A. Grinding Crankshaft

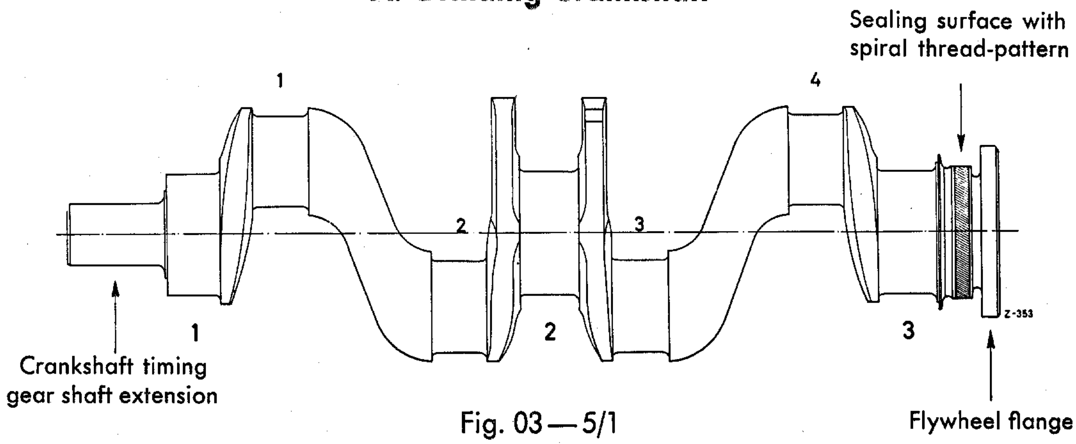


Fig. 03 — 5/1

After cleaning, the crankshaft must be examined for distortion and the bearing surfaces for out-of-roundness, hardness and cracks. If cracks are present, the crankshaft must be discarded. Distorted crankshafts must be straightened. Before grinding, the crankshafts must be recentered. Lathe holding points for checking and recentering are the crankshaft timing gear shaft extension at the front and the flywheel flange collar for attaching the flywheel (Fig. 03 — 5/1). Under no circumstances should re-finishing or turning be attempted at these points. The flywheel flange may only be honed at the side.

If the bearing surfaces are more than 0.03 mm out-of-round or if they are scored, they must be re-ground to the next overhaul stage dimensions.

Re-grinding of crankshaft and connecting rod bearing surfaces must be carried out strictly in accordance with the overhaul stage dimensions and tolerances set forth in the tables which follow. There must be no deviation from the values specified. After grinding, the bearing surfaces and the side contact surfaces must be lapped to an impeccable polish. This applies particularly to the locating bearing. When re-grinding the side contact surfaces of the locating bearing and the connecting rod bearing surfaces, remove as little stock as possible.

After grinding, the crankshaft must be dynamically balanced. The permissible unbalance is 15 cmg. Carry out the balancing operation with the flywheel and the front counterweight installed (see Fig. 03 — 5/18).

In order to maintain the specified radial play, the base bores of the crankshaft and connecting-rod bearings must first of all be measured after fitting the bearing shells, and then the appropriate tolerance to which the crankshaft must be ground is determined in accordance with the bearing play table on page 03 — 5/3. The maximum and minimum radial running clearances laid down in this table must be strictly adhered to and no departure may be made from the limits laid down.

The hardness of the crankshaft journals and crankpins is measured with a scleroscope and must be

68—74

or Rockwell hardness

HRc 55—61.

Localised areas of up to 3% below the specified degree of hardness may be disregarded.
If parts of the journals register less than the minimum degree of hardness, the crank-

shafts must be re-hardened. After being re-hardened, the crankshafts are unstressed for two hours at 180° C. They are then examined for cracks, straightened, centered and re-ground. If there are variations in hardness on one and the same journal, the journal must be normalised before being re-hardened. The journal is heated to 400° C and then allowed to cool off, the adjacent journals being chilled during the operation.

When re-grinding the crankshaft journals, special care must be taken to keep the width of the journals unchanged. This applies particularly to the locating bearing and the crankpins.

The bearing surfaces and side contact surfaces must be lapped to an impeccable polish.

The fillet radii on the crankshaft journals and crankpins must be kept strictly to the specified 2.5 to 3 mm. They should be nearer to the 3 mm than the 2.5 mm limit. It is of particular importance to ensure that the fillet radii are free of scorings.

After grinding, remove all burrs on the oil bores.

Table of Crankshaft Grinding Overhaul Stages

Measurements in mm

Overhaul stage	Crankshaft Journals			Crankpins	
	Diameter of Journals 1—3	Width of Journal 2 (locating bearing)	Width of Journal 3	Diameter of Journals 1—4	Width of Journals 1—4
Standard size	69.96 / 69.94	34.000 / 34.025	34.000 / 34.100	51.96 / 51.94	32.000 / 32.100
1st Overhaul stage	69.71 / 69.69	34.000* / 28.025*		51.71 / 51.69	32.000
2nd Overhaul stage	69.46 / 69.44	to		51.46 / 51.44	to
3rd Overhaul stage	69.21 / 69.19	34.700* / 34.725*		51.21 / 51.19	32.300
4th Overhaul stage	68.96 / 68.94			50.96 / 50.94	

* In steps of 0.1 mm, according to the available check plates.

Permissible out-of-round of crankshaft journals and crankpins	0.005 mm
Permissible conicity of crankshaft journals and crankpins	0.01 mm
Permissible degree of misalignment of crankpins with respect to crankshaft journals expressed in terms of the length of the bearing	0.01 mm
Permissible run-out of crankshaft journal 2 at rest in crankshaft bearings 1 and 3	0.02 mm
Permissible lateral deflection of locating bearing journal	0.015 mm
Permissible radial deflection of fly-wheel flange related to three crankshaft journals	0.02 mm
Permissible lateral deflection of flywheel flange related to three crankshaft journals	0.01 mm

B. Re-bedding of Crankshaft

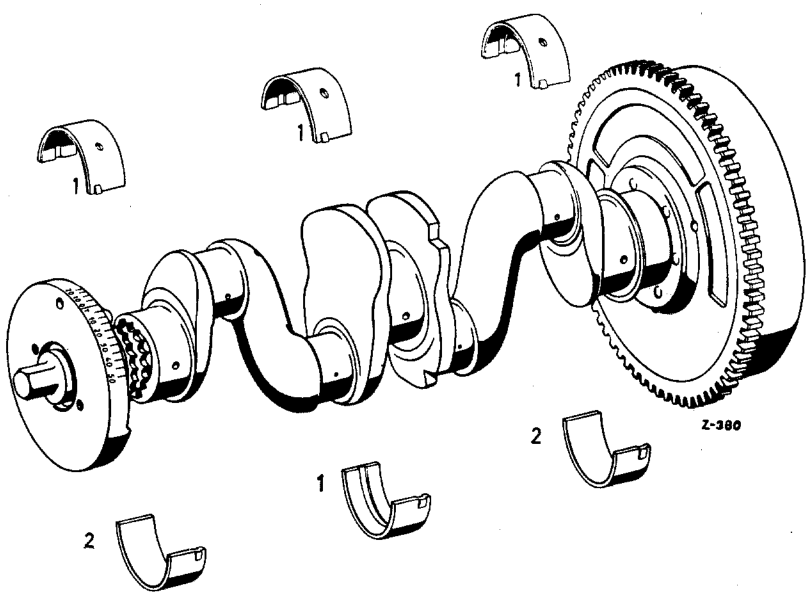


Fig. 03—5/2

Bearing Play of Crankshaft

in mm

Radial *	End play of locating bearing	Crush fit of bearing shell halves
0.045 - 0.065	0.040 - 0.096	+ 0.01

* The radial play shown in the table is an average play which in practice must be strictly adhered to.

The bearing shell halves of the crankshaft bearings are supplied ready for fitting and graded for the various overhaul stages. The three upper bearing shells (1) and the lower center bearing shell half (1) (with oil hole and lubrication groove) are identical and may therefore be interchanged (i. e. when the bearings are new). The same applies to the two lower bearing shell halves (2).

The crankshaft bearings should always be replaced as a complete set of three bearings, i. e. of six bearing shell halves.

The tolerance of the bearing shell halves is ± 0.01 mm at a diameter of 74.519 mm. In the extreme case, there is thus a crush of from —0.01 to + 0.03 mm, the base bore being 74.500—74.519 mm. A crush of + 0.01 mm will usually be obtained. In practice it is unnecessary to measure this slight crush because the bearing shell halves are supplied ready for installation and if the base bores in the crankcase are of the correct diameter, an adequate crush is assured.

The 2nd bearing is designed as a locating bearing. The center bearing cap is for this reason fitted with a check plate on both sides, held in position by two heavy dowel pins (Figs. 03—5/3 and 03—5/4).

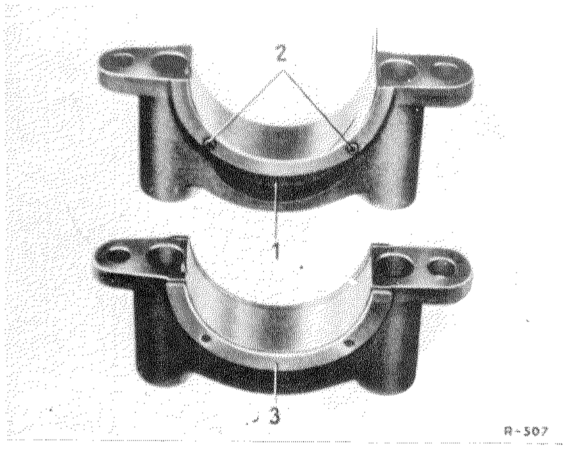


Fig. 03—5/3

1 Crankshaft bearing cap
2 Dowel pin
3 Check plate half

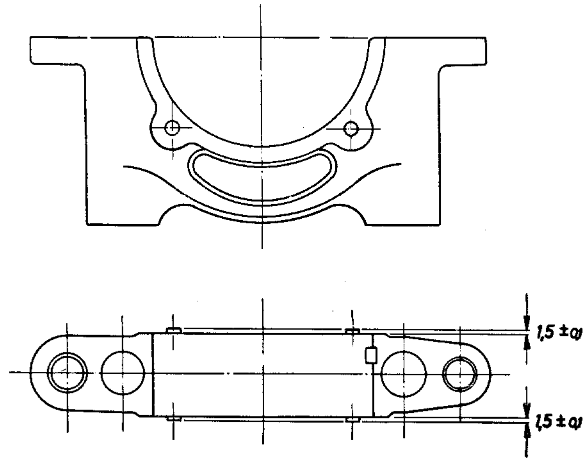


Fig. 03—5/4

The check plates are available in the following thicknesses:

2 mm (standard), 2.05 mm, 2.10 mm, 2.15 mm, 2.20 mm, 2.25 mm, 2.30 mm and 2.35 mm.
Departure from nominal dimensions in each case: —0.020 to —0.027 mm.
The check plate halves must be so selected that the correct end play of from 0.040 to 0.096 mm for the journal of the locating bearing of the crankshaft is obtained.

1. Screw on the bearing caps and tighten the screws to a torque of 8 mkg.
2. After the base bores have been carefully cleaned, they should be measured with an internal micrometer in the three directions A, B and C (measurements are taken at right angles to the separating surface and again at 30° to it) (Figs. 03—5/5 and 03—5/6).

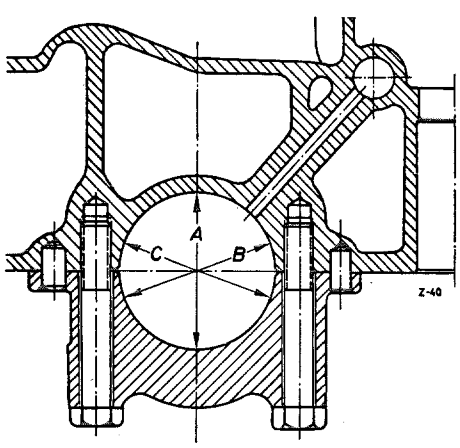


Fig. 03—5/5

The diameter of the base bores is 74.500 to 74.519 mm.

In order to check the bearing bores for conicity, these measurements are taken at the front and again at the rear of the bore.

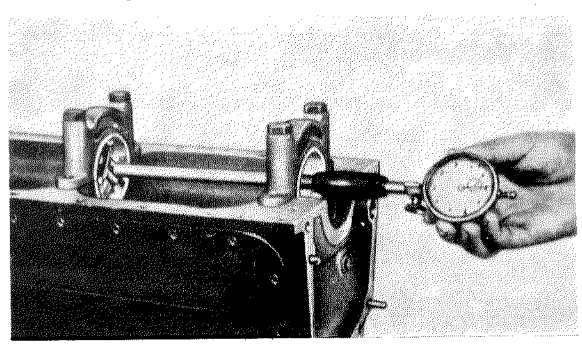


Fig. 03—5/6

Permissible out-of-round	0.01 mm
Permissible conicity	0.01 mm

3. Off-center bearing caps can be brought into position by lightly tapping with a hammer. The bearing cap is centrally placed when all three measurements are identical.

Re-machining of the separating surfaces of the bearing caps and the bearing shell halves is not permissible.

4. The bores should be measured in the same way with the bearing shells fitted.

   The diameter of the crankshaft bearing with bearing shell halves fitted is: Standard, 69.99—70.02 mm, and at 1st, 2nd, 3rd and 4th overhaul stages, 0.25 mm less each time.

The table of crankshaft bearing play given on Page 03 — 5/3 can now be used to decide the scale of tolerances according to which the crankshaft journals are to be ground. No departure in either direction may be made from the specified maximum and minimum radial play values in this table.

C. Reconditioning and Re-bushing of Connecting Rods

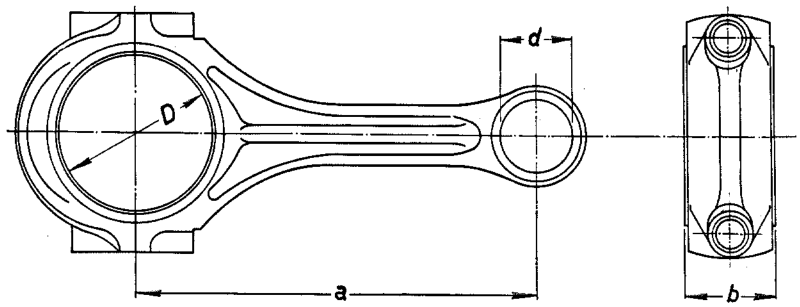


Fig. 03 — 5/7

Dimensions of Connecting Rod

in mm

Distance a	Base bore D	Base bore d	Width b
153.95 / 154.04	55.600 / 55.619	28.000 / 28.021	31.880 / 31.841

1. General

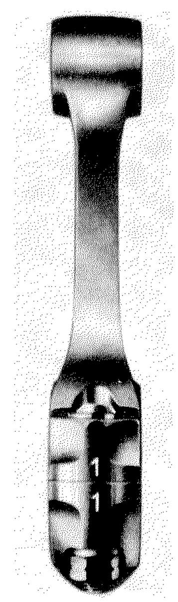


Fig. 03 — 5/8

a) The connecting rods must be so selected that the difference in weight between the complete connecting rod assemblies does not exceed 5 g in any one engine.

b) The etched numbers (1—4) on the connecting rods must correspond to those etched on the bearing caps (Fig. 03 — 5/8).
The figure 1 refers to Cylinder No. 1, the figure 2, to Cylinder No. 2 and so on.

c) The connecting rod with bushing, the piston and the piston pin must have the same color coding so that the crush and the end play values are kept to the specified amounts.
Pistons must be so selected as to ensure that the difference in the weight of the pistons does not exceed 4 g in any one engine.

2. Fitting of Bearing Shell Halves

Bearing Play Values for Connecting Rod

in mm

Radial*	End play	Crush of bearing shell halves
0.045 - 0.065	New 0.120-0.259 After repair up to 0.5	+ 0.01

*) The radial play shown in the table is an average play which in practice must be strictly adhered to.

The bearing shell halves for the connecting rods are supplied ready for installation exactly as in the case of the crankshaft. The upper bearing shell halves (with oil hole) are identical and if the bearing shell halves are new, they may be interchanged. The lower bearing shell halves (without oil hole) are also identical and may be interchanged. Procedure for fitting the bearings is the same as that already described for the bedding of the crankshaft.

The diameter of the base bore is 55.600—55.619 mm; with bearing shells installed, the standard dimension is 51.99—52.02 mm and at 1st, 2nd, 3rd and 4th overhaul stages, 0.25 mm less each time.

Re-grinding of the sides of the crankshaft bearin surfaces and honing of the connecting rods increases the end play. An increase of end play of up to 0.5 mm is quite permissible.

3. Replacement of Piston Pin Bushing

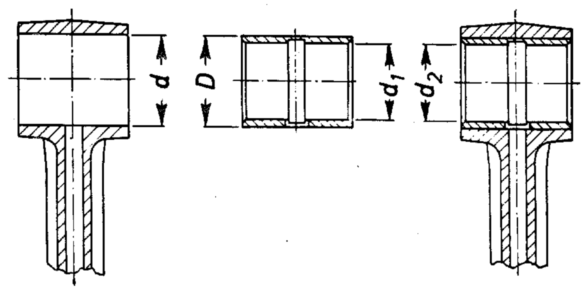


Fig. 03—5/9

Dimensions of the Piston Pin Bushing

in mm

	Base bore d	External diameter D	Internal diameter: Rough-turning dimension d_1	Internal diameter: Final dimension * (bushing pressed into place) d_2
Standard size	28.000 / 28.021	28.048 / 28.035	24.600 / 24.730	25.007 / 25.013
With larger external diameter (repair only)	28.500 / 28.521	28.548 / 28.535	24.600 / 24.730	25.007 / 25.013

* See next Table for tolerances of final-turned piston pin bushing.

Worn piston pin bushings must be replaced. The crush fit dimension of the piston pin bushing in the bore must be at least 0.030 mm. When pressing in the piston pin bushing, care must be taken to ensure that the oil hole is opposite the oil passage in the connecting rod. After pressing in the piston pin bushing, the connecting rod must be unstressed for half an hour at 160°—180° C. Then the bore should be machined to fit.

If the base bore in the connecting rod is worn, it should be honed out to 28.500—28.521 mm and a bushing, 0.5 mm greater in external diameter should be pressed in.

The piston pin play is 0.010—0.016 mm. To maintain the specified play, the connecting rod with bushing and the piston pin must be matched according to their color coding (see Table below). The piston must also bear the same color coding.

Color Coding for Matched Connecting Rods, Piston Pins and Pistons

Measurements in mm

Color	Piston pin bushing bore	Piston pin diameter	Running play	Piston boss diameter
black	25.007 / 25.010	24.997 / 24.994	0.010 - 0.016	24.994 / 24.997
white	25.010 / 25.013	25.000 / 24.997	0.010 - 0.016	24.997 / 25.000

4. Tightening Connecting Rod Cap Bolts

The connecting rod cap bolts are without lock washers and are tightened to a stretch of 0.1 mm (Fig. 03—5/10).

The stretch must be measured with a dial gage or a micrometer and corresponds to a tightening torque of 3.75—3.80 mkg. If the nut is released, the cap bolt must return to its original length. Small variations of up to 0.01 mm, after the nut has been released, are permissible. If the discrepancy is greater, the cap bolt has been tightened too much, i. e. it has been overstretched. In this case a new connecting rod cap bolt and nut must be used.

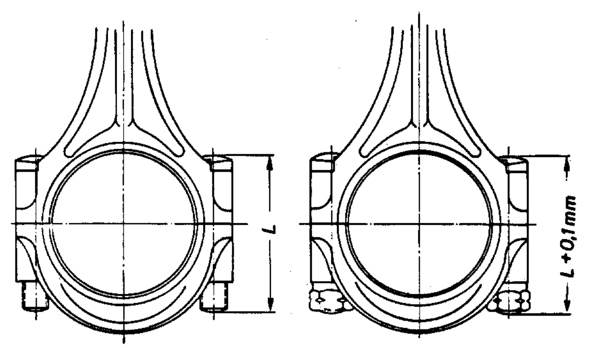


Fig. 03—5/10

It is possible, as an exceptional measure, to tighten the nut with a torque wrench. If a torque wrench is used, the thread of the connecting rod cap bolt and the contact surface of the nut must first be liberally smeared with graphite oil.

The head of the connecting rod cap bolt must not project beyond the edge of the connecting rod and it must be properly seated in the recess. The cap bolt itself must be a tight fit in the bore of the connecting rod. For this reason, two stages of tolerance are specified for the shaft diameter (plain, 10.001—10.008, white, 10.009—10.016 mm). The thicker connecting rod cap bolt (10.009—10.016) is marked at the head with white paint.

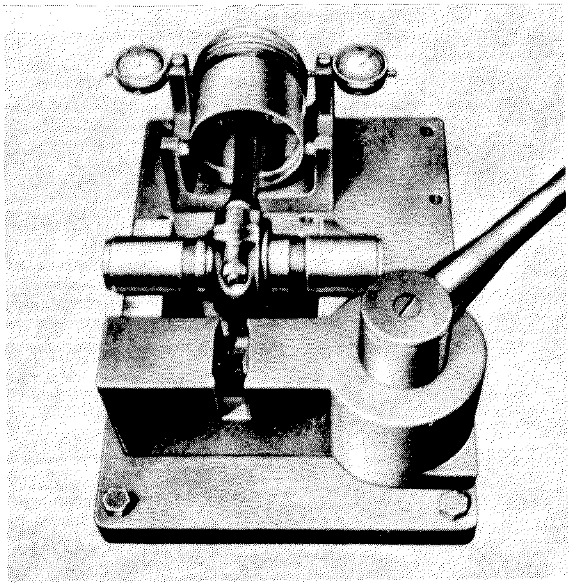


Fig. 03—5/11

5. Squaring of Connecting Rod

After reconditioning and before being installed in the engine, each connecting rod must be checked with a suitable testing instrument to ensure that the bores are correctly aligned (Fig. 03—5/11).

The permissible deviation from axial parallelity is 0.03 mm and the permissible longitudinal distortion is 0.1 mm. In both cases the permissible deviation is calculated with reference to a length of 100 mm.

D. Fitting Pistons, Together with Rings, into Cylinders

In Model 190 "full-skirt autothermic" pistons (so-called slipper pistons with extended skirts) are fitted (Fig. 03—5/12).

The piston play is 0.04 mm.

The piston size is punched on the head of the piston. The piston must be selected so as to correspond with the diameter of the cylinder, allowing a running clearance of 0.04 mm. The pistons are therefore available in three gradings — within the overhaul stages — in steps of 0.01 mm.

If, when carrying out repairs, only pistons of one particular overhaul stage dimension are available, hone the cylinder wall surfaces to match the pistons available.

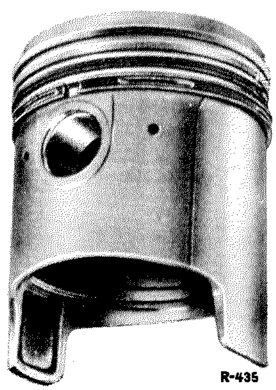


Fig. 03—5/12

Pistons Available

Overhaul stage	Piston diameter in mm
Standard size	84.96 84.97 84.98
Intermediate stage	85.21 85.22 85.23
1st Overhaul stage	85.46 85.47 85.48
2nd Overhaul stage	85.96 85.97 85.98
3rd Overhaul stage	86.46 86.47 86.48

Each piston is slightly tapered. The diameter is greatest at the bottom, at the skirt end (piston skirt). The cross-section at this point is not a perfect circle but an ellipse, the axis A being smaller than the axis B (Fig. 03—5/13).

The diameter of the piston is measured at the lowest part of the skirt end in the direction B. This dimension is identical with the size punched on the head of the cylinder.

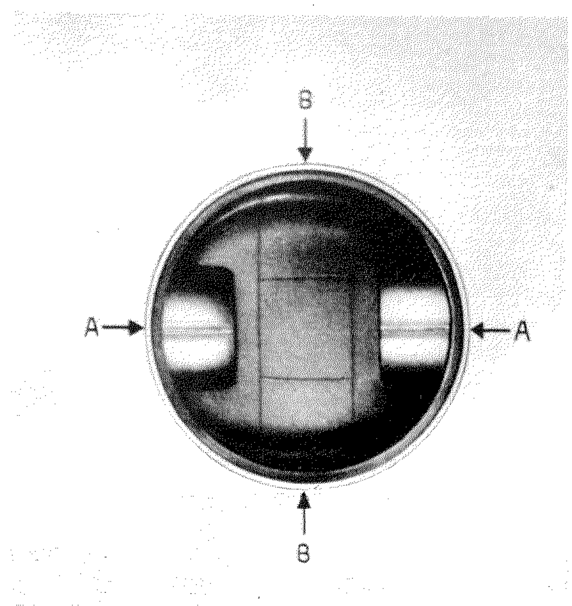


Fig. 03—5/13

When selecting the pistons, care must also be taken to ensure that the difference in weight between the pistons in any one engine does not exceed 4 g.

A check must be made to ensure that the piston rings are inserted in the correct sequence (Fig. 03—5/14).

1. Compression ring 10f85×77.6×2
2. Tapered compression ring 11f85×77.6×2.5
3. Novi stepped ring 85×3 T 16 Nova
4. Novi slotted ring 85×5 T 17 Nova

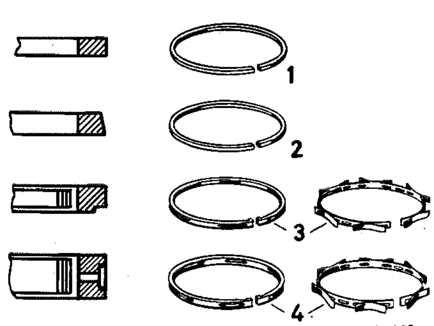


Fig. 03—5/14

When installing the Novi stepped ring and the Novi slotted ring, the corresponding expander must be fitted so that the gap of the expander is at the side opposite the gap of the piston ring in each case.

It is normally unnecessary to check piston ring gap and groove clearance because the piston is supplied together with piston rings and piston pin ready for installation.

For the exceptional case, where piston rings are ordered and have to be fitted individually, the permissible vertical and gap clearances are given in the following list.

Piston Ring Clearances

in mm

	Vertical clearance	Gap clearance
1. Compression ring	0.035—0.062	0.55—0.70
2. Tapered compression ring	0.035—0.062	0.45—0.60
3. Novi stepped ring	0.035—0.062	0.30—0.45
4. Novi slotted ring	0.035—0.062	0.25—0.40

The vertical play of the piston rings in the ring grooves is measured with a feeler gage (Fig. 03—5/15).

When measuring gap clearance, the piston rings must be placed in the bore about 40—50 mm below the upper separating surface of the

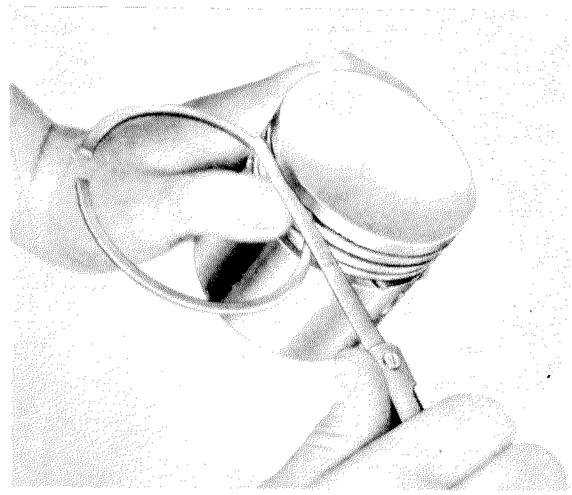


Fig. 03—5/15

crankcase. Make sure that when measurements are taken,
the rings are exactly at right angles to the cylinder wall (Fig. 03—5/16).

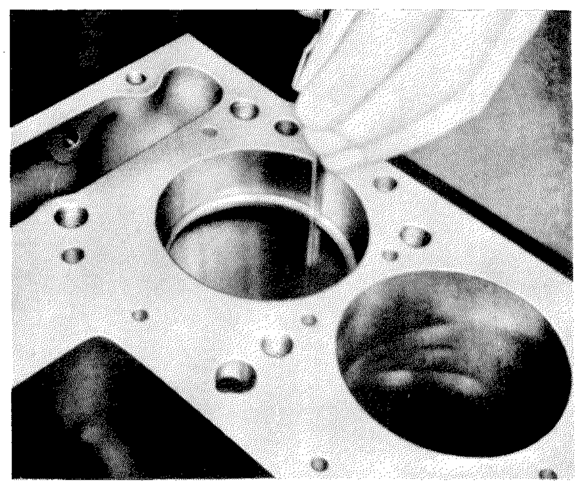


Fig. 03—5/16

E. Replacement of Starter Ring Gear

1. Heat the old starter ring gear and pull it off immediately.

2. Heat the new gear to 200° C so that a light yellow sheen appears on it and then press it quickly onto the flywheel, with the bevelled side, seen from the direction of travel, pointing forward (see Fig. 03 — 5/17).
   The lateral deflection of the shrunk-on ring gear must not be more than 0.4 mm.

F. Grinding Clutch Face of Flywheel

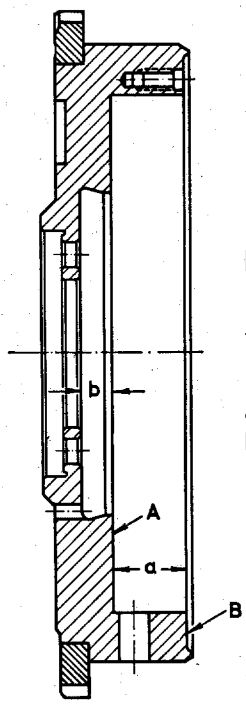


Fig. 03 — 5/17

A = Clutch face
B = Clutch plate fixing surface
a = 29 ± 0.1 mm
b = 12.5 mm

This job must always be done if there are scorings or burnt patches on the clutch face of the flywheel. The clutch face must then be surface-ground or precision-turned on a suitable machine.

The clutch face A may be machined off until the dimension b = 11.5 mm is reached. When the clutch face is new the dimension is b = 12.2 mm. The dimension must not be reduced below b = 11.5 mm (Fig. 03 — 5/17).

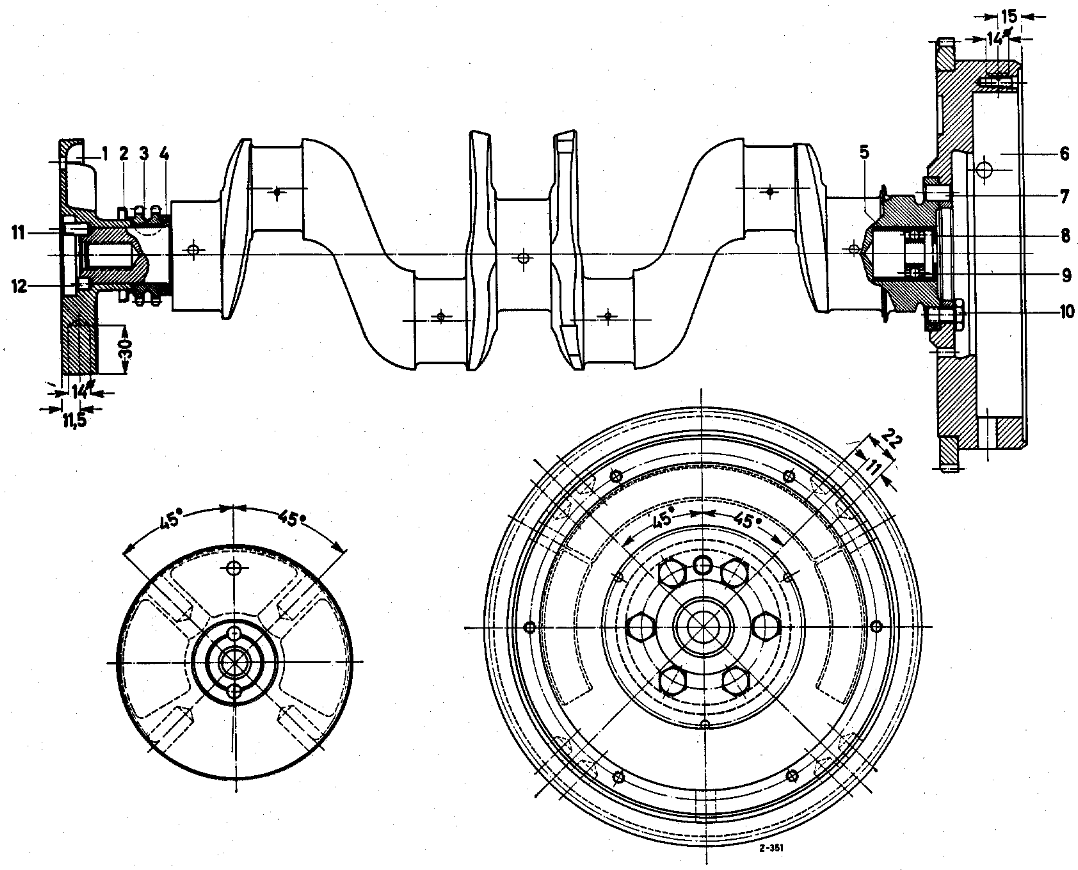
The surface B must in any case be re-machined or turned so that the distance a = 29 mm ± 0.1 is maintained in all cases.

When machining the clutch face, care must be taken to ensure that the surfaces A and B are exactly parallel to each other and also to the flywheel flange fixing surface. The permissible deviation from parallel is 0.05 mm at a diameter of 230 mm.

G. Balancing Crankshaft with Counterweight and Flywheel Installed

The crankshaft has three counterweights: one at the front, on the actual counterweight, one at the middle on the crankshaft and one at the rear on the flywheel. With these three counterweights, each of which has a pre-determined degree of unbalance, the crankshaft is dynamically balanced (Fig. 03—5/18). When the crankshaft is fitted with the counterweight and the flywheel, these three unbalance quantities cancel each other out.

An overall maximum unbalance of 15 cmg is permissible.



Part 1: Front view

Part 6: Rear view

Fig. 03—5/18

1 Front counterweight
2 Oil ring
3 Crankshaft
4 Compensating ring
5 Spacer sleeve
6 Flywheel
7 Dowel pin 10 h8×18 DIN 7
8 Cover plate
9 Annular grooved bearing
10 Stretch screw
11 Dowel pin 8 h8×16 DIN 7
12 Dowel pin 8 h8× 8 DIN 7

The balancing holes in the counterweight are bored with a 14 mm ∅ drill at the circumference in a radial direction. The maximum bore depth of these holes is 30 mm.

On the flywheel, two balancing holes, 22 mm apart and with a diameter of 14 mm and a maximum depth of 8 mm are bored at the circumference in a radial direction. The correct distance from the face side of the flywheel to the bore centers (15 mm) must also be borne in mind.

H. Re-balancing a New Flywheel

A new flywheel can either be balanced together with the crankshaft and the fitted counterweight (see Job No. 03—5, Section G) or alternatively it can be balanced separately, in which case the new flywheel must be made to have the same degree of unbalance as the old one. Since the flywheel is for all practical purposes a disk, static balancing is quite sufficient in practice. For balancing, Arbor Fixture 180 589 00 27 is used (Fig. 03—5/19).

1. Mount the old flywheel on Arbor Fixture 180 589 00 27. Slide the spacer ring with the two dowels onto the arbor and slide on the new flywheel, turned through 180° with respect to the old one, and tighten with the nut. When mounting the old and the new flywheels on the arbor, care must be taken to ensure that both flywheels are perfectly fitted together, with the recesses pointing in the same direction (Fig. 03—5/19).

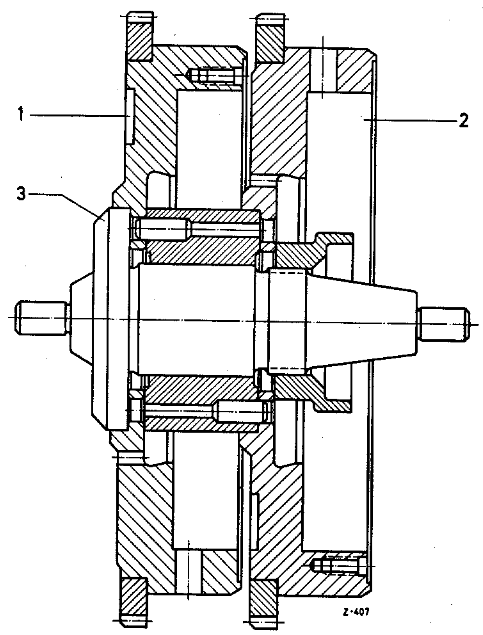


Fig. 03—5/19

1 Old flywheel
2 New flywheel
3 Arbor Fixture 180 589 00 27

2. Now place the arbor with the two flywheels mounted on it on Static Balancer 000 589 15 21 or on two knife-edge engineering rules, the upper edges of which are set exactly in the same horizontal plane, and allow the whole unit to rock into the position of equilibrium (Fig. 03—5/20 and Fig. 03—5/21).

3. If the unit is found to be out of balance, sufficient holes of 10 mm ∅ and 8 mm maximum depth must be bored on the center of gravity side of the new flywheel, on a diameter of 222 mm, for the system to remain stationary at all points of rotation without rocking.

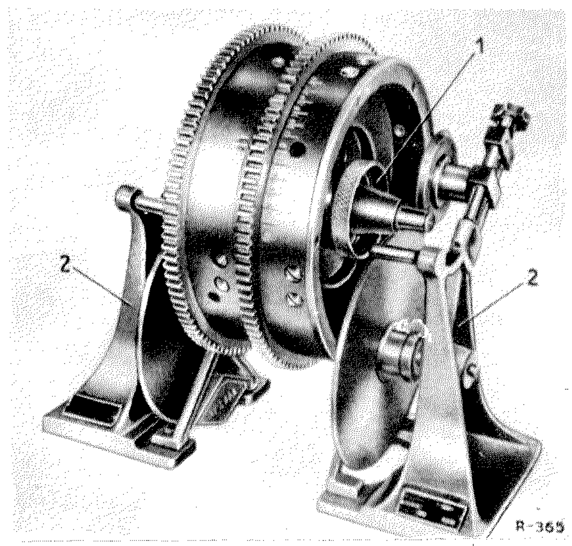


Fig. 03—5/20

1 Arbor Fixture
2 Static Balancer

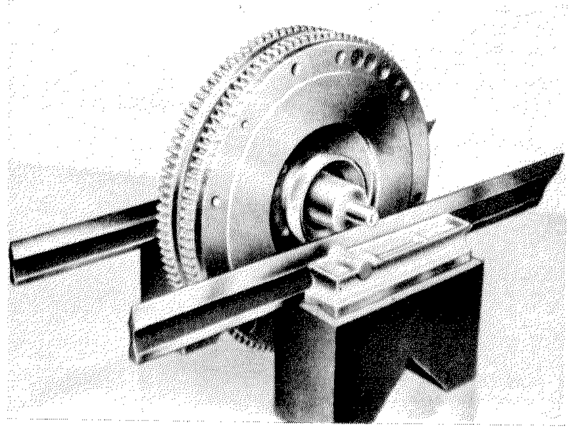


Fig. 03—5/21

The above figure shows two flywheels of Model 220

Note: The dimensions previously given for the balancing holes are only valid for the static balancing of the flywheel by itself, and must not be confused with the balancing holes which are bored when the crankshaft is balanced together with the counterweight and the flywheel.

In order to ascertain how many holes must be bored and how deep they must be, plasticine must be pressed onto the flywheel on a diameter of 222 mm, at the point opposite the point at which the unbalance is found, in sufficient quantity to neutralize the unbalance.

The weight of the plasticine used now gives an indication of the amount of stock to be bored out of the flywheel.

A 14 mm ∅ hole, bored out 1 mm deep, is the equivalent of a weight of approx. 1.3 g.

Example:

The unbalance established with the aid of plasticine applied on a diameter of 222 mm is 19.5 g.

The depth of bore required is then 19.5:1.3 = 15 mm.

As the maximum permissible bore depth is only 8 mm, two bores, each 7.5 mm deep, should be made in the flywheel.

4. After installing the flywheel, run the engine and observe whether it runs without any abnormal vibration.