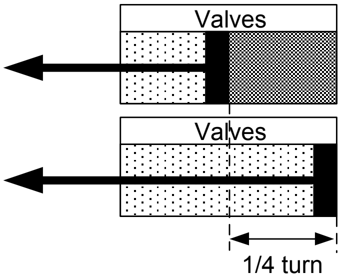
Steam Locomotive Quartering

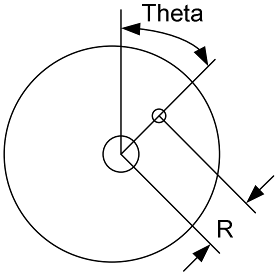
In a steam locomotive, valves linked to the driving wheels admit steam to either side of the pistons in an alternating fashion. Completion of each back-and-forth piston cycle rotates the driving wheels one half turn. Unfortunately, if the locomotive should happen to be stopped with the pistons on each side resting at the far extreme of their travel, it might be impossible to start the locomotive. To prevent this, the linkages that control the valves are arranged such that the piston on one side of the locomotive is always mid-travel when the piston on the other side reaches the far excursion of its travel. This mid-travel difference corresponds to a quarter turn of the drivers, and is thus referred to as "quartering."

Upper drawing shows cylinder on left side of locomotive.



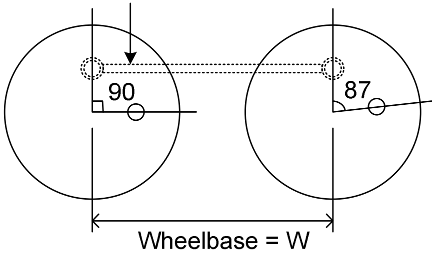
Lower drawing shows cylinder on right side of locomotive.

The pistons connect to the drivers via drive rods, connecting rods, and crank pins. The angular position (Theta, ϴ) of a driver's crank pin is important relative to the angular position of the corresponding driver on the other side of the locomotive. To achieve the "mid-travel difference" described above, the angular position of the crank pin on the left side driver should be one quarter turn (90°) behind that on the right side driver.

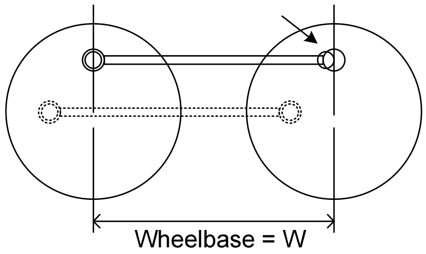


If the value of Theta is different on the two sides of the locomotive, there will be a slight mismatch between the position of the crank pins joined by the connecting rods, causing undesirable wheel slippage every quarter turn as one wheel is forced to repeatedly catch up to the other.

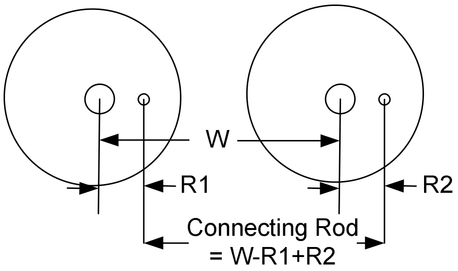
Connecting rod and crank pins on side furthest from viewer. Near side rod not shown.

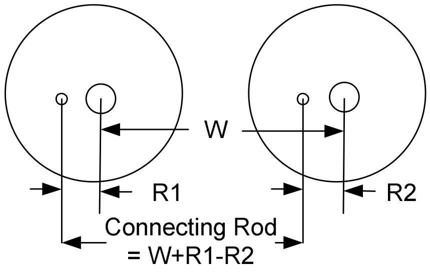


Nearside connecting rod will attempt to correct the position of the right hand wheel causing a slip.



Another dimension of interest is the distance R between the center of the crank pin and the center of the wheel. For a locomotive with two driving wheels spaced W apart, the following diagram would apply:





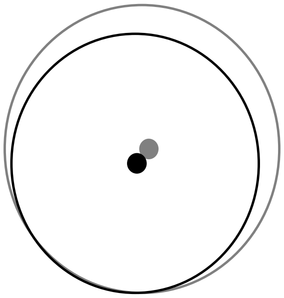
For example, let’s say that the wheelbase (W) is 48 inches, and the value of R is consistent at 10 inches for both wheels. In this optimal case, a 48 inch connecting rod will work perfectly during wheel rotation. As a somewhat extreme example of dimensional mismatch, let’s assume that R1 is 10.1 inches, and R2 is 9.9 inches. With those dimensions, the connecting rod must be 47.8 inches long when the wheels are as shown in the upper diagram and 48.2 inches long when the wheels have rotated a half turn to the position shown in the lower diagram. Since there is no such thing as an elastic connecting rod, a locomotive with this much difference in the crank pin positions would introduce extreme wear to the connecting rod bearings and wheel bearings, if the locomotive ran at all.

The example shown is unrealistic, but variations in the value of R do occur. In particular, the values of R for the four driving wheels of locomotive Number 9 are all different. The worst-case in Number 9 produces a requirement that the connecting rod change in length by 1/8 inch. Examination of the brasses (bearings) on Number 9 shows wear consistent with this problem.

Major steam locomotive manufacturers avoided these problems by boring holes for the crank pins in a “quartering machine” that resembled a lathe large enough to hold a wheel set and equipped with devices similar to horizontal mills at each end of the wheel set. The wheel set was precisely positioned in the quartering machine, and the machine ensured that the angular positions of the crank pins on each side were a perfect 90° apart and that the values for R met specifications perfectly. Smaller locomotive shops had a portable crank pin lathe, a device which could be mounted to a wheel set in place on a locomotive and used to quarter crank pins directly. While requiring a careful, tedious set up, these devices could do a job equal to a large quartering machine.

The variability of values Theta and R on Number 9 are likely due to two factors. First, Number 9 was involved in an accident that is known to have damaged both of its wheel sets. Second, it is very likely that the Portland Company used a quartering machine to quarter the finish pin surfaces, rather than the pin holes. We have found evidence that one of the wheel sets on Number 9 is from a different engine, this replacement wheel set having a different value of R than the original. The other wheel set required, and received, a new crank pin. We have found that this pin was not quartered after it was installed (as Portland Company originally did), and since the pin hole was never quartered, the new pin was in the wrong position.

There are two ways for us to solve the quartering problem on Number 9. The first choice is to remove all of the crank pins, or at least the worst ones (a process that would likely result in their destruction), make new (eccentric) crank pins, locate their exactly correct rotational position, and press them in. The other choice is to use a portable pin lathe that would change the centers of the drive pins as shown in the sketch below. After considering commercially available devices for rent or hire, as well as the first option of replacing the crank pins, we chose to make our own portable crank pin lathe.



Our design, developed by Rick Sisson and Jason Lamontagne, with input from Gordon Cook and Jonathan St. Mary, is based upon that of the H.B. Underwood and Company's Crankpin Turning Machine, 1903. Our machine will be mounted on specially designed alignment plates to ensure proper alignment and proper pin positioning upon completion. While the machine is fairly involved and will take an investment in both cost and time to complete, we feel the time is equivalent to replacing the pins and involves less risk to the old, cast iron wheel centers. We will also have a machine on hand to perform future quartering jobs.

John McNamara and Jason Lamontagne