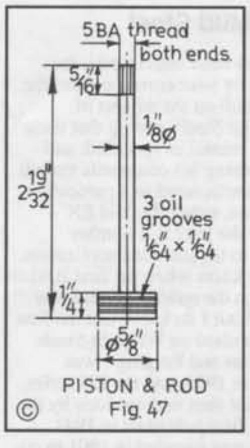
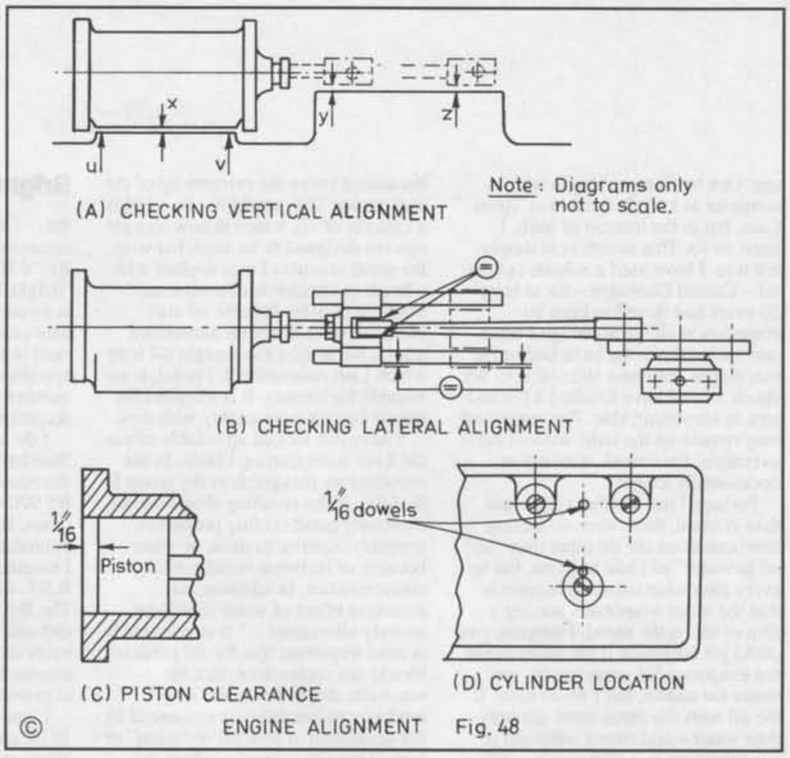
Tubal Cain completes the cylinder assembly, explains how to obtain correct alignments and describes the process of case hardening to enhance the wearing properties of the eccentric sheave and strap

● *Part VIII continued from page 194 (19 February 1993)*

SALLY

Cylinder alignment, eccentric sheave and strap





Piston and Rod

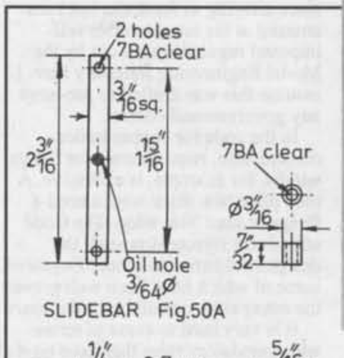
Parts 4 & 5, **Fig. 47**. The material supplied for the rod is free-cutting stainless steel. Reduce this to the 2 19/32in. dimension with a very little over, and machine a very small bevel at each end. Use your tailstock die-holder to put on 10¾ threads at the piston end and 13½ at the other. Check your die on a piece of scrap first, offering the test thread to the crosshead – you need a well-fitting thread here. Remove the burrs at the beginning and end of the thread.

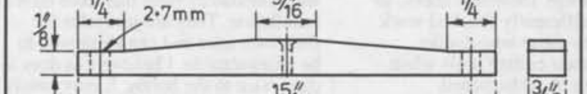
The piston design calls for labyrinth grooves to seal the piston. These are quite effective, but if you wish to use soft packing alter the drawing to a single groove 1/8in. wide and deep. Chuck the stock in the three-jaw with 3/8in. protruding and machine down to about 10 thou oversize. Form the three grooves using a vee-pointed tool with a very small radius on the point. First cut the centre groove, say 25 thou deep, at 1/8in. from the face, then another mid-way between this and the face, then the third the same distance to the left. Part off 1/4in. wide.

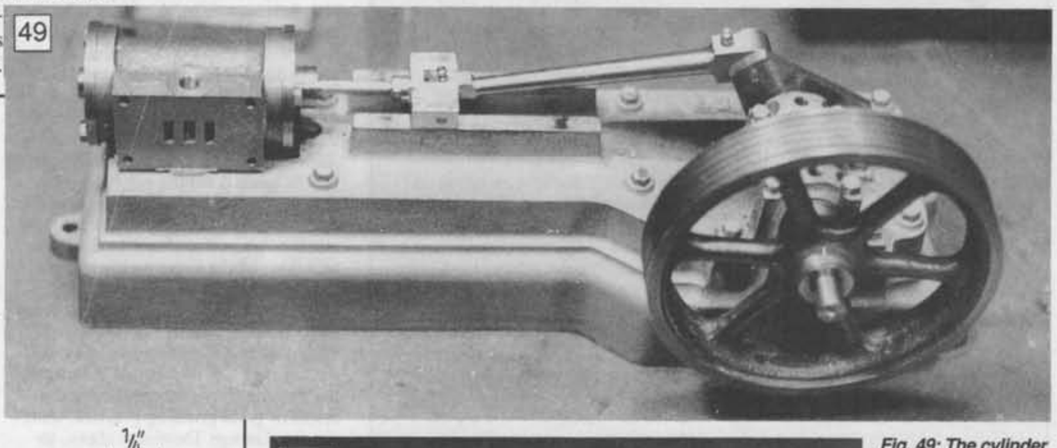
Now set the piston rod in the 3-jaw and use a dial test indicator to see how much shim you need under which jaw to get it running true. (Few 4-jaw chucks will hold material 1/8in. dia). Make a note of it. Rechuck the machined piston, faced side out (i.e. parted-off side in!) and grip the rod in the tail-stock drill vice after screwing it into the piston as far as you can by hand. Gently pull the chuck round to get the rod really tight in the piston. Take out - you should find that there is a fraction of a thread protruding. Give this 3 or 4 light taps, not more, with a ball-pein hammer. Three centre-pop marks around the thread will serve just as well.

Chuck the assembly in the 3-jaw with packing under the appropriate jaw. You will find that the piston runs out a little. Lightly face the end and reduce any of the protruding piston rod to no more than 1/64in. excess. Then machine the diameter. Take *very* light cuts at fine feed, using a tool with a radiused end, (**No iv, Fig. 3B**) very sharp indeed, with zero rake. When nearly to size, check with the cylinder after traversing the first 1/16in. or so of the piston. You need it to be a nice slide fit if the engine will always be run on compressed air, but about 0.001in. clearance if on steam. With soft packing slightly more clearance is acceptable. The final cut should be taken at very slow traverse. Remove all sharp edges.

What, you may be asking, about using an "O" ring? Frankly, I don't recommend these in an iron cylinder. Even with the utmost care there is always risk of a rust film - as much with compressed air as with steam. This fine film embeds into the ring







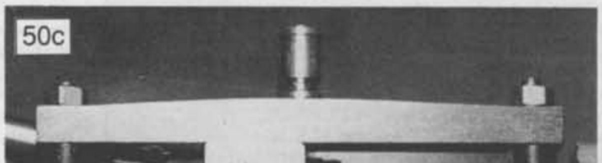


Fig. 49: The cylinder aligning operation in progress.

Fig. 50C: A close-up of the motion work. Note the tapered slide-bars and the oil cups.

material, and acts as a lap, both on ring and cylinder. The ring stops rolling as it should, and you soon find leakage. The second problem I have found is that with engines that are not in fairly frequent use the "O" ring tends to develop a flat, and again, sealing is lost.

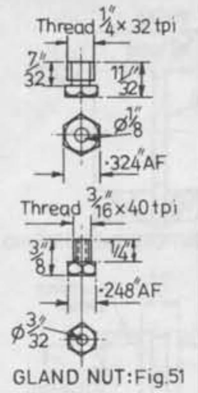
Alignment

Fig.48. The running gear can now be set up for proper alignment and the cylinder fixing bolt-holes drilled and tapped. This is done in three stages. First, the cylinder must be aligned in the vertical plane. Next, the piston travel must be laterally in line with the crank travel. Then the piston travel within the cylinder must be adjusted so that the clearance is correct. Finally, the whole must be refined to give as free a motion as possible. None of this is difficult, but it does take a little time.

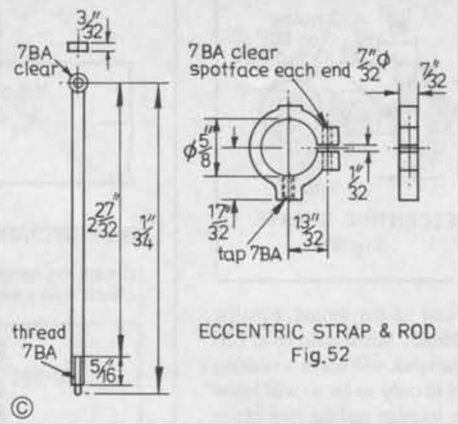
Assemble the piston and rod to the cylinder with the front (gland) cover in place and all screws tigtened. Attach the crosshead with its locknut, the thread engaged for the moment just full depth in the boss. Set the cylinder in place and hold it down firmly with the crosshead central to the guide surfaces. Check the dimensions "y" and "z" in **Fig.48a**. If the crosshead is hard down you need shim under the cylinder. Fit some - paper will do at this stage - to give clearance, and check that the two dimensions are equal at each end of the piston travel. If there is more than 0.002 in. difference measured with feelers you must gently file the pads at "u" and "v" to equalise them. But make sure first that the cylinder is bedding down properly. You will, of course, need to take off the *total* amount, not just the difference, if you have had to pack up the cylinder to get clearance. Work carefully, checking as you go. Ideally, the dimension "x" should be zero, but the accumulation of small errors makes this unlikely.

If the crosshead stands clear of the bottom guide then the cylinder is sitting too high up. Check first that the clearance is uniform, then file the tops of the pads "u" and "v" supporting the cylinder to bring the crosshead down so that it barely touches the guide full length. If you go too far then you will need shims as descibed above. When you come finally to fit the shims, (not now) ensure that the holes for the bolts are large - say 3.5mm - and that there are no wrinkles or folds round the edges. You will almost certainly have to alter the shim thickness when the cylinder is bolted down later.

Now look at **Fig.48b**; first adjust the position of the cylinder until the crosshead runs parallel with the crosshead guides. Lightly clamp the cylinder there. Attach the connecting rod to the crank and swing it down to the crosshead. It should just slide into the notch. You may need either to spotface the main bearing a little more, or fit a thin washer - the former is the most likely. Do this, adjusting until there is a trace of clearance each side of the small end. Check this at both ends of the travel. You may have to alter the lateral attitude of the cylinder to obtain a proper fit at both ends. Fit the crosshead pin and try rotating the crank gently. It may be a trifle stiff, but if there is any binding look for the cause and put it right. You can then tap the cylinder backwards or forwards to obtain the 1/16in. dimension shown in **Fig.48c**. Tighten the cylinder clamp and then gently tap it this way or that until the running is as free as possible. There is bound to be a little friction, but there should be no intermittent binding and no grating movement. The



GLAND NUT: Fig.51



ECCENTRIC STRAP & ROD
Fig.52

most likely cause of the latter is that your shim under the cylinder is not thick enough.

Now spot through the holes in the bed to mark the cylinder - you may be able to get at only two of these holes if the clamp is in the way. Remove the cylinder, drill 2.1mm and tap 7 BA; about 3/16in. deep, but check that this won't run into the bore! Refit, rough check the alignment, tighten the screws and spot through for the third hole. Drill and tap this. You can now set up again, with the screws medium tight, and check alignment all over again. Tap the cylinder this way and that to get the best fit, tighten the screws further, try again, and so on. Once you are satisfied I recommend that you drill two 1/16in. holes as shown in **Fig.48d**, running about 3/16in. into the cylinder, and fit two 1/16in. dowel pins, so that you don't have to go through all this procedure again. I use pins with 10BA hexagon heads for this job - it is more professional, and makes them easier to remove! **Fig.49** shows alignment in progress. The basic engine is now in order and you now have something to show. However, don't be too vigorous in spinning the wheel, for there is as yet no restraint to the cross-head. And please avoid turning the wheel backwards, for that would risk the crankpin coming unscrewed and fouling the crankpit!

Slidebars

Part 48, **Fig.50a**. These are a very simple job as drawn, but you may care to embellish the engine by making them taper as shown in **Fig.50b**. Start by trimming exactly to length, then drawfile to obtain a good finish on all faces. Select the best face for the bottom; this should be finished with fine emery later. To form the taper, mark out the centre of the length and at 1/4in. from each end. At the centre mark two further cross-lines, 5/16in. apart. File the flats at each end, then make a smooth taper from the edge of these to the scribed line at the centre. This does not take long but you must take reasonable care to get them looking alike. Finish by drawfiling again. Now for the holes. To avoid visual offence you must take great care that they lie exactly on the centre-lines. Those with vertical slides can set it up and then grip a piece of 3/16in. dia. stock in the 3-jaw chuck. Adjust the slide until the fixed jaw of the vice *just* touches this 3/16in. diameter. You can then drill from the headstock and be sure the holes are central. You can use the same trick on the drilling machine if you clamp the vice to the table, but you will have to move the bar each time to bring the holes under the drill. Use a 2.8mm drill to give sufficient clearance for the necessary adjustments.

To drill the bedplate, set the bars on top of the fixed guides, aligned with the outside edges. Use a piece of 3/8in. wide flat stock to ensure that there is clearance full length; excess clearance is not serious. Clamp in place (you will need a block of wood within the bedplate and a bar across the two slides) spot through, then drill 2.1mm and tap 7BA.

Spacers

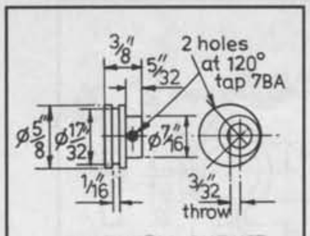
Part 47, **Fig.50a**. Chuck in the 3-jaw and face the end. Centre with a small slocumbe centre drill and then drill 2.7mm 3/4in. deep. Reverse in the chuck and repeat. Part off just a shade over-length, face the exposed end and part off a second piece. Reverse and repeat. Remove the burrs and lightly countersink each end of the holes. Now check the length of one with your micrometer, and note how much must come off to give between 0.002 and 0.003 in. clearance on the face of the crosshead. Reset in the chuck and carefully face off this amount. Note that if you find one too short you must make another! Repeat for all four. Check first with the crosshead in place, just holding the bars down by hand and then with the 9/16in. long bolts in place. If there is any tightness, seek out the cause and put it right - but don't remedy any *excess* clearance yet. Take all down and re-assemble, this time with the cylinder and piston rod attached to the crosshead and the cylinder bolted to the bed. Check the clearance again. You may have to tap the cylinder into alignment if you didn't fit the dowels I mentioned earlier.

Two things can go wrong at this stage. (a) The crosshead may now bear hard on the guide-bars. If so, your shim (if any) is too thick, *or* you have not sufficiently faced down the cylinder seating. (b) The crosshead may bear hard at one end or the other. This means that the cylinder seating is not exactly parallel to the guide faces. The remedy in either case is some careful work with a file, or the fitting of a different shim - or both! Once all is free, look at the upper clearance. A minimum of 0.001 in. anywhere is sufficient, but if there is *visible* clearance then I suggest that you reduce the spacers just a trifle more. There should be no obvious gap. As a final trial, link up the crank and connecting rod. All should turn with no tight spots.

Gland nuts

Parts 8 & 21, **Fig.51**. Although the dimensions differ, the procedure is the same for each. First clean up the hexagon stock, for drawn brass can be a trifle rough. Set in the 3-jaw with about 1/2in. projecting and face the end. Centre and drill 3.2mm or 2.4mm for 1/4in. and 3/32in. rod. (Many practitioners *ream* these holes, but this is not only unnecessary, it can be a nuisance; drilled holes are quite in order at these sizes) Then turn down to the thread top diameter and form the little recess adjacent to the hexagon. This should be 0.205 in. deep and about 3/64in. wide. Bevel the corners of the hexagon at about 30 degrees.

Set up to screwcut 32 tpi, and use your mini screw-cutting tool to form a thread up to 0.017 in. deep. Finish with a die held in your tailstock dieholder. Check the fit to the cylinder cover and the valve-chest as appropriate, then form a small ▶



ECCENTRIC SHEAVE
Fig. 53

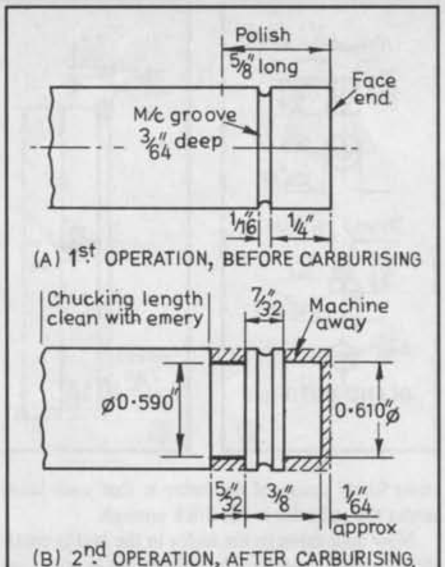


Fig. 54

45 deg. bevel at the end of the thread. Finally, countersink the hole. Ideally this should be at 120 deg. but a 90 deg. countersink will serve – nothing steeper. Take the cutter in only so far as will leave a fine flat face between its edge and the root of the thread. Then part off – *but*, before you have gone right through bring up your little screw-cutting tool to form a bevel on the edges of the hexagon here. Clean off the burrs and lightly countersink this end of the hole.

Eccentric strap

Part 30, **Fig.52**. Set up in the 4-jaw, set true to the circumference of the radii. Face the end, then centre and drill through with the largest drill you can manage - but not more than 9/16 inch. Then bore to 0.625 in. diameter, using the taper and plug gauges made for dealing with the cylinder. Aim for a really good finish. Part off at least 1/64in. over thickness - the parting tool will leave a very unflat surface with so irregular a section in such soft material. Reverse in the chuck, gripping gently, and tap back to a piece of parallel packing behind. Take very light cuts to trim the thickness down to 7/32 inch. If you have any difficulty, fit a thin slice of 5/8in. diameter stock in the bore; this will allow you to use more grip without risk of distortion. Remove the sharp edges to the bore with a scraper.

Trim up the outside profile, and bring the 17/32in. dimension to a face square to the centreline. We again have a set of holes which should, for appearance, lie dead on the centreline. Care in marking out followed by equal care in *starting* the hole is the order of the day. But for the 7BA clear (2.7mm) bolt-hole I suggest that you start at both ends and go half-way through with a 2.6mm drill, then follow with 2.7mm from one end. Note, by the way, that this material is "greedy" and if you have no straight-flute drills (very rare these days) it is wise to stone off the leading edges of the drill, so that there is zero rake at the end of the flutes. The 7BA tapped hole (2.1mm drill) is tapped right through, and the burr on the inside must be removed. Do not split the strap yet, but when you do come to it take care (a) that the slit lies in the centre of the projection and (b) that it lies on the centreline of the bore. The classical way of doing the job (without a vertical slide) is to clamp the piece on the toolpost and cut through with a slitting saw on a mandrel, but you may have to do it with a fine hacksaw.

Eccentric sheave

Part 29, **Fig.53**. The material as it stands is the right diameter, but will need treatment. Grip in the 3-jaw chuck and face the end. Remove the sharp edge and then use fine emery to reduce the diameter to a smooth fit to the strap. (You may well find that it binds on the remains of a burr at the tapped hole!) Now, the material is steel. This is quite in order, but it *is* just a trifle less slippery than cast iron. So, I recommend that you *caseharden* the wearing face. This is a very easy process providing only that you have a reasonable size heating torch. The old half-pint paraffin blowlamp is quite adequate, but the little Gaz type D.I.Y. butane lamp is not man enough. You will, however, need some Kasenit No.1 casehardening compound which can be had from most tool-dealers in ½ or 1Kg tins. It doesn't go bad and will be invaluable stock for future years. The larger model engineer's supply firms also usually carry it as a stock item.

Ordinary mild steel cannot, of course, be hardened by the basic process of simple heating and quenching. But if it is carburised by heating and then burying in the compound for a few minutes the carbon content of the surface will be considerably raised so that on re-heating and quenching in water a fully hardened skin is obtained. *But*, the valuable characteristic is that after the first heating the surface is still soft (about the same as unhardened silver steel) so that we can machine parts of it away if need be then, after the second heat and quench these parts will remain soft and can be machined further – ideal for a job like this. Incidentally, there is no need to worry about the formation of surface scale since the job is not hot for long enough to cause any real trouble.

Assuming you *want* a hard surface on the sheave – not only longer-wearing, but much more slippery and hence causing less friction – begin by chucking the piece with about ½in. protruding, faced end outwards. Use a 1/16in. wide tool to form the groove, the right-hand edge being ¼in. from the face, and about 0.045 in. deep. Remove the sharp edges from the groove and polish it with emery, **Fig.54a**. Remove from the chuck and set it in your hearth on a piece of firebrick, grooved end downwards. Get an old tobacco tin or similar (about 3 in. dia x 1 in. deep) and fill this with Kasenit powder to form a conical mound. Heat up the piece of steel, as quickly as you like, until it is a good red – a bit hotter than you might use to harden a tool but there is no need to "soak" it to obtain uniform temperature throughout. Immediately bury ½in. at the business end in the compound and heap more around it. Leave it there until it has cooled to black with no trace of colour at all. (Or go and have a cup of tea whilst allowing it cool in the compound!) Wash off in clean water – it doesn't matter if it fizzes a little at this stage.

Clean it up with a wire brush then return to the lathe and restore the clean metal surface by the careful use of emery. Chuck as before and machine as shown in **Fig.54b** to remove the carburised surface, which will be no more than 0.005 in. or so thick. Return to the hearth, bring up to the classical cherry red colour, and quench out in clean water. Again, there is no need to soak the component – five minutes of heat will serve – since we are not trying to harden right through. You will find that the rubbing surface is now glass hard, but the remainder quite machineable, so that we can proceed to the next stage - forming the boss and boring the hole.

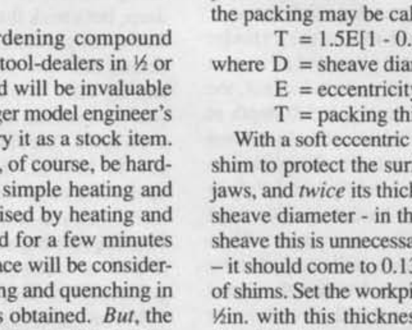
There are several ways of doing this - setting over in the 4-jaw, mounting a 3-jaw chuck held in the 4-jaw and holding it that way, etc. Provided the eccentricity is small I use the 3-jaw-and-packing-piece method shown in **Fig.55**. The thickness of the packing may be calculated from:

$$T = 1.5E[1 - 0.5(E/D) - 0.375(E/D)^2]$$

where D = sheave diameter
E = eccentricity,
T = packing thickness.

With a soft eccentric you must always use some shim to protect the surface from the edges of the jaws, and *twice* its thickness must be added to the sheave diameter - in this case, with the hardened sheave this is unnecessary. Work it out for yourself – it should come to 0.132 in. or ⅛ inch plus 7 thou of shims. Set the workpiece in the chuck, projecting ½in. with this thickness of shim under one jaw. Check that it runs eccentric by the desired offset to within the odd thou or so. Centre the end, and drill 6.2mm, followed by a ¼in. reamer. Run quite fast when drilling (say 400 rpm or more) but reduce to half speed, 200 rpm for reaming, using plenty of cutting oil for both operations. Lightly countersink the hole. Then turn down the boss to 7/16in. diameter, but keep an eye on the left-hand face since the surface of the sheave itself will be hard.

Rechuck without the packing and part off about 1/64in. away from the rubbing face. Maintain a steady feed, especially when the tool point is passing through the hole – excess feed at that point could cause a jam-up. Reverse in the chuck – to machine a good finish on the parted-off face. You can now drill for the grub-screws. You will see that I have indicated two, though the original drawing shows only one. This gives a better grip but, more importantly, you can use a long screw in one hole, with the other grub screw barely tightened, to use as a tommy bar when setting the eccentric.



ECCENTRIC MACHINING
DIMENSION AS Fig.53
Fig. 55

Clean off all the burrs stone the *edges* only of the hard face - and countersink both ends of the hole if you have not already done so. Then fit to the strap with a drop of oil. Clean up the eccentric rod (part 20, supplied ready-made) and fit it to the strap with a locknut. Adjust it so that it does not bind at the bottom of the groove and lock the nut. Fit the 9/16in. 7BA bolt and adjust for a smooth fit; you may, by the way, find it necessary to prise open the slit a little. Sometimes these straps close in when split and sometimes they open out. Then fit the locknut and set aside for the present.

● *To be continued*