticeably and will assist in smoothing out the pulsations of the exhaust gases.

The expense of a good aircraft muffler tends to keep them off most homebuilts. However, any builder can incorporate a standard aircraft muffler into his exhaust system with very little difficulty.

The use of automotive or motorcycle mufflers is an idea of doubtful merit as they are much too heavy for aircraft use. Still, I wouldn't be a bit surprised if someone did come up with a serviceable lightweight muffler that could be used on an aircraft without a high weight penalty.

Building your own open chamber muffler would be more difficult than fabricating the basic exhaust pipe portion of the system. And most of us simply would not undertake the construction of a muffler. The FAA, in its Inspection Aids, reports that exhaust system failures occur frequently in and around the muffler. So, it is evident that the construction of a hand

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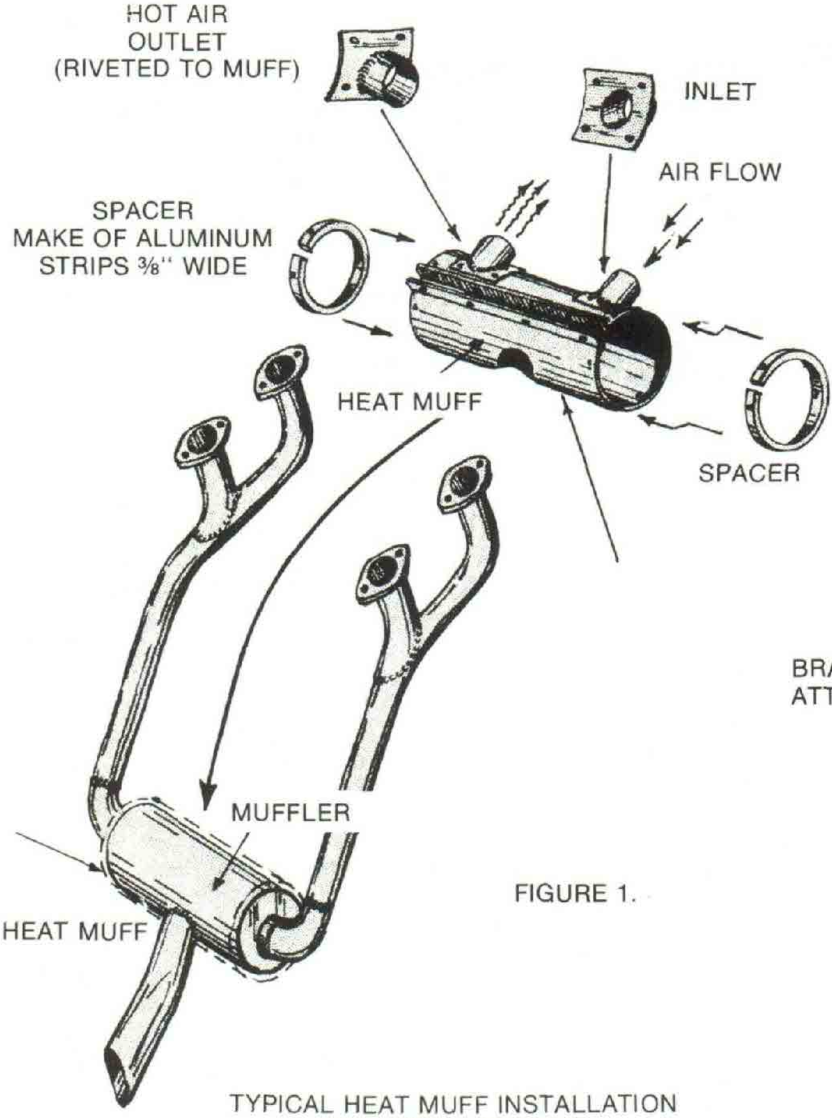


FIGURE 1.

TYPICAL HEAT MUFF INSTALLATION
(UTILIZING MUFFLER)

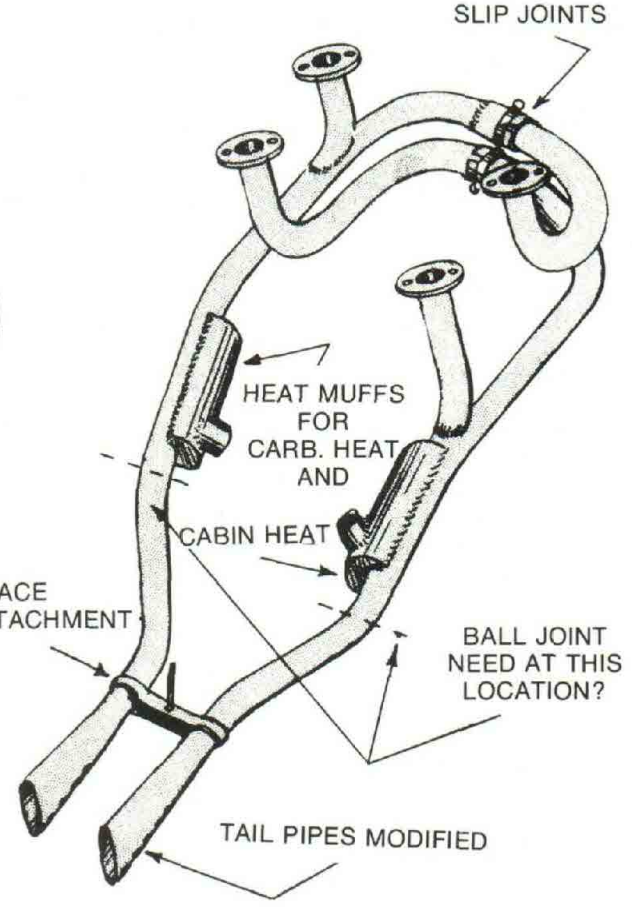


FIGURE 2.

CROSS-OVER EXHAUST SYSTEM (ND MUFFLER)

DESIGNEE CORNER . . .

(Continued from Preceding Page)

made muffler would have to be quite good to be free of similar difficulties.

HEAT MUFFS (Shrouds)

Warm air for heating the cabin, or for warming your feet and ears in an open cockpit job is obtained by encasing a muffler or a portion of an exhaust pipe with a metal shroud (or muff) and causing air to circulate around that hot pipe or muffler. These wrap-around heat exchangers may be made of .015" stainless steel or, in some applications, of .025" 2024 T-3 aluminum. One end of the muff (shroud) is usually open; or an air inlet connection is provided, so that air may be directed into the opening and around the hot pipe or muffler. The downstream end of the muff has an opening to which flexible ducting is attached. The other end of the ducting is then connected either to the carburetor heat box inlet to provide carburetor heat, or to the cabin heat control box at the firewall. It is necessary that a shroud be removable for inspection purposes.

The standard sized air inlet and air outlet opening is 2". Regular aircraft high temperature (red) ducting is used for all hot air hook-ups. Other engine installations like the VW may require smaller ducts as the size of the ducting used should match the diameter of the carburetor heat box inlet. These are often about 1¼" to 1½" in diameter.

HEAT MUFFS FOR VW ENGINES

Although mufflers on VW engines are a rarity, these engines still require some sort of a muff or shroud to provide standby heat (if a float type carburetor is installed). Those tiny muffs seen on some VW engines may be strictly for show as they are bound to be ineffective. The relatively short span of exhaust pipe available leaves very little space for a muff large enough to be effective without augmentation of some sort. It is for this reason therefore, that VW owners attempt to boost the amount of carburetor heat by increasing the radiation area within the heat muff. This is accomplished by wrapping a coiled spring (similar to those used to close screen door . . . at least in the olden days) around that portion of the exhaust pipe enclosed by the heat muff. Such a coiled spring transfers quite a bit of heat and improves the heat output to the carburetor considerably. To provide an even greater heat output, it is possible to use two springs tightly wrapped around the exhaust pipe. Attachment of the springs is accomplished by welding a triangular tab to each end of that portion of the exhaust pipe that will be enclosed by the wrap-around heat shroud. Each end of the wrapped spring is hooked to one of the tabs using the small hole drilled for this purpose. (Figure 4)

Many wrap-around heat muffs are made of .025" aluminum but one of

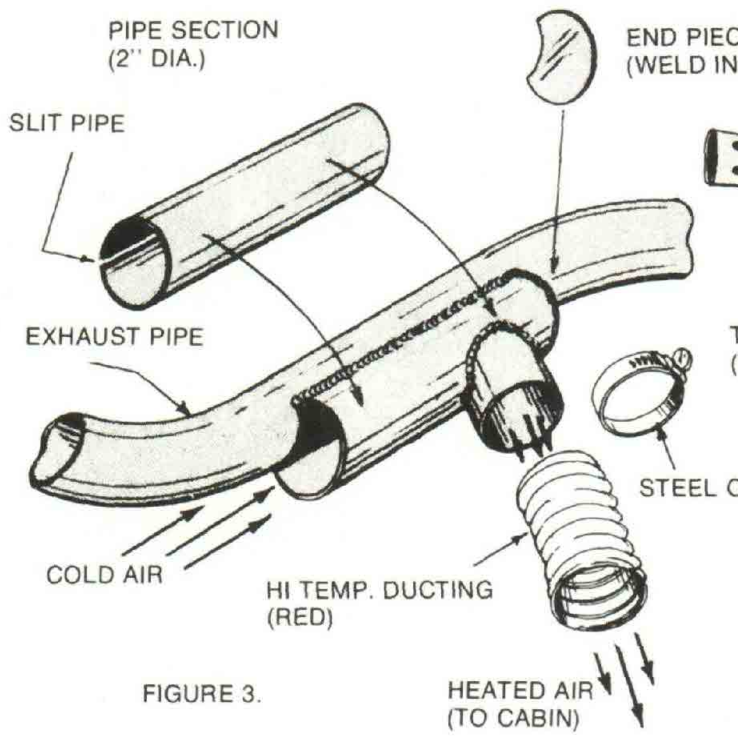


FIGURE 3.

CONSTRUCTING A SIMPLE HEAT EXCHANGER (MUFF)

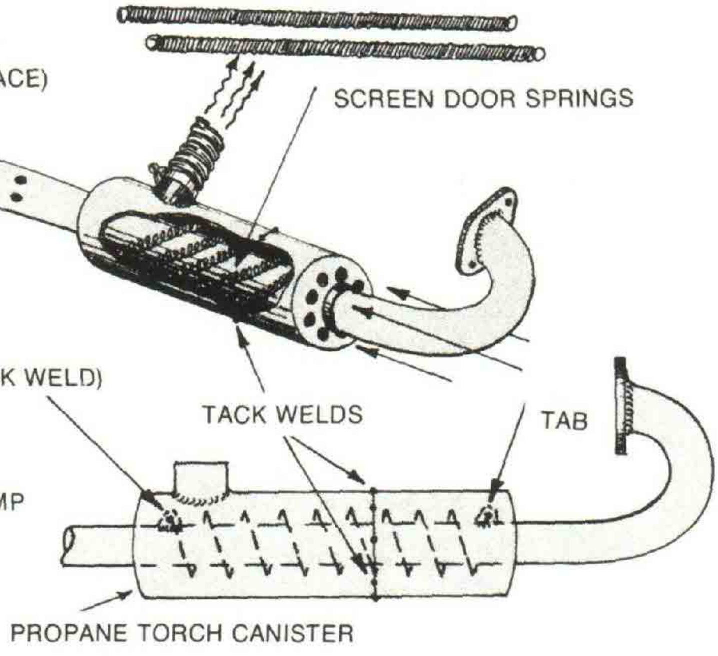


FIGURE 4.

CARBURETOR HEAT MUFF FOR VW INSTALLATIONS

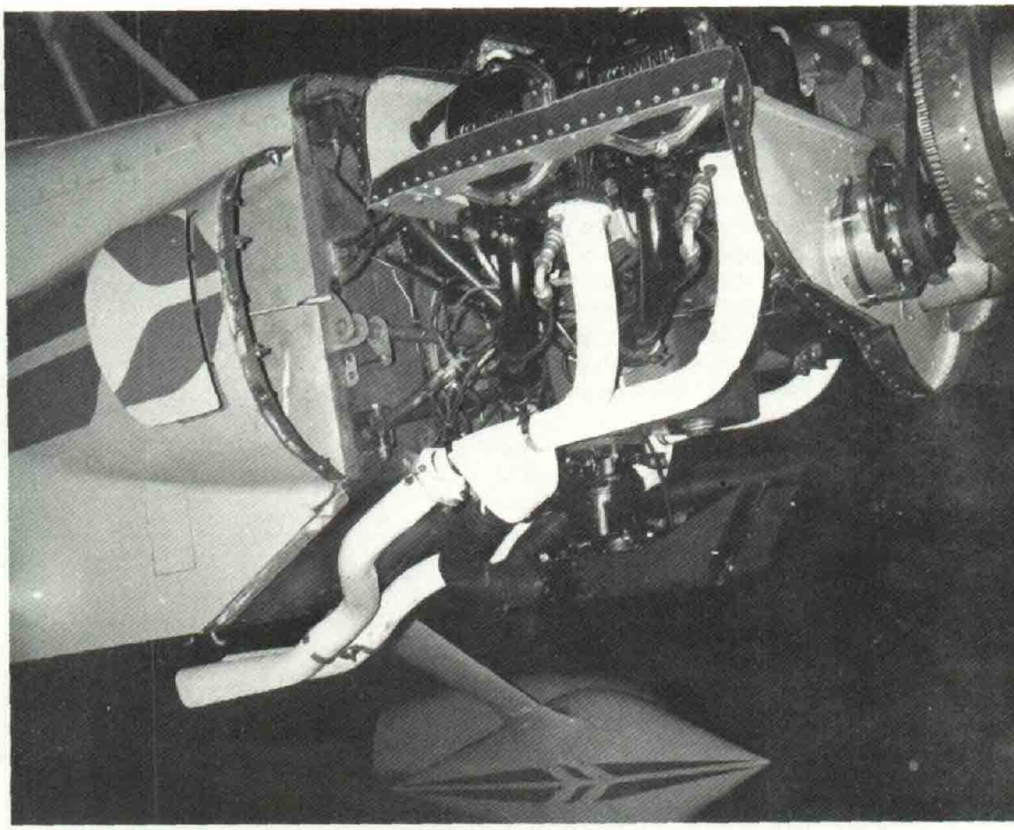
the neatest looking muffs I have ever seen was made from empty propane torch cylinders. You know, the small gas torch cylinders sold thru Sears and most every other hardware store and used by the do it yourself handy man the world over. Needless to add, I suppose, is a reminder that anyone intending to use such a container must exercise caution and assure himself that the cylinder is indeed empty before any welding is done on it. Two such containers can be joined together to obtain whatever length muff you need simply by tack welding them together.

The completed muff makes a professional looking installation with a minimum of work. It will be fairly light in weight and when properly installed, really cleans off the VW intake manifold quickly when moisture and frost appears.

INSPECTION SUGGESTIONS

There is some physical danger in the hot air type of cabin heating system as even a pin hole in the exhaust pipe or the muffler inside the shroud, will permit carbon monoxide to enter the cabin. Although you might think that this is only a winter time problem, it is not so. Carbon monoxide may also enter the cockpit or cabin through openings in the firewall with the cabin heat control in its "off" position.

A related danger is that the failure of an exhaust pipe presents a very



An excellent view of Walter Lane's Turner T-40 exhaust system. Note the heat muff just ahead of the ball joint. This one provides carburetor heat. The pipes are painted with high temperature paint and are not just touched up for this photo.

DESIGNEE CORNER . . .
(Continued from Preceding Page)

real and serious fire hazard. The exhaust flames from a failed pipe can ignite oil or gas fumes present in the engine compartment. This means that a regular check of the exhaust system is essential. A good inspection of the exhaust pipes can be accomplished during each oil change in just a few extra minutes. More difficult, is inspecting the heater shroud areas of the exhaust system as the shrouds hide the exhaust pipes and muffler. Therefore, at some point during your preparations for each recertification inspection, (that's what the FAA calls Annual Inspections for homebuilts) you should remove the shroud from each heat exchanger and inspect the exhaust pipe for failures or signs of impeding failure.

An ice pick or a center punch is ordinarily used to gently probe for weak spots. If you detect any, don't delay in replacing the defective pipe. You may be able to cut out the bad portion and weld in a new section . . . if the surrounding areas are sound. But, it usually does not work to try to weld over an eroded area or to weld a pin hole closed. A cracked bead may sometimes be salvageable in this manner but other areas usually are not.

Two builders can build identical systems. One will be plagued with cracks while the other one appears to be immune. It seems that most exhaust system problems stem from poor welds, lack of proper support, and the effects of vibration. If your exhaust system makes it thru its first 100 hours without any sign of failure the chances are very good that it might last up to 1000 hours without giving you trouble. In most instances any shortcomings in an exhaust system will show up in the first hundred hours of operation.

While the largest frequency of exhaust system failures is attributed to excessive vibration and to thermal stresses, corrosion takes its toll too. Moisture often condenses in exhaust pipes and this combined with extreme heat concentrations, seems to accelerate the development of rust. Gradually the metal is eroded away and pin holes and failures develop. You may have noticed this characteristic particularly in aircraft equipped with automotive pipes as rust forms in their exhaust system components more quickly than on any other parts of the aircraft. Prolonging the life of exhaust pipes has always been a problem and properly accomplished, the painting of the pipes with a high temperature paint will help. A little trick used by the automotive hot-rod buffs to obtain a more durable longer last coating of paint is to pre-heat the exhaust pipes prior to spraying them with the high temperature paint.

An exhaust system is a snap to construct and install . . . if you do not have to install mufflers and heat muffs. A system complete with a muffler and heat exchangers can be a bit difficult to design and to construct properly and may be troublesome to maintain, but the result is a quiet airplane and that's worth it.

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In addition to Tony Bingelis' monthly column, **The Designee Corner,** *EAA Headquarters publishes a monthly Designee Newsletter containing even more "How To" material, a compendium of the previous month's Designee inspections and a summary of all homebuilt accidents occurring around the nation the previous 30 days.*

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