PISTONS TO FIT RECONDITIONED CYLINDERS

Prepared FOR VEHICLE MAINTENANCE SECTION
DIVISION OF MOTOR TRANSPORT
OFFICE OF DEFENSE TRANSPORTATION

by MAINTENANCE METHODS COORDINATING COMMITTEE
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CYLINDER REBORING

DETERMINING SUITABILITY FOR REBORING

Inside micrometers or a cylinder gage should be used to determine necessity of reboring block.

The manufacturer's recommendations should be followed in determining proper limits for reboring.

Measurements for reboring or reringing vary considerably in different operations and under different conditions; consequently, usage should determine measurements to be used in each case.

Many operators have found it practical to use sets of special rings in reringing in order to defer the reboring operation. The best practice indicates that unless it is possible to get approximately 50 percent of the service from a new set of rings that was obtained from the original set, reboring should be considered.

Reports from average operations in various types of truck and bus services show the following results:

BUS

Rings are replaced:

In most cases rings are not replaced until motor is rebored.

City bus: Approximately 10 percent of engines have rings replaced from 50,000 to 75,000 miles, due to ring failure or other causes.

Rings replaced whenever excessive oil consumption is noted as the result of ring wear.

Block rebored:

100,000 to 150,000 miles, or when oil consumption exceeds 350 miles per gallon.

All engines completely reconditioned at 125,000-mile intervals.

TRUCK

Rings are replaced:

Heavy duty: 50,000 miles.

City delivery: 25,000 miles.

Engines up to 350 cubic inches displacement: When oil consumption reaches or exceeds 300 miles per gallon.

Over 350 cubic inches displacement: When oil consumption reaches or exceeds 200 miles per gallon.

Engines up to 250 cubic inches displacement (in a scattered fleet away from supervision): When oil consumption reaches or exceeds 800 miles per gallon.

All sizes: When oil consumption reaches or exceeds 3 percent of gasoline gallonage.

Block rebored:

Heavy duty: 80,000 miles.

City delivery: 40,000 miles.

All engines are rebored when cylinders show maximum wear of 0.019 inch.

However, if maximum wear shows 0.015 inch or greater at time of inspection, block is rebored.

SERVICE STATION PRACTICE

With mileage unknown: When cylinder bore measurement taken 1¼ inches from top of ring travel does not show over 0.005-inch wear, new rings are installed. Ridge at top of cylinder bore is removed.

With mileage unknown: When cylinder bore measurement taken ½ inch from top of ring travel shows less than 0.012-inch wear, new rings are installed and pistons expanded.

CYLINDER REBORING METHODS

Gray iron blocks.—Any good standard boring bar should be used, boring down to within 0.0005 inch to 0.001 inch of the desired measurement. The surplus metal left after boring should be removed by honing. Bore should always be scrubbed with soap and water after honing and dried thoroughly. A clean block should show no dirt when rubbed with a white rag.

Alloy blocks.—Same as for gray iron blocks.

Sleeved blocks; hard sleeves.—The general practice is to rebore dry sleeves (which will not turn in block) in place with a standard boring bar provided sleeves do not exceed 450 Brinell [1] in which case they must be ground and honed with Heald grinder.

Removable sleeves, below 450 Brinell,[1] should be machined in a jig with boring bar and then honed. Above 450 Brinell,[1] the sleeves should be ground and honed or wet honed with Barnes drill and micromatic hone. In either case the jig which holds sleeve must be internally finished on and by the machine used to recondition the sleeve.

INSTALLING PISTONS IN REBORED BLOCKS

It is good practice to follow closely the engine manufacturer's recommendation on proper piston clearances during installation. Occasionally the operator will use pistons made by a manufacturer other than the maker of the ones supplied by the engine builder; in which case the maker of the pistons used can supply the necessary clearances for the particular piston and engine in question.

In cases of emergency, when the piston maker's recommendations are not available, the following information, found to be satisfactory in current practice, is offered for use:

[1] Consult manufacturer for Brinell.

INSTALLATION OF ALUMINUM PISTONS

Before giving the average formula covering aluminum pistons it might be well to explain the various types of aluminum pistons which are in use:

1. Aluminum slotted type.

1a. Aluminum strut type.

1b. Aluminum T-slot with box relief around the wrist pin.

All three types use the same average formula clearance of three quarters of a thousandth of an inch (0.00075 inch) clearance per inch diameter of piston at the skirt and four to five thousandths of an inch (0.004 inch–0.005 inch) per inch diameter of the piston for the ring land clearance.

2. Aluminum T-slot cam-ground pistons.

2a. Aluminum T-slot LO–EX cam-ground pistons.

Pistons of the type 2 and 2a have no average formula for clearance due to the fact that each piston has its own special designed cam dimension.

In case of emergency the average formula as given for 1, 1a and 1b above could be used for types 2 and 2a after first performing the following: Since types 2 and 2a have no box relief around the wrist pin, remove from fifteen to twenty thousandths of an inch (0.015 inch–0.020 inch) on the entire wrist pin sides of the piston *exclusive of the ring land.* This operation prevents the pistons from overheating and seizing. However, this is for emergency use only, since manufacturer's recommendations for tolerances should be used whenever possible. Care should be taken in installing slot-type pistons to see that slot is opposite the thrust side.

3. Heavy duty Lynite round ground.

The average formula for this type of piston is three-quarters of a thousandth of an inch (0.00075 inch) clearance per inch diameter at the skirt and five to six thousandths of an inch (0.005 inch–0.006 inch) per inch diameter of the piston for the ring land clearance.

FINAL FIT CHECK (OTHER THAN CAM-GROUND PISTONS)

Check pistons in cylinders, having on hand two shim stock strips: one to be one-half a thousandth of an inch (0.0005 inch) under and the other one half a thousandth of an inch (0.0005 inch) over the desired clearances, both strips to be ½ inch in width and the length of the cylinder barrel.

Using one strip at a time for test, the piston should slide freely with the undersize strip in place between piston and cylinder, and be tight with the oversize strip in place.

CAM GROUND PISTON CLEARANCE FINAL CHECK

Piston clearance should be determined by checking with a thickness gage, which could be a piece of shim stock material ½-inch wide, length of the cylinder barrel, and the proper thickness size as given for clearance of the cam-ground piston recommendations 2 and 2a. The gage strip should be held parallel to the cylinder barrel with the piston installed with the thrust face (that is, face at right angles to wrist pin) against the metal strip. At this point it should be possible to withdraw easily the metal strip while holding the piston in the cylinder. Thicker and thinner strips may be used to prove whether the piston is too large or too small. A strip of 0.0005 inch oversize (that is, over the manufacturer's recommended clearance) should be tight, and the strip 0.0005 inch under the manufacturer's recommended clearance should be easily removed.

OIL CONTROL

Oil drain holes.—Care should be taken to see that all oil holes are perfectly clean before assembly.

In the event that trouble is experienced with excessive oil consumption, the following practices are proving effective for oil control in many well-managed fleet shops.

Suggestion No. 1.—A chamfer is cut around the piston at the bottom of the oil ring land (oil ring located above piston pin only) about ⅛ of an inch wide, and at an angle of 45° to 60°. Drill 8 holes 3/32-inch diameter perpendicular to the chamfer equally spaced around the circumference of the chamfer. In the case of some T-slot pistons the chamfer will enter the T-slot, eliminating the necessity of drilling holes in that area.

Suggestion No. 2.—A large fleet operator has found that cylinder wear has been reduced and lubrication of the upper section of the cylinder generally improved by cutting a chamfer below each ring slot, *except the top firing ring slot,* without drilling holes in this chamfer. In operations involving a number of engine starts per day, particularly with cold engines, this chamfering procedure provides oil-storage capacity to supply lubrication as soon as the starter turns the engine. See illustration.

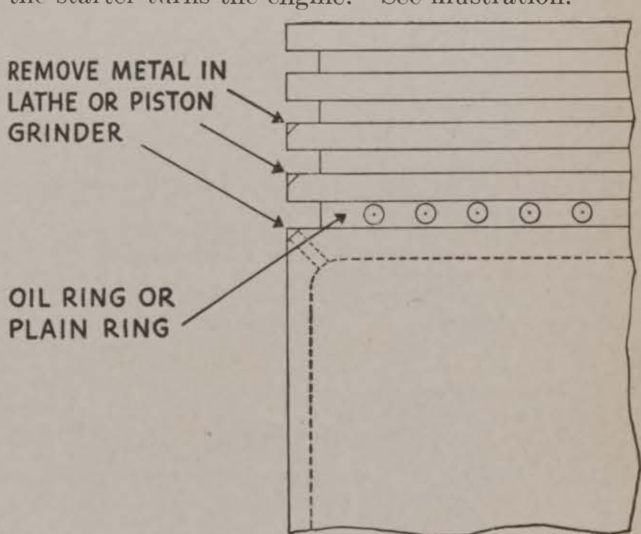

FIGURE 1.—Suggestion No. 2 for oil control.

Some cases of chamfering below the ring slots resulted in too much oil control, which was overcome by installing plain compression rings in the oil slot instead of the conventional oil-control ring.

INSTALLATION OF RINGS

Check each ring for proper end clearance by inserting in the cylinder barrel. In order to be sure ring is square with the cylinder, it is recommended that the piston be pushed against the ring while in the cylinder. End clearances measured with thickness gauge should be: 0.004 to 0.005 inch per inch bore for the top ring; 0.003 inch per inch bore for the other rings.

Where ring end clearance is less than that recommended, the gap can be increased by filing the ends of the ring until the proper clearance is obtained. Care should be taken to file the gap square and true.

Rings must be checked for side clearance in the piston slots to dimensions recommended by the engine manufacturer. Side clearance of piston rings in grooves should be determined by actual test with thickness gages. The top compression ring, being subjected to more heat and higher pressures than other rings on the piston, requires more clearance than the other rings. This ring on the average automotive engine requires a side clearance of 0.0015 inch. A thickness gauge of this size should slide freely between one side of the ring and the ring land. The other rings on the average automotive engine are given 0.001 inch side clearance. As thickness gauges of 0.001 inch are not generally obtainable, all other rings must be checked so that when installed on the piston they will fall freely in the ring grooves. When making this test, hold the piston in a horizontal position and note whether the ring drops down freely when raised up from the under side and released. Rings that do not pass these requirements should be removed to determine whether the fault lies in the ring itself or in the ring groove. Possible causes of sticking are overwidth rings, twisted rings, underwidth ring grooves, or (in the case of used pistons) distorted ring lands, or improperly cleaned ring grooves.

Finally all the rings must be checked again on the piston to be sure that they are free and will not extend beyond the piston slot lands when pushed all the way in the ring slot. Failure to check these two items may cause a tight job and result eventually in cylinder scoring.

It is also recommended, before inserting the pistons with rings installed in the cylinder barrels, that the rings be turned by hand so that all gaps are on the pinhole side with alternate rings spaced 180° or one-half turn from the ring above or below.

Introduction of engine lubricating oil to the piston and rings will assist installation in the cylinders and provide initial lubrication when the job is completed and ready for operation. Extreme care must be exercised to prevent ring breakage when installing pistons in cylinder barrels. The use of a ring compressor is recommended.

CUTTING DOWN PISTONS

In fleet operation where a number of different types and makes of equipment is in use, it is recommended that semifinished pistons be stocked which can be cut down to the sizes required by various cylinder oversize reboring. The prevailing practice in the automotive replacement parts industry is, and for many years has been, to carry semifinished pistons in stock and grind them to various oversizes as required. For the types of use given above, viz, fleet operation and replacement parts industry, this practice results in a great inventory reduction in the number of sets of pistons to be carried for each year and model of any particular engine. It is obvious that one set of semifinished pistons can be machined to fit a cylinder regardless of oversize, be it 0.020, 0.030, 0.040, 0.050, 0.060 inch or a cylinder resleeved to standard.

A large fleet operator using many types and sizes of equipment states: "To carry a selection of standard oversize pistons is wasteful of stockroom space and material, as well as involving the operator in a heavier expense for spare parts than is justified." It is his policy to carry semifinished pistons and then grind and/or cam grind as necessary. The bores to which these pistons were fitted were always reconditioned to a standard oversize. This permitted the use of pistons in more than one cylinder block. For example, a set of 0.040 inch oversize pistons removed from a worn block which would be reconditioned to 0.060 inch oversize could be used in a worn block reconditioned to 0.040 inch oversize. On the other hand, these pistons, if worn, could be ground down to be used in any block of smaller bore. In order to carry out this procedure it is occasionally necessary to widen the top ring groove to take the next width of piston ring, as slight wear of the groove may make it too loose a fit for a standard width ring.

Among shops or engine manufacturers doing engine reconditioning and among fleets where the engines are predominately of one make, the accepted practice is to carry 0.020-inch, 0.040-inch, and 0.060-inch oversize pistons in stock. The reason for so doing is that the first time the motor is torn down, the block is bored and honed to 0.020-inch oversize and refitted with 0.020-inch oversize pistons and rings. Later on the same block is usually bored and honed to 0.040 inch oversize and refitted with 0.040-inch oversize pistons and rings. This process is carried on up to and including 0.060 inch oversize.

The general practice in reboring is to limit this work to 0.060 inch oversize, although exceptional jobs have been reported up to 0.100 inch or above oversize where cylinder wall thickness is known to be sufficient.

METHOD OF CUTTING DOWN PISTONS

In cutting down oversize pistons the following procedures should be observed:

a. Check new piston with original piston to determine proper compression distance, over-all length, pinhole diameter, etc.

b. Rechamfer the inside lower skirt part of piston that contracts the arbor to be used in machining. This is necessary to insure a round and accurately machined piston because pistons become distorted at this point through seasoning of the casting as well as through shipping and handling.

c. The center hole in the head of the piston should be examined to determine whether it is deep enough to accommodate the centers of the machines to be used in finishing. If the centers do not fit properly at this point an out-of-round piston will result.

d. White or red lead should be used in the center hole as a lubricant during machining operations.

e. The clearance recommended by the engine manufacturer for the particular piston should be followed. These clearances are the result of laboratory and field tests and are invariably correct. Where a piston of special design or special material is to be used to replace an original piston, it is advisable to secure the proper clearance from the maker of the piston.

f. Where a large amount of stock is to be removed, the piston should first be turned down on a lathe to within 0.008 to 0.010 inch of the finished size, then finished on a piston grinder to exact size. Pistons that require cam grinding must be finished on suitable cam-grinding machinery to exact specifications. Any attempt to finish cam-type pistons to any other shape is certain to result in damage to the engine. Where cam-grinding equipment is not available, it is sometimes possible to secure cam-type pistons with a milled relief on the pinhole sides, making it possible to round-grind this type of piston.

g. Attention must be paid to the proper clearance of ring lands during finishing operations.

h. Chamfers below oil-ring grooves should be machined where original piston design calls for it. This chamfer should then be drilled to provide proper oil drainage.

i. Sharp edges at the ring lands should be removed with a file or an oilstone before removing the piston from the grinder.

j. Pistons should be carefully washed to remove all chips and grit before installing in the engine.

PISTON SALVAGE SUGGESTION

A large fleet operator reports that where alloy pistons are impossible to obtain on a certain make engine, he has salvaged the old pistons, although the ring lands were badly worn or damaged, by cutting off all the old ring land metal from the body of the piston. Lynite rod, using No. 8 tip, oxy-acetylene flame, was then welded in to the necessary ring land diameter, new ring lands recut and the welded material finished off to the proper size. Caution must be exercised to put wrist pins in the boss and spot weld T-slot pistons, top and bottom slots to prevent warping. This temporary spot weld must of course be sawed or cut again after machining operation. After all welding is completed, pistons should be allowed to cool buried in powdered asbestos for 24 hours.

GROOVES, DEPTHS AND FITS

Piston ring groove depths do not have to be consistent with the final piston size to secure proper ring fit. The practice among replacement piston manufacturers is to machine all semifinished piston ring grooves deep enough so that the grooves will accommodate any ring from standard up to the largest practical oversize. The extra groove depth resulting from using a piston of this type, machined for example to 0.060 inch oversize, is not detrimental since the high piston speeds of automotive and truck engines do not allow any great amount of pressure to be built up in back of the rings. The only exceptions to this are to be found in steam engines, air compressors, and other slow-running pistons where piston speeds are relatively enough lower to allow excessive pressures to build up behind the ring, resulting in excessive ring and cylinder wear.

The above statement is based on data furnished by a prominent piston ring manufacturer as a result of laboratory dynamometer tests and observation of the results of equipment in the field.

Although extra ring groove depth clearance as given above can be tolerated, insufficient depth clearance should be avoided. Depth clearance should be checked by noting the clearance between the ring and the skirt surface of the piston. This measurement can be checked with a depth gage.

Compression rings on cast-iron pistons should have at least 0.014 inch to 0.018 inch clearance at this point.

Oil rings on cast-iron pistons should have 0.034 inch to 0.038 inch clearance.

Compression rings on aluminum pistons should have 0.016 inch to 0.022 inch clearance.

Oil rings on aluminum pistons should have 0.036 inch to 0.042 inch clearance.

Where precision methods of determining these clearances are not available, a steel rule can be used for the purpose. When a steel rule is used, 0.014 inch to 0.022 inch can be represented by $\frac{1}{64}$ inch on the steel rule. Likewise 0.034 inch to 0.042 inch is represented by $\frac{1}{32}$ inch on the rule.

For more precise purposes the following S. A. E. minimum groove data can be used:

Compression ring grooves:

For aluminum pistons	$A = D - (2T + 0.006\,D + 0.020)$
For cast iron pistons	$A = D - (2T + 0.004\,D + 0.020)$
Oil ring grooves, aluminum pistons	$A = D - (2T + 0.006\,D + 0.060)$
Oil ring grooves, cast iron pistons	$A = D - (2T + 0.004\,D + 0.060)$
For all rings	$B = A - 0.10$

Legend: A. High limit for groove bottom diameter
B. Low limit for groove bottom diameter
D. Nominal cylinder diameter
T. Maximum ring thickness

All above procedures are generally applicable to automotive pistons except for special instances as noted. These procedures are not generally followed in Diesel or aircraft engines.

SURFACE TREATMENT

Surface treatment of finished pistons is advisable for both aluminum and cast-iron pistons. As most piston and ring scuffing in a newly reconditioned engine takes place during the "break-in" period, surface treatment can do much to alleviate this trouble. Aluminum as well as cast-iron pistons should be finished to regular clearances and then electro tin plated. While it is not possible to build up any appreciable deposit of tin plate on an aluminum piston, the light coating does in effect fill in the microscopic scratches left in the piston surface after grinding operations. This relatively softer thin layer of tin has the effect of acting as a buffer in temporarily preventing the metal-to-metal contact of piston against cylinder wall until oil in the engine has sufficient time to reach these newly refinished surfaces. Tin-plated surfaces are high in their oil retention qualities. A more lasting result is to be had in tin plating cast-iron pistons because of the heavier deposit of tin that can be applied to cast iron. Cast-iron pistons should be plated so that a surface deposit of 0.0005 to 0.001 inch is obtained. In addition to retaining a film of oil on the surface, a cast-iron tin-plated piston will operate without lubrication for short periods, such as temporary failure in the lubricating system or overheating of the cooling system. As tin plate safely reduces the amount of clearance required between piston and cylinder wall, the life of the piston rings is lengthened because the tilting or rocking action of the piston in the cylinder is reduced. This reduced clearance is not detrimental as tin plate will not score the cylinder walls. It will, however, readily wear off at points of high pressure from unequal expansion in certain parts of the piston caused by abnormal operating conditions. Many cases have been observed where the tin plating has remained on the piston, with little trace of wear, after two and three years of normal use.

In preparation of both cast-iron and aluminum pistons for tin plating the following procedure is recommended:

1. Remove piston pin.
2. Install corks, or preferably rubber stoppers, in both outer pinholes. Disregard the pinhole on the inside as little or no plating action takes place at this point.
3. Install rubber rings or tape up the oil ring groove directly above the skirt to prevent plating of the ring groove.
4. Suspend piston so that the entire skirt area is immersed in the solution. Piston should be suspended from the top ring land with suitable clamping device.
5. After plating, wash piston thoroughly to remove excess chemical deposits.

When trying a tin-plated piston in a reconditioned cylinder it is advisable to oil the piston to facilitate sliding action against the cylinder wall.

Note.—If surface treatment of pistons is not available, it is recommended that the pistons, both oversize or semifinished, cut down to the proper size, be allowed an extra one-thousandth of an inch (0.001 inch) over-all clearance.

WRIST PINS

In cases of piston pin wear in which new pins are not available and wear is evident on wrist pin, it is recommended that pin be ground down providing grinding does not go through case hardening. Not more than 0.005 inch should be ground from the original diameter. Oversize bushings can be installed in the rod and piston. This practice is not recommended in clamp type rods due to their inability to close properly on an undersize wrist pin. In cases where pistons are not bushed and wear is evident in piston boss, wrist pin bushing and piston bosses should be honed out and oversize wrist pins used.

DRY SLEEVES

With the early sleeves, the practice was to shrink the sleeve in dry ice or liquid air and drop it into a properly machined bore. This gave reasonably satisfactory results where the coefficient of expansion of the sleeve was not greater than that of the block. With the advent of very high Brinell sleeves, with what would appear to be a higher coefficient of expansion, this procedure was not as satisfactory as might be expected. Where a plain sleeve of this type is to be used, a shoulder must be left in the bottom of the bore in order to lock the sleeve in place between its shoulder and the cylinder-head gasket so that the sleeve makes a perfect fit with an error of not more than 0.0005 inch. Where it is possible to install a sleeve with a shoulder at the top to register with a groove at the top of the bore, a shoulder in the bottom of the bore is not necessary.

WET SLEEVES

Where wet sleeves are used, the fact that the sleeve probably expands almost as much under heat as does the piston can be taken advantage of to fit the piston with a smaller clearance, always provided that there is room for the wet sleeve to expand in the block.