



## 6 Steam Locomotive Chassis

### Introduction

A model locomotive usually consists of two basic items, the body and the chassis that transports it. This section is a compilation of the processes recommended when constructing a locomotive chassis in order to ensure better running.

These notes are based on the use of chassis parts that are assembled from etched or profile milled components, though the same methods can be applied equally to scratch built parts. It should be noted that there are many different methods of constructing chassis, and the final choice will depend on the builder's inclinations, skills, and ability and willingness to purchase special jigs and tools. These notes cannot reflect all of the various methods employed by different modellers, but do endeavour to emphasise tried and tested methods that do not require high levels of expertise or extensive workshop resources, and that, properly applied, allow good chassis to be constructed.

### 6.1 Initial assembly

Most model underframes rarely conform to the true profiles of prototype frames. The top edge is often reduced to a straight line that conforms to the edge of the running or footplate (the true top edge of the underframe often being reproduced on the running plate at the correct width rather than the often narrow frame width of the model). This is an advantage to accurate construction as it provides a datum from which to assess the trueness of the frames as the frames can be placed with these edges on a flat surface.

Underframes constructed from etched frames

and spacers can become distorted during assembly. To avoid banana shaped frames, initially fit the frame spacers, one to the left-hand frame and one to the right-hand frame, as shown in Figure 6-1. This will distribute the heat during soldering, as it is the unequal expansion that creates the distortion.

Where frames are joined with turned spacers, tightening the fixing screws into the spacers will often distort the frames. This is especially true if countersunk screws are used. The countersink head gives a wedging action that pushes the frames around. To avoid this, substitute cheese-head screws and ensure that the holes in the frames have a good clearance around the screw.

If there is a matching countersink in the frames provided, either substitute left to right to put it on the inside or, if there are features that prevent this, then blind the countersink with a washer under the screw head. Gently tighten the screws checking all the time that the frames remain vertical and straight. Once this is done solder up the frame spacers and discard the screws. The holes on the outside can later be filled with Milliput.

Note that because the turned frame spacers have a large thermal mass, a different technique is required. Solder both ends of the first spacer at once to the frames. Let that spacer cool, and then solder the next, and so on.

If a split chassis pickup is to be used, the frames must be electrically isolated from each other. This requires spacers in Tufnol or plastic blocks. These will be screwed to the frames or bonded using epoxy or cyanoacrylate adhesives, or initially screwed to achieve the correct location, then

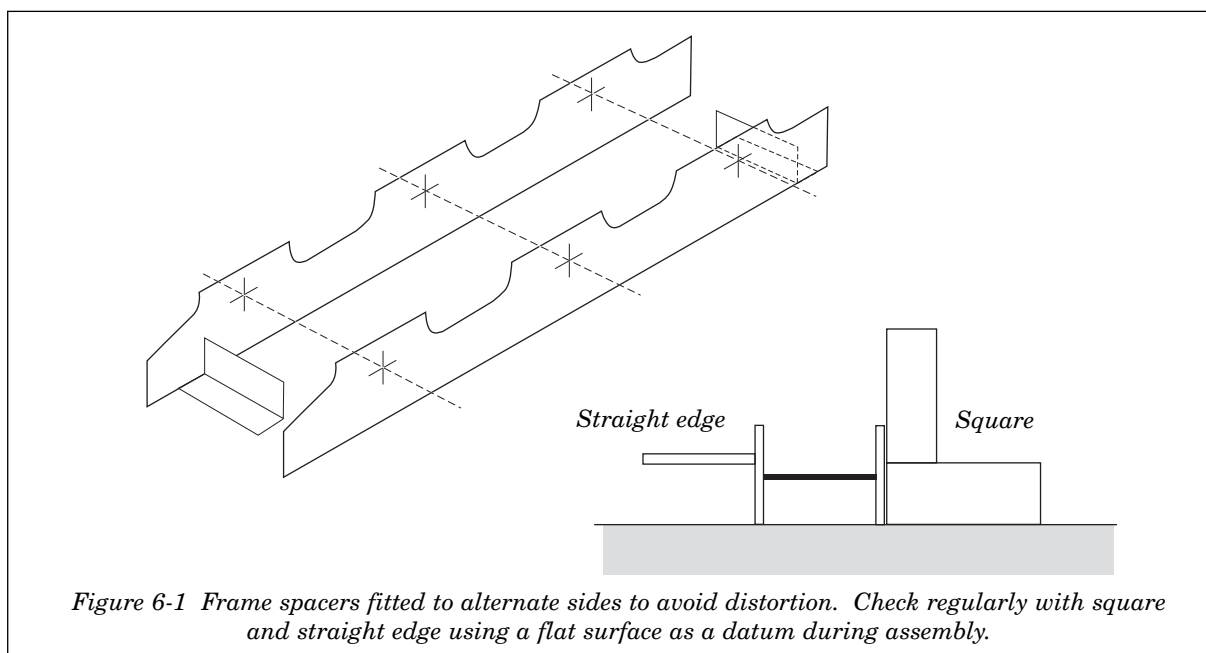
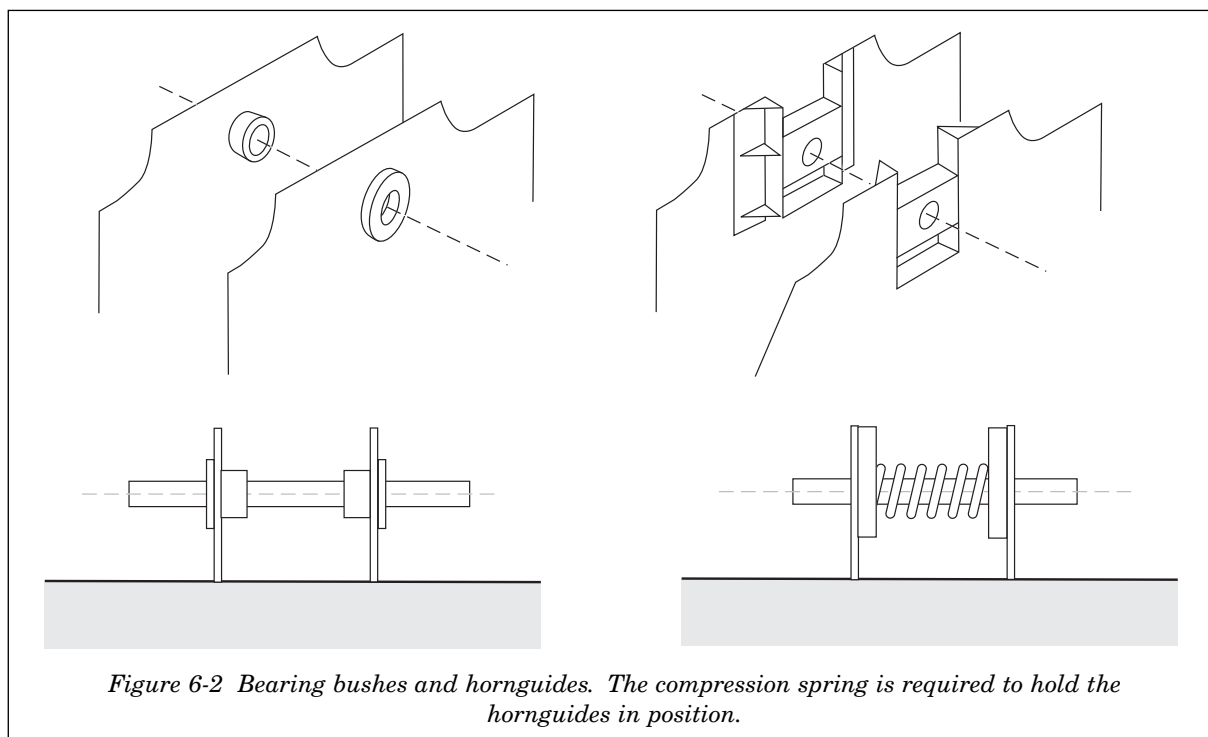


Figure 6-1 Frame spacers fitted to alternate sides to avoid distortion. Check regularly with square and straight edge using a flat surface as a datum during assembly.



bonded. Where screw fixing is used, the same remarks concerning countersink heads apply.

## 6.2 Bearing installation

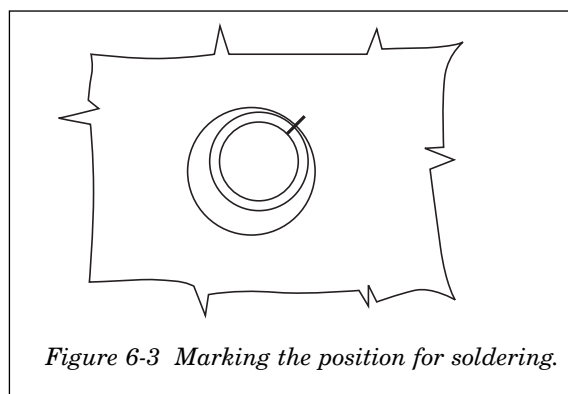
There are two types of bearing in common use, plain bushes and hornguide systems. The former are used in totally rigid frames or in conjunction with the latter for a compensated chassis. A sprung chassis requires an all-hornguide system. Both types are illustrated in Figure 6-2.

### 6.2.1 Plain bearings

These usually take the form of 'top-hat' bearings and it is important that the bearing head seats firmly against the frames. To ensure this, break the edge of the hole in the frames by gently running a drill about three times the hole diameter against the hole to remove the corner. Spinning it in the fingers is sufficient. This will enable the head to seat firmly against the frame. The small radius between the head of the bush and the body outside diameter sits in the chamfer created by the drill.

Before securing the bush, check that the axle running in it is square in two planes to the frames. Using a small engineer's square, sight the blade against an axle fitted in the bushes. As the square cannot be placed directly against the axle, hold the parts up against the light and sight the blade against the axle, rotating the whole so that a diminishing gap between the blade and the axle can be seen. It is possible to spot any taper in the gap if the axle is not square to the frames. Correct the position of the bush that is considered to be out of position.

Do not try to elongate the hole, just enlarge it a



few thou' concentrically with a broach, refit the bush and axle and, sighting along the square again, move the bush in the appropriate direction to get the axle square (Figure 6-3). Mark the required position by striking a line across the bush head and frame. Use either a fine felt tip pen or a scribe. If the hole has not been enlarged sufficiently then take off a few more thou' from the hole. Once the bush is correctly positioned, solder it in place.

Having established the position of the first axle, the coupling rods can be used to position the remaining bushes. Alignment jigs with jury axles, such as supplied for assembling hornguides (Figure 6-4), can be used for this. In this way you will ensure that the axle holes are to the same pitch as the crank pins. Alternatively, chassis alignment jigs are now available from the trade, and provide a ready method of assembling and aligning a chassis. Some modellers dispense with jigs entirely and check the axle spacing on both sides of the chassis using vernier callipers.

### 6.2.2 Bearings in hornguides

In some respects these are easier to get right than plain bearings due to the movement in them. It is necessary to ensure that the two hornblocks supporting each axle are correctly aligned to each other across the frames.

Set up the first pair of hornguides with either a jury axle or an alignment tool. A set of compression springs that fit over the jury axles and push the hornguides and bearing assembly onto the frames are ideal for this (Figure 6-2). The hornguides can be juggled around, sighting the axle against the square until they are positioned accurately. Then, depending on the type of hornguides used, either solder or glue them in place. The same applies when using a chassis assembly jig.

The remaining hornguides can then be positioned using the coupling rods as guides (Figure 6-4 and Photo 6.1) or by using one of the chassis alignment jigs that are available from the trade.

A compensated chassis is simply a combination of the two systems and is treated in the same way but combining the methods. Always start by fitting the plain bearings.

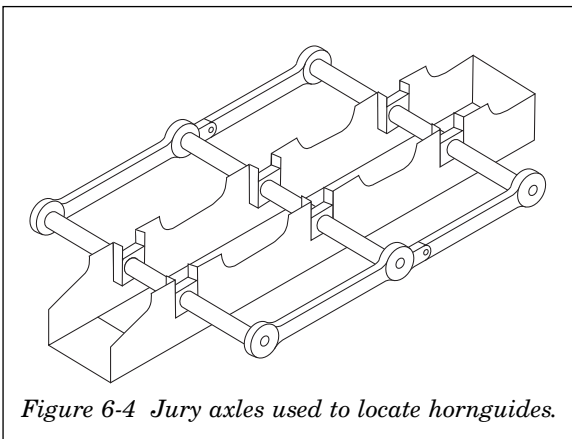


Figure 6-4 Jury axles used to locate hornguides.

Once the bearings have been fitted, the wheelsets should be fitted and the free rolling or otherwise should be checked. If all is well the chassis should roll down a short length of track with one end lifted an inch or so. If there is a degree of "stiction" then the bearings should be opened out by a few thou'. Most standard axles are  $\frac{3}{16}$  in. diameter, and reamers to suit are unlikely to remove any material as the bearing bores are already to size. It is possible to purchase reamers larger than the basic size. A 4.8 mm reamer is 0.189 in. diameter or 0.002 in. larger than the basic size. This seems to work well.

For smaller bores a roll of wet and dry paper, 360 grit will do nicely, can be inserted into the bore and twiddled around in the fingers (Figure 6-5). This should remove the necessary few thou' to free up the axles. For  $\frac{3}{16}$  in. axle bores, where a suitable reamer is unavailable, this tool can also be used. It

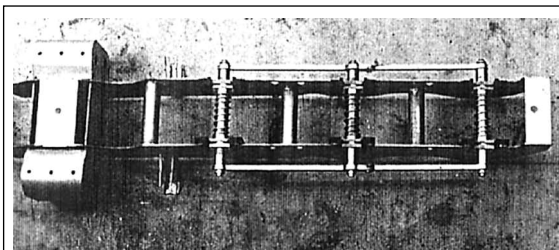


Photo 6.1 A 7mm chassis showing the springs holding the hornguides in position.

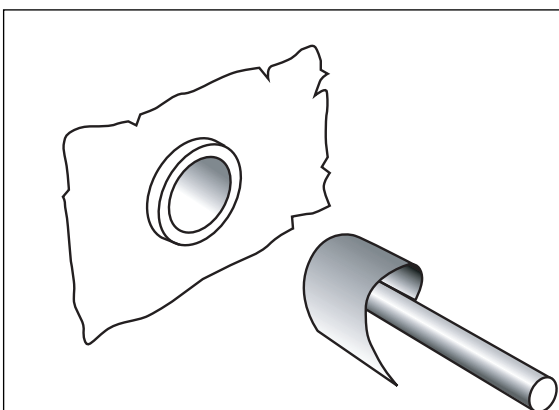


Figure 6-5 Tool for easing the bore of a bush.

may be mechanised by fitting the wet and dry into a slot in a short length of brass tube and the whole rotated briskly in a modelling drill. Beware the brass dust and particles of abrasive that can fly out. Eye protection is essential for this operation.

Some modellers prefer to polish the axle down using wet and dry paper, rather than enlarge the bearings. In such a case, some means is required to rotate the axle as the abrasive is applied.

A problem with hornblocks is that, with time, they will wear, which results in a loss of wheel positioning. (The same happened on the prototype.) Not only is this important for smooth running, but it can cause problems with some prototypes where wheels are very close to motion brackets and brake gear, because this may result in electrical shorts. Whether this becomes a problem will depend on how intensively the model is run. Another option, where the chassis is compensated, is to mount the bearings directly into the compensation beams. If the compensation beams were perfectly rigid, this would mean that the bearing bores on opposite sides of the chassis remain parallel to one another when one bearing is displaced vertically relative to the other. In practice, the beams are usually thin enough that they will flex a little to allow for differences in height. It is, however, important that the beams on either side of the chassis are square because they will not flex longitudinally. It is also helpful if the beam is in the middle of the bearing, or the beam will twist under the weight of the locomotive, which can lead to binding and wear.

### 6.3 The Motion

The first essential is that all the joints in the motion have freedom of movement. Although some parts may only move through a small arc, nevertheless it is necessary that the parts should move freely, one around the other. An example is shown in Figure 6-6.

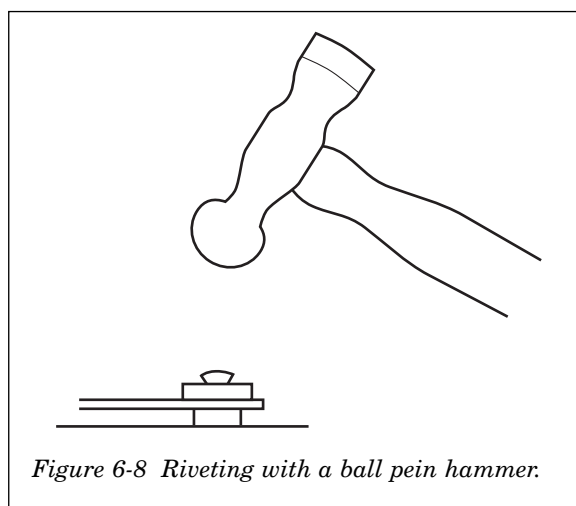
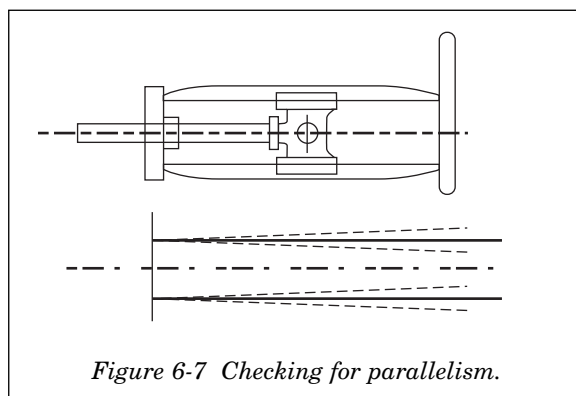
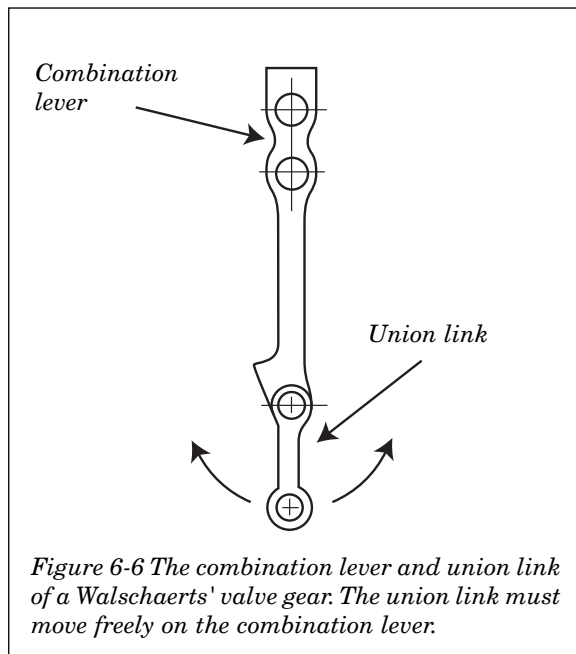
Similarly, the crosshead should move freely and smoothly through the slidebars. The sliding surfaces of the crosshead should be smooth and parallel. The slidebars themselves should be parallel in both planes and especially parallel to the piston rod (Figure 6-7). The easiest test for free movement here is to see if the crosshead will fall smoothly through the slide bars under the influence of gravity. The manufacturers who provide cast brass crossheads and slidebars make this particularly easy. It is usually just a matter of cleaning up the castings and checking the alignment.

The joints between the components are critical to the performance of the motion. The jointing methods that are usually provided by kit manufacturers are either rivets, pins, or small bolts. Dealing first with the riveted joints, the first step is to ensure that the hole is just large enough to fit the rivet supplied. If the hole is too small then open it out with a broach. Do not drill it, because, when the drill breaks through the opposite side of the component, it often ‘snatches,’ picks up material and tries to rotate the part, usually severely bending it or breaking it. With a broach you are in control.

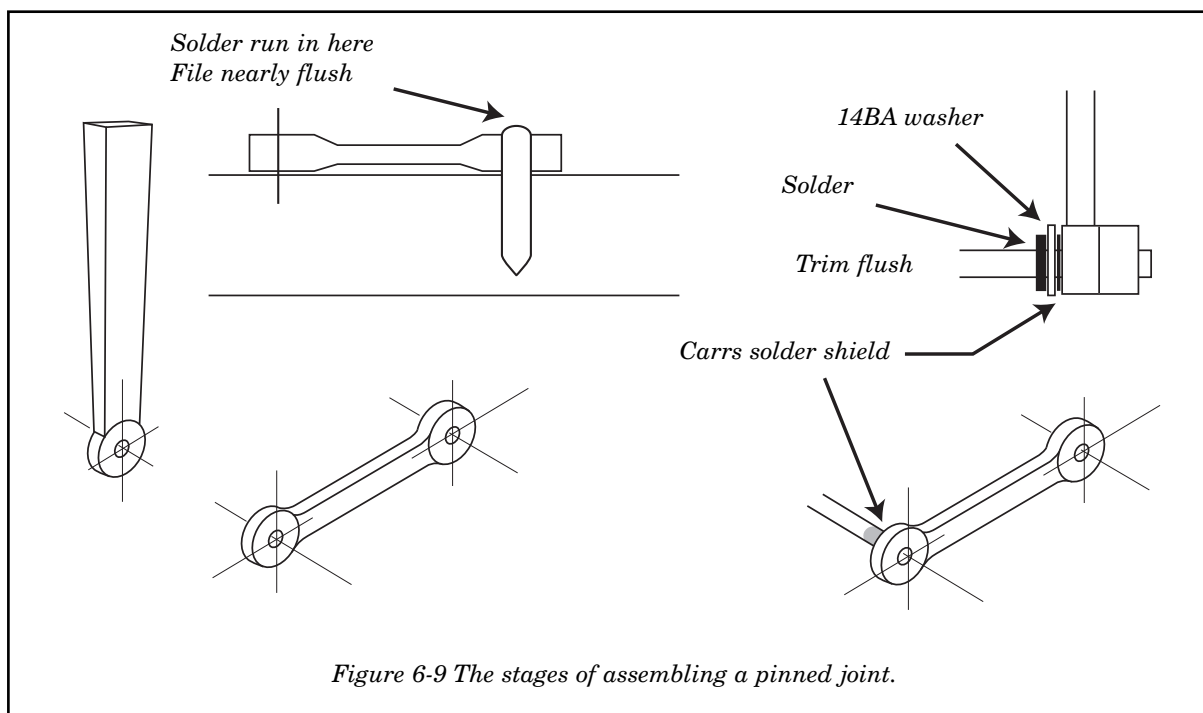
When riveting the motion, it is preferable to fit the rivet with its head at the back of the assembly. It is fairly simple to correctly set the tail of the rivet and to expand it without seizing the whole assembly solid, but an essential tool is a small ball pein hammer. This is a hammer where the end opposite the flat part of the head that has a spherical shape. The ball end is used to set the rivet. To set the rivet properly it needs to have about one rivet diameter protruding through the parts. Tap the rivet lightly with the ball and the edges of the rivet deform into a dome (Figure 6-8). The hammer should be steered around the rivet to obtain an even set. Riveting this way will leave the two components free to move but unable to come apart. The spherical end to the rivet looks neat and tidy too.

Like all things, successful riveting is a technique that can be learned. If you are unsure of your ability, it is as well to practice first on some scrap material. If you are still uncomfortable with the idea, other methods of fixing the motion are available.

A pinned joint can be made by first soldering a pin on one side of the joint. The pin is then passed through the second component and a washer soldered behind. The first stage is to fit the pin.



Generally 0.9 mm diameter brass or nickel silver wire is very suitable for the pin. Cut an initial length of about 3 mm and, using a piece of MDF to support it, solder it into the first component (Figure 6-9).



Remove it from the supporting MDF and coat the pin and the back of the component with Carr's solder mask. By thinning the masking product with isopropyl alcohol, it can be painted on. The masking product should then be dried in situ by applying gentle heating with a soldering iron.

The joint surfaces of the mating component should be similarly treated. Slip it over the pin, followed by a 14BA brass washer. Some kits provide an etched part in place of the washer. Polish the washer on one side on some fine wet and dry and apply a small touch of a paste flux to it. Then apply the iron and introduce the solder. This should run around the washer and onto the exposed pin.

Reverse the components, trim the pin to just above the outer component and file flat just proud of the surface. This then looks like the pin of the real joint. Reverse again and trim the pin flush with the washer, filing down to create a thin head.

Finally, the motion can also be joined using nuts and bolts. Generally, these do not look as prototypical as other methods (there are a few exceptions where nuts were visible on the prototype, particularly on the crosshead), and care must be taken because the head of the bolt and the nut can take up the clearances so that the motion binds. However, it is certainly the easiest method to use. Care must be taken not to over-tighten the nuts or the joints may not move freely. To prevent them working loose during operation it is recommended to secure the thread with a touch of nail varnish. Should it be necessary to undo them at a later date, nail varnish remover will soften the grip to allow easy removal. Solder may be used for the same purpose, but care must be taken to

prevent it penetrating the threads and into the motion parts themselves.

Once the wheels and motion are installed in the chassis, the whole should be as free running as when it was tried with the wheels alone. This is without a motor or pick-ups installed of course. Unless split frames or some other form of current collection that avoids running pickups is used, the pickups of whatever type will introduce a braking element to the chassis (see Part 3, Section 8). However, if done well this can be minimal.

## 6.4 Sideplay and clearances

Apart from the free running aspects, consideration has to be given to the track radii that the locomotive will have to negotiate. This must be decided before construction begins. Part 2 Section 1 contains some advice concerning minimum curvature (but these are guidelines, not unbreakable rules). Depending on this requirement, a greater or lesser degree of side play in the wheelsets will be needed. If there is no side play, then inevitably difficulties will occur. On the other hand, too much sideplay can cause crabbing, buffer locking, and the effect of snatching and lurching into curves is non-prototypical. A good working rule is to use the minimum sideplay necessary for free running. In this context, it should be noted that 0 Fine Standard wheelsets have a maximum over-flanges dimension of 31 mm. When standard 32 mm gauge track is used there is a 'built in' allowance before sideplay is needed. For example, a six-coupled locomotive with an 18 ft (126 mm model) wheelbase on a six-foot radius curve has the 1.1 mm displacement on the centre



axle catered for by this and the normal modelling clearances. Additional sideplay is only required with longer wheelbases and and/or tighter radius curves.

This works well for the majority of 0 Fine scale wheels in use today. However, the Guild standard for wheel dimensions (see Part 1, Section 1) does not specify a maximum over-flange dimension. If using wheels that have unusually thick flanges, additional sideplay may be required. If in doubt, the over flange dimension should be checked with callipers and compared with the values noted here.

There are two main items that may limit the amount of side movement that can be provided. One is the motor/gearbox arrangement, and the other is the limited space behind the crosshead and the crankpin on the leading wheel. This latter feature is common on locomotives with outside cylinders (Photo 6-2).

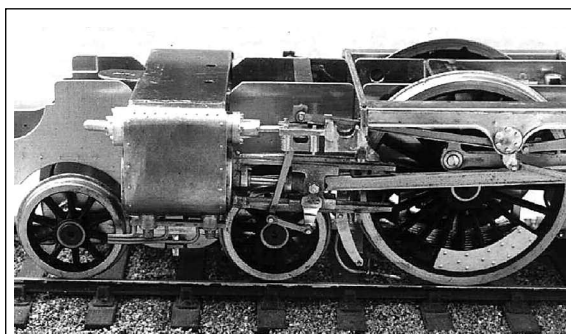
To maximise the clearances behind the crosshead, consider the small end joint at the end of the connecting rod. What arrangements that can be made here will depend largely on the kit. Try to make the joint with a countersunk screw such that its head is on the inside and the nut is on the

outside. The position of the nut may match prototype practice. It will usually be necessary to limit the side motion of the leading wheel and set it to a minimum. It is also possible to cut a counterbore into the coupling rod at this position and fit a recessed crankpin. This follows prototype practice for the same reasons of clearance.

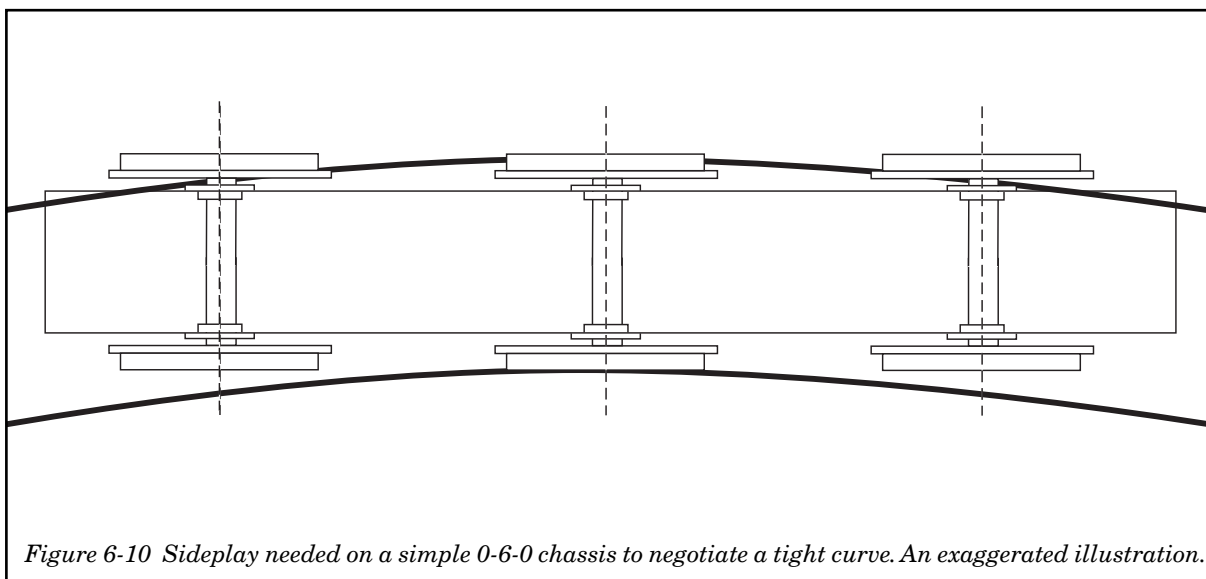
Figure 6-10 shows a six-coupled underframe on a tight model curve and illustrates the amount of sideplay required to negotiate that curve. If the design permits, the sideplay should be limited to the centre axle while the outer axles have the minimum for free running. This will minimise the amount of throw-over that occurs at the buffer beam when negotiating curves. Minimum sideplay of the leading axle also caters for the presence of outside motion.

Wheel arrangements that can cause problems on tight model curves are the 0-4-4T, and to a certain extent the 4-4-0, and single driver locomotives like the Stirling single. In the former case, the late S. Hunter described a solution in the *Model Railway Constructor* that he had applied to a Southern tank engine. It consisted of fixing the bogie frame so that it could rotate and tilt about its pivot but had no sideways movement. The front driving axle was also constrained and the second driving axle given sideplay. This reduced the overhang at the bunker end by about 50%. Figure 6-11 illustrates the principle.

The leading bogie of single driver locomotives is not given sideplay but can swivel. In the case of the Stirling single the presence of splashers on the bogie wheels can be a particular source of trouble. This has been overcome by 'modeller's licence' by making the bogie frames integral with the main frames so that the locomotive becomes, in effect, an 0-6-2. A small amount of sideplay on the second bogie axle gives the steady running required while retaining the illusion that the locomotive is a 4-2-2. The idea is illustrated in Figure 6-12.



*Photo 6-2. This shows the recessed crankpin of a 7mm 'Patriot.'*



*Figure 6-10 Sideplay needed on a simple 0-6-0 chassis to negotiate a tight curve. An exaggerated illustration.*

Using the six-coupled underframe as an example, if the motor drive can be taken to an axle that has no sideplay, a wide range of motor-gearbox types can be fitted, including those that occupy the full width of the frames. Where it is necessary to use an

axle that does require sideplay, it is a distinct advantage to use a narrow combined motor/gearbox unit if possible. This then allows the assembly to move with the axles. The arrangement of the axle bushes in the gearbox may constrain this and the

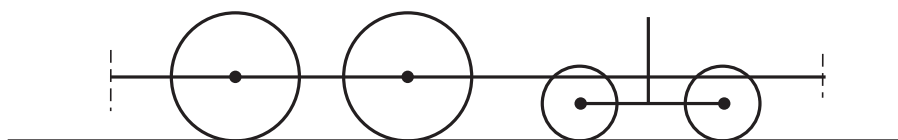


Figure 6-11a Line sketch of a typical 0-4-4T underframe

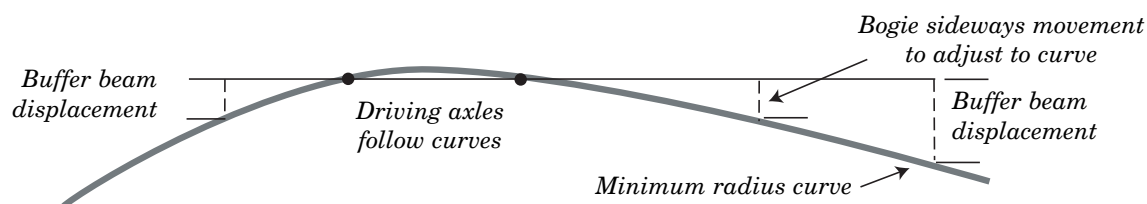


Figure 6-11b Underframe with no sideplay on driving axles

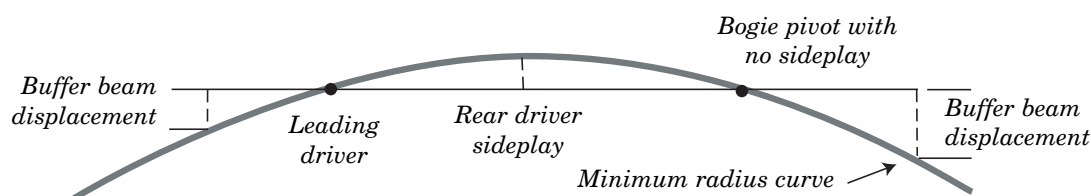


Figure 6-11c Underframe with no sideplay on bogie pivot and leading driver

Figure 6-11 S. Hunter's method to reduce buffer beam displacement. Make a line sketch to scale of the underframe and mark the position of the leading axle and bogie pivot. Draw a curve representing the minimum radius through these points. The amount of sideplay on the rear driver and bufferbeam displacement can be measured from the sketch.

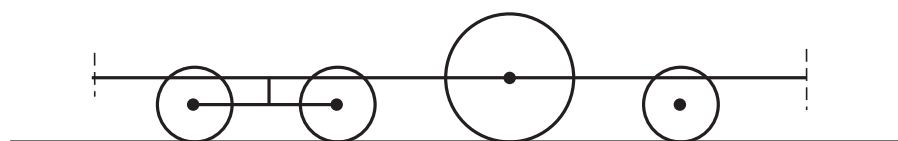


Figure 6-12a Line sketch of a typical 4-2-2 underframe

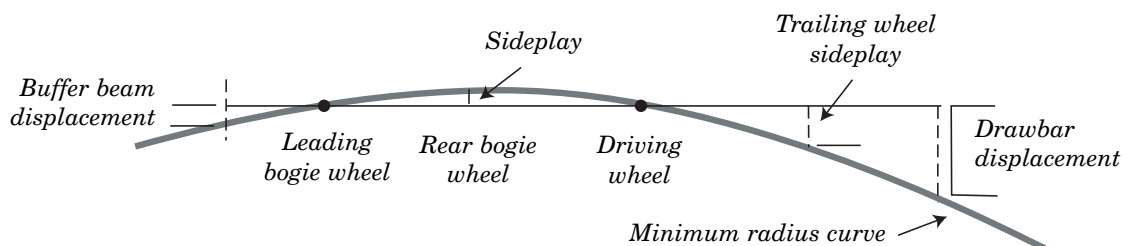


Figure 6-12b Underframe with dummy bogie frame. Leading bogie wheel and driving axle with no sideplay. Rear bogie wheels with sideplay.

Figure 6-12 Using 'modeller's licence' to reduce body movement on a single wheeler by making the leading bogie a dummy. Make a line sketch to scale of the underframe and mark the position of the leading bogie axle and the driving axle. Draw a curve representing the minimum radius through these points. The amount of sideplay required on the rear bogie axle can be measured from the sketch.

width of the frame bearings can also have an effect. Generally the limitation on movement can be overcome by narrowing the width of the frame bearings, or, possibly, narrowing the overall width of the gearbox. Whatever the solution, especially if the final drive is a worm and wormwheel, the final gear wheel should be constrained to remain in alignment with its driver regardless of any movement of the gearbox frames as part of the sideplay.

One of the best ways to improve the way in which the locomotive will negotiate curves is to provide

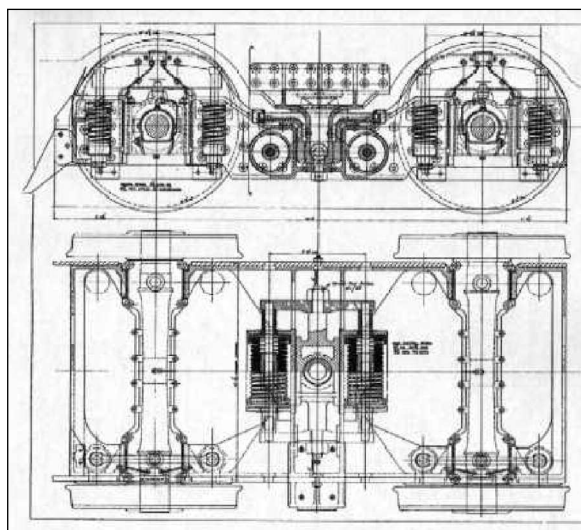


Fig 6-13 LNER bogie springing.

side control springing in the bogie or pony truck. Regardless of whether this is 2-6-0, 2-6-2, 4-6-0, 4-6-2 or 2-6-4, if some form side control can be arranged then it will help steer a locomotive around curves. Figure 6-13 shows the full size arrangement on a LNER bogie. The pair of springs can be clearly seen either side of the pivot. Note that in this instance part of the locomotive weight is carried on the hemispherical pads on the outside the bogie frames. This is the de Glehn system.

On the model this can be duplicated in a number of ways of increasing sophistication. In Figure 6-14, from left to right, the side control springs are: a spring wire, leaf springs and coil springs. It is important that if using a spring wire, it is allowed to deflect as shown in the sketch at top left. This means that one end is rigidly attached, and the other has a point location that has freedom of movement. A simple wire loop to locate the spring will do. The other two versions speak for themselves and a certain amount of ingenuity will be required to incorporate them, that will depend very much on the parts provided.

Side control springs may help to steer the fixed driving wheels into a curve, as illustrated in Figures 6-15 and 6-16. The amount of side control required depends on the weight and speed of the engine, and the radius of the curves that it has to negotiate. It is particularly so for prototypes such as a 2-4-2 or 4-4-2, where crabbing on straights can be as much a problem as keeping the truck on the rail through curves. The position of side control

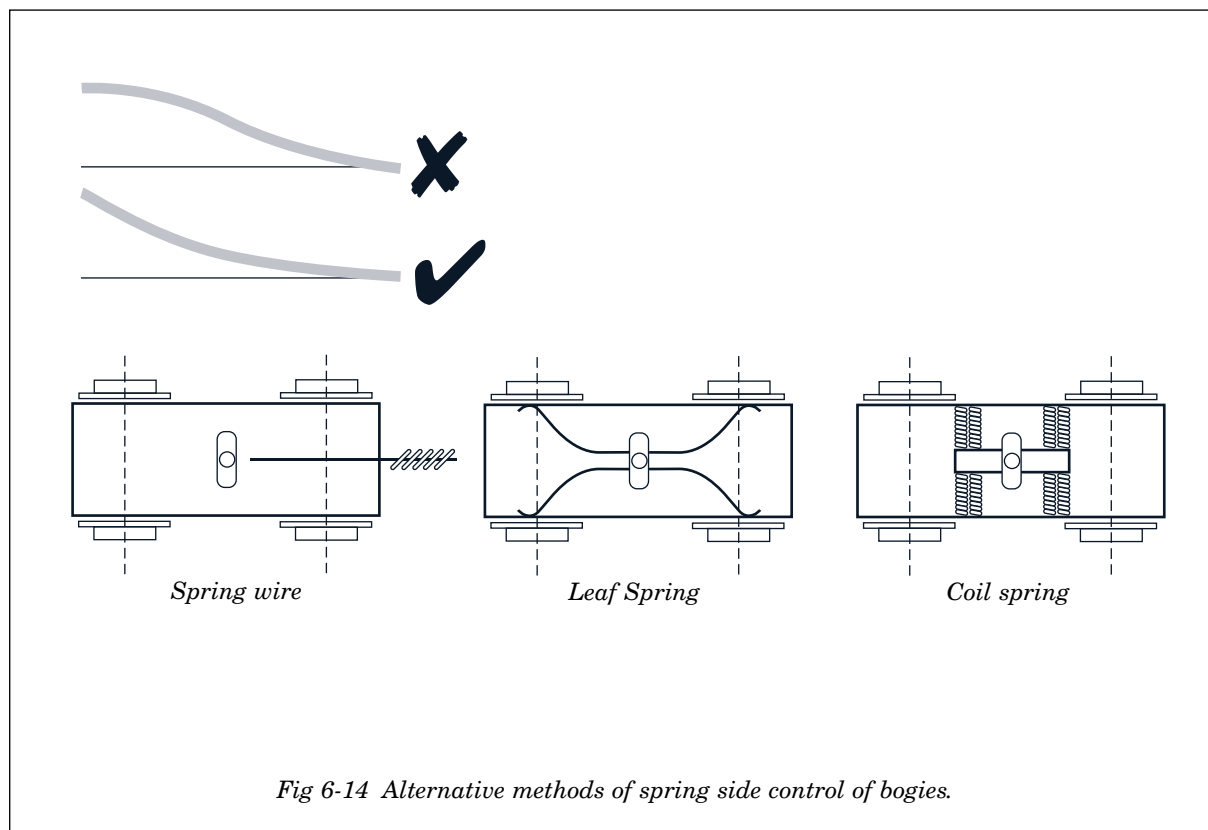


Fig 6-14 Alternative methods of spring side control of bogies.



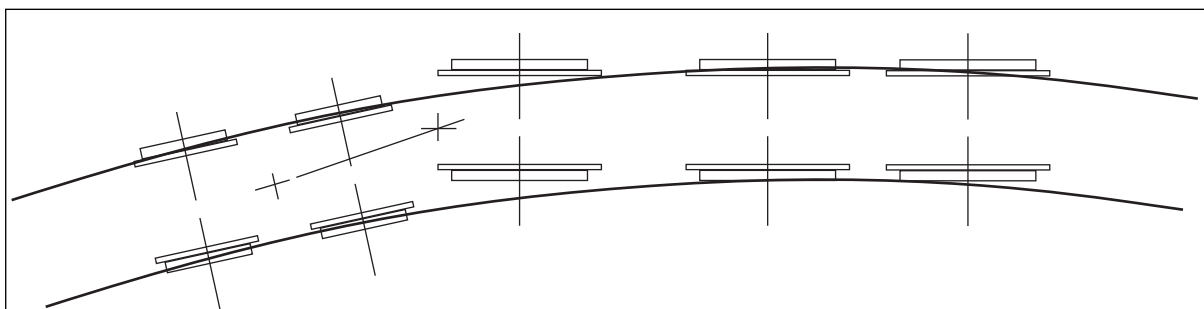


Figure 6-15 Free running bogie has no effect in guiding the locomotive into the curve.

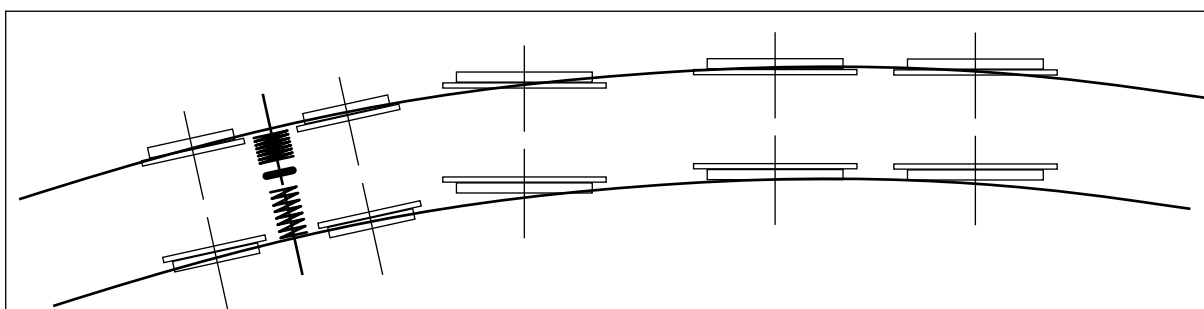


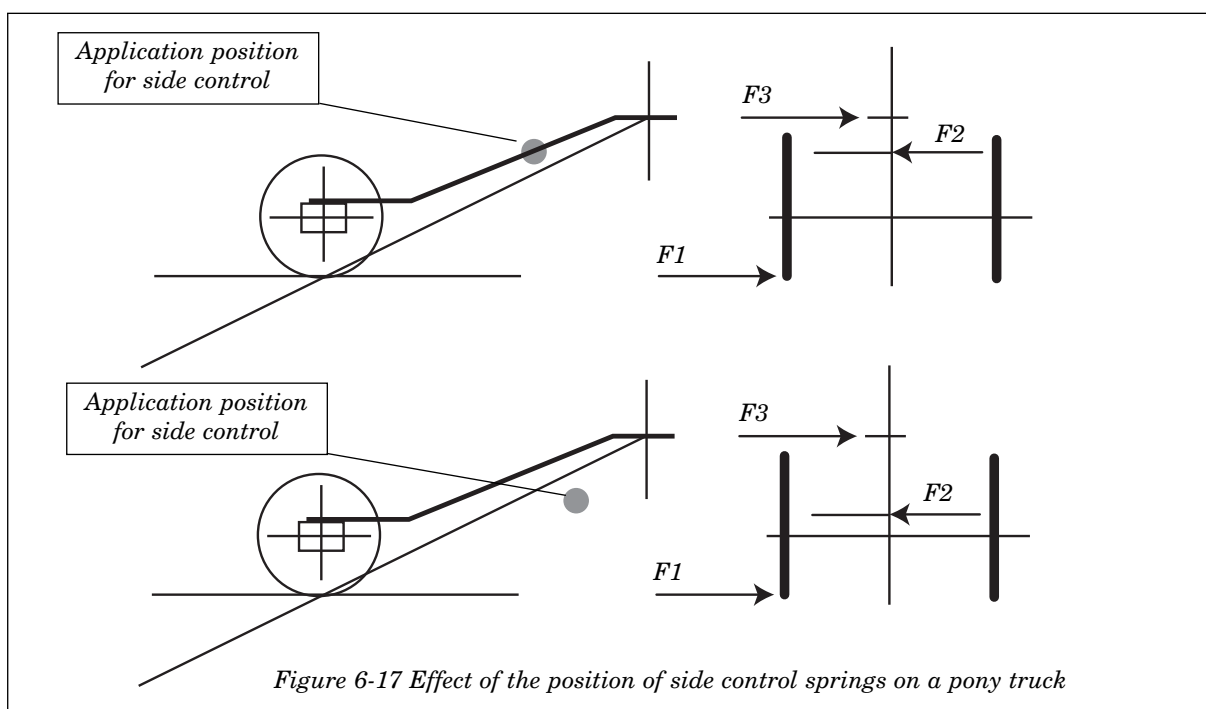
Fig 6-16 Simple sideways springing of a leading bogie provides the guiding effect.

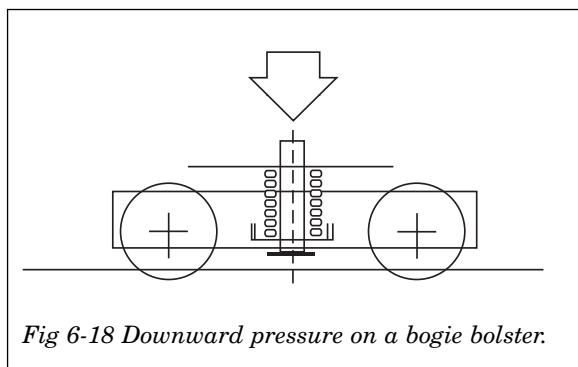
springs in relation to the bogie or pony truck is important, as is explained in Figure 6-17.

This figure shows a pony truck moving on a curve. Force  $F_1$  is the force created by the outer rail acting on the wheel, and  $F_3$  is the force on the pony truck pivot point, that acts on the fixed chassis. Force  $F_2$  is the reaction force exerted by the side control spring. When the side controlling spring is

located above the line shown in the figure connecting the two other reaction points, the result is a clockwise rotation of the truck causing the left hand running wheel to lift. Since it is this wheel providing the reaction force  $F_1$ , it will derail, unless sufficient vertical force is provided. This takes traction load away from the drivers.

The lower part of Figure 6-17 shows how to avoid





this problem. The side control is applied below the line connecting the reaction points. As a result, the truck will attempt to rotate in the counter-clockwise direction, causing the left wheel to press more strongly onto the track, and restrain any tendency to lift. As the lateral force  $F_1$  increases (as the curve gets sharper), this counter-clockwise effect increases, which is what we need. There is no reduction in traction because there is no additional requirement for vertical load from the fixed chassis onto the pony truck.

When using side control springs to bogies and pony trucks, it is useful to put stops on the springs to prevent them acting past the mid point. This gives the bogie a definite centre position and improves side control. Two springs working against each other may reduce the side control, and it is difficult to adjust these springs in our small scale. Side control of a bogie can be done by soldering two spring wires on to the back of the bogie, acting on the centre pivot. Just ahead of the pivot, a vertical plate across the bogie has slots for the spring wires to run in, so arranged that the spring wires bottom on the slots when the bogie is centred.

Some arrangement to apply a downward load on a bogie or pony truck is also helpful to road-holding. A simple downward acting coil spring is usually sufficient (Figure 6-18). The strength of the spring should be only as much as is required to keep the bogie wheels on the track, anything in excess of that will reduce the weight of the locomotive on the driving wheels and the traction will suffer as a result.

## 6.5 Motors and Gearboxes

There is a wide choice of motors and gearboxes available, from the simple worm and wheel to the sophistication of multi-stage units. Worm and wheel units are available as either a simple etched fold-up mounting or an integral motor/gearbox

unit. The latter may be preferred to the simple worm as it does relieve the builder of the potential difficulty of getting a worm gear to mesh properly. Multiple stage reduction gearboxes use a crossed helical gear, which has a much smaller reduction ratio than a worm and wheel, followed by one or more stages of spur gear to link the motor to the axle with an appropriate speed reduction ratio. This arrangement has a higher transmission efficiency than the worm and wheel. This may be important for battery powered locomotives because it limits the current drain, but for most purposes, modern motors are capable of sufficient output that the lower efficiency of a good worm and wheel is not likely to be a problem except where the maximum power available from the motor is required.

Worm gears also produce a significant axial load on the motor shaft that must be borne by a thrust bearing. For forward and reverse running, the direction of the load reverses, and this must also be allowed for. This bearing must be fitted to the motor (i.e. the motor must be designed to withstand the axial loads), unless the worm gear is in a separate gearbox and driven through a cardan shaft, in which case it must be fitted to the gearbox. Not all motors are equipped with axial thrust bearings, but motor suppliers should be able to advise on suitable motors that can withstand the loads to be encountered in service. Helical gears also exert an axial load, but of much smaller magnitude than is typical of worm gears.

In locomotives fitted for DCC, it is important to know the maximum current that the motor will draw, so that a DCC decoder of the correct current rating can be selected. Reputable motor suppliers will normally be able to advise about this.

The reduction ratio will depend on the choice of motor (and hence the speed of rotation), and the speed desired for the finished locomotive. Most modellers prefer to use speeds related to the prototype, and thus a heavy goods engine would not be required to run above a scale 40 mph or thereabouts, whereas an express engine would be geared to run much faster than this. Suppliers of motors and gearboxes can generally be relied upon to recommend a suitable motor and to provide a gear ratio matched to it, providing they know the ultimate purpose of the locomotive. For those modellers wishing to select their own motors and gearboxes, Part 3, Section 3 includes two tables relating prototypical speed and wheel diameters to model motor speed with an appropriate gear ratio.