THE ORIGINAL MAGAZINE FOR MODEL ENGINEERS

Vol. 224 No. 4628 • 20 December 2019 - 2 January 2020

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COVER FEATURE

Double Beam Engine

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EDITORIAL
Editor: Martin R Evans
Tel: +44 (0)7710 192953
Email: mrevans@cantab.net
Assistant Editor: Diane Carney
Club News Editor: Geoff Theasby

PRODUCTION
Designer: Yvette Green
Illustrator: Grahame Chambers
Retouching Manager: Brian Vickers
Ad Production: Andy Tompkins

ADVERTISING
Advertising Sales Executive: David Holden
Email: david.holden@mytimemedia.com

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Group Advertising Manager: Rhona Bolger
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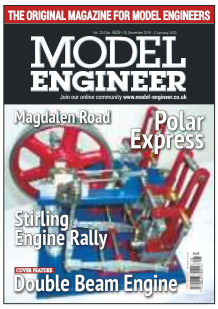

ON THE COVER...

Bob Middleton's double sided beam engine, constructed by Rodney Oldfield (photograph Rodney Oldfield).


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SMOKE RINGS

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Duff Coal

A little while ago I bought a small bag of coal from a trader at a show. I started a fire in the locomotive firebox in the usual way and then shovelled some of the coal in top. Normally there is no problem and I have a fire blazing away in no time. This time the fire simply went out. I tried several times, always with the same result. 'Non-inflammable coal?', I thought, 'now there's a novelty!'

Has anyone else experienced this, or is it just me?

All of us here at *Model Engineer* would like to wish all of you out there – both readers and writers – a very Merry Christmas!

Another Year Gone

I hope you have all had an interesting, happy and productive year. As you will probably know, especially if you are a regular reader, I did at last complete my garden railway, but at the expense of all my other projects. I can now get back to my LBSC 'Pansy' pannier tank and also my Winson 1400, both in 5 inch gauge. These are both at a late stage and perhaps I can actually finish them this year! There are, inevitably, a couple of other projects and perhaps I can move them forward a little too.

Despite my workload I have been able to get to several exhibitions and rallies, all of which have been a welcome diversion from the business of preparing a fortnightly magazine! The first of course is the London Exhibition, which takes place in January of each year at Alexandra Palace. This is one of the leading shows and always worth a visit. Another top show is of course the National Exhibition at Doncaster. This year's show was especially notable in that it hosted the Model Engineer Competition for the first time. It was a great joy to be able to resurrect this iconic exhibition, through the efforts principally of SMEE president Mike Chrisp, show organiser Lou Rex and competition organisers Mike Law and Steve Eaton . One of the highlights of the show, for me, was seeing the look on George Punter's face on being told that he had won the Duke of Edinburgh trophy for his 1913 Saunderson and Mill tractor. He had not realised that the card placed discreetly minutes before in front of his model informed him, and everyone else, of the award!

George Punter learns that he has won the Duke of Edinburgh trophy.

Later in the year, was another top show, the Midlands exhibition at the Warwickshire Exhibition Centre, where the major attraction, for me, was the rake of beautiful 5 inch gauge Pullman cars built by Brent Hudson and Ben Lyons. That was followed, in the same weekend, by the Lowestoft exhibition, organised by the Halesworth club, possibly the largest such event in the East of England and certainly the most varied.

I was also able to get up to the Whissendine steam rally. The high points for me were the visit to Nigel Moon's windmill and the trip down to the pub at lunch time, with a ride on Mike Robinson's Burrell Scenic showman's engine *General Gough*, followed by a run along the Rutland country lanes. A highly memorable experience all round!

Here's to a Merry Christmas and an equally memorable 2020.

Merry Christmas from me and General *Gough!*

The Middleton Double Sided Beam Engine PART 1

Rodney Oldfield constructs another of Bob Middleton's stationary engines.

Bob Middleton was a deep sea ship's Captain and taught himself draughtsmanship; he must have one of those minds that can see mechanical motions in his head. In my opinion he is one of the most talented and remarkable designers of small, stationary engines around today.

Hot off his drawing board, this model was thought up whilst he was sunning himself on holiday and it fits all his criteria – make it different, make it chunky with no castings and leave plenty of scope for embellishment.

As a long stroke engine it is intended for slow running and to his knowledge there is not a full size engine or a model built similar to this. I was fortunate enough to be asked by Bob to have a go at building this engine to see if it works and to see if all the measurements work out.

Bob is so busy he cannot get around to building it himself but he does normally build all his own models and runs them all on steam (12 models so far).

The way of building this model is not set in stone and where I have deviated from the drawings I have tried to indicate this. This is the way and order that I built it, just as a guide.

Make up your own mind and do your own thing using the materials you have and fastenings you think fit and look cosmetically right. The drawings that I include are those I worked from. **Figures 1** to **3** show the general arrangement of the engine.

'ENJOY THE BUILDING and DO YOUR OWN THING'

Base Plate (fig 4)

We'll make a start by drilling the baseplate. I used aluminium plate ⅜ thick and I cut it off at 9½ inches square so I had room to put a good chamfer on. Taking this into account, I marked off the left and right hand centres for the cylinders, the centre for the main column and the two centres for the bearing support columns. Using a $\frac{3}{16}$ inch drill, I drilled them out for the cylinders and put counter bores on the back of the base for the $\frac{3}{16}$ inch Whitworth Allen cap screws I used.

●To be continued.

NEXT TIME
We'll make a pair of cylinders.

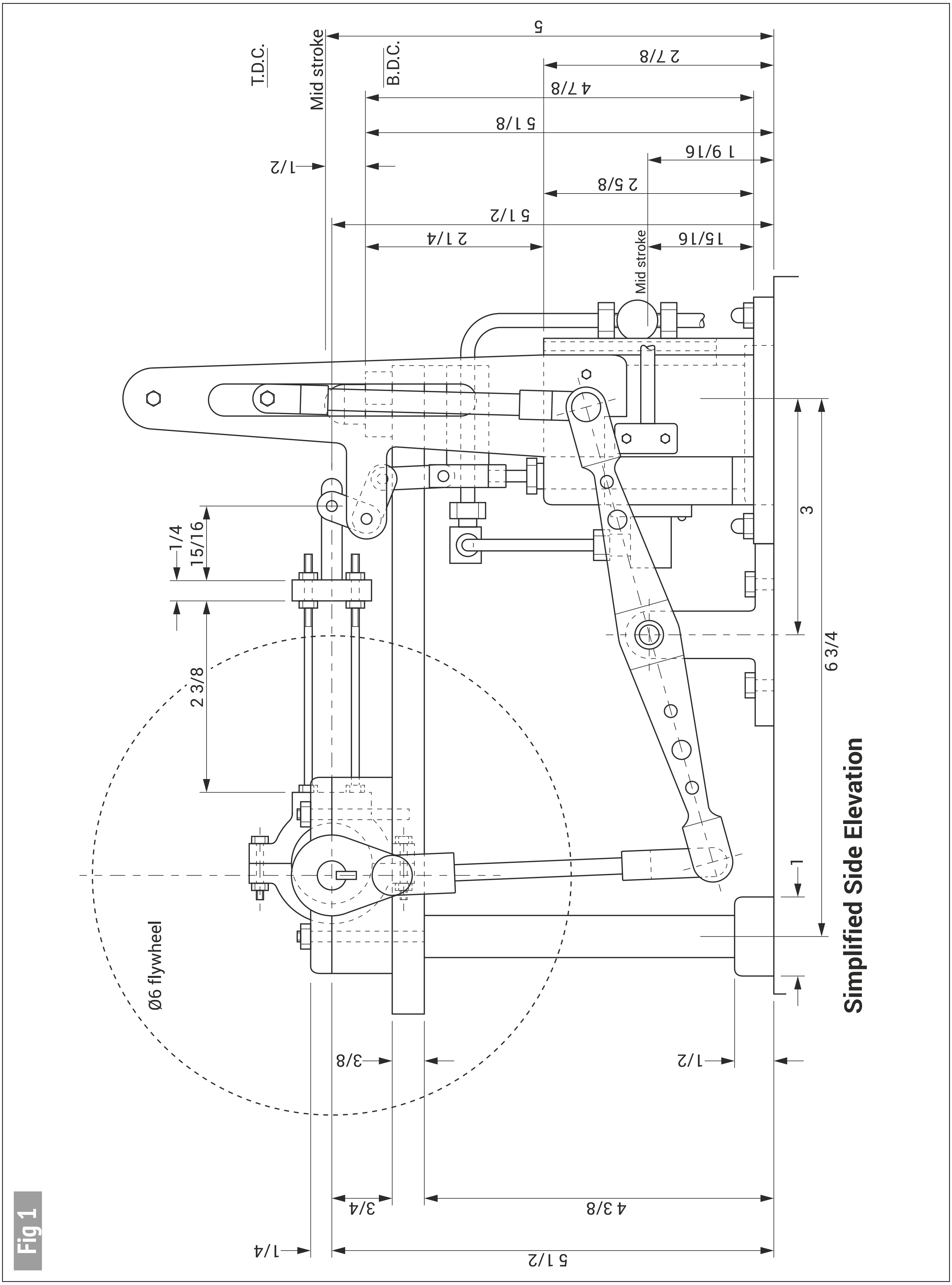
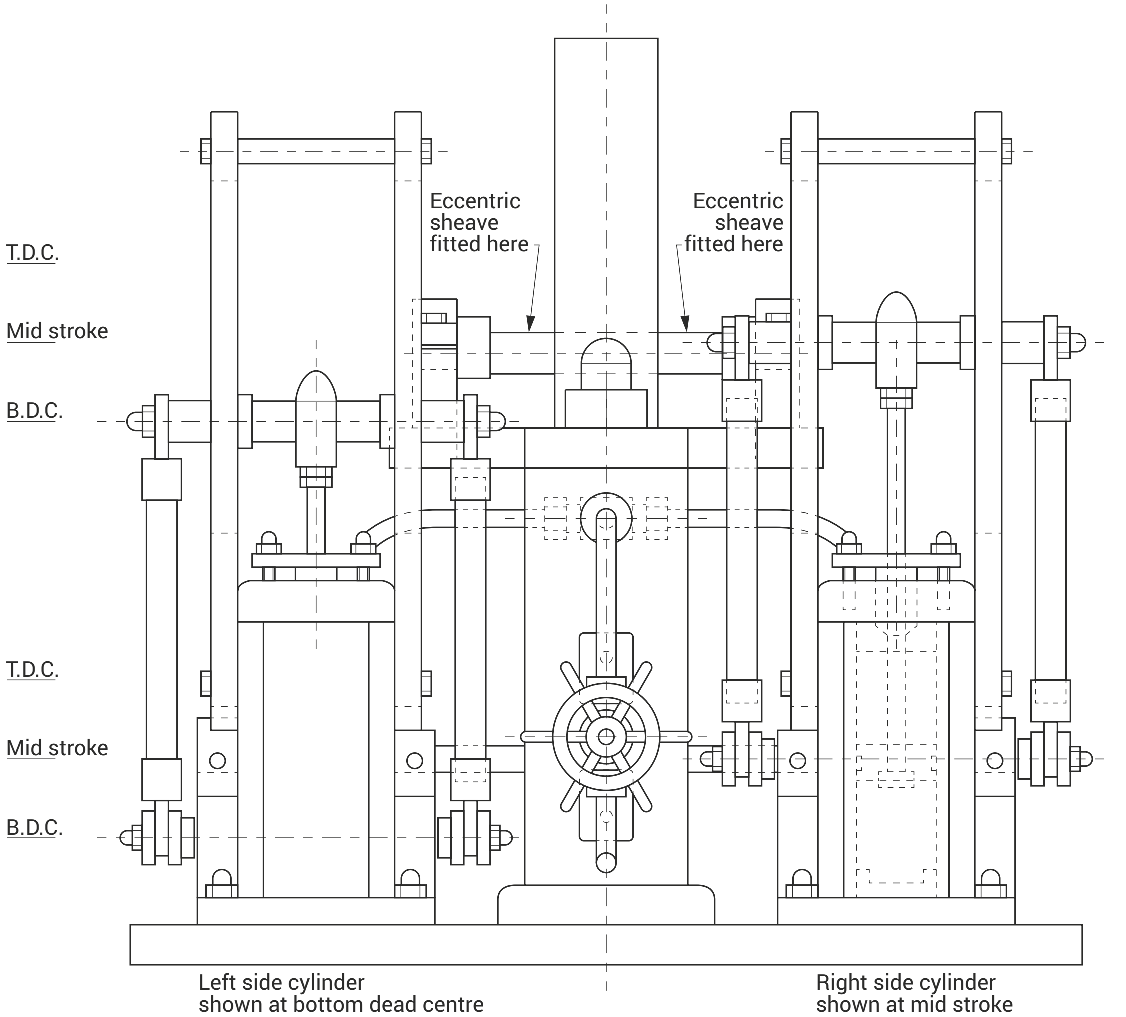

Simplified Side Elevation
T.D.C.
Mid stroke
B.D.C.
5
2 7/8
4 7/8
5 1/8
1 9/16
1/2
2 5/8
5 1/2
2 1/4
15/16
Mid stroke
3
6 3/4
1
1/4
15/16
2 3/8
Ø6 flywheel
3/8
1/2
3/4
4 3/8
1/4
5 1/2

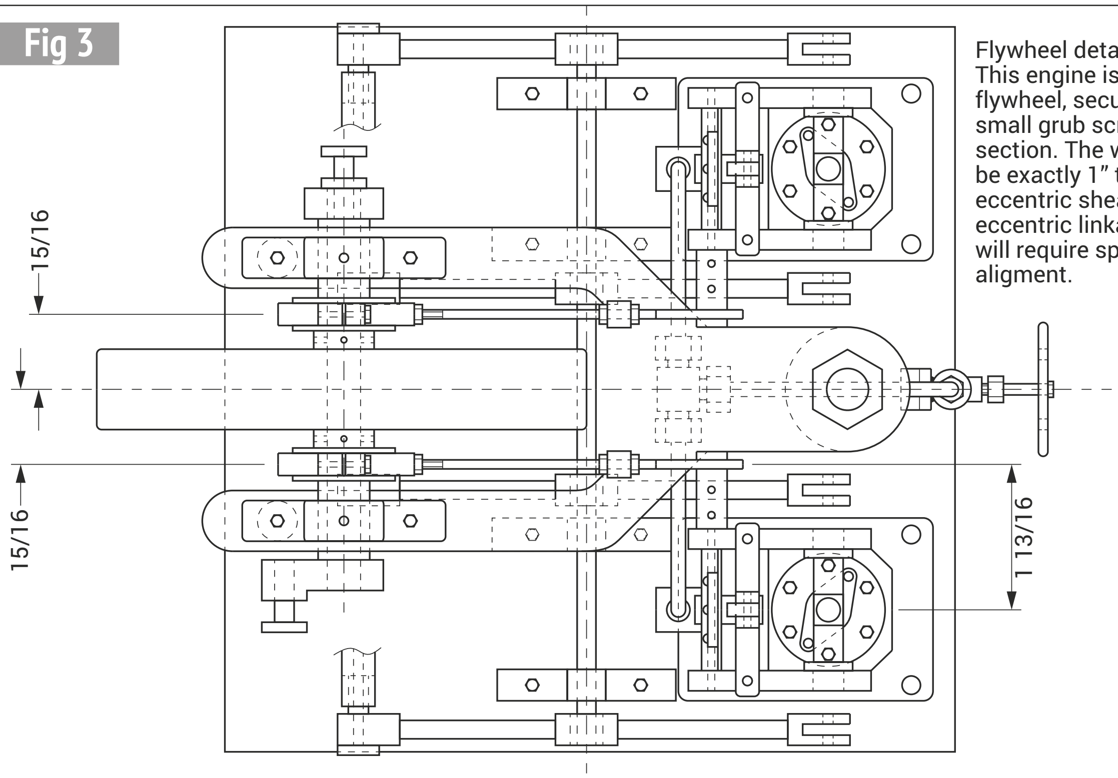
Fig 1

Fig 2



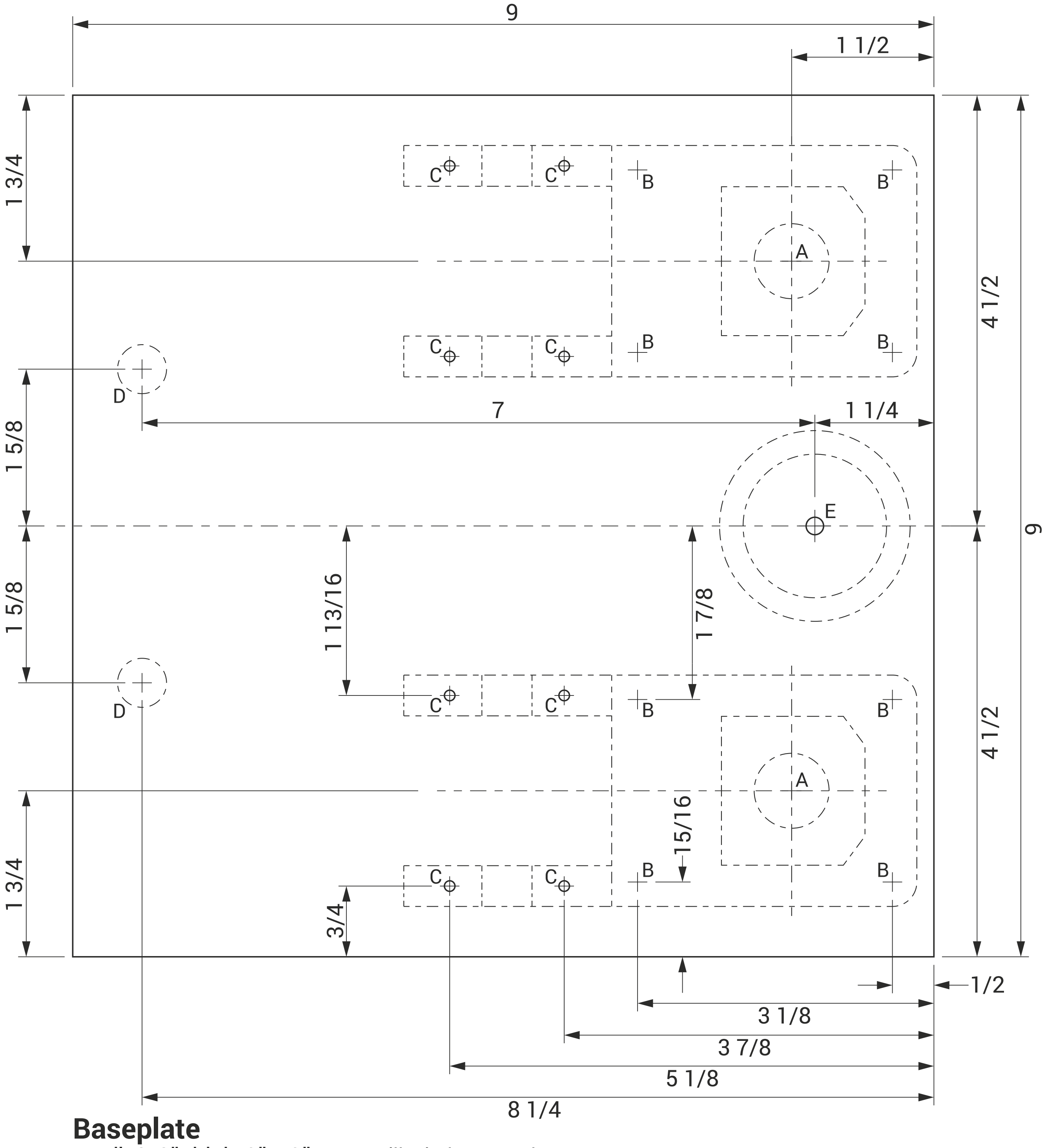
Simplified End Elevation

Fig 3



Flywheel details:
This engine is designed to use a Ø6" flywheel, secured to the shaft with small grub screws through the boss section. The width of the boss must be exactly 1" to ensure that the designed eccentric sheaves line up with the eccentric linkage. Any width less than 1" will require spacers to ensure correct aligment.

Simplified Plan View



Baseplate

Mat'l: 3/8" thick, 9" x 9"

A. Drill 2 holes 2BA clear & c/bore approx. 1/4" deep for nut to secure base spigot.
B. Drill & tap 8 holes 2BA, insert 2BA studs approx. 3/4" long to secure the cylinder mounting plate with 2BA dome nuts.
C. Drill & tap 8 holes 5BA to secure the beam shaft supports with 5BA set screws.
D. Drill 2 holes 2BA clear & c/bore approx. 1/4" deep for set screws to secure the bearing support columns.
E. Drill 1 hole 2BA clear & c/bore approx. 1/4" deep for set screw to secure the main column.

Notes:
This drawing shows a baseplate made from 3/8" steel or aluminium plate. An alternative would be a thin (1/8") steel plate secured to a solid hardwood base. There would have been a series of holes cut into the wood to enable access to the securing bolts.

Fig 4

Backyard Foundry Techniques

Part 3: Sand and moulding

Luker describes how to set up and use your own backyard foundry.

Continued from p.841
M.E. 4627, 6 December 2019

The basics of sand

There are hundreds of different binders (what you need to add to sand to make it suitable for casting) with some backyard guys swearing by their own mix and industry moving away from green sand to phenolic resins or oil sands. My requirement for the casting sand is simple - I get my sand from the local river and I need to put it back into the local river without polluting the ecosystem. Alternatively, the sand will go on my grass or the veggie garden. I also want the sand to be reusable.

With some of the industrial binders you can only recover the sand once or twice before it starts giving poor castings. The sand I use has increased in volume over the years as I've increased the number of moulds I cast at a time but there's still sand in there from when I started casting.

Don't let anyone fool you, provided you can mould with the sand and it allows the gasses during casting to escape you'll be able to use it for casting. One thing that makes sand good for casting is if the grains have flat sides like a cube. Rounded sand grains like beach sand make poor casting sand because the binder has less surface area to cling to. But even with beach sand if you up the amount of binder you'll still come right.

Safety with sand

There's a fundamental safety principle when it comes to sand casting and casting in general. We are all taught that water and molten metal is bad and for kids at school that's fine but we have water in the moulds - what now? If the gasses from the mould can escape you won't have any issues and I have cast in very wet moulds. So molten metal on wet sand is not a bad thing - that's why wet sand around the moulds is not a train smash and some foundries actually do just that.

A wet core on the other hand is looking for trouble and by wet I mean any volatiles that will expand, displacing metal out the mould. If you recall from the first article, I mentioned not to cast over concrete and the same principle applies. The concrete has entrapped water that cannot escape so it violently pushes the molten metal away which could spray hot metal where it's not wanted. If sand is used to cover the concrete, moisture can escape in a less exciting manner.

Green sand mix

With that all said, let's get straight to mixing the sand. My green sand mix is as follows:

4kg sand
400g Bentonite
140g coal dust
160ml water

Bentonite (with water) is the glue or binder for the sand and is typically used by farmers for dams so it is easy to get and is relatively inexpensive. If you find it difficult to source some of the beauty shops sell bentonite for face masks but the quantities are smaller and it's more expensive. The carbon helps by preventing the metal penetrating into the sand (called 'burn on') by burning at the surface of the mould and holding the metal back. The components also come out shinier and less oxidised. Coal dust is an easy one to source and the quantities are quite small so you just grind a little coal dust for your castings. Don't add more than 5% coal to the mix.

Making your green sand is a simple matter of adding the water to the sand and mixing that up properly (I fashioned a mixing paddle from 6mm rod and I connect it to my electric drill). Once that's mixed you can add the bentonite and coal dust and mix the whole lot up. To check if the sand will work make a ball in your hand like you are making a snow ball and compress that tightly. Then use your fingers to pull the sand apart; it should break cleanly into two halves. You can tell if you've added to much water if the sand sticks to your hands when making the ball.

You might have to play around with the bentonite/water/sand ratio to get the best results for moulding. The sand will dry up after casting or standing for long periods and you may need to add water before the next casting session. **Photograph 16** shows a selection of useful sand moulding tools.

>>

Sand moulding tools.

Any sand in contact with the pattern needs to be fine and of good quality. This doesn't mean you need to have two bags of sand. I use a flour sieve to separate fine sand which I use for facing sand. You just need to cover the pattern with facing sand; so large quantities aren't required. The sand behind the facing sand (backing sand) should be coarser allowing gasses to escape.

Core sands

Once again there are many different core sand mixes and you need to find one where the ingredients are easy to come by and you happy with the results. With any core sand you need to make sure there is no moisture or volatiles left after curing otherwise when you pour into the moulds all the metal will come straight back up the sprue. I use an old fashioned linseed oil mix modified from a book I read on casting written in the 1900's and it's as follows:

1kg dry sand
34g starch (I use flour)
15g sugar
22ml linseed oil (boiled or raw doesn't matter)

Mix the flour and sugar with water to a consistency of paint. Cook on a hot plate at low temperature until the texture of the mixture changes - it becomes like a gel. After you've done with the cooking and your wife is done shaking her head this needs to be mixed into the sand, properly. Then finally add the linseed oil into the mix. This core sand doesn't keep so you need to mix it and use it within a week or two.

The core boxes are typically fashioned from rolled plate or a pipe that has been cut open (**photo 17**). Hose clamps are used to compress the pipe closed. The sand is rammed in the core box using a dowel or a piece of suitably sized wood and breather holes are made to at least the middle of the core using a 1.6mm welding rod. If the core is particularly slender I push a 1.6mm welding rod down the centre for increased strength but in general I don't bother as these cores are relatively strong.

The cores need to be baked at 250°C until they stop smoking. This core sand has no strength when still wet (no green strength), so the cores need to remain in the core boxes until dry before they can be handled for final baking.

What I typically do is prebake a number of cores at 150°C for an hour per inch thickness, in the core boxes. To help get the cores out of the boxes I pre-spray the boxes with non-stick spray used for baking. I then remove them from the boxes and finish the baking at 250°C.

Core boxes.

The cores need to stand in such a way that the entire surface area that will contact metal is properly baked. If for example you let a round core rest on its side that area might not cure properly resulting in surface porosity in the casting.

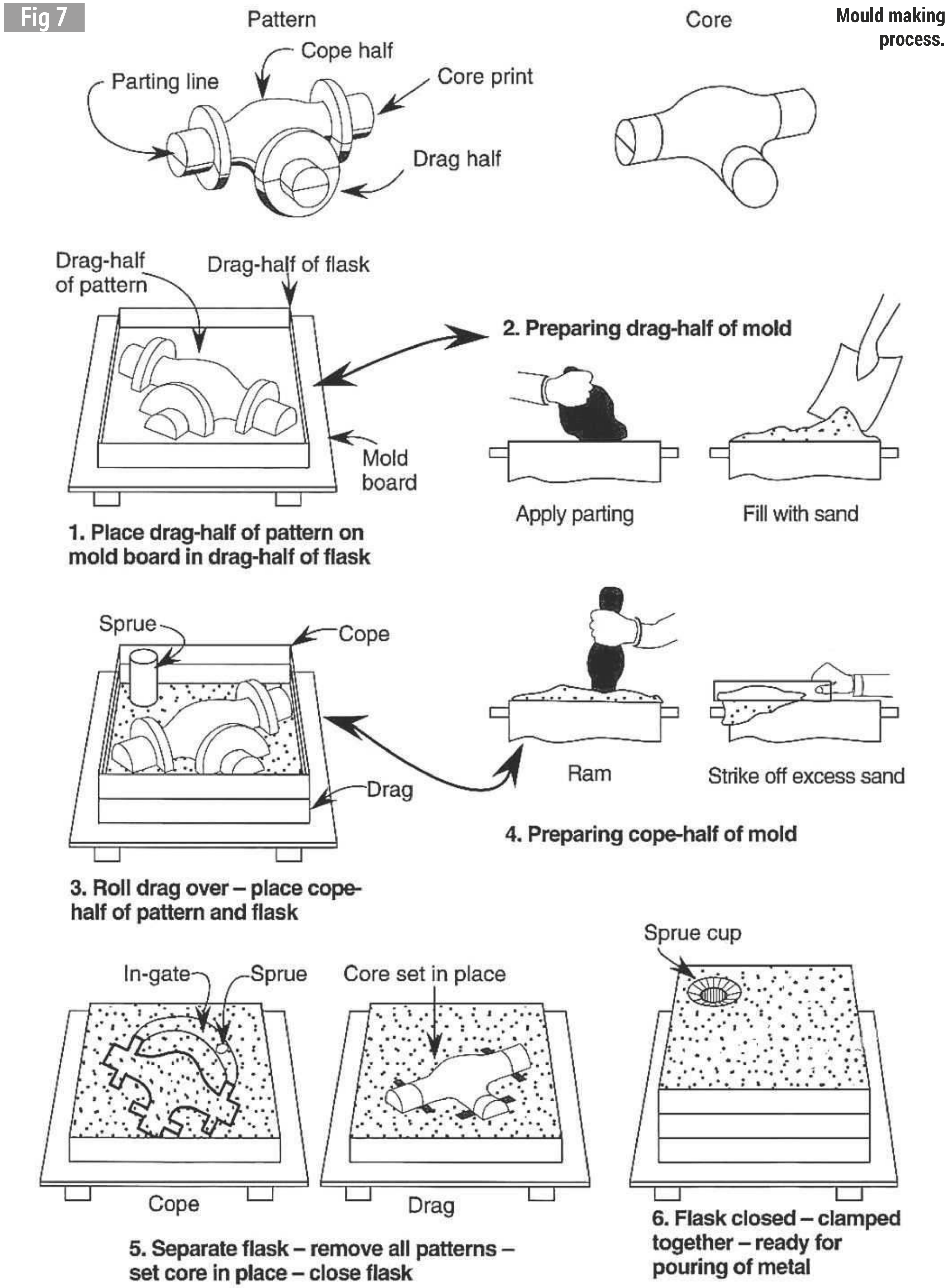
Cleaning the sand out of cored castings is a mission so I normally apply a mould coat to the cores. This gives a much better surface finish and there is less chance for 'burn on'. My mould coat is mixed as follows:

40g graphite powder
30g talc powder (baby powder)
30g bentonite

Mix this with water to the consistency of thick paint and apply to the cores after they have been baked with a paint brush. Then dry out the cores in the oven at 150°C for at least an hour (**photo 18**). Incidentally if you want excellent surface

Cores after baking.

Fig 7



Mould making process.

quality castings or you want to improve metal flow in the mould you can use the same mould mix with methylated spirits and spray it onto the moulds. The surface will need to be flashed with a blow torch and the spirits allowed to burn off. I have only done this a handful of times with very specific castings and generally you don't need to go to these lengths.

Flasks for sand moulding

Flasks, as they called in the casting industry, come in all shapes and sizes and generally they can be made as needed (**photo 19**). I have even used wooden flasks and they work fine but they don't last as long as steel flasks. When making flasks make sure the top and bottom ('cope' and 'drag', but let's keep it simple) align easily. To this end I normally weld tabs, or angles, to opposing corners. If the flasks are clamped together with bolts you don't need to weigh the moulds down when casting. With the sand lighter than most metals cast, the top half might float off resulting in molten metal pouring from the sides of the mould.

Try to keep at least a fingers gap between the angles for clamping; this helps when splitting the moulds to remove the patterns.

Tools for sand moulding

The tools for moulding are simple; a piece of wood makes a good ramming device and some wooden dowels make very good formers for sprues. Your fingers are the best tools for putting any sand back into its place if it decides to wander after removing the pattern. Make sure you push sand gently and don't rub or smear. You'll also need a thin rod to poke holes for the gas to escape and a thicker rod to rap the patterns before removing them, both with a point. I made a fancy device for cutting the ingates but a piece of pipe with the end cut in half will work just as well.

Making the sand moulds

There are hundreds of videos and books on how to make the moulds for casting, so I'll be very brief as this is the easiest bit when it comes to casting (**fig 7**).

Split the flask and place one half with the split line face down. Place half of the pattern face down and dust with baby powder. Remember to leave space for the sprues and risers. Using the facing sand you mixed, compress the sand around the pattern using your fingers and make sure the

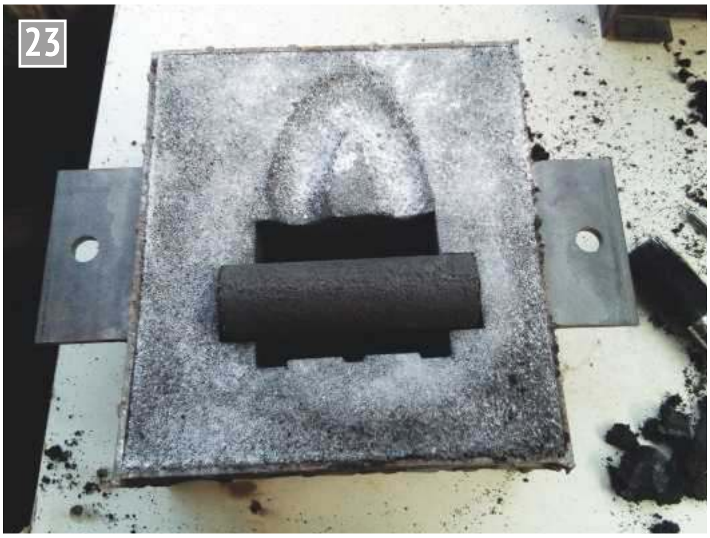
Flasks.

Any sand in contact with the pattern needs to be fine and of good quality.

Rolling the sprue.

Cylinder – top box.

Cylinder – top box with riser and pattern removed.



Cylinder – bottom box with cores fitted and ingates cut in sand.

pattern is completely covered. Half fill the flask with backing sand and ram using a piece of wood. Overfill the flask and ram to above the edge. Using a piece of wood, scrape the excess sand away level with the flask.

You then assemble the rest of the flask and the other half of the pattern, as well as any risers, and dust with baby powder. Generally, the best place for the riser is between the pattern and the sprue, as close as possible to the pattern. Placing the riser above the ingate helps with entrapping any slag carryover in the riser instead of it going straight into the casting. Repeat the ramming procedure but prop a dowel upright for the sprue. Here you don't need to scrape the top and I generally ram higher that the top of the flask. Wiggle the wooden dowel a little and pull it out - it should leave a nice hole. Split the flask carefully - this is where a finger gap between the clamping angles pays off.

There should be an imprint where the dowel was so use your fingers to compress the sand to make a half moon (just bigger than the sprue); this will help prevent excessive turbulence when pouring. Cut a nice ingate from the half-moon under the riser to the pattern. The ingate needs to be big enough for adequate metal flow without freezing. I normally judge by the size of the pattern and sprue but ⅔ of the sprue should be adequate. Up to 1kg I generally stick with the 16mm sprue, 1-3kg the 20mm and the 25mm is saved for when I want to use the sprue as bearings.

> Your fingers are the best tools for putting any sand back into its place if it decides to wander after removing the pattern.

The ingate needs to be pressed flat and it should be smooth for casting. Cut a funnel at the top of the sprue where you going to be pouring and use a kitchen funnel to compress and smooth. A smaller dowel is placed down the sprue and, by **rolling**, the surface is compressed and smoothed. Make sure there are no loose pieces of sand along the path of metal flow.

At this point the pattern can be removed. Using the rapping tool (6mm rod with a point) and a piece of wood the pattern is tapped down lightly and side to side to help with getting it free from the sand. If your pattern has spokes, or any similar areas with sand surrounded by the pattern, don't rap side to side as the sand between the spokes will break when you remove the pattern. Grip the pattern using the holes and hooks described in the pattern making article and carefully remove it from the sand. **Photographs 20** to **23** show the preparation of a mould for casting a cylinder.

Using a thin rod (1.6mm will do) push breather holes from the pattern side through to the top surface and pull straight through. Any high point where gas cannot escape should be vented, especially all risers. Carefully push any sand that has dislodged back into place. That's it – you're done! Close up.

If you want to mould an un-split pattern the principles are the same but first you lightly ram the top flask, push the pattern into the sand to the halfway line, dust and ram the other half. You then split the flask and break out the top and redo as with a split pattern with the sprues etc. Far more care is required when splitting the flasks to prevent the sand from breaking.

With this you have a mould ready for casting. You should cast within two days and I generally cast the next day. Don't fire up the furnace before making the moulds; there's a little work required when managing the furnace, as we'll see next time.

●To be continued.

The Polar Express

Jon Edney tells how the festive spirit is brought to a Cambridgeshire village.

The festive scene.

Alert engine driver.

For the last five years our village in Cambridgeshire has been engaging in a community activity called 'Advent Windows'. Each year a theme is announced and twenty three households around the village are assigned a topic and prepare a decorative window. There is a launch event on December 1st and then each house unveils a window on each day of December, culminating with a big window on Christmas Eve at the Baptist Church. I have seen other locations doing something similar and it is becoming quite popular.

Some people do very artistic windows, some clever or intriguing designs but, of course, being an engineering household we always have a model scene, usually with animated features. Last year we had a moonscape and the 'Clangers' all rose up and appeared in one of the craters. This year the theme is 'Charades' and each window will feature a film, book or song etc.. The idea is that passers-by have to guess the theme. The organiser (knowing my proclivity for trains) assigned us *The Polar Express* which, as many readers will know, is a book and also an animated film from 2004. This film has an iconic scene of a boy, in his dressing gown, staring at a huge locomotive which has magically appeared on his street. If you search the Internet for 'Polar Express' you will immediately see this image.

So the task, obviously, was to replicate the scene with the locomotive and the boy to display in our window. Now, I have been working for some time on a 7¼ inch gauge *Bridget* locomotive (by Ken Swan) but this is not finished – I had just the chassis and the smokebox completed. Also, *Bridget*, as a tank engine, would hardly conjure up the image of the massive locomotive in the story.

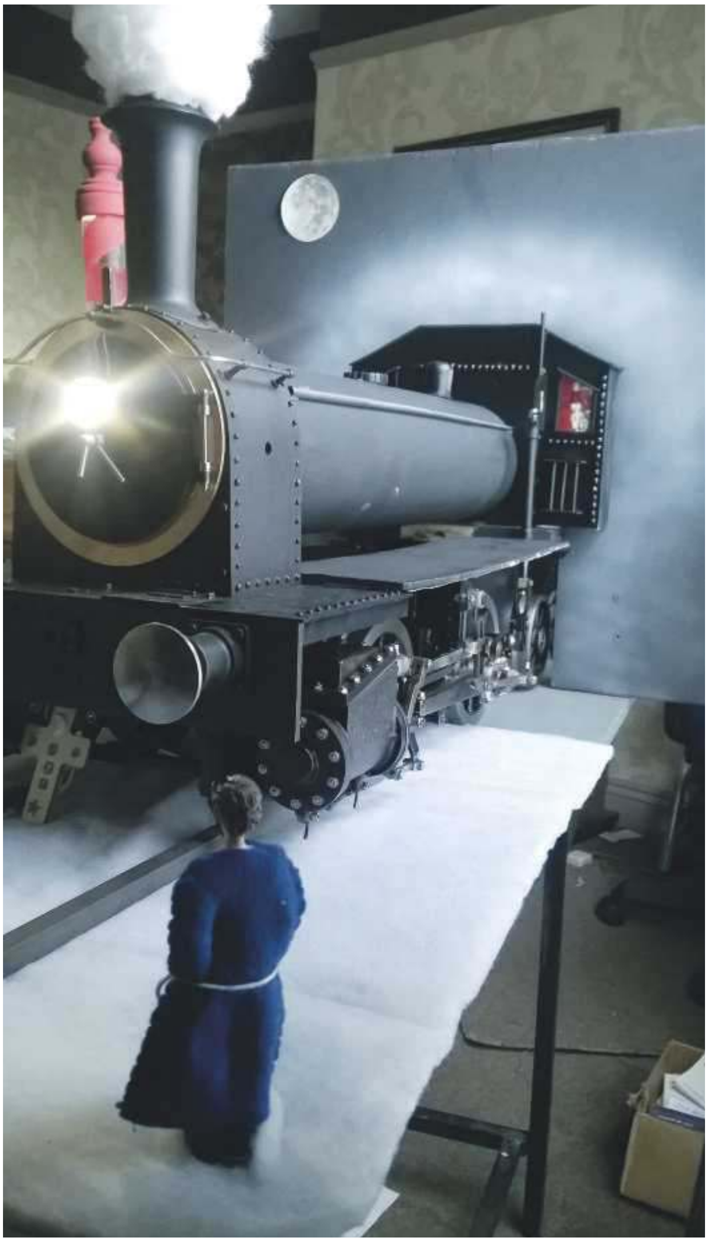
So, I followed the path of all true model engineers and started cobbling together whatever I could find. I used a plastic pipe (designed for an extractor fan) to make a long boiler for the locomotive and stuck a milk bottle top and a rubber bung on top to give the effect of steam dome and sand boxes. After painting it black, I stuck a stainless rod down the side to give the 'cluttered' effect. I didn't have room for a full cab so I made a mock-up cab front about an inch deep and placed it against a plywood back board which was painted black with steam effect from an air brush. The cab itself was made from craft board stuck with hot melt glue. I wanted to add rivets to give a locomotive effect but what could I use? As I sat in the kitchen puzzling, inspiration struck – I saw a jar of dried split peas on the shelf. These were stuck on with superglue and, with the addition of some tubes made from drinking straws and a coat of black spray paint, I had a viable 'cab'. To get steam from the chimney I stuck a bung in the top with a vertical stick and added cotton wool. The boy was a doll's house eBay purchase and my wife kindly made the dressing gown.


In course of arrangement.

An important feature of the locomotive in the film is a large, very bright central headlight. I turned up a suitable headlight from brass and glued in a 2W white LED. This was way too bright so I stuck a piece of translucent tracing paper across the front to give a nice effect and not leave onlookers with a black spot on their retina! The lamp is not actually attached, but hangs on black wires trapped by the 'smokebox door'. Finally, for extra fun I stuck aluminium foil inside the cab and created a glowing fire effect using a red and a yellow LED driven by an Arduino microprocessor.

Just a couple of other details: the meerkat in the cab is just because, for reasons now forgotten, we always include a meerkat somewhere in our window – it is a sort of trademark. The red, stripy pole in the background is supposed to be the North Pole. It is made of acrylic, rotates and is illuminated from below.

The finished result is shown in the photos and I trust that it will give much pleasure to adults and children alike this year. Making it certainly gave me a lot of pleasure anyway!


The finished result.

ME

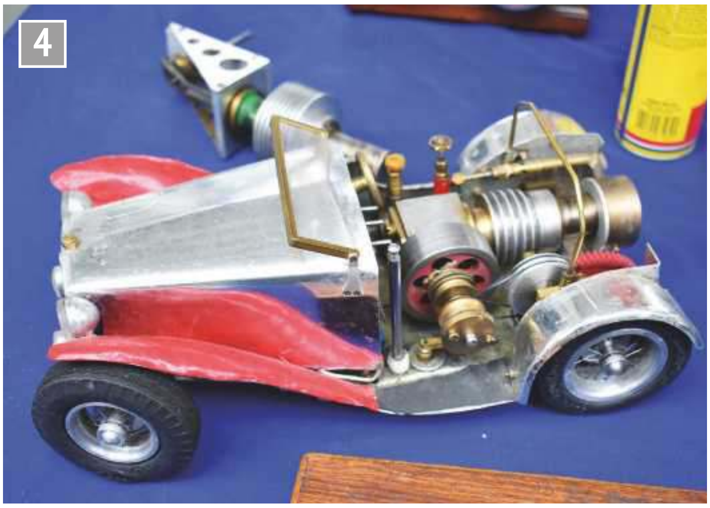
John Arrowsmith visits the Hereford Waterworks Museum, the venue again for this year's rally.

This 1890 Hayward-Tyler hot air engine was working all day.

A group of assorted engines from Julian Wood.

The Stirling Engine Rally 2019

The new experimental gear box produced by Julian Wood.



The old style way of reversing a hot air powered car.

The annual Stirling Engine Society Rally was once again held at the Herefordshire Waterworks Museum. This fine venue is a good setting for these machines simply because they have a number of them on permanent display. This enables visitors to see a couple of full size hot air engines working in typical conditions, doing what they were designed for, in this case, pumping water (**photo 1**).

The rally itself has established a good relationship with the museum and always provides a wide range of models and equipment to complement the museum's own working examples. Julian Wood is the Society secretary as well as being a prolific builder and operator of a wide selection of well built, interesting models (**photo 2**). His latest development is a new, small gearbox for a hot air powered car which replaces the common set of two pulleys to provide forward and reverse motion. This new arrangement is easier to operate and provides more power for the wheels (**photos 3** and **4**). Bob Cannon is a regular contributor to both this show and the Midlands Exhibition and his group of models here showed off some interesting examples and uses of Stirling engines. Among the engines on show was a nicely made working example of a Gamma configured Stirling engine alongside an Henrici configured engine (**photo 5**).

There are lots of simple commercial models available these days and Brian Lowe had an attractive display of a number of such engines (**photo 6**) which contrasted nicely with the scratch built models from other contributors. Andy Badman was showing his nice example of a Rider-Ericsson Hot Air engine (**photo 7**) alongside his Flame Gulper engine, *Chuck* which, to the amusement of many, was making a rather flatulent sound at the end of each stroke. This was apparently caused by the diaphragm valve at the bottom of the cylinder. One exhibitor, David Laycock told me he had bought a small second-hand engraving machine and then wondered what could be done with it, in addition to engraving. The result of his pondering was some nice side plates between which a small hot air engine was mounted - and it was on show here (**photo 8**).

Bob Cannon provided this example of Gamma and Henrici hot air engines.

An attractive display of modern commercial engines provided by Brian Lowe.

A well made example of the popular Ryder-Ericsson Hot Air Engine built by Andy Badman.

David Laycock used a traditional engraving machine to machine the side plates for his engine.

The elegant cooling fan under construction by Jeff Ford.

Tony Goodger is constructing this free piston engine for his model boat.

I had a long conversation with Norris Bomford who was displaying his four-lever Stirling marine engine which he has developed. Mounted in a small boat it can produce enough power for two people to enjoy a leisurely sail at about 2/3 knots (**photo 11**). The multi-tube heater was an interesting part of the engine (**photo 12**) and additional engine control is offered via a small air bleed valve from the crankcase; when used it can add another 20 rpm to the propeller speed. He had a novel way of sealing a leaking gasket around the heater barrel; he had found that the leak was through the gasket material itself so by painting a layer of Loctite around the outside, the internal vacuum sucked it into the material and he hasn't had a leak since.

A really first class Edwardian/ Colonial style fan is being constructed by Jeff Ford who displayed the not-quite-finished machine here. Excellent workmanship showed off an elegant fan which, as Jeff explained, contains an element of art deco styling to complete the model. He has been experimenting with a hard, anodised cylinder but this has not been a success so having done all the drawings himself he is returning to a cast iron burner and will use an electrical band heater rather than a gas burner clamped to the burner to provide the heat, as he thinks this will improve the aesthetics of the finished fan (**photo 9**).

There was an interesting build project featuring a hot air engine mounted in a small boat hull. The engine is using a free piston system where the piston is not coupled directly to the displacer, but relies on the difference in air pressure to enable operation (**photo 10**).

Tony Goodger had a couple of other interesting engines on show, one of which uses a glass hypodermic syringe as a cylinder and a recycled battery case as the piston; he said it was a bit messy cleaning the battery out but the combination works well.

I mentioned above that the Museum has its own small collection of Stirling engines and one of the displays is an interactive one which allows visitors to read about the engine and then press a button to watch it operate. This is a popular feature as the information boards describe the movements which can then be seen in action by simply pressing the button (**photo 13**). A further display, given to the museum by a local businessman, has a good time line section combined with the models so again visitors can discover how these machines progressed (**photo 14**). What this doesn't show, though, is the NASA project to use a

Norris Bomford built this four lever Stirling engine for use in a small boat.

The heater tubes on the four lever Stirling engine.

The interactive display by the Waterworks Museum.

A static display of models with a time line diagram showing progress over the years.

Stirling Engine powered by a nuclear fission generator to provide power for a future base on the moon or even the planet Mars. The project expects this machine to provide around 40KW of power - enough for about eight houses. I wonder what the Reverend Dr. Stirling would think of his 1916 invention being used in such a high tech project as a moon base.

Finally the Museum's own full size Haward-Tyler hot air engine, circa 1890, was working merrily away all day (photo 1) demonstrating how these machines performed their tasks in real life. This one provided a water supply for a local country house.

I hope this short ramble around the annual Stirling rally gives you enough of a taste of these interesting engines to perhaps try and visit next year.

My thanks, as usual, to all the museum staff who contributed to the success of the day and to all the Stirling Engine members who came to display their engines and who did so with great enthusiasm. It was a pleasure to meet you all.

ME

The Barclay Well Tanks of the Great War

PART 56

Terence Holland describes and constructs two appealing, century old locomotives.

This constructional series addresses Andrew Barclay 0-4-0 and 0-6-0 narrow gauge locomotives supplied for use in the First World War. Built without the use of castings, the 0-4-0 design is described as two versions; as-built for the British Admiralty in 1918 and as rebuilt and currently running on the Talyllyn Railway as their locomotive No.6, *Douglas*. The 0-6-0 engines described were built in 1917 and operated on 60 centimetre gauge track at the Western Front in France. These were small, spartan machines of which only 25 were supplied and none have survived into preservation.

Continued from p.786
M.E. 4626, 22 November 2019

Driver's injector on ACC No.1.

Airservice Constructional Corps No.1

Fitting up the injectors on *ACC No.1* is a lot easier than those on *Douglas*. In addition, things look a lot more attractive (although beauty, of course, is in the eye of the beholder!).

Photographs 257 and **258** show the injectors on my engine before the rebuild.

In photo 257, which shows the driver's injector, the original screw-down clack had suffered from dezincification and had been replaced with a 'normal'

ACC No.1 *cab view.*

Fireman's side of ACC No.1.

non-return valve. It's a bit difficult to see but the injector suction is fitted with a brass standpipe that sits directly on the water cock. In this position it is very easy to remove the injector for cleaning – even when the engine is in steam.

Both injectors were fed from the driver's tank (topped up from the pump bypass) and the tender supply was fed to the feed pump only. The water cocks' operating levers were installed in the cab at a slight angle to open and close the cocks, which were fitted each side of the firebox front. The injectors were mounted each side and part way up the tank/bunker front, at a height corresponding to the base of the water tank; this provided an approximate head of four inches. Both operating levers can be seen in photo 258.

In **photo 259**, the original screw-down clack is in place and the crosshead feed pump is prominent. The engine at this time was fitted with an American-type chime whistle (tuned to E minor) on the front of the cab and a small bell whistle was fitted to the steam dome. Note also the incorrect drain cock arrangement – there is no centre steam chest drain - and the conventional Walschaert's expansion link instead of the Barclay-designed link. Even though the engine is fitted with a mechanical oil pump, tallow cocks are fitted to the outer cylinder covers, along with displacement lubricators on the steam chest covers, as

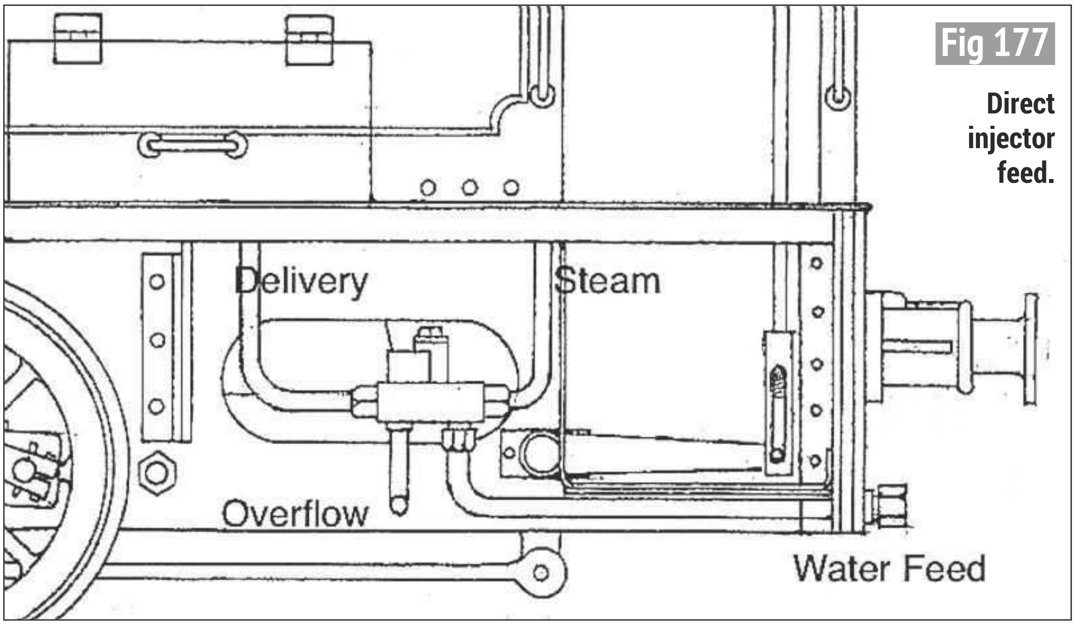


Fig 177

Direct injector feed.

these were prominent features of the original design.

Douglas

As mentioned above, on *Douglas* the injectors are mounted below the footplate. This provides the best possible head of feed water, so normal injector arrangements can be applied. *Douglas* has two injectors situated one each side of the cab; a large unit on the driver's side and small one on the fireman's side. I was tempted during the rebuild to reinstall the injectors to where they were on *ACC No.1*, but this would still have required a fair bit of work. So eventually common sense prevailed, I 'bit the bullet' and went for the correct location under the rear footplate. Mounting in this position, however, means that the feed pipework to the boiler is considerably longer but previous experience has shown that this is not a problem.

The simplest arrangement is shown in **fig 177** where the fireman's injector is fed directly from the driving tender. This arrangement is possible if no feedpump is fitted. In this case the stop valve for the injector feed is located in the tender.

When a tender is used things get a bit more complicated, as can be seen in **photo 260**, which shows the injector pipework on the driver's side, before fitting the side tank. Note that there is no water supply at this stage, as that is supplied from the driver's bunker. **Photograph 261** shows a close-up of the water connection with the bunker installed. The shaft for the driver's water cock runs horizontally to the cab and the operating handle is situated below the drain cock lever.

Photograph 262 shows the fireman's side complete with injector water supply, which tees off from the water feed to the feed pump – see the close-up view in **photo 263**.

When the locomotive is fitted with the fireman's injector stopcock, the pipe from the tender also feeds the crosshead pump; it feeds directly to the pump as it is not throttled on its inlet. See photos 262 and 263. Space is at a premium on both sides of the locomotive, so connecting the injector to its water supply gets a bit tricky. Hence the use of flexible rubber tube for the water feed from each injector stop valve. This does, however, simplify injector removal for cleaning but it is important to ensure that no

260

Driver's injector pipework.

261

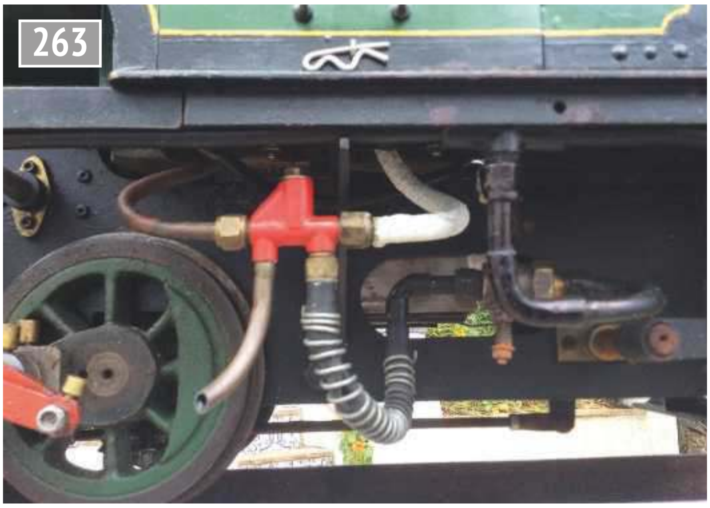
Close-up of driver's injector water feed.

»

262

Fireman's injector pipework.

263



Close-up of fireman's injector water feed.

air can leak in on the suction side. The ideal piping sizes for the injectors are as follows: steam ¼ inch, feed $\frac{5}{16}$ inch and water ⅜ inch, all outside diameter. Where possible thin walled tube should be used. Steam should be supplied via fairly large valves and the water cocks should have decent size passageways similar to that of the feed pipework. Care must be taken to prevent air ingress into the water supply or the injector will not work reliably. Strainers should be fitted to all water supplies to prevent foreign bodies, such as coal dust, entering the injector cones.

In photos 260 and 262 the steam pipes are lagged with string, covered with white filler rubbed in by hand and then painted gloss white. If you don't like the ostentatious look use gloss black – they end up pretty dirty anyway on the real thing.

The locomotive is connected to the tender via a flexible tube – see **photo 264**. If the feed pump is fitted it could be fed from a bulkhead fitting/strainer in the base of the well tank and the tender supply used for the fireman's injector only. It is better, however, if the pump is fed from the tender, which contains some two gallons of water.

Spooky Goings-On

I have a bit more encouraging information regarding the performance of the screw-down, non-return valves on the 5 inch gauge barclay engines (see fig 123, p. 524, M.E. 4596, 28th September 2018). Recent experience, when lighting up in the dark for a 'ghost train' special on Hallowe'en night, gave credence to the inference by Martin Rickers (**ref 56**) in his injector series that a working injector, which is well supplied with water and steam, will have no problems delivering against a restricted feed. But, more importantly for me, it verified that my design of boiler clack worked well, despite being somewhat restrictive.

I was attempting to top up the boiler before taking off into the unknown but couldn't get either injector to work. Eventually the penny dropped – I hadn't opened the screw-

264

Connection to tender.

Fig 178 **0-6-0 injector and feed.**

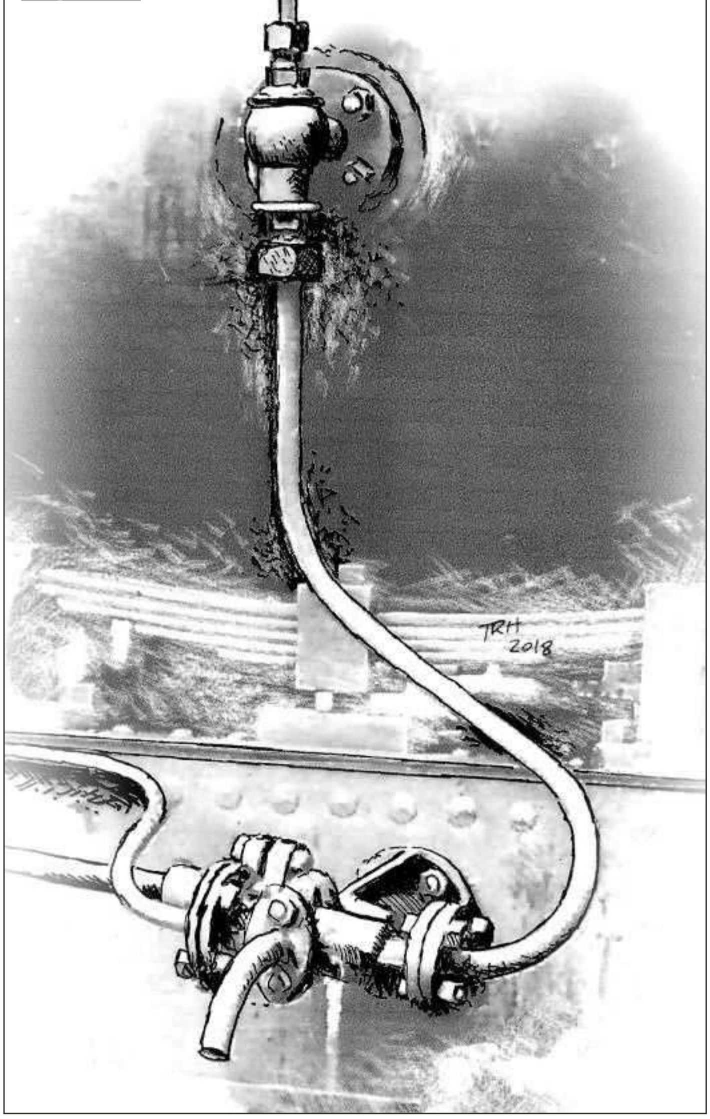


Fig 179

Side view of right hand injector assembly.

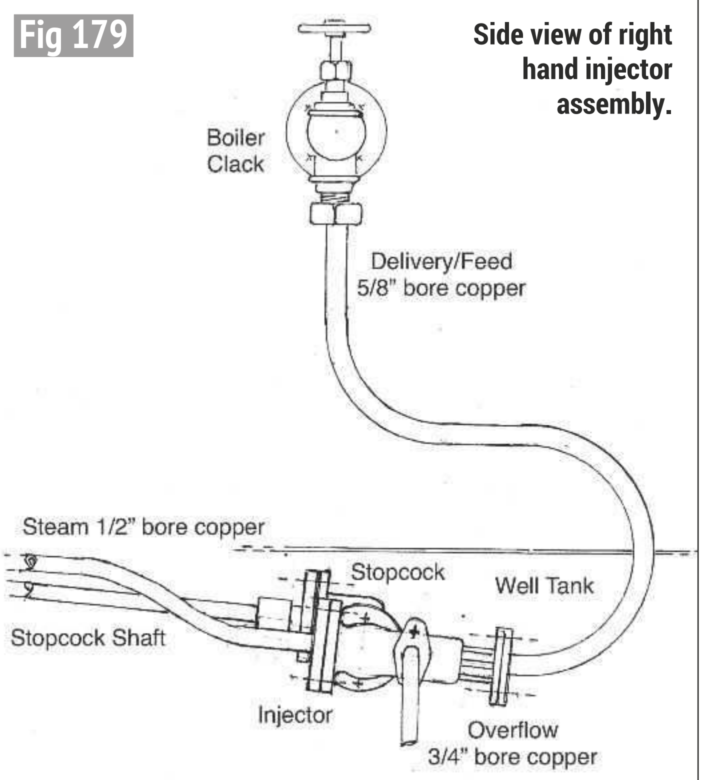
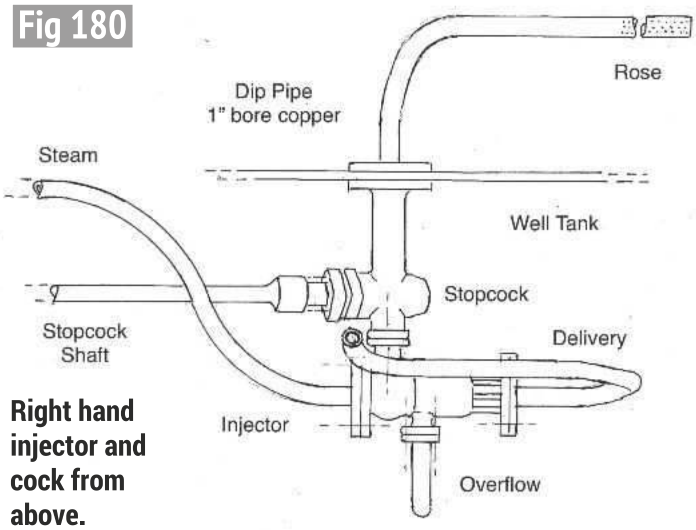


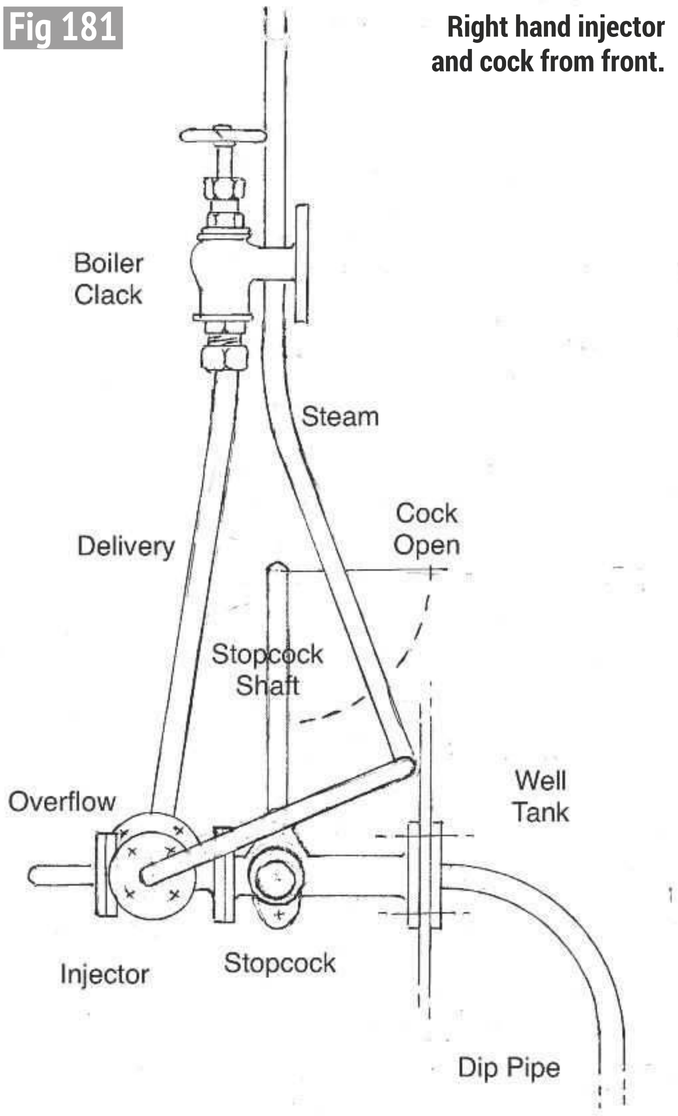
Fig 180



Right hand injector and cock from above.

Fig 181

Right hand injector and cock from front.



down boiler clacks (this is one of the problems with being driver, fireman and locomotive superintendent!). However, before realising this, the driver's injector started working – spooky! - not particularly well but it was definitely feeding into the boiler. On inspection, although both clacks were shut, it was apparent that the right-hand unit had not been completely tightened down – but just enough to bed the 'O'-ring and stop water draining back through the injector overflow in storage.

The only logical explanation I can come up with in the real world (avoiding quantum tunnelling and the supernatural...) is that the pressurised outlet from the injector was displacing the 'O'-ring sufficiently to allow water to pass. Once the valves were manually opened both injectors functioned perfectly. It was a bit hair-raising at the time though!

The War Department 0-6-0s

On the War Department locomotives, a loop in the injector feed pipe is necessary. This allows the lifting injector to be fitted clear of the gear frame and far enough forwards so that the feed pipe can enter the rear of the well tank. See **fig 178**, which shows the Barclay injector and its water cock, as fitted to the Class F engines – right hand unit drawn.

If the injectors are fed from the right hand bunker, there is no reason why the position shown in fig 178 cannot be used on the model, as this will provide sufficient head of water. The valve flange (which on the Barclay locomotives connects the water cock to the dip tube in the well tank) can be used to connect to a pipe that crosses the frame to a similar flange on the right hand side. Water can then be supplied to both injectors from the bunker via the water cocks. Provision will need to be made for easy removal of the injectors for cleaning.

According to the Barclay drawings of the 0-6-0, the strainer on the end of the suction pipe was a simple affair. The end of the dip pipe into the well tank was blanked off and ⅛ inch diameter holes were drilled around the pipe for a distance of 6 inches – I wonder how many injector problems this caused in the Flanders mud?

Schematics of the Barclay injector and its water cock, taken from the original 1916 drawings for the 0-6-0, are presented in **figs 179**, **180** and **181**.

Inspection of figs 179 to 181 indicates that the installation of conventional miniature injectors would not be too difficult on the 0-6-0. In fact, **fig 182** shows that the injector » assembly would be quite conspicuous and it would add a bit of technical interest to an otherwise Spartan machine.

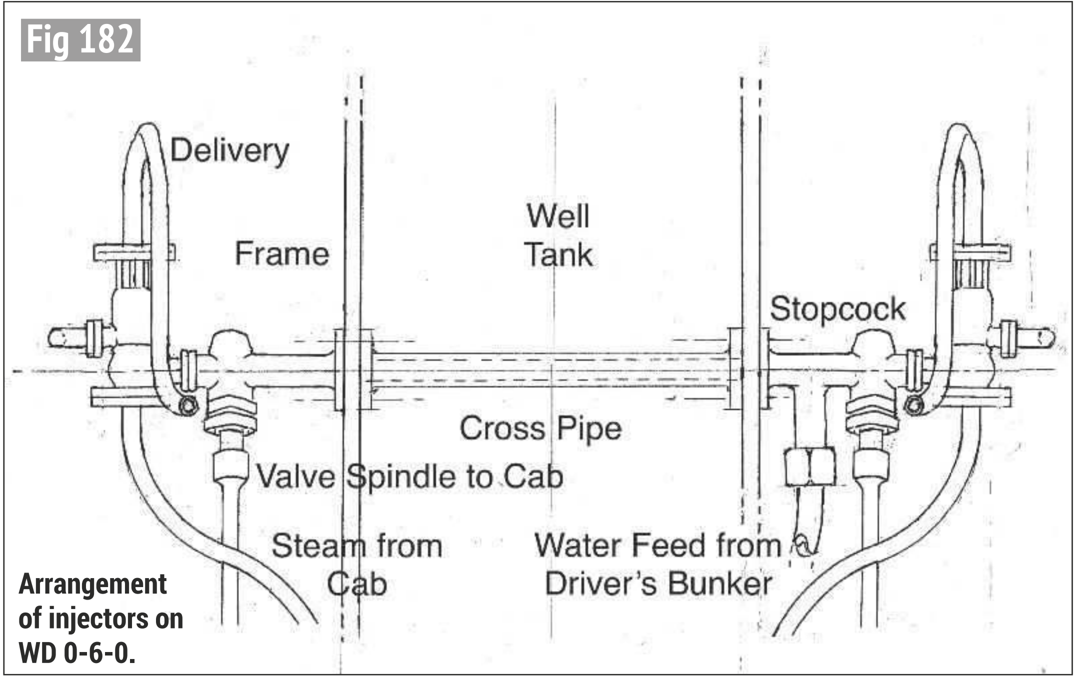
Slight modification would be needed to the injector body to bring out the water connection to the side and handed units would result. Connection to the pipework would have to be via union nuts to make the injectors easy to remove for cleaning. Dummy flanges could be screwed on the bodies as a compromise.

Figure 182 gives some idea of the water supply arrangements using the same flange penetration of the well tank, which would result in the injectors being at the correct height. The tee-piece connects the cross pipe to the driver's bunker via a strainer fitted in the bunker.

Some idea of scale is given by the four inch measurement between the frames.

●To be continued.

Fig 182



Arrangement of injectors on WD 0-6-0.

REFERENCE

56. Martin Rickers, *Some Performance Data for an Unusual Injector*, Model Engineers 3691, 3693 and 3695, October 1982.

NEXT TIME

I shall discuss fittings for these locomotives, both commercial and home-made.

NEXT ISSUE

- **Wheel Profiles**
  Hiroyuki Watanabe explains how the correct profiles may be achieved on locomotive wheels and brake blocks.
- **Midlands Show**
  John Arrowsmith completes his tour of the Midlands exhibition with a look at the club stands.
- **M.E. Beam Engine**
  David Haythornthwaite makes the crossbar and crosshead for the *Model Engineer* beam engine.
- **Brill Tram Truck**
  Ashley Best makes the cross beam for the Brill 22E tram truck.
- **Slot Cars**
  Henk de Ruiter revisits slot cars, with a look this time at some vintage 1960's/70's chassis.

Content may be subject to change.

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MODEL ENGINEER

PART 1

Magdalen Road Revisited

Jeremy Buck invites us back for a further tour of the Magdalen Road garden railway.

Siding as originally configured with No. 8783 leaving the running shed. The steep gradient is apparent, as are the unsatisfactory transitions between track panels.

Introduction

It has been commented by a reader of my description of my 5 inch gauge garden railway (M.E. 4528, 19th February 2016) that the narrative ended rather abruptly and that there was, perhaps, more of the story to tell. Accordingly, readers may be interested to read about my locomotives, embracing as they do second-hand purchase, overhaul, kit bashing, building from scratch, their operation, my workshop arrangements and recent improvements to the garden railway infrastructure.

Railway developments

The railway was comprehensively described in my previous article and the installation of signals, mooted in that article, remains an unfulfilled aspiration. For those who do not have access to that article, the railway is ground level although for topographical reasons much of it is actually elevated. It comprises a covered terminal station with turntable and run-around loop with a siding giving access to the workshop.

The main line is out and back, reversal being effected by a 'balloon' loop. The basic layout remains unchanged. What has changed is the means of access to and from the locomotive storage sidings in the workshop. The original arrangement comprised a steep incline, reminiscent of those required for access to elevated coaling stages at South African Railways locomotive sheds, from the 'main line' up to two bench level sidings (**photo 1**). In practice, this proved unsatisfactory at the vertical transitions for locomotives of even quite modest wheelbase. There was also a risk of the locomotive running away when traversing (not in steam) the incline which was, in any case, of no value as a siding for parking rolling stock in normal operation.

I had, some years ago, purchased a lifting table to eliminate the need for lifting locomotives manually but had found its value somewhat compromised by its relatively poor mobility inside and outside the workshop. However, replacement of its original wheels by heavy duty castors transformed its mobility. With this, and some other minor modifications, the table became suitable for providing the change in level of the hitherto inclined siding (**photos 2** and **3**), thereby bringing into play an operationally useful siding with approximately level alignment. Although not visible in the photographs, the table is latched onto vertical guide rails at each end. These maintain the table in its correct »

The lifting table at running shed level.

The lifting table at main line level.

plan position during raising and lowering and assure stability. As part of the same project the vertical alignments of the main and loop lines were reconfigured to reduce the change in gradient at the station throat and a head shunt off the loop line was added (**photo 4**).

Operation

The railway is normally operated on a 'one engine in steam' basis which obviates the need for the signals that we presently do not have. Although normally the railway is operated by my son and me, one-person operation is possible and not inconvenient. This is because the driver can complete a normal out and back run without need to dismount to change the points, which are spring controlled. The switch rails of the main to loop point in the station and the 'balloon' loop (**photo 5**) out in the country are sprung so that a locomotive or train can pass through the diverging track only in the trailing direction.

Four LMS liveried (LNER teak would be better but I cannot have everything) Aristocraft coaches provide the principal rolling stock and it is very satisfying to see, smell and hear one of our locomotives tackling the maximum 1 in 60 gradients with all four behind the drawbar (**photo 6**). We do not do passenger hauling - the ventilators on the coach roofs would, in any case, make the ride rather uncomfortable. A small selection of wagons allows us to run a goods train. Having rolling stock to provide suitable loading for whichever locomotive is steamed certainly makes for a more interesting operating experience.

Of course, the elevated track in the station area does not make for a realistic background to locomotive and train but neither does the grossly overscale driver. The eye needs to be, and is, selective.

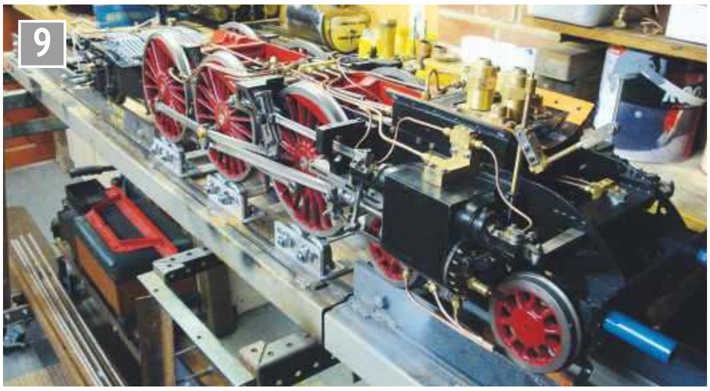
The reconfigured siding and a new head shunt on the loop.

Point at the entrance to the 'balloon' loop, showing the spring control.

Maximum load on 1 in 70 gradient approaching the station and with steam to spare.

North side of workshop showing running shed. The nearest line is taken down, because it conflicts with the turntable parked below, when the railway is in operation and doubles as the head shunt.

South side of workshop showing the fixed bench, with traverser, and mobile bench beyond.



Mobile bench with rolling road installed and A4 being set up for valve setting.

Chain block in use during assembly of the A4.

There are also positives. One of the drawbacks of a ground level 5 inch gauge railway, especially as one gets older, is gaining access between the frames where necessary for preparation and disposal of steam locomotives. Carrying out these activities with the locomotive on the bench level elevated track within the workshop is certainly kinder on the back, and as much preparation as possible is done here, but I prefer to keep smoke, ash and water outside as far as possible. Steam raising is therefore done after the locomotive has been lowered to track level in the station.

The head shunt may not be visually attractive but, at 18 inches above ground level, it does provide a tolerable access to facilitate lubrication of inside motion during preparation, and for dumping the contents of the ashpan and cleaning between the frames during disposal.

Workshop

I built the garage/workshop some thirty years ago and remember thinking how spacious it seemed to be when completed. Thirty years on it seems far too small and there is no room for a car. However, by careful planning I have been able to fit my workshop in along with a growing collection of rolling stock. Benches sufficient to accommodate two 5 inch gauge tracks extend along both sides. That on the north side is fixed and serves as the running shed with accommodation for up to four, but more usually three, locomotives (**photo 7**).

An additional demountable track on this side provides siding space for up to two locomotives, and doubles as the aforementioned headshunt. On the south side is the erecting bench (**photo 8**). This

>>

comprises a fixed bench, below which the Aristocraft coaches are stored. The two tracks on the fixed bench comprise a traverser so that both than be accessed from a mobile bench which, among other things, facilitates the transfer of stock from the running (north) side to the south side for assembly/ maintenance – as well as allowing access to both sides and under locomotives under construction or repair.

Originally configured with 5 inch gauge rails welded down to steel box section longitudinal bearers, the bench was later modified to allow a rolling road, with the necessary flexibility to accommodate one, two or three coupled axles, to be inserted (**photo 9**). Suspended from the roof above the outer track and mobile bench (in its parked position) is a runway beam and chain block which facilitates the single-handed lifting of the boiler on and off a locomotive chassis (**photo 10**). The roof, runway beam and chain block are more than capable of supporting the largest locomotive, although I do not normally have a need for this.

The workshop proper (**photo 11**) is equipped with workbench, Myford ML7-R lathe, Meddings ½ inch bench drill, Tom Senior Type E milling machine, bench grinder, air compressor, brazing hearth and Sievert propane torch, MIG welder and the usual hand tools.

View of workshop proper.

Locomotives

Although I am a chartered civil engineer by profession, albeit now retired, and have derived much pleasure from designing and building the railway infrastructure, my real passion and the reason for it all are the steam locomotives which reflect my interest in the Great Eastern, Great Northern, and London and North Eastern Railways, and the Beyer Garratt Locomotive.

The notes that follow are not in any way offered as instructions on how to do things but rather as the experiences of one man working, largely alone, on miniature steam locomotives. I have deliberately concentrated on the problems encountered and overcome - an area which appears to me to be somewhat neglected in the model engineering press.

Y4 No 226

The first locomotive, which has now been in my care for over fifty years, was the ex GER 0-4-0 tank class B74, later LNER class Y4 (**photo 12**). I described the origins of this in my earlier article and I would only add that until the superheater, which is non radiant and of conventional copper return flue construction, warms up water consumption is quite heavy, which requires frequent filling of the side tanks which feed the injector. The twin axle driven feed pumps are not so effective on our railway which involves repeated starting and stopping, but they will, at least, reliably feed water from the tanks, the contents of which sometimes get too hot for reliable injector operation.

I long ago removed the hand pump from the nearside tank (in order to install the prototypical coal bunker) and installed it in the driving truck (**photo 13**) which carries supplies of coal and cold water. All moving parts of the locomotive are easily accessible for inspection and lubrication. A reliable performer for many years and deceptively powerful for its size, this is ideal motive power for the railway.

●To be continued.

Y4 0-4-0 No. 226. Over 50 years old (the locomotive, not the driver) and still going strong.

The Y4 driving truck in front with water tank (hand pump feed only) and coal bunker. The driving truck behind was built for the Stirling Single but can be used with all of the tender locomotives. It has no water or coal capacity.

PART 64

Garrett 4CD Tractor in 6 inch scale

Chris Gunn paints the belly tank and fits the ashpan.

Continued from p.780
M.E. 4626, 22 November 2019

This article has been written to guide the builder through the construction of the 6 inch scale Garrett 4CD tractor designed by Chris d'Alquen. The writer has previously built a 4 inch scale Garrett and a 6 inch scale Foden wagon so has the benefit of considerable experience in larger scale modelling. Most machining can be done in the average home workshop but the supplier from whom the castings and drawings are currently available is able to provide a machining service for the largest items if required.

Belly tank

The next major item to be painted was the belly tank. In an earlier episode I described how the tank had been sand blasted and primed and now it was time to continue with it.

I blew the dust out with an airline and applied some Black Jack to the inside of the tank, a job made easier as the top was still open at this stage. Then I applied, or perhaps slathered is a more accurate word, several coats of Black Jack on top of the primer, allowing several days between coats to let it seep into any gaps. As I went along, I used white spirit to clean off any Black Jack that had run through any of the holes. At this stage I was a bit complacent as I thought the tank was sealed, purely by examining it visually. I elected not to assemble everything and test it with water as more or less everything I put on it would have to come off again before the tank was painted.

As I am writing this *after* the engine has been completed, I can tell you that the tank was *not* water-tight when finally assembled and I had to try and seal the leak with the tank *in situ*, with access only through the two hand holes in the side. This took several attempts, mainly because I could not see what I was doing. I had one seam that was not closed and found the Black Jack was running out through the gap. After several attempts I sealed the outside with insulating tape, which stopped the sealant flowing through the hole, and let it harden.

I thought long and hard about how to proceed with painting the belly tank and in the end I decided to paint it and line it with none of the items that bolt to it fitted. I reasoned that the lining would be a lot easier that way. After that was completed I would add the fittings utilising the open top, then mask the tank and then add the curved top. I made a start by applying undercoat and adopted the same procedure as I did with the tender, namely painting a horizontal surface and turning the tank over. I did not touch the top as I would paint all of it when I added the curved top.

I studied some pictures of the belly tank lining on full size engines and found quite a few had a thick black line that went from the tank edge and past the rivet line giving a very wide black line. I thought this would be a bit overbearing in half size. In the end I decided to settle for a single yellow line with an inverted corner. There was not room for much more in the space available above and below the manholes in each side of the tank.

I proceeded as I did with the toolbox mentioned in the first section, by cutting some corners from the frisket film and applying them, painting the corners and then joining

Drawings, castings and machining services are available from A. N. Engineering: Email: **a.nutting@hotmail.co.uk**

Finished belly tank end.

Fitting the belly tank top.

up the corners with the lining tape. **Photograph 540** shows the completed belly tank end (apologies for the flash reflection).

Once the bottom section was painted and lined, I added the fitments accessing everything through the top. In the meantime the curved top had been slathered on the inside face with Black Jack. I used M5 button head socket screws instead of rivets to fit the top to the tank along the front and back edges of the tank and I used M5 countersunk screws to join the top to the butt joint strips along the other edges. **Photograph 541** shows the top fitted and being cleaned up. The piece of angle held in place with masking tape is to stop me sanding the button head screws by mistake.

Once all the screws were in, the two butt strip joints were sanded flush - screw heads and all - cleaned off and then Isopon was used to fill the gaps and screw head holes. When dry this was sanded and rubbed down until it could not be seen. **Photograph 542** shows the finished top, primed.

The top of the tank was painted with primer, undercoat and top coat but no lining was applied as the top of the tanks would carry duckboards.

Once painted the M5 button head screws look like rivets unless one looks very closely indeed. Most of them are under the boiler and the duckboards cover the few that are not. I felt that this method of construction was a reasonable compromise and making the top in one piece would have restricted access in this scale. It probably would be a different story in full size.

I am still not sure if sealing and testing the tank off the engine would have been more time consuming than my way, bearing in mind the amount of dismantling that would have been needed. However this was a first for me and if I did another I might do it differently.

Top primed.

Make and fit the ashpan

If I can backtrack again to the point before the tender was re-fitted and when the engine was on its wheels, that was the time to make and fit the ashpan. The pan itself was made to the drawing, as were the grate supports and the grate itself.

When I was employed we used to make gas heated pallet branders and the only material we could use for the branding plate supports was a heat resistant stainless steel that we bought in 150mm wide x 6mm sheared bars. I had some off-cuts and this was ideal for the job. The only problem was cutting and drilling it. In the end I cut it into strips just over 25mm wide using a grinder with a 1mm thick cutting disc. Then I held ten pieces on edge in the vice on the Bridgeport and skimmed the edges with my carbide tipped fly-cutter, which was the only cutter that would look at it! Once it was cleaned up all I had to do was to drill it, which was a nightmare. I got through a few drills until I flooded it with suds and drilled it really slowly. All I had to do then was make spacers from some free-cutting stainless and I adapted some stainless steel air cylinder tie rods to hold it all together. It was hard work for a simple item, but I am sure it will stand up to the heat when the time comes.

I deviated slightly, I think, from the ashpan mounting. I had seen what had been done on another 4CD, which was to fit a hinge pin to the rear of the foundation ring and a matching receptacle on the end of the ashpan which would allow the ash pan to be dropped when the pin was pulled, yet leave the ashpan still attached to the boiler so it could easily be swung back into position with the grate still inside.

The whole ashpan and grate drop right away when the pins are pulled on my 4 inch Garrett, but it is a horrible job to get it back together; one needs two pairs of hands … if not three!

To create the hinge, I took a piece of ⅝ inch EN3B about 4 inches long and turned 2 inches of it down to 3/8 inch with a really generous chamfer on the end. Then another piece 2 inches long was drilled 13⁄64 inch diameter right through. The piece with the hole in was tack welded to the ashpan flush to the top of the pan, then I set the ashpan under the boiler in the correct position and welded the section with the pin onto

Ashpan support pin.

Damper complete.

Damper lever.

Damper rod.

the rear of the foundation ring. It was much easier to do this while the tender was off the engine. This allows the pan to drop in an emergency and also to be moved sideways to be completely removed. The front end of the ashpan is held up by a pin which passes through the top of the ashpan and is located in a couple of straps attached to the bottom of the boiler. **Photograph 543** shows the ashpan support pin.

The damper is fitted to the front of the ashpan and this way it can be made a good fit. The flap is supported by a pair of supports which can be screwed or riveted to the ashpan. I made these from a piece of 12 x 16mm steel cut to length. The two bolt holes and the bearing hole were drilled and then the support was mounted on an arbor made from an 8mm bolt, the web thinned down and the boss formed on the lathe.

The hinge pivots were made from ½ inch bar and drilled for a $\frac{5}{16}$ inch rod which forms the axle. The flap, hinges and flap supports were assembled and held with G-clamps so the holes could be spotted through.

The hinges were then welded to the damper flap, the operating lever was made from a short chunk of 2 inch angle - the holes were marked out and drilled first - then the profile was cut to match the holes and fitted to the damper flap. The whole thing was assembled as shown in **photo 544**.

Next, I made a pin to screw into the operating lever which would then connect to the damper operating lever. When I came to fit the operating rod, I found the left hand side of the engine (from the driver's position) very cluttered with the steering shaft and the flywheel brake brackets in the way. There was more room on the right side so I made another bracket and fitted it to the other side of the damper flap. **Photograph 545** shows the ashpan in position with the pin to connect to the operating rod.

The operating rod is threaded behind the gears and I brought it up just above the reversing lever pivot. I modified the end of the pivot to create a pin for the rod to notch onto and the end of the rod was fitted to a brass handle that can be easily operated from the tender. **Photograph 546** shows the lever end of the damper rod.

I can report that in practice the ashpan is a joy to empty. I pull two split pins and then the retaining pin and the pan drops down on its hinge; the grate and all the ash can be removed and the procedure reversed in a matter of minutes so I always start with a clean ashpan.

This seems a good stopping point, next time I will carry on with some of the final details.

●To be continued.

The Stationary Steam Engine PART 1

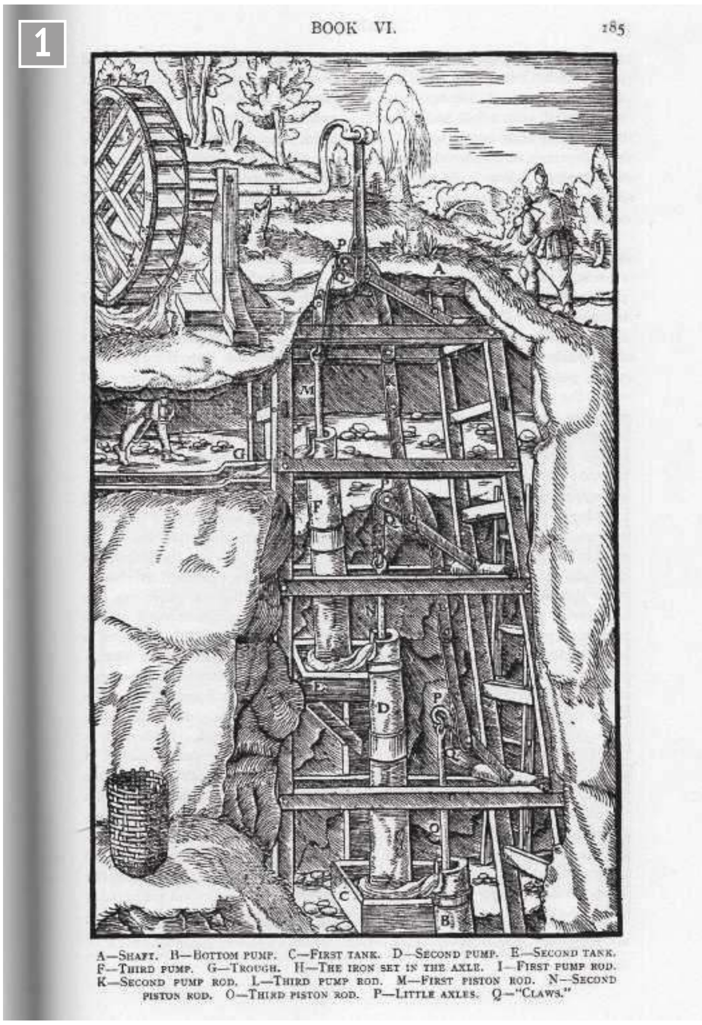
Ron Fitzgerald takes a look at the history and development of the stationary steam engine.

Preface

Writers have been chronicling the history of the stationary steam engine for almost as long as the machine has existed. In the seventeen-thirties, J. T. Desaguliers (**ref 1**) was amongst the first, not only to give a historical summary of the development of the steam engine but also to introduce a clutch of misconceptions and unwarranted speculations, a tradition that took firm root subsequently.

Over the next two-hundred-and-fifty years an extensive literature grew up, some knowledgeable and reliable but often tending to partisanship and hagiography sprinkled with a dose of technical and thermodynamic nonsense. This copious bibliography tends to become unwieldy from the point of view of those interested in the subject but not inclined to pursue a full course of study. The short articles that follow are intended to bridge this gap whilst at the same time clarifying some issues that have tended to be distorted or misrepresented in the past. It is also an attempt to give an insight into the interaction between the rising science of thermodynamics and the business of steam engine building. The comfortable supposition that the two existed in separate bubbles is woefully incorrect.

I would like to take this opportunity to offer the following articles as a memorial to the contribution that my friend the Reverend Dr. Richard L. Hills made to the history of the steam engine and to the history of technology generally. Richard died in May 2019 before he could proof read my script. It is poorer for this loss.



Agricola's De Re Metallica. Book VI. Hoover Edition, p. 185.

Mine water pumping before steam

The industrial revolution in the coal industry was already two hundred years old when the first practical steam-powered water pumping engines appeared. The dissolution of the monasteries in 1538 led to a huge transfer of landed estates and the first concerted exploitation of England's mineral wealth. Burgeoning demand for coal to replace the nation's failing wood supplies was met by a generation of coal owners who radically changed mining from an appendage of farming into a large scale, heavily capitalised industry.

John Neff (**ref 2**), who first drew attention to this revolution in 1932, identified changes in technology as central to everything that happened, an empathy with technology that has not generally been matched by later economic historians. With few exceptions, most writing in this area is characterised by a high degree of technological sub-literacy, a failing that is particularly apparent in works on the coal industry. Significant technological developments which were essential to growth have been inadequately understood, especially in regard to need for pumps to clear water from the ever-deepening pits.

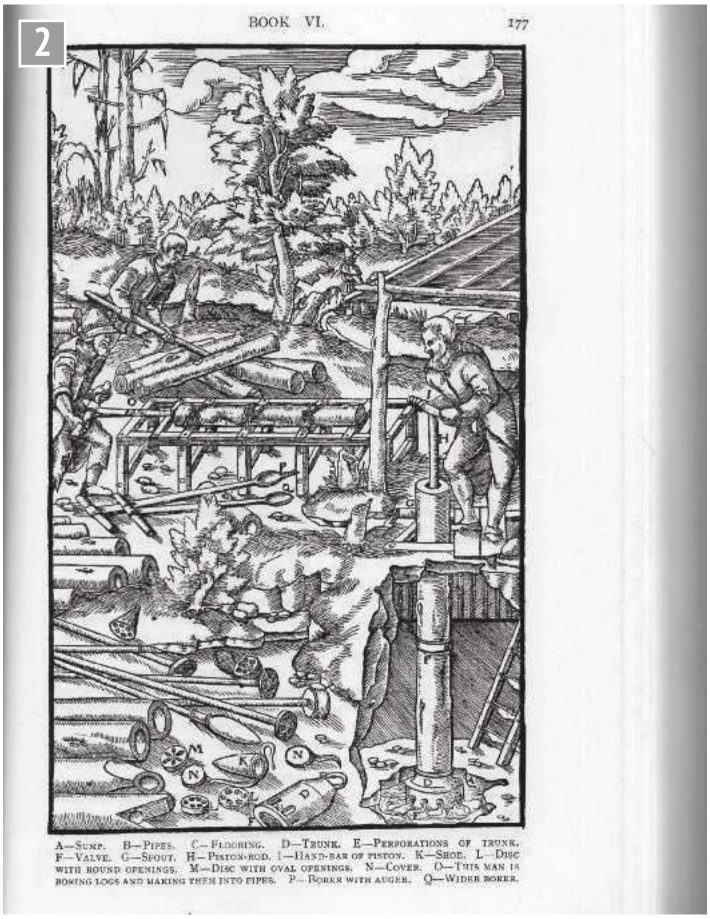
Amongst the more egregious sins is the repeated statement that pumps making use of suction in their lifting phase were incapable of raising water beyond the limit imposed by atmospheric pressure. This ignores the fact that majority of these suction pumps were bucket pumps (**ref 3**). The true potential of the bucket pump is overlooked because of the failure to appreciate that it relies upon suction for only part of its water raising action.

The feature that enables it to exceed the limit of atmospheric lift is the incorporation of flap valves into the body of the piston. During the up-stroke of the pump, atmospheric pressure acting upon the surface of the water external to the pump barrel drives it into the vacuum that forms below the rising piston. During the down-stroke the pressure under the piston opens the flap valves allowing the water to flow through the piston valve ports until, at the lower limit of the stroke, the water entrained during the suction stroke will have been transferred from below to above the piston. During the subsequent up-stroke the weight of water above the piston keeps the valves closed and the water on the top side of the piston is lifted.

Successive strokes of the piston add to the column of water in the upper part of the pump barrel which acts as a rising main connecting the pump barrel with the surface. At a convenient point the level of the water in the rising main reaches an off-take where it flows away.

In the mid-sixteenth century, Georgius Agricola in his *De Re Metallica* discusses the bucket pump in two forms (**ref 4**), one using a leather piston and the other using a perforated solid piston with a plate valve covering its top surface (**photo 1**). Although the component parts are clearly detailed the operating cycle is less well dealt with. Because of this confusion later writers have failed to recognise that Agricola is describing a bucket pump, an error that might have been rectified by a closer observation of the evidence of the illustrations, several of which show pumps discharging water from the top of the pump barrel. This implies that the water has passed from below the piston to above the piston and the pump barrel above the piston must be entirely filled by a column of water. Hence, it must be assumed that the piston has a transfer valve and that the pump is working as a bucket pump. Disassembled pump parts are shown in a further plate (**photo 2**) and scattered around the surface are pump barrels, pump rods with mounted pistons and perforated pistons with valve parts which are clearly the constituents of bucket pistons (**ref 5**).

De Re Metallica was written in Latin, the international language of technology. It spread rapidly through a knowledge hungry Europe. The Willoughbys, the greatest coal mining family in Nottingham, had a copy in their library by 1611. Whether it introduced new pumping technology to such experienced mining engineers is questionable. The Willoughbys were at the forefront of the radical change in mining technique that was to be fundamental to Neff's revolution in coal mining, change that centred upon the replacement of bell pit mining by gallery mining and



Agricola's De Re Metallica. Book VI. Hoover Edition, p.

with it, the demand for more sophisticated ways of handling mine water disposal.

Early mining was predominantly carried out by sinking clusters of bell pits. The individual working comprised an inverted cone shaped excavation of sufficient depth to reach the shallowest coal seams. Drainage was a matter of bailing the water with a bucket from a sump.

As the scale of mining grew the scattered pattern of bell pits was supplanted by vertical shafts from which galleries were projected within the coal seam. Coal extraction progressed up the dip of the coal so that water could flow by gravity to the lowest point of the mine where a water gallery conducted the runoff to a sump beneath a dedicated drainage shaft. In a wet pit the quantity of water far exceeded the capacity of hand bailing and from the earliest times of gallery working powered pumps were essential. These might take various forms but the bucket pump was gaining in importance as its construction was improved by the introduction of metal barrels and pistons.

The illustrations in *De Re Metallica* all show pumps bodies and pistons made almost entirely of wood. Mention of metallic construction is also absent in Agricola's text. From this it is reasonable to assume that metal pumps had not acquired currency in mining at the time that he was writing. Fifty years later Nuremburg craftsmen had introduced brass and bronze for pump work. One of the first recorded uses of metal bodied pumps in England is associated with fire fighting engines (**ref 6**). In 1625, the Londoner, Roger Jones, imported the idea from Nuremberg, patenting it in the same year as his death. William Burroughs, a foundry owner of Lothbury, who may have been a partner of Jones, continued to develop the appliance until, according to Fuller's *Worthies,* it amounted to a new invention. John

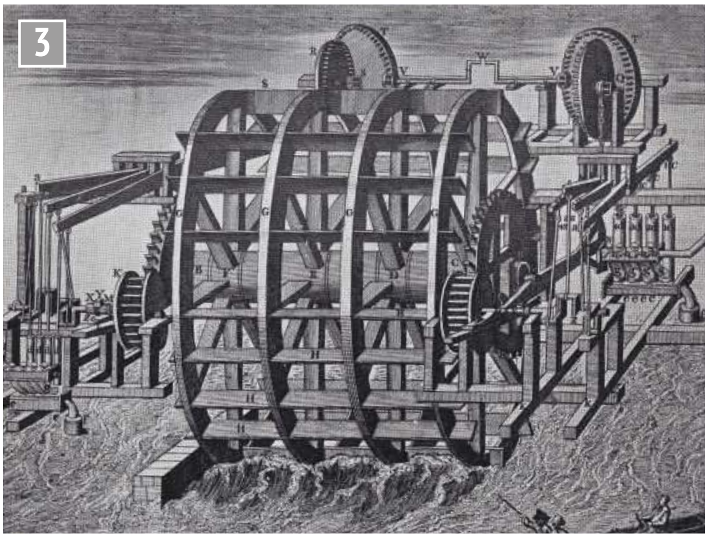
Bate in his *Mysteries of Art and Nature* published in 1654 had probably also seen the brass Nuremburg pumps. He used them in his own water pumping engines and recommended their more general use whilst the well-known pumps of Sir Samuel Morland were made of brass according to his advertisement of 1675. There can be little doubt that the brass pump had become widely adopted in mining by the third quarter of the seventeenth-century.

Cast-iron as an alternative to brass seems to have been uncommon until Darby's work at Coalbrookdale improved both iron smelting and moulding technology. Coalbrookdale was a pioneer of thin-walled iron castings and was producing cast iron pipes from 1715 (**ref 7**). Cast iron pipes bolted together by flanged couplings replaced the earlier bored elm timber pipes with tapered spigot and socket joints. The improved hydraulic integrity that resulted allowed the continuous riser pipe to replace the tandem pump lifts shown by Agricola.

The main factor limiting the depth to which these pumps could work was the power available to raise the pump load. Horse powered pumps were common but where water sources were available the waterwheel was the preferred power source. If adequate surface water supplies were available, coal seams in excess of 300 feet deep could be worked by waterwheel powered pumps.

A water drift or sough located part way up the shaft, into which the pump could discharge, might reduce the lift of the pumping machinery to only a third of half of the total shaft depth. For a century after 1620 a good half of the Tyne's output came from collieries which were being de-watered by water powered pumping engines (**ref 8**). At least 25 'coalmills' were in use in the seventeenth century South Tyne coalfield and from 1670 Sir Thomas Liddel at Ravensworth on the Tees was using three wheels in cascade formation, the last of which was below ground. By the sixteen-forties, the Gascoigne's collieries at Garforth near Leeds were taking water from the Cock Beck to dams which supplied the wheels and pumping engines (**ref 9**) and the Outwood pits north of Wakefield (**ref 10**) had a water powered pumping system.

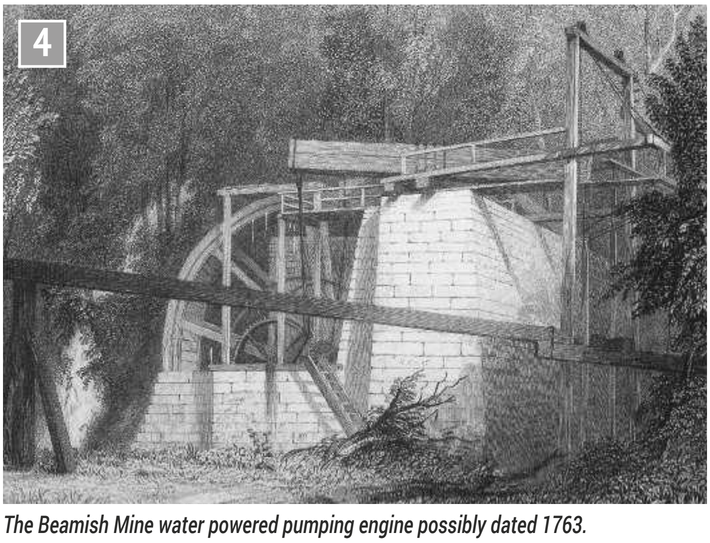
At the time of Agricola it was commonly the practice to locate the water wheel alongside the pit with its axle extending over the shaft. A crank attached to the end of the axle drove the pump rods directly. Complex, heavily timbered, supporting structures were needed over the shaft eye to support the axle bearing and the crank but at some point a less obstructive alternative emerged, the rocking beam with its pump end overhanging the shaft. The origin of this type of beam pump is unclear but George Sorocold, who had been heavily involved in mine pumping engines in his career, used rocking beams, commonly known as bobs, for the London Bridge Waterworks engine in 1701-2 (**photo 3**). There is nothing to show that they were a novelty at this time.



George Sorocold's London Bridge Waterworks Engine of 1701.

Up until the mid-eighteenth century only the deepest and more heavily water-logged coal pits were beyond the capability of a good water-wheel driven pumping system. Both in Britain and on the continent there is ample evidence to show that sophisticated water powered beam pumps continued in use long after the steam engine became available (**photo 4**).

●To be continued.



The Beamish Mine water powered pumping engine possibly dated 1763.

NEXT TIME

We turn our attention to the Newcomen engine.

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A New GWR Pannier PART 13

Doug Hewson decides that LBSC's well-known GWR pannier tank design needs a make-over.

Continued from p.798
M.E. 4626, 22 November 2019

As you might expect I have provided a small laser cut set of parts for the reverser (**fig 22**), not only to save a bit of time but so that you know that it is accurate - not that I don't trust you to make it accurately. (Anyway, stop digging Hewson!) There are also the two trunnions included to sit it on.

Now, if you want to make a proper job you will need to do a little bit of watch making to form the proper hinged latch spring. This will involve making a little plunger and drilling upwards into the reverser.

Bottom end of the reversing lever.

Top end of the reversing lever.

The location of the reverser in the cab.

Photograph 95 shows part of the reversing lever and **photo 96** shows the rest of it. I have also shown Frank's reverser on his own engine (**photo 97**) but it is just a pity about the spring! I don't think I had finished the drawing when he made that.

As you will see, the lever requires bending out to give room to operate it without the driver crashing his knuckles on the coil springs which have now appeared in the cab. Anyway, even if you are building *Pansy* it would still be very nice to put the bend in it to make it look that bit more authentic. The rest of it can be made following my drawings.

The pin for the bottom of the lever needs to be made from ¼ inch diameter rod and it will of course need to be a smidgen over ⅛ inch. You can pop a 5 or 6BA nut on the end just to give it a very slight gap to the shoulder so that when you tighten it, it will not hold the lever tight.

For the top end you need to turn a nice little handle out of stainless steel. You use 3/16 inch bar. Turn it to the shape shown on the drawing and tap it 5BA so that it can be screwed on to the handle. Once you have done that you will then need to silver solder it on to the main lever. Hopefully you will have enough of a fillet on the underside to form it to the shape shown.

I have also shown the two little guards which fit on the cab floor to cloak the two sides of the lever. They just require a couple of bends along them. They also appear in one of the laser cut kits which I have provided. There is also a reach rod in the laser cut kit. This connects the reverser to the arm on the valve gear (for those who may be building a locomotive for the first time). I have shown one of Guy Harding's photographs (**photo 98**) and it shows the far end of the reach rod (in black, at the back of the photograph) mainly to show how this end has a fork joint on it. As the reach rod is ⅛ inch thick it means that all you need do is to cut the end off and silver solder a piece of 3/8 inch x 16swg steel on to either side to form a fork and then file it to a similar shape to the one you had earlier.

Now, I think it is time to make the lubricator. One thing that any hard-working locomotive needs is a good reliable lubrication system and once we get that working you can run your pannier in on the bench. When I

>>

Reverser.

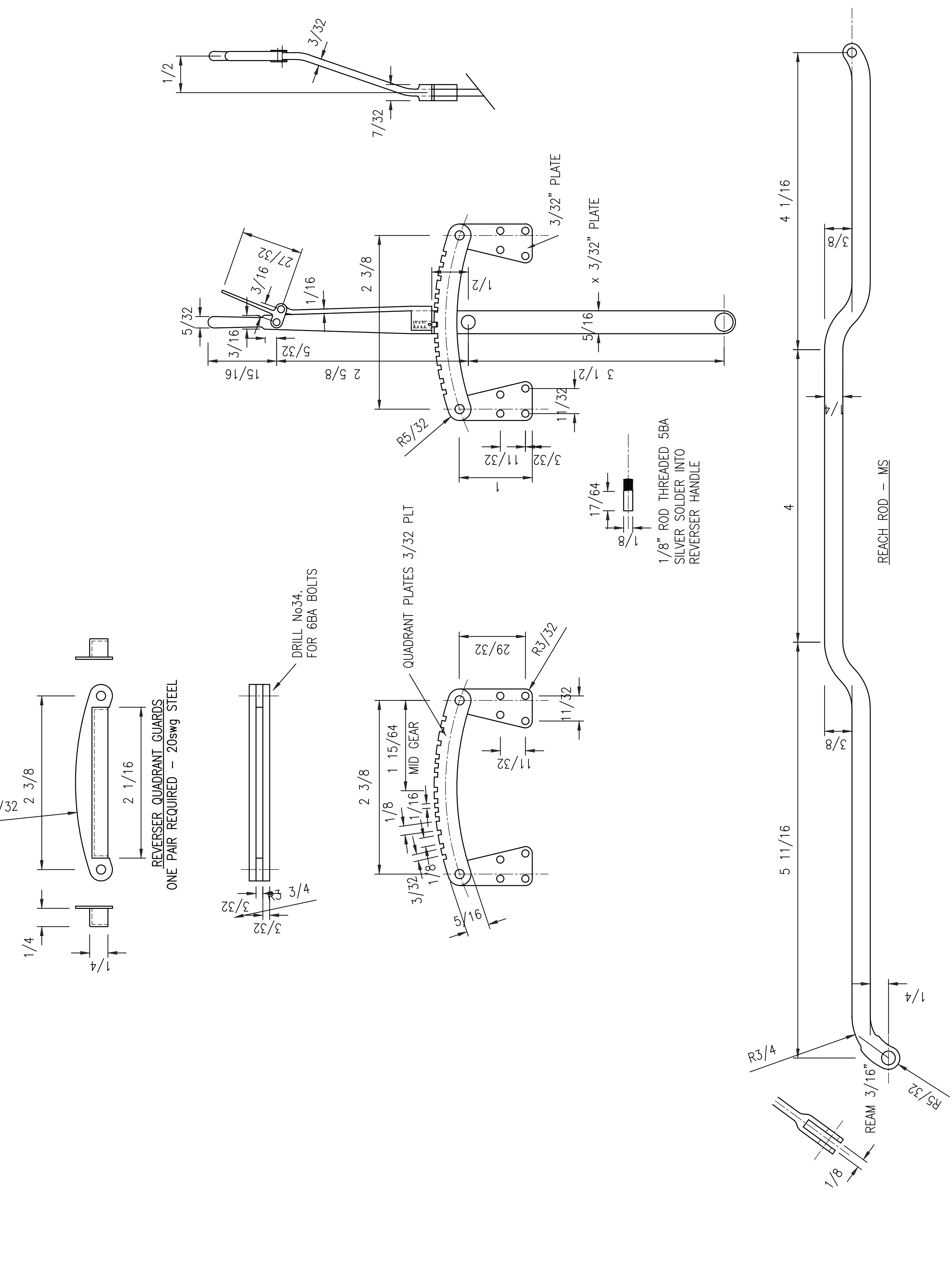


Fig 22

The forked end of the reach rod.

Wrapping up the tank for the lubricator.

Using a specially made plate to get the size and shape right.

Checking the tank is square.

built my original Y4 I used a standard oscillating cylinder LBSC type lubricator which is generally quite reliable. When it was nearly completed (but unpainted) it was in steam at least twice a week as I was building my railway in the garden at the time, so it was always hard at work shifting muck and ballast as everything had to go by rail.

At the time, Jim Ewins had just described making a new type of uniflo lubricator pump in one of the first issues of *Engineering In Miniature* so I made one like that. This was a vast improvement, so it is what I am using here (**fig 23**). It took half the time to make but I have modified it further to do away with the Scotch crank - the cam now works directly on top of the piston with a return spring, as you will see later.

Another very useful feature with this design is that it means that a cross shaft can be used across the tank, allowing a priming wheel to be fitted to the other end. This really is a useful feature as the handwheel can be used to pump some oil into the system when lighting up. When you first open the regulator you get an immediate slug of oil going straight into the cylinders.

Anyway, enough waffle for now. I have shown roller clutches in this design and these can be supplied off the shelf by any good bearing supplier. They generally also stock silver steel rod as well so you can also buy a length of that whilst you are at it. 3 or 4mm (preferably 3mm) will do fine and then you can make the housings to suit. However, I just happened to have a brand-new ratchet mechanism sitting in a drawer so I used that. You therefore have the choice as the photographs and description show the ratchet type and the drawings show the roller clutch type.

For some reason everyone seems to design lubricators with brass tanks but why on earth this should be I have no idea. They are hardly likely to rust away! Steel makes a far better job for taking paint and nothing looks worse than a work worn locomotive with paint chipped off showing bare brass all over.

Anyway, this one is hidden away nicely. Furthermore, there are some disgusting designs around with great lumps of brass prominently displayed on the side platforms (not ‘footplates’ please!) with little attempt to make them look like part of the locomotive or - heaven forbid - that they should ever look anything like a scale lubricator. On a full-size locomotive there will be multiple pumps delivering oil to various parts and on an 8F, for instance, the pumps are set to deliver 2oz per hundred miles and I think most model engineers use that in an afternoon! I spent a day on 9681 on the Dean Forest Railway and was watching the sight feed lubricator as we were on the way up the line. I was quite amazed to see that there was only one blob of oil going up the pipe about every telegraph pole. Furthermore, these cylinders are 17½ inches diameter whereas our little ones are only 1½ inches so think about that.

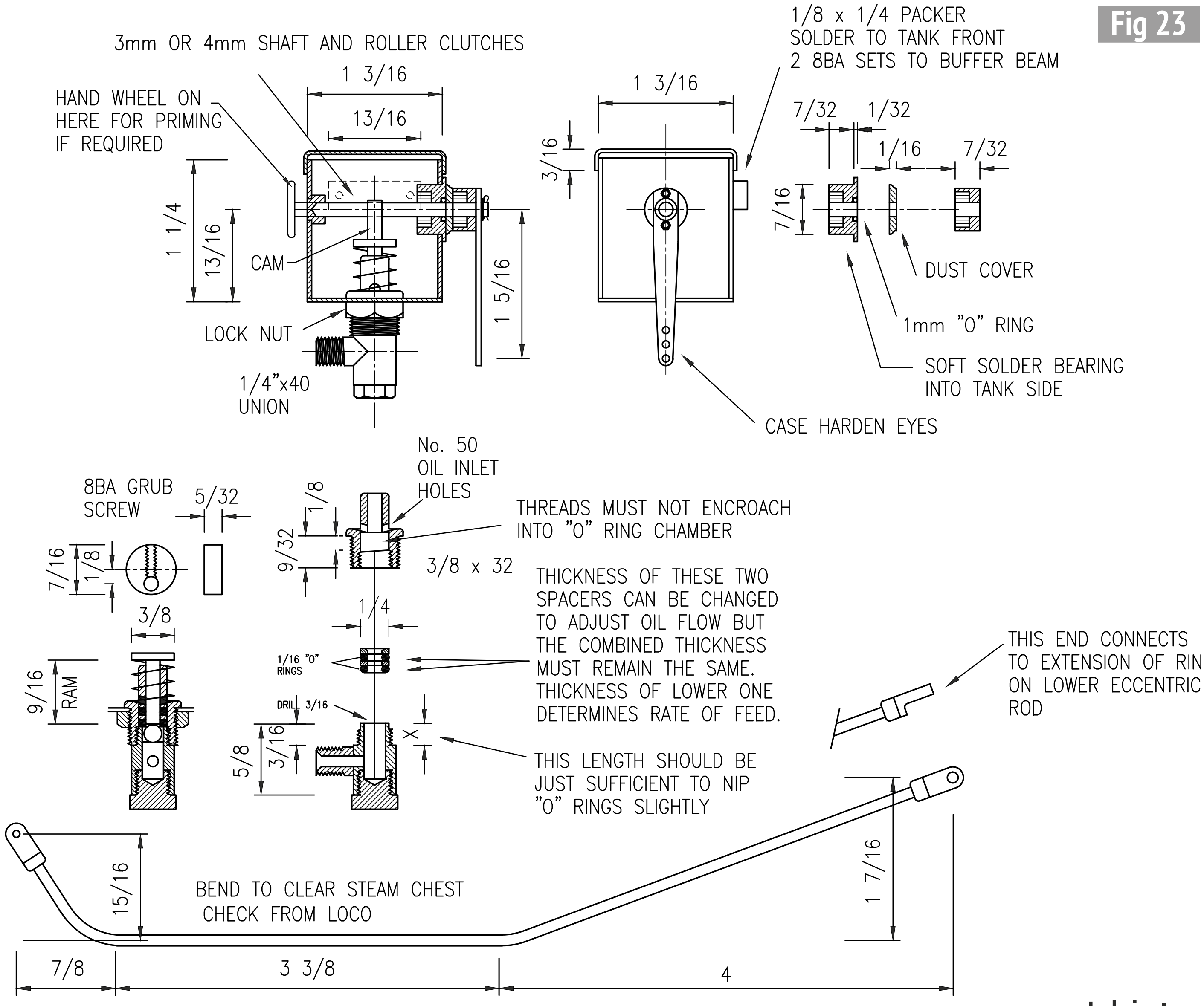
To make the tank you can use 20swg steel plate 1¼ inches deep and $1\frac{3}{16}$ inches square, with a fairly tight-fitting lid. **Photograph 99** shows a Y4 lubricator being made using a piece of ¼ inch round bar to wrap the plate around. I would wrap it round so you get a seam down one side as you wouldn’t really want it where you are going to fit any bushes in it. **Photograph 100** shows the next stage, where I used a specially made plate to form the inside of the tank, and **photos 101** to **103** show the following steps. Next, silver solder the bottom in by leaving a small overlap all around it and then you can file it flush all round to complete the job. In the top you will need a small filler cap made from ⅜ inch tube or similar. **Photograph 104** shows the plate I used for the bottom of the tank.

Now, if you are using the roller clutches you need to make the bosses and the clutches need to be a made a light press fit in the housings. You might also have to grind a small boring tool to make these. They need to be such that you can just press the

Trimming the tank.

Soldering the seam.

Fig 23



Lubricator.

Soldering the bottom of the tank.

clutches in with a good thumb pressure even if it means two or three attempts to get them right. Once you have mastered that, the rest is fairly plain sailing and similar to the ratchet system, except that with the clutch system the arm is bolted to the outer housing.

I began by marking and drilling a couple of holes in the sides of the tank and making some brass fittings for the bearings. These holes must be dead square across the tank, of course, and it will depend on whether you choose to use the roller clutch design or the ratchet. Some ¼ inch brass hexagon is what you now require so centre and drill down No.41 for a depth of about ¼ inch or so. Turn down the outside to 3⁄16 inch diameter for 3⁄16 inch length and thread 3⁄16 x 40. Part off to leave a hexagon head 3⁄32 inch thick. Make another one the same and then chamfer the end of the rod, centre and drill down No.22 to a depth of 5⁄16 inch or so and tap 3⁄16 x 40. Part off a 3⁄32 inch slice, chamfer again and part off another slice. If you now thread a piece of 3⁄32 inch silver steel across through the fittings it should be a nice free fit.

The mechanism I had in stock was for the LBSC type lubricator so the shaft was too short. I made a new one from 3⁄32 inch silver steel rod and if you choose not to buy the complete mechanism you can at least buy a ratchet from one of our various suppliers. They are a good push fit on the shaft, so I pressed mine off the old one and then pressed it on to the new one.

The new shaft for the roller clutches needs to be 1¾ inch long with one end turned down to 0.075 inch for about ¼ inch and threaded 8BA and the other end just needs a hole through for a 3⁄64 inch split pin. For the ratchet mechanism the shaft needs to be 25⁄16 inches long with a similar thread on one end and 5⁄16 inch of 7BA thread on the other. However, it is best to press the ratchet on first otherwise you will ruin the thread. The ratchet needs to be 5⁄16 inch from the end of the shaft.

●To be continued.

NEXT TIME
We'll complete the lubricator.

Steam Turbines Large and Miniature

PART 21

Design and manufacture of blades

Mike Tilby explores the technology, history and modelling of steam turbines.

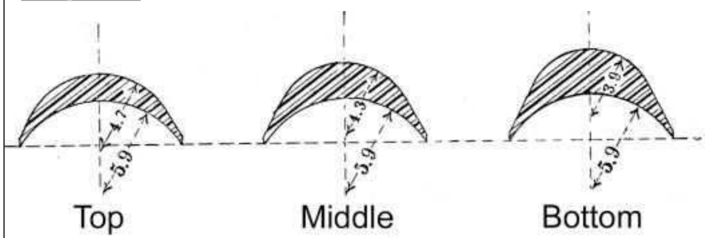
Continued from p.803
M.E. 4626, 22 November 2019

The blades designed by De Laval for his impulse turbines had cross-sections as shown in **fig 75**. This general shape was used for many decades by builders of single stage, multi-stage and velocity compounded impulse turbines and can probably be referred to as the classic form of impulse blade. An approximation to this blade shape has also been adopted by most builders of model bladed turbines.

This basic shape can be varied in a number of ways but, to attain best efficiency, the design details must conform to certain principles. These will be described below. It will also be explained why, in some full-size turbines, it can be impossible to attain an ideal blade shape for all conditions (and why this is especially difficult in model turbines).

To overcome this problem, a new and markedly different form of turbine blade was invented in the 1920's by the Swedish engineer Alf Lysholm. This development was made initially for application to railway locomotives and was later used in Nigel Gresley's famous LMS 6202 (*Turbomotive*). However, the important contributions by Lysholm and the British Engineer Rupert Alexander Struthers to the design of the turbines in LMS 6202 have been completely overlooked in two recent books about this locomotive. The background to and details of Lysholm's invention will be described in the next article, after we have considered the more commonly encountered blade designs.

Fig 75



Cross-sections at 3 positions through the blade of a 20 hp De Laval turbine built about 1905. Dimensions are in mm.

Blades for reaction turbines underwent a gradual development in form but, from the start, their shape was very different to De Laval's impulse blading. As discussed previously, reaction blading does not seem appropriate for model turbines. However, no account of steam turbines would be complete without a summary of what, I think, were very interesting developments in the shape of and the manufacturing methods used for these blades.

Manufacturing methods

Turbine blades have complex shapes, must be very smoothly finished and were needed in very large numbers. These factors posed particular challenges for developing practical methods of manufacture. There are two basic approaches and both were used right from the start, the very first successful steam turbines. One method is to machine blades and rotor out of a solid piece of metal and the other is to make the blades separately and then attach them to the rotor.

For many years now, manufacture of full-sized turbines has made use of sophisticated CNC machining centres and fascinating examples of these in action, cutting individual turbine blades or whole small rotors as can be seen on-line (**ref 70**). Even more recently, additive machining (i.e. 3D printing) has been applied by Siemens to the manufacture of blades.

Back in the 1880's the early Parsons turbines each required many hundreds of very small blades (often less than ¼ inch high) and so it was impractical to make and then attach them individually. In contrast, the early De Laval turbines comprised a single disc with fewer, larger blades. Therefore, it was feasible to make individual blades and then attach them.

»

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Blades of Parson's first turbine, made in 1884 and now in the London Science Museum (image from Science and Society Picture Library).

Small reaction blades

The blades in Parson's first turbine were crudely made by cutting slots at a 45 degree angle into the periphery of the rotor discs (see **photo 56**). Similar slots were cut into the inner edge of half- rings to form the rings of stationary blades. It seems likely that Parsons always realised that straight slots were not ideal but they were a practical compromise. Small turbo-generators made using this method were mainly used on ships, including those of the Royal Navy. An early improvement in blade design, made in 1888, was to undercut the leading edges of the blades with a groove. Then each of these leading edges was bent with pliers to give a slightly curved shape (**photo 57**). This gave a 25% improvement in efficiency. Over 300 turbo-generators of up to 75 kW were made with blades cut from the solid.

Medium sized reaction blades

As the size of his turbines increased, Parsons and his colleagues invented alternative methods of making blades. These developments enabled an accompanying change in shape of the blades. As has been mentioned in previous articles, Charles Parsons had an amazing engineering instinct. An anecdote that demonstrates this very well concerns the choice of shape that should to be adopted for blades made by the new method.

In 1896, during a discussion of this topic, Sir Charles was asked what blade shape would be the best. He thought and then sketched, on a scrap of paper, a shape that he said would have the highest intrinsic efficiency. That shape resembled what we would now call an aerofoil although, at that time, the concept of aerofoil had not been invented and, initially, there was no experimental evidence to support Parsons' belief in his blade sketch.

In the early years of turbine development Parsons devised variations on the same basic shape to suit various circumstances (**fig 76**(A)). That basic blade form remained the standard profile in the Parsons works for over 40 years. During this period, a very large amount of money was spent on research involving a team of scientists to develop improved blade profiles, but the resulting profile differed only slightly from Parsons' early sketch (**fig 76**(B)) and showed only a slight improvement in efficiency.

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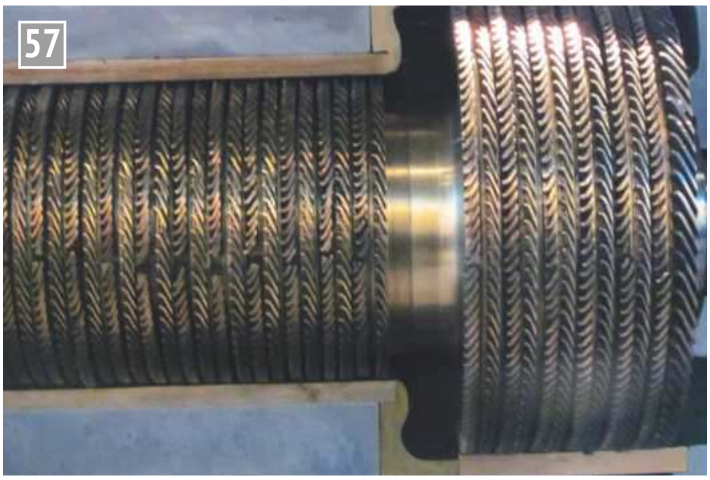
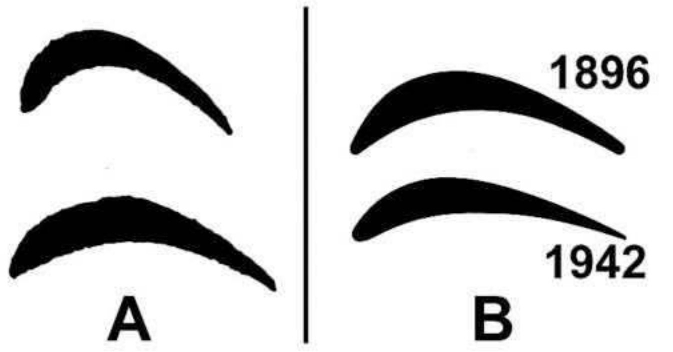


Blades in turbine No. 261 made in 1889 by Clarke, Chapman, Parsons & Co. It was originally installed in HMS Gleaner *and is now in the National Museum of Scotland, Edinburgh (photograph is included by kind permission of the museum).*

Fig 76



A: Two examples of the numerous Parsons blade profiles. These illustrate different degrees of blade curvature and are ink stampings made about 1900 as a record of the actual blade shapes. B: Comparison of the basic profile drawn by Parsons in 1896 with the basic profile of blades as made in 1942.

The blade shop

Manufacture of blades was a major part of the construction of a turbine and, at Parsons, the various specialised processes entailed were located in a large area known as the blade shop. As far as the production engineer was concerned, two key features were of particular importance regarding turbine blades. First was their complex shape and, second, was the prodigious numbers in which they were required. For example, the blades in the turbines powering a single large ship could easily total well over a million.

The first method that was used routinely was to stamp blades out of thin metal. They were formed with the curved shape and with notches and serrations at one end which enabled that end to be securely held in a matching groove machined in the body of the rotor. Later the blade profile was created in long strips of metal by drawing through specially made sets of dies. The strips were then cut up to the desired lengths. Correct gaps between adjacent blades were created by inserting specially made spacer blocks into the grooves in the rotors. The very large number of blades required is illustrated by **photo 58** which shows a small section of a rotor partly bladed by this method and destined for one of the first Parsons' turbines to be installed in Lots Road power station in about 1908 (see part 8). Rolling was also used to prepare the

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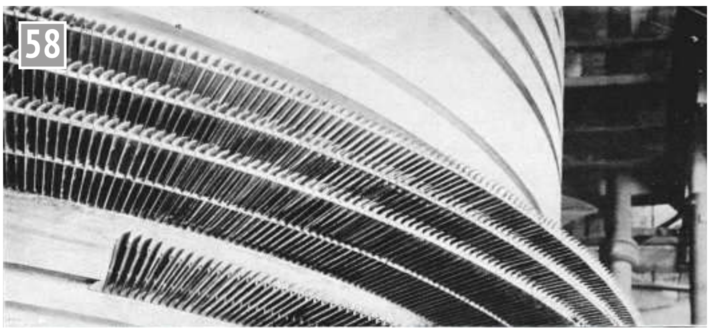

Partially bladed Parsons rotor for Lots Road power station, about 1908.

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Section of Parsons rotor blading photographed from both faces. This was constructed by brazing together blades and spacers cut from drawn strips. The wires that can be seen passing through the blades are lacing wires and were brazed to each blade to improve stability. Note the thinned tips to reduce effects of any rubbing that may occur against the cylinder.

strips prior to drawing and in both procedures special precautions were required because of problems due to the curved tapering edge of the blade form and the need to ensure a good surface finish.

Inserting blades one at a time into the rotor grooves was a very slow process and a major improvement in speed of manufacturing was achieved by assembling groups of blades and spacers in special jigs. This was called the rosary method because the components of each group were held together by a length of wire that was threaded through holes in their bases. Many of these groups could be made while the rest of the rotor was being machined. It was then a much quicker task to insert the assembled groups into the rotor grooves and secure them by caulking.

Photograph 59 shows a group of blades made by a later modification of this process in which the components were brazed together. After carefully cleaning their bases, a group of blades was assembled in a jig and the bases of the assembly were dipped into molten flux and then into molten brass. Later this process was replaced by heating the assembled blades with gas torches and applying brass spelter. Later still, vacuum brazing was used. A few years ago I saw this last method still in routine use at Siemen's (ex-Parson's) Heaton factory in Newcastle but I gather that blade manufacture at those works where it all started in 1889 has now been terminated.

After brazing, the root section of the assembly was finished by milling the bottom and side surfaces. The latter were specially contoured to fit matching grooves around the rotor and all the machining was done on a curvature to match the radius of the rotor groove for which it was destined.

The methods of blade manufacture just described were used for small to medium size blades (up to about 10 inches long). For larger blades completely different methods were used and these will be outlined in a later article. For now, we'll switch to impulse blades.

Impulse blades

Part 6 described how, when Gustav De Laval first made his impulse turbines in the 1880s, he designed the rotor with a thickened hub so as to reduce the stresses that result from the high centrifugal forces generated by high rotational speeds. He also faced the double challenge of making very concave blades shaped as shown in fig 75 and of attaching them to a rotor in a way that could withstand very high centrifugal forces.

To create blades with the correct shape, initially each was made by drop forging. Then an accurately shaped root was machined on the base of each blade so that it would fit accurately and tightly into a matching slot in the periphery of the disc (**fig 77**).

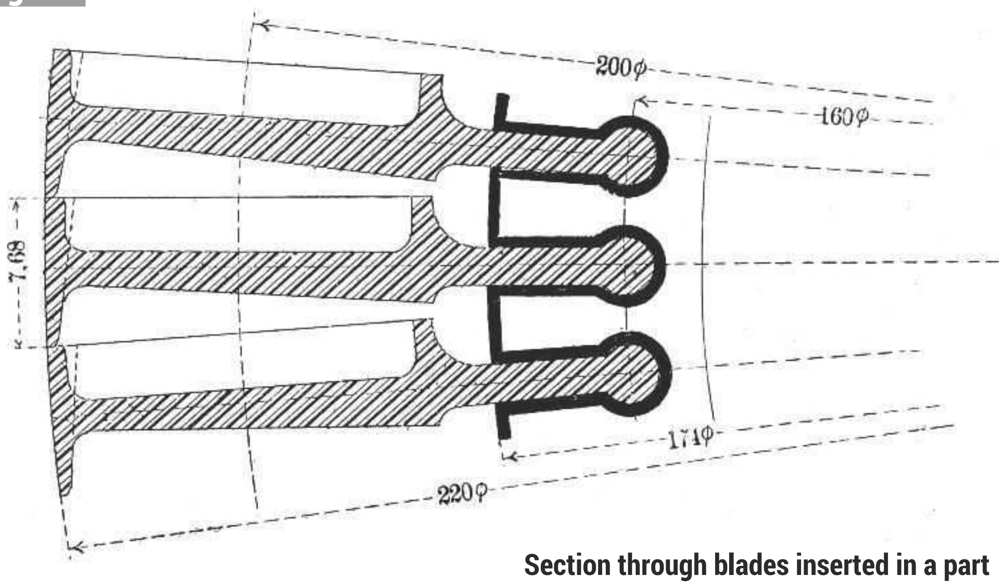
Impulse blade profiles

Maximum efficiency for impulse blades is attained when they cause the steam to change direction with minimal frictional loss of absolute velocity. This requires that smooth flow of steam is disrupted as little as possible by turbulence as it passes around and between the blades (**fig 78**(A)). To achieve this smooth flow it is important that a number of details in the design of the classic impulse blade shape should follow some well-established principles.

Firstly, the inlet edge should be thin so as to present as small a hindrance as possible to the flow of steam. A thick edge causes more turbulence in steam as it meets the blade (**fig 78**(B)). Secondly, the exit edge should also made thin. When the trailing edge is thick, a wake of turbulence arises in the steam (see **fig 78**(C)) and this also reduces efficiency. There is, of course, a limit to the extent to which the blade edges can be made thin because the metal must resist stresses arising from machining processes and they must be reasonably resistant to later damage. Also, as will be described later, some methods used to machine the blades of model turbines place restrictions on the exact shape that can be cut.

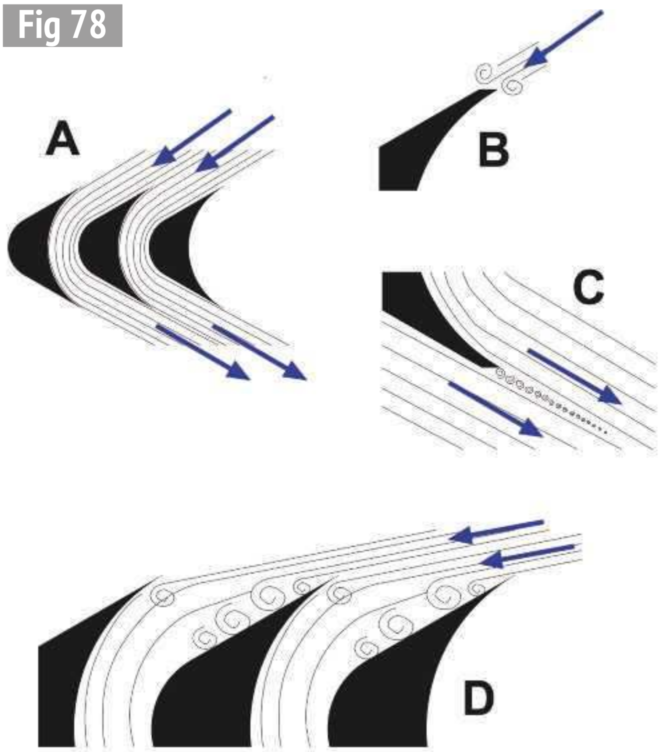
The third design feature (discussed in detail below) is that the surface of the blade at the inlet edge should be as well

Fig 77



Section through blades inserted in a part of the rotor of a 20 hp De Laval turbine made about 1905. The thick lines denote the surface of the rotor. Dimensions are in mm.

Fig 78



Diagrams to show problems with steam flow around impulse blades. A: Ideal smooth flow; B: Turbulence at thick inlet edges; C: Trailing wake at thick outlet edges; D: Turbulence and flow separation resulting from poor alignment of steam flow with blade inlet surfaces.

aligned as possible with the direction of the flowing steam. Poor alignment leads to losses due to formation of turbulence and eddies etc (**fig 78**(D)). Fourthly, the surfaces of the blades should be smooth so as to minimise frictional losses as the steam flows across them (see part 11).

The fifth design feature is that the gap between adjacent blades should be the same at entrance and exit and should either be of constant width along the passage or should be slightly narrower in the middle so as to discourage eddy formation (see part 11). Finally, the width of the gap between blades should be optimal. This last aspect will be discussed in the next instalment.

Alignment of steam flow with the blade surface

This topic warrants some further explanation, especially if the blade shapes developed by Alf Lysholm are to be understood properly. The angle at which steam approaches the plane of a rotor is determined by the angle of the outlet of the nozzle (although there is slight uncertainty about the actual angle of the steam jet because the sloping end of a typical nozzle causes the direction of the steam to change slightly). However, the effective angle at which steam enters the blades is very different to the angle at which steam approaches the plane of the rotor.

When we see things as a typical observer we are stationary relative to the turbine casing and both the blade and the steam are moving but at different speeds and in different directions to each other. In **fig 79**, a very short time after steam leaves the nozzle at point **A** it meets the rotor blades at point **O**. In the same time, point **P** on the rotor also moves to point **O**. The distance **PO** is shorter than **AO** because the blade moves more slowly than the steam. However, if we could view things while sitting on the moving blade the steam would simply appear to flow from point **A** to point **P**. So, relative to the blade, the steam flows from the nozzle along the line **AP.** The distance along **AP** is shorter than distance **AO** and this shows that the steam velocity measured relative to the blade is slower than when measured relative to the nozzle. Also, **AP** is at a different angle relative to the rotor than is **AO**. Since the steam enters the blades along line **AP**, it is the angle between **AP** and the plane of the rotor that matters and with which the blade surfaces at their entrance must be aligned in order to give the smooth flow of steam that is necessary for best turbine efficiency.

Finding the entry angle

The blade entry angle can be determined using trigonometry or graphically using pencil and paper or a CAD program. In all cases lines are used to represent movement, with length of lines being proportional to speed and orientation of the lines representing direction of movement. We start by drawing the black line **AO** (fig 79) representing the steam velocity relative to the casing. We then draw the horizontal red line **AB** representing the velocity of the rotor blades relative to the casing. Then, the dashed blue line **BO** represents the speed and direction of steam relative to the moving blades.

In fig 79 the steam speed is about twice the blade speed. The steam flows from the nozzle at an angle of 18 degrees relative to the plane of the rotor but it enters the blades at an effective angle of 34 degrees. This is the most efficient ratio of blade to steam velocity and so it is unlikely this ratio would ever be exceeded. In fact, for single stage turbines, especially model turbines, the maximum blade velocity is generally much less than half the steam velocity (see **parts 6 and 7**).

If the rotor speed is decreased (or the steam speed is increased), then the effective entry angle changes as illustrated in **fig 80** where the steam is 5.5 times faster than the blades. With the same nozzle angle of 18 degrees, this condition gives an effective entry angle of 22 degrees. If the rotor were stationary the entry angle would be the same as the nozzle angle, so in this example the maximum possible range of entry angle is between 18 and 34 degrees.

Exit angles

Velocity diagrams can also be used to predict the velocity of steam as it leaves the rotor at point **X**. In the examples in figs 79 and 80, for simplicity, we assume the steam does not experience any friction as it flows through the blades. Therefore, its absolute speed is undiminished as it leaves the rotor. We also assume that the blades are symmetrical which means the angle of the leaving edge equals that of the entry edge (although this does not need to be the case) and that the steam flows out at the same angle as the exit edge of the blade. Using these assumptions we can draw the dashed blue line **XC** representing the speed and direction of steam leaving the rotor as measured relative to the rotor.

We can also draw the red line **XD** representing the blade velocity. Then we draw the black line **CD** that represents the steam flow relative to the turbine casing. Figure 79 shows that when blade velocity is about half the steam velocity, the steam leaves the rotor flowing much slower and almost all its movement is in the axial direction. In contrast, when the blade speed is much lower than half the steam speed, it leaves the rotor with considerable velocity and flows largely in the circumferential direction (fig 80), showing that the rotor has utilised only a small fraction of the available kinetic energy.

A good illustration of how impulse blades were designed to match steam velocities can be found in velocity-compounded (Curtis) turbines. The steam slows down as it passes through each velocity stage. Since the blades in all these stages move at the same speed, this causes the angle of the steam path relative to the blade to increase. The blades are designed so that their entry angles increase to match the steam direction, as can be seen in the blade profiles shown in **fig 81**. (In part 20 it was explained that volume flow rate equals velocity multiplied by flow area. Since steam slows down as it passes through the Curtis blades the flow area needs to increase. This was achieved by progressively increasing the length of the blades moving from right to left in fig 81).

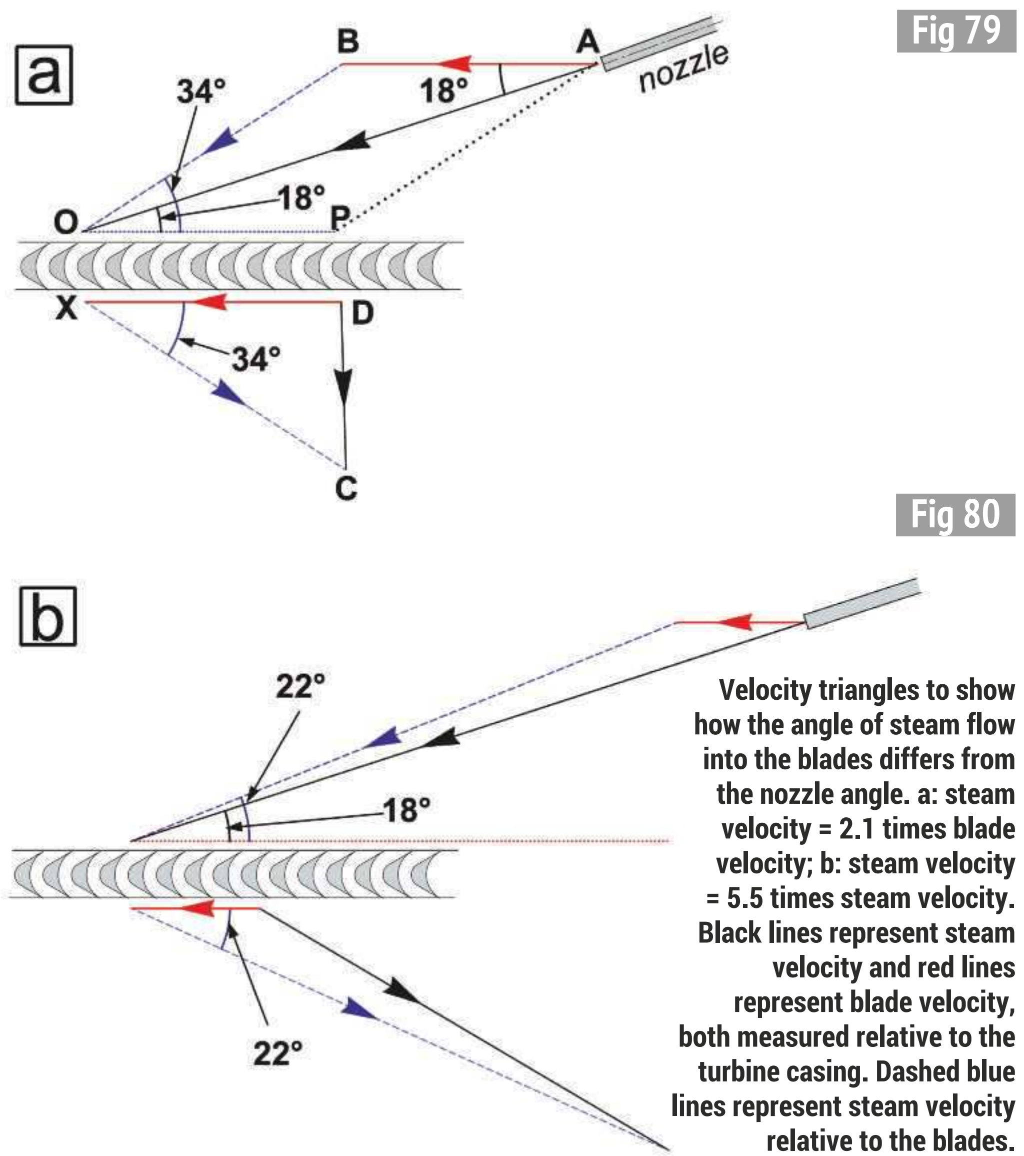
Implications for model turbines

The key point to remember is that the ideal blade entry angle depends on rotor speed and steam speed as well as the nozzle angle. In full size turbines, these speeds are likely to be known to a reasonable degree of accuracy, especially for turbines that spend most time running at a fixed rpm, as in turbogenerators. However, turbines in ships often had to run at a range of speeds and this was especially so in turbine-powered railway locomotives. The situation with model turbines is even worse because, not only do we generally require a range of rotor speeds for model boats and locomotives, but also we are not sure of the velocity of steam as it leaves our nozzle(s) or what rotor speeds will actually be attained when we have built our turbine.

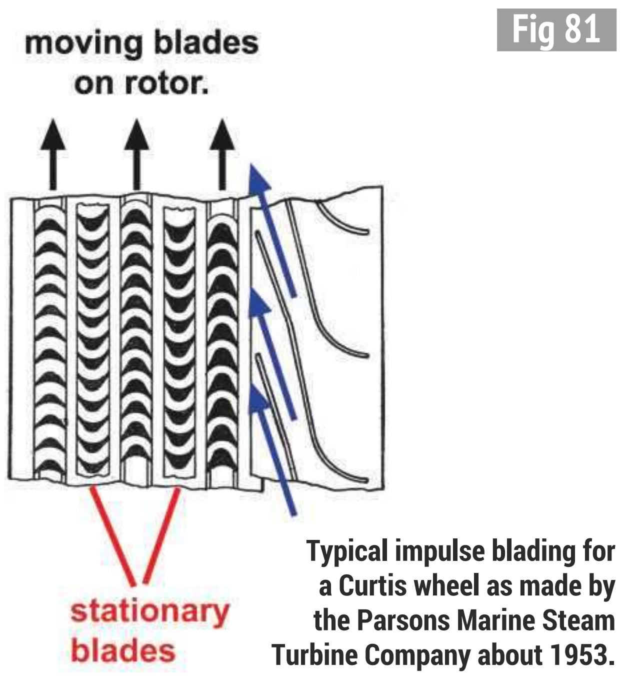
Acknowledgement

I thank Frederick Graham for telling me much about blade manufacture and for casting his expert eye over a draft version of this article.

●To be continued.



Velocity triangles to show how the angle of steam flow into the blades differs from the nozzle angle. a: steam velocity = 2.1 times blade velocity; b: steam velocity = 5.5 times steam velocity. Black lines represent steam velocity and red lines represent blade velocity, both measured relative to the turbine casing. Dashed blue lines represent steam velocity relative to the blades.



Typical impulse blading for a Curtis wheel as made by the Parsons Marine Steam Turbine Company about 1953.

REFERENCE

70. CNC machining of turbine blades: www.youtube.com/watch?v=xZOiNdkJ8SU www.youtube.com/

NEXT TIME

The next article will describe the alternative blade form that Alf Lysholm invented in order to overcome these problems.

CLUB NEWS

Geoff Theasby reports on the latest news from the Clubs.

First of all, I wish to apologise to both John Beddows and John Billard for misattributing the photo of the firebox loo in *M.E.* 4622. John Billard, Editor of Reading SME, took it and not John Beddows.

On visiting Newark recently, for an amateur radio event, we drove past an evocatively-named company, Shed World. Is that not redolent of cobwebby premises full of spades and mowers, or a heated 'Man Cave' equipped with comfortable seats, hi fi and kettle, or maybe a work bench, component stocks and test equipment; a forge, machine tools, welding gear, toolkit for building beach buggies (that dates me!) boats etc. ? A place where one may think, write poetry, music, or, dare I say it, magazine articles?

The piece below about Sheffield SMEE set me thinking. (That's my first time this week and its only Thursday!) Maybe we are perceiving a decline in model engineering because there are no more steam locomotives being manufactured? When there was a huge variety (BR acquired 400 different types on its formation in 1948) we were spoilt for choice. Now, locomotives look like powered coaches with no visible activity. Discuss.

Onwards and Shedwards...

In this issue: Corliss valves, vexed, an exhibition, a popular meeting, a silent knight, an automatic monorail and a Gala.

The Oily Rag, October, From **City of Sunderland Model Engineering Society** has little to report, since no one has submitted an article. Consequently, only Editor, Peter Russell has been anywhere, or made anything - unless, of course, you know better...? Peter visited the Science Museum to see their Corliss valve engine in operation. He is building a model of this type and watching it moving gives him a better idea than studying the drawings. He also visited Bletchley Park, of codebreaking fame, and noticed the amateur radio station there. He was in awe of the aerial - a rotating beam, on a tower. President, Noel Maw was invited to Wylam for lunch with friends. This gave him the opportunity to visit a National Trust property, currently closed. It is very small, more like a croft, but is where George Stephenson was born in 1781. A tailpiece refers us to a YouTube video about '11 mad engines....' starting with the DB605, running, as fitted to the Bf109 of WWII (a very rare engine in the 21st Century) followed by a Napier Deltic in locomotive D9009 and a ship's diesel engine. The other link wouldn't work, so I am still ignorant of how an engineer cracks an egg.

W. www.csmes.co.uk

I visited the National Emergency Services Museum at an off-site location, which could have been much better signposted, in the middle of a huge industrial estate 'somewhere in Sheffield'. Directions were not on the website, but available by personal enquiry. www.emergencymuseum.co.uk A memorabilia fair was scheduled for the same event, which was okay if you collected fire hydrant fittings or helmets.... They also store their spare vehicles there. This 1941 NFS fire tender has a very spartan interior (**photo 1**) but has a great Turk's Head or, more accurately, Monkey's Fist attached to the bell above the cab in an early version of 'Blues and Twos' (that takes me back to my Scouting days and the Ashley book of knots – Geoff). The Bedford turntable ladder dates from 1943, with a Merryweather ladder. Only 50 were made and almost all have GXN or GXM registrations (the location of the Home Office?) and a Bradshaw Electric tow truck also attracted my eye. It is probably used for moving the vehicles around, as it would be impractical to keep them all in charged batteries and fuelled/oiled just to move a few yards. Bradshaw is the UKs biggest industrial electric vehicle maker; their products use lead-acid batteries and current models can tow up to 25 tonnes.

W. www.bradshawev.com

The Frimley Flier, October, Journal of the **Frimley & Ascot Locomotive Club** also has not much to report due to lack of copy. Plans for winter maintenance are in hand so there is no need to be idle, get down to the club site and help! A peeved, not say vexed, Editor, Andrew Douglass, regularly clears the site of scrap and found two tins of paint in the bin. This is not 'scrap', especially when one loses its lid and spills white paint all over the black interior of his car!

W. www.flmr.org

NFS fire tender interior.

Sheffield & District Society of Model & Experimental Engineers' *Steam Whistle* included with the October issue a reproduction of their 1949, 6th Exhibition catalogue (Vice President, J. N. Maskelyne, one judge being E. T. Westbury - both names known to me). It runs to 32 pages! As well as adverts from local engineering businesses, including two lathe makers, several tool suppliers and Percival Marshall, publishers of *Model Engineer*, it refers to its track of 380 feet, then at Mosborough Moor. Among the exibitors are I. Law (who he?) and Arnold Throp. Also included are contributions from the local Aeromodellers' Society, Ship Model Society and Model Yacht Club. In *Steam Whistle* proper, Pete Nash writes of his visit to America to see the restored 'Big Boy', but also of visiting Promontory Point, where the two railway companies, Central Pacific and Union Pacific, met and joined up the first transcontinental route across the US. One of the leading suppliers of rail, he informs us, was Wilson Cammell of Dronfield, making 700 tons per week, each rail marked. Some of it still exists on the Nevada North Railway, now a tourist railway in a former copper mining area.
W. www.sheffieldmodelengineers.com

On Track, October, from **Richmond Hill Live Steamers**, has this rather different aspect of a locomotive view; Gary Lewellyn seen through the 'Electric Henge' atop his 1950s Fairbanks-Morse GF-6C of which only 59 were ever made (**photo 2**). https://www.youtube.com/watch?v=RbvWbn0R-Po It is hauling forty-five 80 ton wagons, that's 3,600 tons! Its horn would not be out of place on a ship (see 4½ minutes in). The club has been given a BR lamp in memory of David A. Churchill.
W. www.richmond-hill-live-steamers.tripod.com

I have received, via the Newcomen Society, the Engineering Heritage Australia magazine for September. Items include the Melbourne Suburban Railway electrification, a review of the Timber Truss Bridge Book. There were once 420 such bridges in NSW alone. This is followed by an account of the building of the concrete Gladesville bridge, Sydney. When opened in 1964, it was the longest such bridge in the world. It also includes an article on Lighting the Streets with Electricity, covering several Australian cities. Then an item on Honeysuckle Creek communications station, near Canberra, set up specially for the moon landings. https://www.engineersaustralia.org.au/Communities-And-Groups/Special-Interest-Groups/Engineering-Heritage-Australia/Previous-Magazines

St Albans & District Model Engineering Society, October *Newsletter* has gone paperless! Only electronic copies will be published from now on. Its appearance is rather fine, lots of white space, pale blue type for emphasis and a grey background for some items. A recent club night produced over 40 attendees, more than many meetings heretofore. The club exhibition went well, with 122 responses to a questionnaire issued to visitors. This is very gratifying and they are now being analysed. Then follows an uncommon item, 'An introduction to Facebook' - a simple guide to getting set up as a FB-er. It's not the devil incarnate, nor will you be led astray if you are sensible. A mystery object previously pictured has been identified and a short video exists. https://www.youtube.com/watch?v=GqS3LNI3H3M&feature=youtu.be Beware of backgrounds! No prizes but for the adulation of an admiring audience...
W. www.stalbansmes.com

Grimsby & Cleethorpes Model Engineering Society sends *The Blower,* September, from which I see that I missed the Garden Railway Show in Elsecar. I do not receive missives from this fraternity, for some reason. I should be more proactive. Editor, Neil Chamberlain provides an item on matters which often go unremarked, planning for the Annual Gala, which begins at least four months previously and covers safety, emergency services, noise, lost children, litter, evacuation, etc., not to mention a flypast, which needs a year's notice and airspace clearance too. Then, publicity, printing, catering and so on. All done in spare time, after work or by neglecting model making! So, Thank You. The *actualité* was a great success, hot and sunny all through and results are expected to be favourable. The flypasts were by a Dakota and a Spitfire, on different days. The Lancaster was booked, but its take-off was delayed by fog, as it was overnighting in Wales. Uncle Wainwright sold over £1,000 worth of goods raising £207 for the club. After the Gala finished, a swift half of lemonade was called for so a small convoy set off for the House of Easement, with a fine roller leading the way. Steve Cooper was invited aboard and took this fine shot from his privileged position (**photo 3**).
W. www.gcmes.com

Electric henge. *(Photo courtesy of Amy McLellan.)*

Ryedale Society of Model Engineers, September *Newsletter* reports that the 1st September meeting was offered 'showers' in the weather forecast. Several people were caught unawares when seemingly the UK's entire rainfall for the day landed on Gilling! A week later, the steaming bays were full but passengers were there none. Adlestrop revisited!

Pilot's eye view from a steamroller. (Photo courtesy of Steve Cooper.)

1943 Austin turntable ladder.

A photo from the Mainline Rally shows half a dozen spectators seated and just watching. Is this some sort of Holiday Camp? Later in the month, a group of bikers arrived and took tea with the membership. A gentleman who did driver training now wants to volunteer. He has no locomotive, but does posses a 1909 Daimler with a Knight double sleeve valve engine. A useful idea, the 'Silent Knight', but disposing of the extra heat limited its development in terms of increased power output. Editor, Bill Putman requests more copy, either e-mail him or accost him at the club with thy mighty tomes. ('Twas brillig and the mighty tomes did thus assemble in the Clubhouse – Geoff)

W. www.rsme.org.uk

Plymouth Miniature Steam's *Goodwin Park News,* Autumn, says club locomotive *Hernia* broke a piston rod so they have been lent a Class 66 by Plym Valley Railway for as long as is required. What generosity and neighbourliness! Tim and Max Symons write on the Birth of the Wickham Trolley. Not the 'real' one but a 7¼ inch gauge version for young Max, inspired by the Ride on Railways version. Tim should have checked earlier, but was lucky in that it fitted in his car with one inch to spare... At a local fete, the portable track gave a ride to Blackmore Vale Brass, 'Band on the Run' says author Anne Malleson.

W. www.plymouthminiature steam.co.uk

P*rospectus*, October, from **Reading Society of Model Engineers**, relates that Editor, John Billard and members visited the private Spinney Railway, a 7¼ inch gauge track in Surrey. Track circuits, deep tunnels, branch lines and full interlocking from four signal boxes! David and Lily Scott, in a tour of the North, called at Polly Models for a look round. They noted the warm family atmosphere and picked up some goodies for David's 'Jinty'.

W. www.prospect parkrailway.co.uk

City of Oxford Society of Model Engineers' *CoSME Link,* autumn, says that Secretary, David Price was very pleased and surprised at the success of the new extension. He was closing up the site one day when the last of the visitors departed. "Quick now, or you will have to stay until next week". "Sorry, I can't do that, as I am flying home to Kathmandu tomorrow!" There's no answer to that. The Dreaming Spires Rally brought 23 locomotives from 16 clubs over three days. The Tanat Valley Railway near Oswestry has the collection of one gentleman, now residing in a home, of industrial monorail equipment intended for temporary use on building sites etc. Some locomotives, powered by JAP, Simplex, BSA or Lister engines, are driven but some have a simple automatic stop mechanism at each end of the track. Thus, a train of bricks, concrete mix etc. can be despatched to stop without further action at its destination. Ian Varty has driven some of these locomotives and says that the ride - with no suspension of any sort and the inevitable damage caused by its very temporary and oft-relocated use - was spine-jarring, nay, injurious. I have written before of seeing this type of railway in use during the construction of the Aire Valley main sewer in the 1950s or '60s.

https://www.irsociety.co.uk/Archives/16/Monorail.htm W. www.cosme.org.uk

More fire appliances for pyromaniacs, this is an Austin K2 with Merryweather turntable ladder (**photo 4**) and here is Wentworth Woodhouse's fire pump trailer. Note the extinguisher on the wall, in case it catches fire... (**photo 5**).

And finally, I showed my Facebook feed to my psychiatrist. He wants to talk to all of them.

Contact:
gefftheasby@gmail.com

Wentworth Woodhouse fire pump trailer.

DIARY

DECEMBER

22 Newton Abbot & District MES. Running day at Lindridge Hill. Contact Ted Head: 07941 504498.

22 North Wiltshire MES. Public running, Coate Water Country Park, Swindon, 11am-dusk. Contact Ken Parker: 07710 515507.

22 Rugby MES. Public running 3-6pm – visiting locos welcome with boiler certificate. More info. at rugbymes.co.uk.

22 Tiverton & District MES. Running day at Rackenford track. Contact Chris Catley: 01884 798370.

24 Romney Marsh MES. Members' social afternoon, 2pm. Contact Adrian Parker: 01303 894187.

26 Sutton MEC. Boxing Day run, 10am-4pm. Contact Paul Harding 0208 2544749.

27 Bradford MES. Mince pie steam-up, 11am until frostbite sets in, Northcliff track. Contact: Russ Coppin, 07815 048999.

29 Newton Abbot & District MES. Running day at Lindridge Hill. Contact Ted Head: 07941 504498.

29 North Wiltshire MES. Public running, Coate Water Country Park, Swindon, 11am-dusk. Contact Ken Parker: 07710 515507.

JANUARY

1 Plymouth Miniature Steam. Members' day, 10.30am onwards. Contact Rob Hitchcock: 01822 852479.

3 North London SME. Members' videos, slides and photographs. Contact Ian Johnston: 0208 4490693.

7 Romney Marsh MES. An evening with Andy Nash, 7.30pm. Contact Adrian Parker: 01303 894187.

8 Bradford MES. Bits and pieces evening, 7:30-10pm, Saltaire Methodist Church. Contact: Russ Coppin, 07815 048999.

8 Brandon DSME. Meeting at The Ram Hotel, Brandon, 7.45pm. Contact Mick Wickens: 01842 813707.

8 Leeds SMEE. Members' current projects. Contact Geoff Shackleton: 01977 798138.

15 Bristol SMEE. Talk: 'TSR2, the Grandfather of Tornado' – Jock Heron. Contact Dave Gray: 01275 857746.

14 Romney Marsh MES. Members' social afternoon, 2pm. Contact Adrian Parker: 01303 894187.

17-19 London Model Engineering Exhibition, Alexandra Palace. See www.meridienneexhibitions.co.uk/events/london-model-engineering-exhibition

21 Romney Marsh MES. Talk: 'The Silver City Story' – Paul Ross, 7.30pm. Contact Adrian Parker: 01303 894187.

22 Leeds SMEE. Meeting night – 'The First Train in Spain from Warrington' – Richard Gibbon. Contact Geoff Shackleton: 01977 798138.

28 Romney Marsh MES. Members' social afternoon, 2pm. Contact Adrian Parker: 01303 894187.

FEBRUARY

4 Romney Marsh MES. Talk: 'Judging Models at Exhibitions' – Harry Paviour, 7.30pm. Contact Adrian Parker: 01303 894187.

5 Brandon DSME. Meeting at The Ram Hotel, Brandon, 7.45pm. Contact Mick Wickens: 01842 813707.

5 Bradford MES. Film evening, 7.30pm, Saltaire Methodist Church. Contact: Russ Coppin, 07815 048999.

5 Leeds SMEE. Meeting night – 'Drill Sharpening' – D.A.G. Brown. Contact Geoff Shackleton: 01977 798138.

11 Romney Marsh MES. Members' social afternoon, 2pm. Contact Adrian Parker: 01303 894187.

15 Brandon DSME. Running day. Contact Mick Wickens: 01842 813707.

18 Romney Marsh MES. Talk: 'Narrow Gauge Railway Visits' – Mike Jackson, 7.30pm. Contact Adrian Parker: 01303 894187.

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