PERSONAL INTRODUCTION

As a young boy living in a small village in the southern half of Catalonia, I used to spend time playing with friends near the railways tracks and watching trains passing along. For some reason, trains always fascinated me, and although the steam era was already over during my entire childhood, I later on developed an admiration for steam locomotives and everything steam related. As a young adult, I obtained an university degree on Industrial Engineering and I have since worked in that field. Already approaching my 50's, I introduced myself into the world of live steam and soon started with a steam locomotive project. Now, it’s a pleasure to present this steam pump to all the live steam enthusiasts like me.

A STEAM OPERATED FEED WATER PUMP

The proposed project is a modular design of a double cylinder, steam operated pump for water feed of miniature locomotive boilers. It’s based on the old Van Brocklin duplex pump concept, but redesigned from the ground up with some innovative features and 3D drawn from scratch in metric units. It is suitable for large size 5” gauge and medium sized 7.25” and 7.5” gauge locomotives.

THE PUMP

The finished pump is shown in **Photo 1**. A section view illustration, showing the internal parts is represented in **Illustration 1**. The pump most important features are listed next:

Design:

- Modular design. Individual parts can be made based on standard tolerances by a team of people or ordered to a CNC service. No difficult adjustments or special tooling are required during assembly.
- Easy to make. In order to support a cleaner design and be easier to make and assemble, the pump is designed with an increased number of individual parts, rather than less parts that are more difficult or trickier to produce.
- No soldering skills required. The pump assembly is all screwed, so no special skills are required.
- Reliable static sealing. Sealing between parts is performed with commercially available Aramid type gaskets or FKM o-rings.
- Scalable. The pump is currently presented to a particular size, but it is easily scalable to a bigger or a smaller size thanks to its highly modular design.

Pump features:

- Self starting. It does not get stuck due to the presence of water condensates.
- Guided ball valves. Balls in water check valves are guided and have limited travel. This enhances repeatability, and prevents ball rebounds or valve action inconsistencies.
- Ceramic ball valves. The pump uses lightweight Silicon Nitride balls for quick action and precise ball seating.
- Off the shelf, commercially available, piston and rod seals. The use of standard PTFE based hydraulic components, makes it long lasting, and easier to maintain.
- Little or no lubrication required. Thanks to the use of PEEK HPV plastic polymer for the steam valves, the pump can run reliably on saturated steam or moderately superheated steam with little or no lubrication.

Cons:

- Its particular design, and the choice of the early Van Brocklin concept makes the pump taller than equivalent ones of the same piston size and stroke. This may or not be an inconvenience depending on whether the intended use is prototypical or just functional.
- No special effort has been put on prototypical looking features such as special bolts or the

presence of particular cosmetic features. The pump is essentially presented as a functional unit only.

PART GROUPS

All the parts involved on the making of the pump except the gaskets and commercial items are shown in **photo 2**. The pump also require several commercial items that are shown in **photo 3**.

I organized the construction of the pump in several sets of parts that I assembled separately where appropriate before mounting them together. In particular, I considered the following groups:

1 - Water valves.
2 - Water cylinders.
3 - Steam cylinders.
4 - Steam valves.
5 - Pistons and Actuators

These are represented in **Illustration 2**. In the following sections I will disclose the relevant details as well as important tips for the making of the pump parts based on these groups. Finally, there will be a section on the final assembly and the operational aspects of the pump, and a section for the testing of the pump.

THE PLANS

Over the length of the article the full set of 2D plans with dimensions and annotations will be provided. Exploded views showing only the relevant parts for each group, as well as partial part lists with the items involved, will be available too.

I used the ISO drawing standard for the original plans, but I was happy to adapt them to the magazine conventions for as much as possible. Some features of the original drawings still remain that I think is worth to comment. The most apparent one is the keeping of ISO Shaft and Hole tolerances. For simplicity, I only used "h7" and "H7" tolerances. For those who are not familiarized, "h7" specified on a shaft means that its diameter can be undersized between the exact dimension to around -20 microns. "H7" on a hole means a diameter that is oversized from the exact dimension to about +20 microns. In practice this usually implies a slide fit or a slight push fit for the cylindrical matting surfaces.

WATER VALVES

Table 1 is the components list for the Water Valves group, including the required commercial items. **Figure 1** is an exploded view of the Water Valves assembly. **Figures 2 to 10** are the full set of 2D plans for the custom parts in this set.

As materials, I used leaded gunmetal in suitable 12 mm thick bar form for the Inlet and Discharge Blocks and the Inlet Manifold. I also used standard grade 1 mm and 3 mm thick brass sheet or bar for the Spacer Sheet and the Top Cover. I made all these parts on a small manual mill with DRO. The valve seats require a lathe.

The housings for the balls in the Inlet and Discharge Blocks are quatrefoil shaped and they consist on a central bore with a diameter 0.5 mm bigger than the ball diameter, and 4 machined lobules around it. This keeps the ball fully guided when it moves up and down. The four semi-cylindrical lobules allow water to pass freely around the ball.

It is best to machine the Inlet and Discharge Blocks from the bottom side, ie mounted upside down on the mill (**Photo 4**), and to make all the holes and geometry in a single setup before turning over the blocks to machine the water passages on the upper side. This is done to make sure the ball seats remain perfectly aligned with the ball housings. It is also important to keep the location of the water passages in mind at all times to prevent undesired interference with other part features and to avoid internal leaks or malfunctioning. By strictly following the dimensions on the plans, this should not be an issue.

The Ball Seats are designed to be replaceable parts that are inserted at the bottom of the Inlet and Discharge Blocks. Each seat require two 10 mm OD x 1 mm thick o-rings (total 16) to create a static seal between the matting parts (**Photo 5**). The upper o-rings seal radially against their pocket in the Ball Blocks, and the lower o-rings seal axially against the part immediately below, i.e the Spacer Sheet or the Inlet Manifold. The o-rings can be either Nitrile or FKM although I tend to use only the latter as a matter of material standardization for all my o-ring needs. **Photo 6** shows the Ball Seats already inserted on the Inlet Block.

Gaskets were made from an automotive grade, 0.5 mm thick Aramide fiber gasket material. They can be ordered already cut to size to an automotive aftermarket parts supplier, or machined sandwiched between fiberboard wood panels on a mill in the usual way, or simply cut them to size by hand based on the already machined parts. In the later case, it's easier to drill first all the holes on the mill and then cut the external shape to size with a sharp cutter by using the metal parts as patterns. My particular approach was mixed and I found to get similar results with any of the methods. **Photo 7** shows the Spacer Gasket in place, as well as the Spacer Sheet ready to be put on top of it.

I chose Silicon Nitride ceramic balls for the water valves instead of the usual Stainless Steel because they are lighter, stronger, and less prone to surface scratches. Ceramic balls are reported to be more fragile to strong sharp impacts than metal ones, but I found that breaking them is extremely unlikely, and this will not happen in the conditions of the pump. The balls for the water valves are 7 mm diameter and I found them on eBay. Before final assembly, balls should be carefully pressed against their seat to guarantee a perfect seal in their close position. I used a vice for that operation, as I feel it gives you more control about the applied pressure, but I have seen this being done by giving the balls a sharp hit with a plastic hammer.

For clarity purposes, screws were not listed on the table of parts as I thought I could just make a brief mention of them on this description text. So I used regular A2 stainless steel M3 socket cap screws for that. I initially specified M3x16 for the Top Cover, M3x12 for the Inlet Manifold and M3x25 for the Inlet Block, however during assembly I found safer to extend a bit the length of the ones packing it all together, so I used M3x20 mm instead that I did cut to size, approximately to 18 and 14 mm respectively for the Top Cover and Inlet Manifold, as they were not standard available lengths. **Photo 8** shows a partial test assembly of the Water Valves. A detail of the full assembly will be presented on the final assembly section.

The Water Inlet and Discharge ports are specified on the drawings to suit German model engineer M8x0.75 metric fittings, but of course nothing prevents us to make them to imperial sizes. The most suitable replacement size is possibly 5/16" x 40 tpi, but I shall leave that to the reader discretion and needs.

WATER CYLINDERS

On **Table 2**, I represent the list of parts that correspond to the Water Cylinders group. **Figure 11** is an exploded view of an assembly of the same.

The different parts can be made out of solid block of leaded gunmetal bar or rod of a suitable size. The full set of 2D plans are presented in **Figures 12 to 17**.

I ordered the external shape of the Water Cylinders Block to a CNC service and then added all the remaining features on my manual mill with DRO. The external dimensions are 32x32x64 mm, so this is the amount of material required. The kidney shape of the Block is optional really. I just designed it that way because it was not more complicated to make, once I decided to use a CNC service for that, and it also lightens a bit the set. However, nothing prevents us to leave the back face flat, or to replace the round shapes by 45º chamfers for easy machining, or even leave all sides flat with a totally rectangular shape for the part. The later approach would be really easy and the same plans would still apply because all dimensions would remain referred to geometric features that will still be present.

One important thing to consider is that the two cylinder bores must be machined at a very precise distance between them, because this is a fundamental dimension that aligns the water and steam cylinders on the final assembly. **Photo 9** shows the Water Cylinder Block clamped on the mill and ready for the final threading operations.

I also ordered the Water Cylinder Flanges and Covers to a CNC service. They are not particularly difficult to make on a lathe and a mill with divisor plate or XY coordinates. There is a couple of tricky aspects that is worth to mention though. The housings for the Rod Seals on the back side of the Water Cylinder Flanges do not leave a lot of room for the other side cuts that match the Water Cylinder Block water passages. This aspect may not be that obvious by just looking at the plans, but it is important to keep that in mind to avoid perforating the part.

The diameter and depth stated for the Rod Seals housings on the plans must be fully respected as this is based on the seal manufacturer specs. The proposed type of seal, and the proper way to insert them in place, including the making of a simple tool for that, will be disclosed at a latter stage, in the context of the final assembly section.

The Water Cylinder Covers and Flanges must be made a slide fit in the Water Cylinder Block to facilitate assembly. Gaskets can be made according to the suggestions given for the Water Valves. **Photo 10** is a test assembly of the Water Cylinder Flanges into the Water Cylinder Block. The screws for the Water Cylinder Covers are M3x8.

STEAM CYLINDERS

The group of parts for the Steam Cylinders are listed in **Table 3**, and shown in an assembly exploded view in **Figure 18**. As with the Water Cylinders, I made all the metal parts from leaded gunmetal bar or rod. The construction plans are in **Figures 19 to 24**.

To make the Steam Cylinders Block I started from a piece already cut to size by a CNC service with the kidney shaped contour. As with the Water Cylinders Block, this particular shape is entirely optional and the part can be made totally flat on the back side, or chamfered at 45 degrees instead of rounded.

The steam cylinder bores were made with a boring tool in the usual way. Perfect surface finish and diameter is important to prevent premature wearing of the piston seals, but the commercial seals being used are relatively tolerant on these aspects, and the boring operation is thus not as critical as it may seem as long as it is performed to a relatively good standard.

The pump works by cycling steam input to the four possible admissions of the two steam cylinders. The steam valve on top of the left cylinder actuates on the right cylinder and vice-versa. This requires a number of steam passages traversing the block to reach the opposite cylinder, and they must not interfere each other. As this can be tricky to figure out, I think it is worth to dedicate some additional lines to them:

Illustration 3 shows the proposed location of all the steam passages which will meet the desired requisites. I colored light blue the exhaust passage, and used four additional colors ranging from red to purple to show all the admission passages. Drill holes must be performed on all the block faces at defined locations and depths, which will ultimately meet to create the desired passages, as can be seen on the section views of **Figure 19**. After drilling, the extra holes will need to be closed and sealed, but this will be discussed in the context of the final assembly section. For now, a short length of M2.5 thread can be performed on them, which will allow sealing with M2.5 set screws and sealing paste.

I recommend to start by drilling the exhaust passage and all the passages at the top level, as shown in Section T-T. After that, continue with the lower level passages as shown in Section U-

U. Finally perform the passages connecting both levels as shown in Sections X-X, V-V, and W-W. The inclined section of the Yellow colored passage at the lower level is easier to drill after machining the admission ports at the cylinder ends, and this one is the only exception. For the other passages, it is best to drill them prior to machining the cylinder ports, because otherwise it would not be possible to use a centre drill to spot the right drilling points. **Photo 11** shows the setup I used to perform the inclined passage. The block was clamped at approximately 30º and since this is not a particularly crucial angle I just used a triangle tool to approximately position the part on the vice.

The remaining operation to be performed on the Steam Cylinder Block is the machining of the slide valve ports. Special care must be taken to make sure they are machined at the exact centre of the block width.

Finally, a last flattening pass over the steam ports, ideally with a facing blade tool, is strongly recommended to remove chances of leaks on the steam slide valves (**Photo 12**). This operation can be done at this time or can be delayed as part of the final assembly.

I ordered the Steam Cylinder Flanges and Covers to a CNC service according to the planned tolerances. They are not particularly difficult to start on a lathe and finish on a mill with coordinates. A partial assembly test should be made at this stage to check that these parts are a slide fit into the cylinder bores.

As previously, gaskets were made from automotive grade, 0.5 mm thick Aramide fiber gasket material. The required screws for the Water Cylinder Covers are M3x8.

STEAM VALVES

Table 4 is the components list for the Steam Valves group, including the required commercial items. **Figure 25** is an exploded view of the corresponding assembly. **Figures 26 to 32** are the 2D plans for the making of the parts.

It is best to start with the making the Steam Chest Block and Steam Chest Cover. **Photo 13** shows the early machining operations on my mill and **Photo 14** shows the finished parts. There's no special consideration on that except that dimensions and centers must be carefully respected. Particularly, the inner hollow distances and centering of the steam chest in the actuator rod direction (24 mm dimension on the plans) are of crucial importance because that determines the ultimate travel of the steam valve. Also, the side bores for the actuator rod must be perfectly centered on the height of the steam chest block to fully enable pump modularity, for example if you want to swap the position of the steam inlet. I specified M8x0.75 for the inlet port, but this can be replaced by an imperial sized thread if required.

I made the actuator seal cover, shown in **Photo 15,** out of a small cut of 2 mm thick brass sheet on my mill, included the round edges that I machined by holding and rotating the part from the centre. **Photo 16** shows the procedure I used. That is a way not to be generally recommended, but it worked for me with the tools I had at the time. If you ever need to do that, just make sure you are not climb milling the part to avoid getting trouble with the cutter forces wanting to pull the part out of control.

The Steam Slide Valves and and Steam Valve Clips work together to provide adequate distribution and sealing of steam while the pump is operating. **Photo 17** shows them together. The Slide Valves are held in place by the Valve Clips which in turn are driven by the Actuator Rods. The Actuator Rods have a diameter recess that coincides with the length of the Valve Clip, where the later is mounted. The Valve Clips must be a slide fit with both the Actuator Rods and the Slide Valves for the system to work smoothly. In particular, the Slide Valves must be free to move against their matting surface on the Cylinder Block, so that they take advantage of the steam pressure for sealing, and adapt as they get some wear. When assembled, the Steam Chest Cover prevents the Valve Clips from getting out of their place. This particularity will be discussed in more detail during the final assembly stages.

I chose PEEK HPV material for the Steam Slide Valves. This is a bearing grade plastic capable of high temperatures and with low friction coefficient. I purchased it online from davis-plastics.co.uk in the UK. They provided an excellent service and were able to cut a short length of 20 mm diameter rod for me. **Photo 18** shows the received item, and **Photo 19** shows the final milling step of the Steam Slide Valves made of that material, which was performed during final assembly.

The Steam Valves group also has two identical gaskets made in the usual way. On the final assembly, this will be all secured on the Steam Cylinder Block with M3x20 socket cap screws.

At this stage, a test assembly is worth to try. **Photo 20** shows most of the parts for this group in place, just on top of the Steam Cylinder Block. The Actuator Rod Seals are not yet mounted to make things easier at this step. The Actuator Rods are inserted from the sides of the steam chest. The Slide Valves are left free on top of the Cylinder Block, and clipped to the Actuator Rods with the Valve Clip parts. The Valve Clips are inserted from the top of the Steam Chest Block, and thus the Steam Chest Cover prevents them to lift off. The travel of the Steam Valves can be checked at this point by slightly pulling and pushing the Actuator Rods. The end of travel is defined by the Valve Clips hitting the inner walls of the Steam Chest Block, and this must coincide with the Steam Valve fully opening the steam ports on the Cylinder Block at each end of travel.

PISTONS AND ACTUATORS

In **Table 5** the list of components for this group is presented. On **Figure 25** the same components are presented in an exploded view of the corresponding assembly. In this case the assembly drawing shows only one of the sets required, however, two identical ones must be made to complete the pump. Also, due to the way the drawing software autogenerated the list of items for this assembly, the item quantities appearing on the table represent only half the quantities required for the pump. This is important to be aware of when reading the plans. **Figures 33 to 40** are the 2D plans for the said parts except the required commercial items.

As I did with previous items, I ordered the parts requiring a lathe to an external CNC service. On this group, the ones requiring more care are the Cylinder Spacers. They need to be made with accurate concentricity because they are responsible for the ultimate centering of the water and steam cylinders. Also, the relative position of the flange holes must match the position of the slot feature for the Actuator Arm.

Although I did not make the Cylinder Spacers myself, I would start by turning all the inner and outer cylindrical features with the part held on the chuck from the water side, in a single setup before parting the part on the lathe. The remaining features can be created on a mill with DRO. The part has small flat cuts on the flange sides to help holding it consistently on the mill vice. These are also helpful to prevent the parts interfering each other during final assembly. These cuts are the first things to do on the mill after all the lathe operations. The central slot for the Actuator Arm and the flange holes can be easily spot at the right position based on said flat cuts.

The Piston Rods and Actuator Arms entail less complexity, and they can be made with less difficulty.

To make possible the use of commercial hydraulic seals for the piston sealing, both the Steam and the Water Pistons are split into two parts. I named these parts the Piston Washer and the Piston Nut. A pair of them joined together make a single piston featuring a groove to hold a piston seal, as well as a female thread to screw the Piston Rod. The piston also provides three key holes to use a special tool on them, which will be disclosed next.

SPECIAL TOOLS

Several specially made tools are required to facilitate the pump assembly. Particularly, the Rod Seals are difficult to insert by hand so they require some helping tools. Also, a couple of key tools are necessary to firmly screw the pistons in place. **Figures 41 to 45** are the 2D plans for these tools. They are all shown already finished in **Photo 21**.

For the rod seals I made a sort of cylinder and rod pieces with special chamfers that are able to hold a seal at one end. The seal is placed at the end of the tool rod, slid into the cylinder tool, and pushed into place on the pump part.

The keys for screwing the pistons are just cylindrical rods with flat cuts at one end for using with a spanner. At the other end 3 mm dowel pins are inserted that match the key holes on the Piston Nuts. **Photo 22** shows the tool for the Water Pistons next to the Water Piston Nut. The making of these tools are pretty straightforward.

FINAL ASSEMBLY

At the beginning of the article I showed all the machined parts, and all the commercial items involved in the making of the pump (**Photos 2 and 3**). The gaskets were the only remaining single items that I did not show together, so I am presenting them now on **Photo 23**. On that capture there is a minor error involving the Water Valve Gasket (item number 9 on the plans) as it has some missing holes that I eventually drilled at a later stage. Unfortunately, I failed to take a replacement photo, but I still think that showing this one is informative. These three photos together represent the entire set of parts that make the pump.

As stated before, the pump uses commercially available rod seals. I purchased them online from seals-shop.com in Germany. The items that I used belong to the "Turcon Variseal M2S" family. I selected the specific references based on the rod diameters in use as shown in the plans. The seals are made of a manufacturer specific grade of carbon filled PTFE material. Allegedly, the recommended housings on the machined parts are compatible with suitable imperial sized o-rings, so these seals may be replaced by simple o-rings in the usual practice, if the pump is not going to work heavily or with hot superheated steam.

The first thing to do is to insert the seals in the Steam and Water Cylinder Flanges using the described helper tools. **Photo 24** shows the Water Cylinder Flange ready for the seal to be inserted using the smaller tool. When inserted to the flange, the open face of the seal must point inwards, that is, facing the pressurized end of the flange. This is crucial for the proper operation of the seals. **Photo 25** shows a seal on the water side already in place. The same operation shall be repeated for the 4 flanges including the ones on the steam side, as shown in **Photo 26**.

The Steam Cylinder Blocks require some of the drill holes we performed to create the steam passages to be closed and sealed. For this I used high temperature, silicone based, sealing paste with M2.5x3 set screws. I bought the sealing paste locally, but it can be found online from the Loctite brand. One instance of the procedure is shown in **Photo 27**. There is a total of 7 holes that require sealing, two on the Cylinder Cover face, one on the Cylinder Flange face, and four on the Steam Valves face.

Now screw the Cylinder Spacers to the Water Cylinder Blocks while packing the Water Cylinder Flanges and Gaskets in between (see **Photo 28)**. Note that there are gaskets between the Cylinder Blocks and the Flanges, but none are required between the Flanges and the Cylinder Spacers. Use M3x10 socket cap screws for that. Carefully insert the Piston Rods to prevent damaging the seals. Do it from the Steam Cylinder Block side and insert the Actuator Arm in the Cylinder Spacer slot at the same time (see **Photo 29**). Finally, put the Steam Cylinder Flanges in place and screw the Steam Cylinder Block with the relevant Gaskets using M3x10 socket cap screws. At this point your assembly should look like **Photo 30**.

Next, it is time to mount the pistons. The pump is designed to use industry standard seals for hydraulic applications. Again, I found them online from seals-shop.com. In this case I used "Turcon Glyd Ring T" references of the appropriate bore diameters (as depicted in the plans), along with FKM o-rings from the same manufacturer. They are all pretty standard items which any major seals or aftermarket hydraulic components dealer should be able to supply from alternative manufacturers if needed.

Start by mounting the steam side pistons. First insert the Steam Piston Washer as shown in **Photo 31**. Then insert the seal ring as in **Photo 32**, and finally screw lightly the Steam Piston Nut with the o-ring placed around it as shown in **Photo 33**. It is important to assemble it in the described exact order to prevent damaging the seal. Repeat the same steps for the other steam piston and the water pistons, as shown in **Photo 34**. Use two spanners to tighten the piston nuts together by means of the helper tools described earlier. This is shown in **Photo 35**. Finally, screw the Water and Steam Cylinder Covers with their gaskets in place using M3x8 socket cap screws. An early assembly test of that last step was depicted earlier in **Photo 10**.

The following operations cover the assembly of the Steam Chest and Steam Valves. Start by inserting the Actuator Rod Seals on the sides of the Steam Chest Block as shown in **Photo 36**. The open side of the seals must point inwards. Next, screw the Actuator Seal Covers to prevent the seals getting out of their place using M3x6 socket cap screws. Since the threaded holes reach the inner area of the Steam Chest Block, they must be sealed in order to prevent any leakages. I used high temperature sealing paste for that as shown in **Photo 37**. Finally, insert carefully the Actuator Rods through the aligned seals as shown in **Photo 38**. This can be a bit tricky because the second seal will be approached from its open side, so there is some real possibility of damaging it. The key to avoid trouble is having the chamfers on the Actuator Rods as clean as possible and totally free of any sharp edges.

Photos 39 and 40 show the pump just before mounting the Steam Slide Valves, Steam Valve Clips, and the Steam Chest Cover. The important thing to consider at this step is the proper fit of the Steam Slide Valves. In particular, we must make sure that the Slide Valves are just shy of touching the surface of the Steam Cylinder Block ports without being too loose. If the Valve is too loose on the surface of the ports then the pump may not have a consistent start as some steam will scape the valve before there is enough pressure on the Steam Chest for it to close the ports. On the contrary, if the Valve is tight, or it is being forced down by the Actuator Rod, then the Actuator Rod Seals are not working concentrically, which may imply external steam leakages around them, and ultimately a premature wear of the same.

About the Slide Valves, I allowed for some extra thickness when I first machined them and made small adjustments during assembly by incrementally cutting what was oversize, until I was satisfied with the fit. **Photo 19** depicted in a previous section was taken during one of these adjusting steps. As a general rule, I consider a maximum gap of approximately 0.1 to 0.3 mm as adequate for the Steam Slide Valves over the ports. This can be checked by temporarily screwing the Steam Chest and its lower Gasket onto the Steam Cylinder Block leaving the Steam Chest Cover unmounted. After that, remove the screws and put the Steam Chest Cover in place without forgetting the upper gasket. The pump at this stage should look like **Photo 41**.

The only remaining step is assembling the Water Valves and screwing them with its Gasket to the Water Cylinders Block. **Photo 42** shows the Water Valves subassembly before joining the rest of the pump.

This completes the pump assembly.

TESING THE PUMP

The pump should be tested first on low pressure air and no water in order to make sure the steam side is working properly, the pump performs the full cycle, and there are no leaks that may require fixing. Once that's done the water side can be tested by pumping actual water.

Photo 43 shows my basic testing setup. The pump is held on a normal vice and a second smaller vice is used to hold a manometer and a miniature ball valve. There is also a plastic bowl where water is recirculated. The water inlet pipe is submerged in a small depth of water, and the pump discharge is conveyed to the bowl through a ball valve. The manometer is placed before the valve to display the pressure in the discharge pipe. The small ball valve is used to gradually add pressure to the system. For the purposes of testing I am calling it the "load" valve. On the Steam side, there is a pipe that is connected to an air compressor through a regulating ball valve (not shown). The compressor has a pressure regulator that allows me to set any fixed pressure that I would like to test with.

The test begins by providing a small air pressure to the pump to make it start moving and recirculating some water. If the pump is well done and there are no internal leaks, a pressure as small as 0.5 to 1.0 bar should be enough to have it freely pumping water.

At full load, the pump should be able to keep pumping water with an air pressure of less than 2/3 the water pressure, or preferably less than 1/2 the water pressure. During the test, the water pressure is increased little by little by gradually closing the "load" valve. As the pressure increases the pump may loss speed, so some more opening of the air valve might be required to compensate. For the testing I set my air compressor at 6 bar. I obtained in excess of 10 bar on the water side as shown in **Photo 43**. which indicated a proper operation of the pump.

When the pump is used as the feed water device for a boiler, we strictly only need a bit more water pressure than the boiler (or steam) pressure. However, it is normal practice for all steam pumps to work with much lower pressure than the possible one. This is done to account for losses due to steam condensation in the pump, loss of pressure in boiler pipelines or check valves, pump leaks due to use and wear, internal friction of the pump, and so on, hence the recommendations above.

This sets the end of this article.