The Gurney Steam Drag 'The Lord of the Isles' at Riverside Museum

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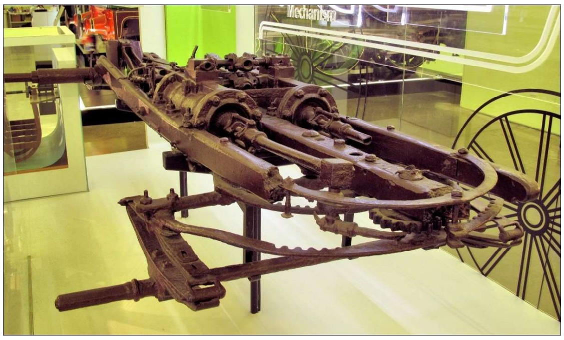
1.0 Introduction. Glasgow Museums has in their collection the remains of the steam carriage known as the Gurney Drag (I.D. No. 1889.99), dating from 1831, **Figures 1** and **2**. This exhibit is one of the most important in the museum collection as it is a unique survivor (admittedly in a much-reduced state) from the early days of steam driven motorised transport. The timing of this Technical Note is appropriate, as it is over 250 years since Nicolas-Joseph Cugnot (1725 – 1804) built his full sized steam wagon (cart), in 1770, **Figure 3**, ref. 1; just a year after James Watt's patent, ref. 2. Interestingly, 1770 was also the year that Richard Lovell Edgeworth of Bath and Ireland (1744 – 1817) proposed the idea of the endless railway; an idea that would come up again and again in connection with road vehicles.



However, before going any further an acknowledgement is required: Dr. Michael Nix formerly Research Manager for Transport and Technology at Glasgow Museums and the late Alistair Nicoll Volunteer Guide at Riverside Museum produced a detailed paper, reference 3, on the Gurney Drag. The information in reference 3 is of significant importance in understanding the history, usage and technical aspects of the drag, as at one time it had been wrongly attributed as being the Russell carriage partly as a result of an error in Fletcher, ref. 7 page 102. It is now known that the drag in the Glasgow Museum collection is the steam carriage 'The Lord of the Isles' built by Sir Goldsworthy Gurney for trials in Scotland in 1831. The paper by Dr. Nix and Alistair Nicoll is included in **Appendix 3** for information.

This Technical Note details and discusses some features of the steam carriage the Gurney Drag along with a Timeline, **Appendix 1**, of persons involved in the early development of steam carriages from Cugnot in 1770 to Gurney in 1832. **Appendix 2** discusses some technical issues of relevance to early steam carriages, which have a bearing on why steam carriages were ultimately not successful.

2.0 Sir Goldsworthy Gurney and Steam Driven Vehicles – Things you need to Know. There are a few details that you need to know about or at least consider in relation to Sir Goldsworthy Gurney (1793 – 1875) and steam driven vehicles, for the transport of passengers and goods, in the time period we are interested in; i.e. from 1770's to early 1830's.

In the past, most people did not move about the country very much. Cities and towns had small populations. Most people lived on and worked the land. Only armies on manoeuvre or princes of the realm moved any distance from their seat of power or influence. If anyone did travel it was by foot or by horseback, if they could afford it.

Goldsworthy Gurney in earlier life, ref. 4.

(1) By steam carriage we mean a steam driven vehicle with a carriage[(1)] for the transport of passengers and goods. The steam power plant that drove the vehicle could be integral with the carriage, a typical arrangement is shown in **Figure 4**, or on a separate articulated vehicle, commonly called a steam drag, where the passengers and goods would be on a separate carriage pulled (dragged) along by the drag. The steam carriage we have in the museum is a steam drag, a typical arrangement of working would be as shown in **Figure 5**. The main issues were that the drag, in the event of a break down, could be replaced by another and with its steam engine and boiler separate from the passenger carrying carriage, was inherently safer for the passengers in the event of a boiler explosion.

(2) The key requirement was that the vehicle (carriage or drag) required a safe, reliable, lightweight, compact and economic power plant. At that time the only option was the steam engine and its associated essential equipment: boiler and furnace, fuel bunker[(1)], water tank, condenser (if it had one), feed pump, feed water heater (if it had one), connected pipework and valves, and transmission shafting to the wheels (or other means of propulsion). The early steam systems operated at low pressures (less than say 5

pounds per square inch) and had low thermal efficiency of say a few percent (much later marine triple expansion engines were developed, on Clydeside, which could achieve about 12% thermal efficiency). The result was that the early low pressure steam systems, such as designed by James Watt for mines and factories, were totally unsuited for vehicles as they were not compact and light enough. The introduction of the high pressure boiler, with pressures greater than about 30 pounds per square inch, made steam systems for vehicles a possibility provided the whole arrangement could be made: safe, reliable, could raise steam quickly enough and in sufficient quantity for sustained running at speeds up to say 12 or 15 miles per hour or more.

(3) The state of the roads was an issue. In the past most roads were just tracks for moving cattle and sheep. The Romans did built and maintain proper roads for their military needs but when they left, in around 400 AD, their roads generally deteriorated. The first turnpike act was introduced in 1707 and was the start of some improvements. Riding in a carriage was an uncomfortable experience for the passengers due to the state of the roads. This was also a technical issue for steam carriages; the power plant required to be lightweight and compact and this was at odds with the rough state and variable surface of the roads, not to mention the gradients to be encountered. The state of the roads really required a *robust* power plant. It was not until Thomas Telford (1757 – 1834) and John McAdam (1756 – 1836) introduced significant improvements that modern roads began to appear[10]. However, it took many years for these modern roads to become established throughout the country, ref. 47 and 61. The introduction of elliptical springs from around 1804 did improve matters.

(4) The early stream carriages would be in competition with the existing horse driven carriages. By the time period we are interested in (around the 1770's to early 1830's), a typical horse driven stage coach service for passengers and light goods (or mail coach introduced after 1784) would comprise of: four horses, driver, armed guard, a carriage with four passengers inside. Later up to three passengers were allowed outside on the roof, one next to and two behind the driver, but not next to the guard or the mail. Depending on the state of the roads, in the summer months an average speed of around 7 to 8 miles per hour or 5 miles per hour in winter could be expected. For the mail coach there was a right of free passage through the turnpike. A system of staging posts (at around 10 mile intervals) for the change of horses and needs of passengers became established; though for the mail coach service the collection and delivery of mail was the priority with little thought for the comfort of passengers.

(5) Clearly any steam carriage had to offer at least an equivalent service and be safe and reliable enough to compete with a hose driven coach service. The cost to the passengers would also have to be competitive. Some horse coach proprietors and others did succeed in getting local turnpike bills passed whereby heavy tolls were applied to steam vehicles thus making them uneconomic compared to horse-drawn vehicles, ref. 3 and 4. There was also vested interest at work, countermeasures (sabotage) in the form of loose stones were put in the way of the passage of carriages.

(6) Gurney was a Cornish surgeon, inventor and engineer[2]. While on holiday at Camborne he saw Richard Trevethick's early experiments with high pressure steam engines mounted on wheels driving vehicles, references 4, 6 and 10. This seems to have inspired him to get involved in designing, patenting, building and promoting steam driven carriages in the years from 1825 to 1832, i.e. a relatively short period of around seven years in which he was active in the business of steam carriages. His vehicles were built by the Gurney Steam Carriage Company at Gurney's Regent's Park works in London. Testing was generally carried out around the park's barrack yard and at several places in London.

(7) When you look at a Gurney steam carriage, like that shown in **Figures 4** and **11** and a drag **Figure 5**, the thing that strikes me, as an engineer, is how advanced the vehicle is for its day (recall that the steam railway locomotive Rainhill Trials only took place in 1829, i.e. just at the time Gurney was actively involved with steam carriages). For that reason I have attempted to show by means of a **Timeline, Appendix 1**, just who was involved and what were the key events and influences in the development of the steam carriage from Cugnot's 1770 wagon until Gurney quit the steam carriage business around 1832.

3.0 Early Steam Carriages --- a Timeline. There were many persons involved in the introduction of steam driven vehicles; some ideas were only pipe dreams, some ideas were actually patented, others did produce small working models, a few did build and get running actual steam carriages but failed for technical and/or commercial reasons. There was also competition from the railways and opposition from the horse coach proprietors, ref. 3, 7, 8, & 9. **Appendix 1** is a short list (**Timeline**), mainly based on Fletcher references 7 and 8, of those persons with an interest in steam carriages on common roads and what contribution (if any) they made in the years from 1770 to 1832.

By inspection of the Timeline it is clear that a great deal of time and effort was expended by many persons with an interest in steam driven vehicles on common roads. Several persons were (or would become) the most eminent engineers of their day. Lots of ideas were put forward and many ideas were actually used in the course of trials and experiments. Some ideas took time to mature while other ideas persisted long after they were shown to be erroneous or just not suitable for the task involved.

By the early 1830's we can say that significant progress had been made in engineering technology and sufficient understanding of heat engines and boilers for potentially successful steam carriages to be built by at least three entrepreneurs; Gurney, Hancock and Maceroni. In the end however, the businesses of these three entrepreneurs were not sustainable for various reasons including: commercial, technical and opposition of vested interests including countermeasures (sabotage).

4.0 Some Features of the Museum's Gurney Drag. The remains of the original Gurney Drag shown in **Figures 1** and **2** consist of: the chassis (a framework of three perches), the steam engine cylinders, front and rear axles, and steering racks with spring suspension. The whole remains are largely covered in a reddish brown preservative paint[37]. What has *not* survived are: the wheels, the superstructure and the boiler.

The Gurney steam drag shown in **Figure 5** is the nearest we have to the drag in the museum collection, **Figures 1** and **2**. At first glance the museum remains look very similar to the drags depicted in **Figure 5** and **6**. The method of steering by its front wheels (by curved radiused rack and a gear pinion), the number of cylinders (two), the piston rod guides with roller type crossheads, the working of the cranks (at 90 degrees to one another) and the number of wooden framework perches (three) are the same. The leading dimensions of the museum drag are as given in **Figure 8**, ref. 41. The overall length is 9 ft 5 inches over the centre frame (central perch). This compares with 10 ft 10 inches scaled from **Figure 5**. However, as can be seen on **Figures 1** and **2**, part of the front of two of the perches and rear of all the perches are missing; as is the cross member between perches and towing bar. When this is allowed for, the museum drag, **Figure 8**, seems to be essentially similar in size and layout to that depicted in **Figure 5**. However, there are detail differences as follows:

(1) **Steering**; there are *two* steering radiused toothed racks (curved gear racks) on the museum drag but only *one* rack shown on the drags in **Figures 5** and **6**.
(2) **Water Feed Pumps**; these force pumps are driven from the end of the pistons on the museum drag, but driven from the piston rod on the drag shown in **Figure 12**.
(3) **Main Steam Valve Gear**; the double gab (X - type) valve gear is used on the museum drag, but an elliptical ring type valve gear is shown on Gurney's coach **Figure 19** and drag shown in **Figure 20**.
(4) **Expansion Valves**; the museum drag is fitted with expansion valves, the steam supply goes to the expansion valve steam chests then to the main valve chest. Gurney's coach and drag shown in **Figures 19** and **20** are *not* fitted with expansion valves; the steam supply goes direct to the valve chests.
(5) **The Spur Gear on the crankshaft**; there is a spur gear, in a central position, on the museum drag crankshaft, **Figure 31**. This spur gear is *not* shown (or mentioned) on any Gurney coach or drag and, as far as I know, nobody knows what this spur gear is for?

It is worth having a look at what these differences are in some detail.

4.1 The Steering. The museum drag was steered[19] by the turning of the front wheels by a radiused toothed rack and pinion, shown in **Figures 13** and **14**. The steering wheel and post are missing but they would likely be as shown in **Figures 5**, **6** and **12**. As seen in **Figures 13** and **14** the museum drag has two steering racks with teeth on the *inside* of the arc. The reason for having two racks is not known. The pinion of the smaller (inner) rack is missing, but if it was of the same dimensions (the teeth on both racks seem to be similar pitch) as that on the larger (outer) rack then a smaller turn, of the steering wheel, would result in a quicker response to give full lock on the steering.

The steering post must have been removable, to transfer it from one rack to the other, but we do not known how easy it was to do this although the attachment seems to be a taper pin as seen in **Figure 13**. Looking at **Figure 14** we can see that both racks are connected to a cross member, which is pivoted to the central perch by a bolt that passes through the central perch and a pivot support bracket which must take the weight of the front end of the drag and any live (dynamic) loads from the road. When the drag is steered the cross member is driven by whichever rack is in use; both racks are connected to the cross member so both racks move in unison. The cross member sits on elliptical springs, which are attached to the wheel axle. Hence the steering loads are transmitted from the drag through the springs to the wheels(20), which turn in the same direction as the steering wheel.

4.2 The Water Feed Pumps. Like all steam boilers it is essential to have a certain amount (level) of water in the boiler. Because the boiler is working at pressure it is necessary to have some means of force pumping the water into the boiler while under pressure. Gurney in his 1828 steam coach, **Figure 19**, used a small auxiliary (donkey) steam engine to drive a reciprocating feed pump(21); the water being taken from a tank under the coach and pumped to the boiler via a coil at the top the furnace to give feed water heating and so to avoid cold water being injected into the boiler(22). The steam engine was controlled by a valve (cock) within reach of the attendant (stoker(19)). There was also a hand operated feed pump at the rear of the coach which could be operated by the attendant.

By the time we get to the steam drags, Gurney is driving the feed pump from the piston rod of the main engine cylinders; the feed pumps being just below the engine cylinders, **Figure 12**. However, on the museum drag a different arrangement is employed; the feed pumps are the long pipes (tubes) extending from the engine cylinder end covers, i.e. the pumps are driven from the centre of the engine pistons, **Figure 15**, with suitable sealing glands on the cylinder covers and pumps. The pumps are single acting and draw water, from the tank in the body of the drag, through a suction valve and discharge to the boiler. It is not known: how the pumps were controlled, if there was a feed water heater, or if there was an additional hand operated pump fitted.

4.3 The Cylinder Valves – the Main Valve Gear. Like all reciprocating steam engines the cylinders require to intermittently allow steam to enter and exit the cylinders. This is typically done by a valve on the side of the cylinder and this is the case with the Gurney carriages and drags. Our museum drag also has expansion valves, in addition to the main valve, see **Section 4.4** below. The main valve controls:

- Manoeuvring, i.e. running forward, stopping and reversing the drag.
- Directing the steam to either side of the piston to give a double-acting engine.
- Directing the exhaust steam to exit via the chimney(31).

On the Gurney coaches and drags this was arranged by a valve chest (valve box or steam chest) on top of each cylinder. The valve within the chest is shown to be a ‘D’ type slide valve(28), ref. 58, driven by an eccentric on the crankshaft, a basic arrangement is shown in **Figure 16**. In this arrangement the slide valve is driven by a single eccentric, per cylinder, on the crankshaft. The eccentric rod is pin jointed to the double-ended rocking lever with a centre pivot. The top end of the rocking lever is pin jointed to the valve rod (spindle). In this basic arrangement the slide valve cannot be made reversing. However, by a simple mechanical arrangement the slide valve can be made reversing as follows, with reference to **Figure 17**:

1. Separate the eccentric rod from the rocking lever by removing the lower (backward) pin.
2. Attach an elliptical ring, with notches at the ends of the ellipse major axis, to the rocking lever.
3. Arrange a pin to pass through the end of the eccentric rod and locate the pin in the lower notch of the elliptical ring.
4. Arrange to have reversing levers (or other equivalent arrangement) so that the eccentric rod (and its pin) can be lifted so that its pin will locate in the top notch of the elliptical ring and thus reverse the direction of travel of the slide valve as the eccentric turns.

Figure 18 shows Gurney’s coach of 1826 with a reversing lever and elliptical ring (each cylinder would have its own ring) at the ***forward*** end of the cylinders. In Gurney’s later coach of 1828, **Figure 19**, the elliptical rings have been moved ***rearwards*** towards the end of the cylinders and the reversing lever lifts the eccentric rod by a cord and pulley system. The Gurney steam drags of 1831, employed by Dance, also have the elliptical rings to the ***rear*** of the cylinders; the eccentric rod was lifted by a lever system, **Figure 20**.

In the case of the museum drag a different arrangement is employed, but achieving the same reversing result. Instead of an elliptical ring the double gab (or ‘X’ type) arrangement(29) is used, see **Figure 21**. This arrangement was not new it was introduced by Carmichael’s of Dundee in 1818, Shields ref. 33, Diagrams of the museum drag valve gear are shown in **Figures 22** and **23**. In this arrangement the rocking lever has pins top and bottom, **Figure 21**. The gab on the end of the eccentric rod can be lifted (or lowered) by actuating the reversing lever. The gab has notches, which engage the appropriate rocking lever pin to go forward or reverse as required. Why Gurney changed from the elliptical ring type gear to the gab type gear is not known.

4.4 The Cylinder Valves – the Expansion Valves. The museum drag is fitted with expansion valves, on the top of the main valve steam chest, as shown in **Figures 24** and **26**. The valve within the chest is a 'D' type slide valve[(28)]. Gurney's previous drags were not fitted with expansion valves the steam went direct to the valve chests, **Figures 6** and **12**; the power output would be controlled by application of the throttle valve[(30)]. The only reason Gurney would want to fit expansion valves would be to give better control over the amount of steam supplied to the main valve and hence to the cylinder. This is done by cut-off of the steam supply as a percentage of the piston stroke, ref. 66. Adjusting the steam cut-off makes full use of the steam pressure and gives better control of the expansion of the steam in the cylinder leading to better fuel economy, ref. 50 and 65. After cut-off the steam would expand in the cylinder doing useful work (something that was known about from the days of James Watt). By this means the power output of the engine could be controlled by utilising the expansion valve to vary the steam cut-off, **Figure 25a**.

The means of operating and control of the expansion valves on the museum drag have not survived. **Figure 26** shows a close up of the right side cylinder valve chests. It is seen that the expansion valves have small stuffing boxes forward and aft (the stuffing boxes on the left side expansion valve chest are broken off). **Figures 27a** and **27b** show the end on views of the valve chests. The remains of an expansion valve spindle can be seen in the forward stuffing box, **Figure 27b**.

To get an idea of how the expansion valves might be operated we can look at what Gurney had used before on his coaches. However, the various diagrams of these coaches, **Figures 4** and **11**, are not detailed enough to show the expansion valve details and even the description in various references is often not clear and so some guesswork is required. Here is my interpretation of how the expansion valves were operated:

(1) With reference to **Figure 28** this shows the arrangement as used on the 1826 coach and described by Gordon in reference 31. The steam supply after passing the throttle valve enters the main valve chest via pipework leading into the side of the valve chest. Just before the pipework enters the valve chest there is an expansion valve (cock) which is operated by a lever connected to an expansion rod and a coil spring. The spring opposite end is attached to an 'L' shaped support bracket bolted to the side (outer) perch. The opposite end of the expansion rod, near to the crankshaft, is attached to elbow levers between the side perch and eccentric. These elbow levers are actuated from the eccentric as it rotates with the crankshaft, but Gordon ref. 31 does not make it clear how this is achieved. The elbow levers are pivoted to the side perch and there must be some means on the eccentric that can actuate the elbow levers, as the eccentric revolves, thus pulling on the expansion rod to open the expansion valve and allow steam to enter the valve chest. The coil spring would be designed to return the expansion valve to its steam off position once the eccentric had rotated. According to Gordon ref. 31 the expansion valve cut off the steam at one-half or two-thirds of the engine stroke but it is not known how the cut-off was set at the beginning of the journey or if it could be adjusted during the journey?

(2) With reference to **Figure 29** this shows the arrangement used on the 1828 coach and described in the patent of 1827, ref. 69. We know that this coach was designed to work expansively, the steam being shut off at half stroke by a cam on the axis of the rear wheels, ref. 24 and 32. The arrangement is much like that described above for **Figure 28** but reference 69 calls the expansion valves sluice valves and the spring return is a lever rather a coil spring. The method of actuating the elbow levers is by cams rotating with the crankshaft. These cams are positioned on the outside of the side perch so the elbow levers have to be dog legged so that the expansion rod can line up with the expansion valve. Note that the main valve eccentrics are positioned between the crankshaft web and inside of the side perch.

(3) Gurney's previous drags were not fitted with expansion valves but it is worth looking at how the eccentrics were placed. As seen in **Figure 6**, like the 1828 coach, the eccentrics are positioned between the crankshaft web and inside of the side perch.

If we now look at the museum drag, the rear end view is shown in **Figure 30**. It can be seen that the eccentrics are between crankshaft webs and inside of the side (outer) perches, which are splayed out along their length so that the width between the side perches can accommodate: the central perch, two cranks and two eccentrics. Thus the museum drag has eccentrics placed essentially like the previous Gurney drags shown in **Figure 6**. If the expansion valves were to be driven from the crankshaft, via elbow levers and expansion rod, then a device (say like a cam) would need to be outside of the side perches (i.e. like that on the 1828 coach, **Figure 29**) as there does not appear to be sufficient space, for a cam, between the eccentric and the side perch. However, in the case of the museum drag the side perches, which are broken at the axle, are attached by bolted clamps to a sleeve on the rear axle, **Figure 31**. This sleeve would not be rotating and hence cams would not operate. The sleeves have two holes (one with a plug) on each rear axle, which presumably are lubrication holes for the rotating axle within? So it would appear that there is no provision, on the museum drag, for cams like that shown on **Figure 29**.

Is there any other evidence? **Figure 32** shows a detail on the side perches, adjacent to the forward end of the cylinders, where there is a cut out evidently for the base of a bracket. I believe this to be associated with the fixed point on the drag body as discussed previously in **Figure 12**. However, I could be wrong about this and might this be for a spring support bracket, like that shown in **Figure 28**, or a lever spring like that shown on **Figure 29**? If so, then this would suggest that the expansion valves were returned to the off position by some means similar to that shown in **Figures 28** or **29**; but allowance would need to be made for the distance between the side perch and the expansion valve centre line. All this is speculation, at the end of the day, I just do not know how the expansion valves on the museum drag were actually operated.

4.5 The Spur Gearwheel on the Crankshaft - what is it for? As seen on **Figures 31**, **33** & **34** there is a spur gearwheel at mid point on the crankshaft with a slot for the gear passing through the central perch. The purpose of this gearwheel is not known. As far as I know, it is not shown on any drawings and not described on any patent or other text. Could it be, that as David West suggests in connection with the valves, in ref. 67, that Gurney might have recycled a carriage chassis[28]?

5.0 Summary. In summary, we can see from the above discussion and the Timeline in **Appendix 1**, that during the period of time from Cugnot in 1770 to around 1832 when Gurney essentially gave up on the steam carriage business, a great deal of time and effort was expended by many persons with an interest in steam driven vehicles on common roads. Several persons were (or would become) the most eminent engineers of their day. Lots of ideas were put forward and many ideas were actually used in the course of trials and experiments. Some ideas took time to mature while other ideas persisted long after they were shown to be erroneous or just not suitable for the task involved.

By the early 1830's we can say that significant progress had been made in engineering technology and sufficient understanding of heat engines and boilers for potentially successful steam carriages to be built by at least three entrepreneurs; Gurney, Hancock and Maceroni. In the end however, the businesses of these three entrepreneurs were not sustainable for various reasons including: commercial, technical and opposition of vested interests including countermeasures (sabotage).

The fact is that the construction of a reliable steam carriage for use on common roads was a much more difficult task than it first appears. Evans in, reference 47, gives an account of the issues involved and comes to the conclusion that the root cause of the failure of the steam carriages was technical issues, the carriages 'were simply not good enough technically to do the jobs they were designed for'. Refer to **Appendix 2** for a very brief discussion of a couple of technical issues mentioned by Evans.

By the 1830's it was becoming clear that the way forward for transport was by steam railway locomotion. The locomotives themselves could be made robust and capable of sustained running at speed, and the rail system provided a hard, smooth, continuous railway that engineers, like George Stephenson, ensured that the gradients encountered were not unduly demanding of the steam locomotives at that time. It was the competition from the railways, and not steam carriages, that finally put the horse driven coaches off the road.

Nevertheless, steam driven vehicles continued to be developed throughout the 19th and into the 20th century, references 7, 8, 35, 36, 37, 38, 40. In particular: traction engines for agriculture (an example is in the museum collection), road rollers for civil engineering, cars (an example of a 'Stanley' steam car is in the museum collection), steam lorries (an example of a 'Sentinel' waggon is in the museum collection) all became acceptable means of road transport and locomotion until replaced by more efficient, cheaper to run, cleaner running, and lighter weight, petrol and diesel driven vehicles we have today.

6.0 Notes.

(1) I use the term carriage or coach interchangeably throughout this technical note. In the terminology of the day the chassis framework (to which the power plant, wheels, carriage body, etc. was attached) was generally called perches. The fuel used was generally coke, chosen to avoid smoke. References 24 and 32 refer to the fuel as coke *and* charcoal. Reference 48 refers to the fuel as coke *or* charcoal.
(2) Gurney's interests included: development of the steam-jet (blast pipe), cleaning of drains, ventilation of mines, improvements in the use of 'Limelight' in theatres and his invention of the Gurney Heating Stove, ref. 4 & 6.
(3) Reference 12 explains that: 'To overcome the irregularity of the motion. It was proposed to use racks and/or ratchets to transmit the reciprocating movement of the piston to the rotating shaft.'
(4) Reference 12 explains that: 'Most engineers of the time originally thought it impractical to try to connect the beam to the crank.' Murdock's arrangement is what is often called a 'Grasshopper' engine, ref. 23.
(5) As reference 12 explains; the early engine builder's thought that with a horizontal cylinder the friction would be excessive and the weight of the piston would wear away the wall of the cylinder. Symington was one of the first to utilise a horizontal cylinder. The concerns regarding friction and wear were unfounded.
(6) Reference 12: suggests that the use of a condenser on the small model was most unlikely. It appears that few steam carriages had condensers (Gurney did not use them) the difficulty was that tallow (used as a lubricant at that time) separated out rendering the condenser ineffective.

(7) Differential gearing for road vehicles is generally credited to Richard Roberts of Llanymynech and Manchester (1789 – 1864) who invented a compensating gear around the 1830's (though the principle was known from antiquity). This allowed both driving wheels to turn sharp corners without sliding, ref. 7. Prior to this the most common arrangement was to have only one wheel keyed to the driving axle and a clutch could engage both wheels if required on say a steep hill (Gurney used clutches on his 1826 (or 1827) coach). Alternatively an iron pole known as a carrier bar (or peg rod or driving-arm or T-arm) between the shaft and outer rim (felloes) of the wheel was used (Gurney used this method on his steam drags, **Figures 6** and **7**) to transmit the load (torque) between the shaft and the felloes thus avoiding any heavy loads being transmitted through the wheel hub (nave) and spokes. Interestingly 'Sentinel' steam waggons, like we have in the museum, have a differential gear as normal on a modern vehicle. However, the waggon is designed to have the facility to lock the differential, by means of a pin on the right side rear wheel, so that both wheels turned in unison. With both wheels locked any corners would need to taken with as large radius as possible, ref. 38.

(8) It is unlikely that any real benefit resulted from the backward exhaust pipes on a steam engine. However, in a high performance fighter aircraft, like the Supermarine Spitfire, the exhausts from each cylinder were pointed backwards to form ejector exhausts specifically to provide extra thrust to offset the engine cowling humps in the air stream, March ref. 15 page 33.

(9) Most engineers prior to 1801 and for many years after (including Gurney) thought that there would not be sufficient adhesion between the road and wheels to move carriage up a gradient without the wheels sliding and that some additional assistance such as "propellers" (legs or mechanical traveller) would be required. Trevithick's experiments around 1801 proved that, provided the gradient was not too steep, there was sufficient adhesion between the road and wheels so that no additional assistance was required but it was many years before this fact became accepted.

(10) Evans, ref. 47 quotes: 'In the 1830s the Turnpike Trusts were administrating 22,000 miles of road in England and Wales; there were about 4,000 miles of canal; and perhaps 400 miles of railway.'

(11) Fletcher, reference 7, states that Maceroni was helping Gurney from 1825 to1828. However, other references e.g. ref. 26 state that he attached himself to Gurney in 1825 and only stayed six months.

(12) Fletcher, reference 7 and Herbert, reference 24 make it clear that the idea was for use on roads. However, Herbert, in reference 25 makes it clear that Seaward's intention was for this idea to be used for propelling vessels on canals or other shallow water.

(13) Fletcher, reference 7, quotes 1826 but Herbert, reference 24, suggests 1827. In general, the dates of Gurney's carriages and drags are somewhat uncertain and at times it is necessary to read the references in detail to establish (if possible) which carriage or drag is being discussed.

(14) Luke Herbert, references 24, 25, and Alexander Gordon, references 30, 31, describe the working of this road carriage.

(15) Luke Herbert, reference 24, Elijah Galloway, reference 32, and The Mirror, ref. 48 describe the working of this coach.

(16) Thurston, reference 23, Luke Herbert, reference 24, and Elijah Galloway, reference 32 describe the working of this coach.

(17) Alexander Gordon, reference 30, and The Mirror, ref. 49 describe the working of this drag.

(18) The Gurney boiler steam pressure was 70 pounds per square inch. The saturation temperature (boiling point) at this pressure is 316°F (157.8°C). A sudden fracture at this pressure and temperature would result in the boiler water immediately flash to steam potentially severely scalding anyone who had the misfortune to come into contact with it.

(19) The driver was referred to by various names such as: coachman, director, steersman, guide & engineer or conductor. The stoker was also referred to by various names such as: fireman, engineer or attendant.

(20) Although invented in 1816 by Georg Lankensperger and patented by Rudolph Ackermann in 1818, ref. 42, and known about before that, ref. 43. The Ackermann steering arrangement seems not to have found much favour on steam carriages, although D. Redmund of City Road, London appears to have used an arrangement after the manner of Ackermann's patent on his carriage (which was like a design copy of Hancock's Enterprise carriage, Fletcher ref. 7), Herbert ref. 25 page 627. On a modern steam lorry, like the 'Sentinel' waggon in the museum collection, dating from 1916, the steering head is designed to allow the wheels to pivot and there is a tie rod between the wheels, like an Ackermann arrangement, that would avoid turning loads being transmitted through the springs, ref. 38.

(21) This auxiliary steam engine also drove a blower (forced draught fan), **Figure 19**, to provide a forced draught of air for the furnace to aid combustion and avoid a tall chimney. Gurney's later drags used his steam blast into the chimney to provide the draught for the furnace.

(22) Technically since the feed water is heated by the furnace gas exiting the chimney (rather that the system steam) it is an economiser. Heating the feed water before it entered the boiler was a worthwhile addition to any steam boiler system. It avoided thermal shock resulting from cold water entering the hot boiler and helped to improve the thermodynamic efficiency of the system reducing the operating costs. The museum 'Sentinel' steam waggon has a feed water heater heated by the exhaust steam from the engine, ref. 44.

(23) As reference 34 explains; the shoe-drags were not so needful as expected. The carrier bars were removed from the outside of the wheel to the inside for reasons of strength and appearance.

(24) David Napier the marine engineer, ref. 51, should not be confused his cousin and namesake David Napier the founder of the engineering company D. Napier & Son, ref. 52 and 53. Reference 52 has a Napier family tree showing the connections of the Napier family including Robert Napier the notable shipbuilder and known as 'the Father of Clyde Shipbuilding'.

(25) The dates of this service seem to be uncertain. Note 19 of ref. 51 quotes the steam carriage ran in 1827 and 1828, as does ref. 52. However, in David Napier's Memoir, page 20 of ref. 51, he seems to suggest an earlier date (at the time he purchased the Glenshellish estate in 1826, see Note 17 of ref. 51) and he seems to believe that his steam carriage was the first that carried passengers for hire on common roads. Vessey, ref. 53 quotes; about 1826. Nicholson, ref. 54 seems to suggest 1829.

(26) The Magazine of Science and School of Arts of 1845, ref. 55, shows a line diagram of 'The Artizan Steam Coach', ref. 56, a new steam coach for common roads. The text states: 'The variety of boiler we have adopted is that invented by Mr. David Napier, and used in a number of steam vessels.' The assumption here is that this refers to David Napier the marine engineer. The diagram shows a design with a vertical boiler and cylinders mounted vertically on each side of the boiler and over the crank axle. So this could meet the description given by Nicholson in ref. 54. However, the diagram also shows a rather strange mechanical linkage imposed between the cylinders and the crank (hardly a direct arrangement). The idea of the arrangement seems be to allow for the springs to be effective. So it is difficult to be really sure if the line diagram represents Napier's carriage on the Kilmun and Loch Eck service in 1827 and 1828 or not? Reference 55 does also mention: 'That a greater power may be given out in ascending hills, is accomplished by a variation in the degree of expansion; an expedient presenting no difficulty, and already practised in steam navigation.' This statement is consistent for the times; expansion valves (sluice valves) appear to be used on Gurney's coaches (of 1826 and 28), were in use on the museum drag (of 1831), and were still in use for many years later. For example, expansion valves are fitted to the museum model marine engine for the SS *Simla* of 1853, ref. 57.

(27) David Napier (about 1785 – 1873) the founder of the engineering company D. Napier & Son, ref. 52 and 53, should not to be confused with his cousin and namesake David Napier the marine engineer who was born at Dumbarton in 1790 and died at Kensington in 1869, ref. 51. Reference 52 has a Napier family tree showing the connections of the Napier family including Robert Napier the notable shipbuilder and known as 'the Father of Clyde Shipbuilding'.

(28) An internal inspection of the museum drag was carried out using a six millimetre video endoscope, in 1999, **Figure 35**. The results are published by Dr. David West in reference 67. This confirmed that: (a) The upper chest (i.e. the expansion valve or sluice valve chest) contains a 'D' type slide valve on a single port which leads to the main valve chest. (b) The main valve is also a 'D' type slide valve with standard porting arrangement (i.e. there would be three ports; one exhaust port and two steam supply ports, one for each end of the cylinder to give a double acting engine). (c) The exhaust cavity of the main 'D' valve has a central transverse bar across the valve but not the full depth, i.e. the valve cavity is not divided into two. (d) When the main valve in its mid-travel the transverse bar almost covers the exhaust port, i.e. In mid-position it would almost completely obstruct the steam flow through the exhaust port as shown in **Figures 36** and **37**. (e) At or near full valve travel it would obstruct the steam flow from the cylinder to the exhaust port as shown in **Figures 38** and **39**. It is not known why Gurney used this arrangement but David West wondered if it relates to Gurney's theories on his steam blast. David West also thought that in connection with the cylinder and valve gear arrangements, but especially the sluice valve suggest that either Gurney used an older design (cf. 1827 patent), or he may have recycled a carriage chassis for the Glasgow Drag.

(29) The double gab (or 'X' type) valve gear driven by a single eccentric is derived from the simple gab, reference 59, so as to allow for ease of reversing. There are examples of the of the simple gab gear in the museum collection; on the PS *Industry* side lever engine of 1828 (ref. 86) and the Table engine model. Animations of the *Industry* engine and the Table engine model are to be seen at my web site: www.acwhyte.droppages.com. The double gab gear worked satisfactory provided that a lap or lead was not required; in such a case two eccentrics were required which eventually developed into the well known Stephenson locomotive link motion. Reference 60 has an explanation of these developments.

(30) As an alternative to varying the cut-off, to control the power output, the power output of an engine could be controlled by varying the steam pressure, **Figure 25b**, by means of a throttling valve. All Gurney coaches and drags were fitted with throttling valves. Throttling was quite an effective way to control the output of an engine but was wasteful of steam, ref. 50.

(31) Gurney's steam drags directed the exhaust steam to the chimney to create a steam blast; thus avoiding the previous arrangement on the coach of 1828, **Figure 11**, whereby a blower fan created a draught of air through the furnace, **Figure 19**. Gurney was one of the claimants for the introduction (invention) of the steam blast, so successful in the locomotive Rainhill trials, ref. 68.

(32) There are detail drawings for an 1786 model and animations on the Internet at the following link:
https://www.modelengineeringwebsite.com/Murdochs_1786_carriage.html

(33) A video of a replica of Trevithick's *Puffing Devil* can be seen at Wikipedia: Richard Trevithick.
(34) Reference 19 has photographs of a working replica, built by the late Tom Brogden, of Trevithick's London steam carriage.
(35) Dr William Harland was three times Mayor of Scarborough. His son, Sir Edward Harland was the renowned shipbuilder and co-founder of the shipyard Harland & Wolff of Belfast, ref. 77.
(36) It appears that Gurney and Colonel James Viney had a short lived partnership under the firm Gurney & Co. that was dissolved by mutual consent in 1827, references 10, 78 and 79.
(37) As seen from **Figures 1** and **2** the drag is painted in a reddish brown colour presumed to be a protective layer. However, as seen in an underneath view of the drag, **Figure 14**, the reddish brown paint does not cover the whole drag. Examination of the drag appeared to show earlier coatings to exist under the reddish brown paint. In 2007 an examination of tiny samples of the surface coatings from several locations on the drag was conducted using an Nikon Labophot fluorescence microscope. **Figure 41** shows the results of **Sample 2: from the wooden perch on the proper left side (see photo)**. It can be seen that the stratigraphy of finishes under visible light (on left) and with UV illumination (on right) there are no less that 11 layers of finishes; from Layer 1 – grey preparation through to the top Layer 11 – brown paint with several colourful historic paints between. **Figure 40** shows where a small area (near Sample 2 shown in **Figure 41**) of the reddish brown protective surface layer was removed from the left side perch to reveal a green under layer.
(38) From an announcement poster, in Oakley ref. 87, which includes some description of the model and the full size carriage (if it had been built); it seems that this steam carriage model was also seen at work in Glasgow in January 1828.

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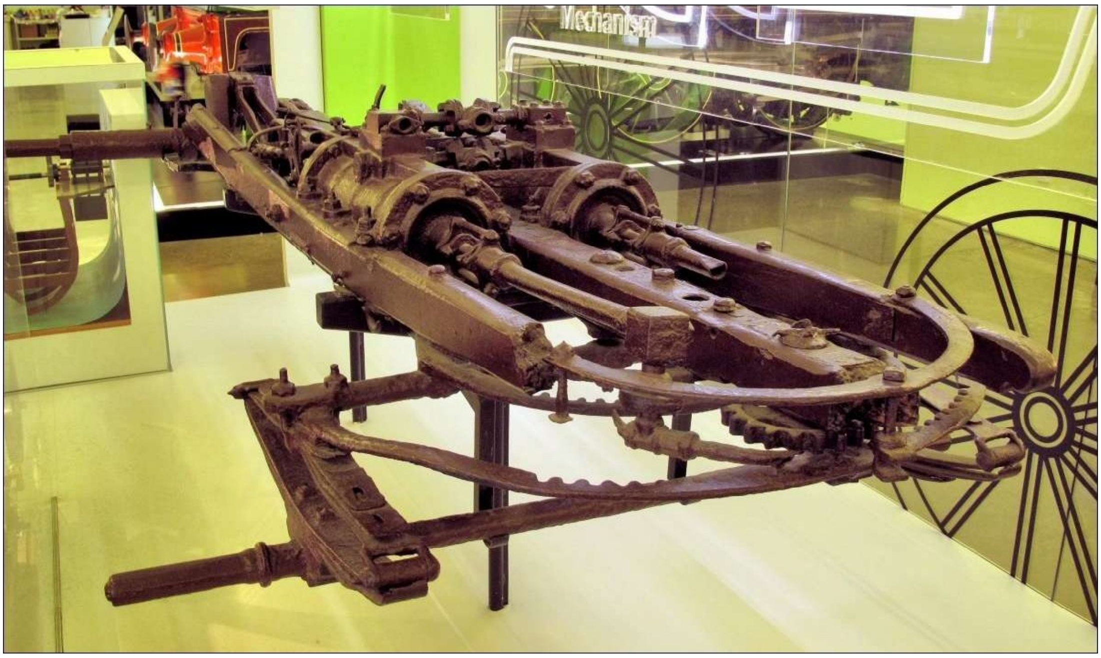


Figure 1, The remains of the Gurney Steam Drag at Riverside Museum, Glasgow 2019. The drag is largely covered in a paint of reddish brown colour[(37)].

Figure 2, The remains of the Gurney Steam Drag at the old Museum of Transport, Glasgow 2006.

Figure 3, Cugnot's 1770 Steam Wagon in the Musée des Arts et Métiers (Museum of Arts and Crafts), Paris. Wikipedia, ref. 1.

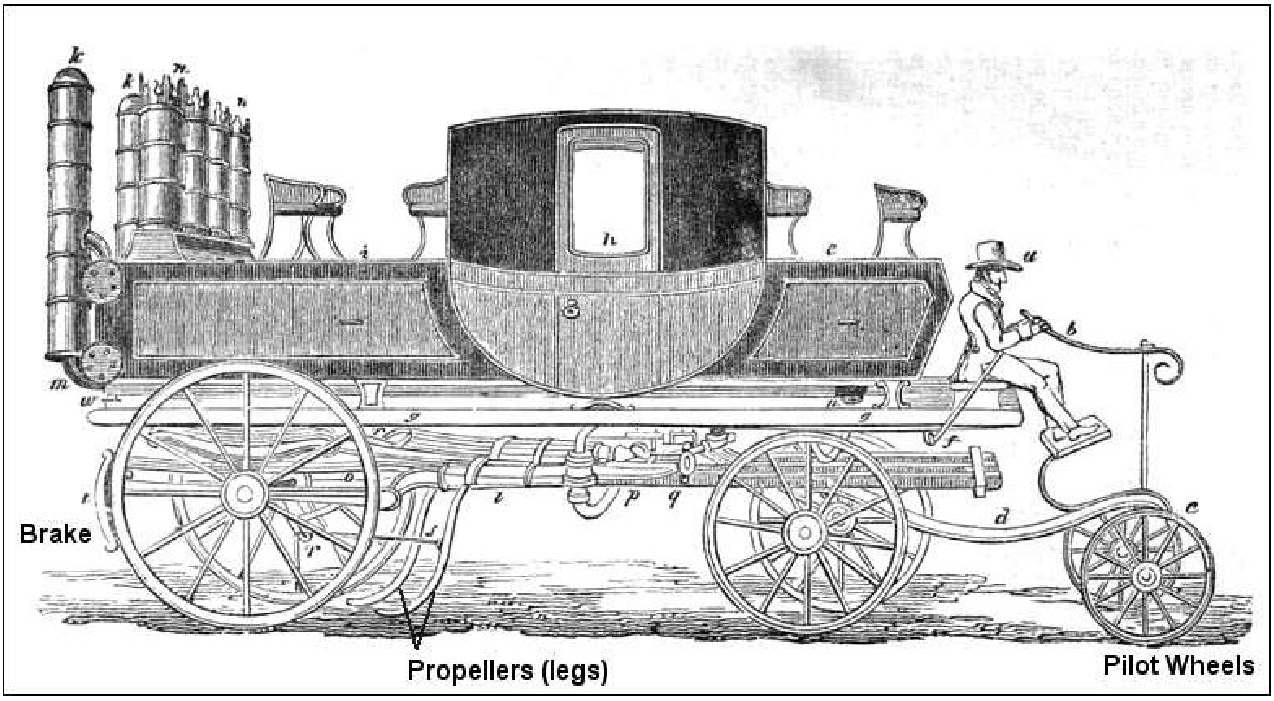


Figure 4. A Gurney steam carriage (coach), Herbert ref. 24 with added text. This 1826 (or 1827) six-wheel coach had pilot steering and a brake on the rear wheel. The coach is also fitted with propelling legs i.e. a 'Mechanical traveller' which could be put in motion to assist going up hills in addition to the main rear wheel drive. These legs were found to be not needed and subsequently removed, ref. 7.

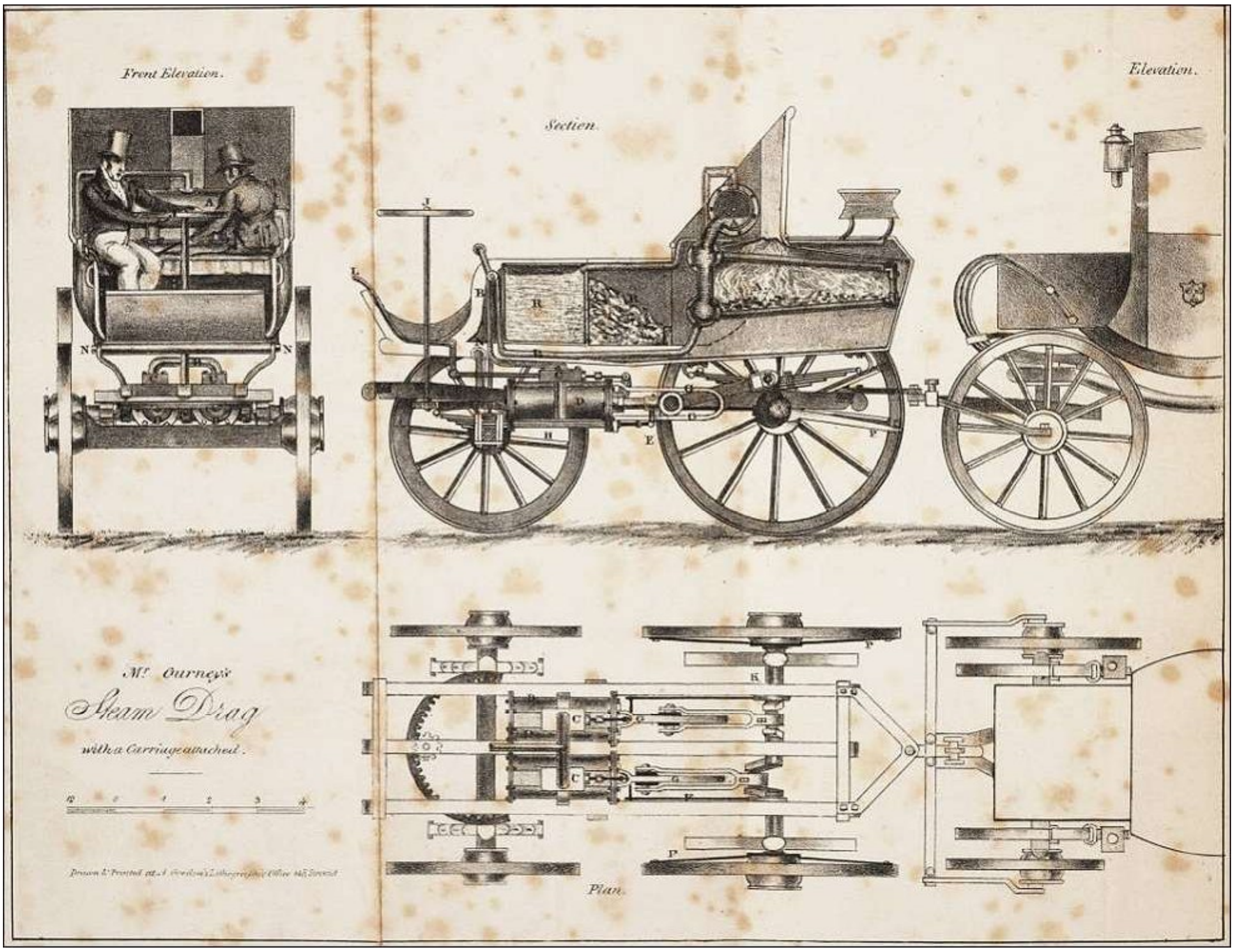


Figure 5. A Gurney steam drag pulling a carriage, 1831, Gordon ref. 30. Additional text is given in **Figures 12** and **20** for explanation. This drag is the nearest we have to the museum drag, but there are detail differences as discussed in the main text **Section 4.0**.

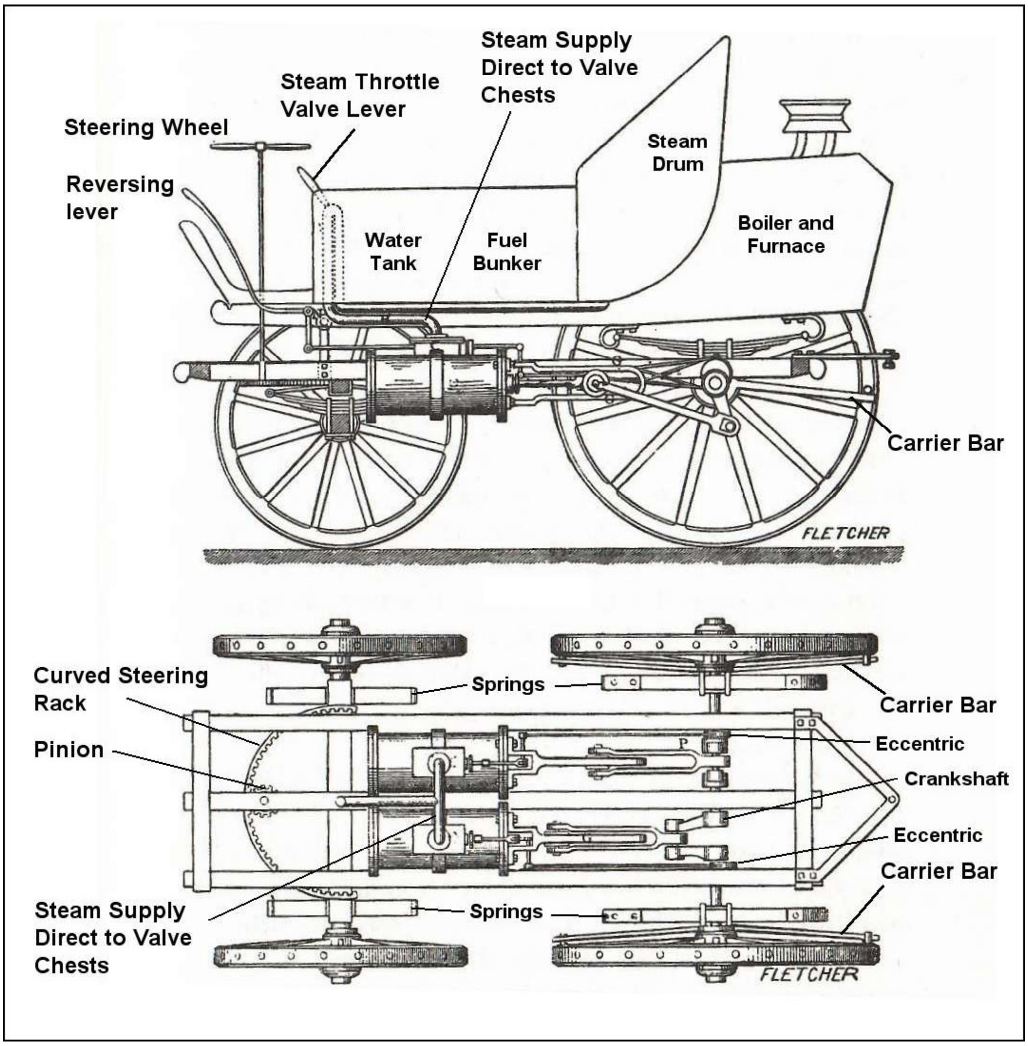


Figure 6. Gurney's steam drag used by Sir Charles Dance's coach service between Gloucester and Cheltenham, 1831, Fletcher ref. 7 with added text. Note the steering by means of a pinion and curved rack with teeth on the <u>*inside*</u> of the arc. Like **Figure 5** this drag is the nearest we have to the museum drag but there are detail differences as discussed in the main text **Section 4.0**.

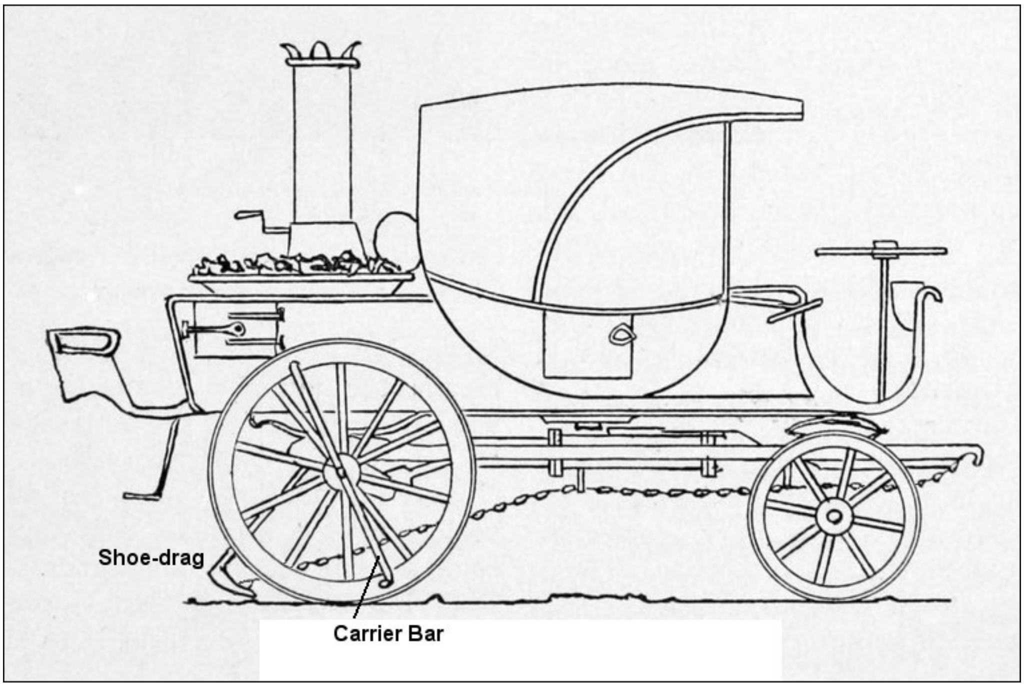


Figure 7. Gurney's steam drag used by Sir Charles Dance's coach service between Gloucester and Cheltenham, 1831, showing a shoe-drag and a carrier bar, Herbert ref. 25 with added text.

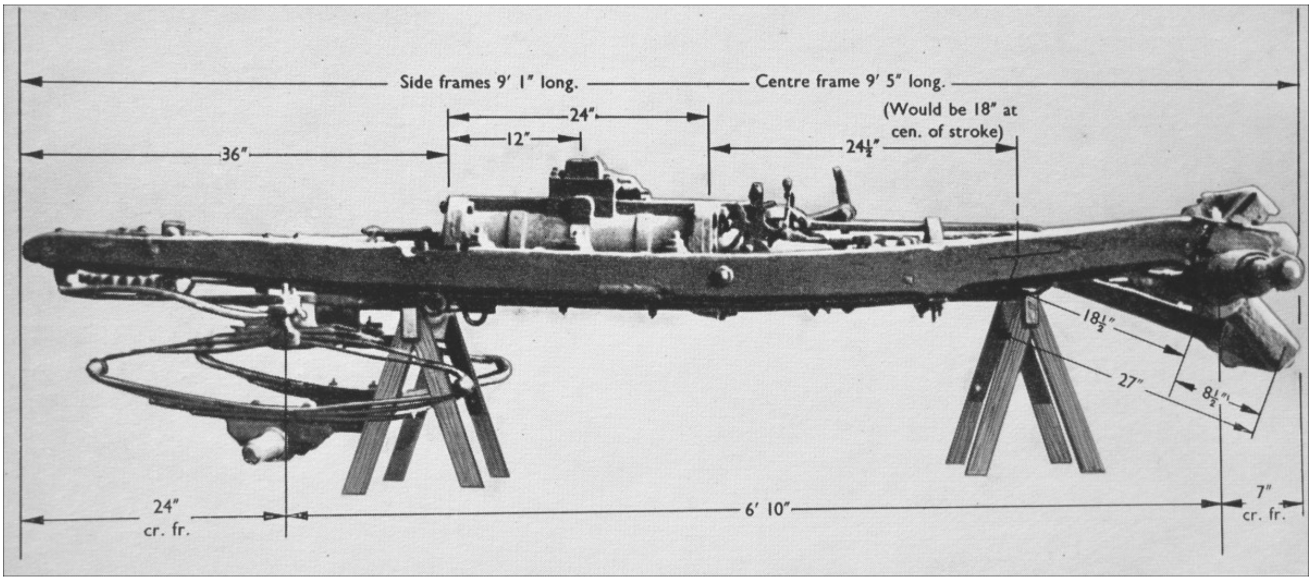
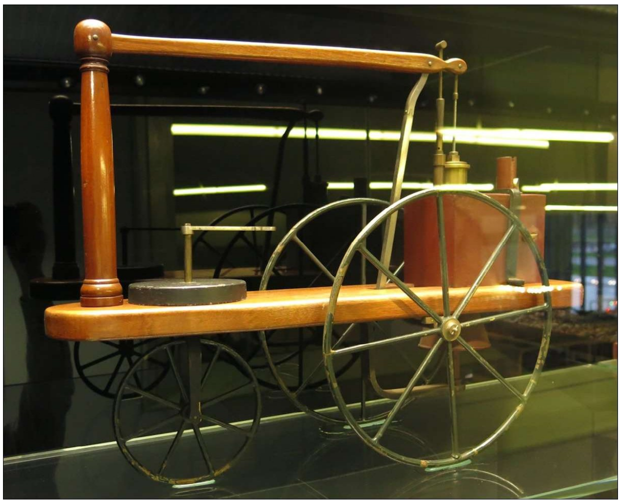


Figure 8. Leading dimensions of the remains of the Gurney Drag, ref. 41.
The overall length is 9 ft 5 inches over the centre frame (central perch).

Figure 9, William Murdock's small (model) steam road locomotive. Replica model(32) on display in Riverside Museum.



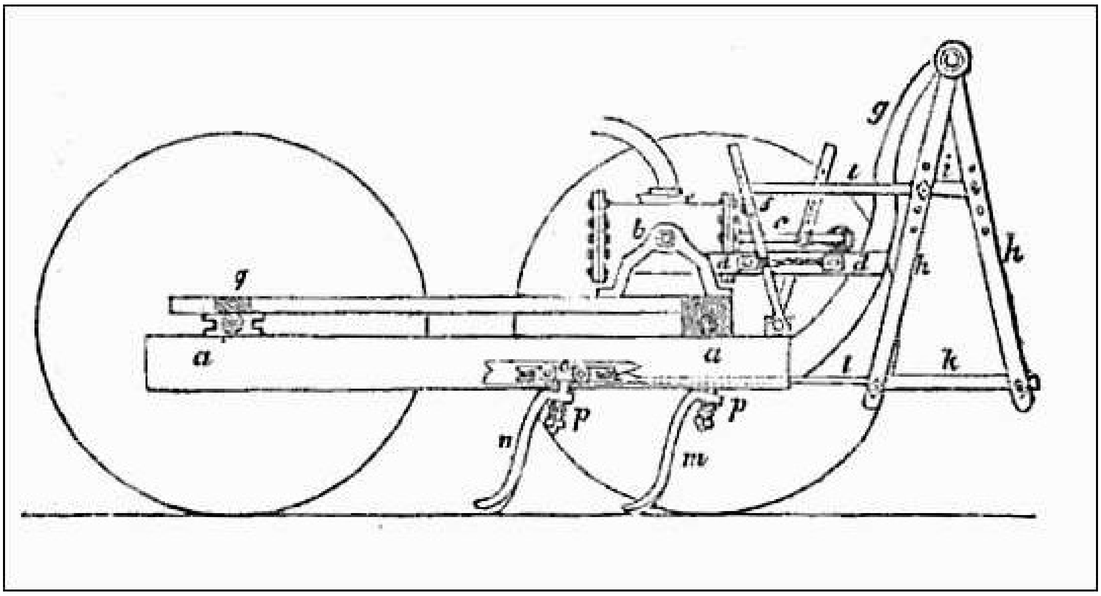


Figure 10, Line drawing based on Gurney's first patent No. 5170 of 1825. The steam boiler is not shown. This drawing shows that Gurney intended this carriage to be moved by propellers (legs) in the manner of a 'Mechanical traveller'. The wheels were only to support the weight of the carriage. The rear wheels pivoted for steering. References 24, 25, 30 & 31 describe the working of this road carriage.

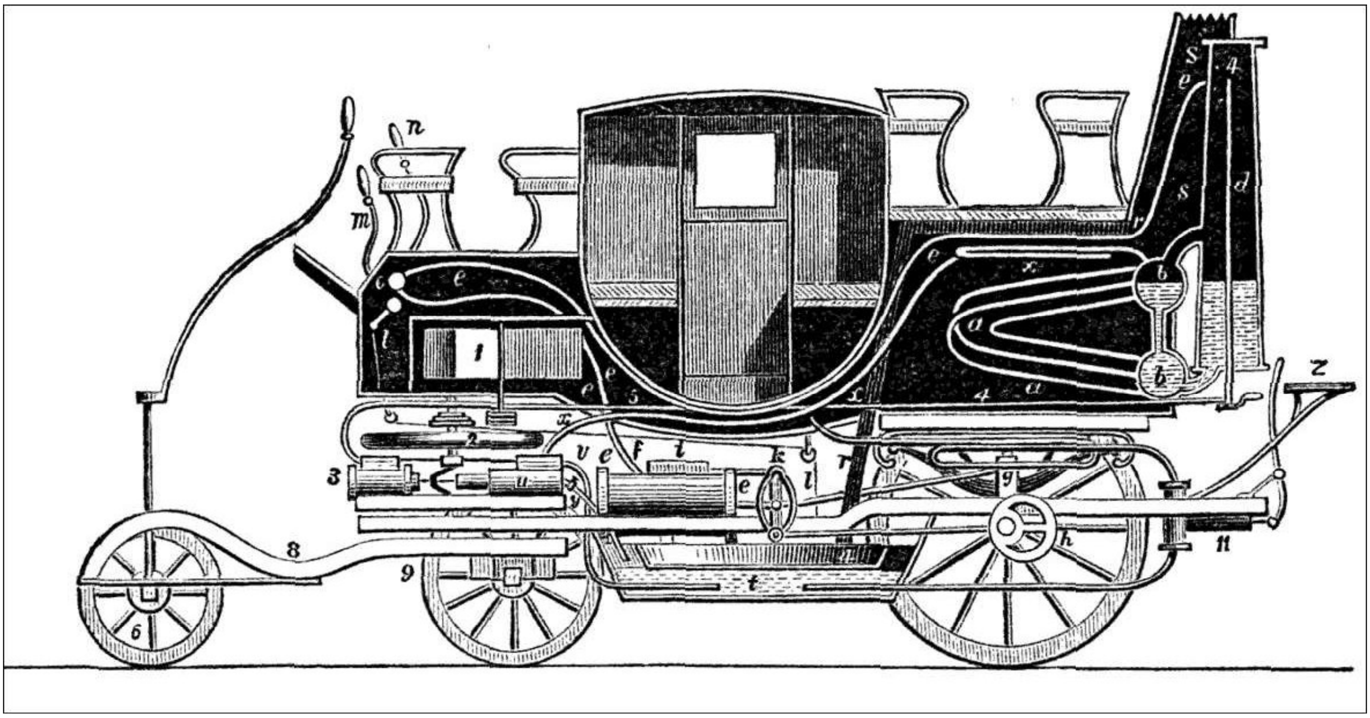


Figure 11. Diagram of Gurney's 1828 steam coach, Thurston ref. 23. This carriage had a many patent improvements compared to the previous coach of 1826, **Figure 4**, including not requiring propelling legs which were previously found to be unnecessary, ref. 7. Further detailed description of this coach is given in **Figure 19**.

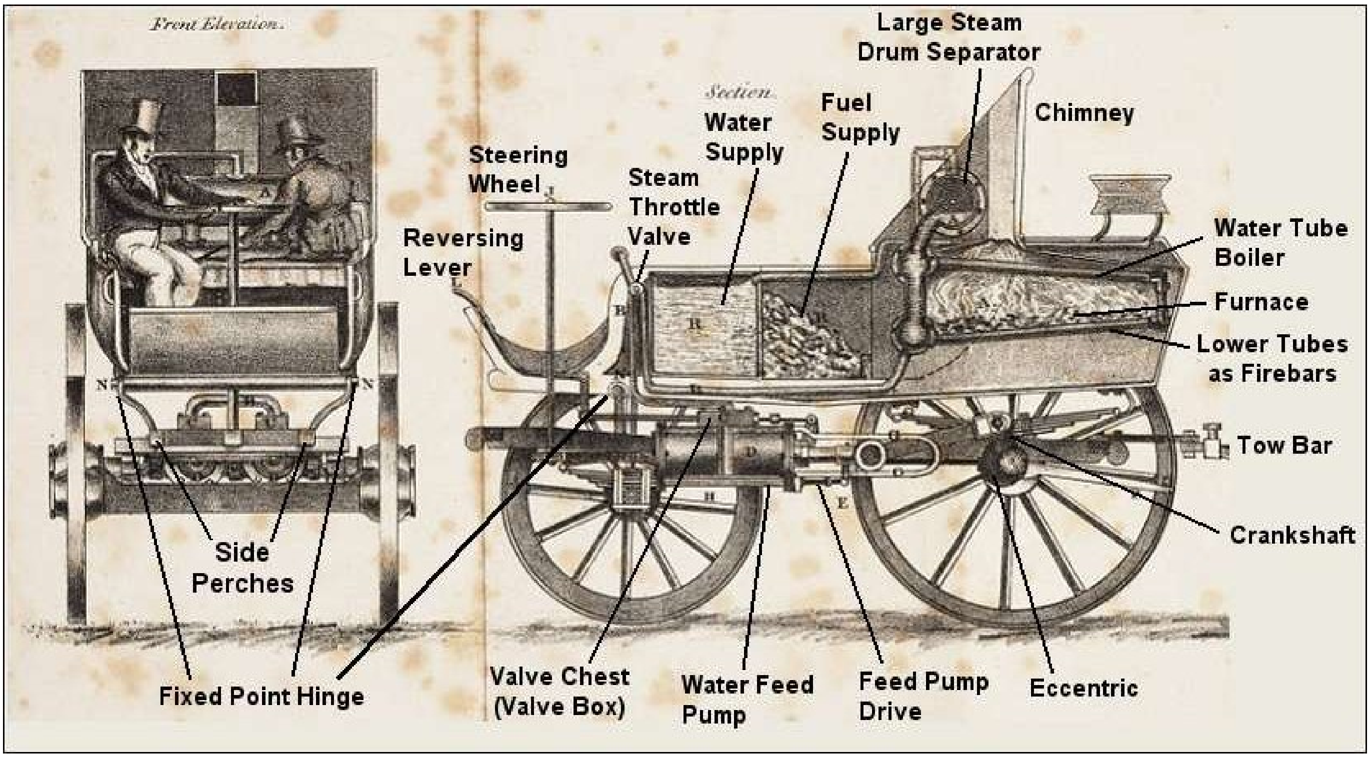


Figure 12. Gurney steam drag of 1831, Gordon reference 30 with added text. Note that there is a fixed point on the drag body at 'N' where there is a hinged support, which connects to the side perches. This allows the body to rise and fall, about the hinge, when the elliptical springs above the rear axle come into play. The steam pipes were brought close to the hinge so that there was less disturbance and a better chance of keeping the pipes steam tight, ref. 30. The water-tube boiler uses the lower tube bank as firebars. A large horizontal steam drum formed the steam separator, which replaced the vertical separators on previous coaches.
Further details are given in **Figure 20**.

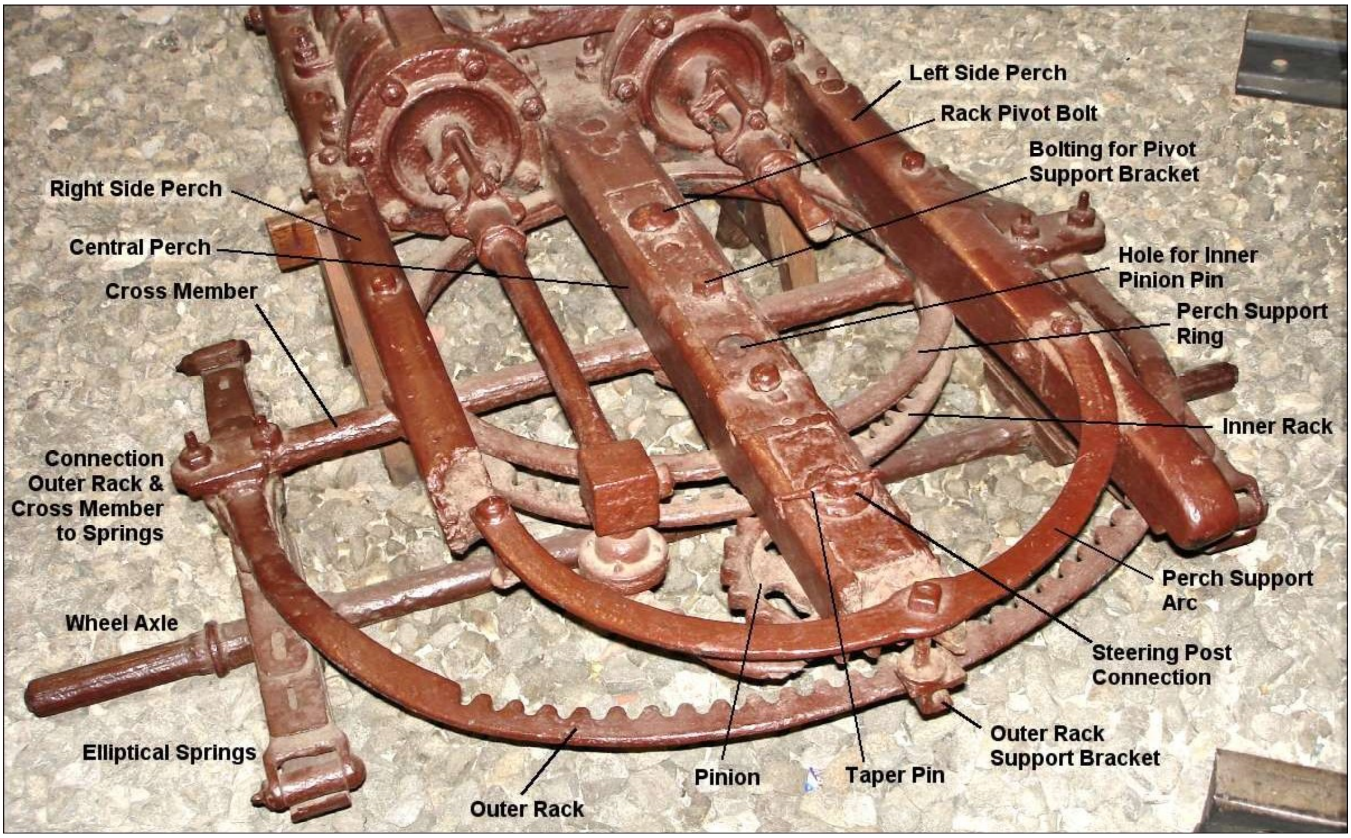


Figure 13. Gurney's Drag showing the two steering radiused toothed racks and gear pinion from above. The outer rack is part of a semicircle the inner rack is part of a complete ring. Note that the three perches are maintained in alignment by bolting to a support arc and a support ring. The two racks are connected to the cross member, which is pivoted to the central perch by a bolt. When the drag is steered the cross member is driven by whichever rack is in use so both racks move in unison. The cross member sits on elliptical leaf springs, seen in **Figure 14** below, which are attached to the wheel axle. Hence the steering loads are transmitted from the drag through the springs to the wheels, which turn in the same direction as the steering wheel.

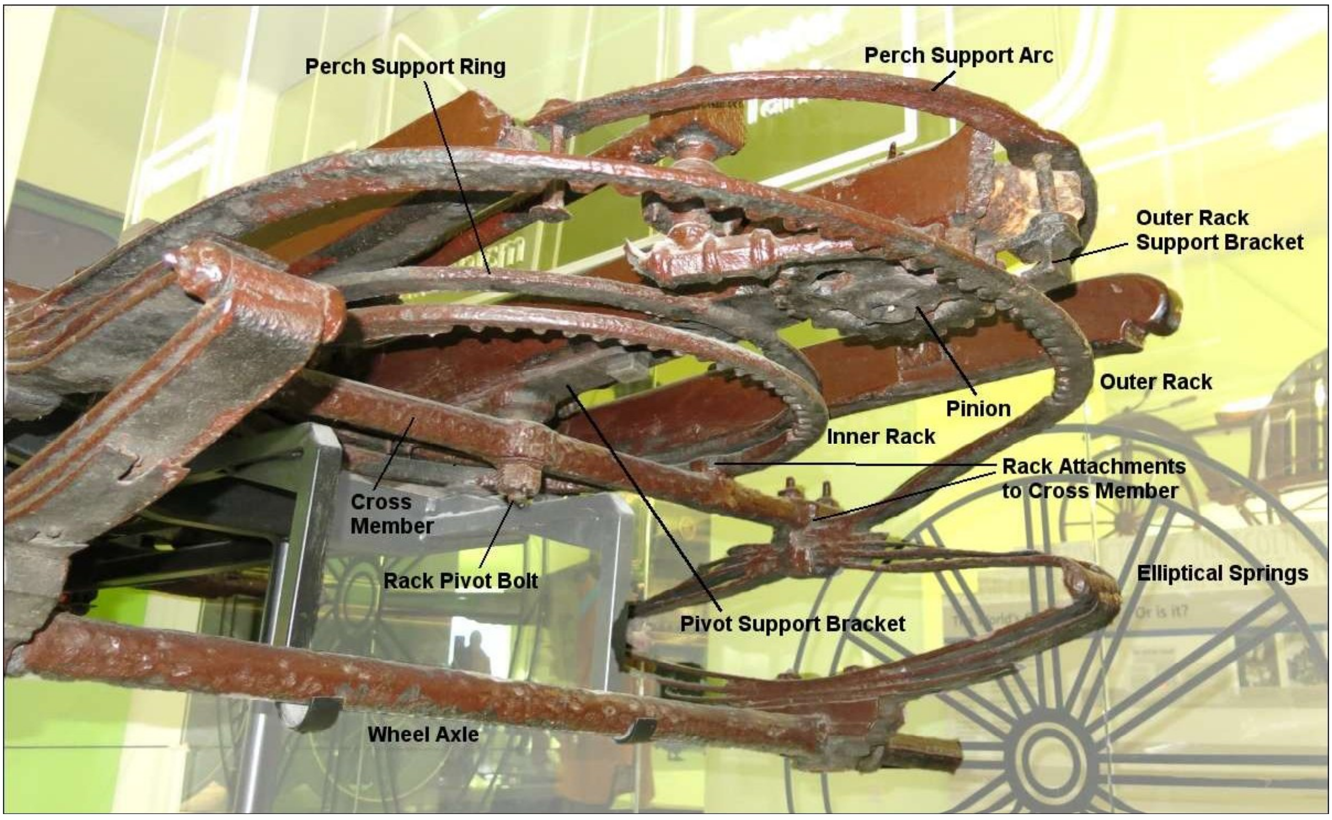


Figure 14. Gurney's Drag showing the two steering radiused toothed racks and gear pinion from below. Note that the reddish brown protective paint does *not* cover all of the underside of the drag, refer to **Note (37)**.

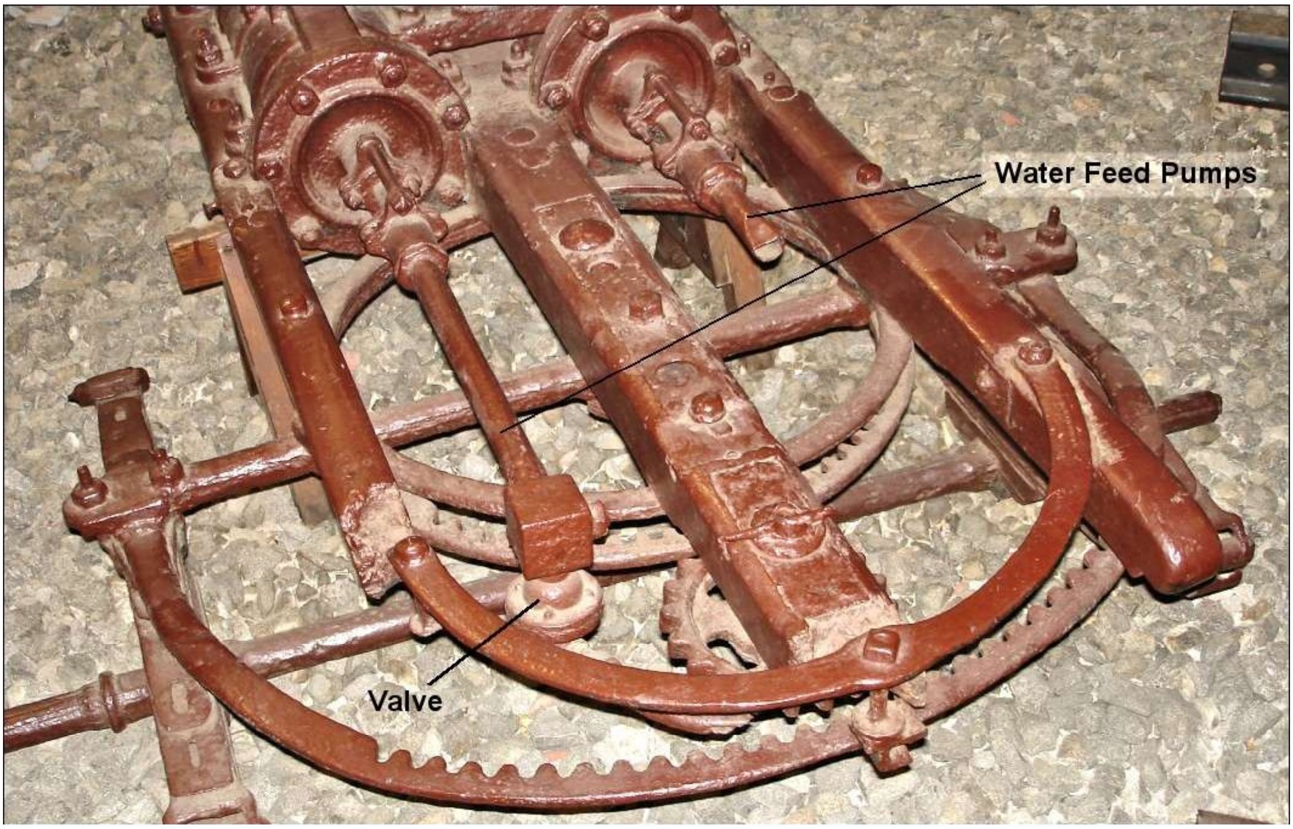


Figure 15. Gurney's Drag showing the boiler water feed pumps. The pumps are driven from the centre of the engine pistons with suitable sealing glands on the cylinder covers and pumps.

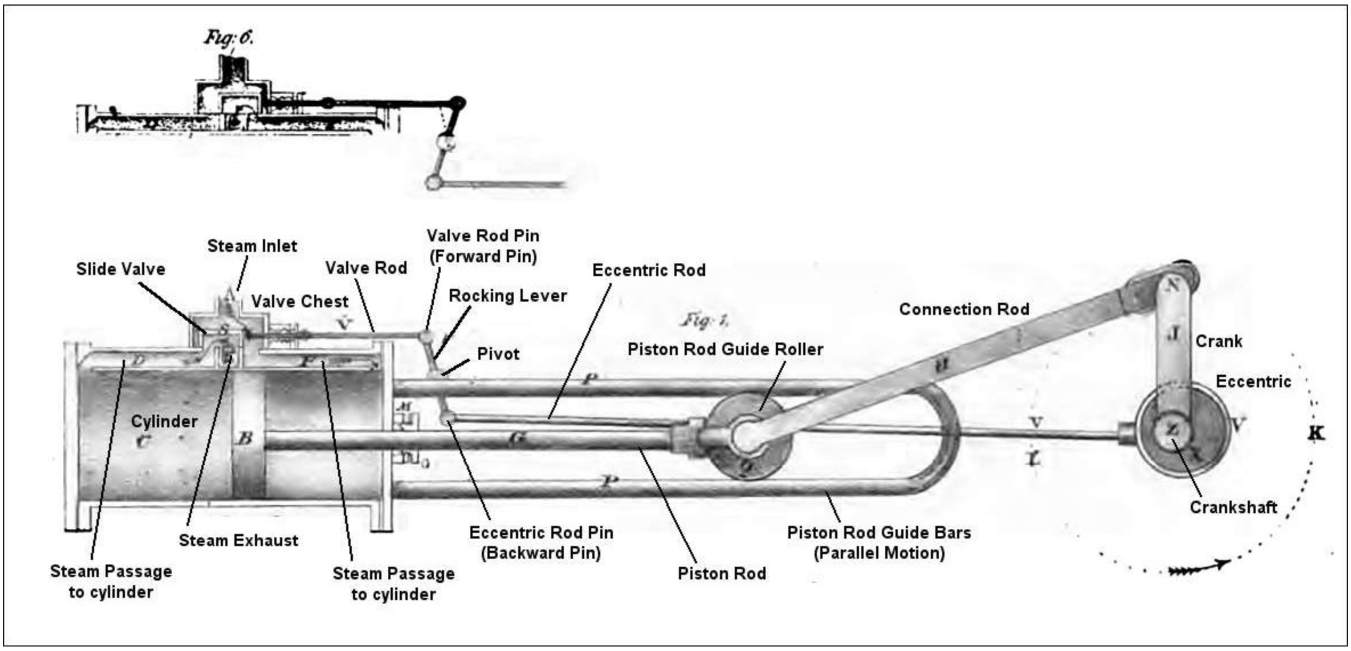


Figure 16. Basic arrangement of a steam engine with slide valve driven from an eccentric on the crankshaft, Gordon ref. 31 with added text.

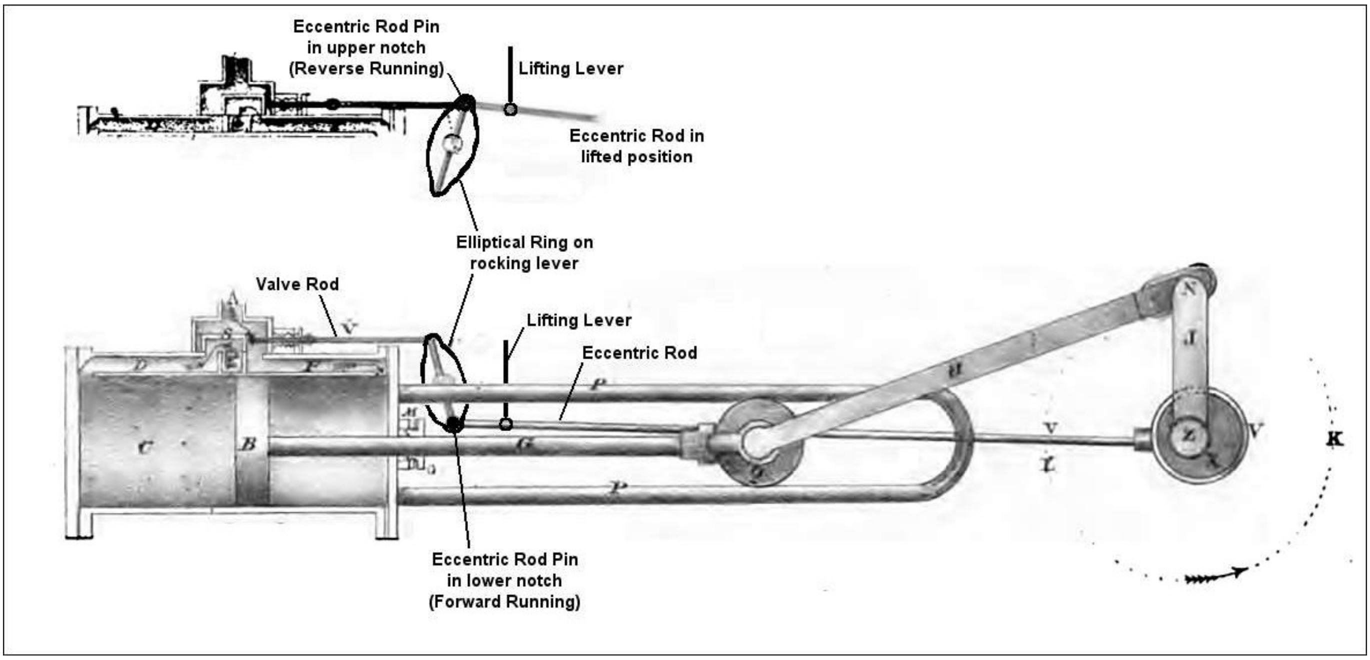


Figure 17. Arrangement of a steam engine with slide valve and a reversing mechanism, based on Gordon ref. 31 with added text and elliptical ring and lifting lever added.

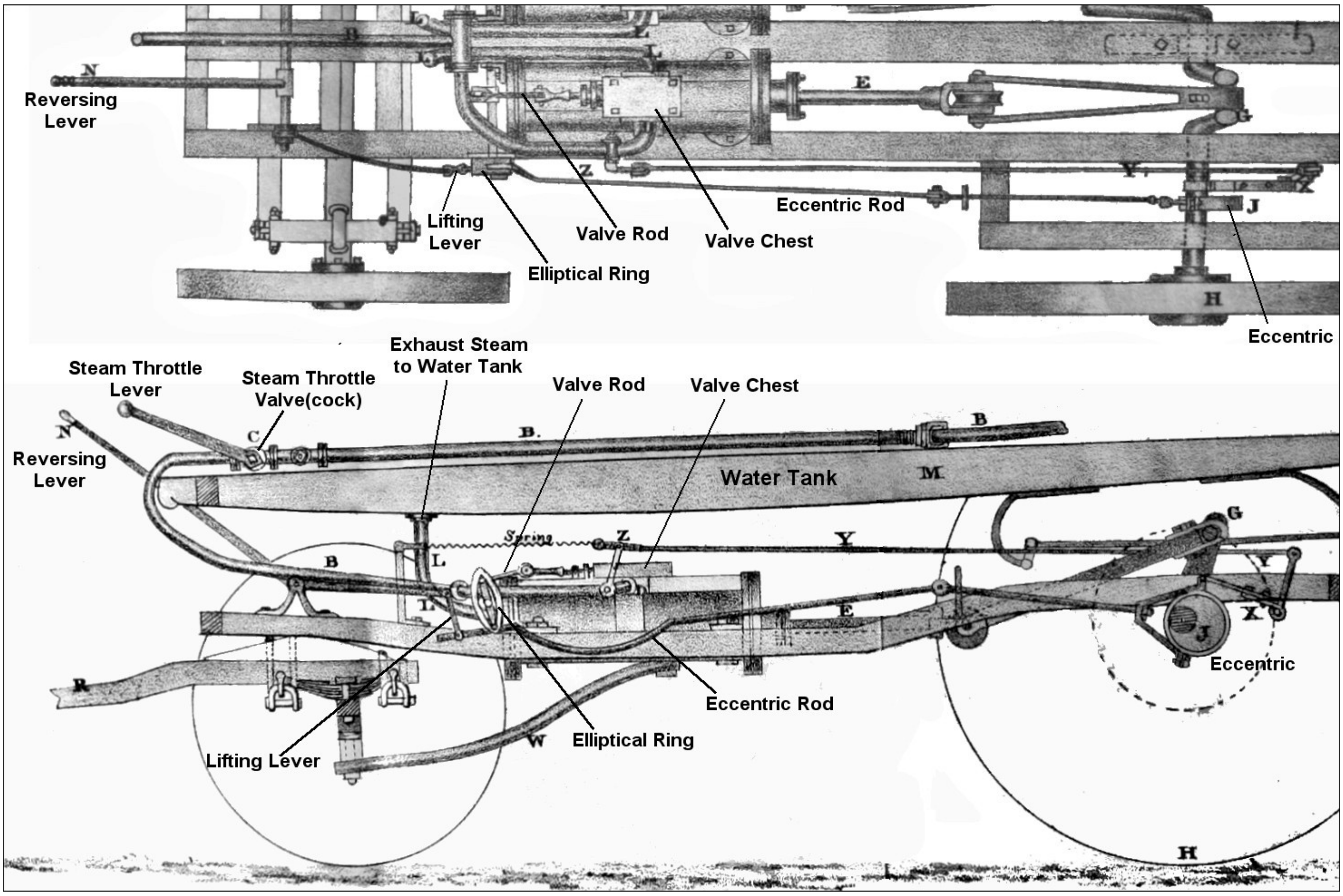


Figure 18. Gurney's coach of 1826 showing the reversing lever and elliptical ring (each cylinder has its own elliptical ring) positioned at the *forward* end of the cylinders. The single reversing lever lifts the eccentric rod of each cylinder by a lever system, Gordon reference 31 with added text.

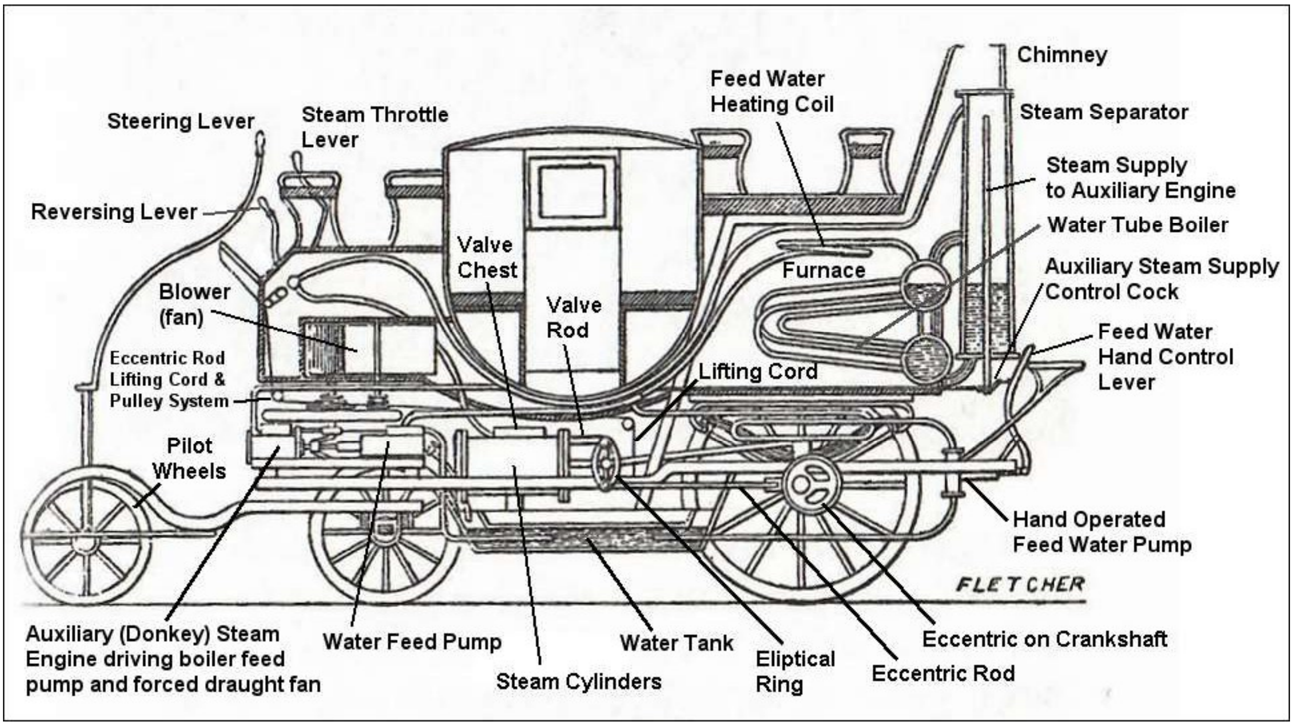


Figure 19. Gurney's coach of 1828 showing the reversing lever and elliptical ring (each cylinder has its own elliptical ring) valve gear positioned at the _rearward_ end of the cylinders. The single reversing lever lifts the eccentric rod of each cylinder by a cord and pulley system, Fletcher reference 7 with added text.

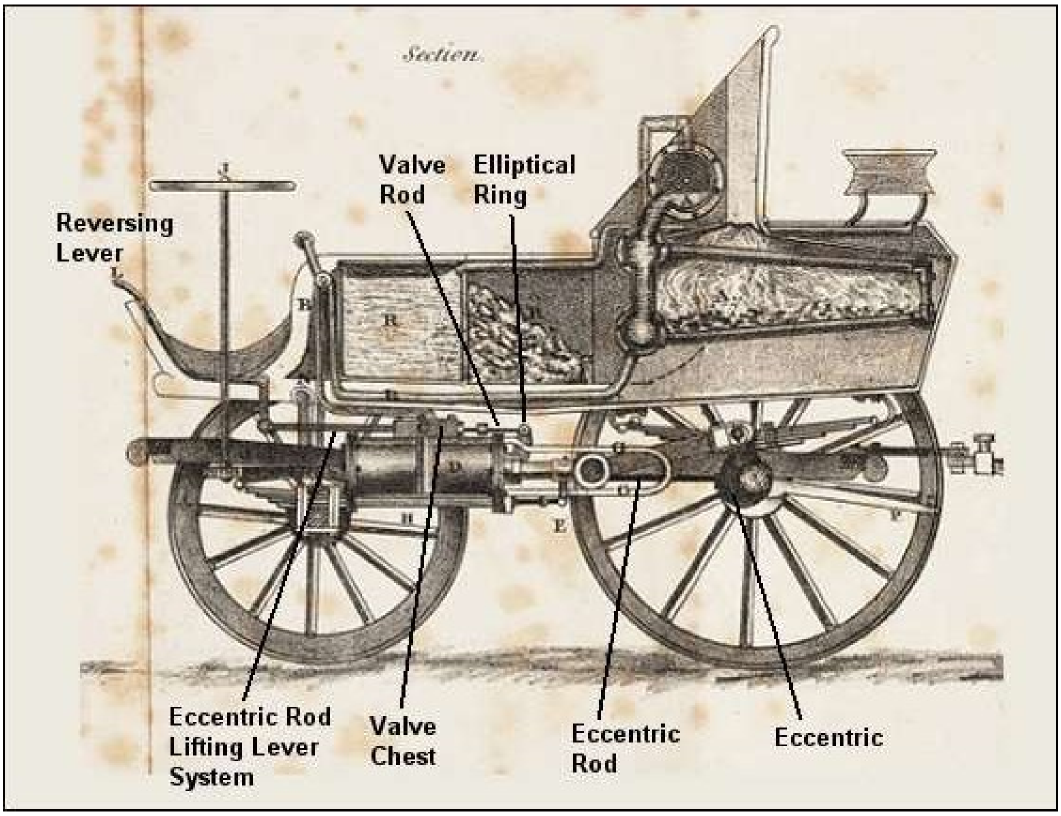


Figure 20. Gurney's steam drag of 1831 showing the reversing lever and elliptical ring (each cylinder has its own elliptical ring) valve gear positioned at the _rearward_ end of the cylinders. The single reversing lever lifts the eccentric rod of each cylinder by a lever system, Gordon reference 30 with added text. Further details are given in **Figure 12**.

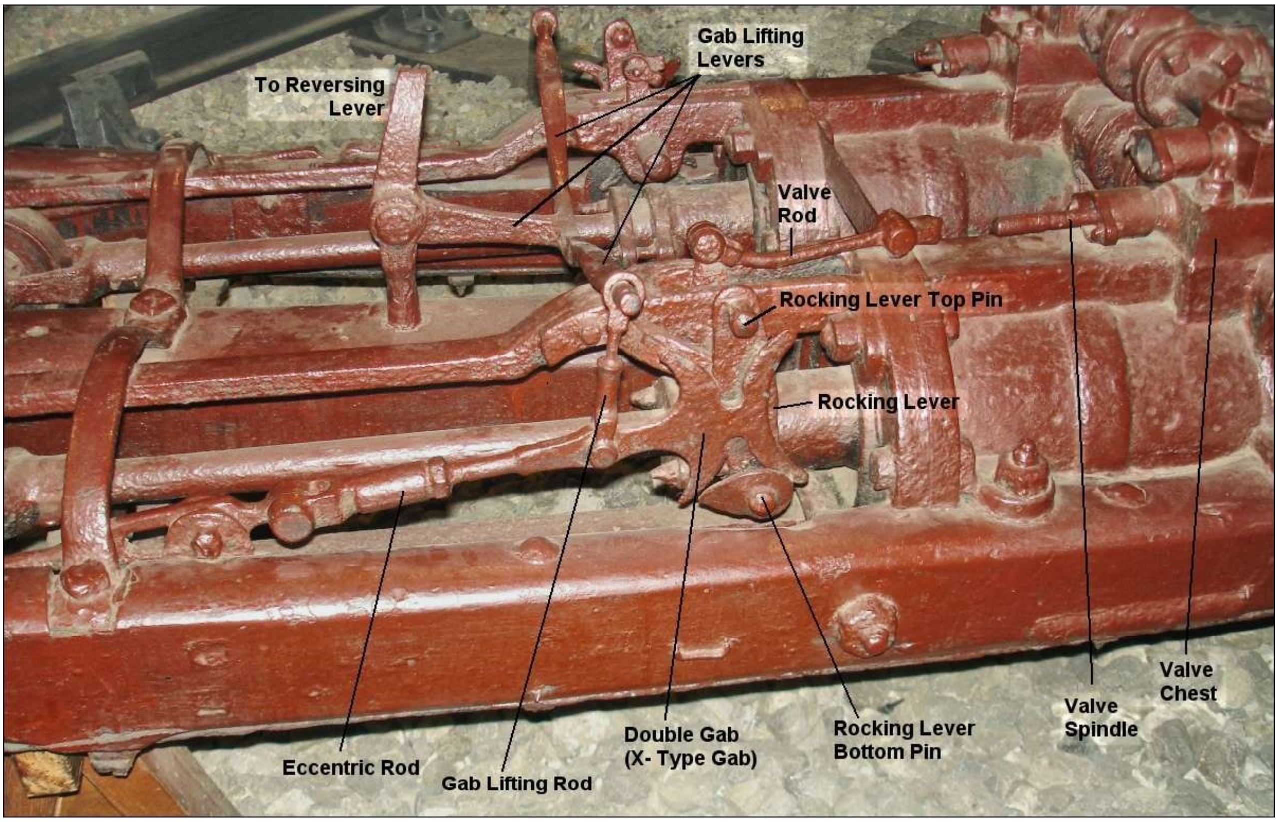


Figure 21. The remains of Gurney's Drag of 1831 uses a double gab gear (X –type gear) to reverse the direction of the slide valve by actuating the reversing lever. This type of gear was known from 1818.

Figure 22. Diagram of the museum Gurney Drag set for Forward Running.

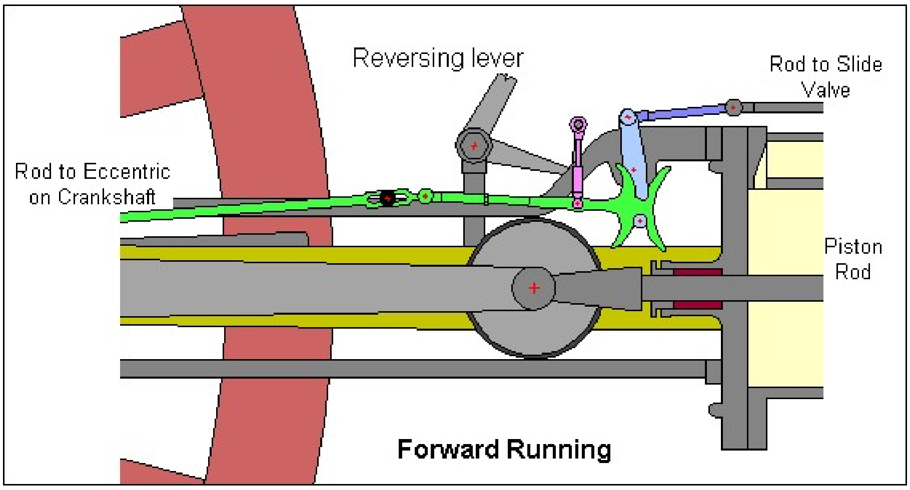
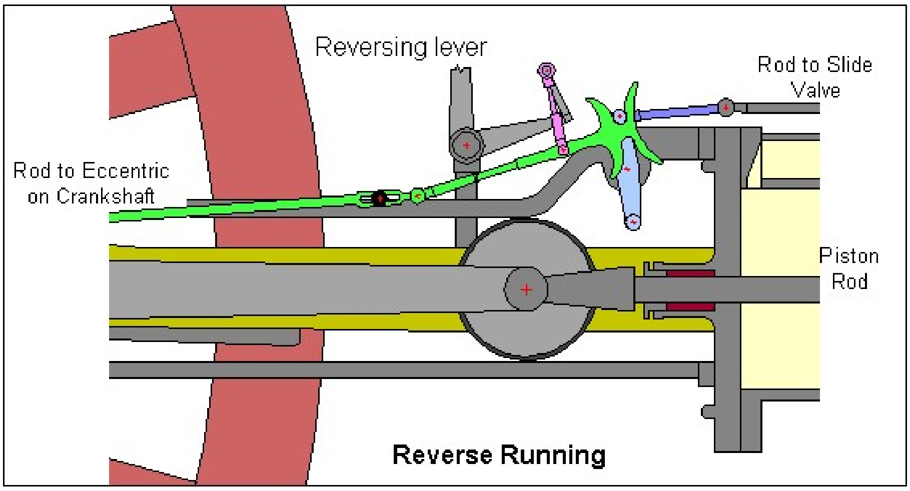


Figure 23. Diagram of the museum Gurney Drag set for Reversed Running.



Gif animations of these valve gear can be found at my website: https://acwhyte.droppages.com/animations.htm

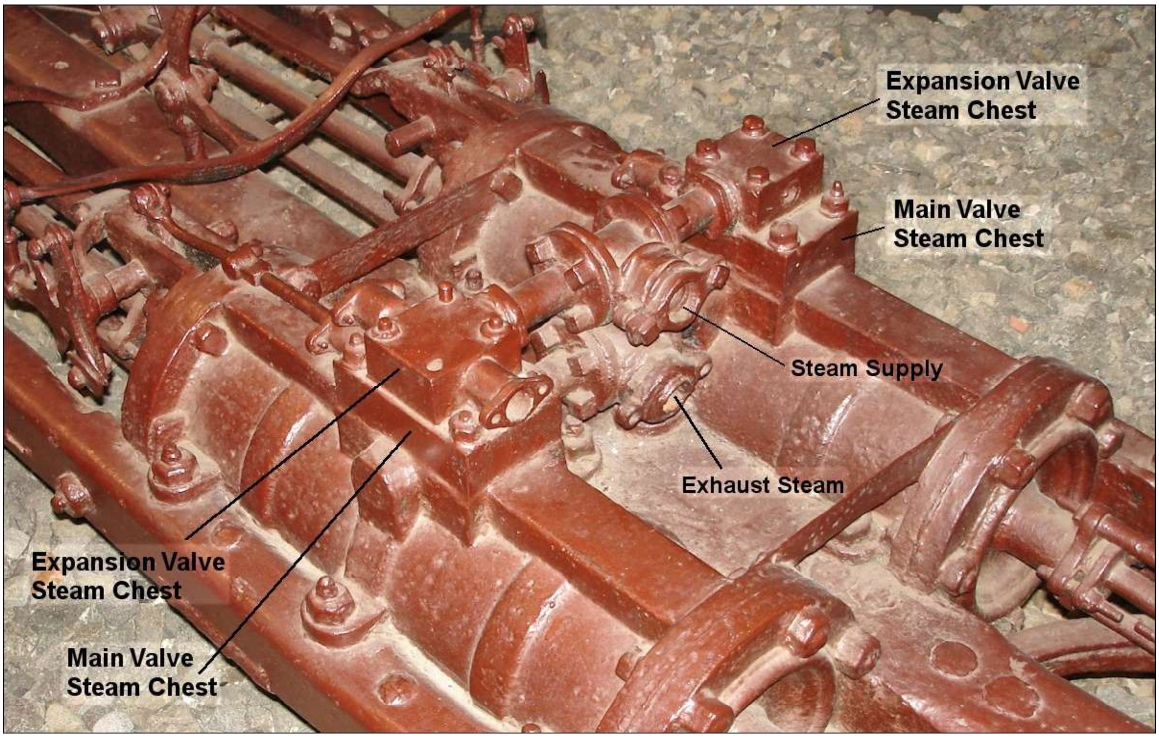


Figure 24. Gurney's Drag of 1831 showing the main and expansion valve steam chests on the top of the cylinders. The steam supply would come direct from the boiler via a throttle valve. The exhaust steam would be directed to the chimney as a steam blast.

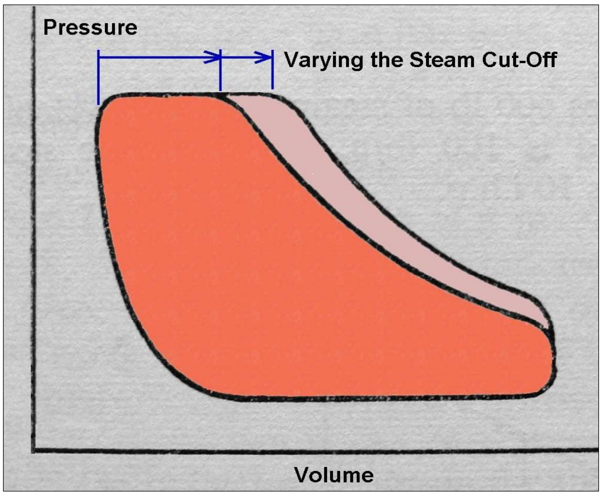


Figure 25a. Indicator diagrams showing the effect on the power output of the engine by varying the steam early cut-off. The smaller the pressure – volume diagram the lower the power output.

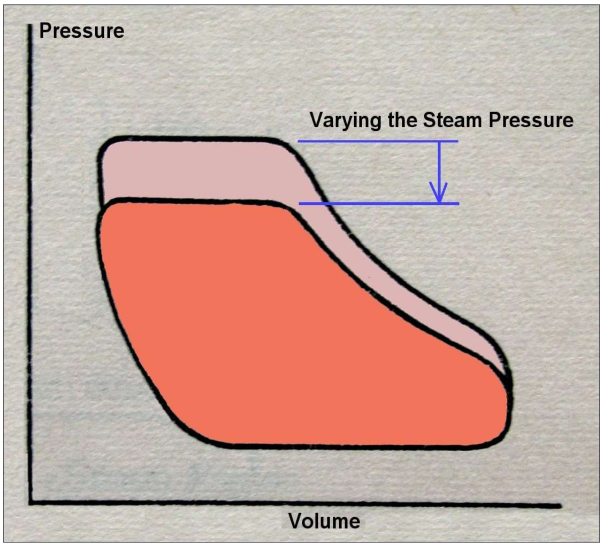


Figure 25b. Indicator diagrams showing the effect on the power output of the engine by varying the steam pressure by throttling. The smaller the pressure – volume diagram the lower the power output.

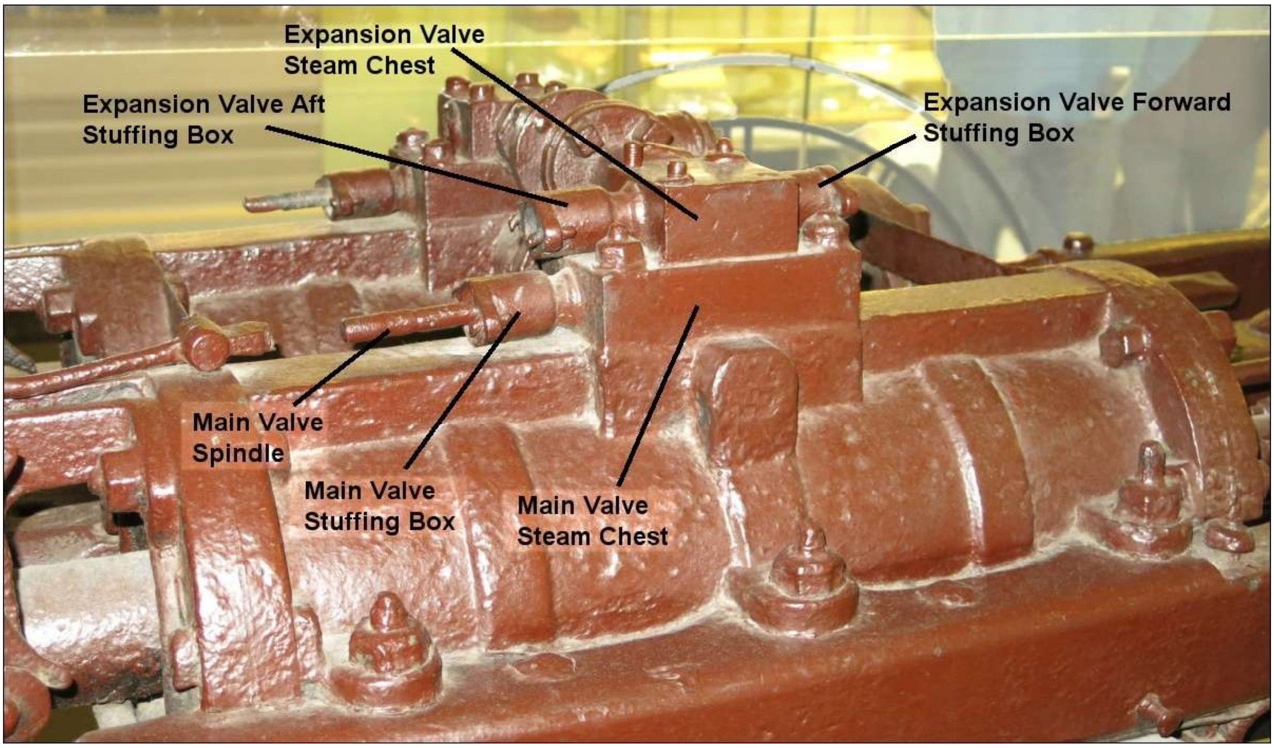


Figure 26. Gurney's Drag of 1831 showing the main and expansion valve steam chests on the top of the cylinders. The main valve has one small stuffing box. The expansion valve has two small stuffing boxes, fore and aft.

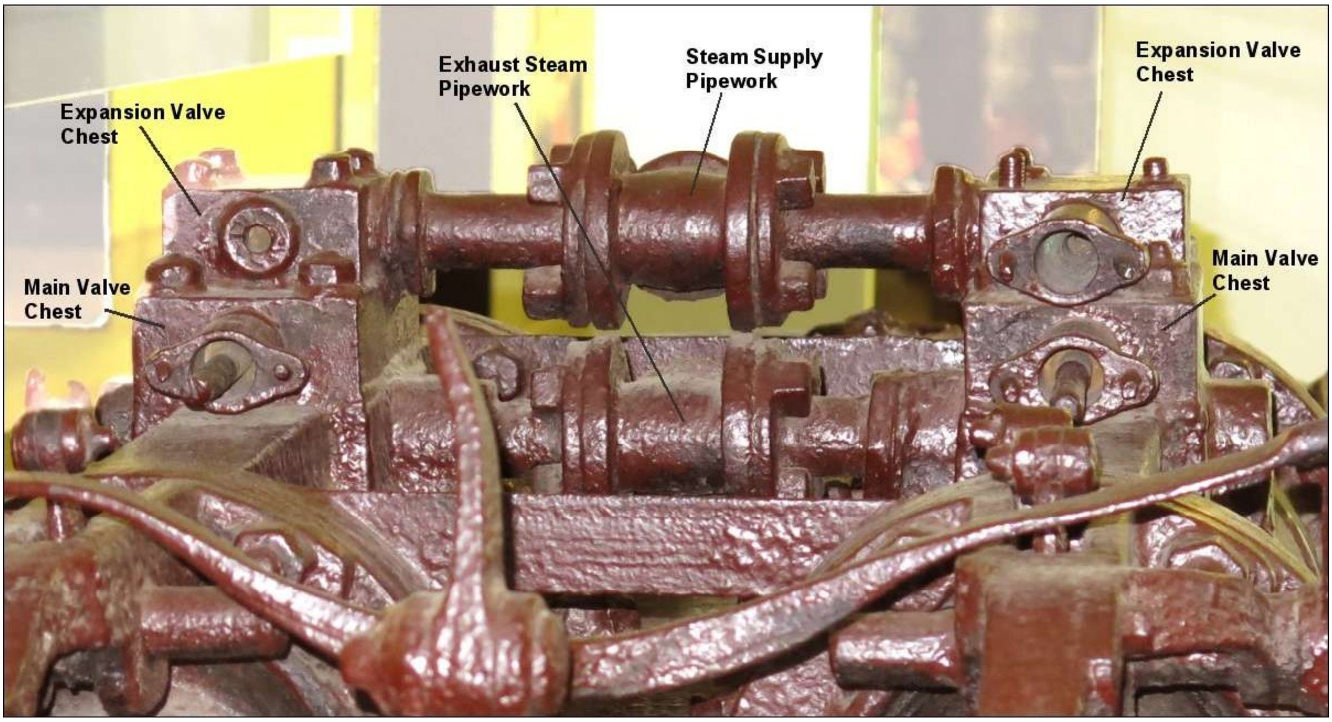


Figure 27a. Gurney's Drag of 1831 showing the main and expansion valve steam chests on the top of the cylinders. View looking forward.

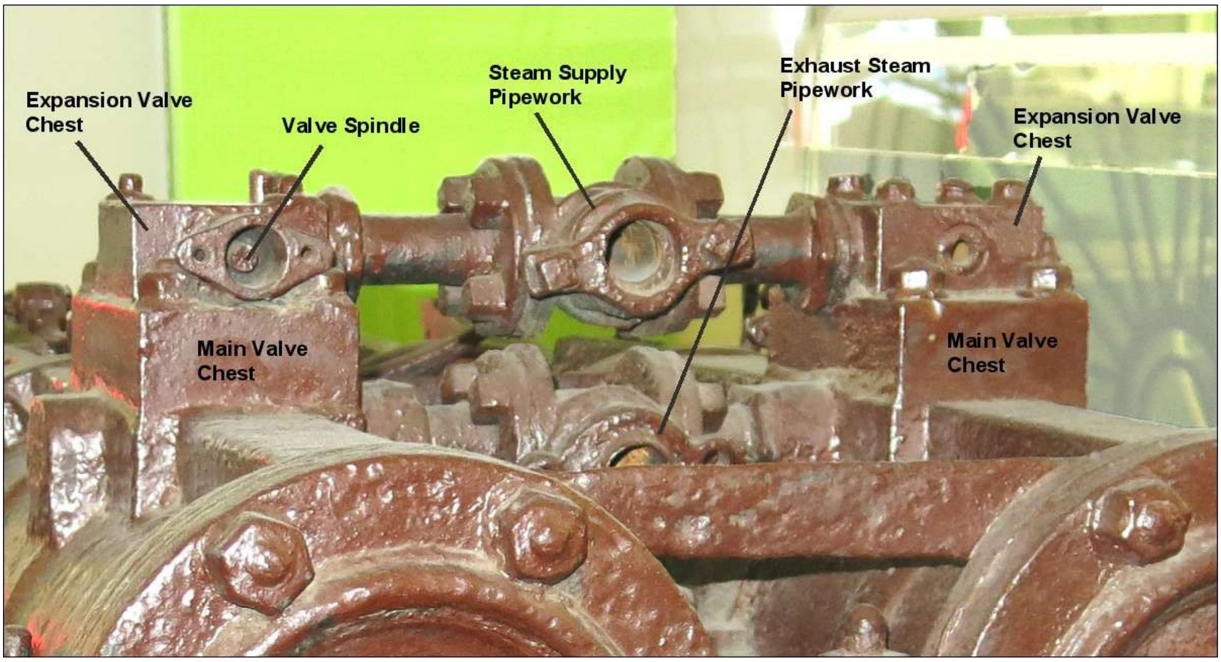


Figure 27b. Gurney's Drag of 1831 showing the main and expansion valve steam chests on the top of the cylinders. View looking aft.

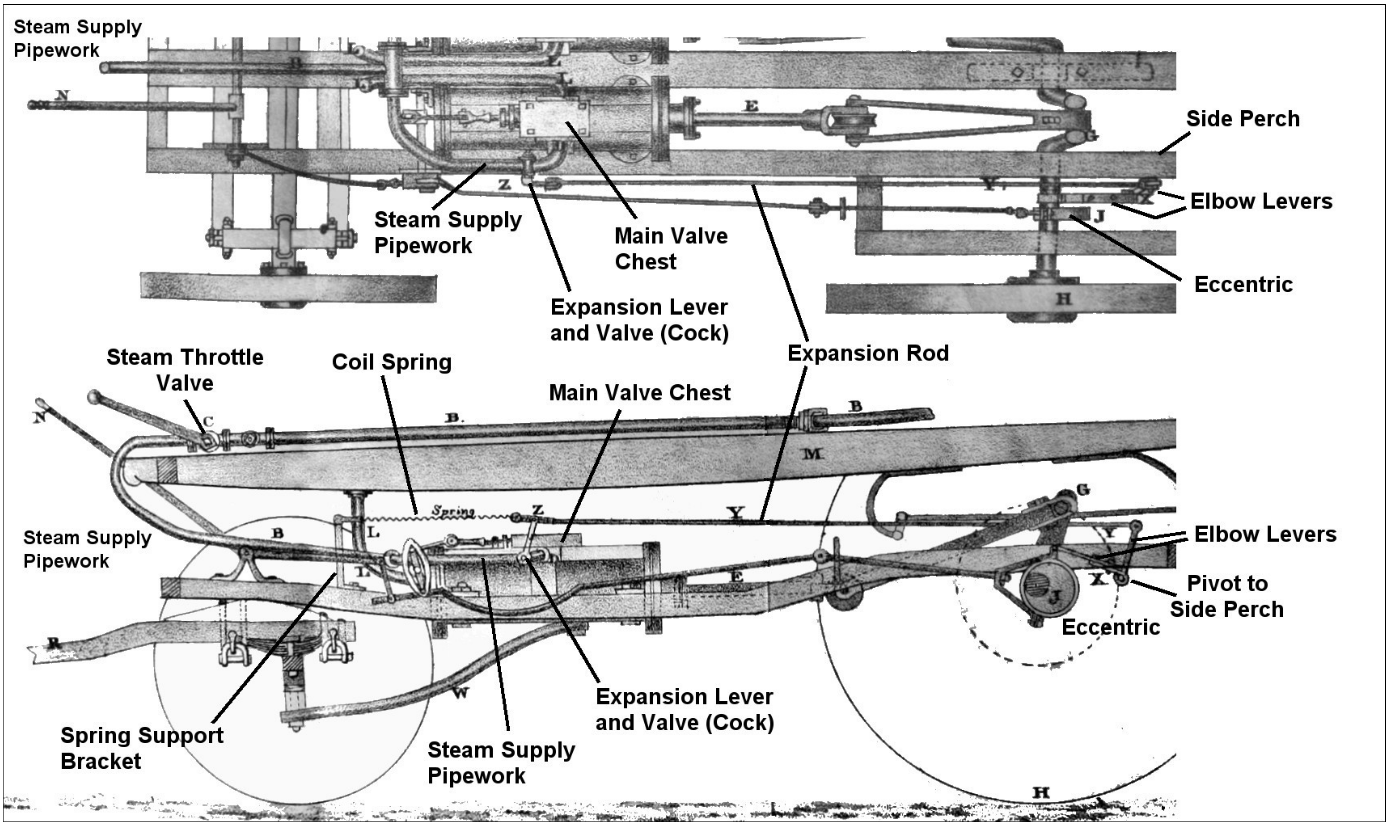


Figure 28. Plan and elevation of Gurney's coach of 1826 showing the details of the expansion valve (cock) and the method of actuating the valve from elbow levers at the crankshaft. A coil spring, attached to a support bracket on the side perch, is used to return the valve to the off position. Gordon reference 31 with added text.

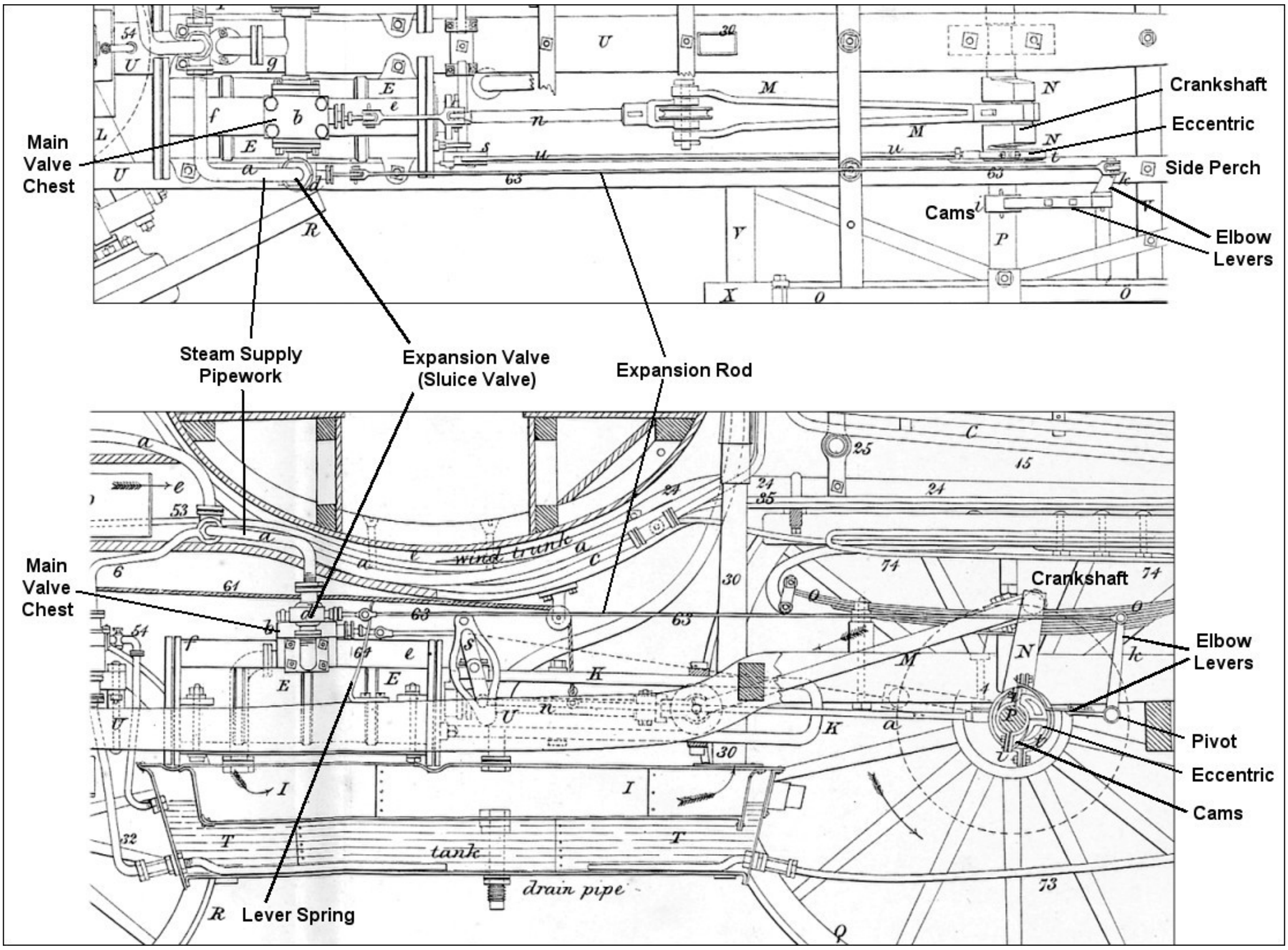


Figure 29. Plan and elevation of Gurney's coach of 1828 showing the details of the expansion valve (sluice valve) and the proposed method of actuating the valve from elbow levers and cams at the crankshaft. A lever spring, attached to the side perch, is used to return the valve to the off position. Patent reference 69 with added text.

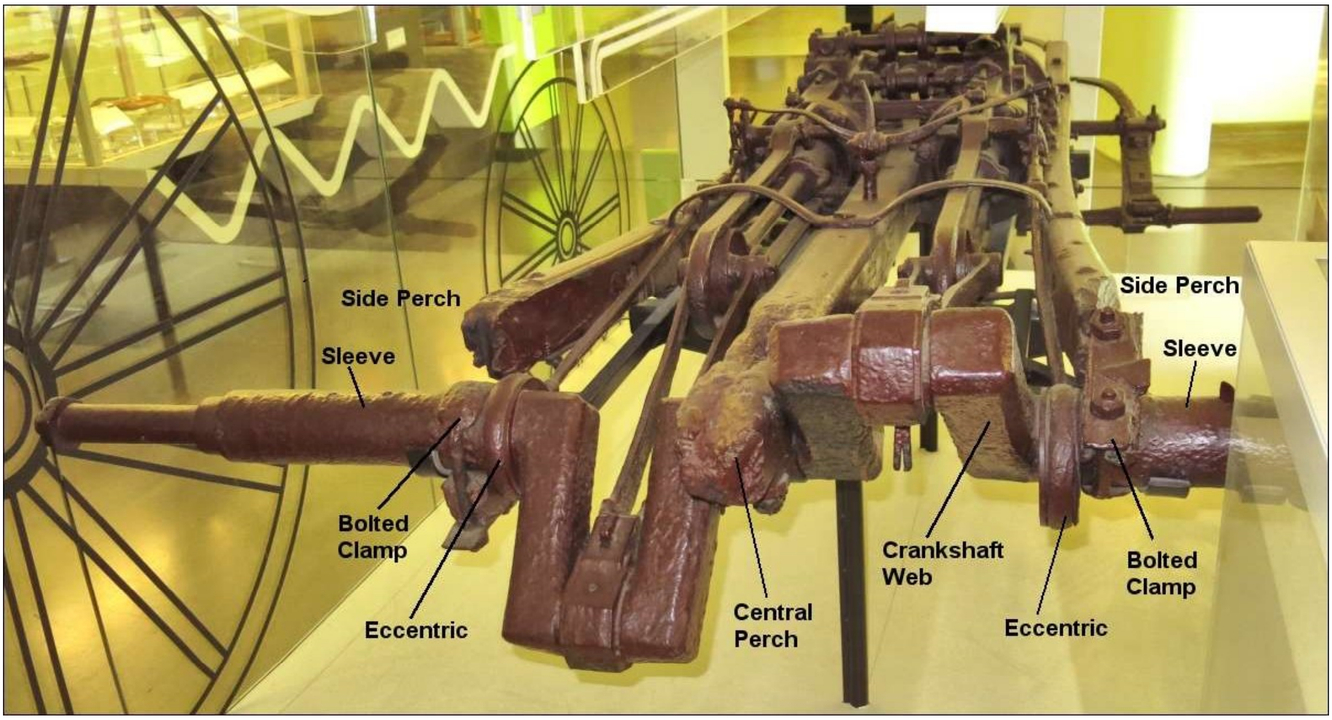


Figure 30. Rear end view of Gurney's Drag of 1831. Showing the relation of the crankshaft, eccentrics, central and side perches and rear axle sleeve.

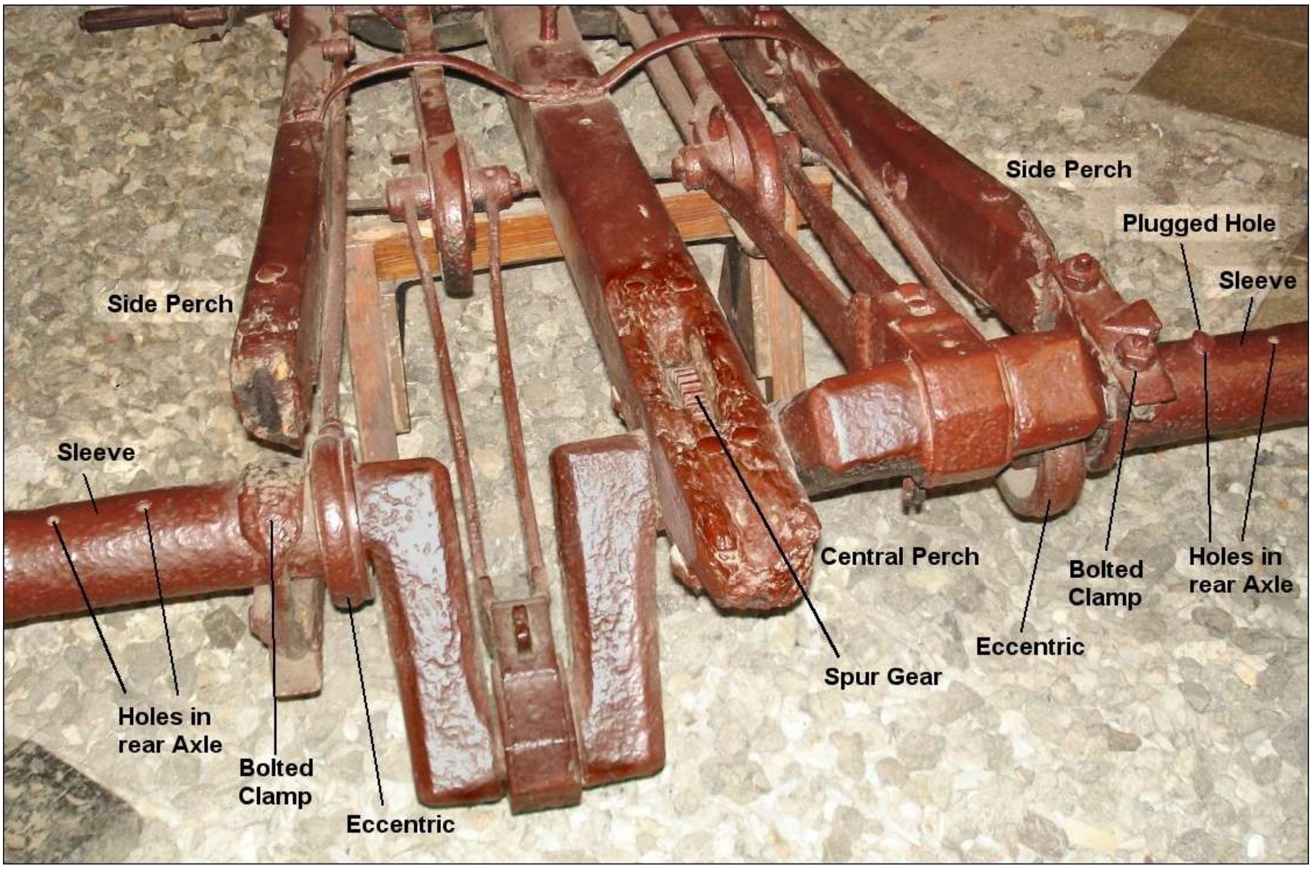


Figure 31. Rear end view of Gurney's Drag of 1831. Showing the holes on the rear axle sleeve and the crankshaft spur gear protruding into the central perch.

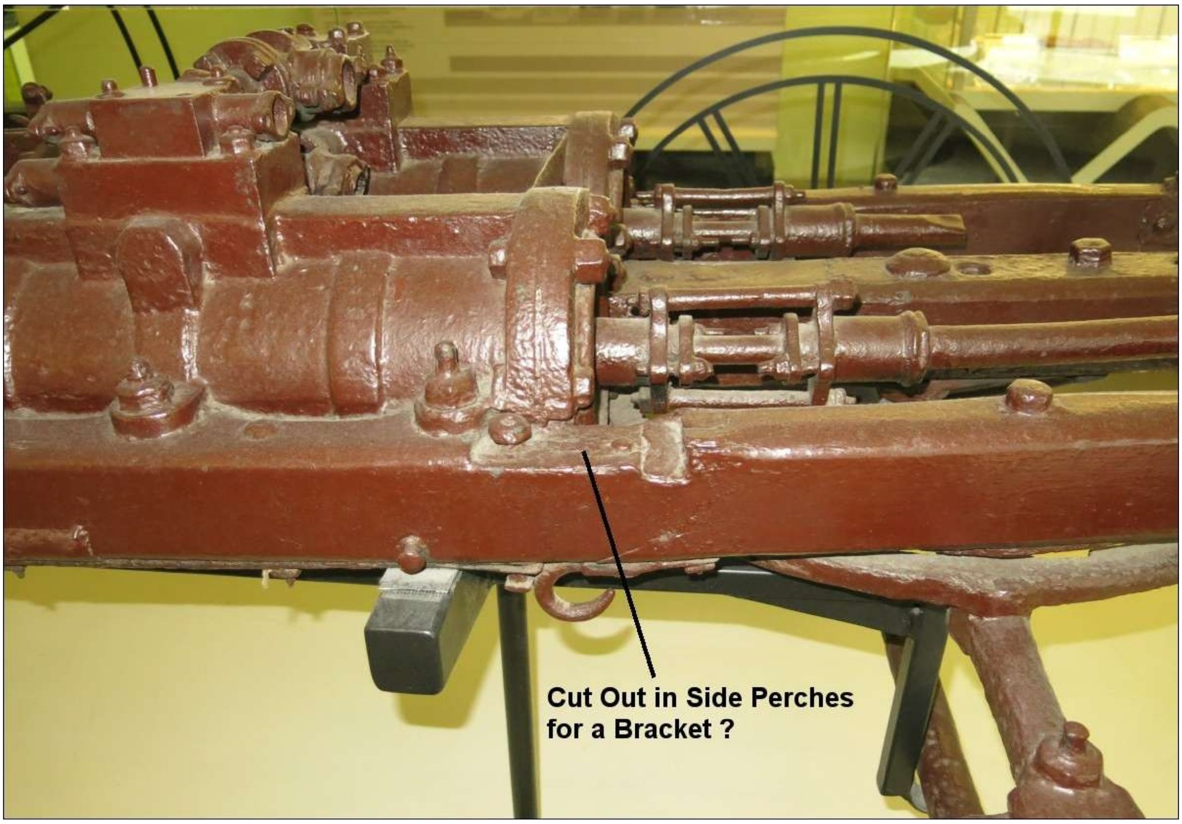


Figure 32. View of the right side perch showing a cut out for a bracket. The left side perch has a similar cut out.

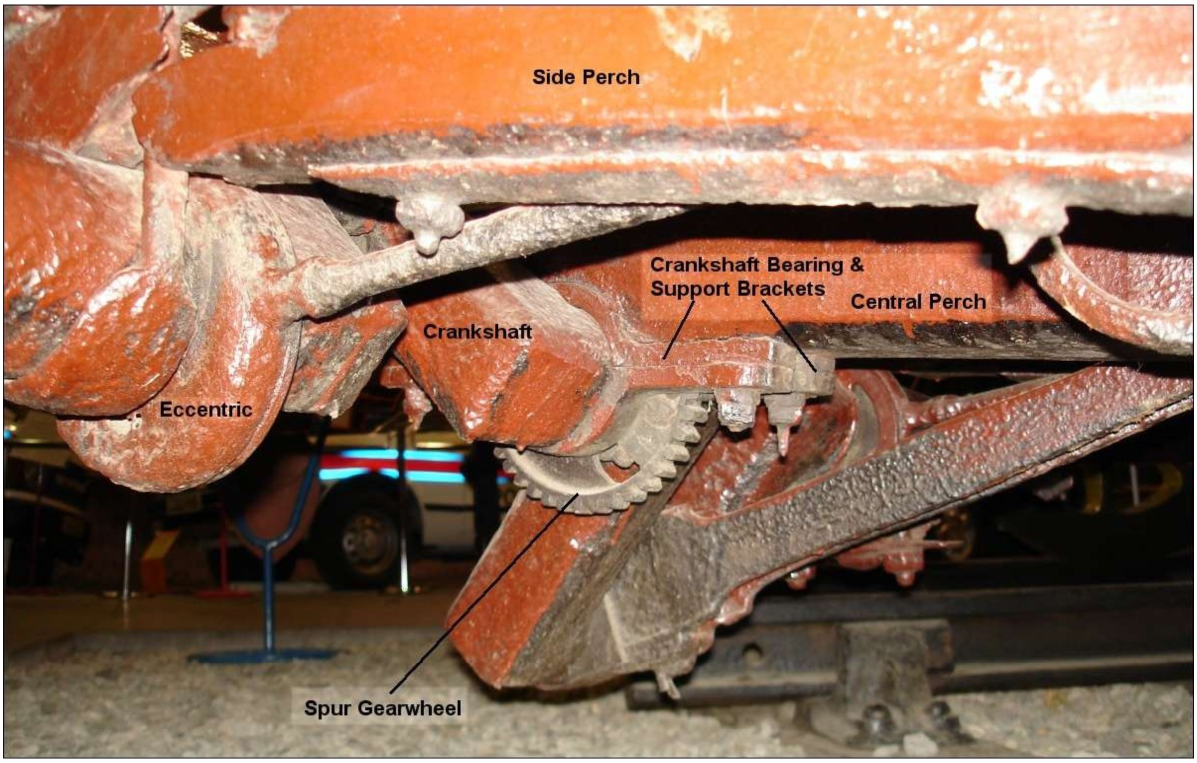


Figure 33. Gurney Drag, side view of the spur gearwheel from underneath.

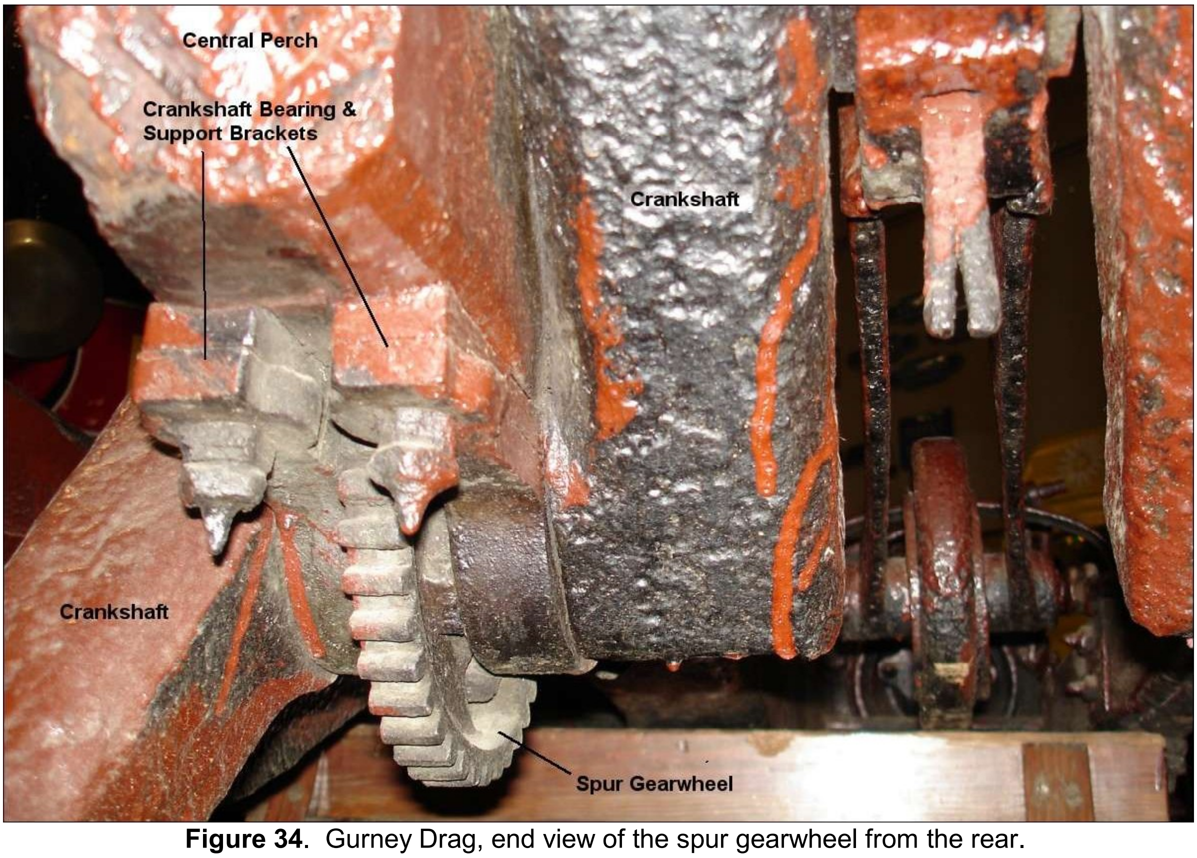


Figure 34. Gurney Drag, end view of the spur gearwheel from the rear.

Figure 35. Inspection of the Gurney Drag valve chests, by six millimetre video endoscope, at Museum of Transport 1999. From left: Dr. David West, Matt Shaw of Olympus Industrial Keymed Ltd., Ruth and Tom Brogden, and Alistair Smith museum curator. ©CSG CIC Glasgow Museums and Libraries Collection.

Figure 36. Inspection of the Gurney Drag valve chests, by six millimetre video endoscope, at Museum of Transport 1999. View of the main slide valve from the exhaust steam passage with added text. This view shows the transverse bar, which almost covers the exhaust port, when the valve is in mid-travel position.
©CSG CIC Glasgow Museums and Libraries Collection.

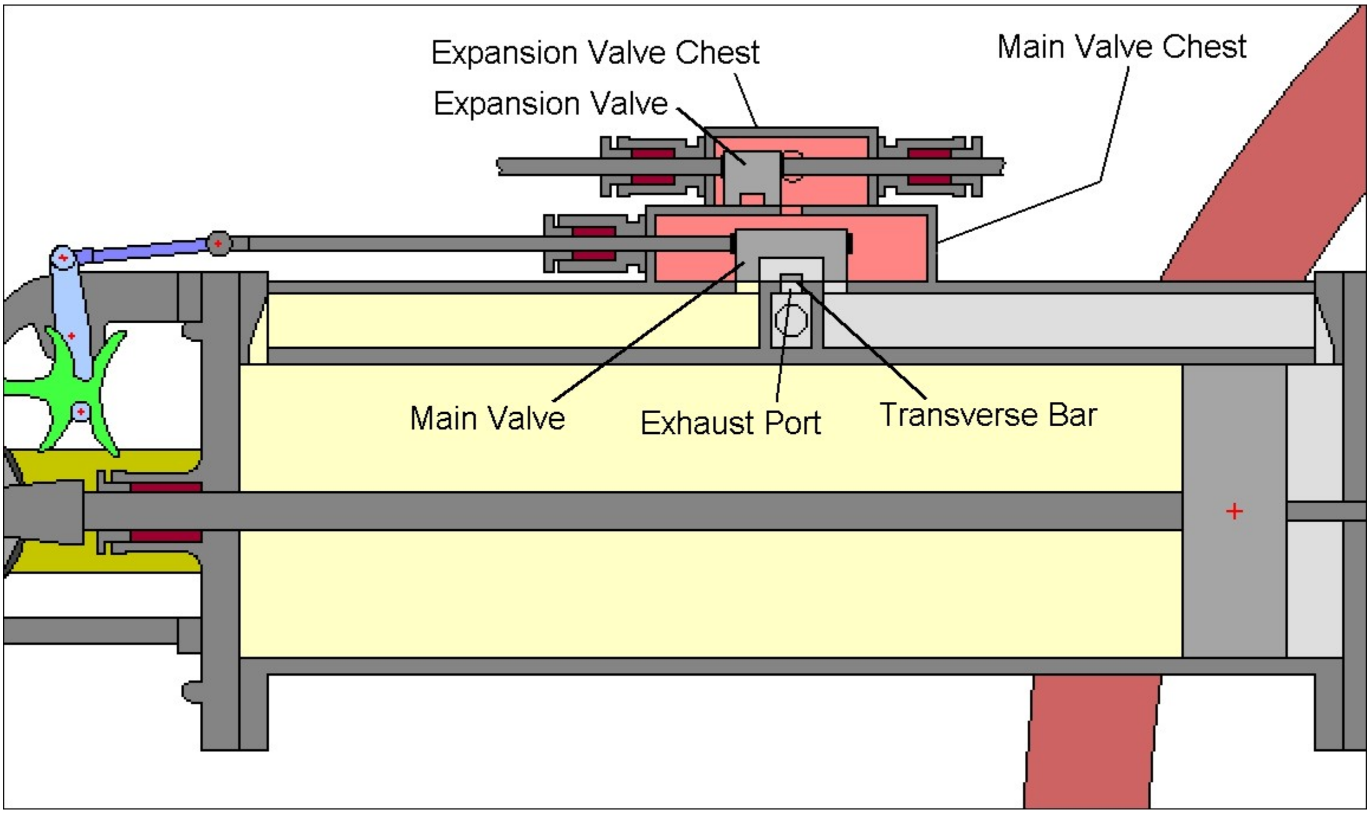


Figure 37. Diagram of the Gurney Drag valve chests and slide valves based on the six millimetre video endoscope tests, at the Museum of Transport 1999. The main slide valve in its mid-travel a transverse bar almost covers the exhaust port, i.e. In mid-position the steam flow through the exhaust port would almost be completely obstructed, see **Figure 36**. Gif animations of this valve gear can be found at my website: https://acwhyte.droppages.com/animations.htm

Figure 38. Inspection of the Gurney Drag valve chests, by six millimetre video endoscope, at Museum of Transport 1999. View of the main slide valve from the exhaust steam passage with added text. This view shows the valve at almost full travel moving towards the left. The transverse bar is about to allow full opening of the valve passage but the bar would obstruct some of the steam flow from the cylinder to the exhaust port.
©CSG CIC Glasgow Museums and Libraries Collection.

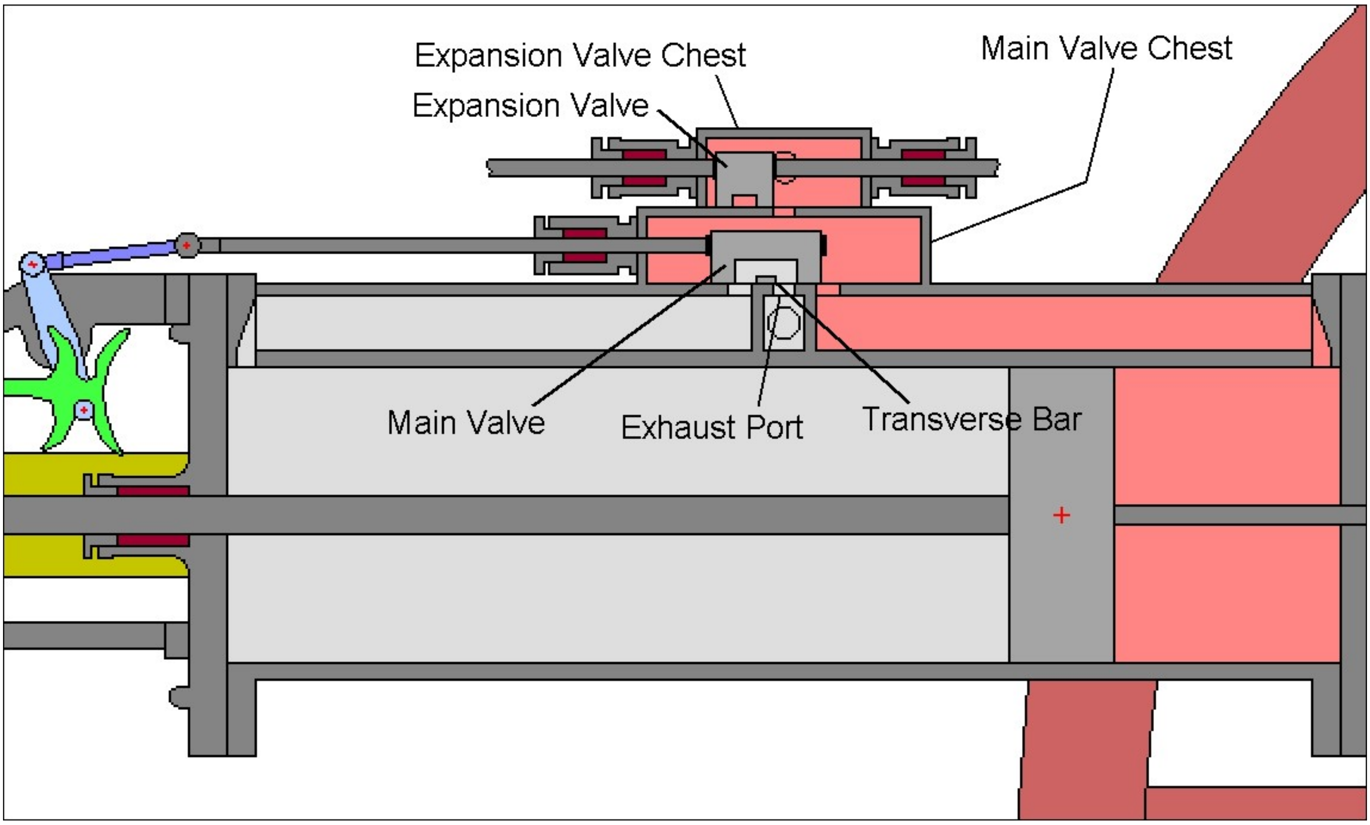
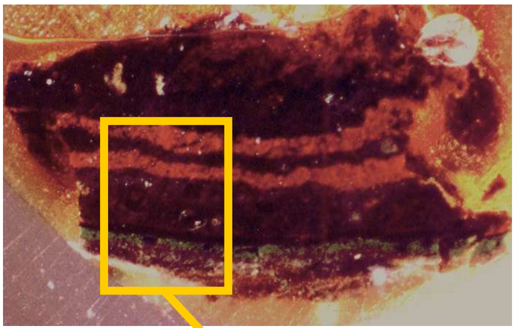


Figure 39. Diagram of the Gurney Drag valve chests and slide valves based on the six millimetre video endoscope tests, at the Museum of Transport 1999. This view shows the main slide valve at almost full travel moving towards the left. The transverse bar is about to allow full opening of the valve passage but the bar would obstruct some of the steam flow from the cylinder to the exhaust port, see **Figure 38**.
Gif animations of this valve gear can be found at my website: https://acwhyte.droppages.com/animations.htm

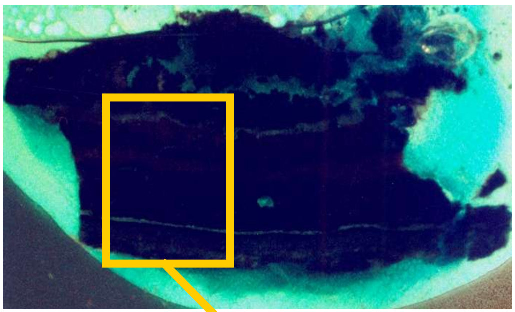
Figure 40. Preliminary Examination of the Finishes of Gurney's Steam Drag, 2007. Showing where a small area (near Sample 2 shown in **Figure 41**) of the reddish brown protective surface layer was removed from the left side perch to reveal a green under layer.

Sample 2: from the wooden perch on the proper left side (see photo).

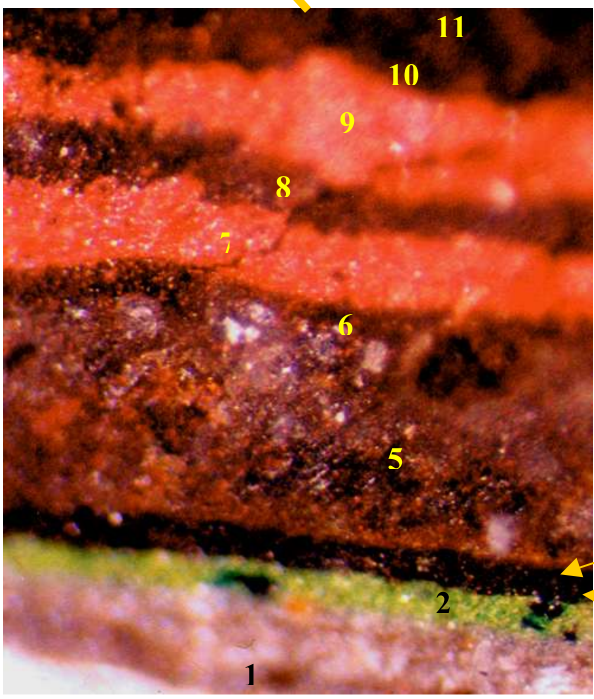
The stratigraphy of finishes is as follows:
Layer 11 – brown paint
Layer 10 – dark layer (glaze paint?)
Layer 9 – red paint
Layer 8 – dark layer (lining? glaze paint?)
Layer 7 – red paint
Layer 6 – dark layer
Layer 5 – dark layer
Layer 4 – black layer (possibly lining)
Layer 3 – black paint (possibly lining)
Layer 2 – green paint
Layer 1 – grey preparation



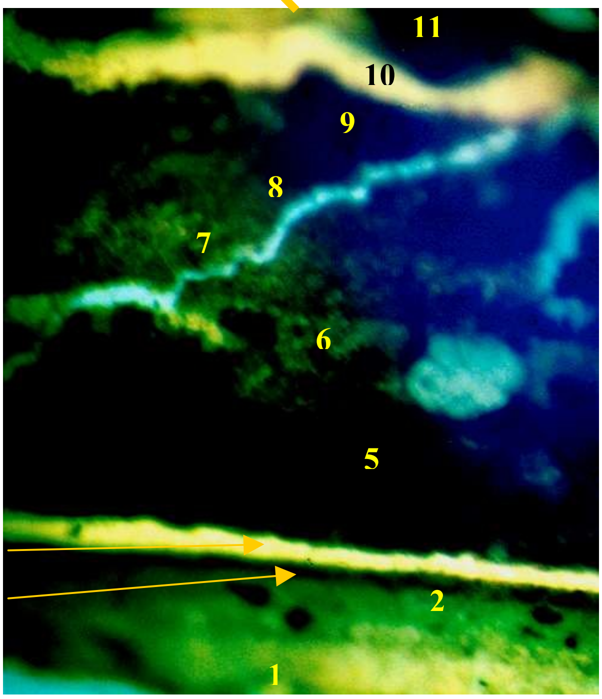
20 x magnification



20 x magnification



4
3



100 x magnification

100 x magnification

Figure 41. Preliminary Examination of the Finishes of Gurney's Steam Drag, 2007. Results of the stratigraphy of finishes, under visible light (on left) and with UV illumination (on right), for **Sample 2** shown above. ©CSG CIC Glasgow Museums and Libraries Collection.

Appendix 1: Timeline, Persons involved in the early development of steam carriages from Cugnot 1770 to Gurney 1832. (Mainly based on Fletcher references 7 & 8).

Date	Name	Comments
1770	**Nicholas Joseph Cugnot** (1725 – 1804) of Lorraine, France	Cugnot built a full sized steam wagon (cart), in 1770. He had built a small version of the wagon the year before, in 1769, ref. 1; in the same year that James Watt had patented the separate condenser, ref. 2. The Cugnot's wagon (fardier à vapeur), **Figure 3**, is a three-wheel vehicle, with two wheels to the rear and a single wheel forward. The engine and boiler was supported over the front wheel. The front wheel with the power unit was articulated to provide the steering. The engine had two cylinders and drove the front wheel by a ratchet and pawl system on each side of the wheel[(3)]. It was claimed that the wagon could seat four passengers and could move at a speed of 2.25 miles per hour, ref. 1. After a few trials and an accident (hitting a wall) the wagon was abandoned. Although this full size wagon could carry passengers it was not really a practical machine. 1770 was also the year that Richard Lovell Edgeworth of Bath and Ireland proposed the idea of the endless railway; an idea that would come up again and again in connection with road vehicles.
1781/84	**William Murdock** (or Murdoch) of Cumnock (1754 – 1839)	Murdock worked for Boulton & Watt and was later a partner. He was instrumental for the introduction of gas lighting but he was also an inventive mechanical engineer. Among his mechanical inventions are the oscillating cylinder engine, the long D slide valve and the sun and planet wheels for the transmission of rotating motion, ref. 11. In 1781/84 he built a small (model) steam road locomotive that was ready for trials in 1784 and would be the first successful steam road locomotive made in England – but it was only a model[(32)]. A section of this model locomotive (the cylinder is ¾" dia. with a 2" stroke and driving wheels were 9¼" dia.) is shown in Fletcher ref. 7 fig. 4. A replica model is in Riverside Museum and is shown in **Figure 9**. The design has three wheels but in this case the power unit is placed over the rear wheels. The front wheel was used for steering and could be fixed in position to enable the model to run in a circle. The engine cylinder was vertical and drove a beam with a connecting rod for actuating the crank[(4)]. The valve motion was a double cylindrical slide valve. The model was capable of a speed of 6 to 8 miles per hour, ref. 7. Murdock was not encouraged by Watt and he never developed his road locomotive further.
1784	**James Watt** (1736 –1819) of Greenock	Watt had concerns over the use of high steam pressure and was against the idea of steam locomotion on common roads. He was persuaded to produce a specification and patent but no carriage was ever built.
1786	**William Symington** (1764 – 1831) of Leadhills	The steamboat pioneer William Symington and his father completed a working model of a small road locomotive, in the form of a steam coach, in 1786, shown in Fletcher ref. 7 fig. 6. The coach had four wheels with steering at the front and the power unit over the rear wheels. The boiler was cylindrical and had a safety valve. The drive between the cylinders and rear axle was by chains, racks and ratchet[(3)] (on the Dalswinton steamboat of 1788, Symington used ratchets and chains). The cylinders were horizontal[(5)] (a horizontal cylinder with a connecting rod and crank was a key feature on the *Charlotte Dundas* steamboat of c1801/03) with a condenser below[(6)]. Although the intention was to build a larger version of the coach, this never occurred. Symington devoted his attention to other projects, such as steamboats, for which he is justifiably famous.

1786	**James Sadler** (1753 – 1828) of Oxford	The pioneering English aeronaut invented a rotary engine and patented a double-cylinder steam engine. Experiments made applying the steam engine to driving wheel carriages. He was persuaded by Watt to stop his experiments.
1787	**Oliver Evans** (1755 – 1819) of Newport, Delaware	Obtained exclusive right to make and use steam carriages for 14 years, in the state of Maryland, from May 1787. In 1805 he succeeded in producing a temporary steam carriage to move a steamboat from his works to the riverside where the wheels were removed and the boat launched. Could be considered the first amphibious vehicle.
1788	**Robert Fourness** of Otley, Yorkshire and **J. Ashworth**	Robert Fourness and J. Ashworth took out a patent for driving travelling carriages, references 7, 8, and 13. It is not entirely clear if a carriage was built to this patent but Fletcher writing in 1904, ref. 8, gives a description and drawings of a little steam carriage built in 1788. The design, which was advanced for its day, see ref. 8 figures 1 and 2, included a three cylinder inverted engine transmitting power to the crankshaft by spur gearing, heated feed water and a safety valve fitted to the boiler. The carriage (ref. 13 described it as a steam tractor) had four wheels. The front wheels provided pilot steering and only one of the rear driving wheels was keyed to the main axle so as to allow the carriage to turn sharp corners[(7)]. It is not known what became of this steam carriage.
1789	**Thomas Allen** of London	In 1860, the Earl of Caithness read a paper on steam carriages for use on common roads to the British Association for the Advancement of Science. Thomas Allen is mentioned as having invented a steam carriage to carry goods and passengers. No account of this carriage has been found.
1790	**Nathan Read** (1759 – 1849) of Warren, Massachusetts	Nathan Read, ref. 14, made important contributions to the design of steam boilers with his invention, in 1788, of a vertical multi-tube fire box boiler that was suitable for steamboats and steam carriages, ref. 7 and 8 fig. 3, i.e. it was strong, light, compact and safe. In 1790 he designed and patented a four wheeled steam carriage, ref. 7 fig. 7. The cylinders were horizontal and drove the rear wheels by a rack arrangement attached to each piston rod. Steering of the front two wheels was by chains secured to the front axle actuated by a vertical spindle and hand wheel. A feature of this engine was the exhaust pipes, which were specified to point backwards so that the reaction of the exhausting steam should assist the forward motion of the carriage[(8)]. A model based on the patent was built but it appears that he did not pursue the matter further.
1796/1803	**Richard Trevithick** (1771 – 1833) of Cornwall	Richard Trevithick is recognised as the "father of the high pressure steam engine" and the inventor of the steam railway locomotive, ref. 16 and 17. However, he also had a serious interest in steam road locomotion in the years from 1796 to 1803. He built models of steam road locomotives from around 1796 and one, from 1798, is in the Science Museum South Kensington, illustrated in ref. 7 figs. 8 & 9. It was just around this time when Trevithick is believed to have developed his high pressure engine. Trevithick decided to build a full sized steam road locomotive but before doing so he crucially made some experiments, around 1801, to show that it was feasible to move a wheeled vehicle up a gradient without the wheels sliding[(9)]. He built his pioneering steam road locomotive at Camborne in 1800/01, known as the '*Puffing Devil*'[(33)], ref. 7 figs. 10 & 11. The boiler was cylindrical and intended for a working pressure of 60 pounds per square inch (previously Watt type engines worked at around 5 pounds per square inch at most) ref. 7 fig. 12. A safety valve was fitted. The engine was simple in construction there was no: air pump, condenser, parallel motion,

	Richard Trevithick, continued.	beam, sun and planet wheels, etc. The vertical cylinder was let into the boiler. The exhaust steam was led into the chimney to create a blast and there was a feed water heater. A bellows was provided to give a force draught but was not used after the first trial, The trial which took place at Camborne, on Christmas Eve 1801, and set out with several persons amounting to a total load of 30 cwt up Beacon Hill (a gradient of about 1 in 20, ref. 17) at a rate of 4 miles per hour; and upon a level road of 8 or 9 miles per hour. The carriage stuck on the hill due to lack of steam; even with the use of the bellows and the hot blast there was insufficient steam available. But the trial had shown just what was possible. Trevithick, in partnership with Andrew Vivian (1759 – 1842), ref. 18, secured a patent in 1802 for high pressure steam engines for propelling carriages on common roads. In the following year a London steam carriage[34] was built, ref. 7 figs. 13 & 14. This London carriage had improvements over the Camborne vehicle: it had a proper carriage for eight or ten passengers, it was not so heavy, it had a horizontal cylinder which added to the steadiness of motion, and larger diameter wheels to enable it to more easily pass over rough roads, ref. 7 & 17. Journeys of 10 miles were made through the streets of London. Speeds were at the rate of 8 or 10 miles per hour. Due to the costs involved Trevithick and his partner abandoned the steam carriage business. Trevithick went on to put his energies into the construction of railway locomotives for which he is justifiably famous.
1808	**John Dumbell**	Patented a rotary steam engine (steam wheel) intended for drawing carriages and wagons on common roads. Never got beyond a proposal.
1810	**Major Pratt**	Fletcher ref. 7 claims Pratt proposed to drive a carriage, by any means of motive power mounted on the carriage, by endless chains working over pulleys with arms pivoted to them. The arms carried spikes. The motion of the chains drove the spikes into the ground, thus causing the carriage to be slowly driven along. However in relation to ploughing by steam, ref. 71 fig. 21 shows Major Pratt's machine hauling itself along by means of Mattock like spikes but there was no steam powered units available at this time to put the idea into practice. Another reference, ref. 72, refers to a ploughing arrangement not steam carriages!
1812	**John Stevens** (1749 – 1838) of New York and Hoboken, New Jersey	Of American steamboat fame. Published a pamphlet, in 1812, urging that railroads and steam carriages should be preferred to canals and canal boats.
1812	**W. Palmer**	In 1812 Palmer suggested the use of endless chains or rollers as a substitute for wheels of carriages.
1813	**William Brunton** (1777 – 1851) of Dalkeith and Pentrich, Cornwall	Brunton obtained a patent, in 1813, for the 'Mechanical traveller' consisting of a combination of levers resembling the legs of a person walking, ref.7 fig.15, though it was also called the '*Steam Horse*', ref. 20. The idea of the "mechanical traveller" or "propeller" was supposed to overcome the supposed difficulty of insufficient adhesion between the wheels and the road (note that: Wood ref. 21 and Herbert ref. 25 show the machine on rails rather than on a common road) – even though Trevithick around 1801 had already shown that there was sufficient adhesion between a pair of wheels and a good road to propel a carriage[9]. Experiments were made on one of these machines but the machine only travelled at 2 miles per hour, ref. 7. On a later machine, in 1815, through some carelessness, the boiler exploded and many persons killed, ref. 20, the first recorded railway disaster. Brunton subsequently abandoned the project.

1814	**Thomas Tindall** of Scarborough	Patented a steam engine for driving all sorts of carriages including conveyance of passengers, for ploughing or working threshing machines. Supported on three wheels with the forward being the steering wheel. The engine, via spur gearing, drove four pushers or legs, which on coming into contact with the ground drove the carriage forward. This would seem to be a form of 'Mechanical traveller'. It was also proposed to assist the engine by a form of a horizontal windmill driven partly by the wind and partly by the exhaust steam for the engine.
1816	**Joseph Reynolds** of Ketley	Patented a steam engine for conveying passengers on ordinary roads or for agricultural implements. The boiler being suspended on trunnions such that the boiler would be kept in the horizontal position when travelling up or down hills. Each driving wheel had separate gearing and could be made to revolve in opposite directions for turning in a small space. Two or more travelling speeds were provided and a clutch for throwing the pinions out of gear; brakes were also fitted to the driving wheels.
1819, 1821,1824	**David Gordon** (1774-1829) of Castle Douglas	Gordon was the Inventor of a portable gas apparatus. In 1819 in conjunction with William Murdock he made calculations and carried out experiments for using compressed air as a motive power for road locomotives, ref. 7. In 1821 Gordon took out a patent for the use of a very large wheel (or drum) to form an endless railway for common roads, ref. 7 fig. 16. In 1824 he patented his idea of the 'Mechanical traveller;' a double cylinder engine with a six-throw crank (three cranks to each cylinder) driving propellers (legs) to push a carriage along, ref. 7 fig. 17 and 18. Experiments were carried out but the speed was not satisfactory. One of Gurney's light boilers was also fitted but again experiments were disappointing. Gordon abandoned the project after six or seven years and four distinct carriages having been convinced that applying power to the wheels was the proper mode of propulsion. Grace's Guide reference 73 has additional information on Gordon's carriages.
1821	**Julius Griffiths** of Brompton, Middlesex	In 1821 Griffiths patented a steam carriage intended to be used expressly for the conveyance of passengers on the highway; the specification states that the ideas were partly communicated by foreigners. A carriage was constructed, ref. 7 fig. 19, and has been termed the 'First steam coach constructed in Britain expressly for the conveyance of passengers on common roads', ref. 7. The double-bodied cab was carried between the front and rear axles. The carriage was constructed by Joseph Bramah & Sons a company famous for his locks, machine tools and hydraulic machinery, ref. 22. Power was communicated by rods connected with toothed-wheels geared to the hind-wheels. To avoid vibrations the boiler and engine at the rear were suspended by chains and spiral springs. Testing was carried out, but no public trials were conducted. The trials failed due to the boiler being unable to generate the required quantity of steam and the project was abandoned. The carriage remained in Bramah's yard for some years and was seen by many with an interest in the steam carriage business. Herbert ref. 25 has a description of the working of this carriage and also states that the carriage was chiefly designed by foreigners.
Around 1822	**Goldsworthy Gurney** (1793 – 1875) of Cornwall	In 1822 Gurney constructed a small locomotive, which worked with ammoniacal gas. The results of his experiments were so satisfactory that he turned his attention to steam carriages, ref. 7 and 23.

1823	**Samuel Brown** (1799 – 1849) of Brompton, London	In 1823 Brown patented a locomotive for use on common roads. Later fitted up a carriage propelled by his patent gas vacuum engine; said to be the 'Father of the gas engine.' Canal Gas Engine Company formed for applying the engine to vessels on canals or rivers. Gave up due to expense, ref. 7 and 74.
1823/24, 1829, 1832	**William Henry James** (1796 – 1873) of Holborn and **Sir James Anderson** (1792 – 1861) of Buttevant Castle, Cork, Ireland	In 1823 James patented a tubular steam boiler for road locomotives. In 1824 he introduced a steam drag with two sets of double cylinders. Each set of cylinders would drive each hind wheel, ref. 7 figs. 24, 25 and 26. Working pressure was 200 pounds per square inch. The idea of a separate set of cylinders to drive each wheel gave independent motion when turning corners. An arrangement of cocks and the front axle allowed the amount of steam admitted to each engine to be automatically controlled. The whole of the machinery was mounted on laminated elliptical springs. James was not able to build a carriage upon these lines. But after getting connected with Sir James Anderson, James in 1829 carried out experiments on a steam coach, ref. 7 fig. 27, with an engine similar to that described above but with two tubular boilers. A demonstration was carried out with fifteen passengers on a rough gravel road in Epping Forest at a speed of 12 to 15 miles per hour. Following a boiler tube burst the carriage was able to return home, on one boiler, at a speed of 7 miles per hour with more than twenty passengers, ref. 7. After this demonstration the coach was dismantled and construction of a superior tubular boiler was commenced. A steam drag for drawing carriages behind was constructed and ready for use in November 1829. Ref. 7 fig. 28 is a representation of the outside appearance but internal details were different. In 1832 another patented steam drag was conceived but with different working parts from earlier engines. Ref. 7 fig. 28, illustrates the arrangement, which utilised a chain drive. It is not certain if this drag was ever built as Sir James Anderson appears to have fallen into pecuniary difficulties about this time, ref. 7.
1823, 1827	**James Neville** of Shad Thames, London	In 1823 Neville took out a patent for a steam boiler intended for steam carriages and in 1827 patented an improved locomotive, ref. 7 fig. 30. Neville believed that additional adhesion was required on plain wheels, ref. 75. The periphery of the wheels being provided with spikes to prevent slipping. For very steep inclines, elastic steel plates (springs) could be attached to the wheel, ref. 7 fig. 29. The steel plates were made rough by projecting steel studs on the outside of the plate. Neville also utilised oscillating cylinders placed horizontally beneath the carriage an arrangement designed by Andrews (see below). Note that Neville steered his carriage with a radiused rack and pinion. The rack teeth were on the <u>*outside*</u> of the rack arc, ref. 7 fig. 30. Gurney used a similar arrangement on his steam drags, including the museum drag, but with the rack teeth on the <u>*inside*</u> of the arc (see below).
1824, 1826/27	**Timothy Burstall** (1776 – 1860) of Leith, Edinburgh and **J. Hill** of Leith and London	In 1824 Burstall and Hill were granted a patent for a locomotive engine. A carriage was construction, ref. 7 fig. 20, with a peculiar boiler details are described in ref. 7 and Herbert ref. 80. The water was kept in a separate vessel and only supplied to the boiler as required. It was proposed to heat the water from 250°F to 600°F keeping it in the separate vessel and then only applying it to the boiler when steam was required. Needless to say this boiler was not satisfactory. A further innovation was that all four wheels were used as drivers (i.e. a 4–wheel drive) by means of bevel gears with the final drive by ratchet and spring pawls, ref. 7 figs. 20, 21 and 22, this allowed the carriage to turn corners without sliding. This arrangement only allowed forward motion, the ratchet wheel had to be locked when

	Timothy Burstall and **J. Hill**, continued	backing up the carriage. Another method was patented and this allowed the drive both forwards and backwards by means of a double bevel clutch. In spite of these innovations and repeated experiments no real success was achieved, ref. 7. In 1826 they obtained a further patent with improvements a completed carriage exhibited in Leith, Edinburgh and London in 1827 but was soon abandoned, ref. 7. This carriage would be the first powered vehicle in Scotland, ref. 45. A 1/4 scale working model was also constructed in 1827, ref. 7 fig. 23, and exhibited in Edinburgh and London(38). The boiler was of the ordinary vertical conical type and seems to have performed well but no actual full size carriage was ever built. In 1829 Burstall took part in the Rainhill Trials with the steam railway locomotive '*Perseverance'* but it was withdrawn from the trials when it failed to reach the required speed of 10 miles per hour, ref. 46.
1824	**Walter Hancock** (1799 – 1852) of Stratford, London	Hancock Invented a novel form of steam engine in 1924, which he thought was very suitable for steam carriages because of its simplicity, lightness and comparative cheapness. He made a model steam carriage and later one on a larger scale. These proved his engine was practically useless for steam carriages. Hancock persevered and would later built successful carriages (see below).
1825	**Goldsworthy Gurney** (1793 – 1875) of Cornwall	In 1825 Gurney patented (British patent No 5170) and built a steam locomotive propelled by legs similar to Brunton's and Gordon's arrangements, ref. 7, i.e. it used a 'Mechanical traveller' to propel the vehicle(14), which is shown in **Figure 10**. This was not an auspicious start given that twenty or so years before, Trevithick had already shown that applying power to the wheels was the way forward(9). Nevertheless, Gurney did experiments with this vehicle and did ascend Windmill Hill near Kilburn, ref. 7. Gurney eventually resorted to a combination of the propelling legs and the wheels, ref. 30 and 31, which influenced his thoughts on his next carriage. This first attempt at a working carriage seems to have inspired Gurney to proceed to built a proper coach (see below). During 1825, Colonel Frances Maceroni (1788 – 1846) of Manchester became interested in Gurney's work on steam carriages. For six months(11) Maceroni associated himself with Gurney's Regent's Park works and persuaded several friends to invest in the steam carriage business, ref. 26. Maceroni would later become one of Hancock's successful contemporaries, ref. 7, (see below).
1825	**John Seaward** (1786 – 1858) and his brother **Samuel Seaward** (1800 – 1842) of the Canal Iron Works, London	In 1825 the Seaward's patented a method of propelling road locomotives by means of a wheel or wheels connected by a swinging frame to the crank of a steam engine, ref. 7 fig.31. The propelling wheel(s) could accommodate inequalities of the road and the tyres had projecting teeth (spiked wheel) to give a hold or bite to the ground to prevent slipping. The weight of the carriage being taken by separate wheels, ref. 24. Seaward's idea has been repeatedly revived and patented in modified form over the years, ref. 7. Clearly such ideas of spiked wheels would have an injurious effect upon the road(12).
1825	**T. W. Parker** of Edgar County, Illinois	Parker built a large working model of a steam carriage of light construction with three wheels in 1825. The leading wheel, as well as the two hind wheels, were driven by a double cylinder engine. Many persons examined this model carriage. A description of the carriage and engine is given in reference 76.
1826	**Frederick Andrews** of Stanford Rivers, Essex	In 1826 Andrews patented some improvements in steam carriages. He appears to be the inventor of the "pilot" steering wheel, ref.7 fig. 32. Gurney's steam carriages were fitted with pilot steering (see below). Thomas Aveling re-patented this form of steering in about 1860, ref. 7. The pilot steerage consisted of a single disk or wheel (Gurney used two wheels)

	Frederick Andrews, continued	running between two shafts (Gurney used a single pole or shaft), which are connected to the leading axle of the coach. As the pilot wheel is turned (steered) right or left by the steersman's[(19)] lever the front wheels of the leading axle follow in the same direction, ref. 7. Andrews also introduced the idea of oscillating cylinders, working in trunnions, placed horizontally to be unaffected by the motion of the springs. Neville also used this arrangement (see above) but Andrews was the designer, ref. 7. In the Andrews steam carriage the crank axle was within a tube that passed through the water space of the boiler, ref. 7 fig. 33. Andrew's carriage proved unsuccessful due to the failure of the boiler.
1826 (or 1827)	**Goldsworthy Gurney** (1793 – 1875) of Cornwall	In 1826[(13)] Gurney constructed a coach about 20 feet long to accommodate six inside and fifteen outside passengers, **Figure 4**. The coach had six wheels, two pilot wheels at the front and four main wheels supporting the coach body and power plant. The two main wheels at the rear were connected to the crankshaft and were the main means of propulsion. The coach was steered by a lever acting on the two pilot wheels[(15)]. The engine and valve details are discussed in detail by Gordon ref. 31. This coach utilised Gurney's patent boiler to supply steam to the 12 horse power engine, ref. 7, 24 and 32. The speed of the coach could be regulated from one to ten to twenty miles per hour, ref. 32. In addition to the rear driving wheels (driven via ratchets and clutches, ref. 24), two propellers (legs) were provided i.e. a 'Mechanical traveller' was included. This 'Mechanical traveller' was intended to assist when climbing hills. However, the coach was found to go up Highgate Hill, Stanmore Hill and Brockley Hill without the driving wheels slipping so the 'Mechanical traveller' was not needed and subsequently removed, ref. 7. This was Gurney's first real attempt at a proper working coach but it was not to be his last (see below).
1827 & 1828	**David Napier** (1790 - 1869) of Dumbarton	David Napier[(24)], the notable marine engineer built a steam carriage to run a service[(25)] between Kilmun and Loch Eck in 1827 and 1828, ref. 51. Little is known of the details of this carriage but Nicholson, ref. 54 states: 'That a single cylinder engine drove each driving wheel, the engines being mounted vertically over the cranked axle and driving it direct'[(26)]. Due to the softness and hills of the road and want of knowledge of boiler construction the speed was not as expected and the project abandoned, ref. 51, and substituted with stage coaches (i.e. horse driven coaches), ref. 54.
About 1827	**James Nasmyth** (1808 – 1890) of Edinburgh	In about 1827 Nasmyth (later famous for his invention and development of the steam hammer) built a small working model of a steam carriage. At the request of the Scottish Society of Arts he built an experimental full size carriage capable of carrying eight passengers, ref. 27 page 121. The waste steam was used in a steam blast into the chimney to create a draught. The trials on this carriage were successful. However, the Scottish Society of Arts did not consider it to be of any commercial use and Nasmyth wanted to continue his studies and prepare for the work of practical engineering. He proceeded no further with his steam carriage and the carriage was broken up and the two high pressure engines and boiler were sold, ref. 7 and 27.
1827	**Dr William Harland** (1787-1866) of Scarborough	William Harland[(35)] Invented and patented a steam carriage for running on common roads in 1827. A working model of a steam coach incorporating a multi-tubular boiler with a revolving surface condenser was built. A design for a full size carriage was prepared but the construction was not completed.

1827, 1829 & 1832	**Walter Hancock** (1799 – 1852) of Stratford, London	Following from his early attempts in 1824 (see above). Hancock in 1827 invented his well known boiler which tended in later years to make his steam carriages so successful, ref. 7. His first carriage, ref. 7 fig. 41, was supported on three wheels and utilised oscillating cylinders working the leading wheel, which could swivel for steering, was far from satisfactory and subject to numerous alterations. In 1829 he built a ten seater bus called the "Infant", ref. 28. By 1831 Hancock commenced running this steam coach regularly for hire between Stratford and London, ref. 7. This was a successful coach. No propellers or other appendages were required. The coach was capable of ascending steep hills such as Pentonville Hill, which has a rise of one in eighteen to twenty. By 1832 improvements were made, ref. 7 fig. 42, including replacing the oscillating cylinders by fixed vertical cylinders and a blower fan for the furnace. A chain drive drove the rear axle. The wheel axles were sprung and the carriage body, machinery and boiler were protected from road shock, ref. 28 and 47. Speed was at a rate of nine to fifteen miles per hour on a level road and six miles per hour ascending a hill, ref. 7. Hancock went on to construct several successful coaches, during the 1830's, but eventually gave up the enterprise due to commercial reasons.
1827/28	**Goldsworthy Gurney** (1793 – 1875) of Cornwall	In 1828 Gurney built a new steam coach, ref. 7 fig. 36. In outward appearance it looked little different from the previous coach, discussed above and **Figure 4**, but had in fact a number of patented improvements based on specification No. 5554 of 1827, ref. 69, including[16]: an auxiliary (donkey) steam engine driving a blower fan (to direct air to the furnace to aid combustion and avoid the necessity of a tall chimney) and a water feed pump (to pump water into the boiler via a heating coil), a hand operated feed pump, **Figure 11**. Needless to say propelling legs were not required, these having been previously found to be not necessary. Normally only one rear wheel was driven, to make it easy to turn tight corners without the wheels sliding[7], but both wheels could be driven when required such as when going up steep hills, ref. 7. Many experimental trips made with this carriage over a period of eighteen months. This was Gurney's last attempt at a coach; in the future he decided to built stream drags (see below) believing that the separation of the carriage from the power plant was a safer arrangement for the passengers.
1829	**Goldsworthy Gurney** (1793 – 1875) of Cornwall	In 1829 Gurney developed a steam drag to pull a separate passenger carriage and thus avoid the criticism and risk of having passengers seated next to the high pressure boiler (the steam pressure was 70 pounds per square inch). This arrangement allowed the drag to be replaced by another in the event of a breakdown. The arrangement is shown in **Figure 5** and is the nearest (but not identical) to the museum drag, see **Section 4.0** of the main text.
1829	**Colonel James Viney** of the Royal Engineers	Colonel Viney[36] patented a boiler in 1829 intended for use with steam carriages. The boiler was arranged with several concentric hollow cylinders containing water, between which was an annular space or flue for the fire gasses. The boiler does not appear to have been ever tried out.
1830	**John Rawe** and **John Boase** of Albany Street, London	Rawe and Boase in 1830 obtained a patent for Improvements in steam carriages. The specification of their patent, ref. 83, describes their ideas with drawings. The carriage was supported on four wheels and steered by aid of a guide wheel arranged *behind* the fore wheels (as opposed to a pilot wheel in *front* of the fore wheels). Two horizontal cylinders underneath the carriage drove the rear wheels. The boiler was cylindrical with wrought iron spiral tubes. A fan above the boiler increased

	John Rawe and **John Boase**, continued	combustion. There was no chimney, the exhaust gasses being directed, by the fan, downwards underneath the carriage, ref. 84.
1830	**John Henry Clive** Of Chell House, Staffordshire	Clive took out a patent in 1830 for the improvements in the construction of locomotives and other machines and carriages. He wrote many articles on steam carriages under the signature 'Saxula' in *Mechanics' Magazine*, ref. 7 and 81.
1830	**Mr Lea** of Hoxton	A mechanic who apparently constructed a small model of a steam carriage.
1830/34	**W. G. & R Heaton** of Birmingham	Built several carriages under a patent of 1830 and put a steam drag on the road between Worcester and Birmingham in 1833. In this same year a company was formed for the purpose of constructing a carriage capable of keeping an average speed of 10 miles an hour. After repeated trials with a new carriage in 1834 Messrs Heaton dissolved their contract with the company due to the inability to do more than 7 or 8 miles an hour. A description of the machinery, which appears to be complicated, is given in ref. 82.
1831	**Sir Charles Dance** (1785-1844) retired Life Guards officer	Sir Charles Dance was an English motoring pioneer who in 1833 ran a steam coach service between the Strand, London to Brighton, ref. 29. Prior to this, in 1831, he commenced to run a seam coach service between Gloucester and Cheltenham using three of Gurney's steam drags which Gurney had developed, in 1829, to separate the power plant from the passenger carriage(17), ref. 62, 63 and 64. The arrangement is shown in **Figures 5**, **6**, **7** and **12**. The shape of this drag is what the coachbuilders call a "brisca", ref. 30. The advantage of the steam drag was: in the event of a breakdown, the drag could be replaced by another and with its steam engine and boiler separate from the passenger carrying carriage, was inherently safer (or perceived to be inherently safer) for the passengers in the event of a boiler explosion(18). The drag did not use pilot steering like Gurney's previous coaches; instead there was a radiused rack and pinion, with teeth on the ***inside*** of the rack (unlike Neville who used teeth on the ***outside*** of the arc (see above). The pinion had a pivot pin (bolt) to the drag centre frame (central perch). The steersman(19) upon turning the steering wheel (and hence the pinion), say to the right, had the effect of turning the rack and front axle, with the wheels, in the same direction as the steering wheel. There is a fixed point hinge support, see **Figure12**, on the drag body. This allows the body to rise and fall on the rear axle springs. The steam pipe connections are kept close to this fixed point so they can be kept tight, ref. 30. The other end of the hinge support is attached to the side perches. Looking at the museum drag shows that there is a cut out for a bracket on the side perches, see **Figure 32**. Was this to support the hinge or was it for something else, see **Section 4.4** of the main text. The steam supply from the boiler is controlled by a throttle/stop valve, which directs the steam to the valve chests (valve box) on the upper side of the cylinders (there does not appear to be expansion valves on these drags). The exhaust steam was directed to the bottom of the chimney flue where it would form a steam blast and thus provide a draught through the furnace, i.e. unlike Gurney's previous coach, **Figure 11**, there was no need for a blower fan. The rear driving wheels were free to rotate on the rear axle, on which is the crankshaft. The engine had two cylinders with cranks at right angles; so that at least one of the cranks would be off dead centre and hence the drag could be manoeuvred at all times. **Figure 6** shows that the rear wheels were driven by an iron pole known as a carrier bar (or peg rod or

	Sir Charles Dance, continued	driving-arm or T-arm) between shaft and outer rim (felloes) of the wheel. This avoided any heavy loads (torque) being passed from the wheel hub (nave) through the spokes to the felloes. It was normal that only one wheel would be fitted with a pole; so that the drag could turn sharp corners without the wheels sliding(7). However, both wheels could be fitted with a pole when necessary such as when ascending steep hills. **Figure 7** shows another diagram of the Gurney steam drag, ref. 25. In this diagram the carrier bar is on the outside of the wheel, also shown is one of the shoe-drags that could be applied to the rear wheels and used as a brake on steep hills(23). Prohibitory turnpike rates and obstructions (heaps of stones laid across the road) ultimately put Dance's carriages off the road, ref. 7, 62 and 63. The steam drag shown in **Figures 5** and **6** is the nearest we have to the remains of the drag in the museum collection, **Figures 1** and **2**. We can say that in general they are essentially similar, but they are not identical in detail – the features that are different are discussed in **Section 4.0** of the main text.
1831	**Messrs. Napier** of London & Glasgow	In 1831 David Napier(27) of London took out a patent with two cousins James and William Napier of Glasgow for a steam drag, ref. 52, 53 & 54. The construction of which is shown in ref. 7 fig. 34 and Vessey ref. 53. In this design the crankshaft was placed in front of the steering wheel and a belt (Fletcher ref. 7 refers to a chain) drove the driving wheels at the rear. The boilers were mounted horizontally beneath the drag body. The two steam cylinders were bolted to their boiler and secured to the under frame. The body was mounted on spiral springs to the under frame. Steering was by a radiused rack and pinion, with teeth on the *outside* of the rack. However, according to Nicholson, ref. 54, there is no record of their having built this vehicle, and there is nothing to show it ever ran, ref. 52.
1831	**William Summers** (c1809 – 1881) and **Nathaniel Ogle** (1797 – 1856) of Southampton	In 1831 Summers and Ogle built two steam carriages noted for their extraordinary high speed on common roads. The boilers were similar to that on American fire engines and worked at a boiler pressure of 250 lbs. per square inch. The first carriage, ref. 7 fig. 35 used two cylinders while the second carriage used three cylinders. Both carriages were mounted on three wheels, ref. 7 and 85. The draught through the boiler was by a fan driven by the engine rather than exhaust steam blast to the chimney. The maximum speed obtained was 32 miles an hour.
1831	**Mr John Squire** and **Colonel Frances Maceroni** (1787/8 – 1846) of Manchester	John Squire (Gurney's former employee, carpenter, ref. 26) had built a steam carriage. In 1831 he met with Colonel Maceroni (who previously had been associated with Gurney, see above) who found the carriage superior to Gurney's but with a somewhat defective boiler. Later, in 1833, Maceroni and Squire jointly patent an efficient multi-tubular boiler. Their partnership lasted a year. Maceroni's carriages ran well, ref. 7 fig. 47 shows one of his carriages, which worked at a boiler pressure of 150 lbs. per square inch and could carry eleven persons. Colonel Maceroni was one of Hancock's successful contemporaries though he was often short of funds, ref. 7.
1832	**Goldsworthy Gurney** of (1793 – 1875) of Cornwall	By 1832 Gurney had ceased to build steam carriages at his own expense. Gurney petitioned the House of Commons to sanction a grant for expenses incurred in attempting to introduce steam carriages. A grant was recommended and a repeal of the Turnpike Acts. However, the Exchequer refused the grant and the Lords threw out the repeal of the Turnpike Acts. Gurney quit the steam carriage business, ref. 7. Gurney went on to do other useful things and in 1863 he was knighted by Queen Victoria in recognition of his inventions and discoveries, ref. 4 and 6.

Appendix 2: Technical Issues.

A2.1 Introduction. The engineers designing and building the early steam carriages had to solve many technical problems, which are a challenge even today. The range of materials was largely limited to cast and wrought iron. Any connections would be by mechanical means such as screwed joints or riveting. If any welding was to be done it would be by forge welding, i.e. mechanical hammering. If we look at a couple of issues mentioned by Evans in reference 47: Crankshaft failure and Boiler tube leakage. Plus a third issue; Bolt failure in the steam chest of the boiler, which the engineers Murdock and Aitken of Hill Street, Glasgow considered to be the reason for the accident to the museum steam drag in June 1831, as explained by Nix & Nicoll in reference 3.

A2.2 Crankshaft failure. Crankshafts are subjected to cyclic forces and moments in all three directions. The effects of dynamic shock loads and cyclic loads leading to fatigue and sudden fracture were not well understood in the early 1800's. The engine situated under the coach body was exposed to the elements and from dirt, dust and grit from the road. Lubricants available would be limited and method of lubrication of the bearings would be rudimentary.

The main issues that would be addressed today are:

- Analysis of the applied loading over the life to be expected and a detailed stress and fatigue evaluation would be carried out using analytical and numerical (finite element analysis) techniques.
- The material chosen would likely be an alloy steel with suitable properties such as: strength, ductility, and fracture toughness (a material property) to resist dynamic shock loading.
- Detail design features and surface finish to give a long fatigue life.
- Adequate lubrication of the bearings and protection of the engine from foreign bodies (grit, dust, etc.). A more modern vehicle like the museum 'Sentinel' steam waggon, from 1916, has the engine and crankshaft totally enclosed in a crankcase and a great deal of attention is paid to lubrication of the parts, ref. 38 and 44.
- Inspection and quality control to ensure the part meets the specification requirements and is free of significant defects, i.e. is it 'fit for purpose'.
- Prototype testing would be carried out in advance of production release.

A2.3 Boiler tube leakage. The boiler used by Gurney is an example of a very early water-tube boiler, i.e. a boiler where water flows through tubes and is heated by surrounding furnace gasses. Description of his boiler is given in references 30, 32, 69 and 70. Reference 30 being applicable to his steam drags, which employed a large horizontal steam drum separator (on some boilers Gurney used vertical separators), **Figure 12**. A big issue for Gurney is that seamless tubes were not available and he had to rely on wrought iron rolled up and the seams forged by hammering. This gave particular problems as the lower tubes were used as the furnace grate firebars – an extremely aggressive environment for any kind of water-tube boiler, **Figure 12**.

Water-tube boilers generally can raise steam quickly and supply steam at high capacity. It was also considered safer, than other boilers at the time, because the amount of water contained was relatively small that in the event of leakage or explosion the damage or risk of injury was perceived to be low.

The main issues that would be addressed today are:

- The Pressure Systems Safety Regulations would apply.
- A water-tube boiler would be designed and constructed to a recognised standard code of practice (something the boiler insurance companies would insist on) such as BS1113 (now replaced by BS EN 12952). The scope of which covers: Materials and design stresses, Design of the thicknesses and reinforcement of the pressure parts, Manufacture and workmanship, Inspection and testing including non-destructive examination such as radiography and ultrasonic examination, Valves, gauges and fittings.
- Only certain materials can be used in steam boiler construction. Generally these will be steel with required properties such as: strength, ductility, fracture toughness, creep rupture and corrosion/erosion resistance. The acceptable steels would cover a wide range of materials for use in different parts of the boiler depending on the operating conditions (pressure, temperature, additional loading, fatigue, fracture, corrosion/erosion considerations) and would include: carbon and carbon manganese

steels through to low alloy chrome molybdenum vanadium steels through to high alloy austenitic stainless steels.
- Boiler materials would be weldable (except for bolting which is not normally welded) by electrode or gas welding methods. The welders would be qualified and work to accepted welding procedures.
- Seamless tubes are now available that would be butt welded to other tubes and/or pipe fittings.
- Many standard pipe fittings are now available, with recognised pressure – temperature ratings, such as: Tees, Elbows, Bolted Flanges of various types e.g. long weld neck, taper hub, blind flanges. The sealing of these flanges with suitable spiral wound gaskets is now available.
- In-service inspections would be carried out to ensure continued 'fitness for purpose'.

A2.4 Bolt failure. As explained, by Nix & Nicoll in reference 3, the engineers Murdock and Aitken of Hill Street, Glasgow considered the reason for the accident to the museum steam drag in June 1831 to be a bolt giving way in the steam chest of the boiler. For any item of pressure equipment especially one that is operating a high temperature, like a steam boiler, the failure of bolting connecting pressure parts together would be a serious matter. For the Gurney drag the usual boiler pressure was 70 psi (4.8 bar) at the 'ordinary rate of travel', ref. 3. At this pressure the saturation temperature (boiling temperature of water) is 316°F (157.8°C). Hot water at this pressure suddenly dropping to atmospheric pressure (14.7 psi) as a result of any compromise of the pressure boundary, like a bolt failure, would result in the water instantly flashing to steam. This rapid phase transition of hot water into steam is potentially hazardous as the volume increase as the water turns to steam is very great and can lead to catastrophic equipment failure and severe burns to personnel. In Gurney's day, bolting technology would not be well understood; the materials available, the joint gasket seating and sealing requirements, the mechanics of maintaining a tight joint and the importance of initial preload and maintaining the preload to ensure a long service life would not have been fully considered.

The main issues that would be addressed today are:

- The choice of materials would now include a range of steels from carbon steel to alloy steels and stainless steels with known elevated temperature mechanical (strength) properties including stress rupture properties for those materials that will be used in the creep range.
- The design of the bolted flanges and screw threads would be in accordance with relevant British Standards specified in a code of practice such as BS1113 for water-tube steam plant (now replaced by BS EN 12952) taking account of the design conditions i.e. design pressure and temperature.
- The strength of screw threads would follow the guidance of BS 3580:1964 Guide to the Design Considerations of The Strength of Screw Threads and other design rules such as: EN 1591-1 "Design rules for gasketed circular flange connections".
- Any special joints and types of bolted flange connections would need to be shown to be suitable for the design conditions taking account of the strength requirements of the Bolting-up condition and the Operating condition of a relevant pressure vessel code of practice such as the Modern Flange Design (Taylor – Forge) method in PD5500 (or other analysis in BS EN 13455) Pressure Vessels including the design stress values for the bolting material.
- Thermal differential expansion between the bolts and flange including thermal transients and differences in coefficients of thermal expansion (austenitic stainless steels have a coefficient of expansion about 50% higher than ferritic steels). For operation at elevated temperatures the effects of bolt relaxation due to creep in the bolt, flange and gasket needs particular evaluation in order to avoid leakage.
- The stiffness of the flange components must be high enough so that flange rotation is not excessive otherwise leakage at the gasket joint may occur; there have been cases of bolted flanges that meet strength requirements but were found to be not stiff enough to prevent leakage occurring at the joint.
- The assembly preload and the method of how this is achieved.

The assembly preload is critical for safe operation, gasket sealing and a long service life. Some of the necessary considerations are:

- Alignment for the correct functioning of the flange joint.

- Gasket seating and sealing requirements, to avoid leakage, taking account of materials, gasket factor and seating stresses. In certain critical applications a zero leakage flange joint by seal welding may be required.
- Resistance to joint separation from pressure, mechanical and thermal loads and moments (flange joints for high temperature piping applications can be subject to a flexibility analysis requiring resistance to moments and forces due to: cold pull, deadweight, and thermal expansion as required by a code of practice such as BS806, Specification for design and construction of ferrous piping installations for and in connection with land boilers.).
- Repeated (cyclic) loading and vibration can lead to loosening and loss of bolt preload and subsequent leakage and eventual fatigue failure of the bolting (the screw threads and other areas of bolting have high stress concentrations, which can have a detrimental effect on the fatigue life). For a long fatigue life applications, the correct amount of preload throughout the service life is essential; as is a fatigue evaluation of the bolting using a fatigue design curve with an appropriate fatigue strength reduction factor (for threads this shall not be less than 4 unless a lower value is shown to be valid) in a code of practice like PD5500 Pressure Vessels.
- In certain applications, in the event of a bolt breakage or loss of the nut and washer, the loose parts must be captured to stop these parts getting into a critical part of the equipment.
- Finally, the method of applying the preload needs to be considered. This can range from torque control tightening (the least accurate method) to more accurate yield control and bolt stretch methods. Information the tightening of treaded fasteners and lots more information on bolted connections can be found in the Bolt Science website: https://www.boltscience.com as well as ASME PCC-1 standard "Guidelines for Pressure boundary bolted flange joint assembly".

Appendix 3

Glasgow Museums' Steam Carriage 'The Lord of the Isles'

by

Michael Nix and Alistair Nicoll

Dr. Michael Nix formerly Research Manager for Transport and Technology at Glasgow Museums and the late Alistair Nicoll Volunteer Guide at Riverside Museum, Glasgow.

Glasgow Museums' Steam Carriage 'The Lord of the Isles'

Michael Nix and Alistair Nicoll

Abstract

In 1889 Glasgow Museums acquired the chassis, engine and axles of a steam carriage built by Goldsworthy Gurney for trials in Scotland in the early part of 1831. Suffering from mechanical problems, the vehicle had been put into temporary storage in Glasgow, only to be removed and set in motion without Gurney's approval. Its boiler burst. Had the machine been successful Gurney would have faced serious hostility from vested interests in horse transport and agriculture. The nature of this opposition is explored through the regular service established by John Scott Russell between Glasgow and Paisley in 1834, using his own carriages. The clash between the rival factions ended in five road deaths.

Key words

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Glasgow Museums' Steam Carriage 'The Lord of the Isles'

The accession register of Glasgow Museums records the acquisition on 5 December 1889 of 'the Engine of the Road Steam Carriage constructed by J. Scott Russell which ran between Glasgow and Paisley in 1834'. It had been donated by Pierce A. Simpson, Professor of Medical Jurisprudence at Glasgow University between 1872 and 1898. How he acquired this piece of machinery is uncertain, but it is thought the 'engine' was found in a barn on the Paisley road. The object was for many years displayed in the Kelvingrove Museum and Art Gallery as the remains of a Russell steam carriage, a vehicle involved in a fatal accident on 29 July 1834 while travelling with passengers on the turnpike road between Glasgow and Paisley.

Records at Glasgow's Museum of Transport suggest a revival of interest in this artefact during the early 1950s when the object was confirmed to be 'the remains of a Gurney tractor, c. 1829-31'. The incorrect entry in the accession register appears to relate to a false assumption: that since the remains were found on the Glasgow-Paisley road where the Russell vehicle was severely damaged, then it must be the Russell carriage. The error may be partly attributable to William Fletcher whose book, *The History and Development of Steam Locomotion on Common Roads*, was published less than two years after Simpson gave the 'engine' to the museum. The author incorrectly asserts that the boiler on the Gurney machine burst on the same stretch of road.[1] Including the time the label remained unchanged, but not unchallenged, the erroneous attribution was repeated to visitors to Glasgow Museums over a period of about 90 years.

The purpose of this paper is to explore both the technical aspects of the Gurney steam carriage and the vehicle's history, from its construction in London to its 'exploding' in Glasgow. It also aims to examine the level of opposition in Scotland during the early 1830s to such machines through the experience of his successor, Russell, who ran the first regular steam carriage service in Scotland.

* * *

Sir Goldsworthy Gurney (1793-1875) was a Cornishman much influenced in his boyhood by the experiments of Richard Trevithick, a pioneering builder of steam road carriages and railway locomotives. Trained as a medical doctor, he was appointed lecturer in Chemistry and Natural Philosophy at the Surrey Institute in London in 1822. Three years later, having turned his hand to the construction of steam carriages, he took out his first patent on a machine. In 1829, after further development work, he felt confident enough to make a long-distance experimental drive in one of his vehicles between London and Melksham, thirteen miles short of Bath. Amongst his passengers was Sir Charles Dance, a retired Life Guards officer and future business partner of the inventor. Gurney, however, was provoked, according to his biographer Dale Porter, into rethinking the design of his machine by criticism in an article in *Blackwood's Edinburgh Magazine*. Its author pointed out 'the one grand defect, the 'steamery is under the feet of the passengers'. He continued:

The mighty agent which could make mincemeat of the whole cargo at a moments warning is working under the floorboards on which 20 human beings pretend to be at their ease, travelling fourteen miles an hour. Where the journey may end, whether at Bristol or in the other world, is the problem.

In view of the public's fear of exploding boilers, he affirmed 'the machine will never be entitled to popularity, until chance of blowing up is entirely out of the question; which it can scarcely be, while the steam-engine forms part of the carriage'. He advised the detaching of the one from the other with some distance in between.[2]

During the following winter Gurney created a new compact design, described by him in August 1831 as an 'engine carriage', used to draw or drag other carriages 'in which a load is conveyed'.[3] The engineer John Farey, who provided drawings for Gurney's first patent in 1825, considered a separate carriage reduced the apprehension felt by passengers fearful of an explosion, 'and will therefore be preferred'.[4] Dance used this type to run a regular and popular service between Gloucester and Cheltenham during the first half of 1831. He reported that his vehicles (he purchased three at a cost of £1,800) operated

regularly four times a day, for four months, from 21st of February to the 22nd of June, 1831, during which they carried nearly 3,000 persons, and travelled nearly 4,000 miles. They performed the distance (nine miles) in fifty-five minutes, on an average, and frequently did it in forty-five. There were sometimes delays owing to defective pipes in the boiler, which prolonged the time, but no accident, hurt or injury, ever happened to any person whatever; the engines were never out of order, and are as perfect now as they were at first.[5]

Description of the machine

The machinery in the Museum of Transport was built by Gurney in his workshop in the old, colonnaded Ophthalmic Hospital in Albany Street, near Regent's Park, London. What remains of the original steam drag is the chassis, engine, including the front and rear axles and steering assembly with suspension, the whole covered in a very thick layer of preservative paint. Neither the superstructure nor boiler have survived. The chassis's main frame consists of three wooden perches. In section the two outer members, made of two and a half inch wide and four inch deep timber, are over nine feet long with a gentle curve along their length that becomes more pronounced nearer the rear axle. The shaping ensured the horizontal positioning of the engine to accommodate the sprung carriage body above. On the underside the perches are reinforced by an iron strip, one and a half inches by a quarter of an inch thick. Only one perch is complete at the fore part where the end is neatly rounded off. In plan the centres of the two outer perches above the front axle are twenty-two inches apart, but about six feet towards the back they splay outwards to twenty-eight inches to accommodate the axle's driving mechanism. Between the two perches is a third, much more substantial timber four inches square, which is damaged at both ends. Most disintegration to the chassis has occurred at the rear, where the cross member and metal tow bar are lost. This has caused the axle to sag.

At the fore-end of the chassis is a double elliptical leaf-suspension system positioned between the axle and wheel-plate, the whole rotating on a substantial bolt through the central perch. The springs, according to the military engineer and steam carriage enthusiast John Herapath, were intended to avoid the 'danger apprehended in going over rough pitching, from too rapid a generation of steam . . .'. Should these prove insufficient, he argued, then 'one or two safety valves afford the ultimum of security'.[6]

Unlike Gurney's earlier carriages which used two extra leading wheels at the front, this machine was steered by its fore-wheels through a radiused rack-and pinion device. From his driving position the director (who was also the engineer) worked a steering wheel attached to a steering post that passed through the central perch and drove a seven inch pinion directly. There are two racks, the outer one twenty-one inches in diameter, the inner eighteen inches. The outer rack has twenty-four teeth on a 1.125 inch pitch, the depth of indentation between the teeth being three-quarters inches. The pinion driving the rack is seven and a half inches in diameter and has twenty teeth. Obtaining full lock would thus require the driver to turn the steering wheel twelve-twentieths of a turn, or just over half a turn. Full lock would turn the axle forty-three and a half degrees. The inside rack has twenty teeth, enabling a full lock of fifty degrees with a half turn of the steering wheel. It is not understood how easy it would have been to transfer the steering post from one rack to the other, but it must have been removable. It is also assumed that the inner rack had its own pinion which is missing.

Herapeth wrote in 1829 that such a steering system was extremely responsive, whereby the wheels obey the slightest motion of the hand, [and] a trifling pressure of the foot keeps them inflexibly steady, however rough the ground.[7]

Indeed, he had no doubt that Gurney's carriages:

are much more easily stopped, more accurately driven, and more easily turned, and on considerably less ground, than any stage coach can possibly be. Paradoxical as it may appear, the guiding is incomparably more obedient when the carriage is in motion; though over rough ground, than when still on a boarded floor.[8]

At eight miles per hour, a safe turning circle was about 100 feet.[9]

Set three feet from the front of the outer perches and firmly bolted to all three longitudinal frame members is a pair of horizontal, double-acting, long-stroke cylinders, set at their rear thirteen inches apart at their centres. They each have a bore of six inches and a stroke of eighteen inches. These supplied the motive power via roller-type crossheads and tuning fork connecting rods to two nine inch cranks, fourteen inches apart at their centres and integral parts of an extremely strong rear axle. The axle still has large, three inch flat nuts at each end. To preserve parallel motion the small wheel on each crosshead extends from a piston rod and travels along an elongated U-shaped guide supported between the outer and central perches. Running from these small wheels are the conrods which connect to the crank pins. Professor Evans shows that the method was well ahead of railway practice: Robert Stephenson, for instance, was still incorporating inclined cylinders on the *Rocket* a year later. Stephenson's ambition was 'to reduce the size and ugliness of our travelling engines, by applying the engine on the side of the boiler or beneath it entirely, somewhat similarly to Gurney's steam-coach'.[10]

The rear axle is mounted directly under the outer perches. Two cranks are placed at ninety degrees to each other, obviating the need for a flywheel as the engine would start from any position of the pistons. Herapath opined this arrangement:

preserves uniformity of action by constantly having one cylinder on full pressure, whilst the other is on the reduced expansive. The dead points – that is, those in which a piston has no effect from being in the same right line with its crank – are also cleared by the same means. For as the cranks are at right angles, when one piston is at a dead point, the other has a position of maximum effect, and is then urged by full steam power.[11]

The arrangement is very different on the Russell vehicle: he used vertical cylinders connected to a spur pinion gearing system on the main driving shaft.[12] Gurney argued that the velocity of his vehicles was 'limited theoretically' by the quantity of steam, but he thought twelve miles per hour a safe speed, although he claimed experimentally speeds of twenty and more had been achieved.[13]

An article in the *Edinburgh Evening Courant* in 1831, describes the machine, now in the Museum, from direct observation at Leith. It states that the working of the carriage's engine and axle cranks 'exactly' correlates with 'steam boat engines [that] impel the paddles'.[14] Gurney may have appropriated the ideas for steering and horizontal cylinders, but his judicious placing of the latter under the carriage removed dangerous, moving mechanical parts away from passengers and crew.[15] Its position, however, exposed vulnerable working parts such as the eccentrics to stones thrown up from the road surface.

On top of the cylinders are two chests which contain the valves. These are in some ways quite standard slide valves, but details of their operation are still somewhat obscure in spite of the careful internal examination by a six millimeter video endoscope carried out by Dr David West in 2000. The valves still work and are operated via two eccentrics which are small and comparatively flimsy. (Dr West's examination suggests that 'the condition of the innards' is remarkably good).[16]

When working, a supply of steam entered the valve chest assembly from the boiler through a pipe which ran by way of the director's position. Fletcher, in his diagram of an 1829 carriage, shows the throttle valve handle used by the director to regulate the steam flow: increasing the force of steam caused the carriage to accelerate without jerking; lessening the flow slowed the machine down; and stopping the steam altogether formed a counter vacuum in the cylinders, preventing the wheels from turning. The vehicle's forward momentum, according to Herapath, could even be controlled on downward slopes, thus doing away with complicated, road damaging drag shoes that Gurney had used on earlier vehicles. On descents and sharp bends four-horse coaches, Gurney maintained, were far more difficult and dangerous to control.[17] In 1838 the *Glasgow Mechanic's Magazine* reported innumerable accidents caused daily by shaft horses being 'forced to exert their strength in backing the carriage, and preventing its descending too swiftly from its own impetus'. The whole weight, pushing against their necks, often forced them to back onto their hams, causing severe injuries.[18]

Harris states the carriage destined for Scotland was equipped, before its delivery to Leith, with a new braking system devised by Gurney and Herapath.[19] Perhaps he is referring to the relocation of the throttle valve to a position workable by the driver's foot, a development mentioned by Gurney in 1831. Besides acting as a throttle, it also operated as a safety device: if the director, in Gurney's words, 'is thrown off his seat by accident or otherwise [eg, falling asleep], the Engine instantly stops'.[20]

The driving position was also equipped with a handle (shown in the Fletcher illustration) which enabled the director to stop the vehicle more rapidly by reversing 'the motion of the wheels, so as to prevent an accident, as is the practice with the paddles of steam vessels'.[21] The system is still extant on the Glasgow machine although the actuating lever is broken off. It consists of a single, fixed reversing gear, patented by Carmichael in 1818 and much used in the early nineteenth century. Using this mechanism Gurney declared a carriage travelling at eight miles per hour could be brought to a standstill in six to seven yards.[22]

From the pistons exhaust steam was led back via another pipe (now lost) to the boiler where it was liberated at the bottom of the flue in the form of a 'steam blast', a considerable aid to the draught in the boiler and superior to the fan-forced draught in earlier models.[23] In August 1831 Farey stated that, in Gurney's machines, all waste steam from the pistons was 'discharged into the bottom of the upright chimney with a violent vertical jet, in order to accelerate the draft up the chimney . . . [which] . . . gives such an intensity of draft through the fire as was never procured before'.[24] Using his steam jet invention Gurney was able to both urge the furnace and reduce the height of the chimneys on his later designs.

Just in front of one of the cylinders is a long pipe (the equivalent to the other cylinder is broken off), used as a force pump for supplying water from two long tanks under the passengers' seats to the boiler.[25] This was single acting with a valve, worked by the engine and still existing, which enabled water to be sucked in and then expelled via another pipe. Gurney thought the 'derangement' of the pumps was the most likely form of accident.

So what of those parts that have not survived? The commentator at Leith thought the vehicle

had a neat and handsome appearance, very much resembling in its general structure and finishing an ordinary carriage of the barouche kind, only that it is larger, extending more forward, and having two seats, one on each side, running from front to back. It is open in front, but covered in behind with a cover or hood, which appeared moveable, and behind this, on the outside, there is a square compartment, quite similar in shape and appearance to the hind boot of a coach. In this is contained the furnace and boiler for generating steam.[26]

Another spectator noted that 'it resembles a phaeton' and disclosed that 'on the front part of the vehicle is inscribed 'The Lord of the Isles'.[27]

A further eyewitness, also seeing the carriage in Leith, remarked that without the chimney it would have passed 'for a common open chariot, and the existence of the steam machinery about it would scarcely be observed'. The furnace and boiler, he noticed, fitted 'exactly in the situation of the boot of an ordinary coach, and do not occupy a larger space'.[28] Coke, although a more expensive fuel than coal, was used to fire the furnace. It reduced smoke emissions and diminished the risks of frightening passing horses when on the highway. The first mentioned Leith observer also stated that the

furnace is constructed in the usual manner, with a grate and chimney, which rises to a level with the top of the carriage. The boiler consists merely of about forty small tubes like gun barrels, lying immediately over the fire. These are filled with water, and being very thin, and presenting a large surface to the heat, serve to generate the steam very effectually for the supply of the engine. The pipes all terminate in a cylinder about six inches diameter, which Mr Gurney terms a separator, because it separates the pure steam from the boiling water, which the violent ebullition throws up along with it. The water falls down in the separator, and returns back into the generating tubes, while the steam goes off to feed the engine.[29]

In 1831 Gurney vouched that his boiler tubes, approximately three-quarters of an inch in diameter and one-eighth in thickness bound in cast iron ribs, were made with over-lapped edges welded together and were 'not subject to accident'. They could, he claimed, bear up to 2,000 psi, although 70 psi was the usual pressure at the 'ordinary rate of travel'. In an emergency this could be increased to 100 or 120 pounds, the working pressure never exceeding 130. On the pistons, he affirmed, there was never more than 20 pounds, the engines producing twelve nominal horse power. Boilers were inspected every two to three weeks, depending on the lime content in the water, and were designed to facilitate cleaning.[30]

In 1832, Gurney wrote that his relatively light-weight boilers expose a very considerable surface to the fire, [and] the Steam is generated with the greatest rapidity. From their peculiar form, the requisite supply of Steam depends on its continued and rapid formation; no large and dangerous quantity can at any time be collected. Should the safety valve be stopped, and the supply of Steam be kept in greater abundance than the Engines require, explosion may take place, but the danger would be comparatively trifling, from the small quantity of Steam which could act on any one portion of the boilers.

Such danger, he considered, 'need scarcely be taken into consideration.[31] Herapath was of a similar opinion believing that tubular boilers 'annihilated' the dreadful consequences of boilers bursting . 'Should, indeed', he stated, 'a tube burst, a hiss about equal to that of a hot nail plunged in water contains the sum total of alarm, while a few strokes with a hammer will set all to rights again'.[32] However, the greatest risk to Gurney's boilers, according to Farey, was that the tubes were likely to burn out. Their length and narrowness, he asserted, could prevent steam from getting away freely, thereby displacing water. This would make the tubes vulnerable to destruction by the heat of the fire. Interestingly, he took the view that the danger of explosion was 'less than that attendant on the use of horses in draught'. Injuries to passengers, he argued, by bolting horses overturning a carriage would be far greater than from a bursting boiler, 'which must always be kept at a considerable distance from the passengers on account of the heat'.[33]

None of the wheels, front or back, have survived. Gurney gave the rear wheel diameter as five feet, the fore pair being a foot less (the same height between the back and front axles when the chassis is placed horizontally). The tyre widths, at three and a half inches, were more than an inch wider than those usually used on mail and stage coaches.[34] For these vehicles, where the rear wheels averaged about four feet six inches, the tyre width was kept narrow to reduce friction–indeed, some tyres surfaces were convex so the rubbing area on the road was kept to a minimum. Gurney, on the other hand, utilised wider tyres to increase traction. Narrow ones would, he opined, sink into 'every soft or newly-made road, and thus raise a perpetual resistance to their own progress'.[35]

The wheels on the steam carriage also differed from horse carriages in that they were not dished, but 'cylindrical'–'for they turn with the axles'.[36] The arms or ends of the axle on the Museum's vehicle are indeed straight and not canted downwards to correspond with the degree of the dish necessary to align the lower part of the wheel vertically with the road. Power through the axle cranks was transferred to the rear wheels via a carrier, an iron bar fixed to the shaft to form a 'T'. To reduce stress on the spokes, this was bolted to a felloe at the outer circumference of the wheel. Gurney apparently feared the strain imposed on a wheel would be too great if propelled from the nave.[37]

Usually, only one wheel was driven. There was no differential gear to enable the outer wheel when on a bend to rotate faster to prevent 'sliding and consequent cutting up of the road, which in sharp turnings, would result from inflexible constraint'. However, both wheels could be driven to increase forward momentum when, say, ascending a hill, but this meant the director had to stop the vehicle and physically bolt on a T-arm to the undriven wheel. A contributor to the *Times* wrote that by this artifice the

wheels are required to be of no great strength and weight than ordinary carriage wheels; and, like them, they turn freely and independently on the axle, as circumstances require.[38]

Herapath recorded the weight of a steam carriage at 16 hundredweight, increased to twenty to twenty-two hundredweight when water and coke was loaded on board.[39] In June 1831 one of Dance's steam drags, temporarily equipped with three foot driving wheels was reported ascending a 1:20 or 1:25 hill towing nearly ten-tons, including twenty-five passengers, without attaching a lever to the second wheel and without 'surd' or wheel slippage.[40]

The Gurney carriage in Scotland

Just over a week after Dance commenced his service in the English Westcountry, 'The Lord of the Isles' was reported arrived in Leith on 2 March 1831, with six bales of silk and 120 packages of sundries.[41] Delivered to the quayside from the hold of the London and Edinburgh Steam Packet Company's paddle steamship *City of Edinburgh*, it was taken for safe keeping and slight repairs to Piershill Barracks at Jock's Lodge. Being 'long-expected', there was much public interest.[42] Gurney, in his home town of Bude in Cornwall at the beginning of February 1831, travelled to Leith to personally demonstrate his machine. On 13 March spectators at the Barracks watched with 'pleasure' as the carriage performed with its inventor as 'steersman', and were impressed 'that it could be made to turn within a very narrow space'. Gurney the showman announced plans to take it to Glasgow 'in order that the public may have a complete view of the carriage, and of its powers.[43]

Publicising the machine was part of a much wider scheme to develop a regular passenger service on Scottish roads. In 1826 Gurney had granted a license to John Ward, a retired East India Company official, to run carriages on the London and Liverpool road. The astute Ward, however, before committing himself, decided to await technical improvements. In early 1831, considering the invention 'perfect' and impressed by the apparent success of Dance on the Cheltenham-Gloucester road, he approached Gurney to purchase the 'Scotch patent' for £15,000, in three £5,000 installments and with additional mileage duty. Added to this was Ward's offer of an extra £2,000 as an inducement to 'throw in the Liverpool and Edinburgh roads' as well. Not aiming to be a contracting manager of steam coaches, but to sell on the Scottish patent right for the considerable sum of £32,000, Ward proposed running six carriages 'immediately upon the great road between Edinburgh and Glasgow'.[44]

'The Lord of the Isles' commenced its journey from the Barracks and along the Edinburgh and Glasgow road on Friday 17 March. Gurney was accompanied by Dr Anderson of the Bonnington Chemical Works. Unfortunately, 'owing to the straining of the machinery on the passage from London', progress was delayed for repairs at 'Lord McKenzie's seat' at Belmont, two miles westward of Edinburgh. At eight the next morning the journey was recommenced 'at a steady and uniform rate', reaching West Craigs, exclusive of stoppages, at an average speed of nine and a half miles per hour. The first twenty-one miles, *The Scotsman* announced, was completed 'in two hours and ten minutes; one mile was performed in four minutes'. Technical problems, however, slowed the advance, although the *Glasgow Herald* thought this prudent because of 'the crowds of people who flocked on all hands to see the carriage as it passed through the populace villages of Airdrie, Langloan, etc.'. Curious and closely crowding around it, they proved themselves 'enthusiastically favourable'. A not so impressed contributor to the *Glasgow Chronicle* adversely commented that when Gurney '. . . tried to travel from Edinburgh and Glasgow he required horses to help him up the hills'.[45]

Considering it too late in the day to enter Glasgow, Gurney decided to lodge at Mr Low's machine works in Shettleston. The carriage finally arrived at the Infantry Barracks just past 4 pm on the Monday. Thousands of people lined the streets to 'cheer the vehicle in its progress' and it entered Gallowgate 'in grand style'. Army officers were invited to ride around the Barracks. In the finale to the day, in a square 'thronged with well-dressed persons, all anxious to obtain a peep of the carriage', Gurney showed to the amusement of all the carriage's ability to turn three times 'within a circle of 12 feet', that is, in the length of itself.[46]

In the city there was excited anticipation over an exhibition of the vehicle planned for the following Wednesday on the Green (presumably on the carriage circuit created in 1827-8) to 'give the greatest satisfaction to our city populace'. The *Glasgow Courier*, however, claimed 'considerable disappointment' amongst the people because it was only run around the Barrack Square several times in the presence of various scientific gentlemen, some of whom were 'hoisted on board', and whirled along at the rate of nine and ten miles per hour'.[47]

It is uncertain when Gurney left Scotland, but he was in Bude at the end of May. In the interim he had, after the trial run to Glasgow and the mechanical problems following the sea journey, instructed his engineer to pack up the conveyance. He also demanded the removal of 'several important parts of machinery, particularly some connected with the safety valve', to 'prevent any wanton or unjust use'. Returning to London he ordered the carriage's repair in his workshop there. However, this was not done and unnamed individuals had, in the meantime, attempted to mend or replace the parts.[48] On 1 June, the carriage was driven several times around the Barrack Square where, on coming to a standstill in one corner, the boiler, according to the press, 'burst with a tremendous explosion, and shattered the vehicle into numberless pieces'. Two boys, the sons of Mr McLure of the Port Ellington Inn, entered the Square at that very moment and were severely scalded.[49]

Gurney, still in Bude, read of the disaster on 11 June and wrote an immediate mitigation to the Times, attacking the 'unwarrantable experiments made with it, by persons totally unacquainted with the principle, and in opposition to my wishes, and even without my knowledge'.[50] He found support in the reputable engineers Murdoch and Aitken of Hill Street, Glasgow, who in the same year started constructing locomotives for the Monkland and Kirkintolloch Railway - the first built in Scotland. Writing to *The Glasgow Free Press*, they stated the explosion

was not of that disastrous nature as mentioned in the Glasgow papers. The cause of the accident was in consequence of a bolt giving way in a steam-chest of the boiler, which allowed the steam to escape and carried away the top part of the carriage, it being made of light material. No part of the machinery has received any damage, nor did the men who had managed it, and who were on it at the time, receive any injury.

So confident were the two engineers in the principle of this type of carriage they announced their intention to commence building a machine to a similar pattern and that Gurney's vehicle would soon again 'be in action'.[51]

Opposition

Two days before Gurney wrote to the *Times*, James Stone, Dance's superintendant engineer, was penning his own letter, complaining to the inventor about the great level of opposition formed against the steam carriage service between Cheltenham and Gloucester:

This is a very bad place to commence on: we are surrounded with prejudiced people – agriculturalists. Coach proprietors, coachmen and stable boys, and others directly or indirectly connected with them; these, and the old ladies of Cheltenham, I assure you, offer a formidable opposition to any innovation.

On 23 June Stone wrote again to report the breaking of the hind axle on one of the carriages four miles short of Cheltenham, although the machine was able to limp on using one piston. The damage was attributed to the actions of the turnpike trustees who had ordered the spreading of a deep layer of loose stones in a slight depression in the road. (This was part of a broader campaign – ascents were another favoured location for frustrating the progress of steam vehicles.) The effort needed by the steam carriage to pass the obstruction a second time was sufficient to cause the fracture; even horse-drawn coaches and waggons were prevented from getting through. Dance deplored the impediments 'thrown in the way of a new invention' made by the vested interests who feared losses of livelihood and income.[52]

Gurney was also disquieted. In 1834 he attested that

the agricultural interest had become alarmed at his success, and reasoned in the following manner:– Steam carriages, they said, will supercede carriages with horses; consequently there will be a diminution of demand for horses; consequently the same quantity of oats will not be required; farmers will be ruined, and rents will fall.

His carriages were 'violently stopped' by the turnpike trustees . . . and a vast number of road bills were hurried through both houses of parliament'. About fifty in all nationwide, they were calculated to impose heavy tolls on steam vehicles, making them uneconomical to run in competition with horse-drawn vehicles.[53] Yet Gurney and Dance, in opening a regular service, had challenged all whose jobs were directly and indirectly associated with an huge number of horses employed in posting and stage coaching throughout Great Britain. Gurney insisted that to remove those horses by elementary power . . . the national advantage must be in proportion to the number of horses so removed; and if it is shown that one carriage horse can be removed from the road by the present state of the Steam Carriages, I see no reason why every horse so employed should not be so removed.[54]

The opposition showed itself willing to play dirty.

Although the problems encountered by 'The Lord of the Isles' in the journey from Edinburgh to Glasgow and its subsequent damage may have dismayed Ward, he declined to pay the first instalment on the Scottish patent principally 'because of heavy tolls being put on, which amounted in my opinion to a prohibition'.[55] He judged correctly such impositions would extend to more and more roads, but they would far from bar the whole road network to steam carriages.

In Scotland other engineers were at work developing their own machines. In May 1831, for example, just before the 'The Lord of the Isles' calamity, William and James Napier in McAlpine Street, Glasgow, were busily finishing a leather belt driven engine carriage designed to pull an elegant coach, 'beautfully painted green' and jocularly called 'Nae-peer'. Their invention, 'entirely different from that of Mr Gurney', was so arranged that, in case of engine failure, the coach could be easily converted for pulling by horses.[56] James had patented a tubular boiler in 1830 which he successfully introduced into steamships. He also took out a patent with William and David Napier for their steam carriage developments, but they failed to overcome the difficulties of building an effective boiler.[57] In June 1831 a Mr Macdowal of Johnstone was reported fabricating a two-storied carriage, the lower five foot high portion containing the engine and boiler, the upper seven feet providing accommodation for passengers, with a division for separating the classes. The whole stood a further two feet off the ground.[58]

The most ambitious venture was that of the engineer John Scott Russell (1808-1882), a Glaswegian by birth. His short career as a steam carriage builder and proprietor furnishes a useful indicator of the tribulations awaiting whoever risked taking up Gurney's Scottish patent. In June 1833, Russell, a lecturer in natural philosophy at the University of Edinburgh, and William Dauney, a wealthy advocate, formed the Steam Carriage Company of Scotland and the Grove Engine Manufactory in Sciennes, Edinburgh, 'which was intended for general engineering work as well as the construction of Steam Carriages and Locomotive Engines'.[59] Russell superintended the building of four carriages by John Learmouth and Company, one of the leading coachbuilders in the country, 'to ensure the entire and perfect adaption' to his patented steam engines, and six tenders 'for the supply of water and fuel'.

Russell and Dauney failed to come to an agreement with the Bathgate trustees over tolls on the Edinburgh and Glasgow road, and were unable to use the alternative Mid-Calder high road because of an insufficient water supply. Instead, they chose to run their carriages 'experimentally' between Glasgow and Paisley, via Three Mile House at Cardonald. On 28 March 1834 they dispatched 'three of their steam-coaches to Glasgow, with the requisite steam engines, tenders, and other appendages, and with a suitable establishment of conductors, engineers, and servants'.[60] As a public relations exercise one vehicle was dispatched three miles out of the town on the Paisley road, not to show its speed, but to

. . . prove the facility and safety with which it could move along our crowded streets; and that no danger was to be apprehended from horses starting or shying as it passed along . . .[61]

Within weeks the Mid-lothian road trustees were peremptorily demanding 1s 6d prior to carrying passengers and 3s once the service was set up, 'for every time the steam-coaches pass and re-pass' the bar at Parkhouse. Russell, knowing the trustees could not in law charge anything, offered to pay the highest rate for horse-carriages. Although he tried to be reasonable and avoid acrimony, this did not prevent one of the trustees, the Glasgow banker Robert Scot of Dumbreck, threatening to stop the coaches and 'send them to hell'.

Russell's first vehicle left George Square, Glasgow, for Paisley on 31 March at 12 o'clock and ran through Glasgow's streets crowded with sightseers. It reached its destination at 3pm after a stop at Three Mile House to take in water.[62] It was an unexpectedly slow, very under-powered start and three months elapsed before Russell felt sufficiently confident to commence a regular service. On the 2 and 3 July six trips were made per day, each vehicle, travelling at about twelve mph, carrying more than the twenty-six people they were designed to accommodate. Ominously, the *Glasgow Herald* reported

the extraordinary state of the road, which should at this moment be in the best possible condition, but has been just deeply bedded with broken stones, laid on in large masses, for the purpose of injuring the carriages. This is a line of illiberal policy which it is to be hoped the Trustees will not persevere in.'

One carriage suffered a smashed wheel as it forced its way through 'enormous heaps of stones'.[63]

On 26 July the *Glasgow Free Press* announced that, after complaints from carters and carriers, the trustees agreed to lay sand over the deep metal, but it appears more loose stones were spread on two inclines near

Three Mile House. On the 29th one of the wheels of steam carriage No. 3 collapsed after passing through the obstruction:

The machine came to the ground with terrific violence – the boiler was crushed flat – the bottom of the carriage was blown to atoms – and all the passengers, twelve in number, were more or less injured.

Russell hastened to the scene, bringing with him medical help. The next day a press statement denied the accident was in any way attributable to defects in the machinery.[64] In this he was right.

Dauney's and Russell's summons for damages against the trustees, dated 22 October 1834, states that the vehicle passed through loose stones on a slope, damaging the off-propelling wheel. After travelling another 100 yards on a smooth and level road surface, the wheel suddenly 'inclined under the body of the carriage'. The carriage suddenly lurched over to the side, throwing 'the outside passengers from the top' and was further 'depressed from the want of support'. The weight 'occasioned a pressure of the boiler against the ground, whereby the same was crushed and the steam escaped . . .'.[65] Although the proprietors denied an explosion, the press reported a bang heard two miles away and described steam rushing out of the boiler with such force that burning ciders from the furnace and loose stones were blown a considerable distance, sufficient to ignite a bed in a back-room of Three Mile House.[66]

An engraving, apparently from a sketch by an eye-witness artist, published within a few days of the accident and entitled 'Bursting of the Boiler of the Steam Engine on the Paisley Road', shows the lurch to the right, the escape of steam and people thrown from the coach. Its publisher, W.R. McPhun of Trongate, Glasgow, the printer and publisher of *The Glasgow Mechanics' Magazine*, had to defend the image from accusations of 'caricature or burlesque'. He denied exaggeration: '. . . if it be true that one of the unfortunate sufferers was thrown a distance of forty feet, the altitude given to a prominent figure in the plate is rather beneath than above the truth'.[67] A list of those hurt shows nearly all the injuries were caused by being thrown or jumping from the vehicle. The casualties suffered one arm and four thigh fractures, a further thigh injury (three deaths), two brain concussions (two deaths), one ankle sprain and one slight hurt. The engineer, five men seated on the curricle or tender and one passenger in the carriage, a Mrs Sergeant, wife of a Leicester merchant who suffered an amputated leg, escaped without injury. The helmsman and a boy named Angus, who helped serve the furnace, were slightly burned. Two passers-by were scalded, one seriously, and a few, struck by cinders and stones thrown up by steam escaping from the boiler, had negligible injuries.[68]

Public opinion in Glasgow was divided – some blamed the wheel, others the boiler.[69] The wheels, ordered from John Buchanan and Company (their workshops in Ingram and Hutcheson Streets, Glasgow) were closely scrutinised and criticised for their elegance rather than strength, even though newly constructed 'with a view to greater power in rolling over the metal laid upon the road by the trustees'.[70] Evidence presented to a judicial enquiry the day after the accident pointed to the faulty wheel as the accident's primary cause and the injuries a result of falling or jumping off, a verdict deftly avoiding implicating the trustees. Had this accident happened to a four-horse stage coach it is probable little sustained interest would have been shown by public or press. But in the public imagination bursting boilers were greatly feared: McPhun's illustration certainly plays on this. Both Russell and Gurney experienced adverse publicity as a consequence of calamities to their inventions, yet neither they nor their designs were to blame. Steam carriages, seen as a threat to the entire horse-drawn public transport system, were also feared by vested interests whose actions, both legitimate and illegitimate, forced the two engineers into bankruptcy.

Prior to the accident, Russell's steam coach service was described in the *Glasgow Argus* as 'a favourite public project', but the accident severely tarnished its popularity and reputation. For a time, the paper suggested,

a heavy cloud of suspicion will hang over every effort of its enlightened promoters; and the price of humand life will, by many, be regarded as too high a premium for the encouragement, even of an enterprise on the success of which the general community had undoubtedly set its heart.[71]

There had certainly been great enthusiasm in Scotland for steam carriages, but there was a great dread of them as well. People feared explosions, whether travelling by steam carriage or steamboat. Less obvious than technological hurdles to overcome and powerful opponents to defeat, was the task of breaking through a psychological barrier, of winning over those more afraid of being blown up and scalded by a steam boiler than thrown off a speeding, overturning horse carriage.

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[1] W. Fletcher, *The History and Development of Steam Locomotion on Common Roads* (London, 1891), p. 102.

[2] 'Steam Carriages', *Blackwood's Edinburgh Magazine*, XXIII (1828), p. 94; D.H. Porter, *The Life and Times of Sir Goldsworthy Gurney: Gentleman, Scientist and Inventor, 1793-1875,* (Bethlehem, 1998), p. 94.

[3] G. Gurney, *Mr Gurney's Observations on Steam Carriages on Turnpike Roads* (London, 1832), p. 21.

[4] *Irish University Press Series of British Parliamentary Papers: Reports from Select Committees on Steam Carriages and Mr Goldsworthy Gurney's Case with Minutes of Evidence and Appendices. Transport and Communications,* I (Shannon, 1968), p. 41.

[5] *ibid*., p. 45

[6] *The Times*, 8 September 1829.

[7] *ibid*.

[8] *ibid*, 16 March 1830.

[9] *Reports from Select Committees* (1831), p. 22.

[10] F. T. Evans, 'Steam Road Carriages of the 1830s: Why Did They Fail?', in *Transactions of the Newcomen Society*, 70 (1998-99), p. 8.

[11] *The Times*, 8 September 1829.

[12] Fletcher, *Steam Locomotion*, p. 135.

[13] *Reports from Select Committees*(1831), p. 31.

[14] *Edinburgh Evening Courant* (*EEC*), 10 March 1831.

[15] Porter, *Gurney*, p. 128.

[16] D. West, 'Gurney Drag Update II' in *The Steam Car*, 7 (2000), p. 18.

[17] Gurney,*Observations on Steam Carriages,* p. 20.

[18] *Glasgow Mechanic's Magazine; and Annals of Philosophy*, 3 (1838), p. 386.

[19] T. R. Harris, *Sir Goldsworthy Gurney, 1793-1875* (Cornwall, 1975), p. 52.

[20] *Reports from Select Committees* (1831), p. 32.

[21] *EEC*, 10 March 1831.

[22] *Reports from Select Committees on Steam Carriages* (1831), pp. 20-1.

[23] 'Waste steam was used to produce a draft in the chimney of railway locomotives, but the loud puffing noises consequent to blasts of steam being ejected by the alternative strokes of the pistons would have been disturbing to roads travellers and horses. Gurney conducted waste steam to a chamber which converted, using jets, the puffing into a continous and steady blast, 'creating a constant and effective draft

through the fire, unacompanied by any noise' (*The Edinburgh review or Critical Journal* (Edinburgh, 1833), p. 140.

[24] *The Times*, 8 September 1829.

[25] Their positioning, according to an article in the *Glasgow Chronicle* dated 22 April 1831, assisted in boosting weight on the hind wheels to increase traction. Their size, compared with early water tanks at the front of vehicles, enabled longer distances to be traversed.

[26] *EEC*, 10 March 1831.

[27] *Scotsman*, 2 March 1831.

[28] *Glasgow Herald*, 14 March 1831.

[29] *EEC*, 10 March 1831.

[30] *Reports from Select Committees* (1831), pp. 19, 21, 26.

[31] Gurney, *Observations* , p. 21. The safety valve was positioned 'at the option' of the engineer (*Reports from Select Committees* (1831), p. 28).

[32] *The Times*, 8 September 1829.

[33] *Reports from Select Committees* (1831), pp. 7, 41-2.

[34] *ibid*, pp. 19, 28, 95.

[35] Gurney, *Observations* , p. 25.

[36] *Reports from Select Committees* (1831), p. 25.

[37] R.W. Kidner, *The First Hundred Road Motors* (South Godstone, 1950), p. 11.

[38] *The Times*, 8 September 1829.

[39] *ibid*.

[40] Gurney, *Observations* , p. 35.

[41] *Leith Commercial List*, 4 March 1831.

[42] *Scotsman*, 2 March 1831; *EEC*, 10 March 1831.

[43] *Glasgow Herald*, 14 March 1831.

[44] *Reports from Select Committees* (1834), p. 47

[45] Kidner, *Road Motors,* p. 11.

[46] *Scotsman*, 23 March 1831; *Glasgow Herald*, 22, 25 March 1831.It appears neither of the locks were sufficient to turn the vehicle in its own length, but it would not have been far from that.

[47] *Glasgow Courier*, 24 March 1831.

[48] *The Times*, 21 June 1831.

[49] *EEC*, 4 June 1831; *The Times*, 7 June 1831.

[50] *The Times*, 21 June 1831.

[51] *Scotsman*,8 June 1831; *EEC*, 16 June 1831.

[52] Gurney, *Observations* , pp. 34-5, 46. Stone took the carriage to pieces to mend the axle and found the engine in good order 'with the exception of the brasses on the crank' (pp. 40-1).

[53] *Debate on the Presentation of Mr Gurney's Petition for the Repeal of the Legislative Restrictions on Steam Engines Running on Common Roads* (London, 1834), pp. 4-5.

[54] Gurney, *Observations* , p. 31. By petitioning the progress of bills noy et passed into law was halted.

[55] By July 1835 there were about 200 Acts of Parliament.

[56] *Glasgow Herald*, 23 May 1831.

[57] J. Napier, *Life of Robert Napier of West Shandon* (Edinburgh and London, 1904), pp. 89-90.

[58] *EEC*, 13 June 1831.

[59] National Archives of Scotland, CS 96/1047, Duplicate of the Sederunt Book in the Steam Carriage Company of Scotland Sequestration: Explanatory Statement, pp. 83-4.

[60] Glasgow Museum of Transport, Summons of Damages, William Dauney against Robert Scot and Others, 22 Oct. 1834, pp. 1-9.

[61] *Glasgow Herald*, 31 March 1834.

[62] *Scotsman*, 2 April 1834.

[63] *Glasgow Herald*, 4 July 1834.

[64] *Glasgow Free Press*, 30 July 1834.

[65] Summons of Damages, pp. 17-9.

[66] *Glasgow Herald*, 1 August 1834.

[67] *Glasgow Free Press*, 13 August 1834.

[68] *ibid*, 30 July 1834.

[69] *Glasgow Herald*, 4 August 1834.

[70] *Scotsman*, 2 August 1834.

[71] *ibid*.