

of the cotter key up over the nut and the other side downward, unless in particular cases it is found to be distinctly better to bend both sides of the key around the nut.

**Preparing the piston assembly.**—The next operation in assembling the motor is to be assured that the piston assemblies are in proper condition. First, try the wrist-pin bearings. These should be, when cold, quite stiff, so that the pistons will not rock over with their own weight, but will require a fair amount of pressure with the hand. It must be remembered that when the bearings become hot, the aluminum pistons expand considerably more than the steel wrist pins and the bearings become sufficiently loose. If it is necessary to remove a wrist pin, the set screw is loosened and the pin pressed through. Next see that the set screws holding the wrist pins in the connecting rods, are screwed up firmly and properly locked with wire. It is very important that this wire be perfectly tight—can not be moved with the fingers. All carbon should be scraped from the inside of the piston as well as the outside, taking care to use no instrument that will scratch the aluminum. Examine connecting rods for possible cracks.

Next, remove the piston rings and carefully clean out the grooves. Do not pry ring out of groove if stuck, but put piston in hot water and ring can be easily removed. The rings may best be removed by inserting under them three or four pieces of hack-saw blades, the teeth ground off, and carefully sliding the rings from the piston. They should not be sprung more than is absolutely necessary. If the rings show signs of wear and do not have perfectly square and true surfaces, they should be renewed. If a new ring is found to be too thick to slip easily into the slot, it may be dressed down slightly by rubbing the top surface on a piece of fine emery placed on a surface plate. The bottom surface of the ring must never be dressed in this manner, as this is the surface that comes in close contact with the slot in the piston, and the true factory-ground finish should be left intact in order to assure a perfect fit between the piston and the ring. It should be noted that the factory trade-mark is always stamped on the bottom or the most perfectly finished surface of the ring. This will be found in very small markings at the point where the two ends of the ring come together. Any roughness on the pistons must be dressed down with a fine stone, and the pistons may finally be polished with Dixon's graphite, but no free flakes must be left on the surface.

**Fitting the connecting-rod bearings.**—Now that piston assemblies have all been completed, attention can be paid to the connecting-rod bearings. These are fitted much in the same way as the main bearings, except that each is done independently of the others. First, the lower halves should be scraped to a proper fit with two-thirds bearing surface. Then the caps are screwed on and the bearings fitted so that there will be a clearance of not over 0.002 inch. It will not be necessary to determine this clearance with the use of shim stock. The clearance may be determined by grasping

the connecting rod in the hands and rocking it from side to side, taking care that the rod does not slip on the shaft. A clearance of two-thousandths may be easily determined in this manner after a small amount of practice. Another highly important point in the fitting of connecting rods is their perpendicularity. The best way to check this is by measuring the distance between two ends of mandrels in wrist pin and connecting-rod bearings, but much may be determined with the use of a square laid against first one and then the other side of the piston, and resting on some true part of the case. The bolts and studs should now be firmly cottered, as in the case of the main bearings. In placing the connecting-rods on the shaft, it must be pointed out that there is a difference between the two sides of each bearing—the side of the bearing toward the adjacent connecting rod is finished off squarely, while the outside of each pair of rods has a rounded edge on the babbitt lining. While fitting the connecting-rod bearings, and in all subsequent work until the pistons are on, great care must be taken not to let the pistons fall over from one side to the other, in case the bearings are loose enough to allow them to do so. Also, when the shaft is revolved or the motor turned over the same care must be taken with each connecting rod. This is very important, as the weight of a falling piston or rod is sufficient to bend or scar the piston. All nuts and cotter keys in the crank case must now be inspected for looseness. The surest way to accomplish this is to place the fingers on each nut, feeling for any looseness or lack of a key.

**Preparing to mount cylinders, grinding valves, and testing springs.**—The next unit to be added to the assembly is the cylinders; but first these must be inspected and the valves ground in. No serious trouble is likely to have happened to the cylinders unless the motor has become dry and they are scored. They should, however, be examined carefully for signs of this, and all carbon should be taken out by the use of a scraper that will not injure the cylinders. The valves should next be removed by pressing the cylinder against a forked piece of iron or the jaws of a vise which will compress the spring so that the key may be removed. All valve springs should be tested for tension. The proper data are as follows:

Exhaust valve spring, 35 pounds at a length of  $1\frac{5}{8}$  inches.

Inlet valve spring, 16 pounds at a length of  $1\frac{1}{8}$  inches.

While testing these, the intake pull-down springs may be tested. This type of spring should test 40 pounds at a length of  $2\frac{3}{4}$  inches. It is very necessary that the springs test very closely to the required amount, otherwise there will be vibration during operation. If a spring tests only slightly below the correct amount, the defect may be eradicated by the introduction of washers under the spring. It is highly important that these washers be placed under the spring and not out on the stem, for if placed at the latter point, they would increase the weight of the valve and change the operation.

rocked sideways gently until it slides down easily. Just after passing over the rings, however, the cylinder must be held while the four cylinder nuts are screwed on over the top threads on the long cylinder tie-down studs. If the cylinders are dropped all the way down, the nuts can not be put in place without springing the studs outward, which will tend to crystallize the metal. Again, before bolting the cylinders down in place, a thin coating of graphite should be placed on the under side of the gaskets. This will seal the joint tight, but will not seize it like shellac and tear the gasket when the cylinder is removed again. Just as the cylinder nuts are about to be tightened down, the intake manifold should be placed on the intake ports of the four cylinders and screwed up in order to line up the cylinders with the manifold. Then the cylinder bolts should be tightened down gradually and together. The cylinder nuts may be locked with the use of lock washers with a flat washer under each to prevent the sharp edge of the washer from cutting into the aluminum of the crank case. The tie-down spiders should next be put in place, but the nuts should not be screwed down as yet, and the center nuts should not be put on at this time, as they will have to be removed later in order to put on the water manifolds.

**Placing the valve-operating parts.**—The cam followers should now be placed in position. Each should be examined carefully to make sure that the set screw is not so long that it binds the exhaust cam follower. Also, if a flat surface has been pounded on the bottom of the followers, they may be very carefully ground off by hand on a fine stone until the surface is round again. At this point the end play of the cam shaft should be checked, if this has not already been done. There should be practically no end play to the cam shaft, just enough so that it will turn free, and it should be so placed that the cams fall exactly under the center of the holes in the case for the cam follower guides. If the cam shaft is out only a little in this respect, there will be danger that the exhaust follower will ride on the intake cam, or rub against and break down the edge of it. The cam follower guide nuts, like the cylinder nuts, should be locked with lock washer and flat washers. Next, the magneto base may be put in place with a lock washer under each screw.

**Mounting the intake manifolds.**—The intake manifolds should next be put in place, after first examining them carefully for cracks and for trueness along the ports. The gaskets must be carefully picked over, and if the life is gone from them new ones should be used. Care must be taken, however, that the gaskets used on one side are of the same thickness as those on the other so that the manifold will screw down tightly without springing. The gaskets in this case are put on dry.

**Mounting the rocker-arm assemblies.**—While some of the men are working on the manifolds others should be inspecting the valve-operating mechanism. Quite frequently exhaust rocker arms are

to scrape a spot, use a long stroke which will lift the tool off the surface while it is still moving forward; that is, do not stop the stroke of the tool in such a manner that it will leave a nick. Scrape a spot a little larger than that actually covered by the blue spot, as this surrounding area will undoubtedly mark blue on the next trial, and time will be saved by removing this at first. The bearing surface should not be carried entirely up on the sides of the linings, a two-thirds surface being sufficient. When this is procured on the five bearings, attention must be paid to the thrust bearing and gear. Both should be loose and bear no part of the weight. With the end bearing cap screwed down tight it should be just barely possible to rotate the thrust bearing with the fingers. There should always be a clearance between the cam and crank-shaft gears. This can be "felt" by hand as well as seen with a clear eye, and should be between 0.001 inch and 0.003 inch, measured parallel to the circumference of either gear. On no conditions should a cam gear be filed to give more clearance; and if there is tightness here or at the thrust bearing, the trouble is that the bearings are too low and these should be renewed.

**Placing new bearing shells.**—If it is found necessary to put in new bearing linings, these should be pressed into place with the use of a jig, and held while retaining screws are being inserted. It is well also to allow the edge of the lining to extend about 0.0005 inch above the surface of the casing on both sides, so that when the two halves are clamped together the bearing lining may be further and more completely seated. If no new bearing linings are at hand and the shaft must be raised, 0.002-inch shims may be placed under the bearing linings. This is not good practice, however, and is not to be commended. If shims are used they should be cut to cover the whole surface with the exception of oil holes, and should furthermore extend above the surface about 0.0005 inch in order to be pressed down properly into place. If bearings are shimmed, it will be found necessary to scrape a little off the sides of the linings, as the action of the shims makes the horizontal diameter of the bearing 0.004 inch less, while it decreases the vertical diameter only 0.002 inch.

**Aligning and fitting the main bearing caps and shells.**—Having obtained a proper bed for the shaft, the caps must now be considered. These should first be fitted to the case to insure a true surface, with no tendency to rock. Then all should be set up in place, and motor turned over so that shaft will rest on caps. A marking with bluing should be made in this position, and high sections cut away, as was done in the other half. Then allowance should be made for the clearance of 0.0025 inch in the following manner: A piece of 0.002-inch shim stock should first be laid in the bottom of each bearing under the shaft. These pieces should run the whole length of the journal, but should be only about one-half inch wide. By this method the shaft is raised up a trifle over 0.002 inch and the caps may be fitted until they are a very snug fit. This is

should not be pounded with any kind of hammer to free them. Before raising the crank shaft out of its bed, pieces of rubber tubing should be placed over the bearing studs, in order to prevent the shaft from scraping against the threads when it is being lifted out. This is very important, because the threads are much harder than the shaft, and the least touch will cause a nick in the journal. If the bearing has shims between the halves, it is well to prepare a board with nails for the nuts and shims. In laying the shaft down on the bench, care should be taken to rest the shaft on its side on a flat board so that it will get bearing surface at more than two points, giving an equal distribution of the weight of the shaft.

If the shaft is laid down resting on the gear and thrust bearing only, it will almost always bend a few thousandths out of true. The crank shaft should now be thoroughly washed with kerosene, special care being taken to blow out all oil passages. This may well be done by squirting kerosene into the different holes with a grease gun. Shaft should now be very carefully examined for signs of wear and crystallization, which is noted by a peculiar flaky appearance of the steel. If there is any sign of crystallization, the shaft should be discarded. Early crystallization is due to the incessant hammer-like blows delivered to the shaft by the connecting rods, as the engine runs at full speed all the time.

**Removing the cam shaft.**—All of the motor has now been taken down except the cam shaft. First, all of the bearing set screws should be removed. Then a special Curtiss cam gear puller should be fitted to the gear, and the whole shaft and bearings may be easily drawn out. Very light tapping on the sides of the bearings with a piece of fiber and a hammer will ease out the bearings if they bind at all. Before removing the bearings from the shaft, it should be noted whether they are numbered, so that they may be put back in the same order. The cam shaft should now be carefully cleaned, both inside and out, in the same manner as the crank shaft. Then the crank case may be thoroughly washed out and examined for cracks.

fine sandpaper; but if the surface is badly rough, it must be faced off in a lathe. After the surface has been made smooth and clean it should be wiped over with a rag moistened in oil to give it the most polished surface. The magneto should be rotated by hand quickly to see if a spark can be produced across the safety gap. If no spark is obtained, the magneto should be sent to the electrical room for repairs. The magnetos will not be further disassembled than above mentioned without being sent to the repair room. Whenever a magneto is removed from the engine, the distributor must be removed also and not left attached to the wires.

**Timing the magneto with engine.**—If magneto is found to be O. K., it is placed in position on motor. The timing of the magneto on the OX-5 is 32° before top center; of piston distance, about seven-sixteenths of an inch. The motor is accordingly placed in this position with respect to No. 1 cylinder. The magneto is then turned over until the distributor brush is in contact with the segment to be connected to No. 1 cylinder, and then adjusted until the breaker is just on the point of opening. The magneto is then slipped forward into position, great care being taken in meshing the gears not to turn the magneto armature over out of the position in which it has just been set. Very little oil is put on the magneto, just a few drops in the oil holes for each main bearing. The timing should be checked up with two or three other cylinders.

**Finishing up the gear end of the engine.**—After the magneto, the timing-gear cover plate should be put in place, the gasket being shellacked underneath and graphited on top, with due care that it is not doubled under at any point. The screws holding this should be "safetied" with a wire running through all, and drawn tight. This wire must be so run through the successive screws that, if any one of them were to start to loosen, it would immediately draw the wire tighter. Next, the split plate at rear of magneto gear should be replaced. After this plate is in place, the motor is ready for the water pump. The pump should be taken apart to see that the vanes are in good condition and not rubbing on either side of the housing. If they are, the blades must be shifted on the pump shaft and shimmed. This shaft must be very smooth under the packing and all rust must be carefully removed, otherwise it will wear the packing out rapidly and cause the pump to leak. The packing is a wick packing, and a piece about 8 inches long is required. In taking the pump apart the housing opposite the coupling will slide off after the nut is removed, but it frequently comes very hard, so care must be taken not to bend it or injure the gasket between the two halves. The gasket should be covered with shellac on one side and graphite on the other. The screws holding the pump together may be "safetied" with lock and flat washers. After the pump is in place, the air pump is added, if one is used. This is a simple plunger pump, the bearings of which should be looked over for excessive wear.

## THE CURTISS OX-5 MOTOR

### CHAPTER 1.

#### THE DISASSEMBLY OF THE CURTISS MOTOR

**What should be done before disassembly.**—Inspect engine as a whole to determine general layout and consider best order of removal of parts. Notice any fractures or signs of trouble or heating.

Determine direction of rotation of motor. This is done by turning the engine over and carefully watching the operation of the valves of any cylinder, remembering the fact that in the proper operation of a four-cycle motor the inlet valve will open at the same time or immediately after the exhaust valve closes. If the motor were being revolved in the wrong direction, this order of operations would be reversed.

Check valve clearances after making sure that they are at neutral point. All valve clearances should be roughly checked in taking the motor down, at this affords an opportunity to detect a bent or sprung rocker arm. (In taking clearance measurements, the tappets must be held away from the valve stem with one hand to get the full measurement.)

Check timing of valves by piston distance. (Exact method will be described later.)

Check timing of motor as hereinafter described.

**Removing minor assemblies.**—Remove high-tension ignition wires and spark plugs. Be sure to immediately fill spark-plug holes with plugs of soft wood or some other material that will not chip, to prevent cotter pins or other foreign bodies from dropping inside of the cylinders.

Remove carburetor and duplex manifold as one unit after disconnecting water tubes.

Remove inlet water manifolds, breaking the hose joint which is next to the water pump.

**Removing rocker-arm assemblies, manifolds, and pump.**—Next remove rocker-arm assemblies complete by removing two nuts on top of each cylinder, and two at the base of the tie-down straps. In releasing the tie-down straps, tension may very conveniently be taken off the nuts while unscrewing by placing the jaws of a monkey wrench above the tie-down straps and around the hollow push

**Regarding spark plugs.**—The proper cleaning of spark plugs should be demonstrated before these are replaced in the cylinders. Several plugs should be taken apart and the correct method of installing porcelain or gaskets taught. The proper setting for the spark plug points is 0.025". In fastening and tying down the high-tension leads, make sure that they touch no moving part.

#### SPECIFICATIONS OX-5 ENGINE

Type—90° V.

Cooling—Water.

No. Cylinders—8.

Bore—4.0 Inches.

Stroke—5.0 Inches.

Comp. Ratio—4.92:1.

H. P.—90.

Fuel Consumption, Gal. 1 Hr.—9.0.

Oil Consumption, Gal. 1 Hr.—.085.

Oil Circulation—Full Force Gear Pump.



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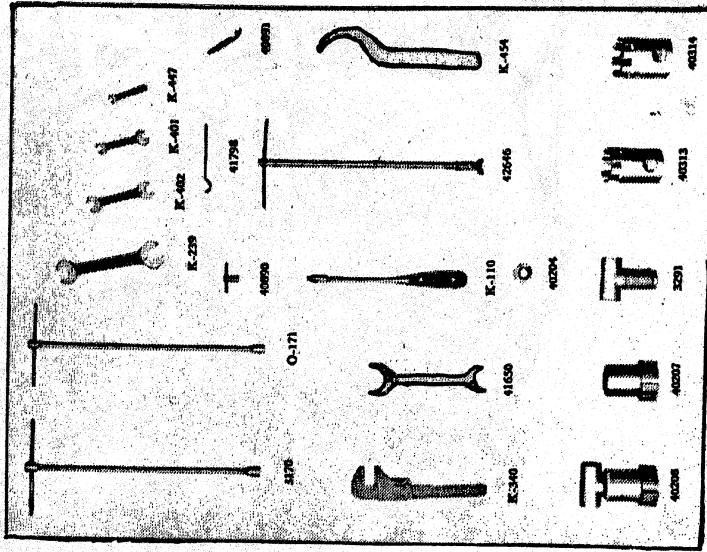
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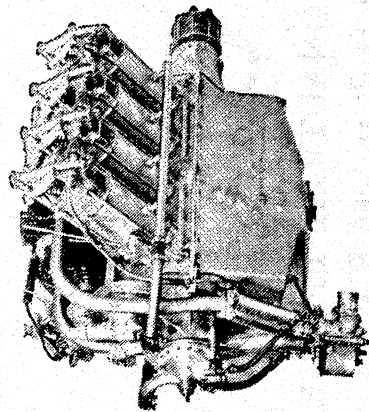
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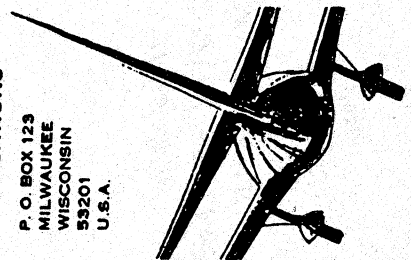
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K-340	9/16" Adjustable Wrench	1	1.00
K-401	3/4" x 1/2" Double End Wrench	1	.35
K-402	3/4" x 5/8" Double End Wrench	1	.50
K-447	1/2" Open End Wrench	1	.25
K-454	Thrust Bearing Lock Nut Wrench	1	.50
N. B. 3	Double End Spark Plug Wrench	1	.80
O-171 A	Piston Pin Clamp Screw Socket Wrench	1	1.00
O-171 B	1/4" Socket Wrench, Swedish Tool Steel	1	1.00
3170A	1/4" Socket Wrench, Swedish Tool Steel	1	1.00
3170B	1/4" Socket Wrench, Regular Steel	1	.50
40291	Screw, Propeller Hub Puller	1	2.00
40294	Seat, Swivel	1	3.00
40297	Body, Propeller Hub Puller	1	5.00
40303	Propeller Hub Puller Assembly	1	5.00
40313	Socket Wrench Crank Shaft Nut	1	.75
40314	Socket Wrench Propeller Hub Nut	1	.75
40346	Water Pump Wrench, Swedish Tool Steel	1	1.00
41650	Water Pump Packing Nut Wrench	1	.75
40890	Master Jet Socket Wrench	1	.30
40891	Mastec Wrench	1	.15
41788	Intake Push Rod Wrench	1	.25



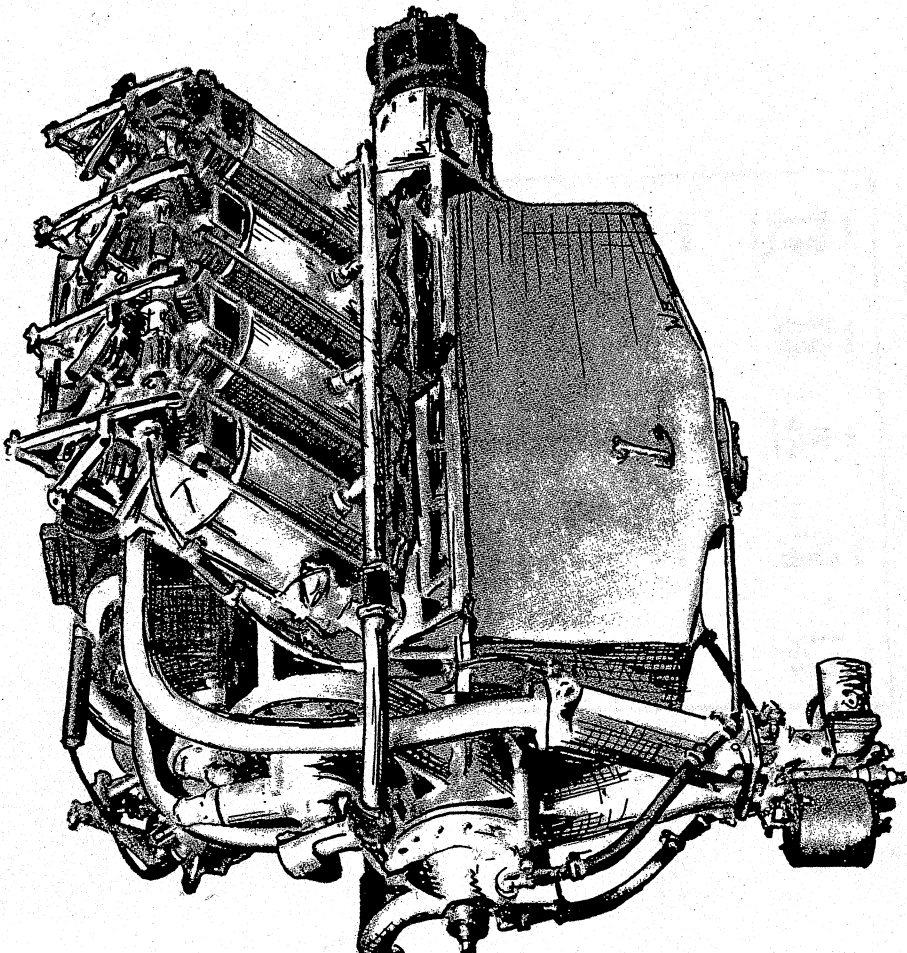
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Curtiss OX-5—90 H. P. Aeronautical Engine

**NICHOLAS-BEAZLEY AIRPLANE CO., Inc.**  
MARSHALL, MO.

*HAND BOOK*  
*and*  
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AERONAUTICAL ENGINE  
90 H.P. at 1400 R.P.M.

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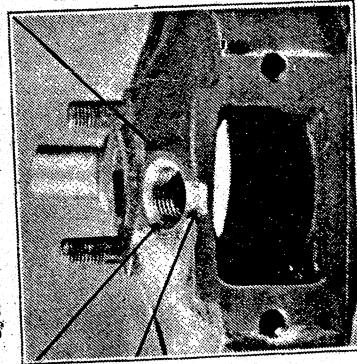
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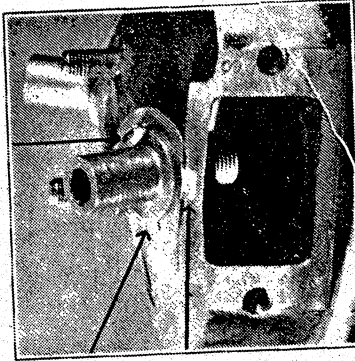
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Cylinder Ready For Installation

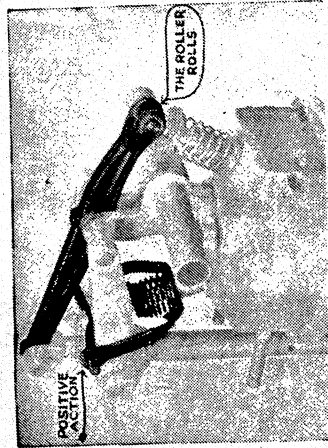
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OXX-6, 100 H. P. Motor, Overhauled .....	750.00
OXX-6, 100 H. P. Motor, Used, Serviceable .....	Write for Prices

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**Placing the sump.**—It is now necessary to turn the engine over in the stand and put on the sump. This should be carefully cleaned, including the strainer, and examined throughout for cracks. The gasket must be complete and perfect, shellacked to the sump, but covered with a coat of graphite on the other side. The bolts must be run up from the under side with a flat washer, lock washer, and nut on the top. When this is secured, the end plate at the thrust bearing may be put on and the retaining nuts wired. The oil pump should be opened and examined, although there is little chance of trouble here. It should be perfectly clean, however. In dropping the pump into place it will be necessary to rotate it until the square end drops into place in the square socket in the bevel gear.

**Placing the carburetor and miscellaneous connections.**—The motor is now turned back right side up, and the carburetor, water pipes, and small oil pipes added. The plugs in the bottom of the carburetor should be removed and the carburetor flushed out to make sure that it is clean. The float mechanism should be examined to make sure that it will function properly. A good combination of jets to use for average condition is: Main 120, comp. 110. But this is affected more or less by the quality of the gasoline and the condition of the atmosphere. It is highly important to have good tight-fitting fiber gaskets under the jets. Lock and flat washers may be used in "safetying" the carburetor nuts. In putting the inlet water pipes on, new gaskets should be used unless the old ones are in good condition. All rubber hose connections in the water system should be coated inside with shellac. The clamps should be screwed tight, but not tight enough to cut into or injure the hose. As an additional precaution against leaks, the hose may be taped with friction tape and another coating of shellac placed outside. This shellac will seize or stick to the rubber, but may usually be broken away by grasping the hose in the hand over the joint and twisting it. The few remaining parts are now added and the motor is complete.

**An inspection.**—Undoubtedly the most important part of airplane motor work is the inspection, so that now the motor must be given a very thorough and rigid inspection. It is well to feel of each nut with the fingers, as in the case of the crank-case nuts. Ignition wires should be carefully looked over for possible chafing. They should be checked over again to see that the right lead goes to the proper plug, and that the ends of the leads are not weakened by the breaking of a number of the strands of the wire. This is a point that is quite important and one which is often overlooked by the mechanic in the field.

rods. Very slight pressure downward on the wrench handle will make it bind and hold down the spring without doing any injury to the push rod. The inlet manifold assemblies complete may be removed next, care being taken to save and not injure the gaskets.

Next the pump and timing gear end plate should be removed.

**Removing magneto.**—The magneto and base plate may now be taken off and the magneto sent to the electrical repair room for overhauling.

**Removing cylinders.**—Nothing remains on the top of the crank case now but the cylinders. If, after all nuts have been removed, the cylinders stick, a slight tap of the hand will release them from the case. They should then be raised carefully, first making sure that the gaskets are coming up complete with the cylinders. When the cylinders are being raised clear of the pistons make sure that someone is holding the piston so that in case the wrist pin bearing is free the piston will not fall over and hit its skirt against the connecting rod. Pistons falling over in this way may be very easily broken, but if not actually broken, the skirt will become at least dented outward or cracked.

Care must also be taken not to bend outward the cylinder tie-down rods. In order not to do this, the cylinder must be raised to the top of the stud and held there while the four nuts are unscrewed over the thread at the top of the studs.

**Revolving crank case; removing sump and connecting rods.**—Now the motor may be turned upside down. (Warning—Make sure that the motor is tightly bolted to the revolving stand by all four legs, and that oil has been drained.) First remove the oil pump and connecting pipe, then the face plate on the hub end of the crank case, then after removing all bolts the entire sump may be lifted off. Here again care should be taken not to destroy the paper gasket that runs under the sump. The strainer may now be removed from the sump and washed with gasoline or kerosene, and the whole sump carefully examined for cracks.

The connecting-rod bearings and main bearings are now exposed. Remove all cotter keys. The caps of the connecting-rod bearings may now be removed, care being taken to hold each rod so that it will fall through when the nuts are released. Each cap should be replaced on its own connecting rod, and all nuts must be released with a proper fitting socket wrench.

**Removing, examining, and handling of crank shaft.**—Before removing crank shaft examine clearance between cam gear and crank-shaft gear in order to determine whether or not the bearings will have to be raised. Then the crank shaft may be taken out. In removing the bearing cap nuts a socket wrench should always be used and should be carefully fitted so that it will never slip. When nuts are removed, the caps can best be lifted with the use of a special tool in the form of a lever with a fulcrum attached. Caps



found bent or sprung. In this case they should be renewed and not rebent. The rocker-arm bearings, if improperly oiled, will wear quite badly and become loose. Bearings in this condition should be taken down and rebushed in the machine shop. Possibly it will be necessary to make new pins. Very careful attention should be paid to the small bearings on this part of the motor. The small water gaskets on this assembly should not be overlooked. They must be shellacked to the rocker-arm assembly, but should be coated with graphite grease on the side next to the cylinders. These gaskets must be cut so that they extend out to the sides around the studs. All moving parts must be properly oiled and especial attention paid to the small oil holes in the rocker arms. These become easily clogged with dirt, and this condition is the cause for a great deal of the wear that so often takes place at this point. The two center nuts holding the water leads are now tightened, as these can not be tightened later without throwing out the valve clearance. Then the four outside ones may be set up, and safely locked with cotter keys on account of the excessive vibration on them. The nuts holding the tie-down straps must be safely locked with lock washers. As the nuts located on the tops of the cylinders are fastened down, the cam shaft should be re-  
 volved so that there will be no strain on the rocker arms when the nuts are being set up.

**Valve timing.**—Everything is now ready for the timing of the valves. On the Curtiss OX-5 the exhaust valve should close 10° past top center. All valve clearance should average 0.010 inch. If a timing disk is available, this clearance should be set on No. 1 cylinder and the gears meshed so that the exhaust valve is just closing at this point. This may be determined by placing a 0.001-inch or 0.002-inch thickness gauge under the rocker arm, the moment that this is released being the moment at which the valve is seated. If the gear teeth do not mesh at this point, the cam shaft should be moved so that the timing will be later rather than earlier, but not by an amount that would be in excess of 5°. After No. 1 cylinder is correct, each succeeding cylinder should be placed at 10° past and the timing checked up. Any small variation may then be corrected by changing slightly the valve clearance. If a timing disk is not available, the engine may be timed by piston distance, though this is not so accurate. In this case the piston should be allowed to drop one-sixteenth inch below top center and No. 1 exhaust valve timed at this point. The remaining clearances should be set at ten-thousandths, as this method is not accurate enough to correct by clearance.

**Preparing the magneto for mounting.**—The magneto should now be installed, but first it should be checked up in the following respects: The breaker-box cover should be removed, and small parts examined for wear or burning. The distributor head should be removed and the distributor wiped out carefully with a dry cloth. If the contacts are black, they may be burnished with very

**Preparatory inspection.**—In building up the motor, the greatest care must be used in the inspection of the parts. The least crack of any kind should be sufficient to condemn the part. Before assembling, all parts must be very carefully cleaned with kerosene or gasoline, and after becoming dry all bearing surfaces must be covered with a coating of oil. This because, if the motor be assembled dry, it may be forced to run for some time before the pump is able to circulate oil to the remote parts of the engine.

**Fitting cam-shaft bearings.**—As the cam shaft was the last part to be removed from the engine, so it is the first part to be replaced. First, examine the cam gear for wear in the teeth, then examine the shaft. It should be tested in a lathe for straightness if it binds in any way. The split bearings must be screwed together tightly without shims and should not have over 0.0015 to 0.002 of an inch clearance on the shaft. These may be tried before replacing the shaft. The bearings, if all right, should be removed from the shaft and tried in their proper location. The cam-shaft bearings should fit in their casings with an extremely light driving fit. If loose, new bearings should be procured. Remove these bearings, slip shaft into position, then replace bearings around the shaft in a position adjacent to the casing which is to retain them. Great care must be shown in determining that the oil holes in the bearings properly register with the holes in the webs and also with the holes in the shaft. Notice the small shoulder on front bearing and see that this is guided properly into its place. Set up retaining set screws. It should now be possible to rotate cam shaft easily with one finger on the gear.

**Inspecting and checking the crank shaft.**—The first operation in fitting the shaft is to cover the journals with a very thin coating of prussian blue and then lay it in its bed to get a preliminary marking. The thrust bearing should also be blued; and it may be noted here that this bearing should have been carefully inspected, especially to see that all balls have a perfectly smooth surface, scars indicating a future break. After rocking a few times, the shaft is removed and all markings examined carefully. Not much can be said on paper about the proper method of fitting bearings, but the following bits of advice and warning should be heeded: First, do not do any scraping until you have considered the markings on all bearings in conjunction with each other, and have decided the effect that the removal of metal from one spot may have on other bearings farther down the line. When it has been decided

**The valve-grinding process.**—After grinding the valves notice must be taken of the valve-stem guides. There should not be any noticeable looseness here, or air will rush in on the intake stroke, ruining the mixture. The valve seats should be inspected next to determine whether there is need of grinding at all. Very small pits may be disregarded, but large ones should be ground out as follows:

- (a) Place a small amount of fine grinding compound on the edge of the valve and insert valve into its seat, taking care not to get any of the compound on the inside of the cylinder walls.
- (b) Grasp the end of the valve stem with a valve-grinding tool which resembles a tap wrench.
- (c) Rotate the valve upon its seat.
- (d) Use very short strokes and lift the valve off its seat at the end of every stroke.
- (e) Very little pressure must be exerted, but the compound must be renewed after a very small amount of grinding.
- (f) The valve must not be pounded down onto its seat. It must be borne in mind that fresh compound continually redistributed on the surface by lifting the valve will accomplish a much quicker and better job than much rubbing under heavy pressure. Moreover, this latter method will cut grooves or rings in the valve seat.
- (g) When it is considered that the valve has a tight seat, the cylinder and valve must be thoroughly wiped with gasoline to remove all traces of the compound, and the valve replaced with its spring for testing. Rubbing the valve around in its seat at this point with a little pure oil on it will usually produce a tighter fit.
- (h) Test by introducing a small amount of gasoline in the manifold and watching inside of the cylinder to see if any of it seeps through inside.

A perfectly seated valve should hold the gasoline without showing any signs of leaking. If the pit holes are very deep, coarser compound may be used in the beginning, but in this case the valve should be finished off with the finer compound. In placing the cotter keys in the valve stem, care should be taken that the ends are bent around far enough so that they will not interfere with the action of the springs, and at the same time that they are not loose.

**Mounting cylinders.**—The next point before placing the cylinders on the motor is to see that the gaskets at the bottom are in good condition. Shellac should be used to hold the gasket on the cylinder, and it is of the utmost importance that no edge of the gasket is bent over, for if this is the case, the whole cylinder will be forced out of line, oil will leak out at the gasket and the inlet manifold will not fit without straining something. In placing the cylinders, great care must be taken not to break or injure the rings. These should be compressed with the hands and the cylinder should be

done in the same manner as the lower caps, only one at a time. They should be scraped until there is a two-thirds bearing surface, and until the shaft may be turned only with considerable force by hand when the cap is completely screwed down. In screwing down bearing cap nuts, great care must be taken not to strain the threads. It is very easy to put too much power into a well-fitting large socket wrench and thus seriously strain the threads. Moreover, only a socket wrench should be used in screwing up these nuts. When each cap has been fitted, shims are removed, and all caps screwed down, after first covering the bearing surfaces with a coat of oil. The shaft should then turn quite freely, and thrust bearings and gears should have proper clearance. In case there is too much clearance, the caps must be filed down. This may be done by drawing the ends of the cap back and forth over a strip of crocus cloth placed on a surface plate. Care must be taken to keep the surface true.

**The "end play" of the crank shaft.**—Nothing yet has been said about the end-play adjustment of the crank shaft. This is determined entirely by the thrust bearing. It will be found that with no thrust bearing there will be allowed about three sixty-fourths inch of end play to the shaft by the webs of the crank case. If the motor is to be used as a tractor, as is usually the case, this end play should be adjusted so that two-thirds of the space is toward the forward end of the motor. This is done so that the forward pull of the shaft will cause the throws to center themselves between the webs as wear appears in the thrust bearing. If it is necessary to set the shaft to the rear, this may be done by introducing a thin shim between the thrust bearing and the shoulder on the shaft. But if the shaft must be set toward the front, it is necessary to put the shaft in the lathe and take a very fine cut from the shoulder on the shaft. No shims can be placed between the thrust bearings and the case.

**Safety locking bearing nuts.**—In regard to the proper placing of cotter pins in the bearing nuts, there is much argument, but the following points stand out preeminent:

First.—No nut must be turned backward or loosened to make the cotter-pin holes line up. If it can not be turned forward to the next slot in the castellations without straining the threads, the nut should be removed, and the bottom surface filed a very small amount. This process should be repeated until the nut will turn nicely up to a slot in the castellations.

Second.—The cotter keys must completely fill the holes in the stud bolt.

Third.—They must be so placed that they do not wiggle or feel loose in any way when touched by the fingers.

Fourth.—The cotter keys must not be bent over with a hammer, but should be bent with a pair of round nose pliers. Bend one side