Building Liverpool

Planning

Even by nineteenth century stands, Cramptons were unusual locomotives. Only a handful were ever built and run in Great Britain, but in 1848 the LNWR constructed what was to be the largest to appear here. Named Liverpool, it had a service life of only ten years, including an appearance at the Great Exhibition of 1851. For its time, the weight, wheelbase, and the huge driving wheels were exceptional in every way. Accounts suggest that it was too heavy for the lightly-constructed track of the time, and spread the rails, which is certainly consistent with the short life.

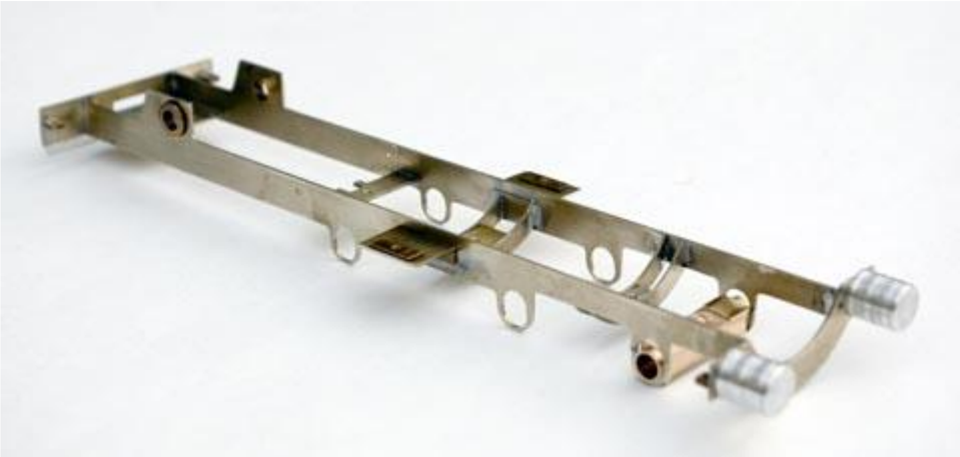
There is a lot in the prototype to interest me as a model builder. The Stephenson's valve gear is outside the driving wheels and driven by a pair of huge eccentrics, and this feature is so obvious that it just has to be modelled correctly. The driving wheels themselves, eight feet in diameter, are striking, and there is an odd collection of leading and carrying wheels. The two front axles have wheels of different diameters, and the centre wheels are flangeless. The outside frames with all their rivets and bolts are another obvious feature.

It is not apparent in the side elevation, but the boiler is not circular. It is egg-shaped, being formed of two semicircles (or almost semicircles), the upper being of larger diameter than the lower, joined together. Clearly the intention was to make the largest possible boiler, but one that also had to fit between the wheels. The firebox too is an odd shape, waisted to fit between the driving wheels, then expanding at the front end where it met the boiler. Internally it is most interesting to the engineer, but thankfully irrelevant to the modeller, with a huge number of narrow boiler tubes, a split firebox, and a species of thermic siphon, the last of these dating almost a century before Mr. Bullied fitted them to his Pacifics.

Altogether it represented something quite out of the ordinary, and the model required a lot of thought and planning. Conventional ideas about a separate chassis and body, the way model locos are usually made, went out straight away. There is not really a footplate at which to split the model at all. The final solution involves a number of subassemblies, bolted together. The "backbone" of the locomotive is the inner frames, spacers, buffer beam, and drag beam. The outer frames and cylinders are attached to this. Other subassemblies comprise the piston rods and slidebars, and the valve gear. The smokebox, boiler, and firebox form another subassembly that bolts directly to the inner frame assembly. The final major component is the driving wheel splashers and the footplate between them.

The construction of the model actually resembles that of the prototype to a much greater extent than is usual. But it was also consistent with an approach to loco building that I had been developing gradually. At one time I followed the common approach of soldering everything up, but more and more that just did not seem the right approach for scratch building. Increasingly I had been using subassemblies for my models. It does require a certain forethought, and of course there are holes to be drilled and tapped to take the bolts that hold everything together. In spite of that, I do find it facilitates the construction, being able to remove and to a limited extent realign parts at will. It also makes the painting so much easier. I took this process further with Liverpool than previously, and it has proved to be the logical development of this strategy.

Inner frames



The inner frames, beams, and spacers, are all cut from 0.7 mm nickel silver on the pantograph milling machine. The frames are an odd shape because of the great difference in size between the driving and carrying wheels, which means that the driving wheel bearings are located in frame extensions above the top edge of the frames, and the carrying wheels below the bottom edge. The front beam and the drag beam are permanently fixed to the frames because there is no easy way or even need to make them detachable.

As the photo shows, the driving wheels run in fixed bearings. The leading axle is carried in a sleeve bearing that floats vertically in slots. When assembled, the bottom of the boiler is in contact with this bearing, and forms a pivot about which the wheel assembly can rock and take up any unevenness in the track. The remaining axles float vertically but are unrestrained. Thus the weight is entirely carried on the leading and driving axles (hopefully more on the driving axle, but that will come later in the story). Given the compensation on the front axle, this should give a stable arrangement. The other axles just go round and carry no weight. The side play of all the wheels is limited by the splashers. On the prototype the central pair of wheels were flangeless, and that was copied on the model. The intention is that the loco will accept a minimum of six foot radius curves. An early track test showed that this requirement was met, much to my relief.

Working backwards from the front beam, there are two spacers with a curved shape. This is because they also support the boiler which is bolted through the holes in the centres of the spacers. The third spacer has small lugs that prevent the motor and gearbox assembly from rotating about the driving axle. The brackets on the outside of the frames are to carry the cylinders.

Outer frames

The outer frames are 0.4 mm nickel silver, also done on the pantograph mill. The step that runs along the outside is soldered along its length, and that also has the effect of keeping them straight. The rivets were done with my rivet press, and the various holes you can see are for the bolts used on the prototype. These will be represented using plastic mouldings from Grandt Line – I don't do absolutely everything myself.

These frames are bolted to the ends of the buffer and drag beams, using small and hopefully inconspicuous lugs, and to the brackets that also support the cylinders, using 12 BA bolts. The frames had to be removable for access to the wheels. If they were fixed, I would have had to allow the wheels to drop from the frames, which is easy enough for the carrying wheels, but a potential nightmare for the driving wheels encumbered with motor, gearbox, and all the rods and valve gear.

Wheels, motor, and gearbox

I will deal with the easy things first. For the motor and gearbox I gave Brian Clapperton, otherwise known as ABC Gears, a copy of the Liverpool drawing on which I had marked up the space in which they had to fit. The motor is in the firebox, then the drive has to go through the ash pan, underneath the footplate, and upwards to meet the driving axle. Brian quickly confirmed that nothing in his standard range would fit such an odd locomotive, but offered to make me a special gearbox, which he did at a very reasonable price. Job done – I did not even have to calculate the gear ratio, Brian did that for me too.

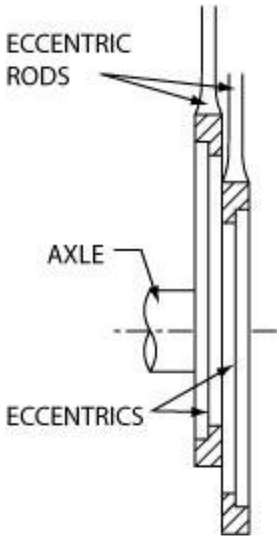
The carrying wheels are Slater's products. I doubt if the spoke profile is quite right, but they are hardly visible behind the outer frames and life is too short for some things. One set of wheels was mounted in the lathe and the flanges were carefully removed, but preserving the coning. The wheels on one side of the loco are shorted out using copper wire, carefully soldered between the tread and the hub, because I am using the split polarity ("American") system of pickup, where the loco and tender are of opposite polarity.

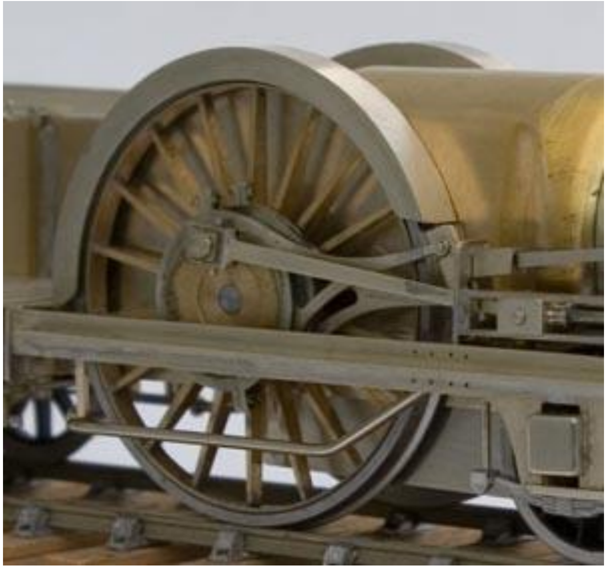
The driving wheels are something else entirely. Of course nobody makes an eight foot diameter, eighteen spoke wheel with extended boss, so there was nothing for it but to make them myself. If I had needed a lot of them, it would have been worth making a master for the wheel centre and having it cast in brass (I doubt that whitemetal would have the necessary strength), but I needed so few that I chose to machine them. Because the manufacturing process is not specific to Liverpool, you will find the notes elsewhere on my web site.

Eccentrics

The valve gear is driven by eccentrics on the outside of the driving wheels. The eccentrics were made with a single step, as shown in the section below. With two eccentrics mounted back-to-back, this is sufficient to hold the eccentric sleeves in position.

The eccentrics were turned from brass bar. This was offset in the 4-jaw chuck and the centre bored for the driving wheel boss to a depth sufficient for all four eccentrics. It was then centred and turned to size. Each eccentric in turn had the step formed, and was parted off. The two eccentrics on each side have to be set 180° opposed to each other. I made up a simple jig to hold them in place and soldered them, before drilling them for the crankpin. Of course some solder got on to the steps where the sleeves run, and had to be scraped away.





Eccentric construction *Eccentrics in place*

Each sleeve and rod was cut from a sheet of 1.6 mm nickel silver to the outside dimensions, clamped on to a faceplate with a backing sheet to avoid damaging the faceplate, and the centre was bored out to be a running finish on the eccentric. This has to be a good fit, otherwise the whole valve gear becomes sloppy. Like the prototype, the sleeve had to be split at the bolted flanges in order to assemble the valve gear. I used a 16 BA nut and bolt for this – this size is just small enough for the purpose. First each flange was drilled 0.85 mm. This sort of thing used to frighten me to death, but gradually I learned how to do it without breaking too many drills (and more significantly, leaving the broken end irretrievably stuck in the part I was trying to drill). A high-speed drilling machine that holds the drill properly centred is important. It should also be equipped with a sensitive feed. I actually use a drill chuck held in the pantograph mill for the purpose. The drill bit should be sharp (of course), and kept lubricated. Ignore the books that tell you brass should be worked dry. For drilling tiny holes, lubricant helps. Almost any fluid is better than no fluid, and in situations like this, I use spit, of which I have a supply conveniently available.

Once drilled, the sleeve was then split at the flanges using the finest piercing saw blade I could find, the cut faces were dressed, and a thin shim was soldered in place to make up the thickness of material lost in sawing. The rod itself was thinned down and correctly shaped. The forked end was made separately and soldered in place. I prefer to make components like this all in one piece, but in this case the forked end would require it to be made from much thicker material, most of which would have to be tediously machined away. Sometimes a compromise is necessary.

Finally the sleeves can be fitted to the eccentrics. Doing up the tiny bolts was a very frustrating process, so much so that I will now do almost anything not to have to disassemble and reassemble them. Actually I cheated. The drawing shows two bolts on each flange. I used only one and that was bad enough. The assemblies were quite tight to begin with because of the last vestiges of solder on the eccentrics, but with the application of oil and a couple of hours running in, they loosened up.

Cylinders, rods, and valve gear

The cylinders are a complicated by the fact that the valve chest and the top of the cylinder assembly is inclined at quite an appreciable angle. The front end is therefore larger than the rear. The basis of the assembly is a thin-walled tube whose outside diameter was turned to be slightly less than the diameter of the finished cylinder. The front and rear plates were soldered to the ends of this tube (everything held together with a bolt through the centre), and then the outer wrapper was soldered in place. I am sometimes asked how I get my corners so sharp. The answer in this case is to make the wrapper slightly oversize, solder it in place, then file it down and finish by polishing it on a piece of wet and dry paper on a flat surface.

The slidebars, motion bracket, piston rod, crosshead, and connecting rod form a separate assembly. The piston rod runs in a tube that goes right through the cylinder, and is secured by a nut disguised as the gland on the front end of the cylinder that screws on to a threaded portion of the tube. The alignment of the piston rod was critical because it projects a long way forward of the cylinder to drive the boiler feed pump, which is that funny shaped thing at the top of the photograph.

I put the piston rod, connecting rod, and crosshead together before assembling them in the slidebars, and it was actually quite fiddly holding the four bars in the correct alignment while soldering them up. Another time, I would make it so that the crosshead can be dismantled and added to the slidebars after rather than before assembly. Sometimes I learn things the hard way.

Boiler and firebox

The boiler isn't round! I've dealt with tapered and sheared boilers before, but not an egg-shaped one. However, the construction method is the same. Two profile pieces were cut and separated by three longitudinals. These were initially screwed in place, the whole thing was soldered up, and then the screws were removed, to form the skeleton shown in the left hand photograph below.

Two of the longitudinals are circular, but the third, located at the bottom of the boiler, is square section and is cross-drilled and tapped in two places. The boiler is located on the frames by means of screws that pass upwards through the frame spacers and into the tapped holes. The wrapper is 0.3 mm nickel silver, which was initially rolled into a circular shape using my rolling bars. This was slid over the skeleton, and with a little bit of persuasion, was made to take up the final shape of the boiler. It was then soldered to the two profile pieces, and along the seam located at the bottom of the boiler where it cannot be seen. As usual, I made the wrapper slightly over length and trimmed it back to the correct size after soldering. The smokebox, by the way, is an identical section to the boiler and so the "boiler" component is actually the boiler and smokebox combined.

The firebox is something else again. When I first looked at the drawings, I could see that the firebox was set higher than the boiler, but I assumed that in plan it simply followed the line of the boiler backwards between the driving wheels. It was only after further study that I realised that, moving backwards from the boiler, the firebox actually swells in height and width. The height then stays constant, but the width dimension almost immediately diminishes again in order to pass between the driving wheels. The designer presumably thought the small increase in firebox volume that this achieved was worth having, but the end result is a complex three-dimensional shape that certainly could not be represented by something as simple as a skeleton and wrapper.

I decided that the best way to make it was to machine the whole thing from solid. Any sort of built-up construction would inevitably lead to joins that would be hard to disguise. So I clamped a large piece of brass bar to the vertical slide of the Myford, put a milling cutter in the mandrel, and set to work. A vertical slide mounted on a cross slide is not the most rigid set up and restricted me to fairly light cuts, so it was not an instant job. Eventually, however, it was done, inside and out, as the photographs show.

It had to be hollowed out because that is where the motor goes, sticking up vertically into the firebox. Later I filled up the space that was not taken up by the motor with lead, to add weight over the driving wheels. The firebox is attached to the boiler by means of a screw through the central hole seen in the photographs above, so that the boiler and firebox can be removed as a unit to allow access to the motor.

All manner of fittings are to be attached to the boiler and firebox in due course, but the immediate need was for the splashers over the carrying wheels. The back-to-back dimension of 0 Fine scale wheels in under scale, and that meant that the boiler had to be cut away behind the splashers to allow clearance (stop sniggering, Scaleseven modellers!). The boiler and firebox were assembled on the frames, the necessary cutaways were marked out, drilled, filed, and generally massaged into shape. I do not claim any engineering sophistication for the process. I think if I were doing it again, I would fill the bottom of the boiler with Araldite to support the skin, and then fly cut the openings for the wheels. Part of one opening impinged on the firebox, which had to be fly cut anyway.

The splashers are simple fabrications, and were soldered in place to hide the holes in the boiler. That was followed by a track test to make sure no shorts occurred between the wheels and the splashers.

Boiler and firebox mounted on inner frames, with splashers ready for assembly

Splashers soldered in place. The rearmost splasher had to be reduced in width because there is so little clearance behind the slidebars, and in doing so lost its front, but where it is, it is hardly noticeable

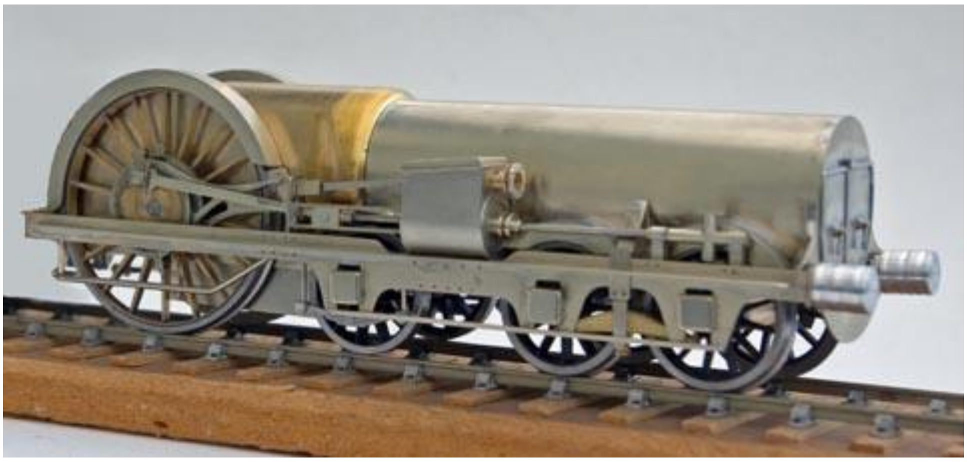
Footplate and ashpan

These are the last two major assemblies. Components for both were cut from sheet and soldered up. The important thing was to ensure everything was accurate and square, because there is not much room around and between the driving wheels. The footplate is stepped over the driving axle, and on the model, I had to make the step slightly larger than scale to clear the gearwheel. Brian Clapperton used the smallest pinion he could, but it still required more than scale space. I pity the poor fireman who had to lift every shovel of coal up and over the step.

The ashpan hides the rest of the gearbox. Both assemblies are screwed to frame spacers.

The story so far

These bits ...



... build into this.

A change of mind

My original intention was to make the boiler and firebox as a single unit that would be secured to the inner frame assembly by two screws through the frame spacers going into the bottom of the boiler, that would lift away for access to the motor and gearbox. As more and more boiler fittings, steam pipes, and various other bits and pieces were added, that became increasingly impractical.

First there were the boiler saddle pieces outside the frames, that you can see in the left hand photograph. These were not part of the original frame assembly (in fact they were an oversight), but were fabricated from pieces of nickel silver sheet and soldered in place. The problem was that they are a very tight fit between the splashers over the first two sets of wheels.

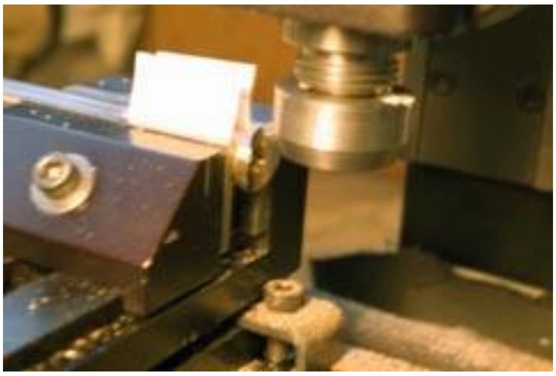
There are also very prominent exhaust steam pipes from the front ends of the cylinders to the smokebox. These are soldered to the smokebox, and bayonet into the cylinders. That means the boiler has to move forward to release the steam pipes before it can be lifted away, but the splashers prevent that and mean it can only be lifted vertically. To compound the problem, I added the pipes from the feedwater pumps to the boiler that can be seen behind the exhaust steam pipes in the photograph. These are soldered to the clack valves on the boiler, and fit loosely into the pumps. Getting the boiler on and off with that lot in place was becoming a fiddle, requiring various parts to be stressed, and I was concerned that before too long something would break.

So the original plan had to be abandoned. The boiler and firebox were split into two separate assemblies. The boiler normally stays in place (it can be removed, just about, for finishing, painting, and lining), and the firebox alone lifts off for access to the works. That meant devising another way to secure the firebox. There was getting to be precious little room underneath, so in the end, one of the screws holding the ashpan was given the double duty of securing the firebox in place as well. There is actually only one fitting bridging the gap between the boiler and firebox, and that is the regulator rod. That ended up attached to the firebox and fitting loosely into the regulator body on top of the boiler. However, that is getting ahead of myself. To finish this little saga ...

Either, I should have spent more time with the drawings, thinking about these problems before I started,

Or, that's just part of the fun of scratch building!

Boiler fittings

The chimney was turned in two pieces (LH photo), just because it was easier that way. There is a little recess in the top of the stem of the chimney, into which the top fits. The base was flycut in the milling machine to match the boiler (RH photo). The scraps of card are to prevent the jaws of the vice from marking the chimney. The clever bit was shaping the flare around the base. Once upon a time I did this by hand using files, but using the neat device shown below in the milling machine, I can take the bulk of the material off using a ball-end cutter.

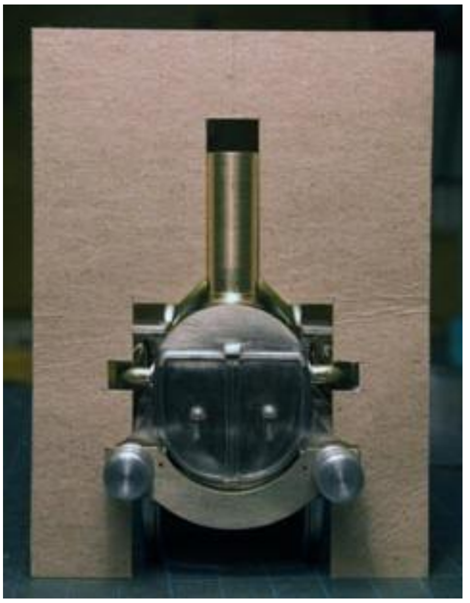
The base of the chimney is threaded and screwed on to an arbor that supports it. The arbor goes through a hole in the big block of aluminium, and is free to rotate and move in and out without wobble. In operation, the base of the chimney is pushed into contact with the guide you can see just in front of the chimney. I rotate the arbor with one hand and keep it in contact with the guide with the other. The cutter, applied as shown, then cuts a path for the flare that follows the shape of the seat. The radius of the cutter sets the radius of the flare, but fortunately ball-end cutters are available in a wide range of sizes.

I originally made this device to mount on the cross slide of the Myford lathe, the milling cutter being held in the chuck, and it was intended for flares somewhat larger than this one (despite the height of the chimney, the flare at the base is actually very small). The setup I used here isn't quite optimal, but it proved manageable. Final finishing was done by hand, and for this I find a rifling file is a very useful tool. This is like a conventional Swiss file, but instead of being flat along its length, it is curved. I guess they were originally used to form the helical grooves that spin the bullets inside rifle barrels – hence the name.

Such a tall chimney must be set exactly vertical, otherwise it looks bad. Cutting the seat correctly ensures it is vertical in side elevation, but the end elevation required some care. I cut a cardboard template that fitted snugly over the frames, with a cut out just the right size to hold the chimney in place so that it could be tack-soldered. Then the template was removed, and the soldering was finished and cleaned up.

The regulator is located in a little box on top of the boiler, and from there the steam is fed to the cylinders through pipes covered with cladding for insulation. The box was a straight forward piece of machining, again with a fly cut base to match the boiler. One big advantage of using a milling machine is the ability to make components like this from solid, which is so much easier than cutting the walls and top individually from sheet material, and soldering everything up, hoping it all stays square. The steam pipes, however, were another of those challenges.

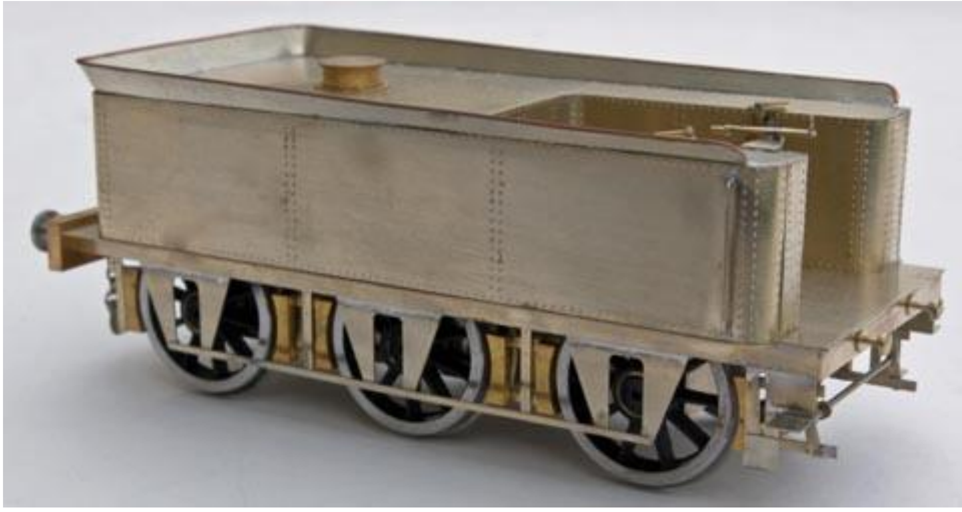
The cladding is roughly semicircular in section, but while the width is constant, the height is not, it tapers from the regular box all the way down to the cylinders. After some thought, I turned a disk of the necessary diameter and width, and using a variety of tools and files, formed the semicircular outer shape. The disk was then offset in the 4-jaw chuck and the centre bored out to boiler diameter, thus forming a ring with the variable height required.



I then removed a section of the ring at the largest radius and soldered the regulator box in place. The lower part of the ring was then sawn away so that the upper part, when sitting in place on the boiler, just touched the tops of the cylinders (I started off too big and carefully cut it back until it fitted). I was afraid that if I tried to solder it in place, the heat would melt the existing joints to the regulator box and I would never get everything back again just so, so I stuck it to the boiler with epoxy. It just rests on the cylinders so that the boiler and cylinder assemblies can be separated. If I were to do it again, I would make the top of the regulator box removable and put a screw through the body into the boiler, but I did not think of that at the time.

The finished boiler assembly

Tender



Originally I was assured that the tender was pure North Western, but Harry Jack put me right on that. What we know of Liverpool's tender did not correspond to LNW tenders of the time. It, like the loco, is unique, but much less obviously.

From a model point of view, the tender is quite simple to construct. The only real feature of note is the tank sides and ends. The tank is formed with round corners everywhere, including the coal space. I made a skelton for the tank, comprising the top and bottom, separated by various spacers, and tried to wrap the sides and ends around that. Initially, I cut the sides and ends as a single piece, which in the flat was nearly 18 inches long. Over a long session, I impressed more than 1000 rivets using my riveting tool, and then tried to bend it to shape, starting from the back forward, intending to make the final join at the back of the coal space where it would eventually be hidden by a load of coal. The first few bends were quite successful, but gradually, small but acceptable errors started to accumulate into large, unacceptable ones, and the whole thing became so unwieldy that the last few bends became difficult to do at all, and even more difficult to do in the right place.

I ended up cutting the whole thing into three pieces, with additional joins at the front of the tank, where there was a join between separate plates on the actual thing, of course. I disguised the joins as best I could, but they are still evident as can be seen in one of the photos. They are, however, less obvious when the tender is coupled to the locomotive.

The flare at the top of the tank was cut in two pieces, joined at the rear of the tank. The pieces were initially cut flat, and wrapped around a cone to form the flare. Working out the various angles is not as difficult as it might seem, and there are details of the process on my web site.

To get some more traction on to the driving axle, some of the weight of the tender is transferred to the loco, by making the rear axle of the tender rigid, and allowing the other two axles to float vertically. The tender was also fitted with well tanks between the axles, and the forward tank was filled with lead (after the photos had been taken) to assist in this.

The photos show the tender complete except for the axleguards. I used some commercial castings for these, which, with a bit of filing, reproduce the prototype quite well. The spring hangers are a rather obvious and characteristic shape, and these were cut separately from nickel silver and soldered in place on the solebars.

Assembly complete

Liverpool was now complete and passed its first proper track test without a hitch. Roy Slaymaker's track at Fawley comprises six ovals of varying radius from above six feet to below five feet. *Liverpool* was designed to handle a six foot radius. In fact it managed the five foot radius track without complaining, although I noticed that the second axle of the loco, which carries no weight, was lifting slightly on the outside rail.

Photo by Iain Hope

Another *Liverpool*!

During the construction, I took Liverpool in whatever its current state was to several shows, where it attracted some interest. Usually that took the form of "What on earth is ***that***?", although a few clever people were able to identify it immediately. As a result of one such showing, I was asked to make another model. It was just a pity that I was not able to start the two models together, as there would have been a considerable time saving that way. As it was, from that point forward in the construction of the first Liverpool, I made two of everything and put one away safely. So when the first one was done and off to the paint shop (I prefer not to do my own painting), I had some of the parts I needed for the second. However, a lot still had to be made.

I also took the opportunity to revise the construction in some respects, based on experience. The main problem with number one was that dismantling was a fiddle. With a prototype like this one, the assembly is never going to be the orthodox split between body and chassis, but I decided that I could make number two a bit simpler. So what I have done here is to summarize the changes.

The biggest change was to allow the wheels to drop out of the inner frames, so that they can be removed without dismantling them from the axles. This may seem obvious now, but for some largely forgotten reason I did not do that for number one, probably because of all the different levels involved. All the axles except the leading axle run in plain bearings (the leading axle is in a sleeve bearing again). The driving axle is rigid and held in place using a simple screw jack arrangement that can be seen in the left photograph.

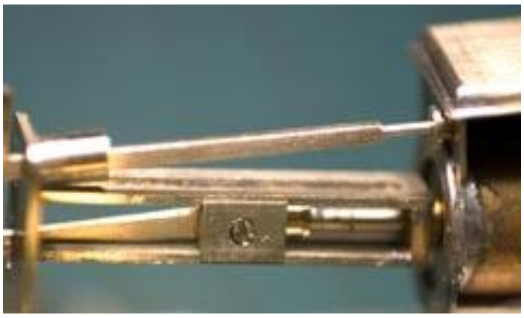
The two centre axles have some vertical float so that the leading and driving wheels always stay in contact with the track, and will be prevented from falling out by means of a wire keeper. Since they should only ever have to come out for painting, that should suffice.

The right photo shows the majority of the inner frame assembly, upside-down. The change here has been to extend the stretchers supporting the boiler outside the frames in order to mount the cylinders, rather than putting the cylinders on separate extensions as before. The frames were slotted where the stretchers intersect them, using a slitting saw of the appropriate width, and when soldered up, the whole assembly is very rigid.

The next big change was the eccentrics. Previously, they were fixed to the wheels, and the eccentric sleeves were each divided and assembled by means of a bolted flange, just like the prototype. The bolts were 16 BA (even that is slightly over scale), and proved to be so fiddly that, once assembled, I did almost anything to avoid having to undo them ever again.

This time, only the inner of the two eccentrics is fixed (using Loctite) to the wheel. The other is loose, and is held in place by means of the crank pin, which passes through a clearance hole in the outer eccentric and screws into the inner. This means that the sleeves can be solid, and simply driop into place on the eccentrics, then everything is secured by the crankpin.

On the inner eccentric, opposite the crankpin hole, is a little pin that locates into a blind hole in the outer eccentric. It is not strictly necessary because the wheel centre keeps the eccentrics in the correct relation to one another, but it was useful during manufacture because I could check the assembly of the valve gear away from the model. The sleeves were later scribed across the flanges to represent the split line, and dummy bolts from Scale Hardware added to finish them.



One final detail to aid assembly and disassembly was to make the pin holding the connecting rod in the crosshead screw in, rather than pushed in. That allows the connecting rod to be released entirely, and means that the slidebars, crosshead, and cylinders can be assembled without having the connecting rod flapping about. A slot for a screwdriver was cut on the inside end of the pin, and this is visible in the photo below, which shows a view of the slidebar assembly not normally seen when the boiler is in place. This is a nice little feature, and I intend to use it in future models where there is enough meat in the crosshead to tap a thread.

Previously I remarked on how difficult it was to make cut outs in the boiler to leave space for the carrying wheels, and this new model gave me the chance to do something better. In this case, I filled the lower half of the boiler with a mixture of "liquid lead" (fine lead shot) and epoxy resin. The lead was for traction purposes, and the epoxy was to stiffen up the skin of the boiler so that it could be machined. I use slow-setting adhesive because getting the mixture in place in the boiler is not a quick process. It then goes in the oven at about 100°C for an hour. The heat first makes the epoxy mobile so that it penetrates throughout the lead, then causes it to set. The photo below shows the boiler set up on the milling machine, in order to make the cut outs. A single point tool was used for this, taking fine cuts. The result was a very satisfactory set of arcs in which the splashers for the carrying wheels could be located and soldered to the boiler.

Finally, here is a photograph of the completed model following Ian Rathbone's magnificent copper plating, painting and lining.