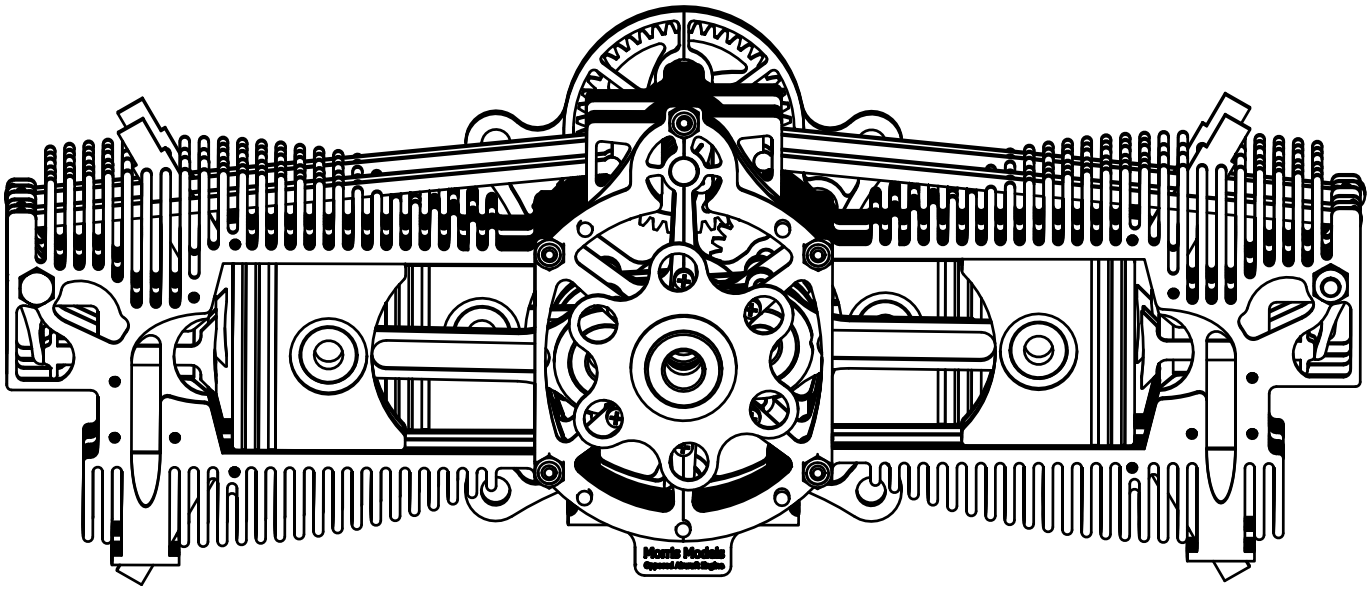
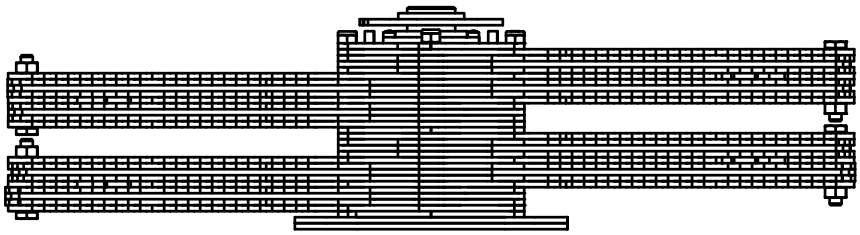
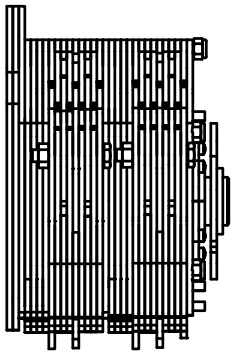
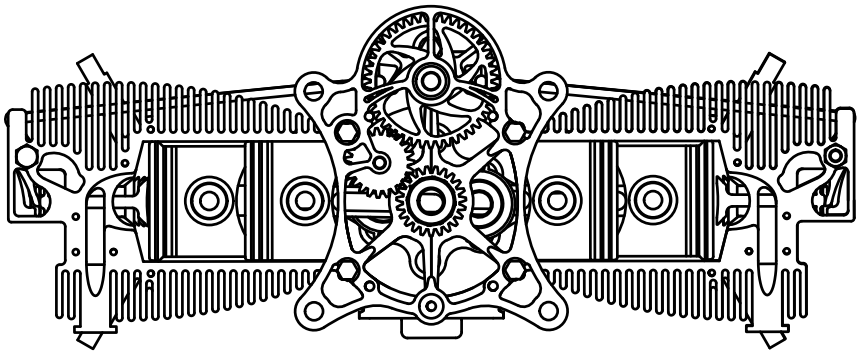
Four Cylinder Opposed Aircraft Engine
Assembly Manual

How to build your skeleton cutaway aviation engine.









Before you Begin

Most of this kit was cut out of baltic birch plywood on a laser cutter. Plywood is a natural product, and every piece is different. Because of this, the laser cannot cut every piece perfectly. This means that in some places, there is smoke and scorching. In other places, the wood did not cut completely and there are splinters hanging on the edges. The more time you spend preparing your parts, the better your completed model will be.

You should begin by making sure that none of the parts are missing. Look over the rest of the steps in this manual, and find all the parts for each step. Check the parts to make sure that they are in good condition. Minor damage can be repaired with glue. Splinters should be removed using an X-acto type knife and sand-paper. Scorched marks can be lightly sanded off. If any parts are badly broken or are missing, you can get replacement parts from www.morrismodels.com.

Many of the parts for this kit are cut from round dowel rods. These form most of the shafts. These also should be sanded for splinters. If you have access to power tools, they can be made to look a little more realistic if you bevel the front of each shaft and drill holes through the bodies of the shaft. The parts shown in this manual have had this done, but this step is for appearance only, and is completely optional.

This engine is designed to be assembled with any type of wood glue. I personally use Elmer's "Glue-All" glue. Do not use Elmer's "School Glue." It will not work. Whatever glue you use, use only enough glue to stick the parts together. Extra glue will squeeze out from between the parts and stick the engine together in places where it should not. Any glue that does squeeze out from between parts should be wiped up with a damp cloth while it is still wet.

Most of the plywood parts have 1/8" or 3/16" holes. These holes are to help line up the layers. As you work, try to keep the glue away from these holes. When you put on a new layer, push short dowel pins into the layers to help line tham up. These are called alignment pins. You should remove the alignment pins after the glue has had a few minutes to dry.

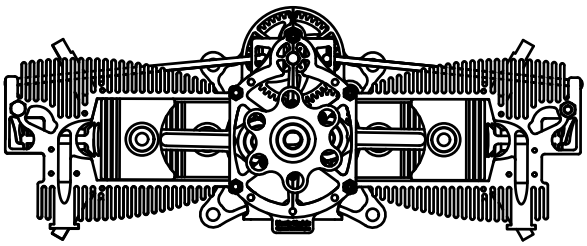
Many people ask if they can varnish, paint, or stain the engine. I do not recomend using paint or varnish, but oil-based finishes or stains are appropriate. Assemble the engine before using them. Another alternative is to use water-based markers. You can color each part before or after it is assembled. These parts absorb a lot of marker ink, so it will take quite a few markers to do the job.

Real engines use oil to keep them sliding smoothly. This wooden engine model would be ruined with oil. Most people use wax when assembling these wooden engine kits to help the parts slide smoothly. This step is optional. I have used candle wax and I have used colored crayons. Either of these will work fine. So does paraffin wax. I have also assembled quite a few of these engines without any wax. This also works. Just don't use wax on your engine before gluing the parts together, as this will interfere with the glue. It will also interfere with staining or painting the parts, so plan ahead.

This manual shows how to build the engine step by step. Sometimes it is hard to explain things in a manual, but easy to understand it on a video. At the www.morrismodels.com web site, you can find a link to an assembly video that shows the same steps that are in the manual. Use this video if you prefer, or use the video to view any steps where you have trouble understanding the manual.

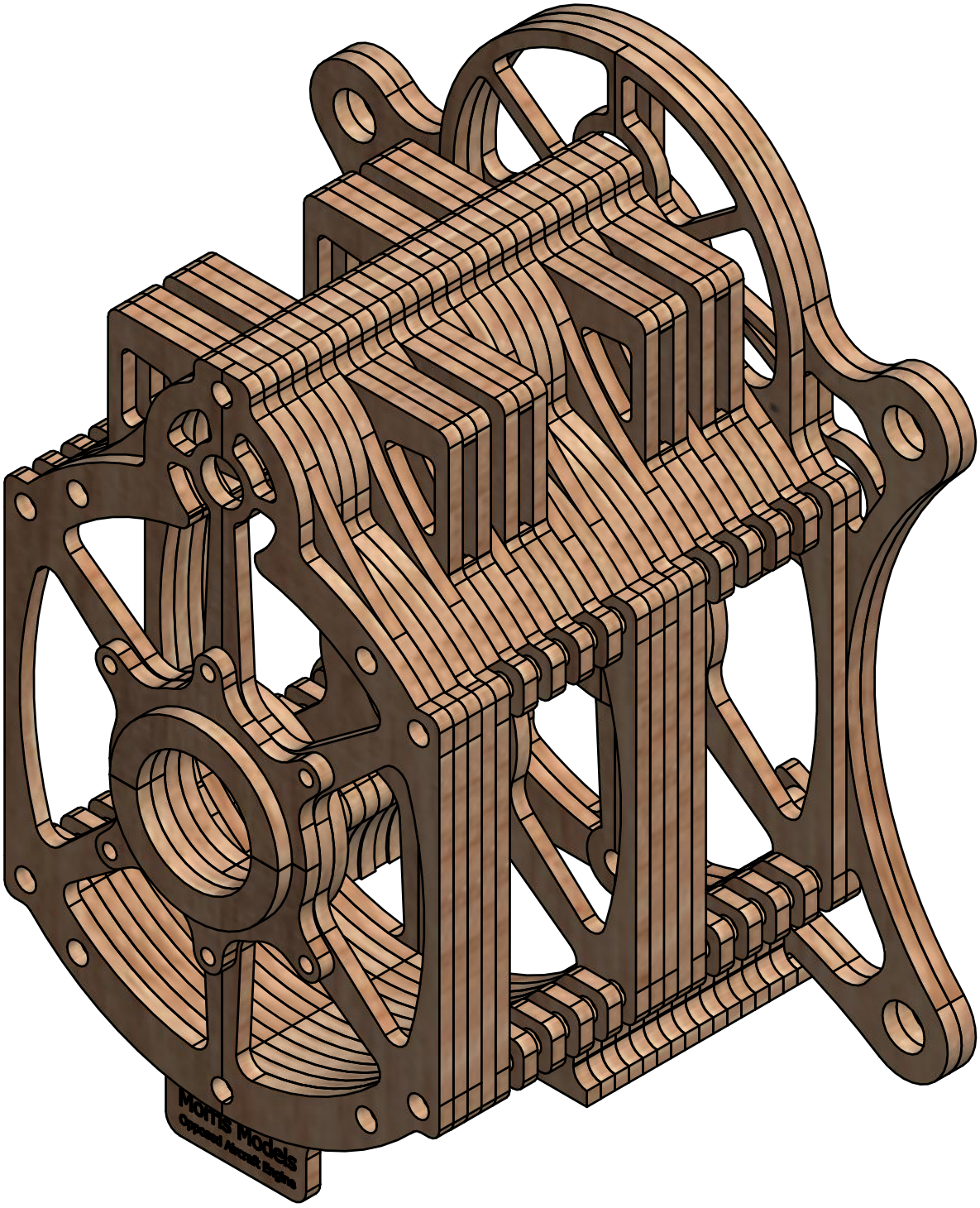
I hope you enjoy building this kit. If you do, you may want to consider building some of the other model kits. We have several more models available on the web site, and we add another model every few months - so check back.

Right and Left



And now a word about right and left. These directions may be confusing in this booklet, and you may think I have made a mistake when they refer to right and left on the engine. When you work on an aircraft engine, you may be facing any direction. However, when referring to the right and left side of the engine, you always refer to the pilot's perspective - sitting behind the engine. I have tried to follow this rule in this booklet.

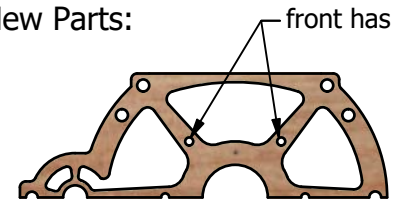
Section 1: Crankcase



The crankcase is composed of 33 separate layers of material, many of them repeating. It is divided into two main blocks with separable walls in between them. An accessory case on the rear of the crankcase houses the timing gears and also provides the engine mounts for wall mounting. The parts are held together by 5 through bolts running in the axial direction, and 6 separate nose peice screws. The hardware is not shown in the diagram above.

Crankcase Nose, Front, and Rear

New Parts:



Case Front x 2

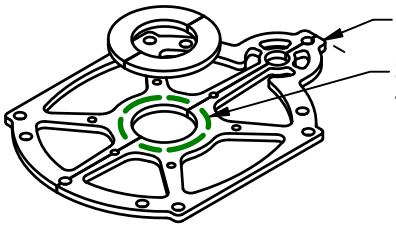
Thrust Bearing Half x 2

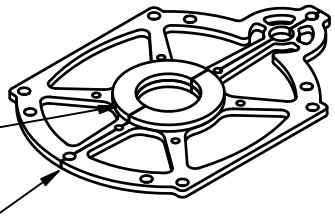
Nose Spider Half x 2

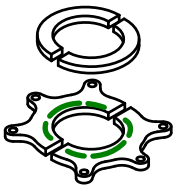
Nose Ring Half x 2

Size comparison: Thrust Bearing Half

The two case front halves are identical. You will need to build one left hand, and one right hand. Set the best combination of faces down in front of you as shown. Glue a thrust bearing half to the bore of each side, also as shown. Clean up any squeeze-out before the glue has time to dry.

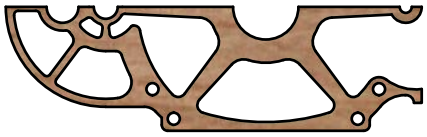




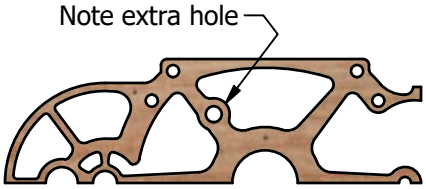


The case nosepiece is assembled identically to the case front. Once agin, lay the pieces out, spread a thin layer of glue to each side, and glue the pieces. Keep the bore alignment true, and clean up any glue squeeze-out.

New Parts:

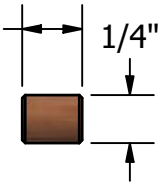


Case Rear Right



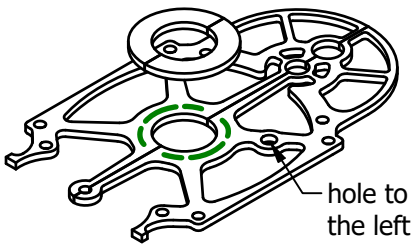
Case Rear Left

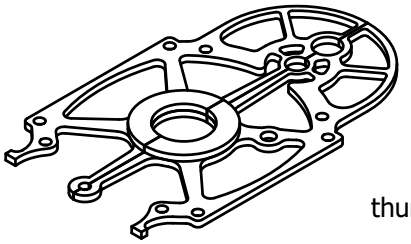
Thrust Bearing Half x 2

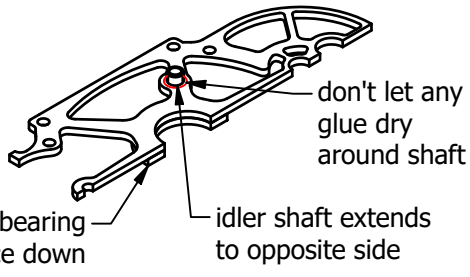


Idler Shaft (full sized)

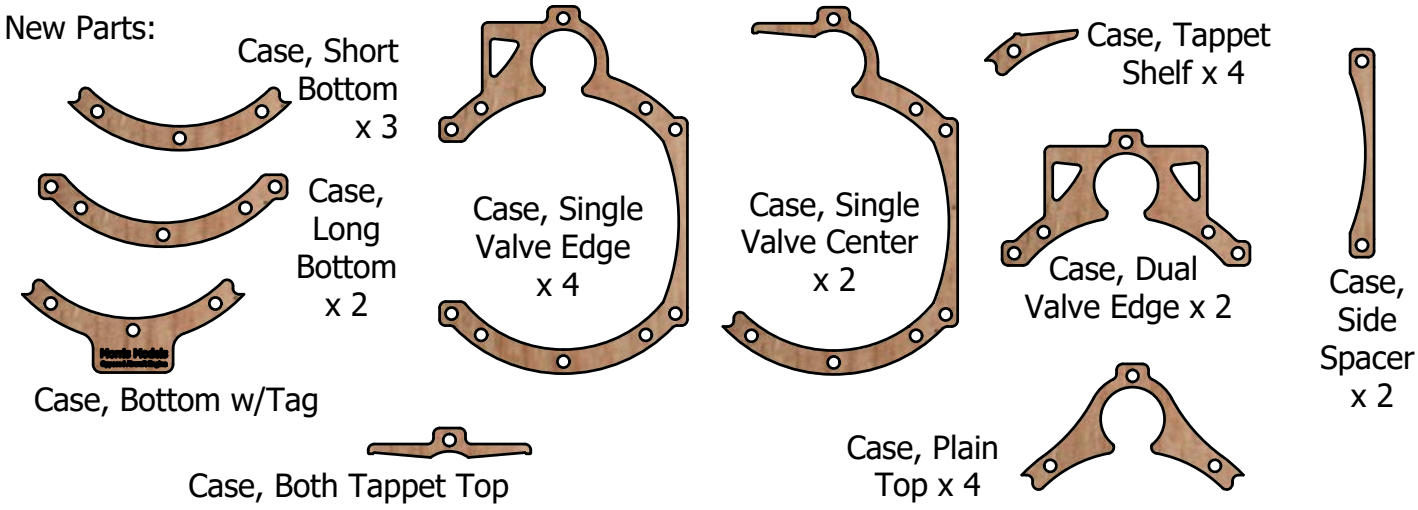
The two rear case halves are not identical. Be sure to arrange them as shown. Glue the thrust bearing halves in the same way as on the case front. Clean up any squeeze-out before the glue has time to dry. After drying, glue the idler shaft in the extra hole on the left rear half, making sure that the shaft extends to the opposite side as the thrust bearing.

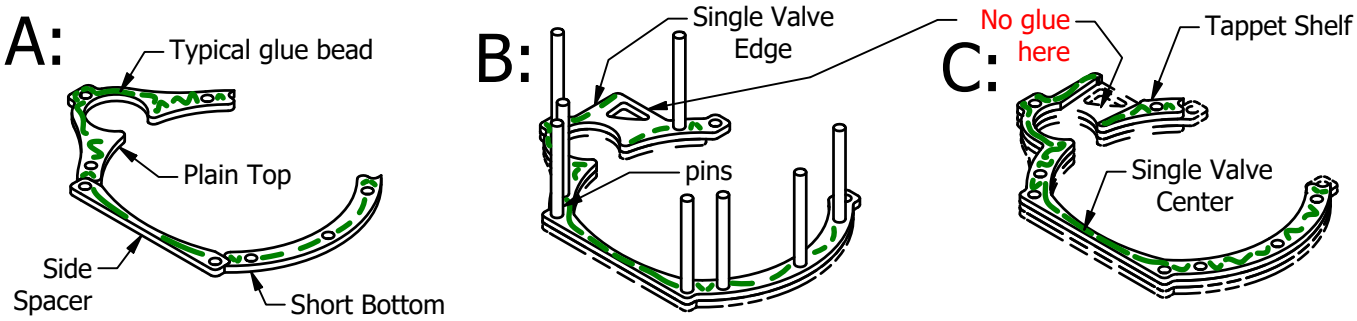






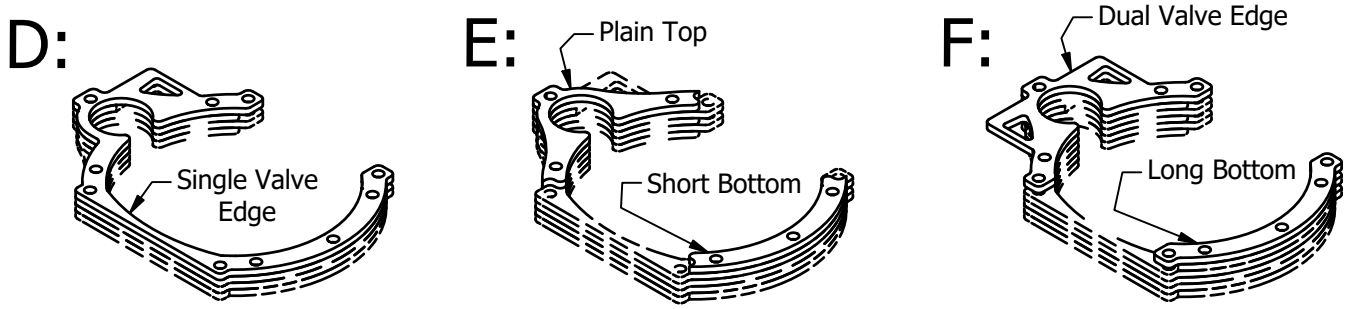
Crankcase Forward Section





Typical glue beads are noted in green.

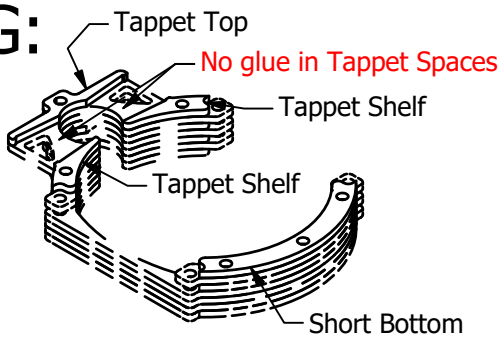
Begin the forward section of the crankcase by laying the three parts as shown. Add a thin bead of glue. Add temporary 3/16" diameter alignment pins, and fit the next layer over the pins. Press this layer firmly onto the first layer. Do not glue the alignment pins in place. Work layer by layer as shown, pausing often to make sure that the alignment pins are not glued into place. Alignment pins are not shown in the next steps, but are used wherever possible. Don't let the glue bleed out into the valve lifter areas as noted in B and C - or into any of these areas in the following steps.



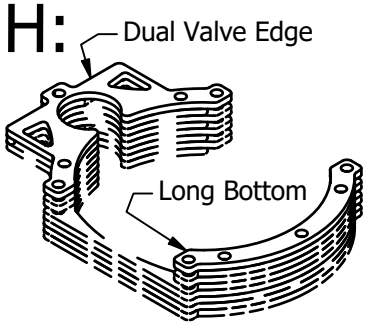
Glue beads similar to above.

Forward Section Continued

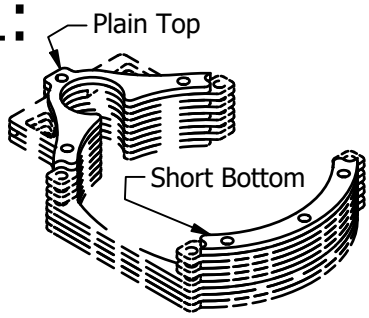
G:



H:

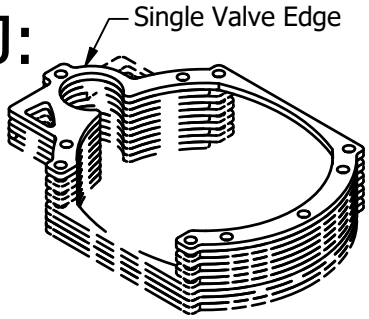


I:



Continue layer by layer, making sure that you clean up any glue squeeze-out and that no glue blocks the valve lifter areas (tappet). Pause regularly to make sure that your alignment pins are not glued into the case.

J:



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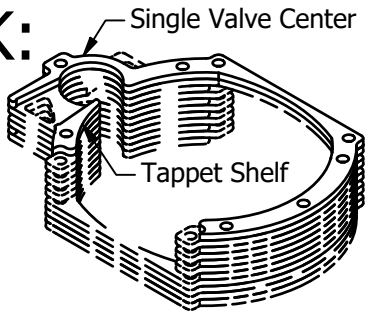
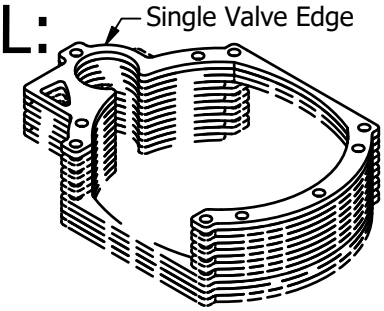


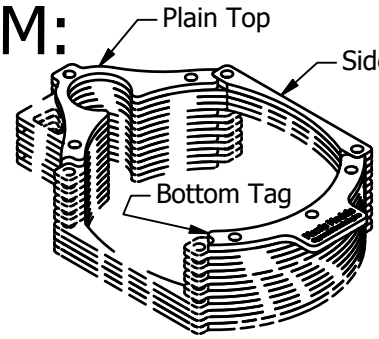
L:



Again, make sure that none of the alignment pins are stuck in their sockets.

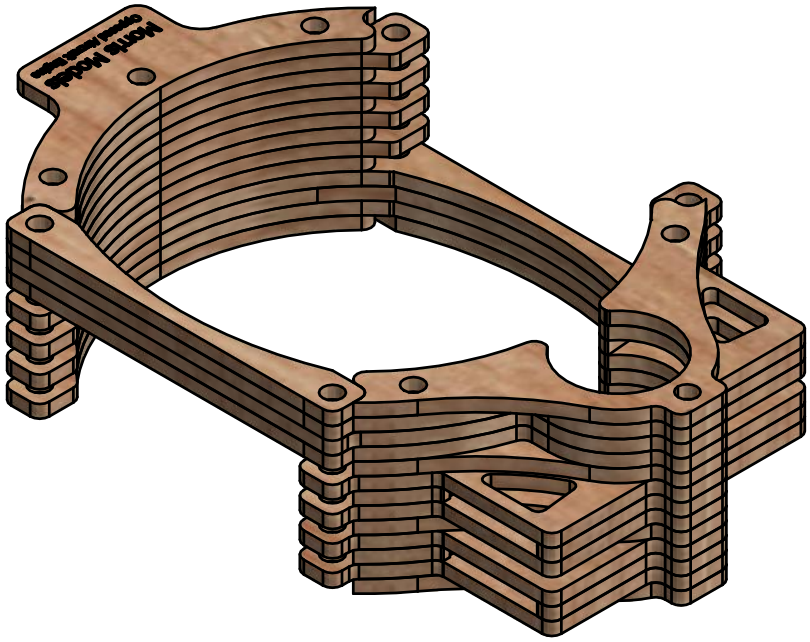
Set the completed forward section of the case aside to dry.

M:



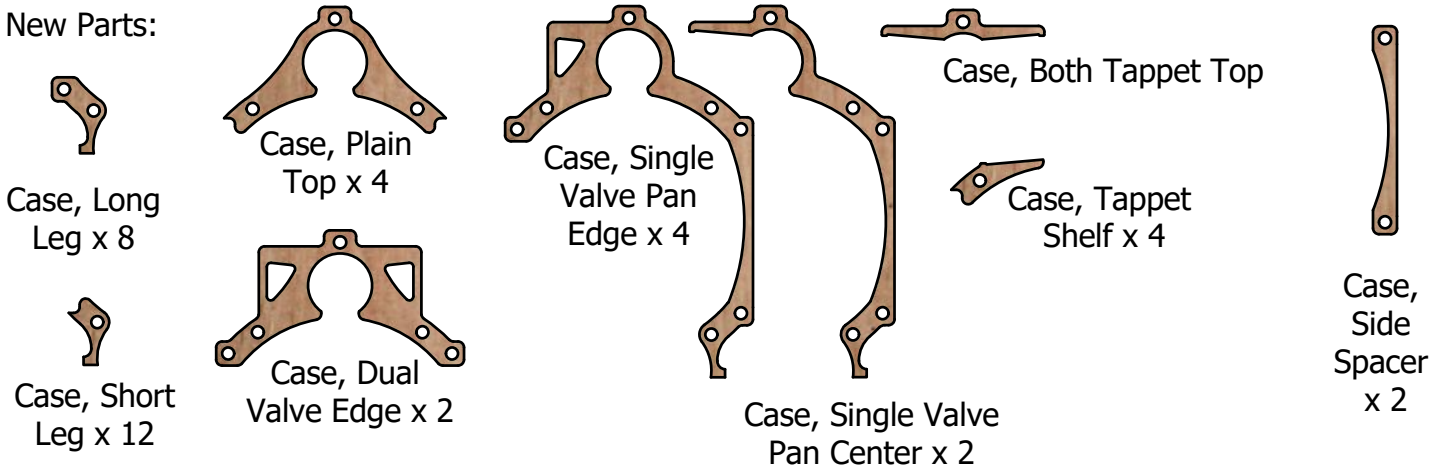
Forward Section of Crankcase

Alternate View Angle

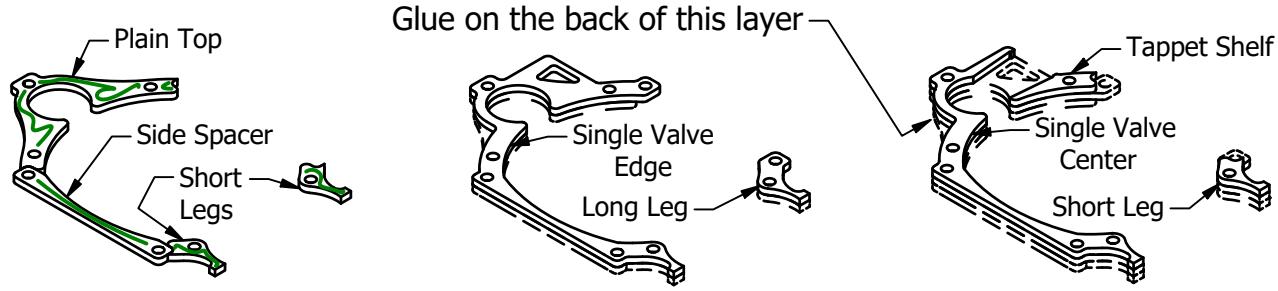


Crankcase Rear Section

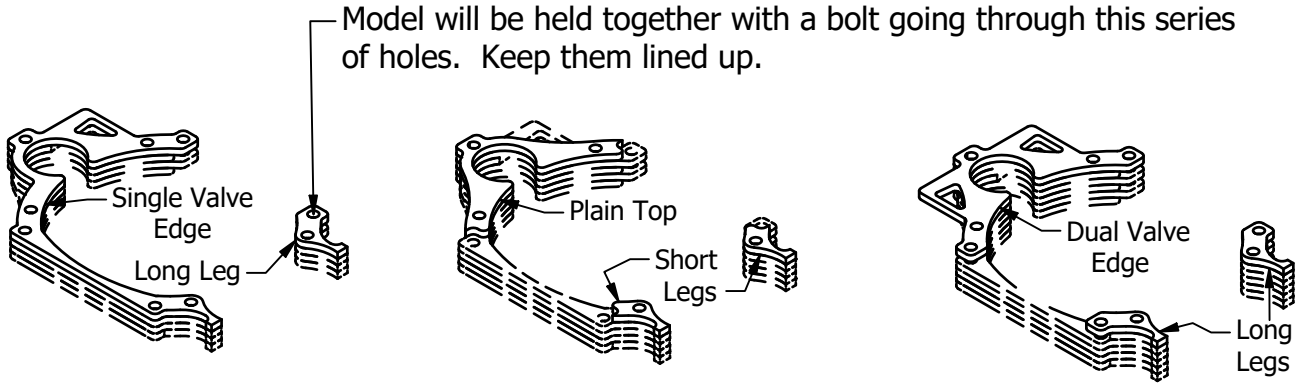
New Parts:



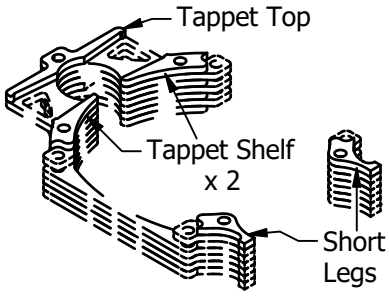
Build the rear crankcase section layer by layer as shown in the diagrams. Glue joints are similar to those in the last section.

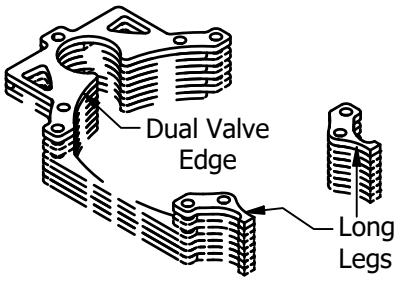


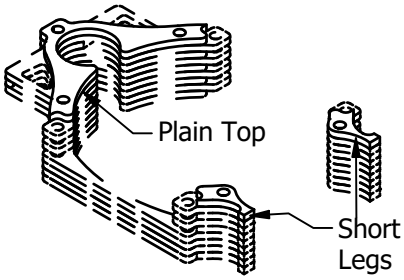
The biggest difference between the forward and rear sections of the crankcase is that the rear section has a cutout in the bottom. In the real engine, this section provides a location for the oil pan. In this model engine, it provides you with an opportunity to demonstrate your advanced modeling skills. Use alignment pins as you continue construction of this part of the engine. The alternating short and long legs produce a series of dovetail slots for the cylinders to join. Keep them straight and aligned as you work.



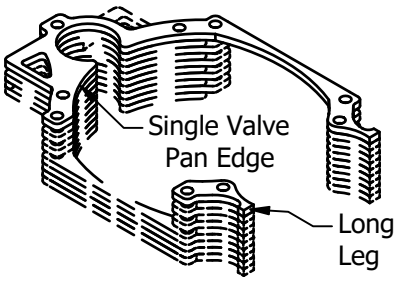
Crankcase Rear Section

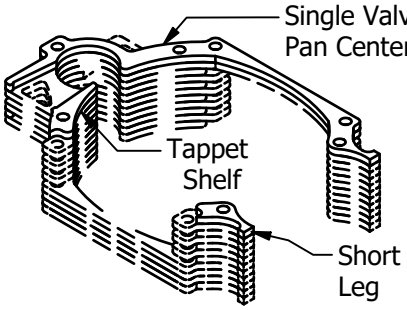


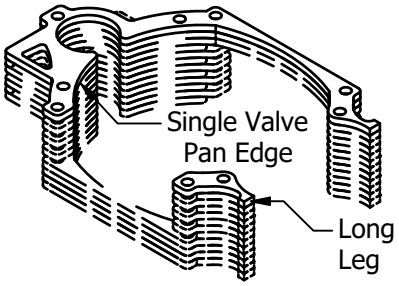


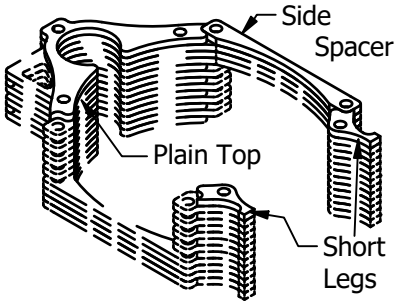


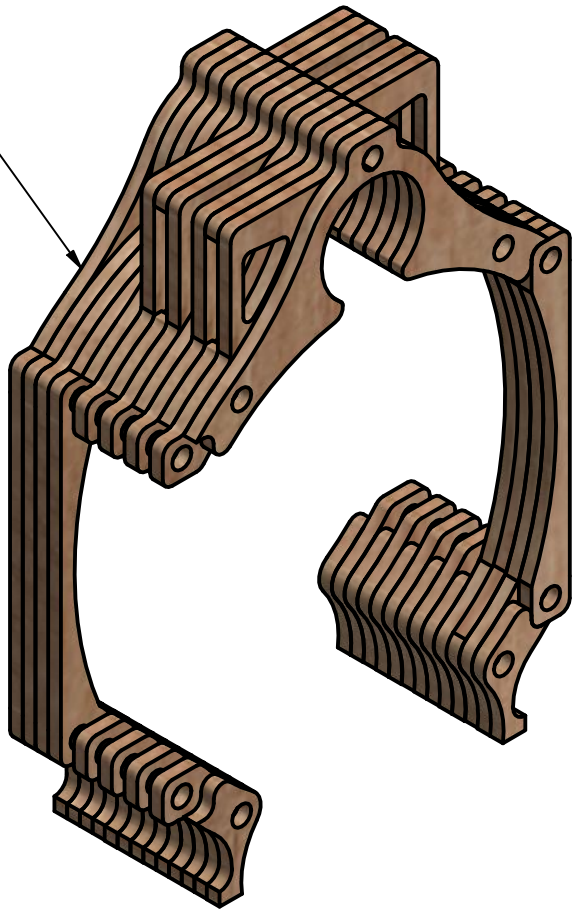
Continue working layer by layer. Careful alignment now will make later assembly possible. Glue the layers down, but don't let the glue get messy. Don't let the holes get glued, either.



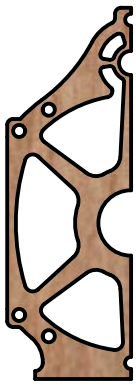




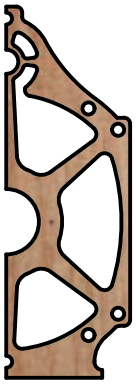




Case Centers - Left and Right

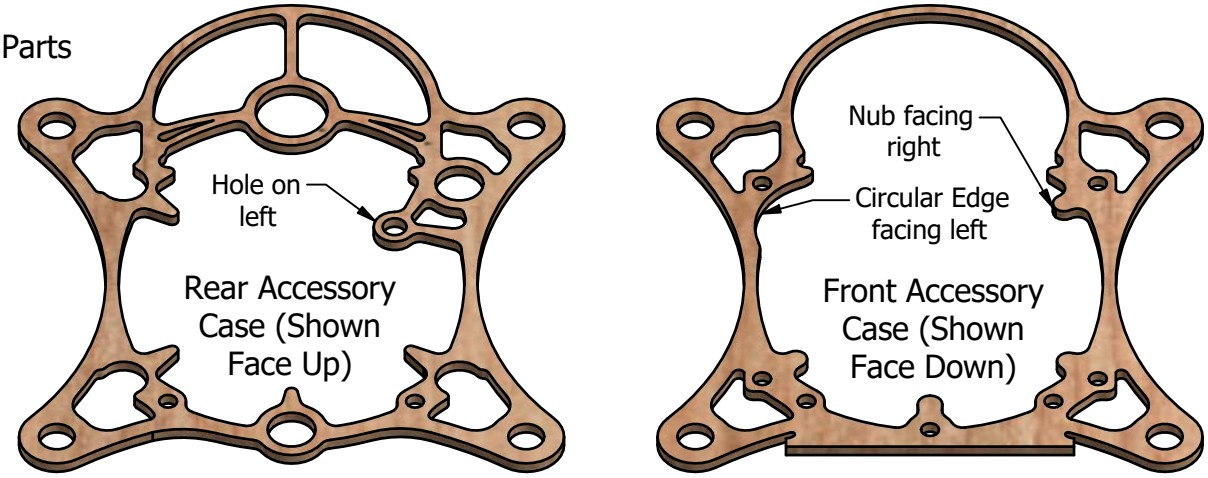


(Symmetrical and inter-changable) These parts are included here for inventory. You will use them when assembling the case in section 7. You don't do anything with them now...

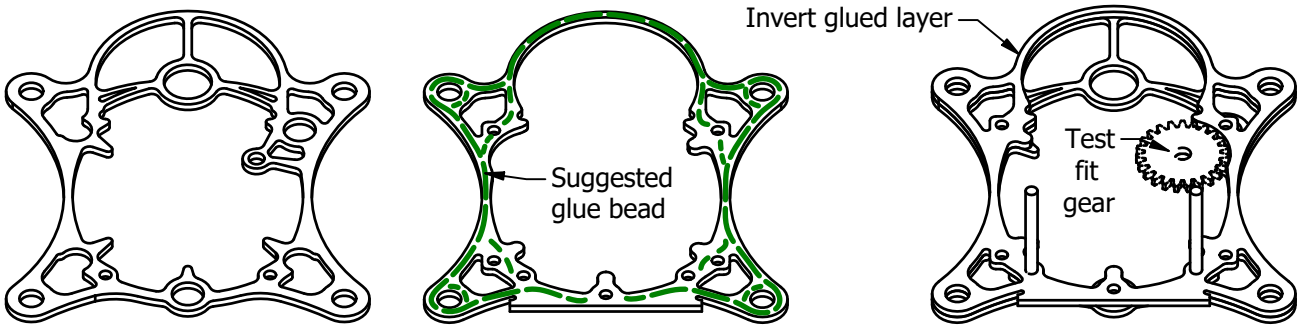


Crankcase Accessory Section

New Parts

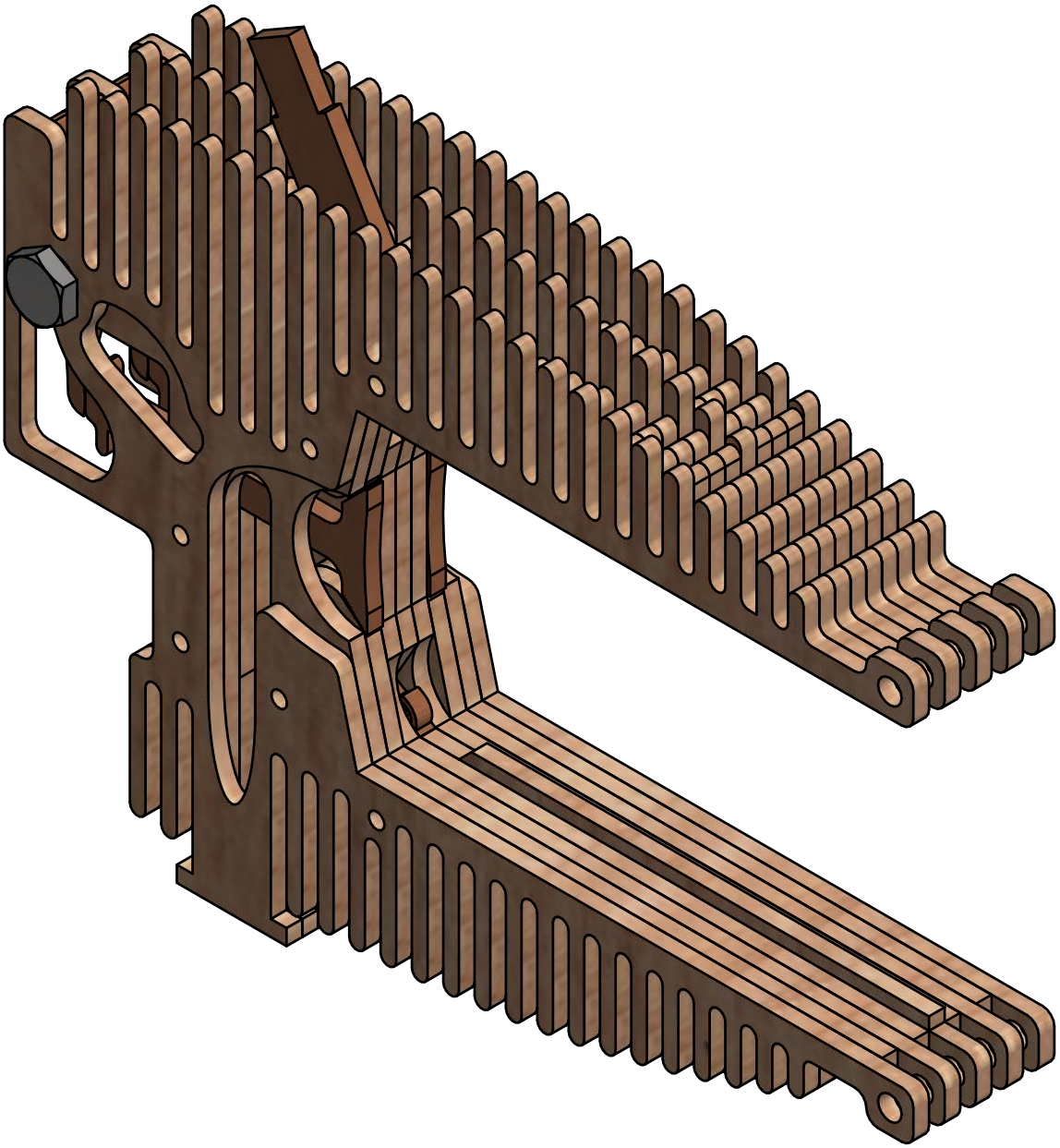


The accessory case parts are not symetrical. Lay out the parts as shown, taking care to observe the identifying details noted. Lay out a thin bead of glue on the front layer as noted below, then invert the front layer and place it on the rear layer as shown. Use alignment pins. The idler gear is shown for reference. Set it in place to verify that you have completed this correctly. Remove the gear and the alignment pins, and set the accessory case aside to dry.



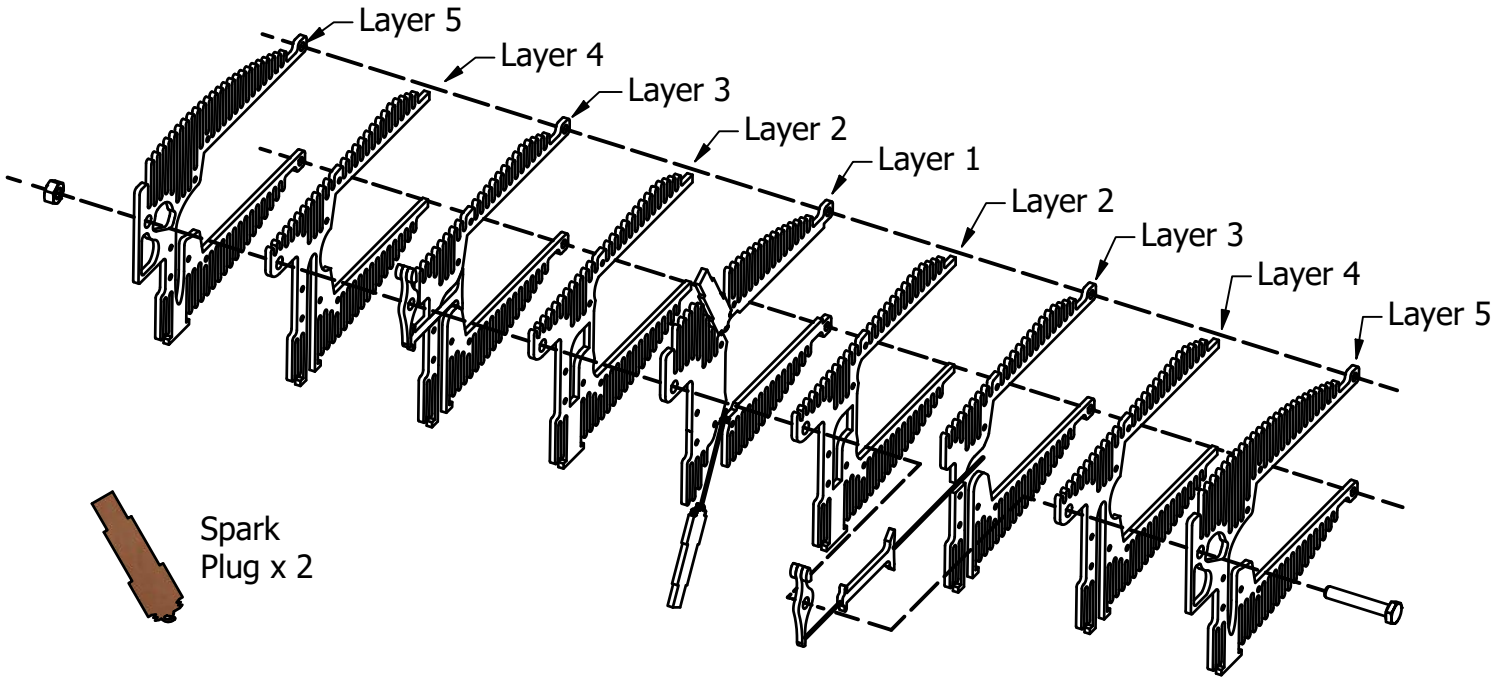
Exploded view of Crankcase

Section 2: Cylinders

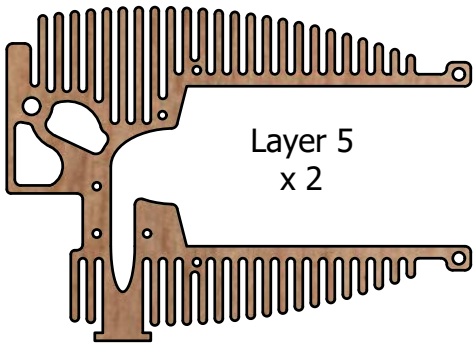


There are four separate cylinders, all of them identical. Each is nine layers thick. The center layer holds a small track for the piston to ride on. Both the intake and exhaust valves are fitted during the construction process, and are not removable. The rocker arms ride on a bolt, and can be removed. There are two non-functional spark plugs in the center layer, which are also not removable. Repeat this procedure four times to build all four cylinders.

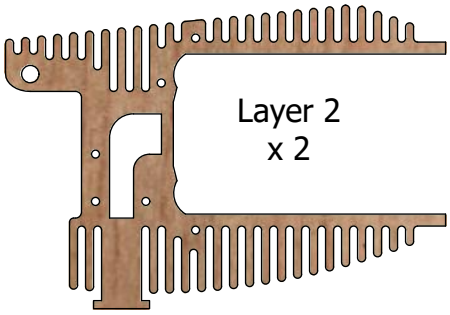
Cylinder Parts (Per Cylinder)



Spark Plug x 2

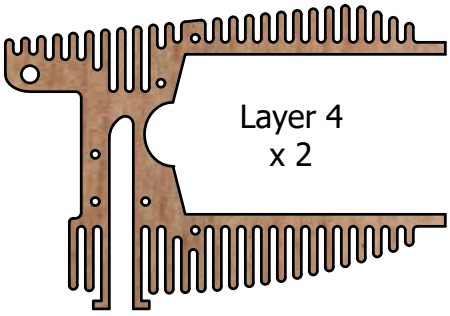


Layer 5 x 2



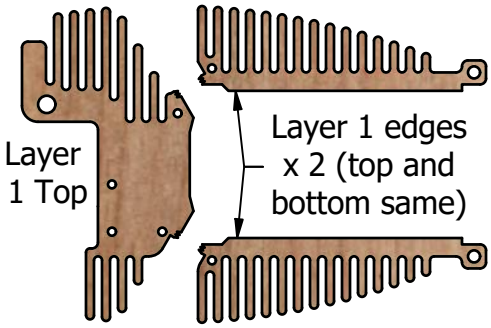
Layer 2 x 2

Spark Plug x 2



Layer 4 x 2

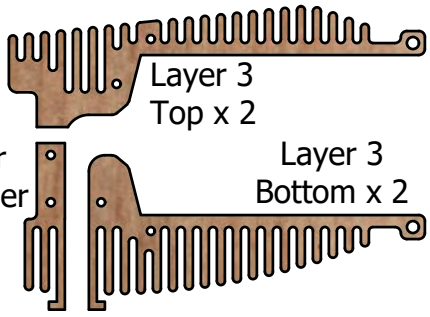
Rocker Caps x 4



Layer 1 Top

Layer 1 edges x 2 (top and bottom same)

Rocker Arms x 2



Layer 3 Top x 2

Layer 3 Corner x 2

Layer 3 Bottom x 2

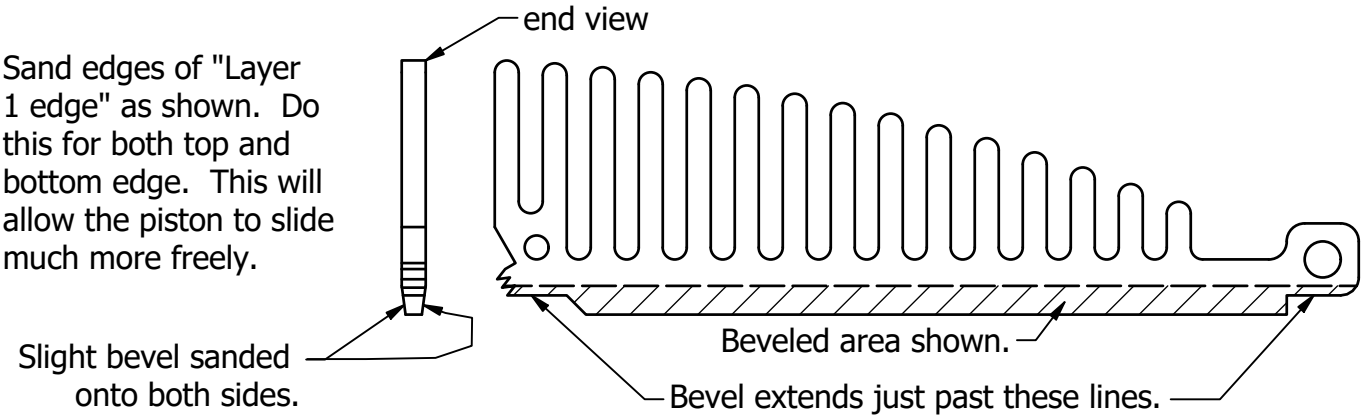
Valve Springs x 2

AN4-12A Bolt (or similar)

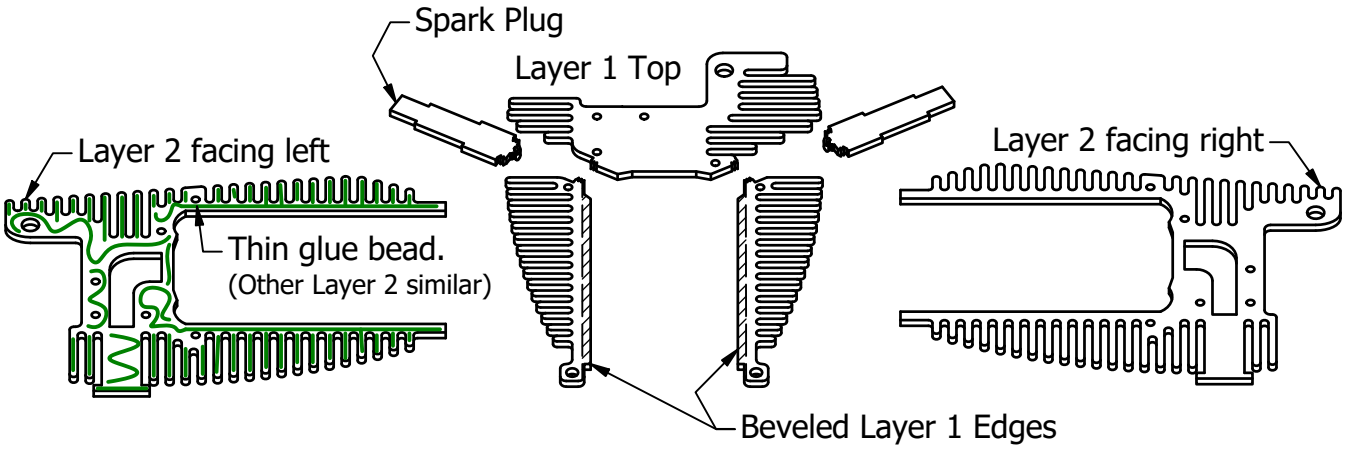
AN364-428A Nut (or similar)

Cylinder Assembly 1

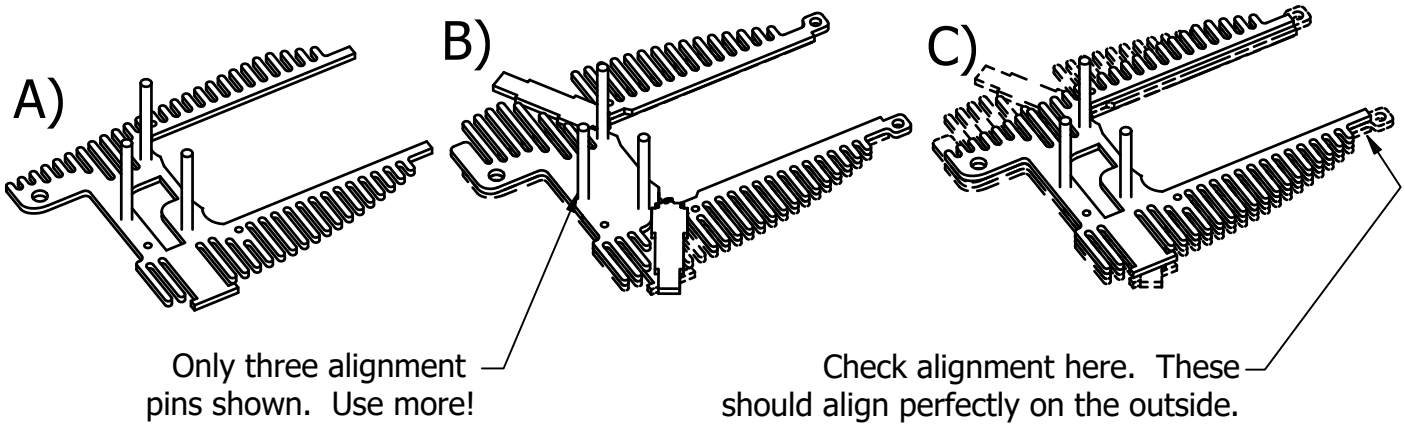
Sand edges of "Layer 1 edge" as shown. Do this for both top and bottom edge. This will allow the piston to slide much more freely.



Lay a pair of Cylinder Layer 2's out with one facing to the left and one facing right as shown below. Lay all three parts of layer one in the center, as well as the two spark plugs. Apply a thin bead of glue to the fins and edges of each Layer 2 (left glue bead shown - right is mirror image).

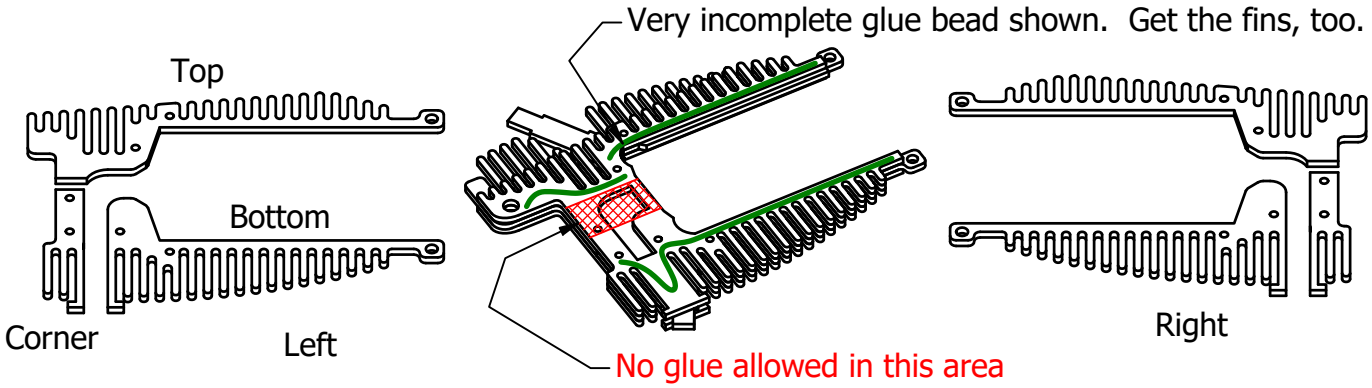


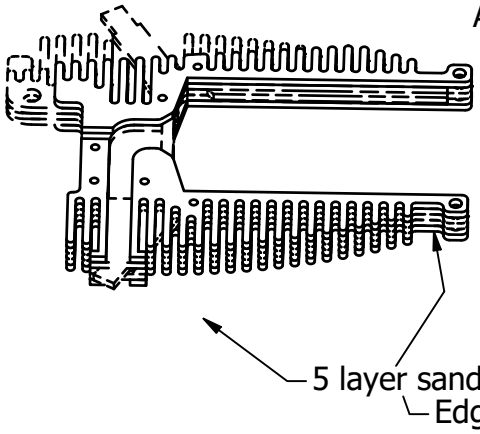
Before the glue has a chance to dry, carefully insert as many alignment pins as practical into one of the Layer 2's with glue (A). Make sure not to get glue on the pins. Carefully set the Layer 1 Top and Edges over the alignment pins and press down firmly. Add both the spark plugs into their sockets (B). Then invert the remaining Layer 2 so that the glue faces downwards. Add it to the growing sandwich (C). Ensure that all of the parts are lined up, then remove the pins and allow to dry.



Cylinder Assembly 2

Locate all the parts of both Cylinder Layers 3 (6 total). Arrange them left and right of the growing cylinder sandwich as shown below.





Add glue to an outside edge of Layer 2 which has already been added to the sandwich. Using as many alignment pins as possible, add the three parts of layer three to the sandwich. Set the sandwich with the freshly glued layer three face down, and add glue to the other side (the other Layer 2). Add the other three parts to this side of the sandwich. Remove the pins, and allow to dry.

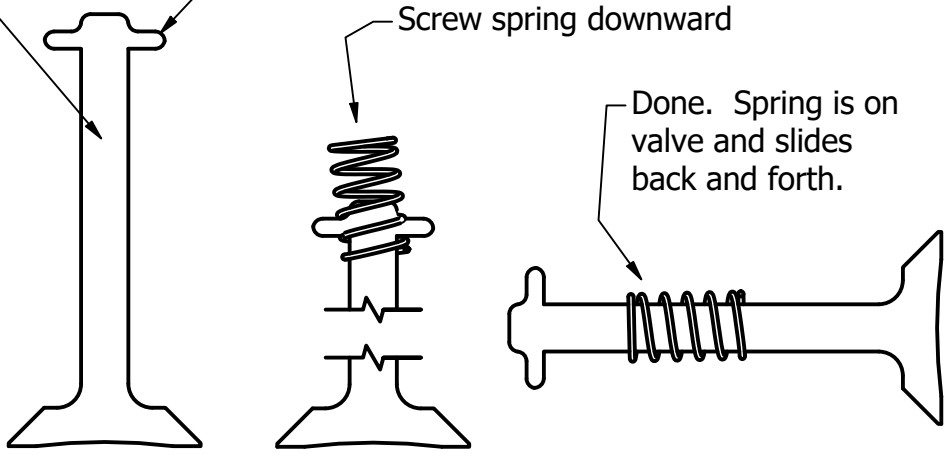
Prepare the valves by sanding one face. The valves must be a little thinner than the other parts of the layer, or they will not slide in and out freely. About 1/64 of an inch is all that must be removed. Dry fit the valves as shown in the next step, and verify that they slide easily before going on.

Sand entire face on one side

retainer end

Screw spring downward

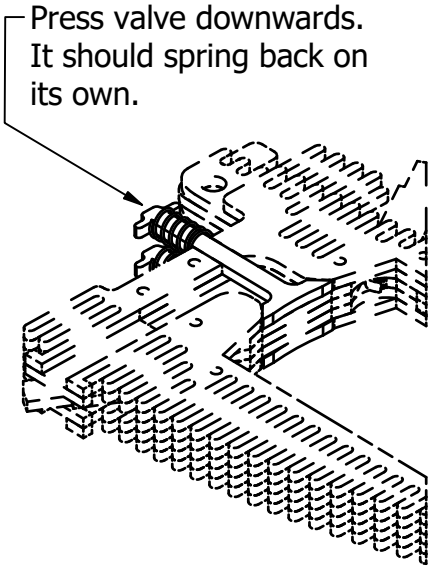
Done. Spring is on valve and slides back and forth.



Thread the springs over the valve spring retainers as shown. You will need to gently spread the ends of the springs before they can go over the retainer ends. The springs should slide freely up and down on the valve shafts.

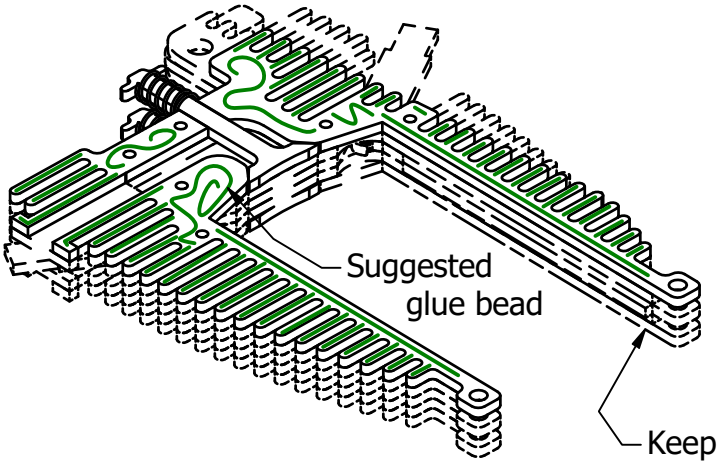
Cylinder Assembly 3

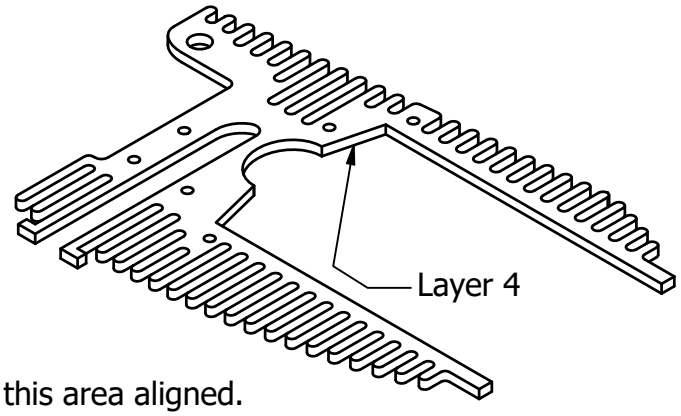
Cylinder is layers are symmetrical. Fit a valve and Layer 4 to each side. Only one side is shown.



It is very important that the valve can slide freely in its slot. Make sure you have sanded one face of the valve (see previous page). Also, ensure that there are no traces of dried glue in the slot that would bind up the valve. If any exist, these must be cut out before fitting the valves.

Compress the spring and insert the valve into the guide slot. The tension from the spring should hold the valve in the slot. Set the next layer into place on the sandwich, and press it downwards. You should still be able to press the valve downwards, and it should spring back closed when you let go. If it sticks in the slot, you need to sand more off of the valve.





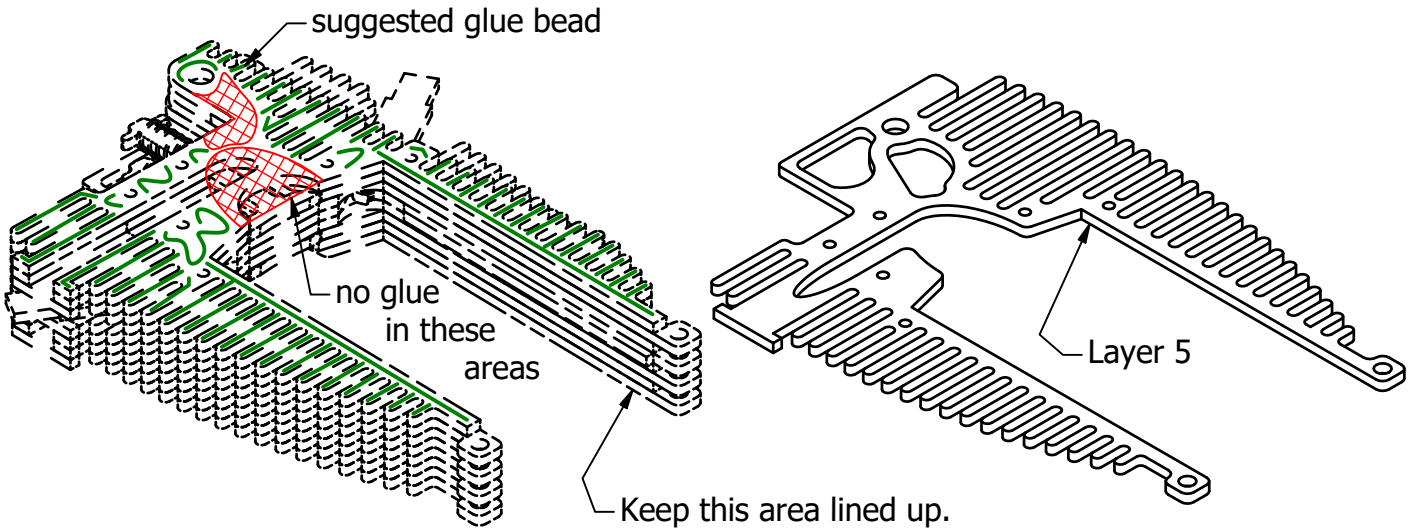
Apply a thin glue bead as shown onto the top of the cylinder sandwich. Avoid the areas around the valve. Use alignment pins, and glue Layer 4 down on the sandwich. Set aside to dry. Once assembly can be handled, invert and fit the valve and layer 4 to the other side.

Much like the valve, the rocker arm will need to be thinned in order to pivot freely. Sand one face until it is thin enough to slide freely between layers.

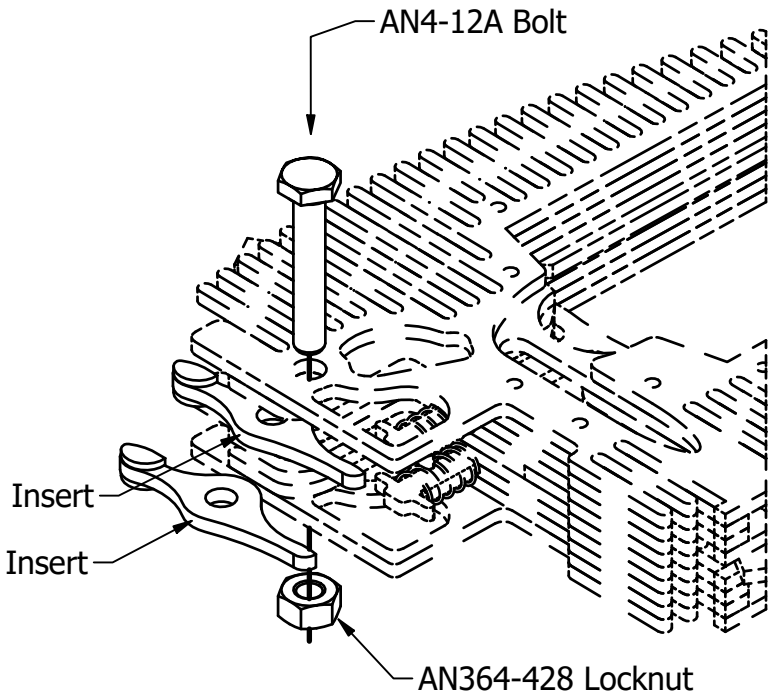
Glue two rocker caps on the sides of the rocker arms, forming a small socket for the pushrod.

Cylinder Assembly 4

Cylinder layers are symmetrical. Fit one Layer 5 to each side. Only one side is shown.



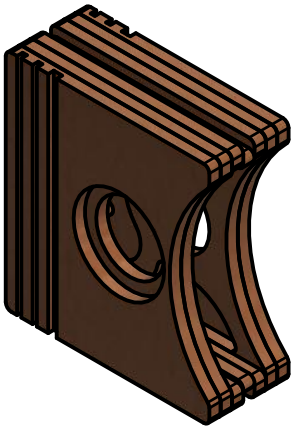
Layer 5 has two cutout areas to allow for visualization. These should not get glued. The diagram above shows their approximate locations, as well as a suggested glue bead. If you set layer 5 in place without glue, you can use a very sharp pencil to outline these areas so you can avoid getting glue on them. Apply a thin glue bead to the rest of the top of the cylinder sandwich. Use alignment pins, and glue Layer 5 down on the sandwich. Set aside to dry. Once assembly can be handled, invert and fit the other side.



Slide the two rocker arms into position, and secure with the 1/4 inch diameter bolt. Secure the bolt with a locknut. Tighten just until the bolt is snug. Don't overtighten. If the rockers will not move easily, sand a bit more off of the face.

One cylinder done.
Three more to go!

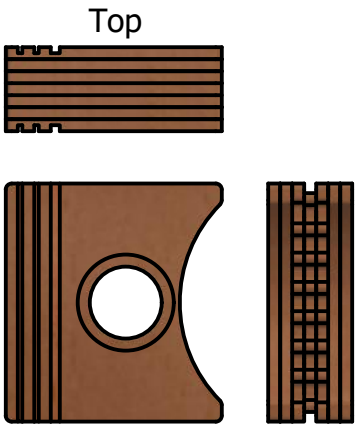
Section 3: Pistons

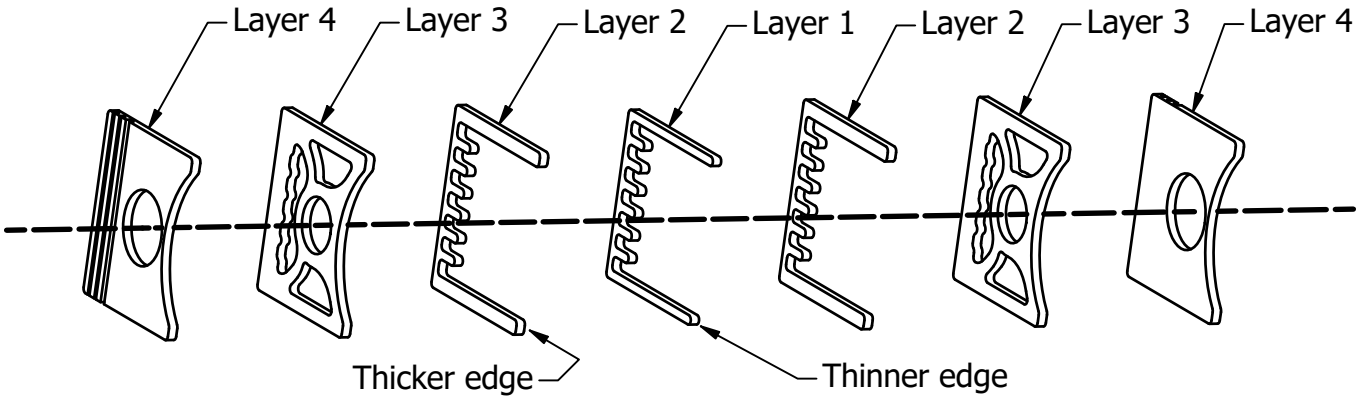


Isometric

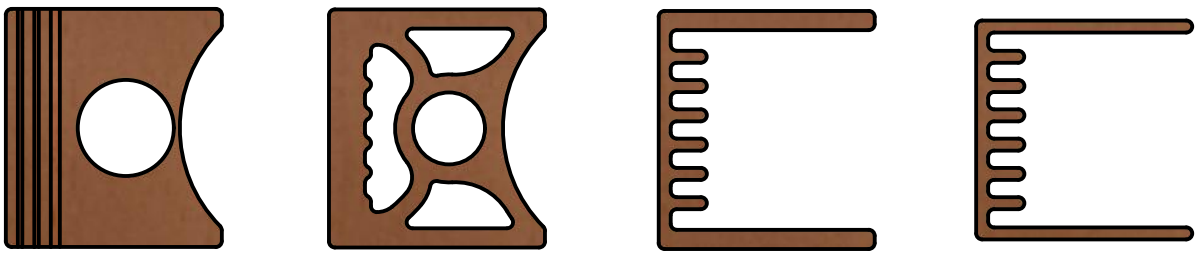
There are four pistons, all of them identical. Each is seven layers thick. The center layer has a small cutout to ride on the cylinder track. Repeat this section four times to build all four pistons.

Work on this section is extra critical, because there are no alignment pin holes. Keep all the layers lined up carefully.





Note: the fins inside the piston transfer heat to the oil. They are an important part of the engine cooling system.



Piston Layer 4 x 2

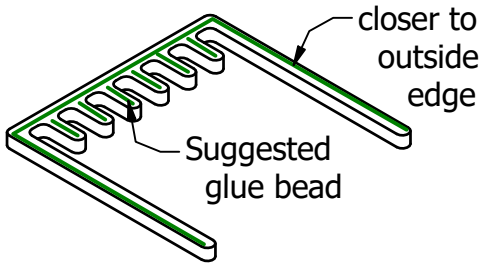
Piston Layer 3 x 2

Piston Layer 2 x 2

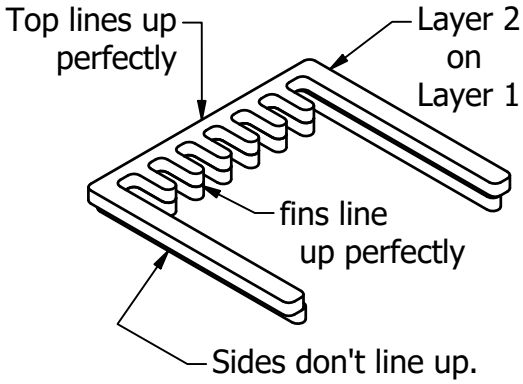
Piston Layer 1

Piston Assembly

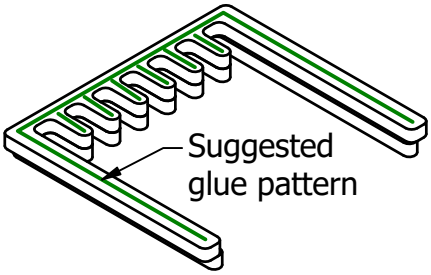
Layer 1



Spread a thin bead of glue as shown on layer 1. Glue layer 2 onto layer one as shown. Set aside to dry. When able to handle, continue.

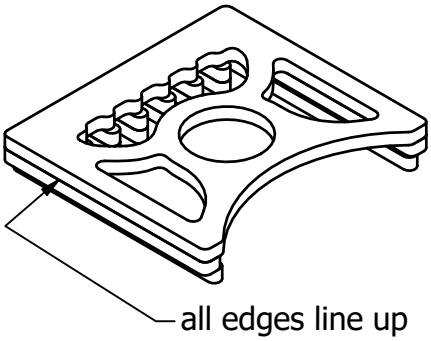


Layers 1 & 2

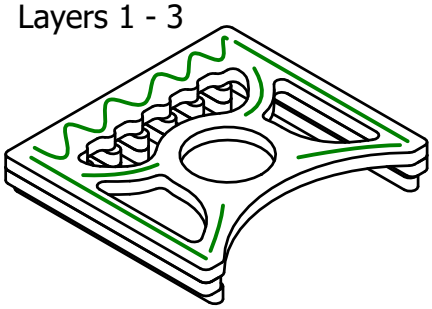


Spread a thin bead of glue as shown on layer 2. Glue layer 3 onto layer one as shown. Set aside to dry. When able to handle, continue.

Layers 1 - 3

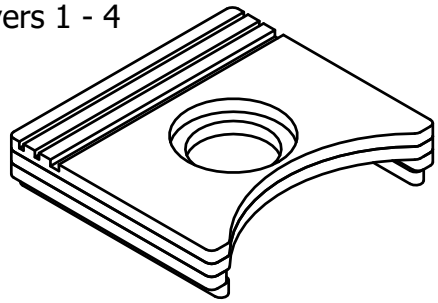


Layers 1 - 3

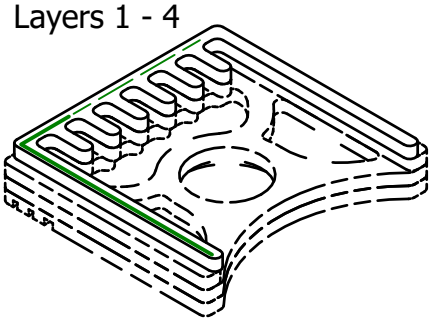


Spread a thin bead of glue as shown on layer 3. Glue layer 4 onto layer one as shown. Set aside to dry. When able to handle, continue.

Layers 1 - 4

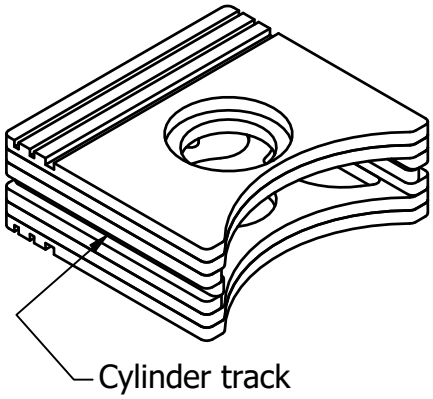


Layers 1 - 4

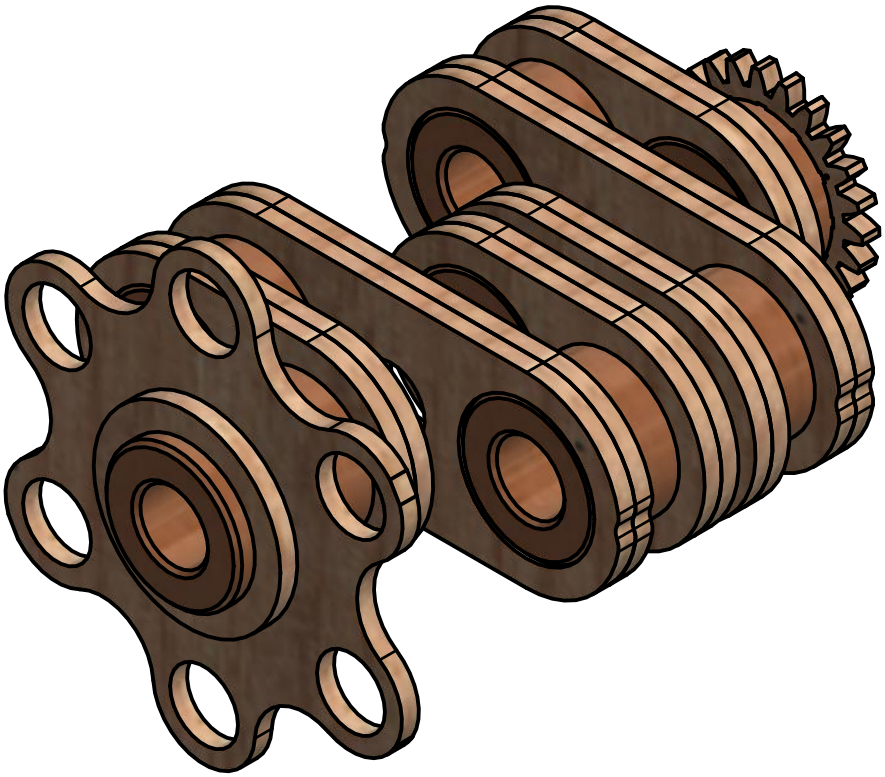


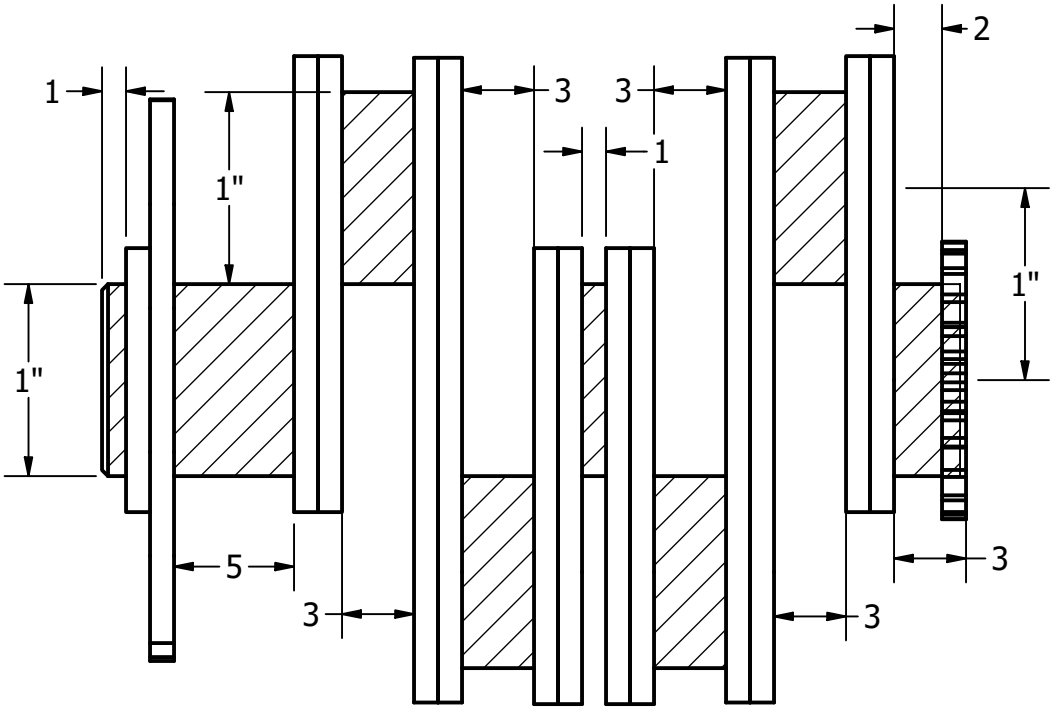
Invert the assembly as shown, and then begin the process again. Follow the same suggested glue patterns. The completed piston should look like the one shown on the right.

Layers 4-3-2-1-2-3-4



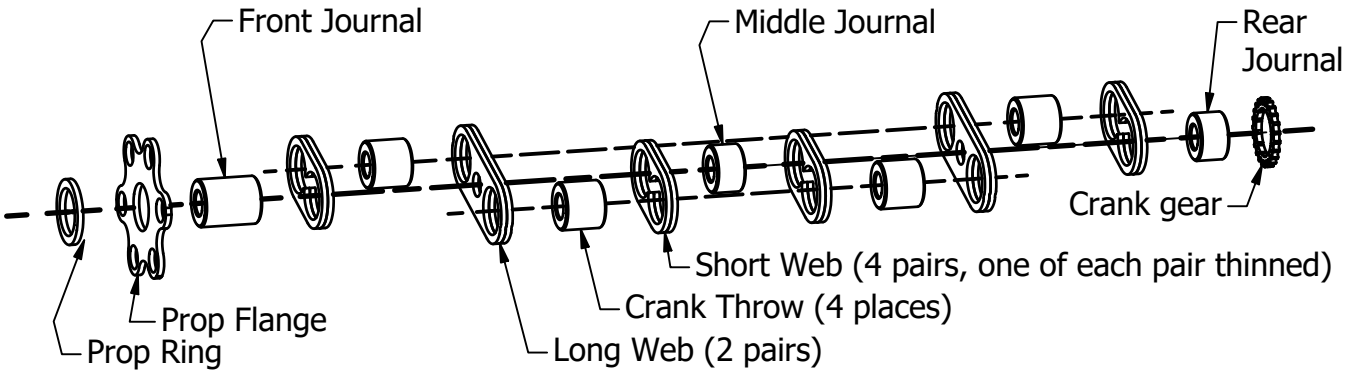
Section 4: Crankshaft





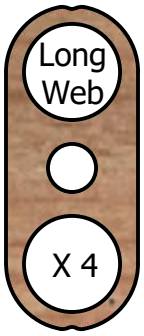
Note: Numbers with " are in inches. Numbers without " are in layers.

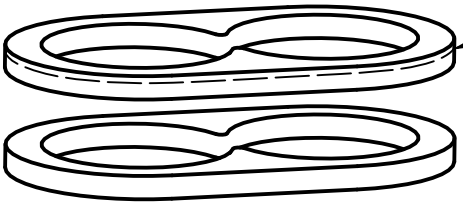
Crankshaft Parts



On an opposed engine, the rest of the engine is literally built around the crankshaft. As the largest spinning parts, the crankshaft has the tightest tolerances and most critical dimensions of any part in the engine. Take your time with this part of the build, and make sure that your dimensions and alignments are as prefect as you can make them. This will pay huge dividends in smooth operation later.

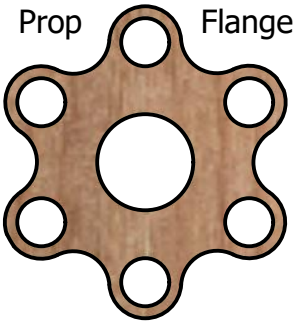
Begin by sanding the faces of four of the short webs. Sand them until approximately 1/4 to 1/3rd of the material has been removed. For a single (standard) sized kit, removing one layer of material is a good guideline. I prefer to use a belt sander for this process. If you don't remove enough material, the engine will not spin freely - particularly after you tighten the case bolts.



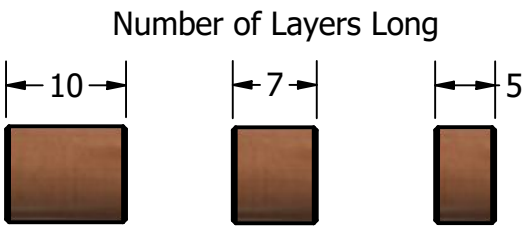


The webs will be glued in pairs. Sand approximately 1/3 of the thickness away from one of the short webs from each pair. The long webs don't require sanding.

(Follow gluing directions on the next page.)



All shafts 1" Dia with 1/2" hole

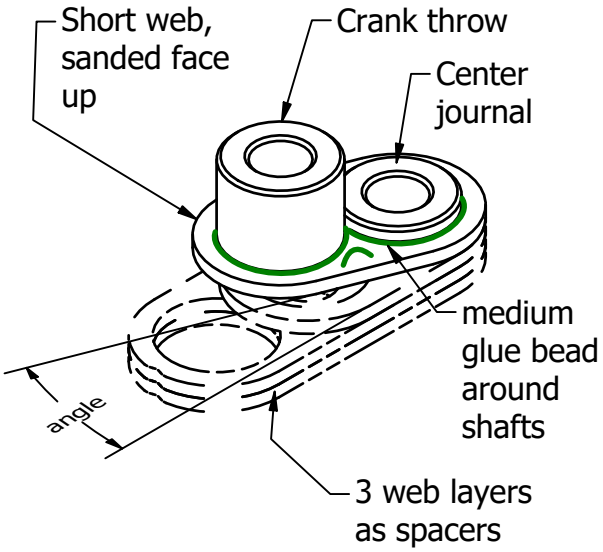


Front Journal

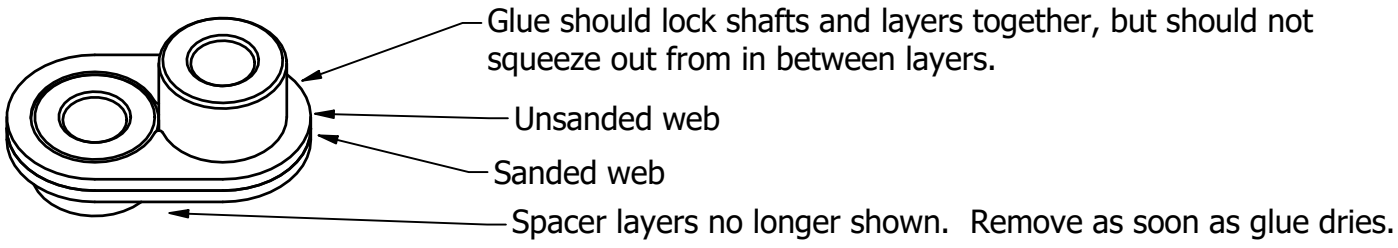
Crank Throw X 4

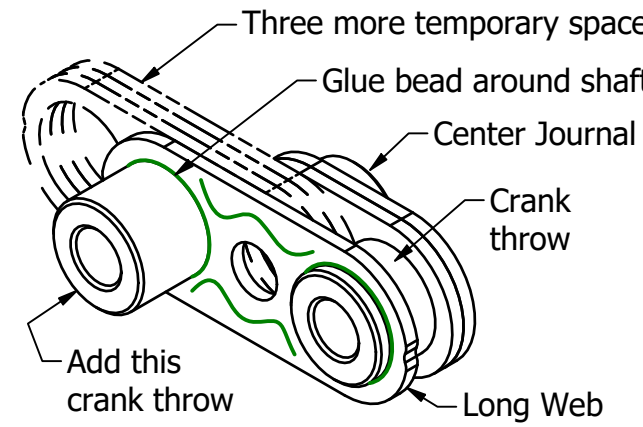
Middle and Rear Journals (1 Each)

Crankshaft Assembly 1

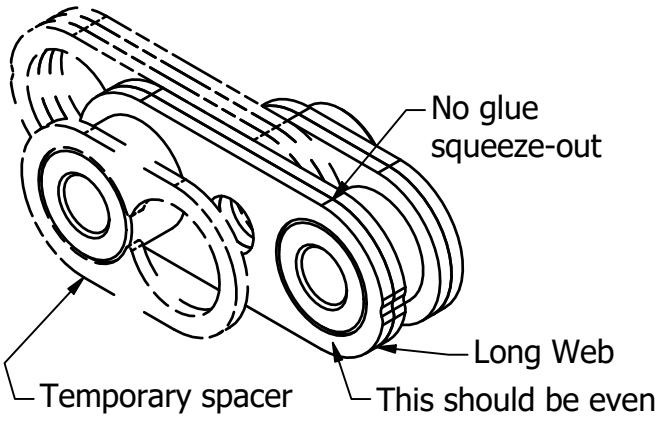


Set three unsanded web layers on top of each other to help control spacing. Insert the center journal into the spacer layers, then place one of your sanded short webs onto the pile with the sanded side facing up. Keep it at an angle to the spacers, so that the crank throw won't slip downwards too far. Place the crank throw into the other hole of the short web. Add a medium bead of glue to the corner between the shafts and the crank web as shown, then place an unsanded short web over the sanded one, pressing it downward into the glue. Make sure that the glue does not stick to the spacer layers. Ensure that everything is straight, and allow this to dry before moving on.



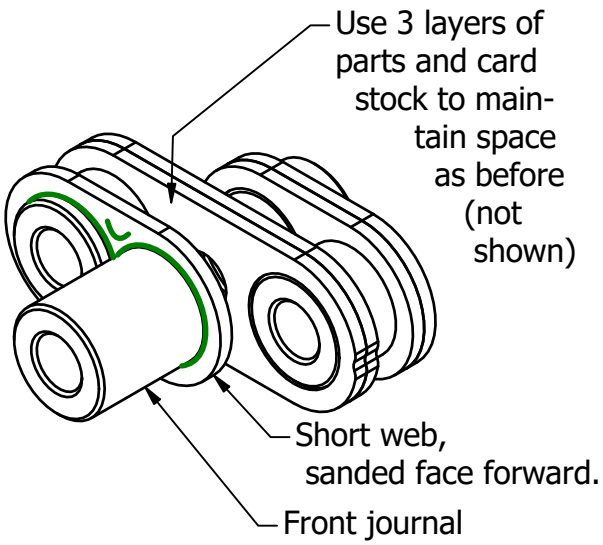


Work your way forward on the crankshaft by placing a long web over the crank throw from the previous step. Add another crank throw, facing forward. Maintain parallelism and spacing by using 3 full layers of parts as temporary spacers. You should also add in the thickness that you sanded away from the short web. This is best done by adding layers of card stock (not shown) to the spacers. There needs to be enough room on the journal to allow the connecting rod to spin freely. It is 3 layers thick.

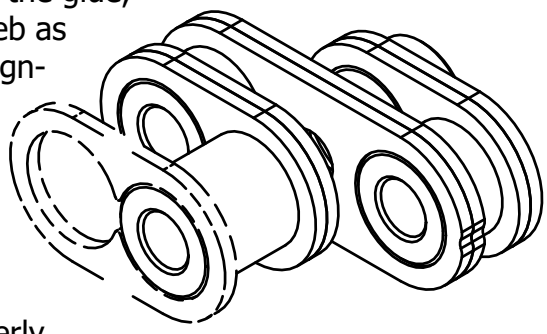


Once the parts are arranged, add a medium bead of glue to the perimeter of the crank throws and a light bead of glue to the other parts of the long web as shown. Add another long web, and place (don't glue) another crank web in the front of the forward crank throw. Let the glue dry before going on.

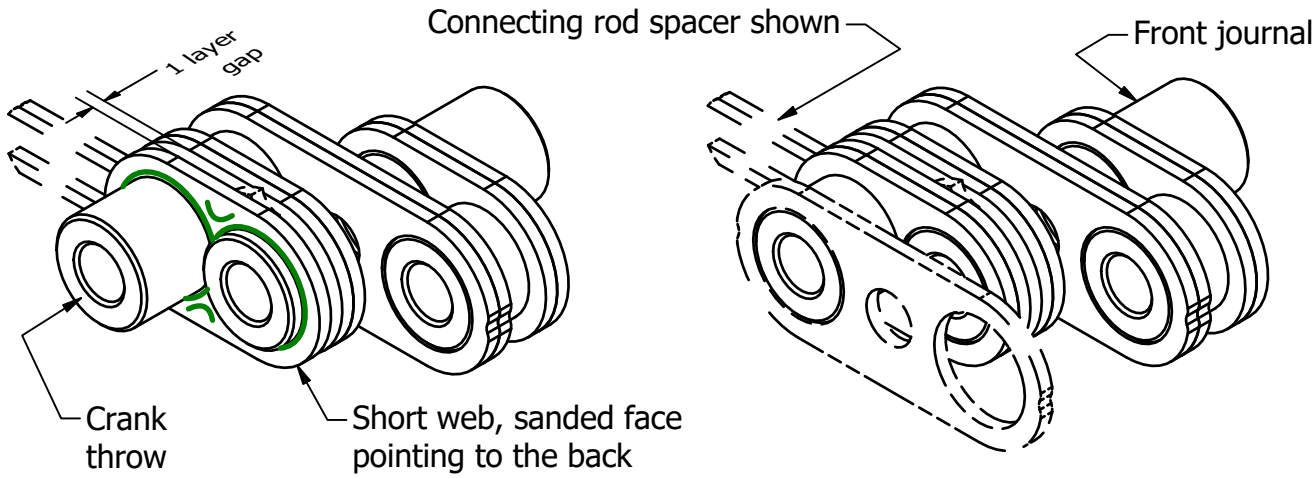
Crankshaft Assembly 2



Continue working your way forward on the crankshaft in much the same manner as the previous steps. Add a short web with the sanded face pointing forward. Add the front journal, and a medium bead of glue around the base of the two shafts. Add an unsanded short web over the glue, and use any web as a temporary alignment tool over the end of the forward journal. Assure that everything is aligned properly, and set aside to dry before continuing.

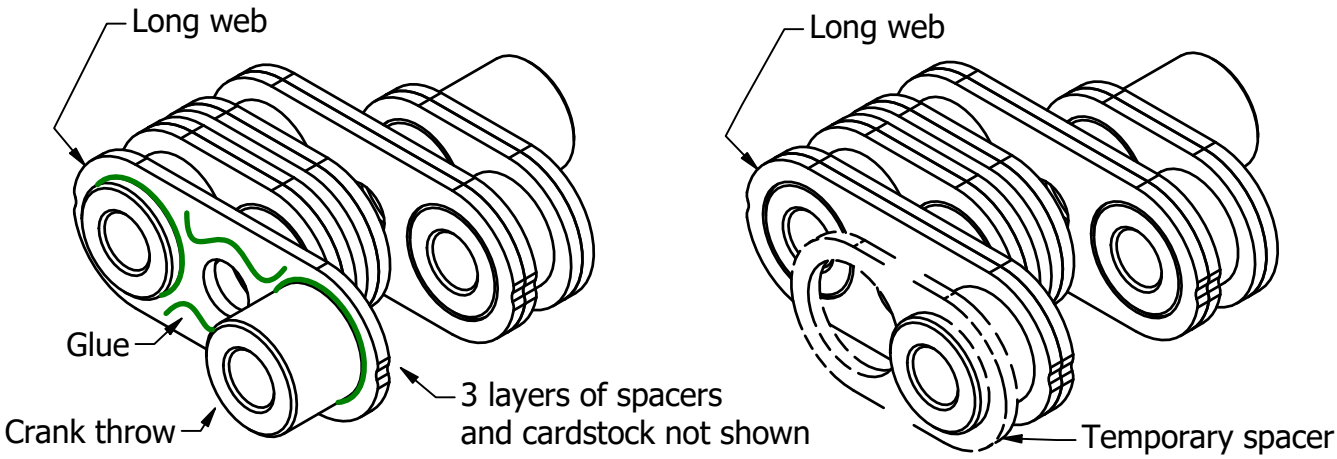


Turn the assemebly around to work on the rear half.

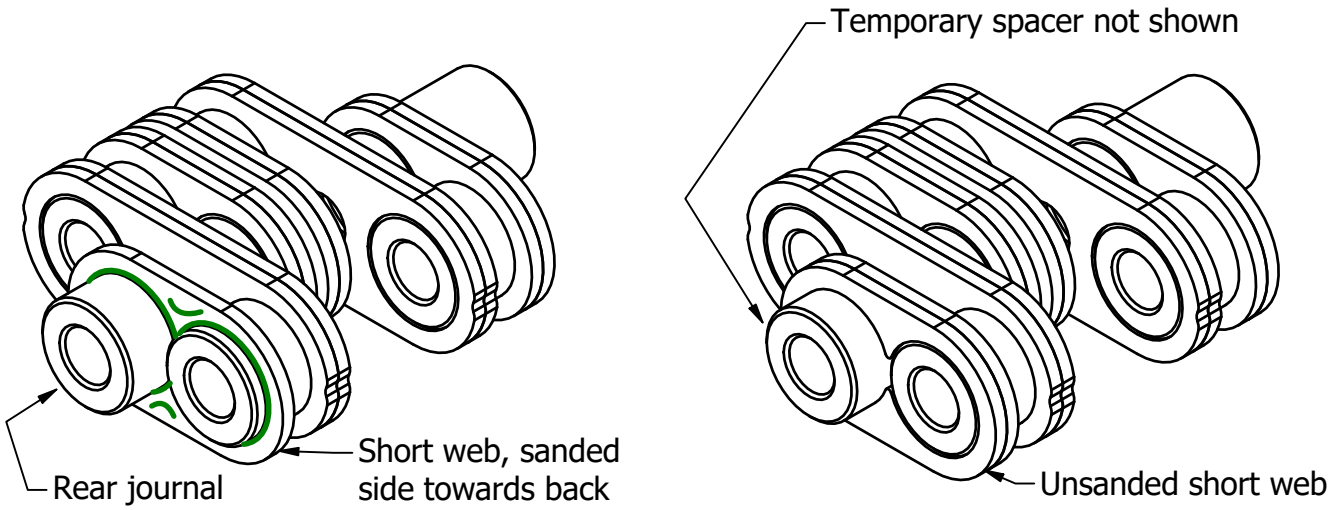


Turn the assembly around to work on the rear half. Completion of the rear half is very similar to completion of the front half. There is a very narrow (1 layer) thick slot on the middel journal. Instead of using 3 layers as before, use one of the connecting rods and a single layer of cardstock as a spacer. Add the sanded short web, the crank throw, the bead of glue, and the unsanded short web to the assembly. Check for alignment, and set aside to dry.

Crankshaft Assembly 3

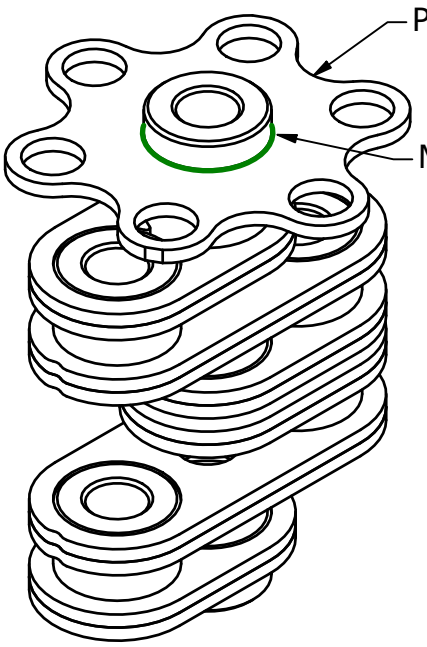


Continue with the now-familiar pattern of placing a long web onto the previous throw, placing a throw into the open side of the long web, and spreading your medium bead of glue around the two shafts. Add temporary spacers and cardstock to maintain parallelism and spacing. Temporarily place one of the remaining web over the end of the last crank throw while the glue dries.

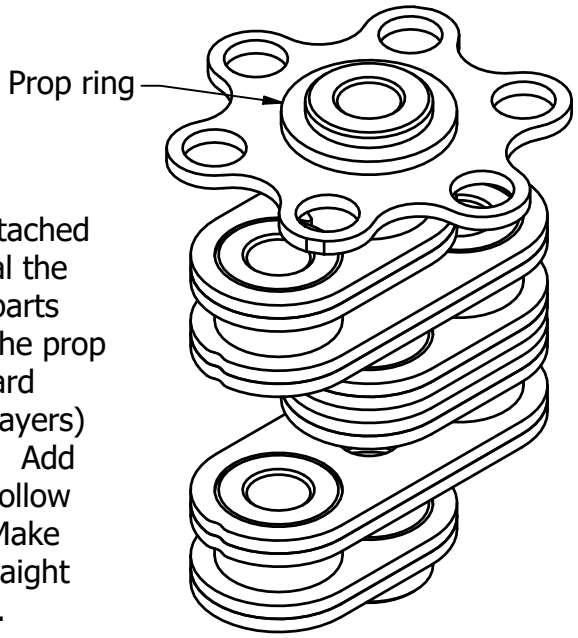


Finish the last crank throw in the same way. Add the short web with the sanded face towards the back of the unit. Add the rear journal (the same as the center journal). Add the medium bead of glue. Use three layers of spacers and an appropriate amount of cardstock to maintain space and parallellism. Add the unsanded short web, and clean up any squeeze out. Use one of the extra crank webs (long or short) to hold the rear journal parallel to the table. Let the assembly dry before moving on.

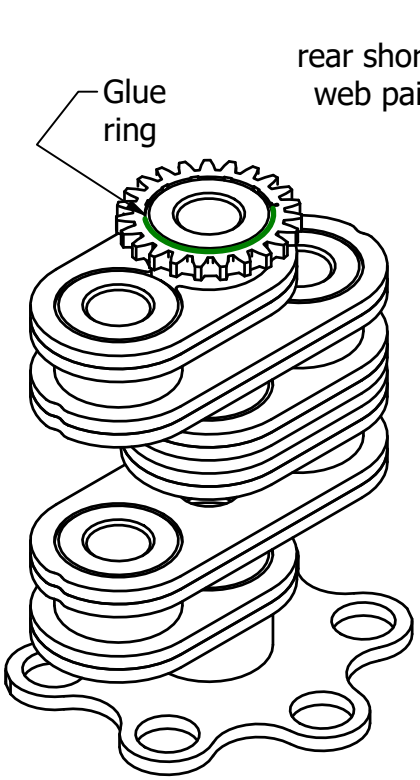
Crankshaft Assembly 4

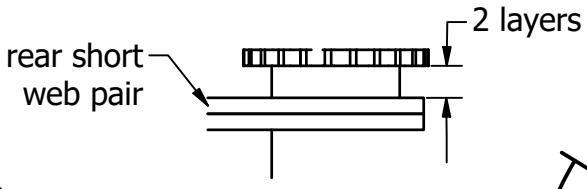


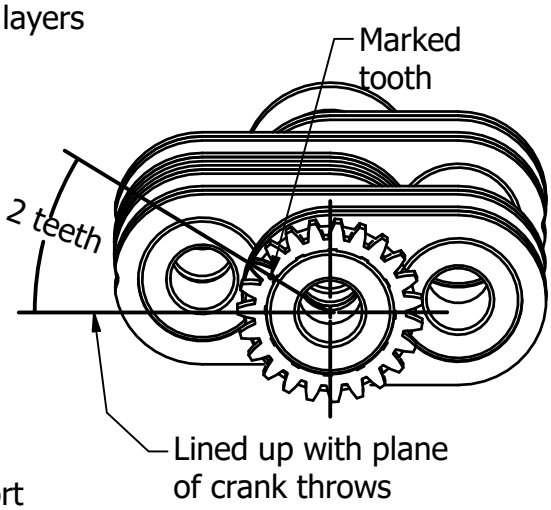
The prop flange is attached to the forward journal the same way all of the parts are attached. Push the prop flange over the forward journal until 1/4" (2 layers) of shaft are exposed. Add a bead of glue, and follow with the prop ring. Make sure everything is straight before the glue dries.



Optional additional ring: There should be an extra prop ring in the kit. If you like, you can start with the extra ring, pushing it down 3 layers over the shaft. Then, add the prop flange and the normal prop ring. This will be a little bit stronger.

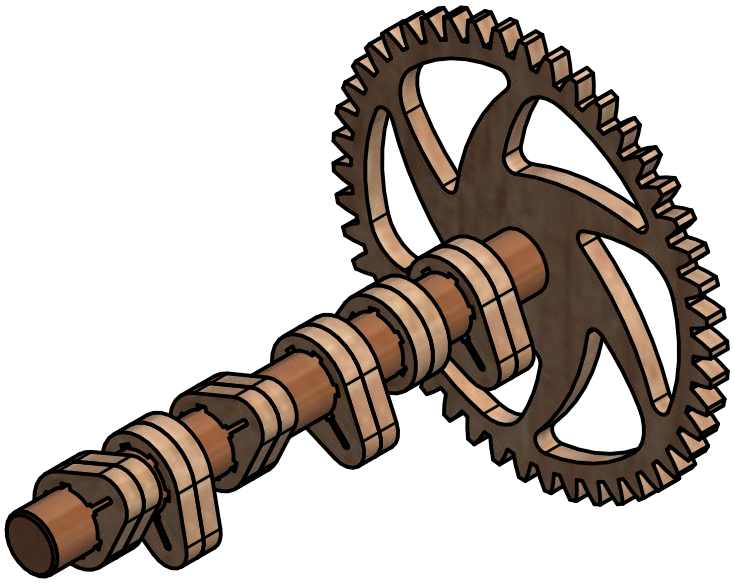




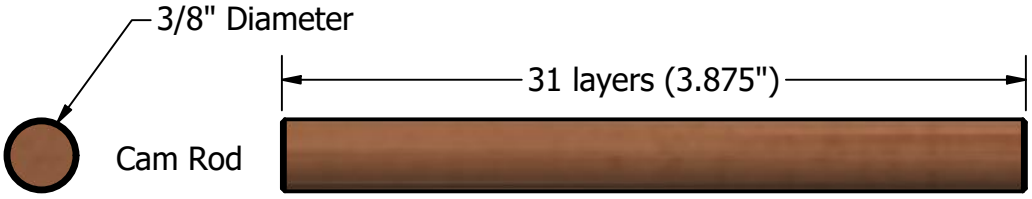


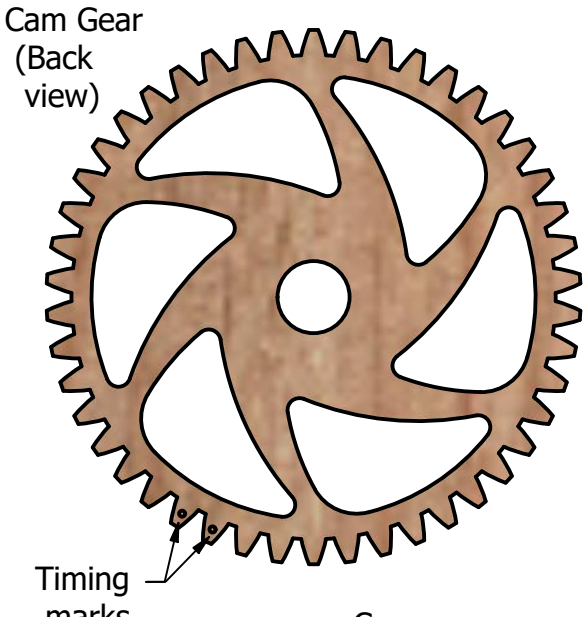
Add the crank gear carefully. Its alignment is highly critical. Begin by pushing it over the rear journal until the space between it and the last pair of short webs is just over two layers thick. (Two unsanded parts and a couple of layers of cardstock is good.) Add a ring of glue as in previous steps. However, there is not a part to add into the ring of wet glue. Instead, gently lift and twist until the glue works its way into the cracks and relief cuts around the gear, securing it to the rear journal. Once the glue is spread correctly, twist the marked tooth to the angle shown above. Let dry.

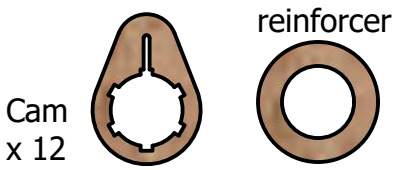
Section 5: Camshaft

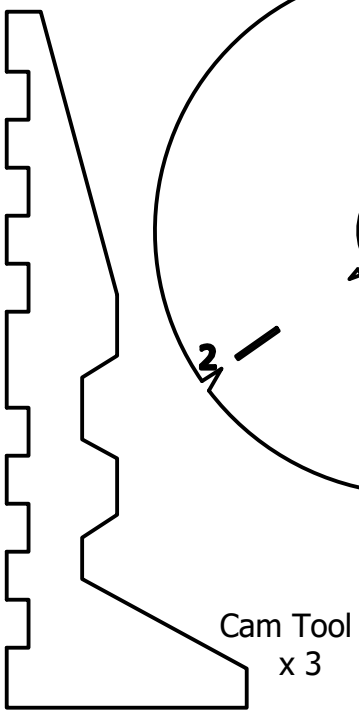


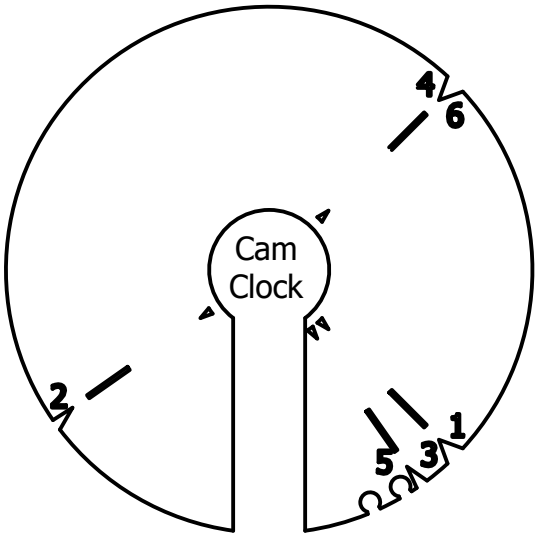
The camshaft spins at 1/2 of the rate of the crankshaft. It has 6 lobes to activate the 8 valves in the engine. This is possible because the center cam (intake) in each set does double duty, activating both intake valves on an opposing pair of cylinders. Obviously, angles are critical on the cam. 3 "cam tool" pieces and a "cam clock" are included to help you accomplish this.



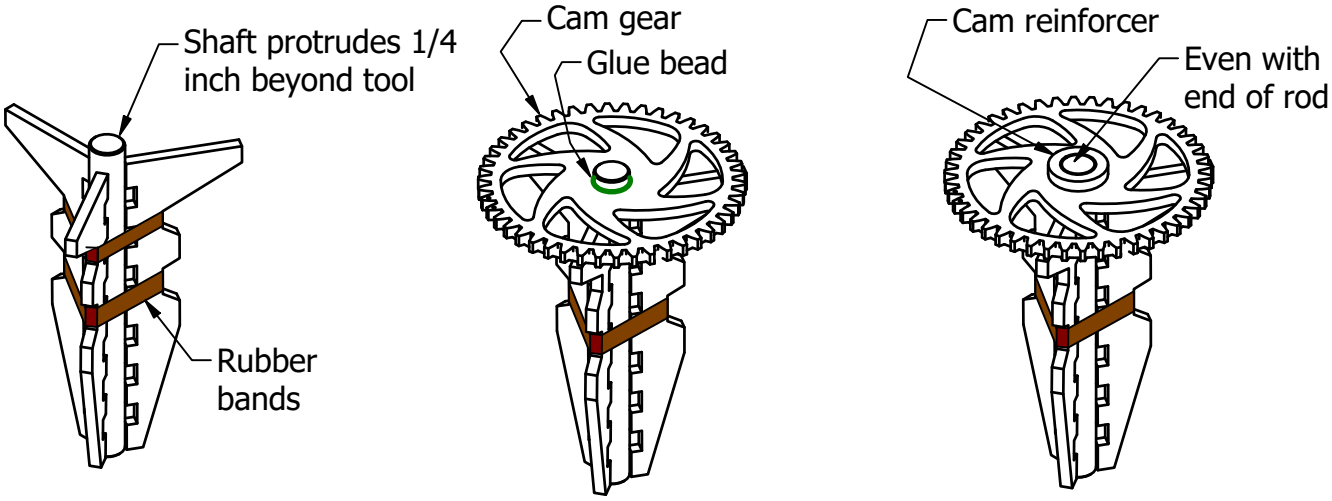




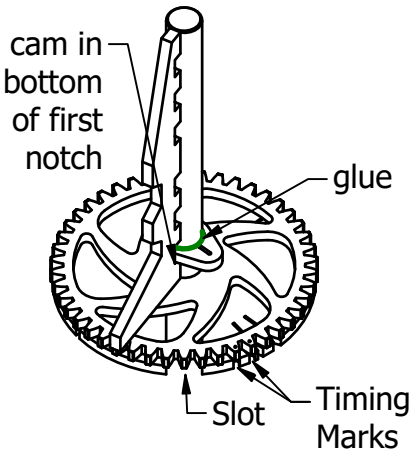




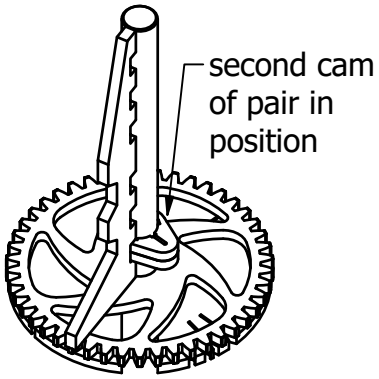
Camshaft Assembly 1



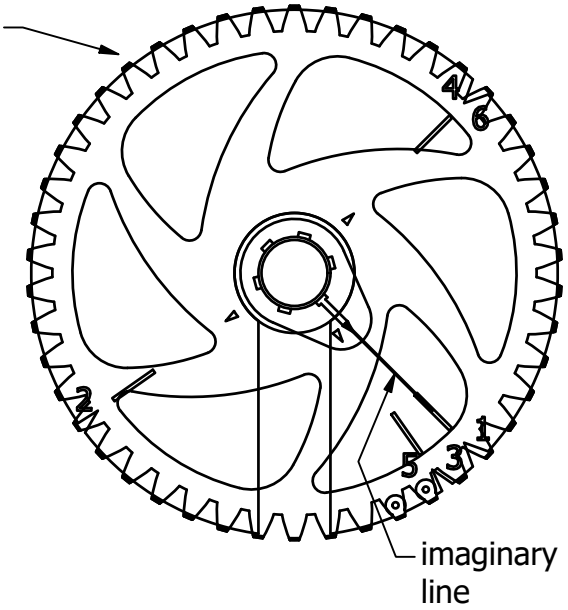
Begin by arranging the 3 cam tools around the cam rod, and securing them with rubber bands. This will help to ensure that the cam gear is set true on the rod. Put the cam gear in place as shown, and add a medium bead of glue to the perimeter of the rod and the face of the gear. Add the cam reinforcer over the top of the gear. Make sure that everything is flat and even. Allow to dry.



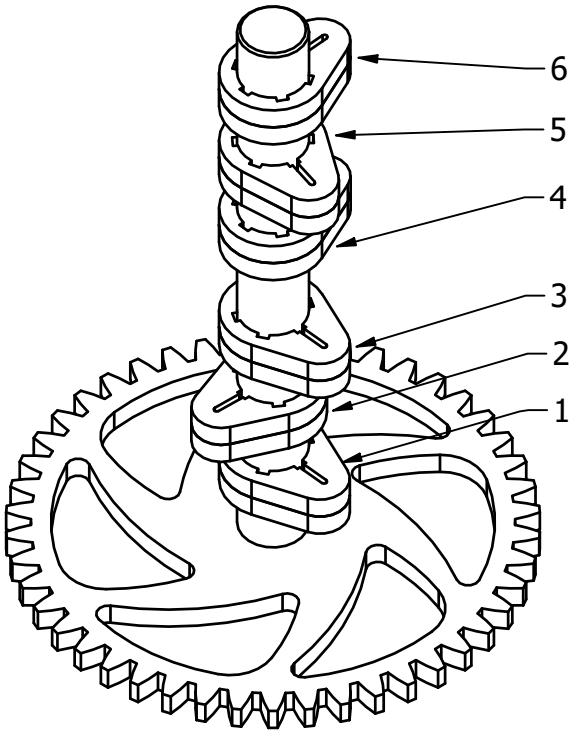
Remove the cam tools, and set the cam clock on a flat surface. The two timing gear cutouts should be to the right of the slot. Set the cam into place on top of the cam clock. Put one of the cams onto the rod, and push it nearly to the bottom. Use one of the cam tools to help establish its position. Pull the tool out of the way and add a medium bead of glue around the cam as shown. Secure a second cam into place with the glue. Make sure that the cam points towards the "1" line on the cam clock. Use the tool to make sure the cam dries in the proper position.

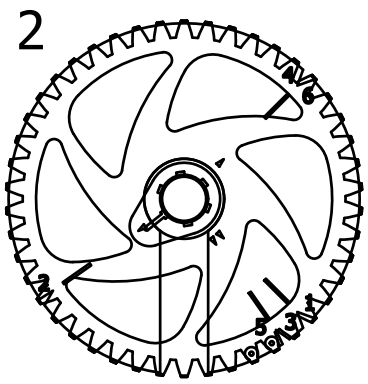


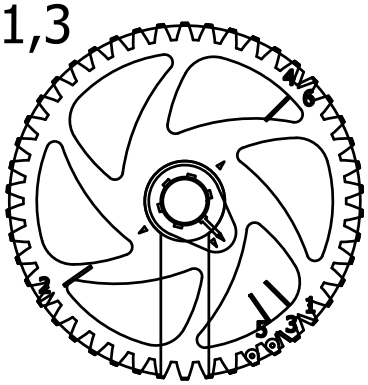
Hidden line view of cam clock with first set of cams aligned with line "1." It may be easier to set the cam clock on top of the timing gear while adjusting cam position. The timing marks must align. The cam can be repositioned until the glue is set. A small flat blade screwdriver can engage the line in the cam and help to adjust its position. Don't forget to check the heights again after setting angle.

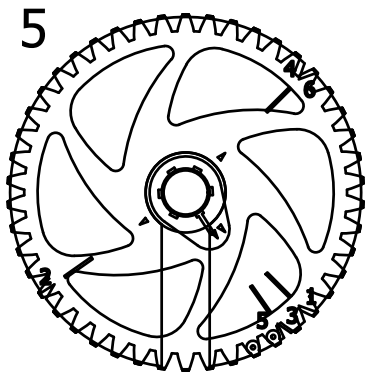


Camshaft Assembly 2





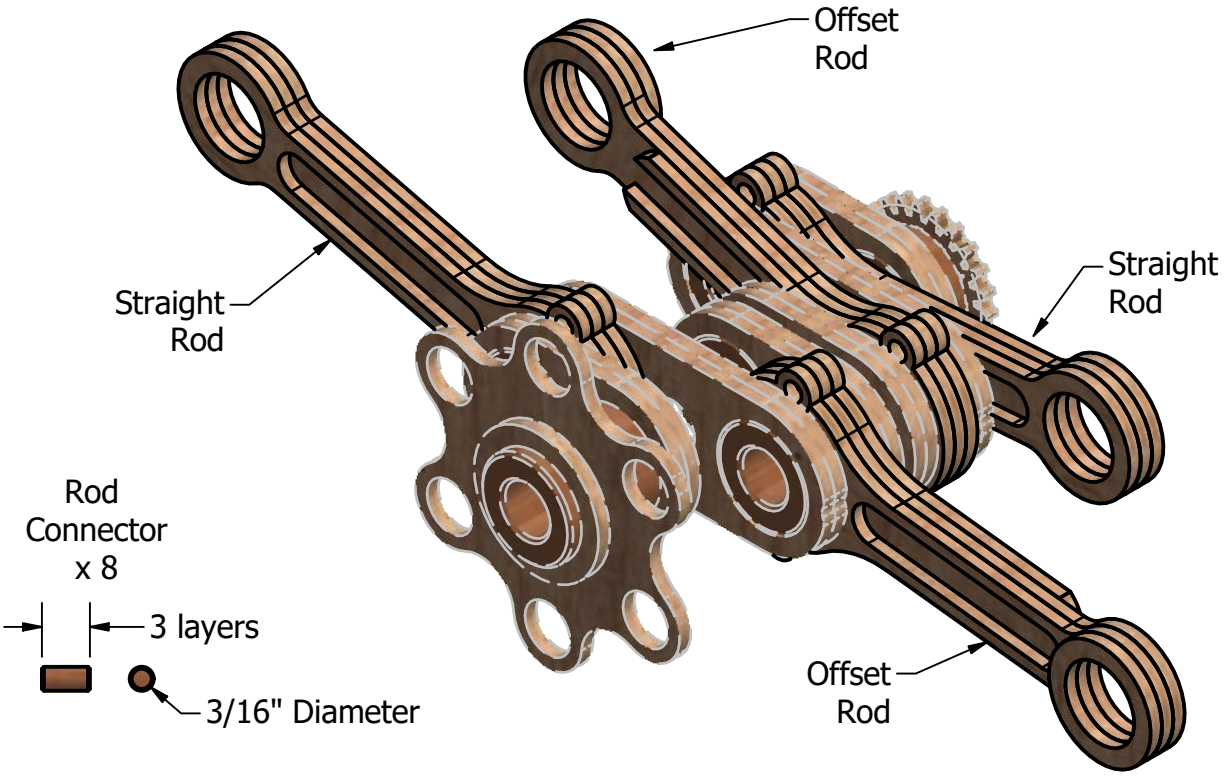




Continue setting the cams the same way you set the first pair. Push one of each set over the shaft, set the depth with the cam alignment tool, and add the second of the pair. Then, set the angle with the cam clock.

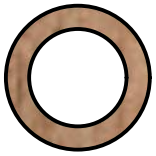
Take your time and get these steps correct. Allow plenty of time for the glue to dry between stages.

Section 6: Connecting Rods

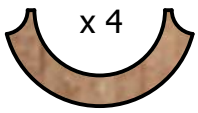


Rod
Connector
x 8

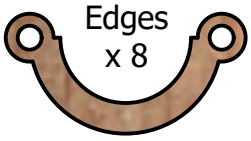
Offset
Rod Ring
x 2



Rod Cap
Center
x 4



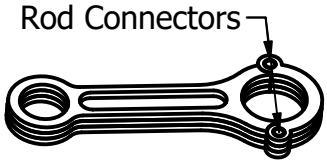
Rod Cap
Edges
x 8



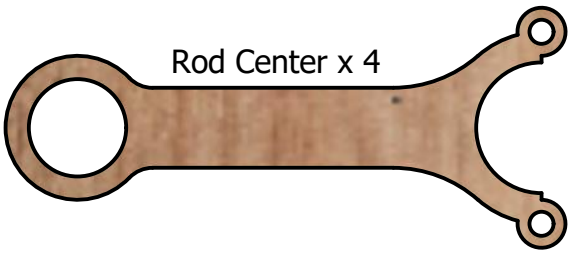
The connecting rods (shown here on the crankshaft) require a slight twist to make our layered construction come out properly. The two center rods are offset by one layer. This means that there are two types of rods on this engine - standard and offset rods.

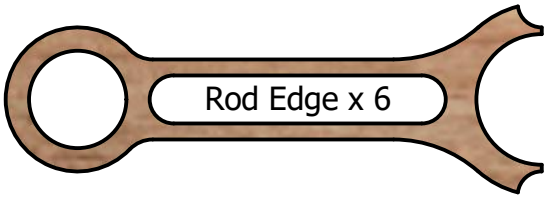
The rods will be pinned together with the rod connectors. This will be shown during later assembly. After finishing the rods, pin them together temporarily to help keep them organized.

Rod Connectors

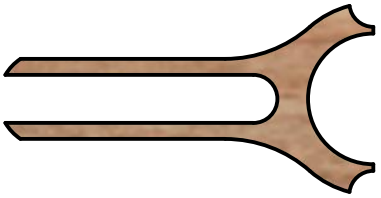


Rod Center x 4



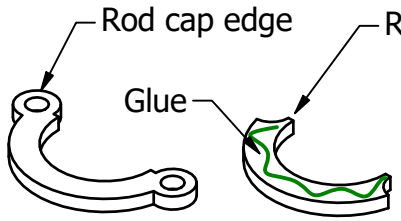


Offset
Rod Edge
x 2

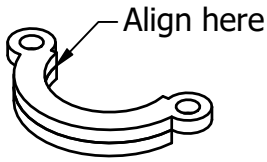


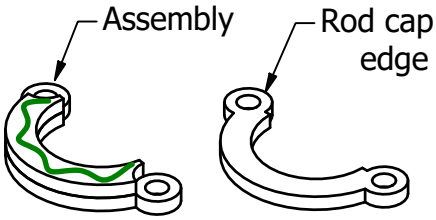
Connecting Rods Assembly

Build Rod Caps x 4

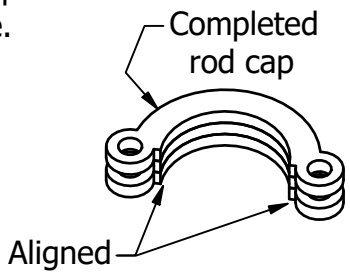


Spread glue on one side of the center rod cap. Glue on edge.

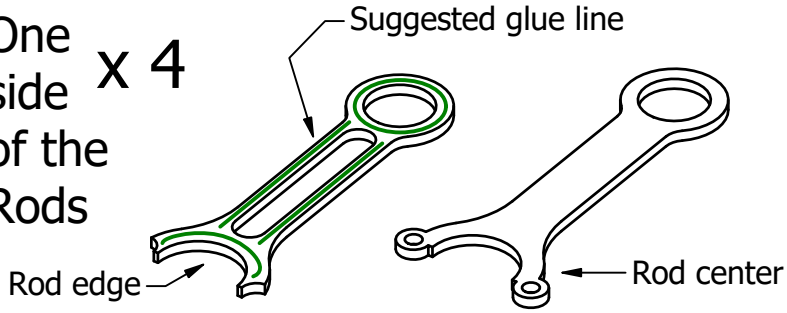




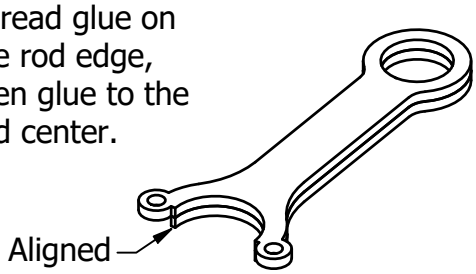
Turn over the assembly and repeat the process. Add another Rod Cap Edge. Allow to dry.



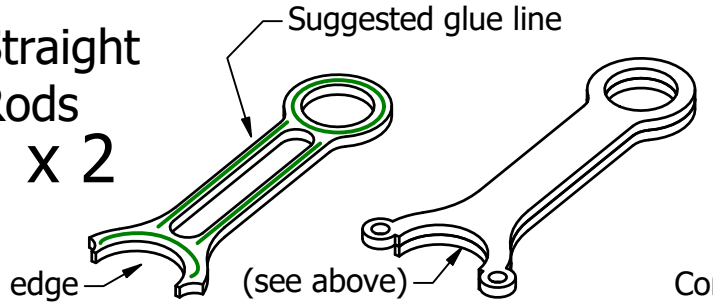
One side of the Rods x 4



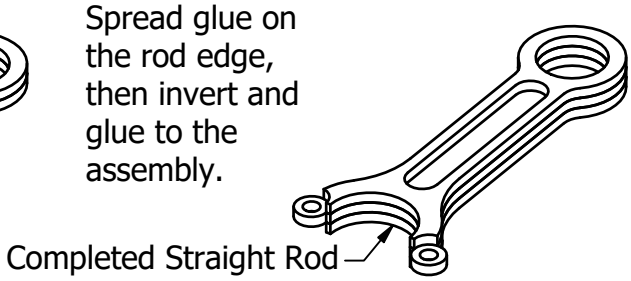
Spread glue on the rod edge, then glue to the rod center.



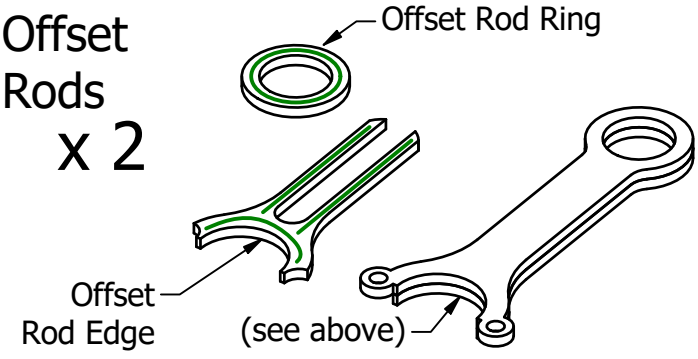
Straight Rods x 2



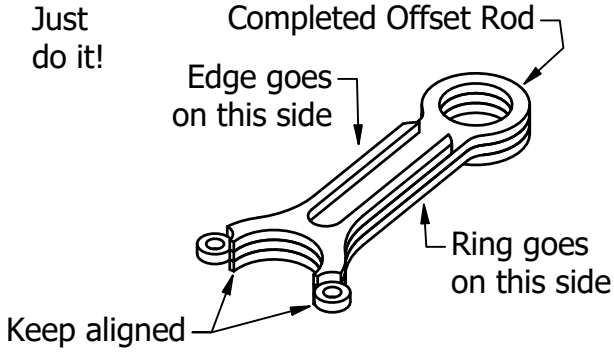
Spread glue on the rod edge, then invert and glue to the assembly.



Offset Rods x 2

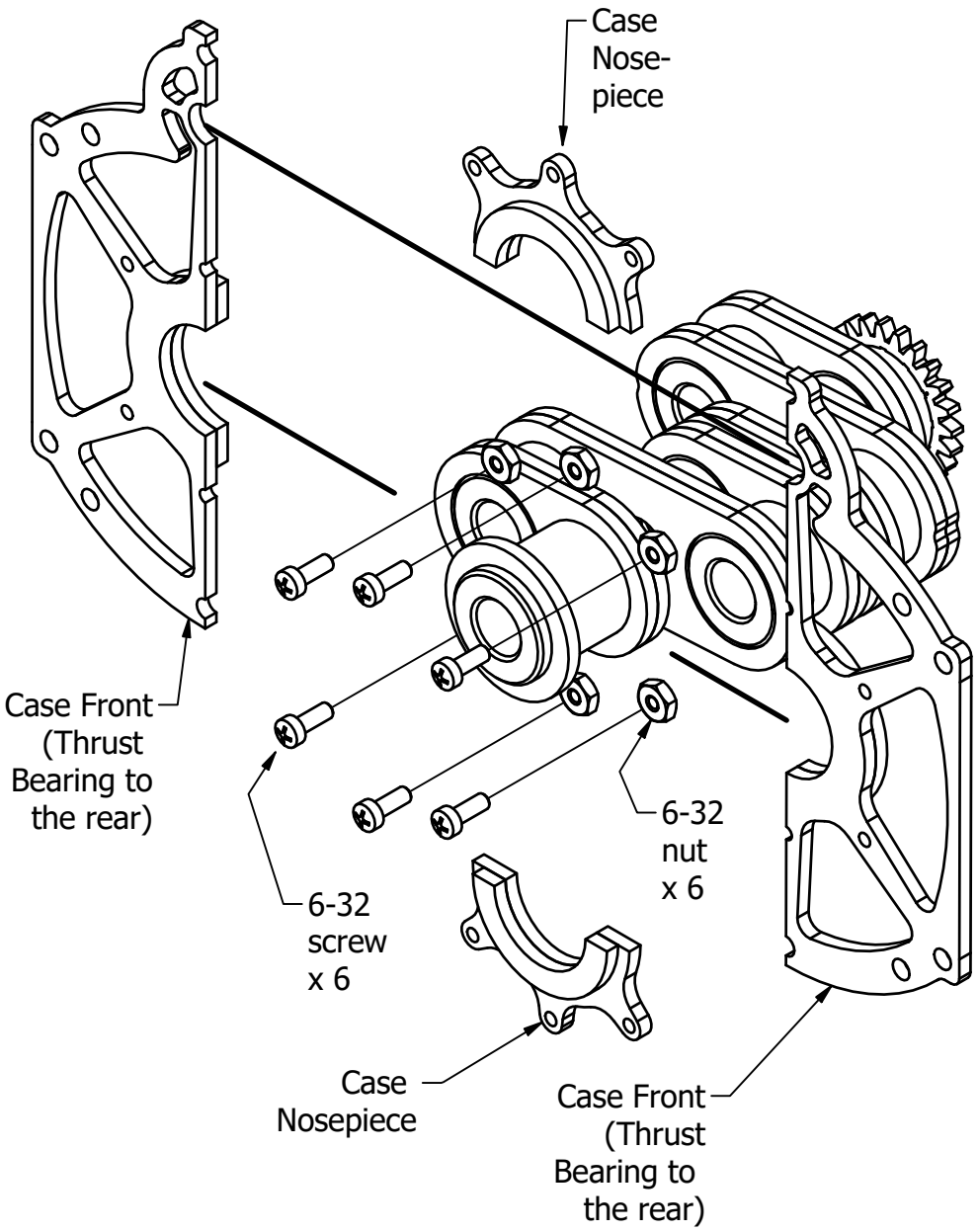


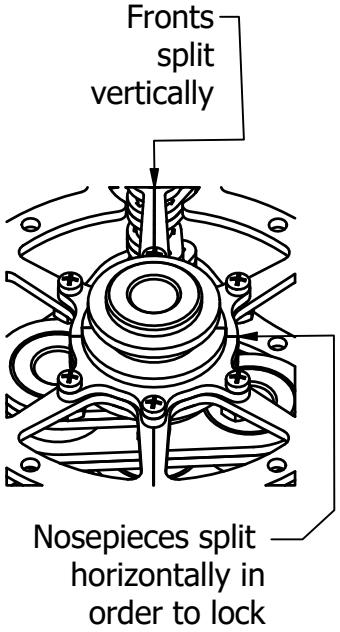
Just do it!



Section 7: Putting it Together

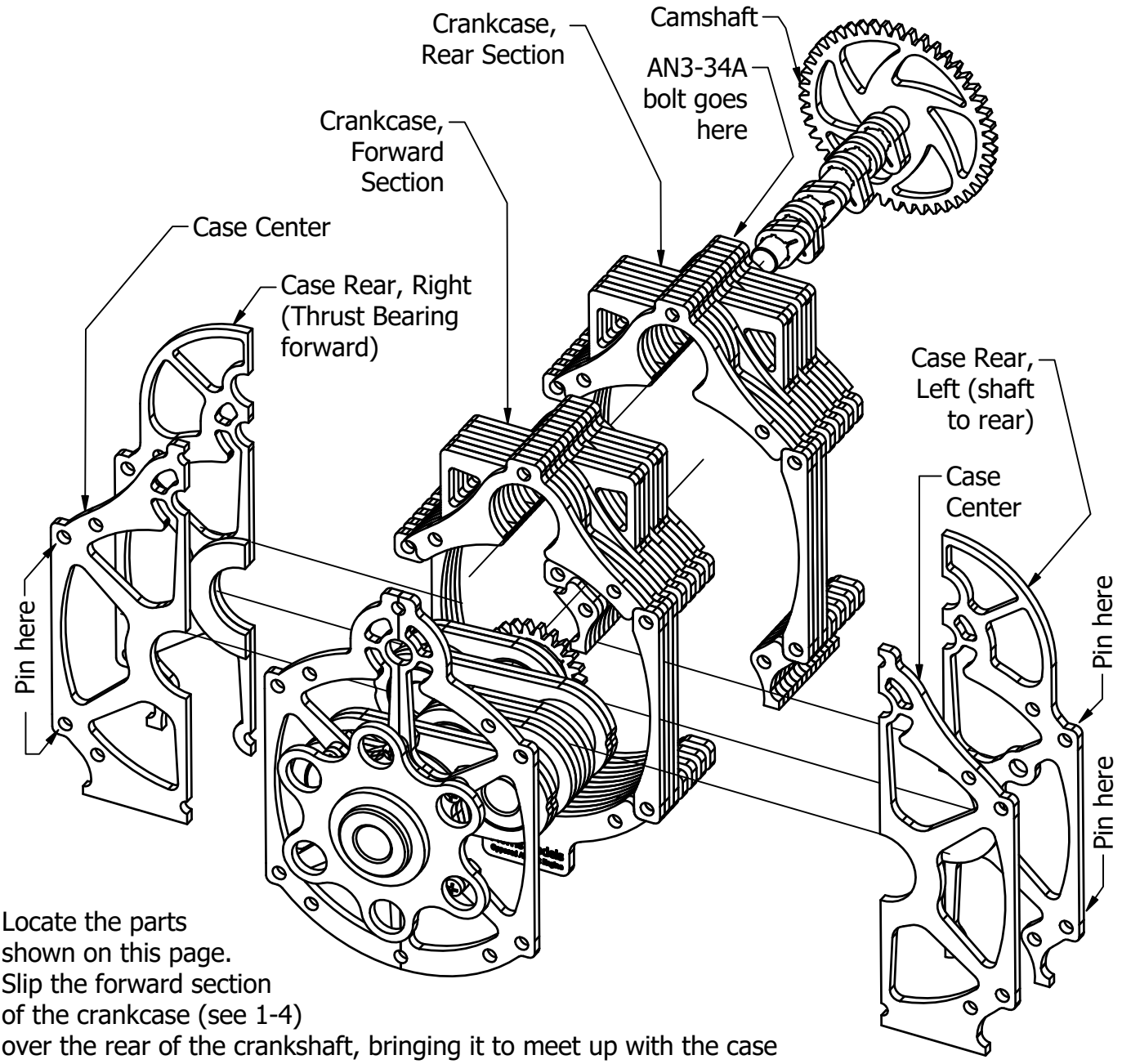
Note: Prop flange not shown on crankshaft for clarity





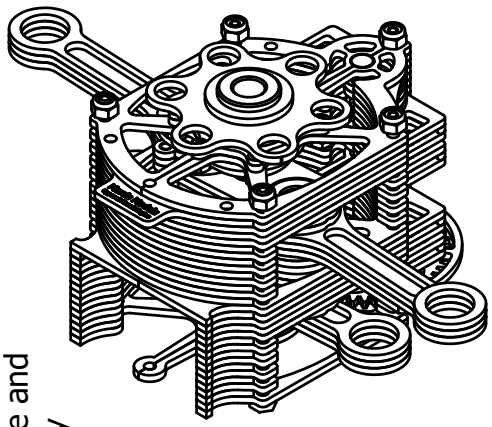
Locate the parts shown. Begin assembly with the case front (left and right) and nosepieces (2x). Slip the two case fronts over the front journal. Attach them together with the two nosepieces, which are slipped on the front of this assembly from the top and the bottom. Secure with 6-32 screws and nuts. This will lock the front into one assembly which cannot be removed without loosening the screws.

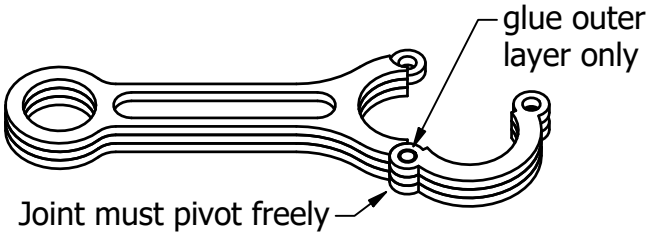
Putting it Together - 2



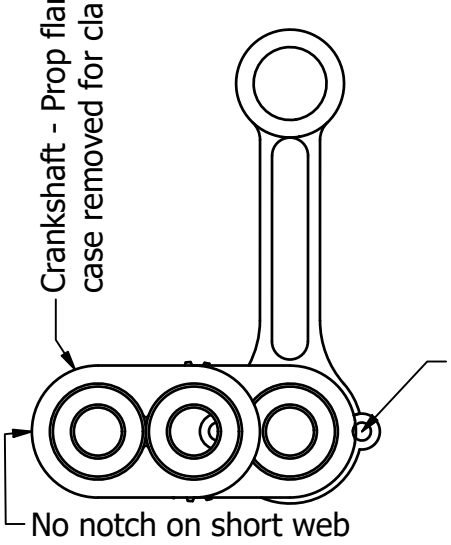
Locate the parts shown on this page. Slip the forward section of the crankcase (see 1-4) over the rear of the crankshaft, bringing it to meet up with the case front affixed to the crankshaft. Slip the rear section of the crankcase over the rear of the crankshaft, bringing it forward to meet the front section of the crankcase. Add the camshaft into the cam tunnel, also from the rear. Separate the front and rear case halves just enough to slip in the case center sections from the sides. These should come to rest over the camshaft and the center journal of the crankshaft. At this point, you need at slip an AN3-34A bolt (the shortest long bolt) into the upper center hole along the ridge of the case. Slip it in from the rear of the case, pulling the camshaft gear far enough out of place to slip the head through its spokes. Push it all the way forward. Slip the two case rear frame in sideways. These should come to rest over the camshaft and the crankshaft as well, but should meet on the rear journal between the last web and the crank gear. Temporarily pin this assembly together with the other long bolts before you continue. Put them in from the rear and add the lock nuts.

Putting it Together - 3



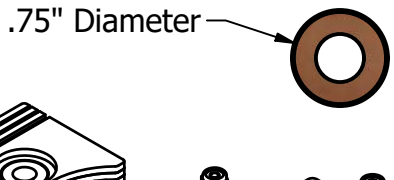


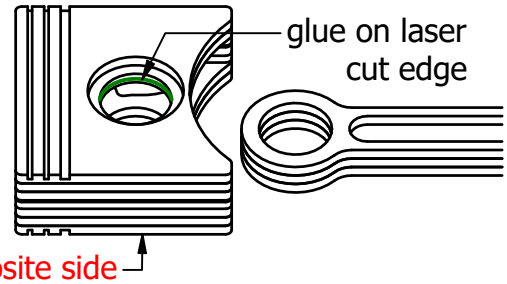
Remove one of the rod pins from the connecting rods. While it not absolutely necessary, I recommend that you glue the remaining pin in position. Carefully place a tiny drop of glue so that the pin is only glued to one layer, and the cap can pivot as shown. **Do this for all four rods.**

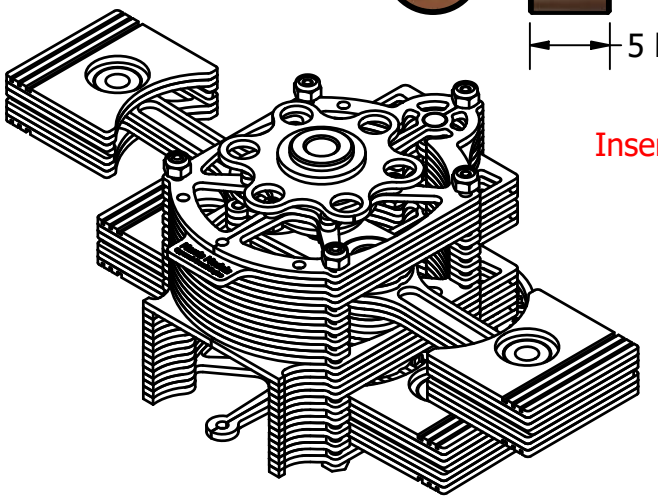


Spread the rod caps wide enough to slip the rods onto the crank journals. Gently press the rod caps closed around the crank journals. The remaining rod pin can now be inserted by bending the rods to a 90 degree angle and inserting the pins from the long web side. This will require some careful maneuvering. There is just enough space within the case to allow this.

Alternative construction sequence: It is also possible to set the rods onto the crank coutside the case, and fit the pieces of the case around the rotating assembly. This is only recommended for those who enjoy 3D puzzles - and it is impossible to describe the process.

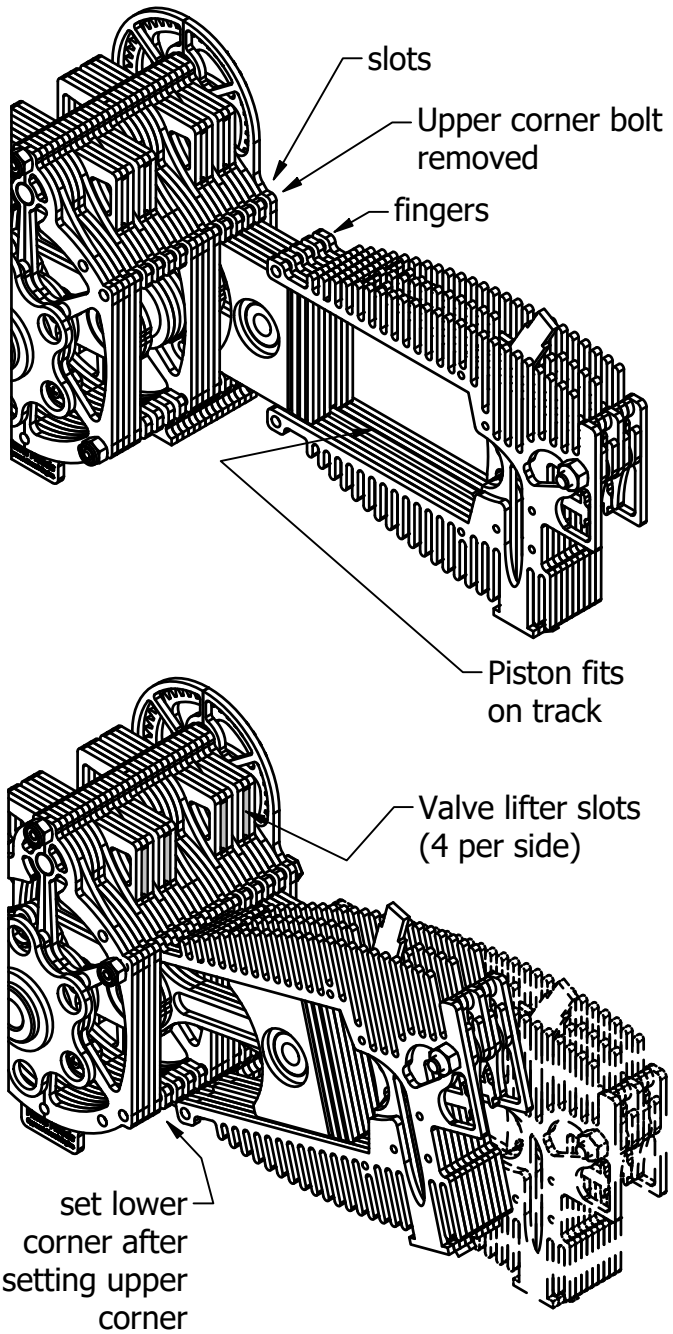






Set the pistons onto the rod end using a light bead of glue on one side. Carefully apply glue to the edge of the hole. Do not apply any glue to the face - just the laser cut edge. Slip the piston into place over the rod, and insert the wrist pin from the opposite side, so that it wipes the glue out of the joint and not into it. The piston must be free to rotate.

Putting it Together - 4



Attach the cylinders to the engine one side at a time. Remove the upper corner bolts from the side you are working on. Gently fit the piston into the track on the cylinder, and then slide the cylinder down towards the case. Engage the fingers on the upper side of the cylinders with the slots in the upper side of the case, and gently work the corner bolt back into place, inserting it from the front of the case. One cylinder is shown, but you may wish to do both of the cylinders on one side of the case at a time.

Once the upper corner is bolted securely, remove the bolt from the lower corner. Fit the lower fingers and slots together, and then gently work the bolt back into position, again working from the front of the case. It may prove helpful to twist the bolt as you press it into place.

Once you have completed one side, follow the same procedure on the other side. Again, insert the bolts from the front side. This will make attaching the accessory case easier in the next step.

If you are having too much trouble with the bolts, you may choose to glue the cylinders into position. This, however, will preclude you from disassembly at a later date. It also makes it difficult to know that the cylinders are really seated correctly.

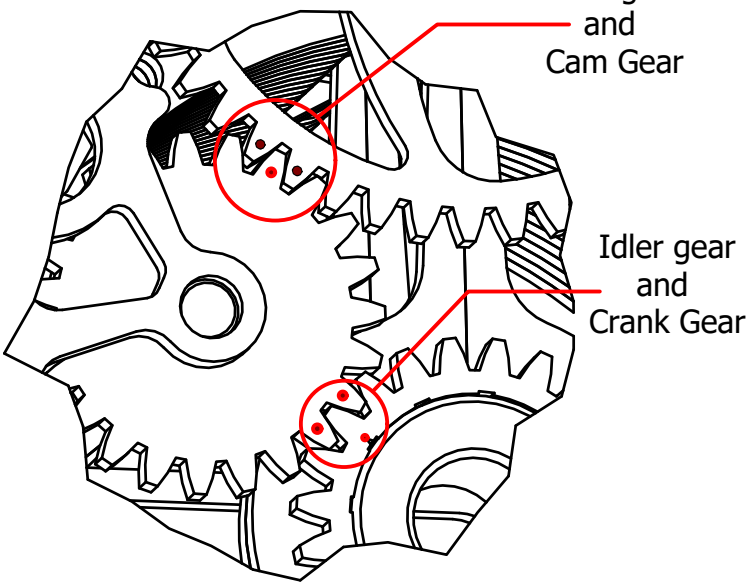
Valve Lifter x 8

The valve lifters, like several of our other layers, will need to be thinned so that they can slide back and forth freely in their slots. Gently sand enough material off of one face that they can slide freely without binding.

After ensuring that the lifters will not bind, insert the lifters into their slots. This should not require force. If it does, stop and figure out what is wrong before proceeding. A stuck lifter can cause all kinds of trouble.

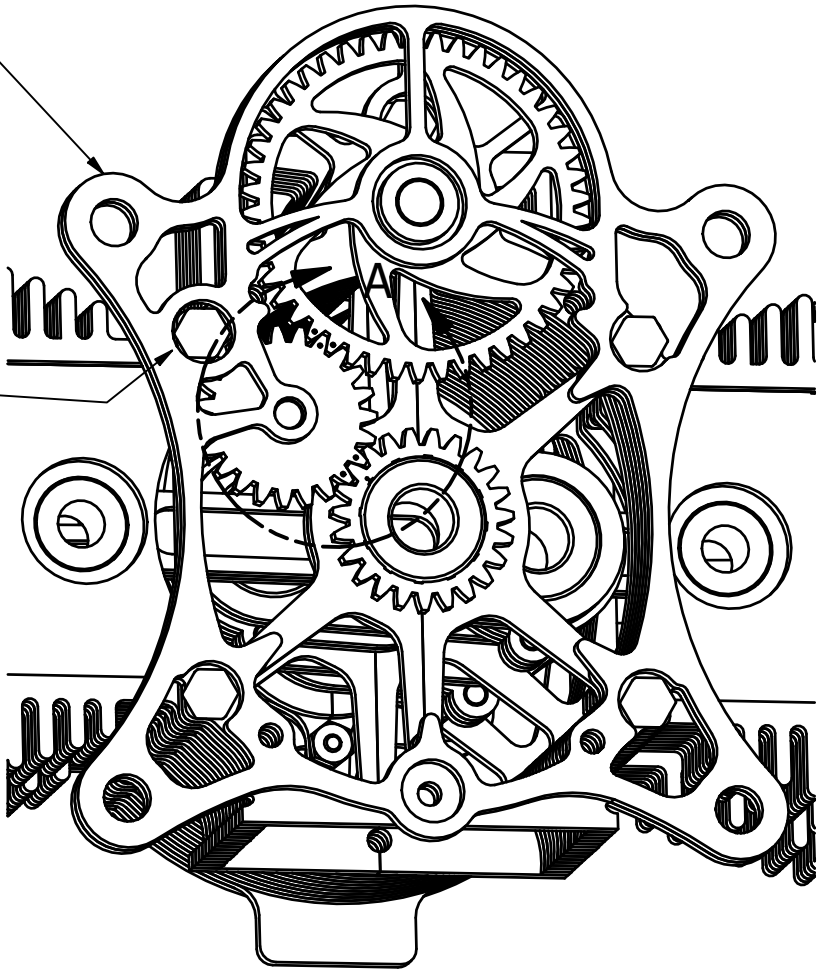
Putting it Together - 5

View A



Locate the idler gear. It may have timing marks (little dots on the teeth) on one side or they may be on both. These marks must mesh with the marks on the cam gear and the crank gear exactly as shown in the diagram on the left, or the valves will open and close at the wrong times.

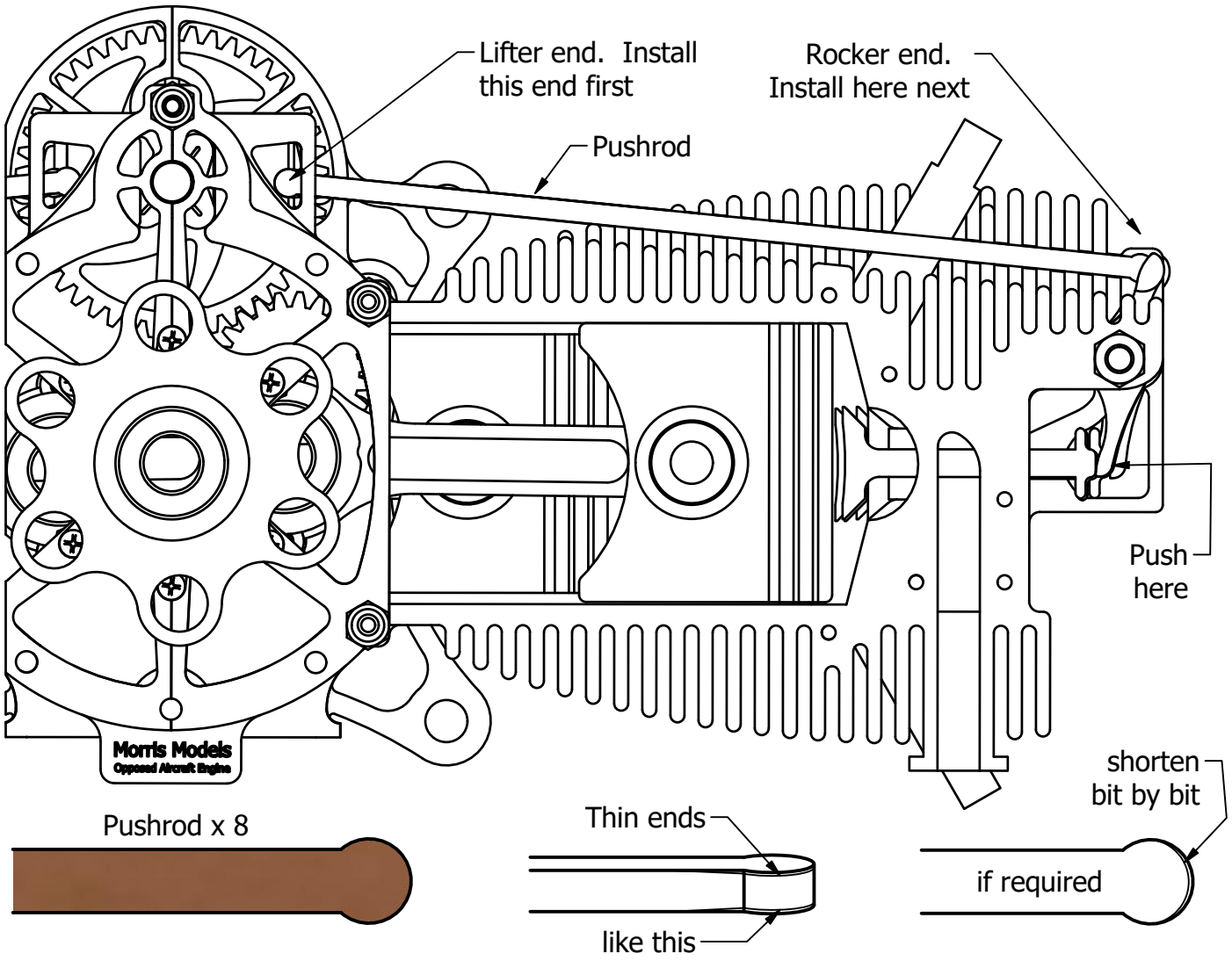
Make sure the camshaft is seated all the way in the engine case. Turn the cam gear to the approximate correct angle. Turn the crank to approximately the correct angle. Carefully slide the idler gear onto the idler shaft with the teeth engaged correctly with both the crank and the cam.



Loosen the nuts if they are in place, and set the accessory case over the tops of the 4 corner bolts. Working one bolt at a time, remove the bolts and re-insert them from the back of the case. They should be just long enough to secure with the locknuts. Secure them, and tighten the nuts down until there is no play. Do not overtighten the nuts. They are very strong, and can crush the little weak layers of wood.

Putting it Together - 6

Front layer of cylinder removed to show pushrod position.



The ends of the rods must be thinned before they can be put into their sockets in the lifters and in the rocker arms on the other side. You need not thin the entire length of the rod. Simply thin the last half inch or so. Test fit each end individually to make sure the fit is good. When ready, fit one end to the lifter in its slot. Depress the valve rocker, and fit the other end into the socket on the rocker. Test spin the engine to make sure everything spins free. Do this for all 8 pushrods.

After the pushrods have all been fit, check to make sure that the valves close completely. When the laser cuts our parts, the kerf is not always the same. We made the rods so that they would be close to correct, but if the err, it will be on the side of being too long. If they are too long, the valves will not close all the way. If this is the case, depress the rocker end and lift the pushrod out of its socket. Gently sand a small portion off the end of the nub, maintaining the rounded shape. Then reinstall the rod and test. Go slowly, removing only a little at a time. It is easy to sand material off of the rod, but quite difficult to sand it back on. Do this for each push-rod that does not allow the valve to close completely.