

## The black art of safety valve design – researched by Roger Stephen

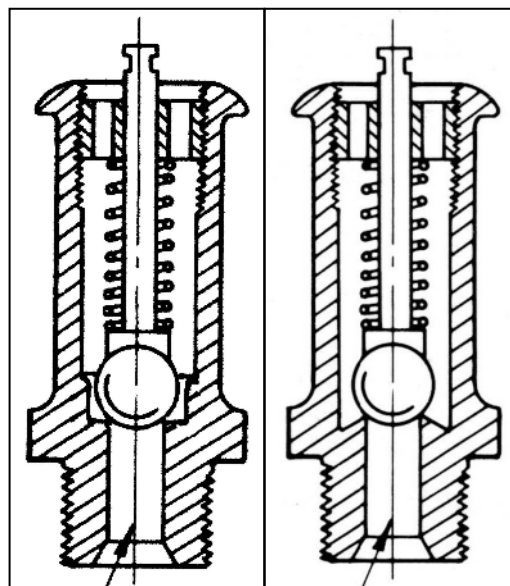
At a Sunday club puffing session Den Blazdell and I did a locomotive boiler test that hit trouble. The loco was extremely well made and sailed through the hydraulic test but had everyone scratching their heads when it came to the steam test due to some very strange behaviour of the 'pop' type safety valves. They were nicely made to a known design but were rather hard to set. Opening at around the working pressure of 80psi they then stayed open until the boiler pressure dropped by 20 or 30 psi before closing, during which time they also vented lots of hot water with the steam. They then stayed shut until opening again at around 80psi, this behaviour being called hysteresis. I decided to do a bit of research to try to get to the bottom of the problem.

So what is a pop valve? Well the thing that makes them different from ordinary safety valves is that the ball that cuts off the steam flow operates in a little counter-bored recess. These are sometimes called Ross pop valves. On opening, the pressure of the steam in the recess acts on the whole cross section area of the ball and pushes the valve fully open instantaneously with a pronounced 'pop'. An ordinary safety valve has no recess, the ball just sitting in space on a plain hole, and opens and closes much more progressively – the drawings reproduced here show the difference between these two types.

It turns out that lots of people have had trouble with pop valves. In addition to the hysteresis they can have a habit of opening so violently that they apparently set up some kind of vortex inside the boiler (think mini tornado) causing water to be sucked up and ejected along with the steam. LBSC wrote of this in his 'Shop, Shed & Road' in 1929 saying "If you make a 'pop' valve of the usual type to work with a decent pop action ..... it usually has a fault often found with full size valves – away goes your water when she pops off. The only way to check this is by increasing the clearance between the upper part of the valve and the recess it operates in, and then it is, in the majority of cases, goodbye to the pop action altogether. One good dodge is to use a ball valve in the 'pop' recess. This gets over all the trouble". Well he may think it solves the problem but I beg to differ as the valves we had trouble with had a ball in the recess! Clearly there is more to it than that.

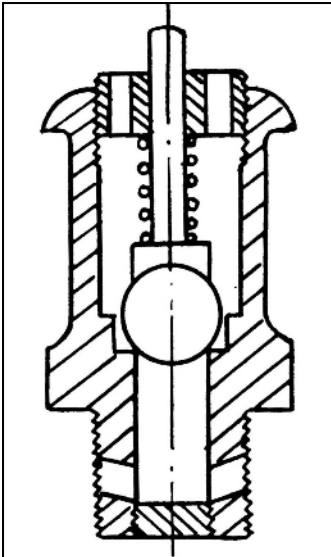
Of course, if your pop valve does not work satisfactorily you can modify it by machining away the recess, making it into an ordinary valve. That should work perfectly satisfactorily but you will probably join the happy band of drivers who frequently have to tap the top of the valve with their shovel when it does not quite close properly leaving a feather of steam blowing off. I certainly do that to the valves on my Princess Marina and I know of lots of other locos whose drivers give them the same treatment. Ordinary valves may also chatter when opening making a rather rude noise! If you really want to pursue having pop valves then you may end up doing lots of trial and error modifying your own valves.

Modifying your valves would involve adjusting clearances inside the valve until it opens and closes reliably over a small pressure range (which can actually be checked on a simple rig using compressed air and a suitable pressure gauge without the need for a test boiler and repeatedly raising steam). It may also involve modifying the entrance to the steam way at the base of the valve to stop the valve sucking up your boiler water. Simply making the entry conical by means of a centre drill and/or countersink (thereby reducing the velocity of the steam there) may be enough. However, Martin Evans in his book 'The Manual of Model Steam Engine Construction' suggests plugging the entry to the steam way and drilling a number of radial holes round the base of the spigot as shown in the drawing of a Ross pop valve reproduced here.



*Above left: Pop type safety valve with the ball operating in a counter-bored recess.*

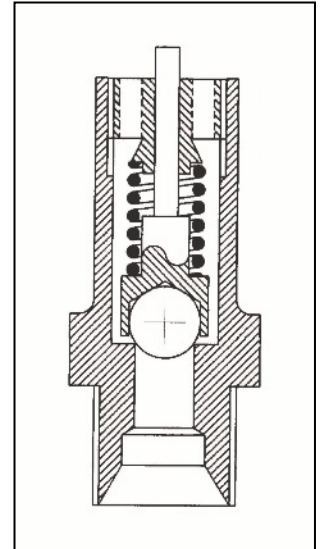
*Above right: Ordinary safety valve with no recess for the ball.*



*A Ross type pop safety valve with a ring of radial holes round the base of the valve spigot which Martin Evans recommends to avoid losing your boiler water when the valve pops open.*

If you do that you need to make sure the radial holes are of adequate size to clear sufficient steam and that the spigot is long enough for the radial holes to clear the bottom of the valve bush in the boiler but not strike the regulator, or anything else, below. An easier option is to go down the Gordon Smith route, but who is he?

Gordon Smith was a keen model engineer with the Burton-on-Trent M.E.S. who resolved to do something about the problems with pop safety valves and did lots of experiments with various designs of them. He discovered that the spring characteristics and certain dimensions inside pop valves are critical to their correct operation. Get one of these wrong and operating problems can arise. Eventually he came up with a design for reliable valve which he called a 'mild pop' valve and wrote up his findings in *Engineering in Miniature* in February, March and April 2001. His valves apparently open and close positively over a small pressure range and because they open relatively gently (hence 'mild pop') they don't empty the water from the boiler. The drawing reproduced here shows how Gordon's safety valves differ from other types of valve. They have no recess, being more like an ordinary valve, and the ball is held inside a little shroud. Note that the correct clearances between the working parts are still important but easier to reproduce in the home workshop than the type with a recess.



*Typical example of one of Gordon Smith's 'mild pop' safety valves. Note the shroud containing the ball and the conical entry into the steam way at the base of the spigot.*

Drawings of Gordon's valves for a wide range of miniature locomotives from 3½ to 7¼ inch gauge together with springs and balls of the correct characteristics are available from Polly Engineering. If you don't want to make your own we believe they also manufacture a range of finished mild pop valves.

Our member whose locomotive safety valves gave us so much trouble on a steam test in July discussed the matter with Polly Engineering and purchased two Gordon Smith design valves. During a subsequent steam test they behaved perfectly, opening and closing positively over a very narrow pressure range and releasing only steam with no sign of sucking up boiler water. Your boiler inspectors, and our member, were very impressed!