This is a draft of instructions for machining the crankcase group. They are offered as a suggested method only, with the realization that experienced machinists will undoubtedly discover other and better methods. Completeness and accuracy, realistically, cannot be guaranteed. Only experienced machinists should expect to be able to successfully machine these parts, and they should always rely on their own judgement.

Note: The crankcase, gearbox front cover and oil pan are machined together and become a set. Since they are match-drilled, replacing one of the parts later will be difficult at best.

Before starting, make or obtain the following parts:

1. Crankcasecrossbolts, nuts and washers.
2. Gearbox front cover attachment screws.
3. Main bearing cap screws and washers.
4. Oil pan attachment screws.
5. Gearbox bearings.

I. GENERAL NOTES:

1. Make sure you thoroughly understand each instruction before proceeding. If anything is unclear, please submit questions by mail, email, or fax.

2. Always double check setups before making any cuts. It doesn't take too much of a slip to ruin some of these castings.

3. Sometimes it is necessary to clamp a soft aluminum part securely on the mill table or in a vise. When doing this, never clamp the parts with steel or other hard metal (hard aluminum, brass, etc.) bearing directly on the casting, as this will cause dents and marks. The only exception to this rule is when clamping a broad, flat surface, so that the clamping force is spread out. Otherwise, use soft aluminum, wood, hard plastic (Delrin), or hard (shoe sole) leather between the clamp and the surface. Of course, the part still needs to be clamped securely enough to ensure that it doesn't get loose.

II. CASTING STRAIGHTENING:

By some magic (called precipitation hardening), the hardness of certain kinds of aluminum can be increased considerably by heat-treating. Not only that, but they do not become hard immediately, as steel does, but there is a period of a day or so in which, for example, a distorted casting can be safely straightened (this period can be extended by freezing the parts, or better yet, keeping them in dry ice - this process is used for high-strength aluminum rivets).

The heat-treating process is as follows: the parts are heated in an oven at approximately 1000 degrees Fahrenheit for 10 to 12 hours, then they are quickly plunged into a bath of water at about 160 degrees Fahrenheit. It is critical that they not be allowed to cool in air. The exact amount of time that is allowed between taking them out of the oven and plunging them into the water depends on the thickness of the casting, but it is on the order of a few seconds. Thin castings must be dumped virtually straight from the oven into the water.

Castings with thin and complex cross-sections are particularly prone to distortion. Straightening is always requested of the casting house, but there is no guarantee that it will be done, or if it is, that the results will be satisfactory. Therefore, before doing anything else, check the castings and (except for the crankcase) straighten them if necessary, after some form of heat-treating. This may be a fair amount of work but machining them without doing so would be a simple waste of the castings.

The amount of straightening that can be done on a casting once it has achieved full hardness after heat-treating is very limited, because it is somewhat brittle. Ideally, the casting should be heat-treated by the process described above again, before straightening, but this requires special equipment. If it can’t be done, the casting should be annealed, which means it will remain soft. For the pieces which are most likely to require straightening, strength is not likely to be an issue. The only part which really may be

adversely affected by annealing is the crankcase, since it is the direct link between the prop loads and the motor mount. Instructions are included below for crankcase straightening, but this should not be attempted unless the engine is absolutely never going to be run with a propeller. Otherwise, contact Dynamotive if measurements indicate that the crankcase needs straightening.

Annealing:

Annealing can be done as follows: using a black felt-tip pen, put some heavy marks on the area to be annealed. Then, heat gradually and evenly (typically with a propane torch) until the marks just about completely disappear. The part will be very hot, so allow it to cool before continuing. This treatment is a variation on the old method of putting soot from a torch on a aluminum sheet and heating until it burns off to anneal the metal.

A. CRANKCASE:

1. The gearbox flange must be flat and at right angles to the main bearing centerline. In order to provide a reference for checking this, first make sure the crankcase bottom is flat. Sanding it may be sufficient, but if not. mount the crankcase upside-down on the mill table, using blocks and shims positioned under the front mounting feet to help level the case. Using a dial indicator, adjust the case until readings taken on all main bearing journals are as close as possible, then clamp it carefully but securely. Next, mill the case bottom flat, aiming for the dimension shown on the drawing, and referencing to the bottom of one of the mounting feet. This dimension is not critical, since it just establishes the oil pan position, so in general try to mill off less rather than more. Another factor to consider is the width of the machined case bottom versus the width of the oil pan. Aim for a nice match.

2. Now place the case bottom on a flat surface, preferably a surface plate or block. Using a square, compare the gearbox flange top and bottom. Also, place the flange directly on the surface plate and check it for flatness. If it needs straightening, the general principle is: support the low parts and push on the high parts. To repeat, don't use hard materials for either, as they will damage the castings. Also, make the support areas as large as possible, and always keep in mind the relative strength of both the supported parts and what you're pushing on when deciding how hard to push. If the flange needs to be tilted, clamp it to a large plate using numerous small clamps (even making them if necessary), clamp the case down, and use a lever to adjust the flange.

3. Ideally, the flange should be no more than .010" out of flat when you're done, and the top should be no more .020" out of square with the bottom.

B. FRONT COVER

The objective is to make the cover flange flat, and also to make it match the case gearbox flange as closely as possible.

1. Lay the cover on the surface plate, and check it with a feeler gauge. Variation should not exceed 0.010", or the flange will be uneven and unsightly (ugh!) when it is milled. If variation is excessive, carefully tweak the cover, using a press. The easy situation is if you need to press on the back (flange) side. Support the flange on either side of the uneven area with wooden or plastic blocks, and lay a piece of wood or a padded square metal bar across the whole cover so one end goes over the high area. Don't use a round rod as it concentrates the load too much. Now press CAREFULLY on the rod on a line between the blocks. Since you will be (hopefully) pressing on the rod close to the high area, it will be pressed down, while the other end of the rod will not do much. GRADUALLY build up your pressing force while you check frequently to see how much effect it is having on the cover. If you need to press on the front of the flange, make a straddle bar out of wood or whatever is handy to give the same effect as the flat bar did on the back of the cover. Alternately, you can place a third block under the inactive end of the cover and clamp that end down on the table while pressing the high area.

2. Now that the flange is flat, match the cover up to the case gearbox flange. If it is too narrow, it will have to be widened (easier said than done!). Included is a drawing of a 'spreading tool' which is made out of aluminum pieces and placed in a vise. The cover is placed over it, and closing the vise causes the tool to enlarge. Once the cover width is correct, it will very likely have to be flattened again. If the cover flange is taller than the case flange, it may not be possible to squeeze it to match. It may be necessary to a) let the bottom hang down a bit, or b) trim the cover to match the case flange.

C. OIL PAN

This part is easier to straighten, since it is thin. The surface that bolts to the case bottom should be no more than .015" out of flat, and the sides should be straight.

III. MACHINING OPERATIONS:

A. GEARBOX FRONT COVER

1. Once the cover flange has been flattened as described above, sand it on a surface plate to trim down any minor irregularities.

2. Clamp the cover down on the mill table and mill the front gearbox faces per the drawing.

3. Turn the cover over and bolt the now true front face down on the mill table and mill the bolt flange per the drawing. There may be some chatter, since the cover is somewhat bell-shaped. Modeling clay or something similar can be stuffed under the cover to deaden it.

4. Drill the flange bolt holes per the drawing. NOTE: don't trust the centering depressions, as some of them are not exactly centered. Use a center or spot drill to adjust them as necessary before drilling through.

B. OIL PAN

1. Carefully clamp the pan in the mill vise, and mill down the casting sprue where it joins the bottom of the pan. If you're really ambitious, use a 1/4" mill and try to mill it even with the pan bottom. However, leaving a little of it won't hurt anything. Now the casting sprue should only be joined to the rear of the pan.

2. Depending on how much you're going to take off the flange, you may be able to just sand it down to provide the gasket surface. If it needs to be milled, the pan must be securely supported and clamped. One method is to make little blocks with grooves in them which fit into the sides of the pan, and are tall enough to hold it up in the vise. The blocks are clamped in the mill vise, then the pan set on them. A clamping bar, which extends over the back of the pan to the mill table, holds the pan down in the vise using a block of wood which fit tightly into the top center of the pan. Complicated, but it works.

3. Drill the attachment bolt holes per the drawing. Do not surface or drill the rear of the pan yet, as this will be done together with the crankcase.

C. CRANKCASE

1. Align the gearbox front cover on the crankcase and clamp it in place. If the flanges are not exactly the same size, try to compromise between overall alignment and lining up the tops, as this is the area that will be seen the most. Carefully transfer punch or spot drill the gearbox flange through the cover holes, just enough to provide a reliable drill center.

2. Support the crankcase vertically, using an angle block or other fixture, and drill and tap the gearbox rear bosses per the drawing. NOTE: On the real Merlin, special bolts with thin square heads run through the upper bosses, with nuts on the back side, while studs and nuts are used on the lower bosses. If authenticity is a primary concern, this can be duplicated. Allen screws in blind holes are simpler and give a nice appearance, but it is of course not scale. If another method is used, and the engine will be

run with a propeller, just make sure that the screws are very strong, since they have to bear the considerable loads generated by the prop. One possibility is to machine them out of Allen screws, since these are comparatively strong. In any case, bolt or screw clearance holes should be drilled as small as possible, to maintain cover alignment. In general, obviously, anything associated with the propeller, which is inherently a very dangerous item, must be done with safety always kept in mind.

3. Leave the gearbox cover off for the moment and firmly support the crankcase vertically on the mill table, gearbox up, with the bottom lined up with the X or Y axis. Measure the top bearing hole, and find the centers of the top and bottom holes, and the front main bearing bosses, using a dial indicator or other method. Nominally, the crankshaft centerline is the same as the lower bearing hole, and even with the bottoms of the front feet, but this is not guaranteed. Zero the mill coordinates on the crankshaft centerline, and attach the front cover. Now find the centers of the bearing holes in the front cover. These may be noticeably off from the zero previously established. The objective is to find the best compromise of positions which will center the crankshaft as well as possible, without having the front bearings be noticeably off-center. If the upper holes are noticeably out of alignment, it may be necessary to turn the crankcase slightly. A slight sideways shift of the prop relative to the crankcase will be much less noticeable than an offset of the bearing hole relative to the gearbox casting. The criteria to keep in mind are the following: the crankshaft centerline should be keep as close as possible to the nominal, and the distance between the machined upper and lower holes must be exactly that on the drawing, so that the gears will mesh properly. The reason for measuring the upper rear bearing hole is to make sure that the selected alignment will result in a full cut in the hole. The bearing must not have a side unsupported, obviously.

4. Now bore the front bearing holes per the drawing, using the exact center distance. Bore the lower bearing hole first, and then the upper one, so that the mill table doesn't need to be move when milling the rear upper bearing hole, which needs to be exactly aligned with the front one (actually the lower one does too, but the upper hole alignment is particularly critical. The upper bearing hole should fit the bearing very closely, possibly with a light press fit (max .001" undersize). The front propshaft bearing can't tolerate too much of a press fit, as it is thin-walled. The lower bearing hole is not as critical because the bearing actually goes in an adapter, which can be machined to fit the hole and the bearing.

5. Now remove the cover and bore the rear bearing holes. Be sure to include the depression behind the upper bearing, as it may be needed to allow bearing extraction. When testing the bearing fit, insert it on an extracting dowel with a small flange which goes behind the bearing, to pull it out. An extracting tool can to made to remove the bearing later by slitting a tubular flanged dowel, springing it into the bearing, then inserting a rod in it to keep it from pulling through. When boring the lower hole, be sure to do the facing operation.

6. Lathe-turn a fixture which fits very closely in the lower rear bearing hole with a flange to fit against the facing done above. The bearing diameter should be about 1/8" longer than the bearing hole depth (so that the crankshaft centerline can be found by touching the endmill to this diameter), and in addition, there should be a smaller projection (1/2" in diameter) which will be used with an edge-finder to find the other axis of the crankshaft centerline. Drill and ream an accurate 3/8" hole through its exact center.

7. Clamp the crankcase upside down in the mill vise, using hard leather or plastic pads to protect it. It must be clamped firmly enough to allow machining, but not to deform it; be careful. Pads which fit into the upper curve of the crankcase sides are best, since the lower part of the crankcase will have less chance of being deformed. Before snugging it down, make sure it is completely level. Locate the crankshaft centerline as described above, by registering the

cutting tool on the fixture's bearing diameter, and edge-finding the fixture's small projection.

8. Next is a critical part of the machining, the main bearing cap groove. Although you can compensate for errors to some extent when you make the caps themselves, it is of course best if the groove is even and has square sides (this is one reason why it is important to avoid deforming the crankcase when holding it in the vise). The bottom of the groove should be even with the crankshaft centerline, and the sides equally spaced from it.

9. Use the edge finder to find the center of the thrust bearing, which is part of the center main bearing boss. This will be the x-axis zero for the next operations.

10. Machine the thrust bearing surfaces, keeping them centered on the X-axis zero.

11. Remove the crankcase from the mill vise, and prepare to drill the crossbolt holes. The crankcase needs to be supported on its side, level, and with the bottom square to the work surface. Drill the crossbolt holes. Once they are drilled, the nut pads can be faced if desired by milling or using a spotfacer on each hole.

12. Now make the bearing caps per the drawing, sizing them to fit snugly into their grooves. Mark each with an identifying number (typically, #1 in the front). Clamp them into their grooves, carefully centering them, and transfer punch the main bolt hole and crossbolt hole positions on both sides. Remove the caps and examine the crossbolt marks. Ideally, the marks on one side will line up perfectly with those on the other, and holes drilled from each side of the cap to the center will meet exactly. In the real world, the holes in the caps will have to be made somewhat larger to allow the crossbolts to pass through the cap. After figuring out what size is required, drill the crossbolt holes in the caps, 1/2-way from each side, then remove the caps and drill out the main bolt holes to finish size, from the mounting face side to maintain hole alignment.

13. For the next operations, clamp the crankcase upside down as in step 4 above, but this time in a movable vise, again making sure the crankcase is completely level.

14. Drill the main bolt tap holes, observing the indicated depth carefully.

15. Tap the main bolt holes. This must be done accurately, so don't do it without some sort of alignment aid. Be sure to use lubricant while tapping..

16. Remove the bearing caps, and wash the crankcase thoroughly (I like to use hot water and dishwashing detergent)

17. Make a fixture which fits in the rear bearing slot, and which has a reamed 3/8" hole exactly on the crankshaft centerline. It will look like a main bearing cap, except that it will have a projection down into the bearing area for the hole. Bolt it into the slot.

18. Now you need to mount the crankcase upside down, using endplates of some kind, so that a 3/8" rod (with tapped holes in each end) passing through the fixtures can be make perfectly level and in line with the X axis, and can clamp the case to keep it from rotating. Another method is to mount the crankcase on a rotary table, with a tailstock to support the dowel. Use the edge finder to locate the crankshaft centerline, and the center of the thrust bearing.

19. Position the crankcase at a 30 degree angle, and mill the cylinder block mounting flange. A depth gauge can be used on the 3/8" rod to measure the flange height.

20. Spot drill the stud holes with a short 3/16" drill, and drill the tap holes.

21. Bore the cylinder sleeve holes.

22. Repeat for the other side.

23. Next will be line boring the main bearing mounts. There are many ways to do this. One is

to mount the crankcase on the lathe carriage, so that the crankshaft centerline is on the lathe centerline. Then, a boring bar with a toolbit sticking out the side is turned by the lathe, and the carriage moves the crankcase. Without a vernier adjustment on the tool bit, it is very difficult to get an accurate I.D. The main bearings will be made to fit, but it would be nice to have a standard size to work to. A shell reamer can be used; cheap ones are available from Wholesale Tools, Inc. Mount the shell reamer on a long rod and drive it with the lathe chuck.

24. Drill and tap the cylinder stud holes. Use a block to align the tap.

25. Align the oil pan on the bottom of the crankcase. Ideally, the front of the oil pan can be aligned with the front of the crankcase mounting flange. However, the oil pan bolt spacing may differ enough from the crankcase boss spacing that the rear screws will not not be inside the boss. The safest method is to center the oil pan screw pattern on the crossbolt pattern. This may mean that the front edge of the oil pan will not be aligned with the crankcase. If it's hanging over a bit, it can be trimmed. Once it is aligned as well as possible, clamp it in place and transfer spot the holes, then drill and tap them.

26. Attach the oil pan to the crankcase, and bolt the crankcase on the mill table, using the gearbox flange. Carefully mill the oil pan rear down to cut off the last of the sprue, and to create a common rear mounting surface on the oil pan and crankcase.