



This article is provided by FMES for your interest thanks to the kindness of the original publishers. FMES makes no representations or warranties of any kind, express or implied about the completeness, accuracy or reliability with respect to this document and any sentiments expressed are not necessarily supported by FMES. Any reliance you place on this document is therefore strictly at your own risk

How many cylinders on a locomotive

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Spring of 2012.

Well, two heads might be better than one but too many cooks spoil the broth, so who is right? This is pretty well the position with the choice of three cylinders on a steam locomotive: some argue that 3 cylinders are better than 2 while others consider 3-cylinder engines a waste of time and money, so who is right? In this country nearly all locomotives were powered by 2 cylinders, mainly placed inside the frames in the 19th century and increasingly outside thereafter, but some railways eventually made extensive use of 3 and 4 cylinders. There is no doubt that 2 cylinders are quite sufficient for a reliable engine. Starting is pretty well guaranteed if the valve gear is designed to provide 80% cut-off in full gear since by the time one piston has reached this point in its travel the crank has moved through about 127° and as the other crank is set at right angles it will be at 37° and well placed to exert turning moment. This also provides a reasonably consistent torque so why on earth would anyone choose to spend money on more cylinders?

For many years no engineer had any desire to add cylinders but as railways progressed 3-cylinder locomotives began to appear for several reasons. Essentially there are two situations in which 2 cylinders are not enough: the first (in order of appearance on our railways) was compounding and the other was to obtain a greater power output. Two-cylinder compounds have serious limitations and although the NER had a go at them, compound locomotives really need more than 2 cylinders and the two major compounding experiences here on the LNWR and MR utilised different arrangements of 3 cylinders.

Now let's look at power output: the work done by the engine is related to the result of multiplying the Mean Effective Pressure and Swept Volume of the cylinders (PV), so if a more powerful engine is needed the designer has to increase either the working pressure or the size of the cylinders, or possibly both, provided of course he has specified a boiler that can maintain the cylinders supplied with enough steam. As an example, the well-known LMS Class 5 has 2 cylinders each of 4.3 cu ft using steam at 225 psi and the next size up, so-to-speak, the Class 5X works at the same pressure but has 3 cylinders each of 3.4 cu ft, an overall increase of 19%. The same additional work could equally have been obtained by sticking with 2 cylinders each with a swept volume of 5.1 cu ft. This would be achieved by fattening the 18½" diameter cylinders of the Class 5 to 20" with the consequence that they would have had to be more steeply inclined (remember the Horwich "Crab") to fit the loading gauge. Alternatively, pressure could have been increased to 270 psi with the corresponding extra weight and maintenance cost. The next class up, the Royal Scot (actually pre-dating the Stanier engines), achieved its design power output by using 3 cylinders and 250 psi boiler pressure. In fact, the decision to use 3 cylinders for the Scots was taken on the basis of 2 being insufficient and 3 being cheaper than 4 cylinders as used by the GWR "Castle" they had just finished playing with. Three were just sufficient when combined with an increase in pressure.

Some railways built 3-cylinder engines when they did not need them for compounding or power, but in the main they were isolated trials or special situations involving just a few engines. Two lines became converts to 3 cylinders and curiously both were absorbed into the same Group in 1923, the LNER, so it is not surprising that this company was unique in favouring the 3-cylinder design on principle rather than as a necessity, at least until a new broom swept clean in 1941, so why was this? In 1907 Robinson of the Great Central brought out 6 large 0-8-4T tank engines for pushing wagons at crawling pace over the hump in the Wath marshalling yard, and the additional cylinder not only provided a more even effort at very slow speed but was essential for generating the required tractive effort with a boiler pressure of only 180 psi. After a bit of experimentation with

express locomotives the GCR had no more use for 3 cylinders but they passed the bug to the NER, the fourth largest company, where things became quite serious.

Darlington was not to be outdone so two years later W. Worsdell came out with 10 engines for the same purpose but with the wheel arrangement reversed to make them 4-8-0T and with the inside cylinder driving the leading axle and the outsides the second. With pressure only 175 psi the extra cylinder was definitely needed to provide more push. The following year the newly appointed CME, Raven, decided to propagate the 3-cylinder idea and put them into a 4-6-2T passenger tank design with a 180-psi boiler. The three cylinders of 16½" x 26" were in a single block and all drove on to the leading axle which carried the inside crank plus 6 eccentrics for the Stephenson link motion thereby making things a bit dodgy for axlebox and big end bearing surfaces. Equal power could have been obtained from 2 cylinders of 19" x 26" working at 200 psi so clearly 3 cylinders were chosen on principle. Over the next few years the NER put 3 cylinders into 200 locomotives of different types, 4-4-2, 4-4-4T, 4-6-0 and 0-8-0 none of which were capable of shifting loads better than their 2-cylinder equivalents on other railways, but boiler pressure was kept down at 160 to 180 psi. The GNR was the southerly neighbour of the NER and they had a fairly close working relationship, as well they might since the GNR ran from London to a field 4 miles north of Doncaster but fortuitously the NER ran from that field to the Border, so that all East Coast long distance trains changed engines at some point.

At about this time Gresley was appointed CME by the GNR and got stuck in to turning out locomotives with a distinctly 20th century look, 2-6-0's and 2-8-0's with 2 outside cylinders and Walschaerts valve gear. Gresley must have weighed up Raven's multi-cylinder steeds and decided not to be left behind, so in 1920 Doncaster turned out a large 2-6-0 with 3 cylinders. The layout was quite different from the Darlington arrangement as the inside cylinder was inclined so as to drive the middle axle as did the outside ones, unfortunately this made things difficult for driving the inside valve so its motion came from the two outside gears through a conjugation system which looked better in theory than it was in practice. Cylinders were 18½" x 26" with boiler pressure of 180 psi. The previous mogul design had 2 cylinders of 20" x 26" and if its boiler pressure been taken to 225 psi Swindon style the third cylinder could have been avoided. Evidently it pleased its designer and thereafter all medium sized locomotives on the GNR carried this 3-cylinder layout (as well as the large Pacifics and LNER 2-8-2's which were of necessity multi-cylindered). Gresley went on to become CME of the LNER in 1923 and 3-cylinder propulsion became the norm until his death in 1941. His successors were clearly not convinced of the merits of this way of doing things and they reverted to conventional 2-cylinder designs generally and adopted 3 cylinders with divided drive and individual valve gear for Pacifics.

Gresley presented his case for the 3-cylinder principle to the IRLE on the basis of advantages in efficiency, repair mileage, hammer blow, uniformity of starting effort, factor of adhesion and earlier full gear cut-off. In reality efficiency can only suffer, increased mileage is offset by more to repair but with Holcroft valve gear mileage actually decreased, starting and adhesion are only marginally improved and full-gear cut-off is neither here nor there. The only significant advantage is the reduction in hammer blow since the arrangement has good reciprocating balance.

Maunsell built 27 of the SECR/SR 2-6-0s in 3-cylinder form without any advantage other than their improved route availability for specific lines with loading gauge restrictions. In 1932 the LMS constructed a 3-cylinder version of its existing 2-6-4T passenger tank specifically to exploit improved starting and acceleration for use on the Tilbury line. The engines were initially welcomed with open arms being so much bigger than the traditional 4-4-2T, but when they were sent to other areas to work alongside their 2-cylinder sisters no operating advantage could be found and all subsequent additions reverted to 2 cylinders. This example of 2 and 3-cylinder equivalent engines working side by side is useful in proving the point: too many cylinders spoil the simplicity.