



**60163 TORNADO**

New Steam for the Main Line



**2007 PRINCE OF WALES**

Building Britain's Most Powerful Steam Locomotive



**3403 ANON**

Recreating Gresley's last design

## ASTT Conference 2022



## The A1 Steam Locomotive Trust



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## A1SLT MISSION & VISION

### Mission:

- To build and operate LNER designed locomotives for Main Line and Heritage Railway use.

### Vision:

- To keep Main Line steam alive (“New steam for the Main Line”)





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£1.25 = price of a pint

Slogan: "Build a brand new A1 for the price  
of a pint of beer a week!!!"

1000 contributors should see it built  
in 10 years.

less and it takes longer  
More and it is a quicker build.

This will work.





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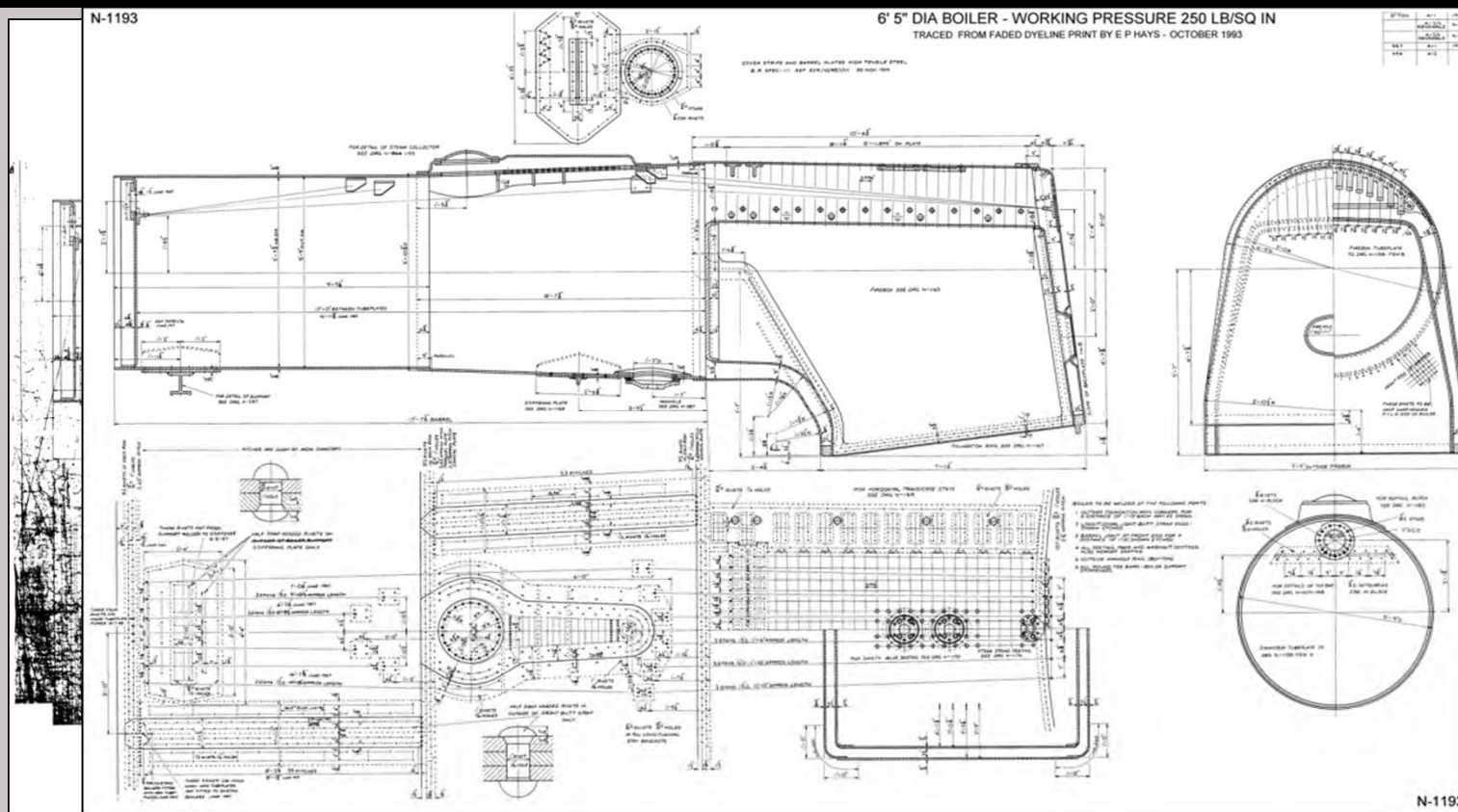
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Poor original dyeline print... painstakingly traced





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# A1 60163 *Tornado*







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## 2008 – first moves at Darlington





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## First Mainline Passenger Train - 31 Jan 2009







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## Naming Ceremony and First Royal Train 19 Feb 2009







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## 'Great Race to the North' for 'Top Gear' 25 April 2009







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## Paddington 2







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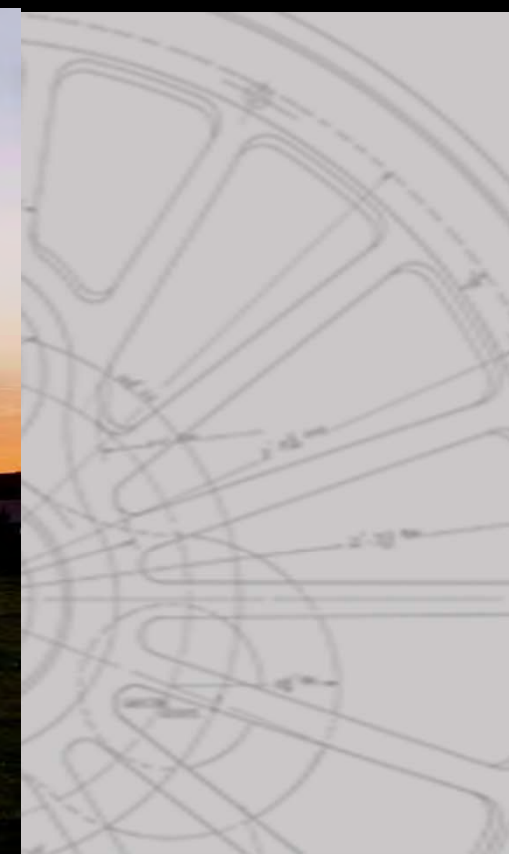
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## Key design principles

- Aesthetically similar to No.2001 *Cock o' the North*
- Whole locomotive to be drawn in 3D CAD
- Existing design to be used except:
  - Alterations to alleviate known problems with original design
  - Changes required to meet modern operating requirements
  - Equivalent *Tornado* design to be used where appropriate
  - Improvements to assist maintenance and life-cycle costs
  - Materials at least equal to and preferably better than original
  - Achievement of compliance with rail industry standards



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# It starts with the drawings...



Gill and the late Tony Lord scanning P2 drawings at the NRM





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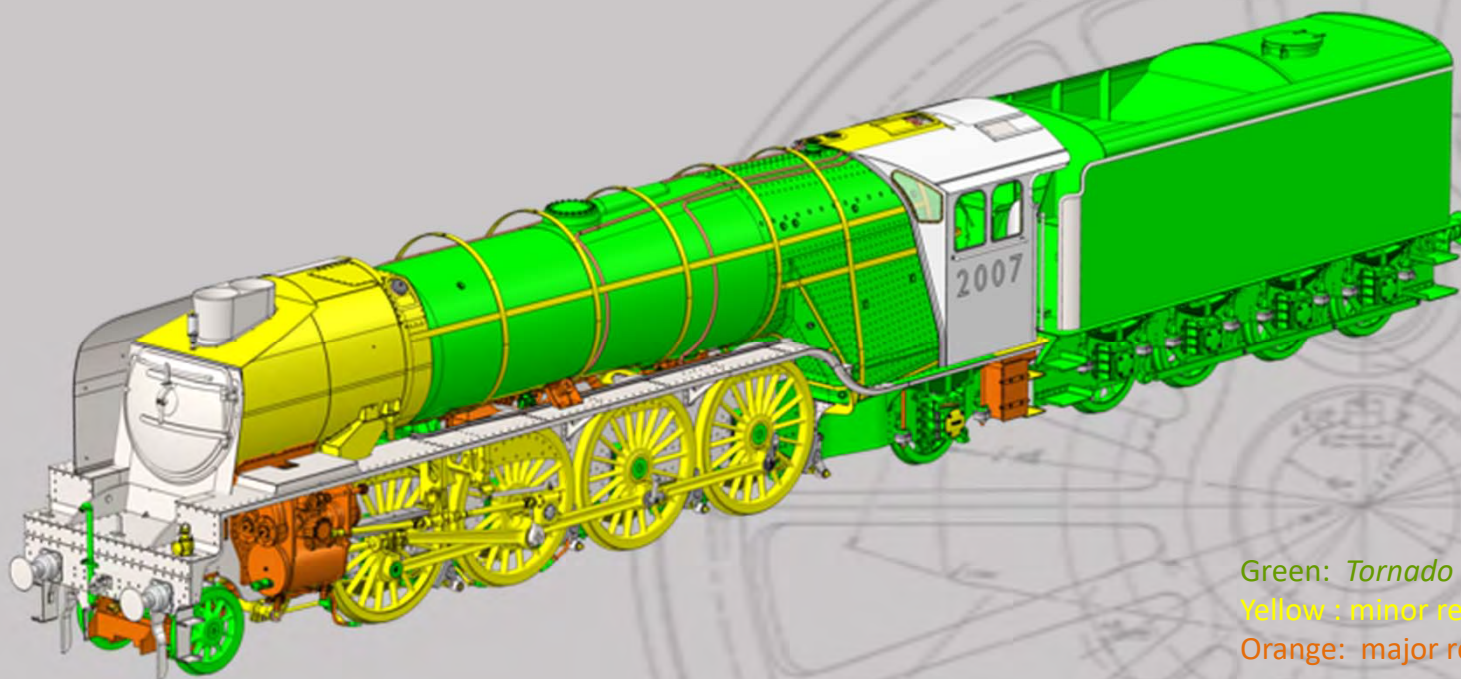
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## Commonality with *Tornado* and new design



Green: *Tornado* design  
 Yellow : minor redesign  
 Orange: major redesign



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## The first parts appear!



James May (from *Top Gear* and *The Grand Tour*) makes the first component at LEEDS Locomotive Works on 20<sup>th</sup> February 2014



The completed smokebox dart







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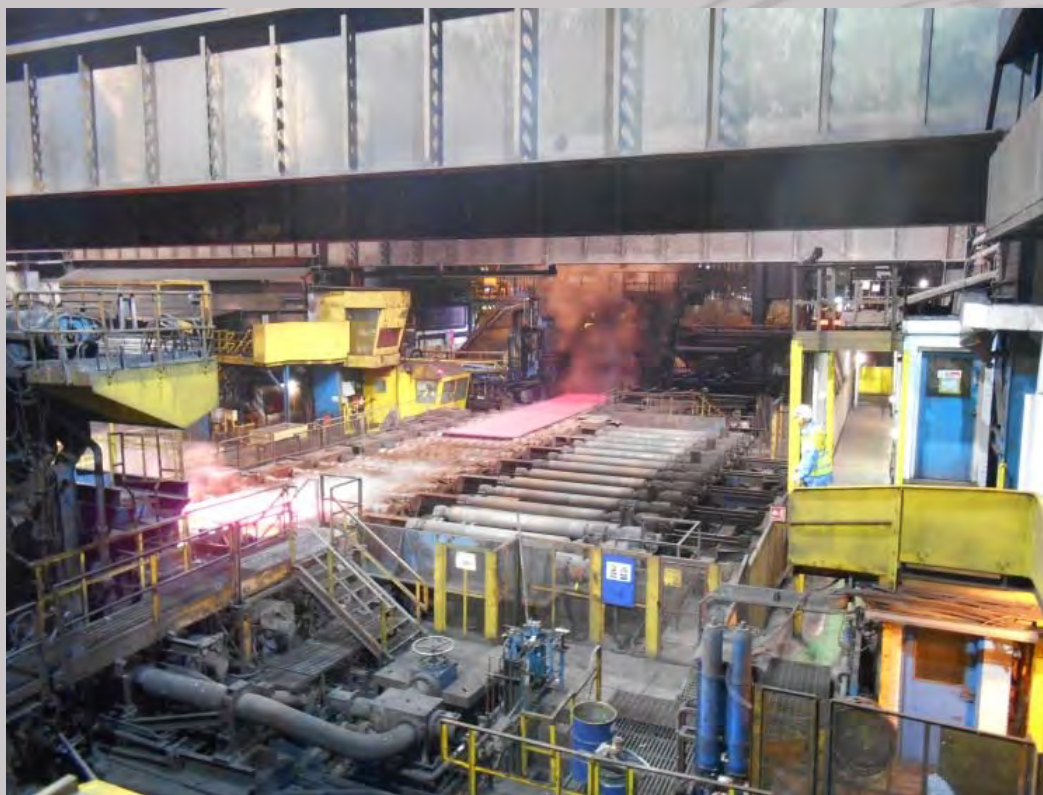
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The frame plate material is rolled 23<sup>rd</sup> April 2014







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## Sir Nigel Gresley's grandsons start the profiling on 21<sup>st</sup> May 2014



Ben and the late Tim Godfrey start the profiler





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## Frame plates



Frame plates CNC machined direct from CAD drawings by Boro' Foundry



A flat pack arrives in DLW





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## Frame assembly and bending





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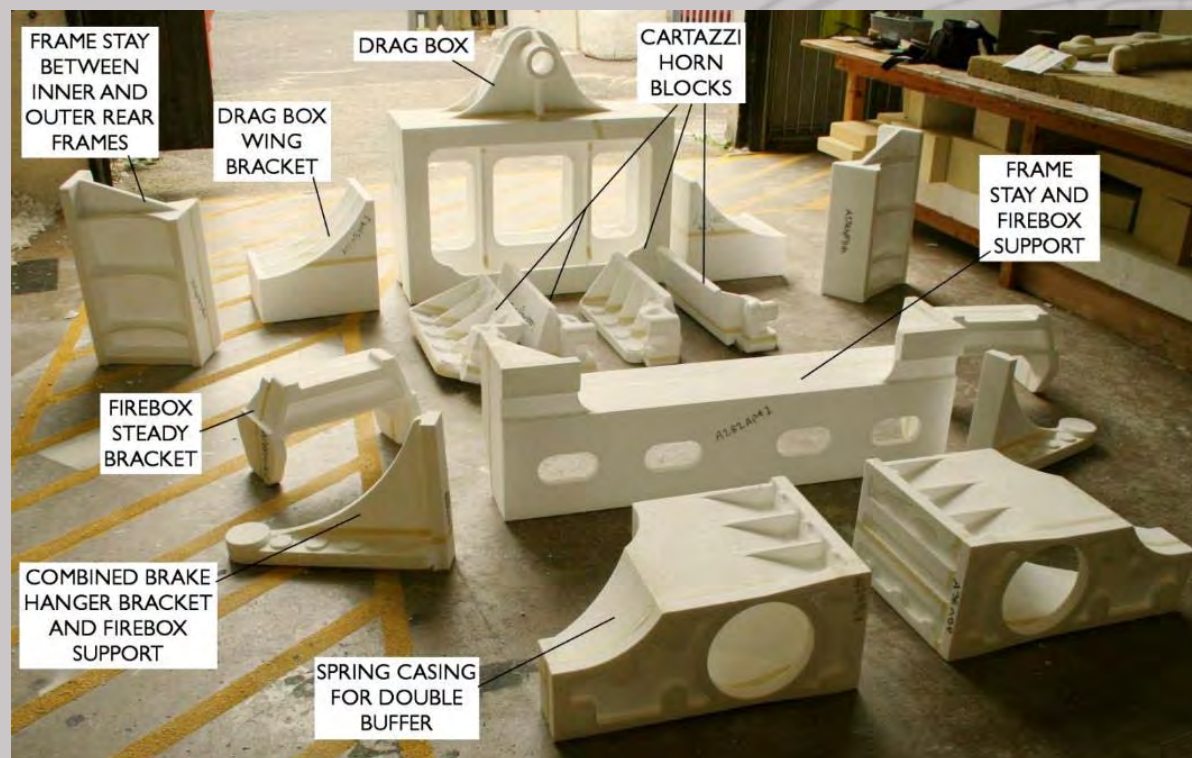
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## Polystyrene patterns for frame castings – castings completed







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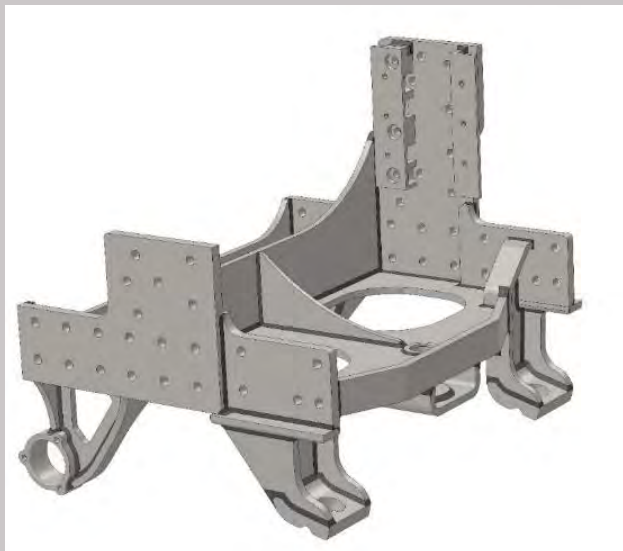


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## Frame progress

Last major frame stay nearing completion





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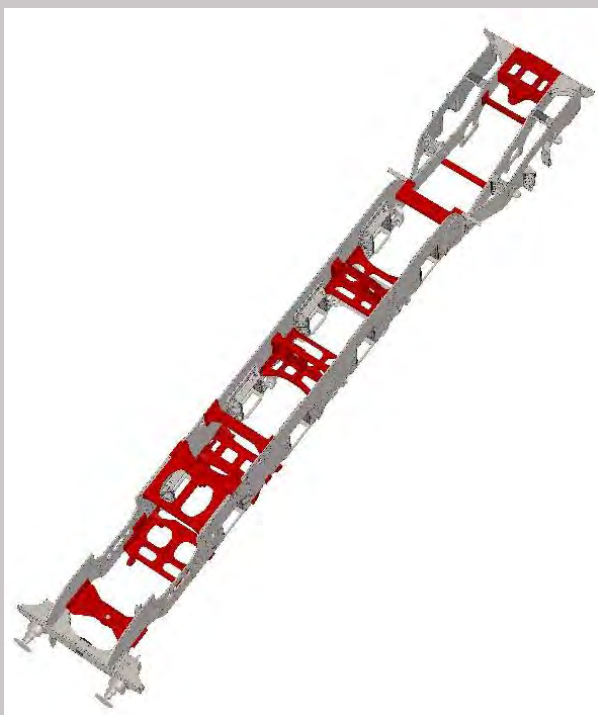
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## Frame progress







## 60163 TORNADO

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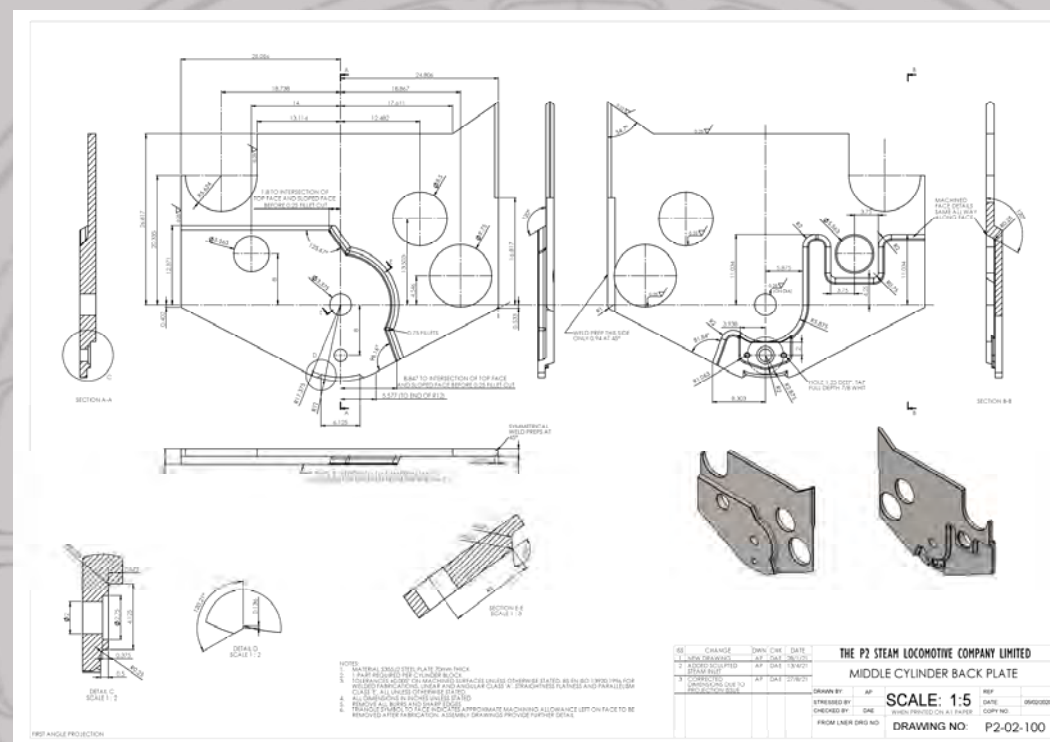
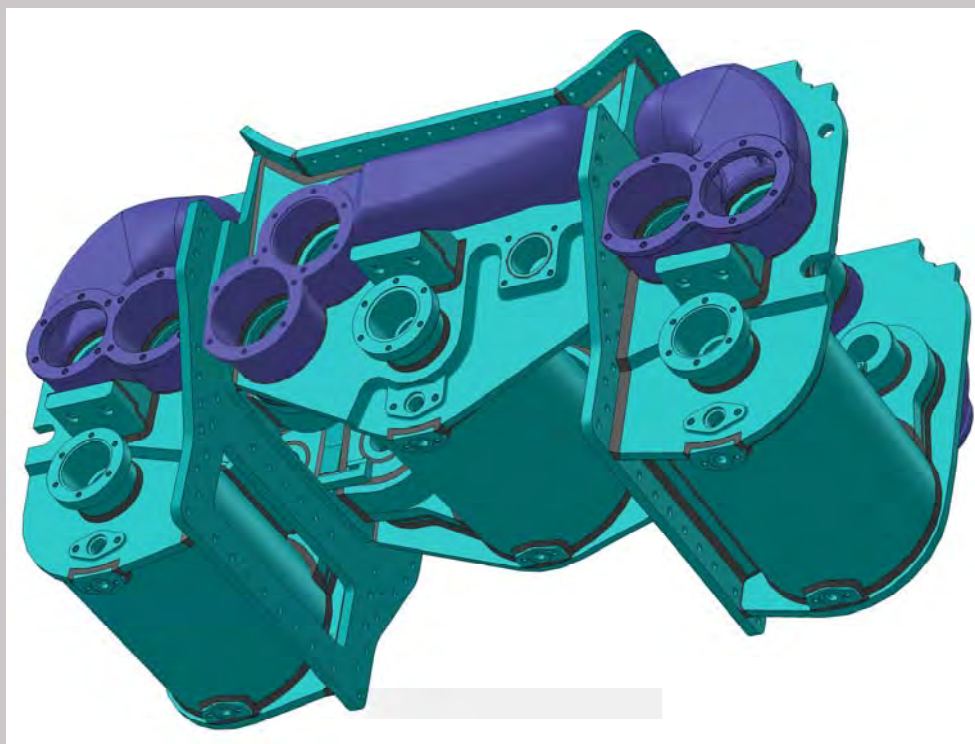
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### Recreating Gresley's last design

# Cylinder block design – 3D CAD model, 62 drawings





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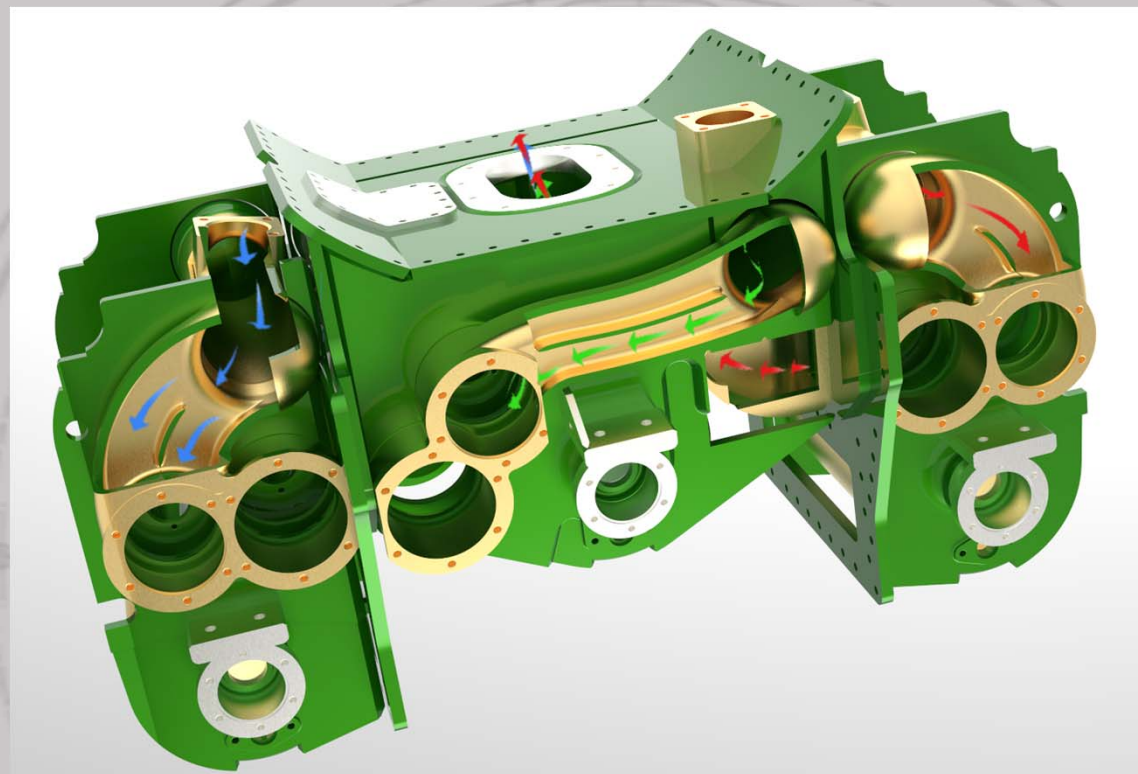
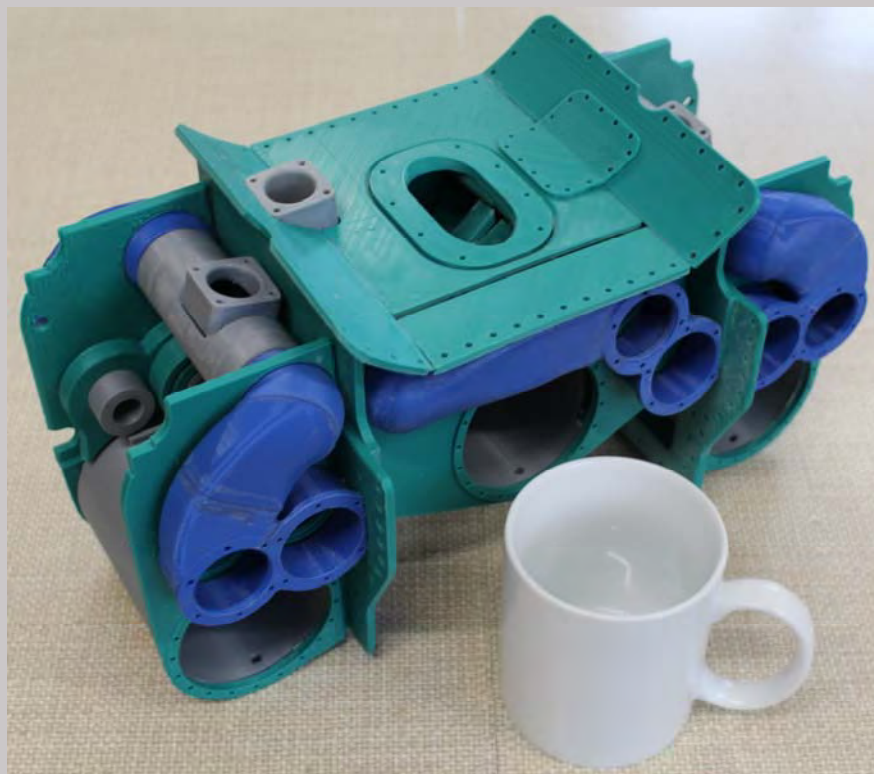
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## Cylinder block 3D printed model and CFD study







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## The Cylinder Manufacturing Club – Launched July 2021



- We estimate that the redesigned cylinder will cost around £250,000 to manufacture
- We are seeking 250 people each donating £1,000 (plus Gift Aid) in up to eight payments of £125pm by standing order
- Special benefits for members of The Cylinder Manufacturing Club



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## Cylinder block construction – steam port castings







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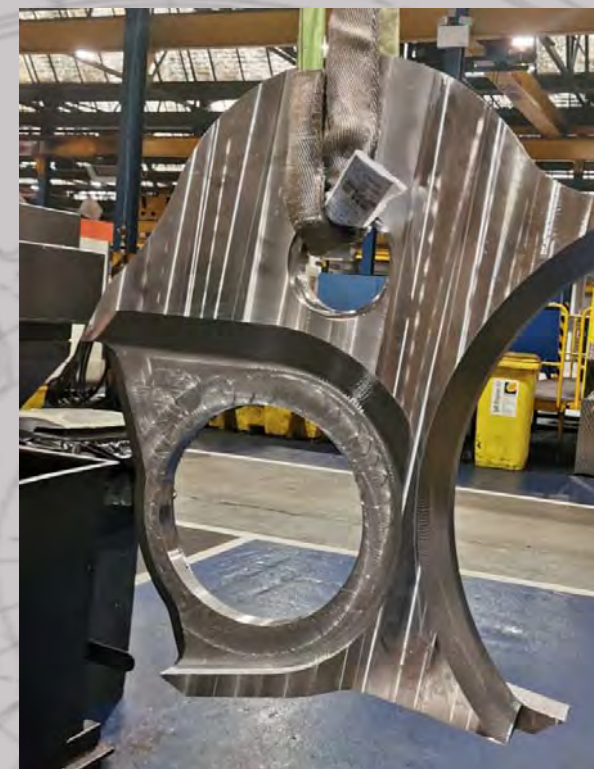
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# First sections of inside cylinder block machined & fabricated





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## Well on the way – trial assembly







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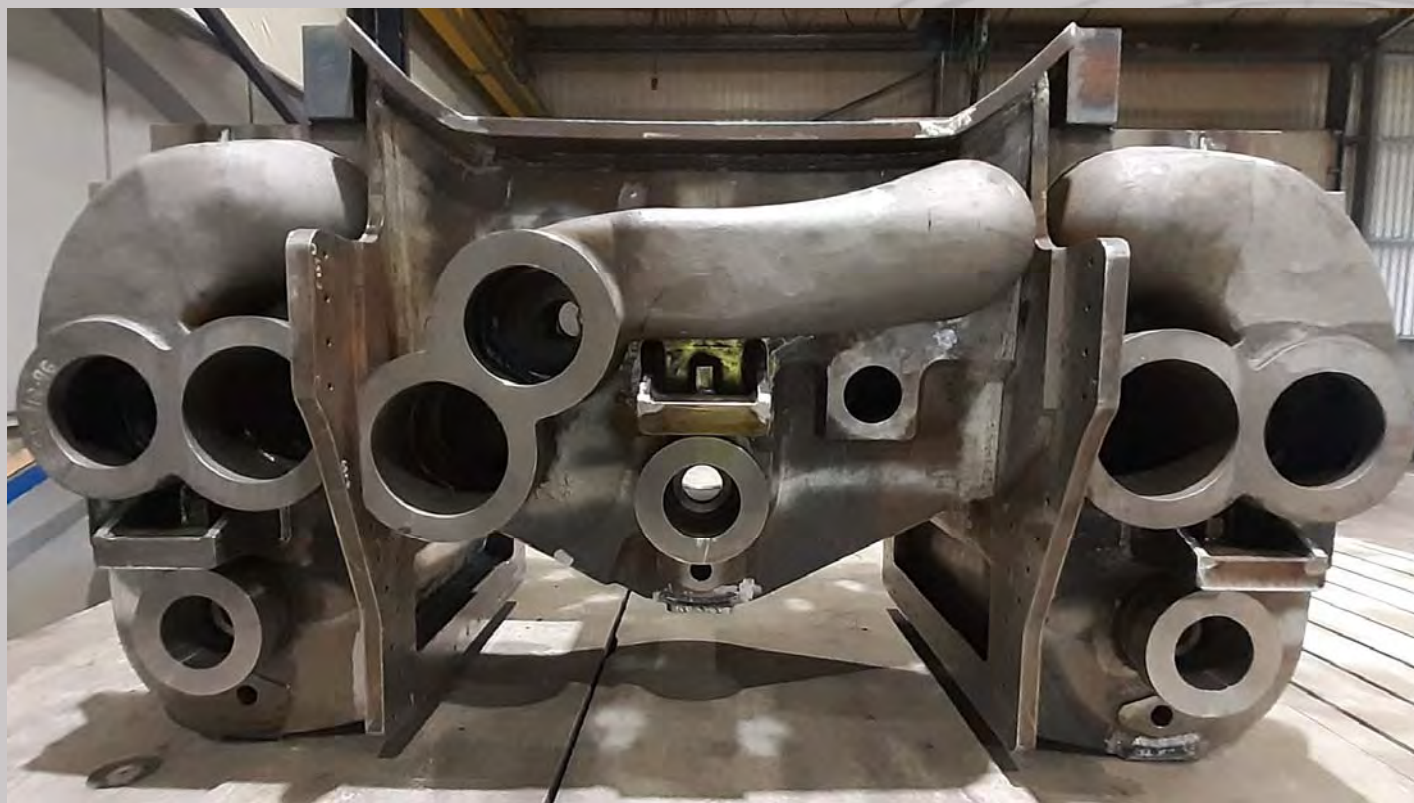
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# Fabrication complete





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# Smokebox



Thanks to generous sponsorship from The Gresley Society Trust the smokebox has taken form starting with a kit of parts which are profiled and rolled from CorTen steel to improve corrosion resistance

The anti-vacuum valve and superheater covers are made and fitted, door hinges and fittings are mounted enabling a trial fit of the smokebox on a temporary frame stay







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## Smokebox



Beading for the smoke lifting plates is formed and the lifting plate joint strip made and fitted





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## Smokebox door pressed from CorTen steel







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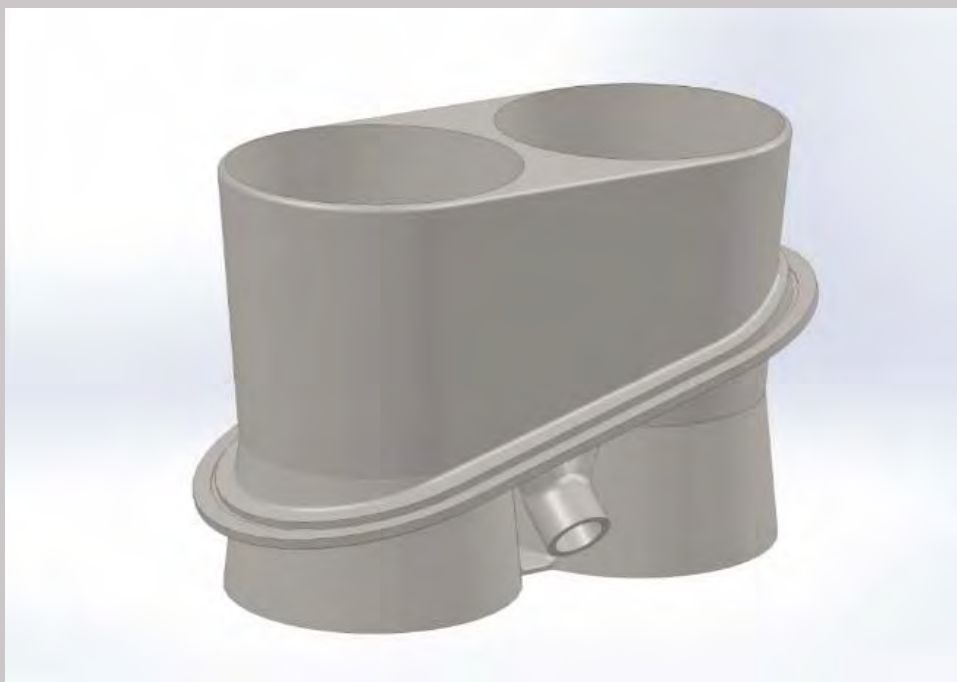
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## Double Kylchap chimney



3D CAD model of chimney



Chimney casting from Spheroidal Graphite Iron



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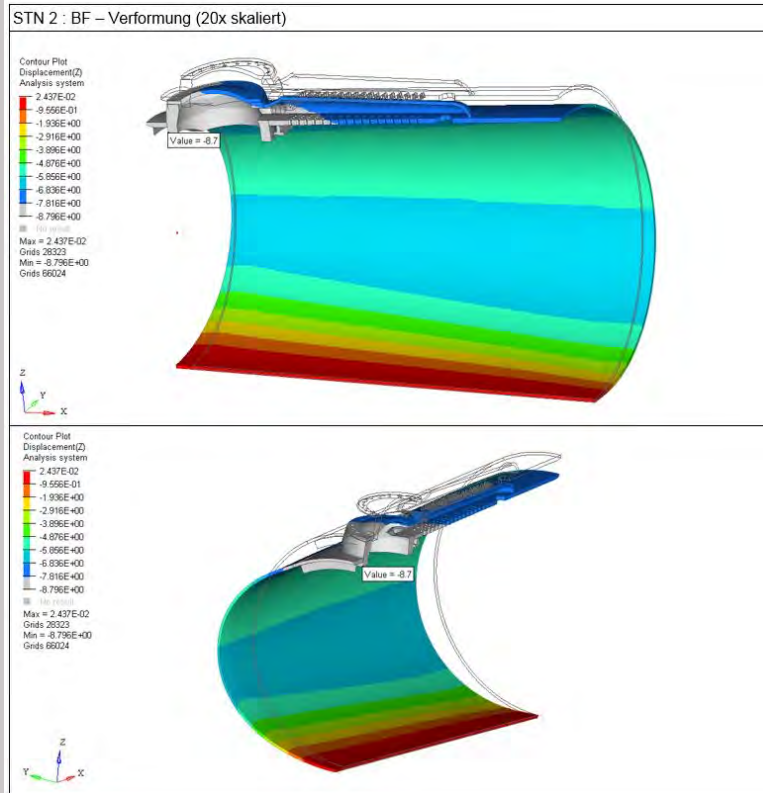
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# Boiler design and construction







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## Boiler Progress





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## Boiler under construction at DB Meiningen

- Covid-19 has been a factor in Germany as it has in the UK
- Progress has been delayed by around nine months
- The first new boiler has passed dimension and X-ray checks – fit out underway
- Second boiler components all to hand ready for assembly
- Boiler one will arrive in late 2022, and boiler two will arrive in 2023







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## Motion

- The coupling and connecting rods on the original class P2s were of a lightweight design using high tensile nickel chrome steel. These proved to be prone to fatigue fracture
- The rods for No. 2007 are based on the post war design for the class A1s using a durable manganese steel and incorporating BR standard rod bushes





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## Motion progress



Arthur Stephenson Engineers at Atherton forging and machining a full set of heavy motion





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## Coupling rod forgings





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# We have a 'Mikado'







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## Valve gear

- No. 2001 was at first equipped with Lentz rotary cam poppet valve gear
- Originally with continuously variable cut-off
- Modified to stepped cams providing limited cut off settings following excessive wear
- Resulted in reduction in economy due to wide steps in cut-off and continued problems with high wear rate
- Investigated an improved version of Lentz/Franklin, Walschaerts or British Caprotti
- Major design study has confirmed selection of improved Lentz/Franklin valve gear



Franklin version of Lentz gear with infinitely variable cams



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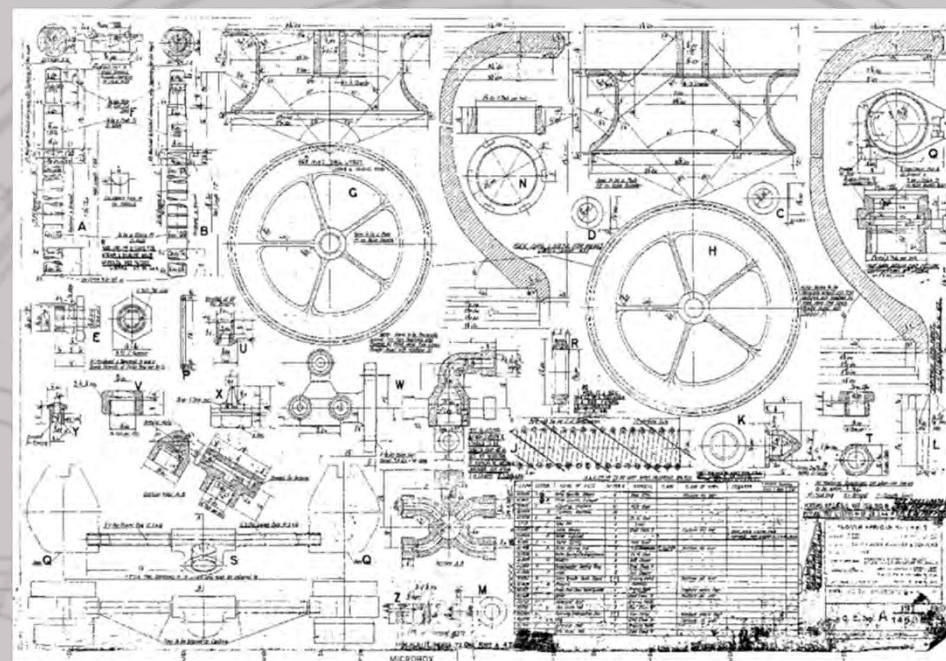
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## Shortage of original class P2 Lentz valve gear drawings



South African 15E class similar in size and built in 1934/5 with Lentz valves





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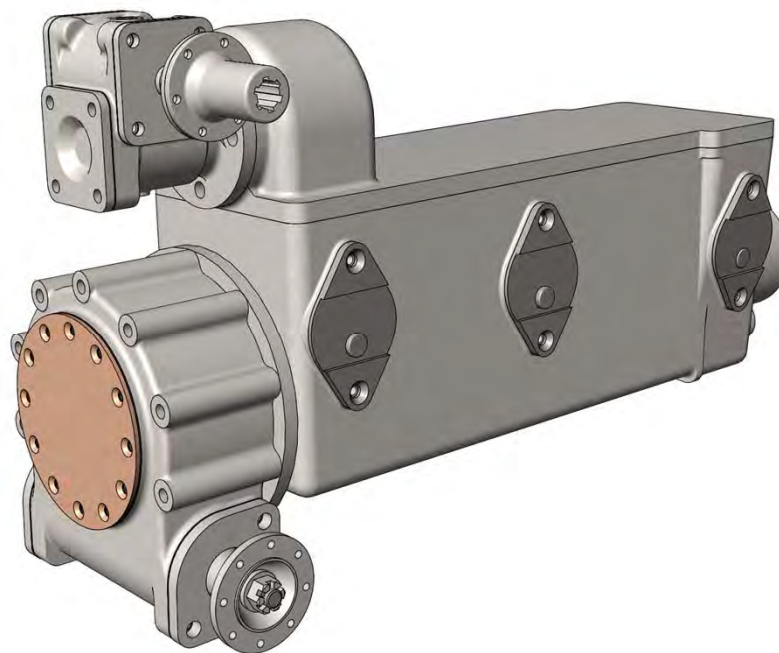
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## A look round the cam box





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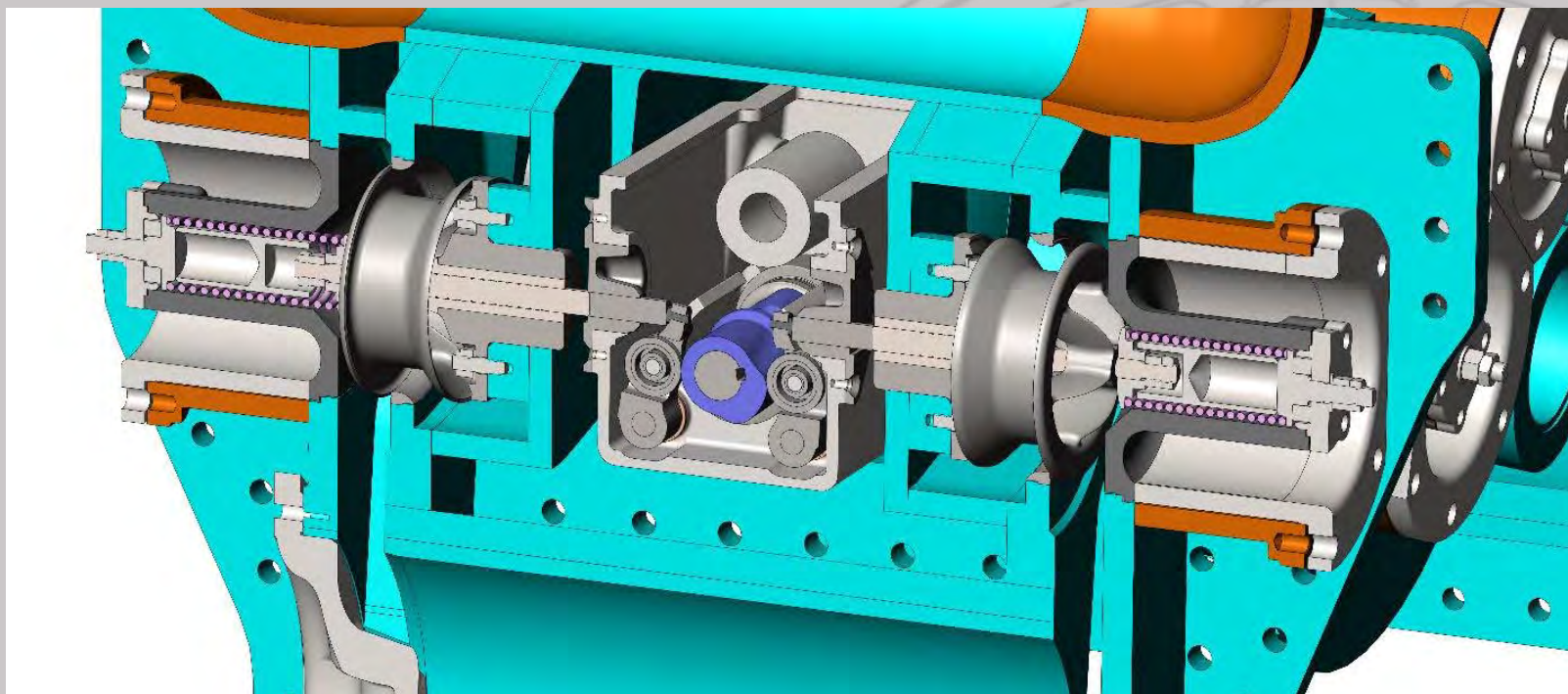
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## How it drives the valves (exhaust valves shown)







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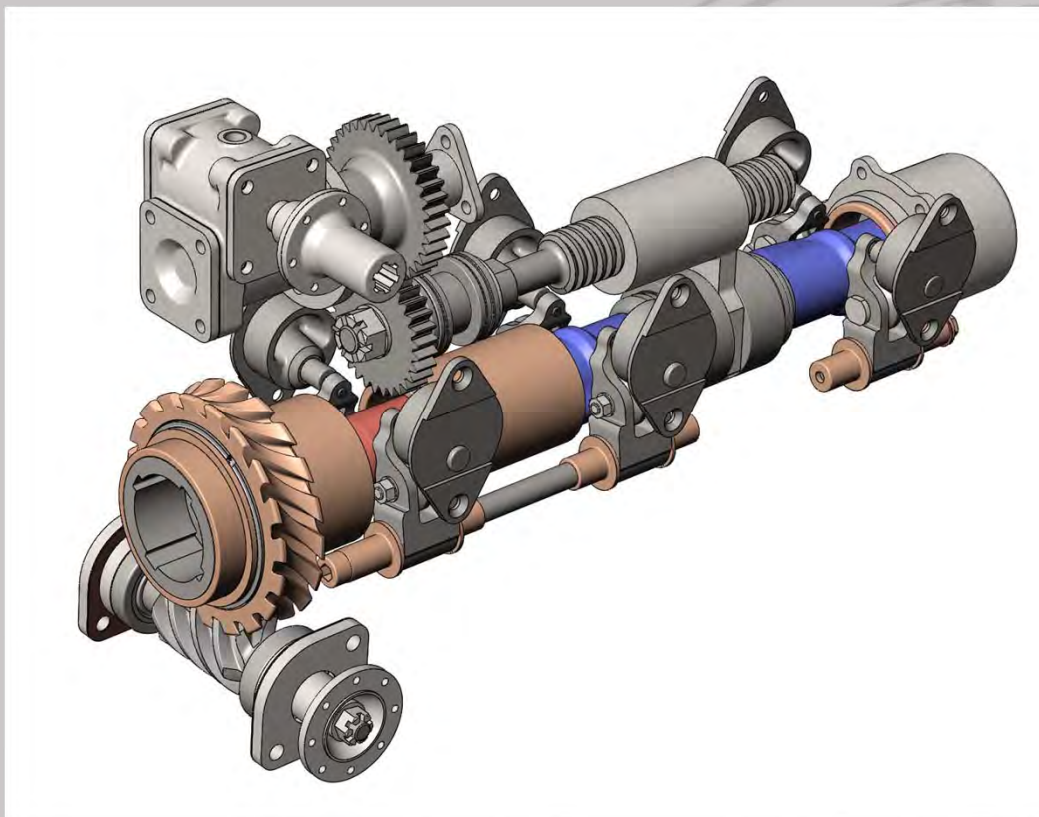
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# Now with it working!





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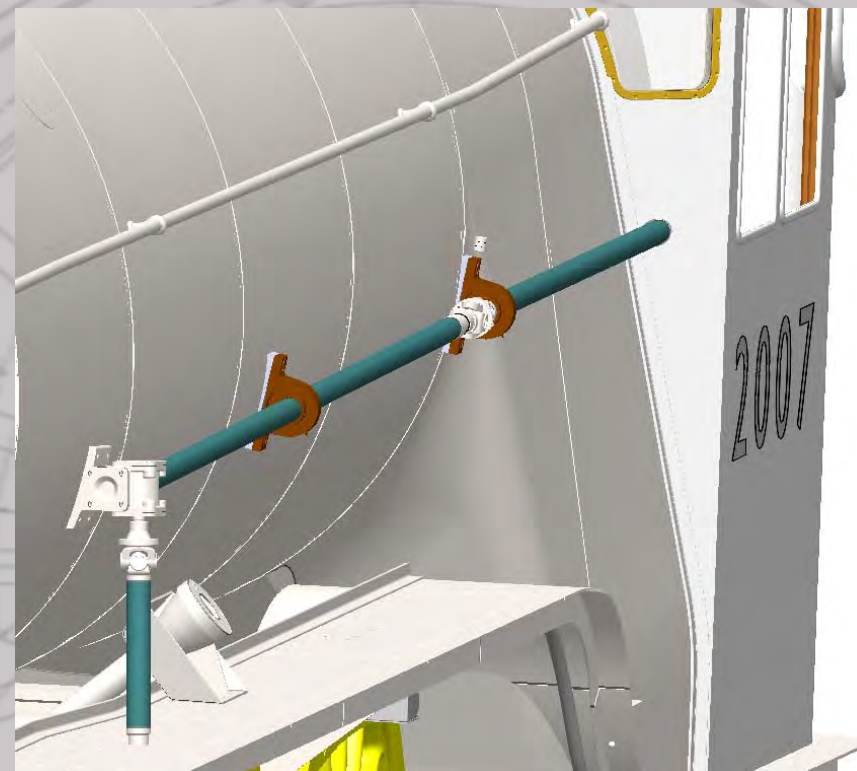
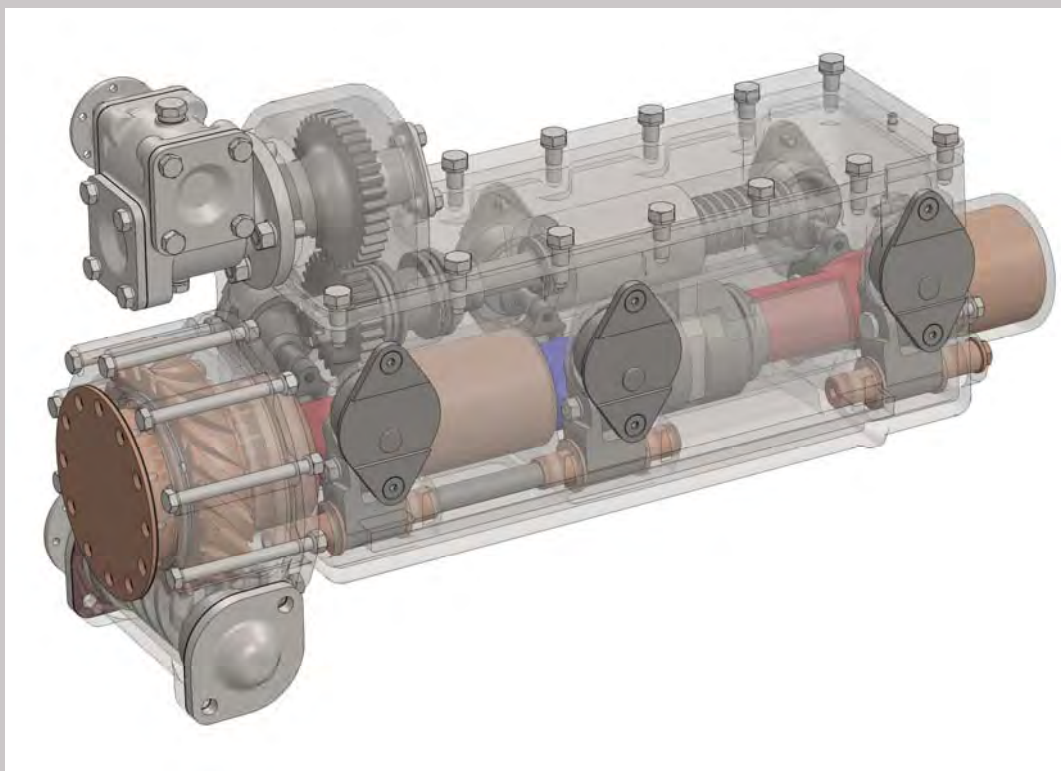
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## Valve gear design – several 3D assemblies







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## Valvegear design – one-third scale 3D printed model of cambox





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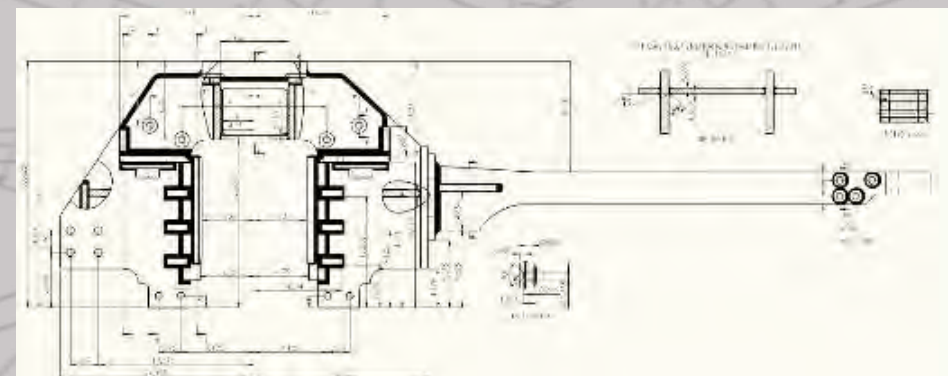
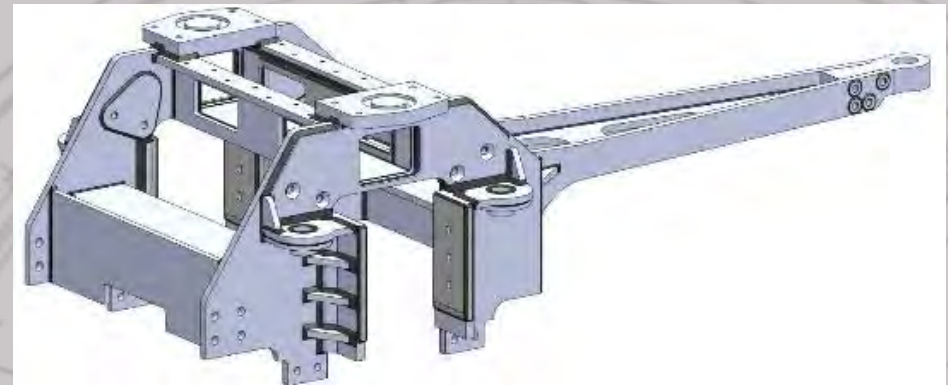
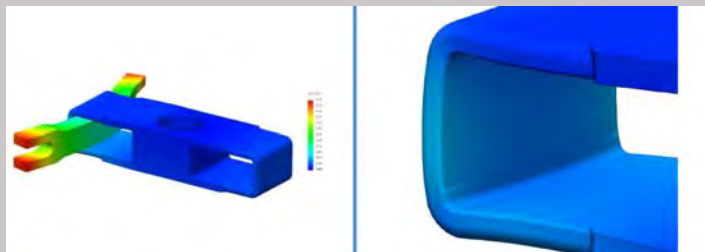
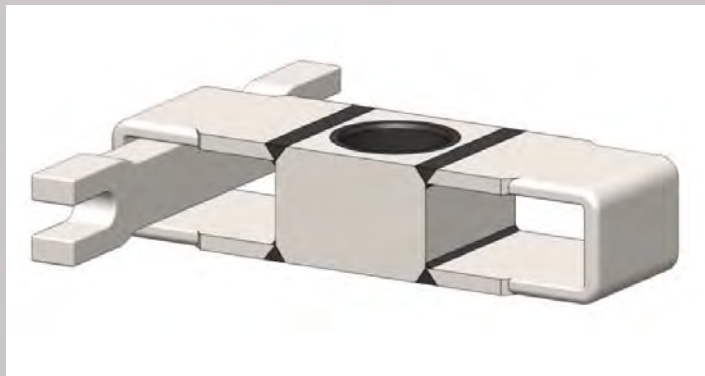


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## Pony truck design

Pony truck crosshead fabrication with side control spring crossbar FEA







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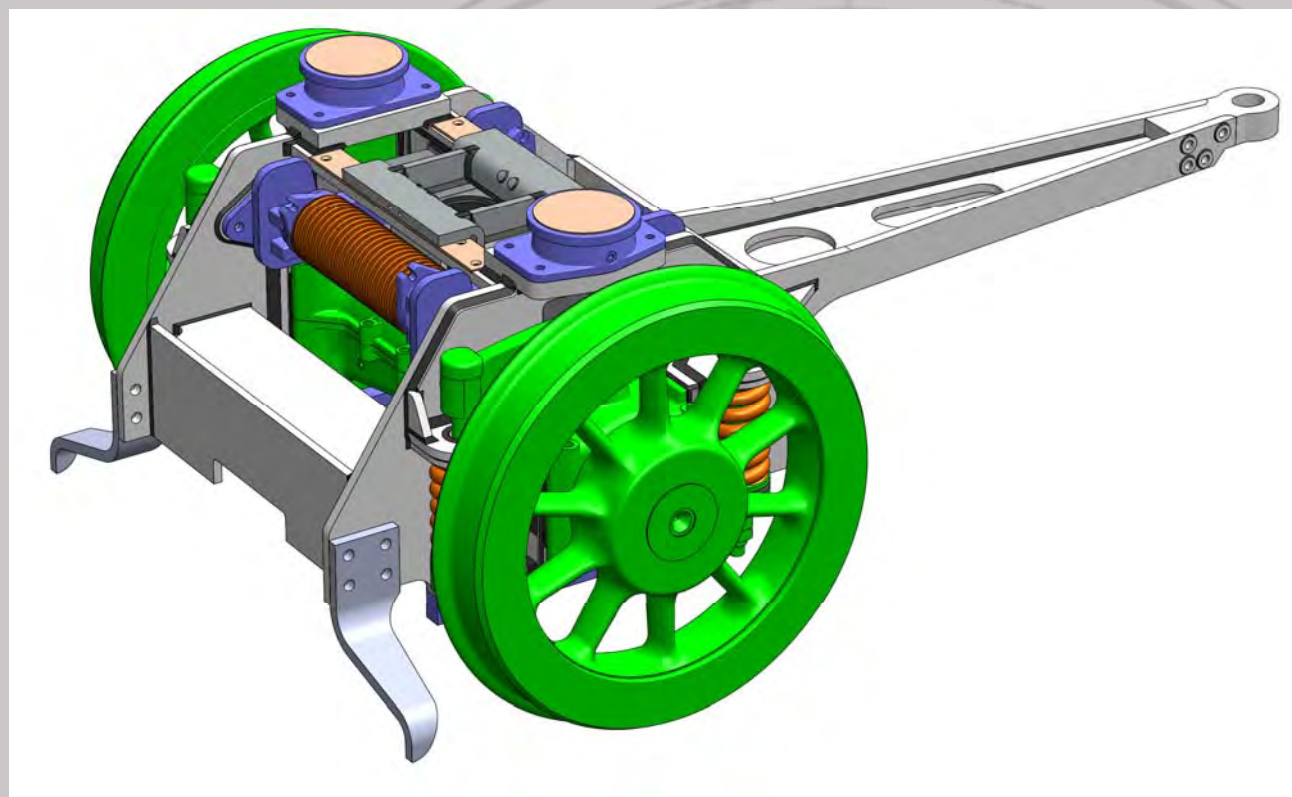


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## No. 2007 pony truck solution

Further modification of Gresley class V2 design for greater side travel and use of roller bearings





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## A design issue – crank axle



19(?) July 1939

P.2 class Engine No. 2005

Crank Axle - fractured through  
journal & wheel seat.  
creeping flaw.

Material : Steel

Makers : (Shafts & Webs) - Monkbridge  
(Web Pin) - Hickens

Age : 2yrs 11 mths.

Mileage : 133,000

Fracture occurred in Scotland  
and reported by Mr Heywood,  
Mechanical Engineer,  
Bowlaids.

Our papers S.208/130

- Five crank axles known to have broken in a class of six locomotives in less than ten years
- Design was same as crank axles on Gresley A1/A3 'Pacifics'
- Two possible causes identified:
  - Higher piston forces with class P2 (larger cylinders)
  - Eight coupled engine less likely to slip at high starting tractive effort
- Proposed solution based on Timken axle design for Peppercorn class A1 modified to incorporate BR BASS 504 principles.





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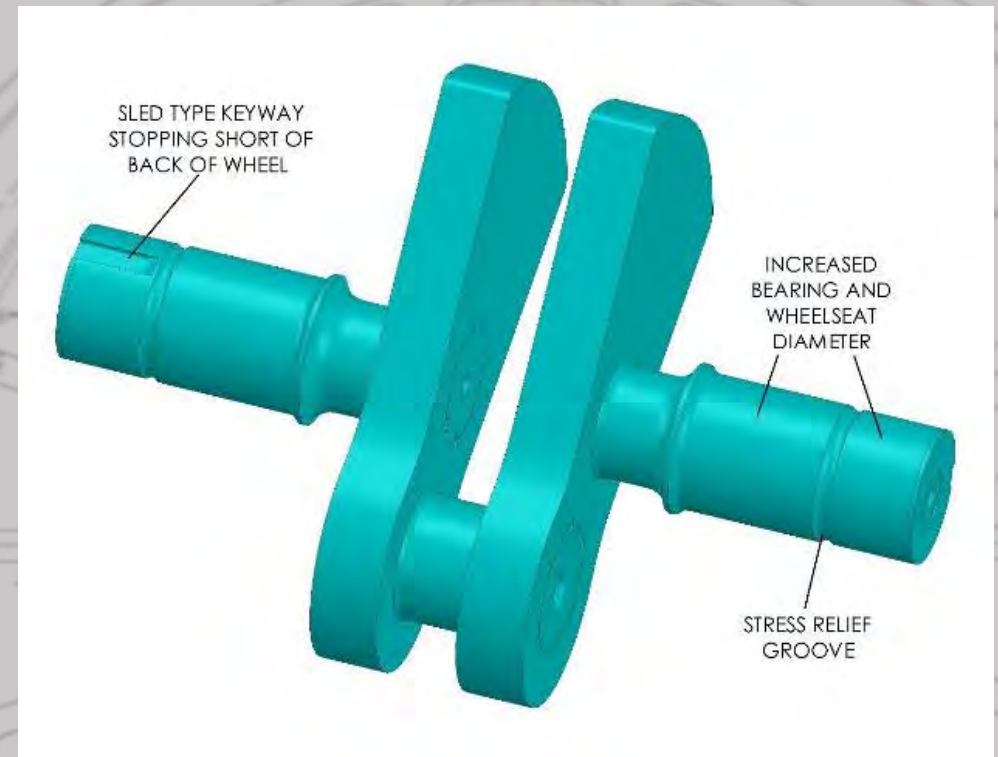


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## Crank axle – the solution

- Current practice BASS 504 design used for axle/wheel interface
- Strongest available A4T axle material used instead of standard A1T
- Wheel and bearing seats increased by 3/8in in diameter
- Crank sweep material upgraded from EN8 used on *Tornado* to EN19 (approx. 25% stronger with improved fatigue performance)
- The solution provides a crank axle with a life well in excess of the 250,000 miles at which LNER/BR renewed them









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From 3D models the driving wheels are cast









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# Completed crank axle and axleboxes









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# Wheelset assembly







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# A full set!



Balance weight manufacture





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## The Injectors Club – Launched June 2021



- We estimate that the live and exhaust steam injectors will cost around to acquire, manufacture and install
- We are seeking 50 people each donating £1,000 (plus Gift Aid) in up to four payments of £250pm by standing order
- Special benefits for members of The Injectors Club



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## Steam fittings under way



Injector control valve machining



More bronze components cast





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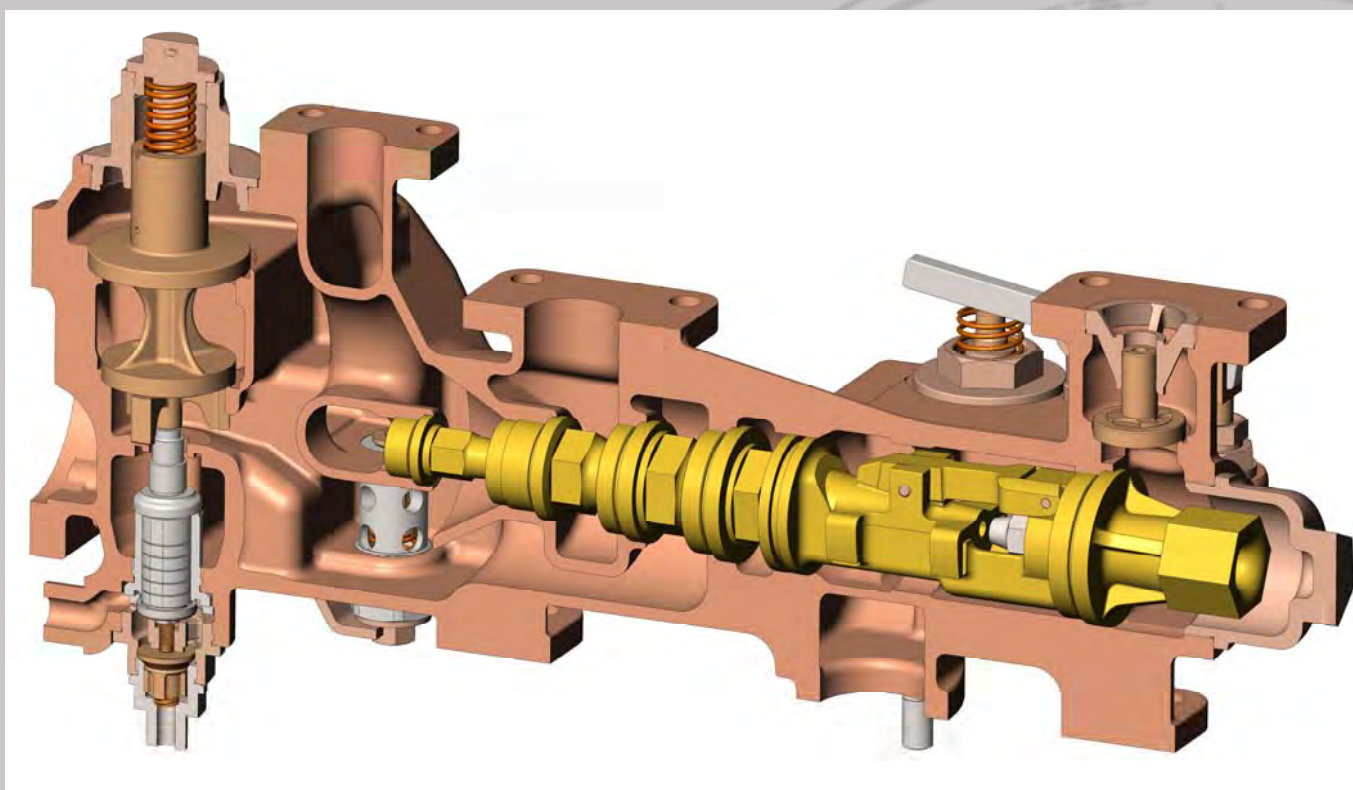
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## Fittings – Class K exhaust steam injector





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## James May and the Slacking Cock Flange



James May visited Darlington Locomotive Works to make another piece of the locomotive – the “Slacking Cock Flange”





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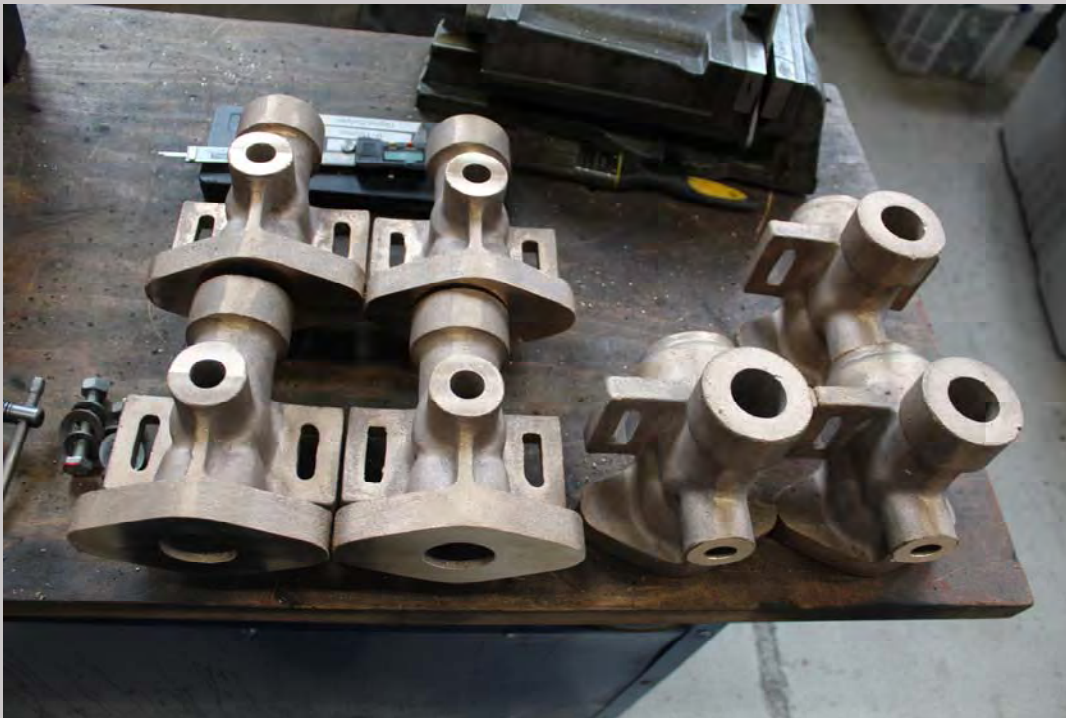
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## Cylinder Drain Cock casting testing



Preparation of cylinder drain cock castings for hydraulic test





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# Fittings







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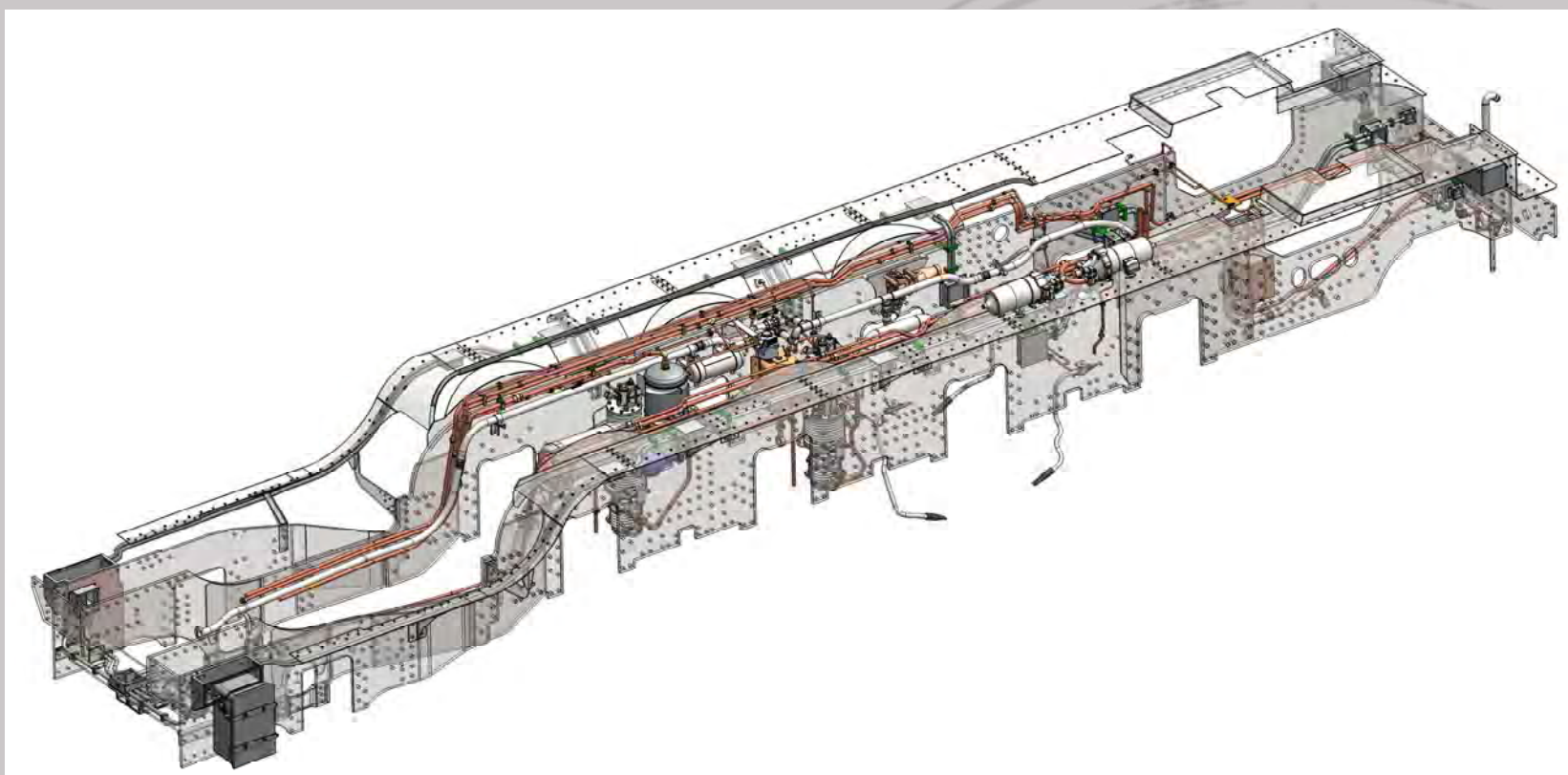
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## Pipework and trunking





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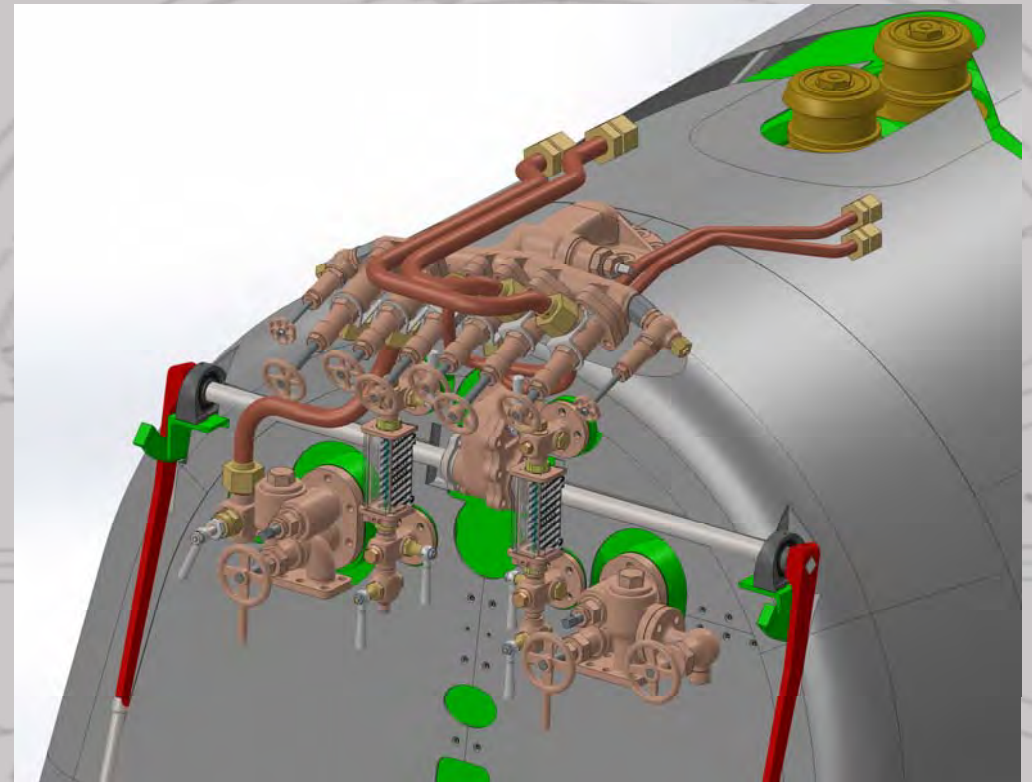


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## Backhead fittings and pipework

- Steam stand installed on boiler, valves modelled and fitted to stand
- Water gauges, combined steam and delivery, and blower valves installed on boiler
- Pipes to air pumps and turbogens routed







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## Cab



With the delay to the wheelsets, cab construction was brought forward





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## Cab







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# Electrical System Principles

- Based on the successful A1 electrical system
- Dual redundant power supplies and electronic battery management
- Steam turbine and axle-driven generators
- Structured trunking system for wiring
- Military components for maximum reliability.





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## Auxiliary Lighting System

- As with the A1, all the lighting will be LED
- The A1's instrument and frame lighting has worked well and we'll be installing similar systems on the P2
- There may be some additional innovations – you'll have to wait and see what these will be!







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## Head, tail and marker lamps



- The class P2s had distinctive headlamps with a flared hood around the front lens
- We'll make replicas of these lamps and fit new LED luminaries inside
- The P2s didn't have Stones marker lamps, so we need a combined head, tail and marker lamp within the same housing
- On the rear of the tender we'll fit recessed marker/tail lamps and lamp brackets for headlamps if needed on preserved railways





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## The Tender Club – Launched In April 2019



- Constructing the tender will cost around £450,000
- We are seeking 250 people each donating £1,500 (plus Gift Aid) in up to 15 payments of £100pm by standing order
- Special benefits for members of The Tender Club

**Tender tank  
now  
complete!**





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## Tender frame





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# Tender frame – detail components







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## Where we are now?





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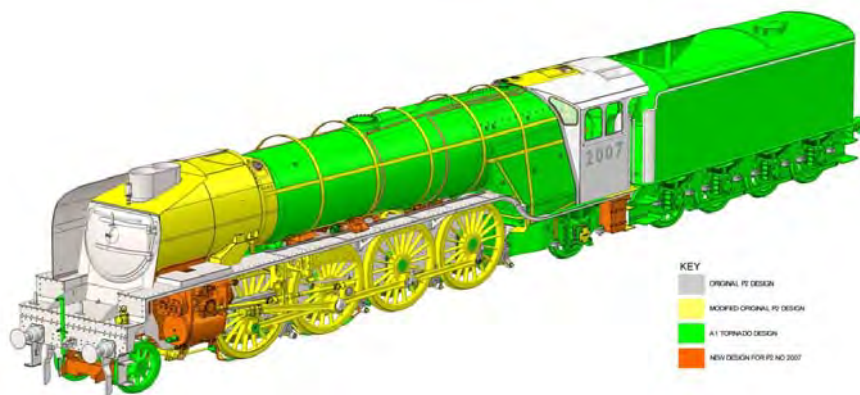
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## P2 2007 *Prince of Wales*









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# HMS Prince of Wales – A Bond of Friendship



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# DLW2 – A New Home Fit For the 21<sup>st</sup> Century





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# Any Questions?