Steam valve and Water Gauge

(original Title Jottings from the Workshop)

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In my last jottings I started to discuss boiler fittings but did not get beyond the subject of feed clacks and non-return valves in general. I promised (threatened?) to continue next time, so here goes! A few months ago I was asked how I managed to make my injector steam valves completely steam tight when closed. I was rather surprised at the question at the time because it had never occurred to me that there might be a problem, but having now thought about it I can see where difficulties might arise. The basic design of the majority of steam valves incorporated in live steam models has not changed for best part of a century and consists of what might be described as a blunt needle valve - see figure 1.

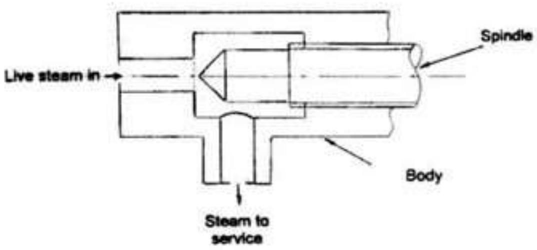

Figure 1
Basic Valve Geometry

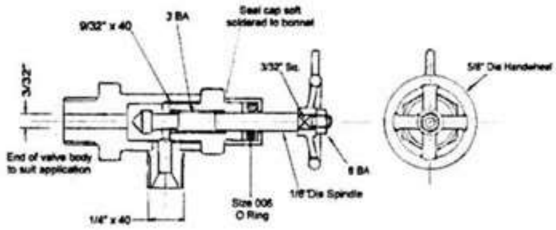

Figure 2
Steam Valve with Captive Spindle

The diagram shows only the business pad of the valve. We will worry about the rest of the device in a moment, but figure 1 serves to highlight the requirements for a guaranteed steam tight shut off. Cleary this will only be achieved if the conical end of the spindle locates exactly on the seating when the valve is closed. If there is any eccentricity between the axis of the thread on the spindle and the centre line of the cone on the end of the spindle or between the thread in the valve body and the valve seating a steam tight seal will not be achieved. It is, of course, possible to design valves with elastomeric sealing of some sort (the old style kitchen tap is an example) but in the small size valves we are usually dealing with it is more trouble to make such a valve then to make the traditional type properly. Figure 2 shows details of the steam valves I have designed for my own locomotives. The dimensions shown are for a typical blower valve or injector steam valve but can obviously be modified to suit any application. The external dimensions of the body and bonnet are not shown and are not critical. If anyone would like a detail drawing a letter via Editor is all that is needed. The first and most important design feature to note is that the spindle is captive - i.e. the valve cannot be opened so far that the spindle screws out of the bonnet. The steam valve designs promulgated by many of the famous designers of the past including such illustrious names as LBSC and Martin Evans, did not incorporate this safety feature which is now considered by most authorities as essential. The current edition (November 2008) of the British Model Engineering Liaison Group Boiler Testing Code is not entirely satisfactory on this matter and appears to leave the requirement to the discretion of the boiler tester. Most boiler testers will, however, insist on the requirement being met. Hopefully this situation will be clarified in future editions of the Code and captive valve spindles will be a mandatory requirement. Retrospective application of such a requirement will not be easy, bearing in mind the thousands of live steam models in service incorporating valves of traditional design with non captive spindles. It is interesting to note that the Australian Miniature Boiler Safety Committee current Code (which in my opinion is far superior to the British Code) does make the requirement for captive valve spindles mandatory, but the requirement is not retrospective to boilers registered before the introduction of the Code. The second feature to note is the use of an "0" ring seal in place of the traditional packed gland. This is a personal preference and results in a smaller, neater configuration and a more reliable seal than a packed gland.

Another important feature of the design is the securing of the operating hand wheel / handle to the valve spindle. Many designs specify the hand wheel to be screwed onto the spindle and locked in place with a nut. Indeed, many commercially available hand wheels are supplied with a tapped hole. This is NOT a sufficiently positive method of securing the hand wheel. If the valve is closed too tightly or becomes tight as the temperature is raised from cold it is possible for the hand wheel and nut to unscrew together instead of opening the valve. I have seen it happen on one of the locomotives steamed regularly on our own track.

The use of a square on the spindle engaging with a matching square hole in the wheel ensures a positive torsion drive. The nut only keeps the wheel in place. The British Boiler Test Code advises the inspector to check the security of valve hand wheels on their spindles whilst it is a mandatory requirement of the Australian Code referred to earlier that operating hand wheels and levers are positively secured to their spindles. Turning now to the manufacture of the valve, the body is fabricated from phosphor bronze. The bonnet and seal cap may be phosphor bronze or brass and the spindle stainless steel. The need to achieve concentricity of the various features has already been mentioned. In the case of the spindle the best way to achieve an accurate result is to screw cut the thread, finishing to size with a die or die nut.

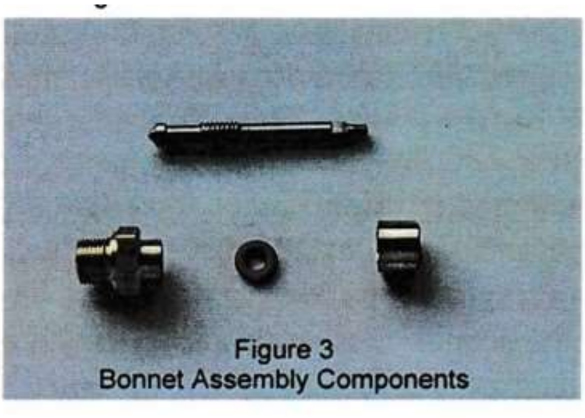

Figure 3
Bonnet Assembly Components

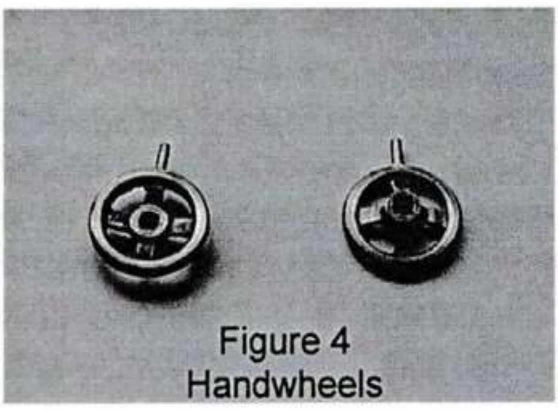

Figure 4
Handwheels

If a BA thread is employed, and in my case it usually is, screw cutting presents a problem on many lathes, including mine! If the plain outer end of the spindle is machined to a couple of thou under the root diameter of the thread it will provide an adequate guide for a die and ensure a true thread. Machine the whole spindle at one setting, including the cone on the business end, leaving a small "pip" for final parting off - there is no need for a sharp point. The threads in the valve body and bonnet must also be care but should not present a if sharp taps and dies are used tailstock die holder to present accurately to the job and the guided by a drill chuck in the The seal cap is soft soldered to bonnet and the "0" ring worked cavity through the spindle hole. Steam Tunet with built in valves into its Be careful to remove any sharp edges and burrs from the cap and the end of the spindle to avoid damage to the "0" ring during assembly. A smear of silicone grease helps, Should the "0" ring need replacement at some future date removal of the old ring is easily achieved by unsoldering the cap to facilitate removal of the debris from the old ring before re-assembly. A set of components for a bonnet Figure 5. assembly are shown in Figure 3.

I make my own hand wheels, machining the profile on the end of a piece of bar and drilling to rough out the space between the spokes before parting off. The spokes are finished to shape with needle files and scrapers. Ideally the square hole would be produced with a small broach but I have never got round to making suitable tooling and do the job by hand with a square needle file. The appearance of the wheel is enhanced if it is dished slightly by pressing in the vice with suitable supports. A small hole is drilled in the rim and a suitable size piece of wire silver soldered in place and trimmed to length for the handle. Figure 4 shows opposite sides of a couple of typical 5/8" diameter wheels. The valve body may be made as a "stand alone" feature such as a blower valve screwed into the back head on the end of a hollow stay or may be made as an integral part of some other feature such as a steam turret as shown in Figure 5. So much for steam valves. Let us now have a look at the design and installation of water gauges.

The water gauge is arguably the most important fitting on the back head of any boiler and must be accurate and reliable. The continuing integrity of any boiler relies on the maintenance of a covering of water over the heated surfaces. In the case of the locomotive type boilers we are usually concerned with this means ensuring that the firebox crown is always covered. Maintaining this situation is the driver's responsibility but he inevitably relies on the water gauge to achieve this and it is important that the gauge does not mislead him with erroneous information. Unfortunately the possible faults either designed into a water gauge or arising from its installation result in the gauge indicating that there is more water in the boiler than is actually the case, The most significant design feature leading to this state of affairs is the choice of gauge glass bore. We are all no doubt familiar with the capillary effect which causes water to rise inside a glass tube when it is dipped into a vessel of water. The effect is the result of forces occurring between the molecules of the water and glass at the interface and the surface tension of the water.

CAPILLARY RISE IN GAUGE GLASS			
Nominal Tube Diameter mm	Tube Bore mm	Theoretic al Rise mm	Measured Rise mm
5.5	4.32	3.5	5
6	2.84	5.2	8

The distance the water will rise in the tube can be calculated for any given tube diameter and is inversely proportional to this diameter. The water in our gauge glass behaves in exactly the same way and in consequence will indicate a higher level of water in the boiler than is actually present. So how significant is the error? I have calculated the capillary rise for a couple of pieces of gauge glass I had in the workshop and have CAPILLARY RISE IN GAUGE GLASS Nominal Tube Diameter mm Tube Bore mm Theoretic al Rise mm Measured Rise mm 5q 4.32 3.5 5 0 2.84 5.2 8 measured the actual rise for the two tubes. The results are shown in the accompanying table. Fortunately the surface tension of most liquids decreases with increases in temperature and in the case of water at 150 deg. C (approximately the saturation temperature at 80 psi) it is about two thirds of the value at room temperature. Even so, the effect is not insignificant and can easily lead to an error in indicated water level of %". Clearly, the larger the bore of the gauge glass the smaller the effect will be. It must be emphasized that it is the BORE of the tube which is significant. The first of the samples I used was a length of tube I had had for some time and which I have used for most of my own gauges. The second sample was a length of tube with a red stripe incorporated, purchased at a recent exhibition.

The red stripe fired into the glass is magnified by the presence of water in the bore and provides a clearer indication of water level. A good idea in principle but in this case I consider the material quite unsuitable and it is destined for the waste bin. Although 0.5mm larger in outside diameter the bore is 1.5 mm smaller than the tube I usually use and could (would) provide a very misleading indication of water level in the boiler. 10 My personal opinion is that the minimum bore of a gauge glass should be 4 mm. The current Boiler Test Code makes no reference to the size of gauge glass but the Australian Code referred to earlier specifies a minimum bore of 3 mm throughout the gauge. Other sources of error arise from installation faults. The most serious of these is the sharing of the top fitting of the gauge with another fitting such as a manifold. This practice is forbidden by the Boiler Test Code. The reason for this is that if steam is drawn off from the manifold by a service (such as a blower of injector)the pressure in the manifold, and therefore the top of the water gauge if it is shared, will fall. The fall in pressure may well be very small - a few calculations for a typical manifold supplying an injector indicates a figure of 0.02 p.s.i Not very much, but this translates to 5/8" rise in the level of water in the gauge glass, Theoretically the top fitting of a water gauge could be shared with a pressure gauge because no steam flow is involved - I saw such an installation at the Midland Exhibition - but it would be better to avoid the wrath of the boiler tester and stick with a dedicated connection for the water gauge! The location of the connection on the back head is also of importance. In particular the clearance between the inner end of the lower fitting and the fire box must be sufficient to allow free flow of water to the gauge without entrained bubbles of steam. Bubbles entering the glass make a nonsense of the gauge reading.

Our own Boiler Test Code is silent on this subject but the Australian Code requires a minimum clearance of 5 mm. The location of the lower gauge fitting should be such that the minimum level indicated (i.e. when the water is just visible at the bottom of the glass) should still leave an adequate covering of water over the firebox crown. 0ur Boiler Test Code states that "when no water is showing in the g/ass there is still a safe level of water above the crown sheet of the boiler'. Whilst we may understand the intent, this is an unsatisfactory statement since if there is no water showing in the glass there is no way of knowing where the level is - the boiler could be empty Better to define the requirement as the bottom (visible)end of the glass being an adequate distance above the crown sheet. The Australian Code defines this distance as being 100/o of the distance between the crown sheet and the outer firebox wrapper. This seems to be a reasonable rule of thumb but will not suit every boiler design. Whilst the positioning of the lower gauge fitting in this way may seem an obvious safety requirement some of our famous designers of the past did not consider it. Ihe Martin Evans drawings for the boiler of my current project show the lower gauge fitting positioned such that the crown sheet of the firebox would be bone dry with water still showing in the glass. I raised the position of the bush %" to satisfy the code requirements. If you are building to a published design it is a point worth checking. The build up of scale around the inner ends of either of the gauge fittings is possible and will result in sluggish movement of the level in the glass. 11 This is readily checked by blowing down the gauge and observing the speed of recovery of the level. This procedure is called for by the Boiler Test Code during the steam test but the check should be made every time the boiler is steamed. Provision should be made in the gauge fittings for access to the internal passages via removable plugs to enable these passages to be cleared should this become necessary.

The matter of blowing down the gauge glass raises the subject of the blow down valve which should, if of the screw down variety, comply with the same rules as all other screw down valves and employ a captive spindle. This valve may, of course, be a "plug" type valve if preferred. This type of valve has the advantage of opening and closing the flow passage very quickly with only g0 deg. movement. For some reason these valves do not seem to be used very often in model practice although they were normal in full size. one of the hazards associated with water gauges is, of course, the risk of a broken gauge glass whilst the boiler is in steam. Full size practice employs isolating valves in the top and bottom fittings and many models follow the same practice. The disadvantage of incorporating isolating valves is that, unless the fittings are rather bulky and over scale the passages are very restricted. Unless built to scale the majority of models are only fitted with a single water gauge and if a glass is accidently broken it is inevitable that the boiler must be shut down as quickly as possible. My own philosophy is that if the glass is broken, put the injector on and dump the fire immediately Figure 6 shows details of the water gauge design I have adopted for my own locomotives whilst figure 7 shows an example of a gauge to this design undergoing pressure testing at 200 p.s.i.

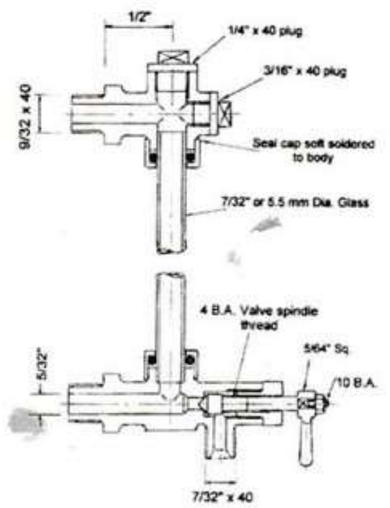

Figure 6
"Artisan's" Water Gauge

Figure 7
"Artisan" Water Gauge on Test

The design incorporates "0" ring sealing for the glass and a screw type blow down valve (Figure 7) with spindle. I have not bothered with a gland or seal on the blow down valve spindle since the valve is only open for a few seconds occasionally. There is no reason why a gland should not be fitted but it increases the size of the fitting and the outstand from the back head unnecessarily. A removable plug is incorporated opposite the top (steam) passage to facilitate cleaning if required. 12 ; The "0" ring seal housings for the glass are of similar design to the seals described for the steam valve spindles, employing seal retaining caps soft soldered to the body of the fitting, The seal groove could be machined from the solid if preferred, there being plenty of room to insert a small boring tool in this case. The advantage of this seal configuration is its relatively compact nature compared with a screwed seal retainer. This helps to achieve the greatest possible visible length of glass within a given space. I consider this important. Significant changes in water level can occur due to ascending and descending gradients and surging due to irregularities in the track. If a short glass is employed management of the water level in the boiler can be difficult and lead to anxious moments! I am sure that I have taken up more than my fair share of space in this edition of LINK so had better close before our editor complains! There is still a great de.al that can be said on the subject of boiler fittings but I think it might be time for something different in my next jottings.