

The Valve Gear Club

DRIVING THE P2 TO BECOME BRITAIN'S MOST
POWERFUL STEAM LOCOMOTIVE

Almost
£5m
raised of the
£6.5m needed
to complete the P2



Follow us on:

**Join today to help us manufacture the valve gear
for Gresley Class P2 2-8-2 No. 2007 *Prince of Wales***



2007 PRINCE OF WALES

Building Britain's Most Powerful Steam Locomotive



The project to build P2 No. 2007 *Prince of Wales* launched in 2013 and has made significant progress. Almost £5 million has been raised, with most large components now manufactured, from boiler to tender.

The Gresley class P2 'Mikados' were the most powerful express passenger locomotives in the UK, designed by Sir Nigel Gresley to haul 600-ton trains over the arduous Edinburgh to Aberdeen route.

The ultimate performance and economy of a steam locomotive depend on optimising the complete thermal system. Assuming the boiler and smoke box are sound, the most important areas for design are the cylinders and valves.

The unique cylinder monobloc was the first step towards building the powerhouse of the P2. This has now been lifted into the frames, marking a milestone in assembly. With that work complete, we turn our attention to the valve gear.

Lentz poppet valve gear is more efficient than Walschaerts valve gear, found on most UK locomotives including *Tornado*. Lentz developed the concept using large passages, large valve areas and suitably controlled valve events to fully utilise the latent capacity of the boiler. Lentz poppet valve gear was fitted on the first P2, No. 2001 *Cock o' the North*, and we will apply this principle to No. 2007.

A full-size 3D printed cam box has been tested for size and fit, allowing the design to be refined and tolerances understood. We are heavily engaged with the supply chain to enable construction of the first production cam box in September 2026. This will be followed by manufacture of the internal components, leading into the trial and testing phase of the valve gear system.

For manufacture and testing of the new design, we need to raise £300,000 - the first £50,000 of which has already been secured and is driving the prototype programme. The Valve Gear Club seeks to raise the remaining funds through donations of £1000, as a lump sum or smaller instalments.

History of Lentz Poppet Valve Gear



No. 2001 *Cock o' the North*

- Poppet valve gear was initially developed in 1907 as oscillating type driven by Stephenson or Walschaerts valve gear.
- First rotary cam (RC) valve gear developed in 1928 – fitted to six D49 engines. These had stepped cams providing a limited number of cut-offs.
- First application of continuously variable gear on the first P2 class locomotive, No. 2001 in 1934.
- No. 2001 reverted to stepped cams at end of 1934.

Lentz Valve Gear and the P2 Class

By keeping true to the valve gear design of No. 2001 and adapting that design to incorporate post war developments, we are able to harness the potential efficiencies and additional power envisaged by Sir Nigel Gresley.

In 1907, Dr Hugo Lentz developed a form of poppet valves where the cams of the oscillating type were driven by conventional Walschaerts or Stephenson valve gear. The original Lentz design was developed to be driven by rotary cams, which in turn take their drive through gear boxes and cardan shafts from the locomotive's wheels. This design was successfully applied to several hundred locomotives worldwide. Poppet valves are also used in internal combustion engines and are activated by cams.

The first P2 class locomotive No. 2001 *Cock o' the North* was fitted with Lentz rotary cam poppet valves. This was unusual as most modern steam locomotives used piston valves, where the entry of live steam to and the exit of exhaust steam from the cylinders was controlled with piston valves driven backwards and forwards by the valve gear. On RC valve gear, the live and exhaust steam cut offs can be set independently. Gresley recognised that poppet valves can result in higher power,

greater efficiency, and reduced maintenance.

The first application of continuously variable gear was on No. 2001 in 1934. When proposed for No. 2001, Gresley requested that the Associated Locomotive Equipment Company provided continuously variable cams, rather than stepped cams, thus providing an infinite number of settings between 10% and 75% cut-off. This fine adjustment was required with powerful locomotives and will enable economical operation of No. 2007.

However, on No. 2001 the continuous cams wore rapidly and required replacement after only 10,000 miles, so stepped cams were fitted, adversely affecting its economy. Fortunately for No. 2007 *Prince of Wales*, the Lentz valve gear was further developed by the Franklin company of the USA during the 1940s which overcame the wear problems with the cams and other maintenance issues.

Lentz-Franklin Valve Gear

The Franklin Company in the USA took on the Lentz patents in the early 1940s and they did what the Americans do best – develop and productionise a basic idea. Metal hardening methods developed through WW2 overcame the grooving problems in early continuous cams, and most components were "beefed up". Additionally, the cam slider mechanism changed from rack and pinion to screw operation resulting in less backlash which, more importantly, cannot back feed into the reverser.



Under Vernon Smith, the Franklin version of Lentz gear with infinitely variable cams were fitted to the K4S.

The original P2s and the new P2 design

We have been fortunate to obtain details of the Franklin developments and have incorporated these into the design of the valves and valve gear for No. 2007, (including copies of the original blueprints of the Santa Fe 3752 - photo on page 3). Combined with modern design software and modelling, we have been able to bring the Lentz-Franklin valve gear into the 21st Century, specifically adapted for the new P2.

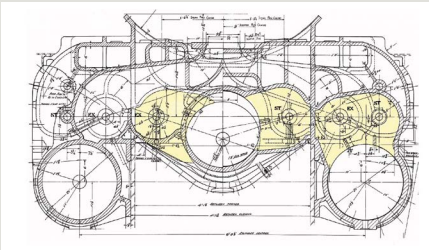
The arrangement of the valves around the three cylinders, with the middle cylinder raised, created an engineering dilemma which was never satisfactorily resolved – until now! Gresley’s solution was to have inlet and exhaust valves on opposite sides of the inside cylinder. This resulted in very large and uneven clearance volumes resulting in lost cylinder efficiency. The live and exhaust steam pipes sat next to each other, only separated by a steel wall, causing massive heat transfer – as much as 100°F recorded in tests at Vitry.

The alterations made in the Elliott design solve two significant weaknesses in the original P2 valve gear design.

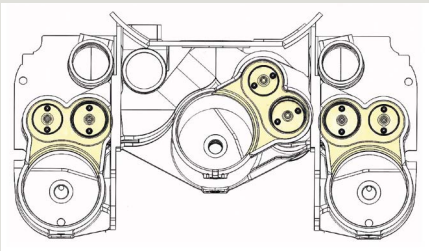
- 1. The clearance volumes are now the same for each cylinder
- 2. The live steam inlets are away from the exhaust steam pipes, reducing inefficiencies caused by significant heat transfer.



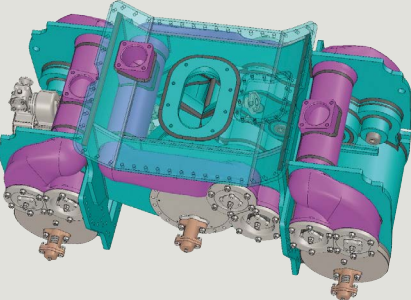
The original monobloc cast iron cylinder block for No. 2001 *Cock o’ the North* (front view).



No. 2001 Clearance Volumes



No. 2007 Solution - David Elliott’s monobloc design deals with these issues most elegantly.



The position of the valves led to a final technical challenge: transferring drive from the right hand cam box inside inlet cams to the valves. The design solution is to use rocking shafts, as illustrated on page 5 The rocking shaft will need to be strong, light and tolerant of high temperatures, so is likely to be a titanium structure.

WE ARE EFFECTIVELY UNTHROTTLING THE CYLINDERS!

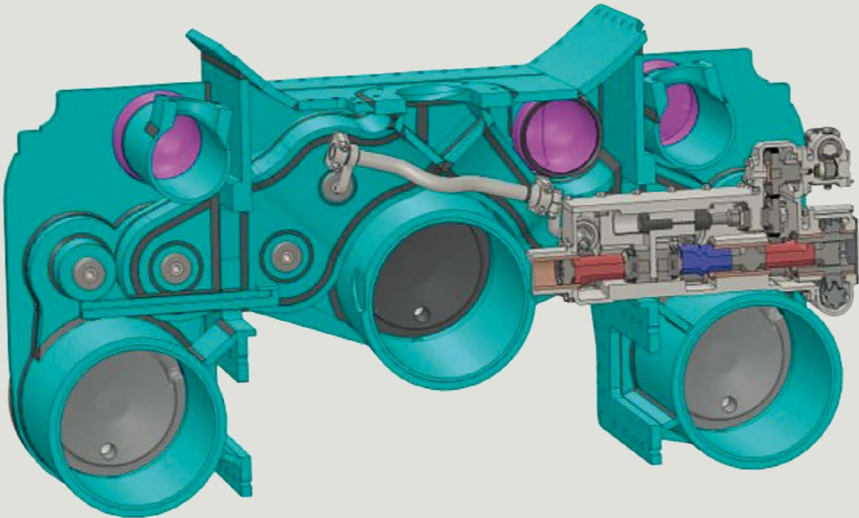
Valve Gear: Walschaerts vs Lentz

	Walschaerts	Lentz
Economy	✓ Walschaerts very highly developed and capable of providing good economy if designed correctly.	✓ Rotary Cam valve gear has separate exhaust and inlet valves with separate cams to operate them, hence timing of inlet and exhaust is independent.
Efficiency	✗ Piston valve efficiency (sealing) degrades with wear	✓ Poppet valves remain steam tight longer between maintenance intervention.
Operation	✗ Limitation of Walschaerts is that both steam and exhaust are controlled by the same valve event.	✓ Poppet valves offer less friction in operation and absorb less power.
Power	Ordinary valve gear and piston rods at high speeds absorb as much as 200-300hp to drive them.	The Franklin-Lentz Gear at 500rpm of 80" wheels require only 3.3hp!

A1 vs P2 (sq. in)

	A1	P2	
Steam valve opening at max cut off	34.19	42.89	Fully open 8" inlet valve
Exhaust valve chest to cylinder port	33	55.02	Fully open 9" exhaust valve

This results in increased efficiencies, and greater potential horsepower. The P2 will be able to consistently produce over 2500hp at the drawbar, with over 3000hp at the cylinders, when climbing hard or at higher speeds. This would be in addition to improved economy at lower speeds and when minimal power is required.



Cam box design for the middle cylinder.

To become a member of The Valve Gear Club, please complete the form at back of leaflet or email enquiries@p2steam.com, call 01325 460163 or visit www.p2steam.com for more information.

Cam box design

Prototype and Manufacturing:

Full-size 3D-printed cam boxes have now been produced and tested to confirm the size and design. The testing has provided valuable learning, which has been used to refine the design and establish the tolerances required for manufacture.

The cam box will then be tested at Darlington Locomotive Works, with loads applied and run for fatigue, replicating the forces anticipated when in use on the locomotive. Given the rapid application and removal, it is anticipated that hydraulic cylinders will be used to replicate the load. Once proven, the valve gear will be fitted to the locomotive for use on *Prince of Wales*.

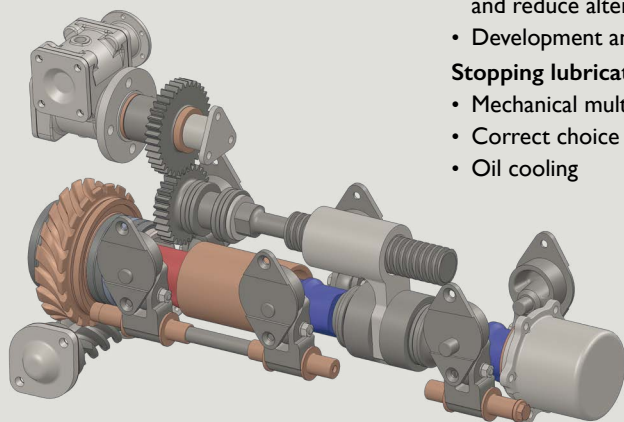
The valve gear design for No. 2007 set out to address the historic shortcomings found on No. 2001 in the following ways:

Avoiding mechanical failure of components

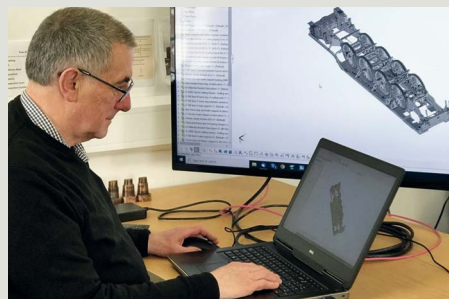
- Use of CAD and FEA design
- Manufacture using high strength materials
- Manufacture of a fatigue rig for test

Other Mitigations:

- > Compared with Walschaerts gear, most components are contained within casings which will reduce risk of the locomotive shedding parts
- > Shear pins will be fitted in the drive to cardan shafts to prevent over-torquing in seizure conditions



Cam shaft design.



David Elliott used 3D CAD to design many elements of the P2, a facility unavailable to the likes of Sir Nigel Gresley!



The 3D printed cambox in place, ready for testing at Darlington Locomotive Works.

- > Locomotive will lose power in event of valve gear failure

Preventing Inferior performance

- Use computer modelling - full thermal and fluid dynamic model to optimise valve events and reduce alterations in service
- Development and adjustment during trials

Stopping lubrication failure

- Mechanical multi-channel lubrication
- Correct choice of oil
- Oil cooling

Yes! I would like to support the P2 Project and join The Valve Gear Club

Sign up on our website at:

www.a1steam.com/p2valvegear

(or scan QR code)

Alternatively, please complete the form below and return to:

The A1 Steam Locomotive Trust
Darlington Locomotive Works,
9 Bonomi Way, Darlington, DL3 0PY.



Why not visit Darlington Locomotive Works and see No 2007 *Prince of Wales* under construction for yourself? Open Days are held on the first full weekend of the month, 10:00hrs to 15:00hrs.

THE VALVE GEAR CLUB APPLICATION FORM

Name

Address

..... Post Code

Email Telephone

☐ I have enclosed a cheque for £1,000 made payable to "A1SLT - P2 Construction Fund" or

☐ I would like to make ten (10) payments of £100

To set up a Standing Order, please complete the following:

Bank / Address

..... Postcode

Dear Sir/ Madam

Please pay monthly on the 10th of each month, the sum of £....., commencing with the first payment on the 10th of (month)..... 202__, to the Barclays Bank Plc, Sort Code 20-61-55, for the credit of 'The A1 Steam Locomotive Trust' (a/c 53835308)

and charge my account no. ____ - ____ and sort code ____ - ____ - ____

This order is in addition to any existing order that is in favour of 'The A1 Steam Locomotive Trust'.

Yours faithfully,

Signature: Date

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For every £1 you donate, A1SLT can reclaim 25p from HMRC - you just need to tick the box below.

☐ Yes: I want the A1 Steam Locomotive Trust (Charity No 1022834) to reclaim tax on all my donations I make on or after this declaration until I notify them otherwise. I confirm I am a UK taxpayer and understand that if I pay less tax than the amount of gift aid claimed, I am responsible for the difference.

From the builders of No. 60163 *Tornado* - the first new main line steam locomotive built in Britain since 1960

Please join The Valve Gear Club and help us manufacture and build David Elliott's final design for P2 class No. 2007, *Prince of Wales*:

The target for The Valve Gear Club is £300,000, with supporters making donations of £1,000 as a lump sum or in monthly instalments of £100.

Thanks to the generous donations of our Supporters, over £50,000 has already been

secured and is driving the prototype programme. As the first cam box is cast following the fitting of the monobloc, we invite you to join 'The Valve Gear Club' today.

Special benefits for members of The Valve Gear Club

- Exclusive Art Deco P2 Poster by Ed Laxton
- Priority to buy a ticket (seat already reserved) on one of the first trains hauled by No. 2007 *Prince of Wales*
- Reasonable access to No. 2007 at all times
- First choice of other components to sponsor
- Opportunity to attend 'The Valve Gear Club Day' when the prototype is tested.



For further information on any aspect of the new Gresley class P2 please visit **www.p2steam.com**, email us on **enquiries@p2steam.com** or call **01325 460163**.
Together we can build this remarkable locomotive!



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