Bringing a 21st Century Perspective to Steam Locomotive Engineering

ALEX POWELL

www.advanced-steam.org

Introduction

UK

- Final UK steam design - 1954
- Final locomotive constructed - 1960
- Designed by rule of thumb and iteration

Overseas

- Chapelon in France 242A1
- New York Central - Niagara
- Norfolk and Western - J Class

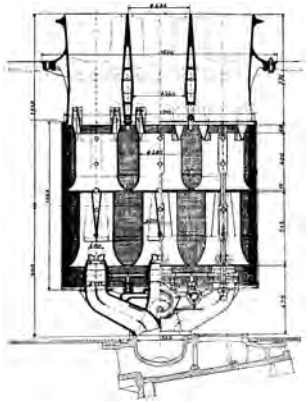
Definitions

- First Generation Steam (FGS): Any locomotive designed or built up to 1960
- Second Generation Steam (SGS): New designs incorporating the best proven modern steam locomotive technology
- Third Generation Steam (TGS): Totally new formats requiring considerable research and development to achieve

Advancements

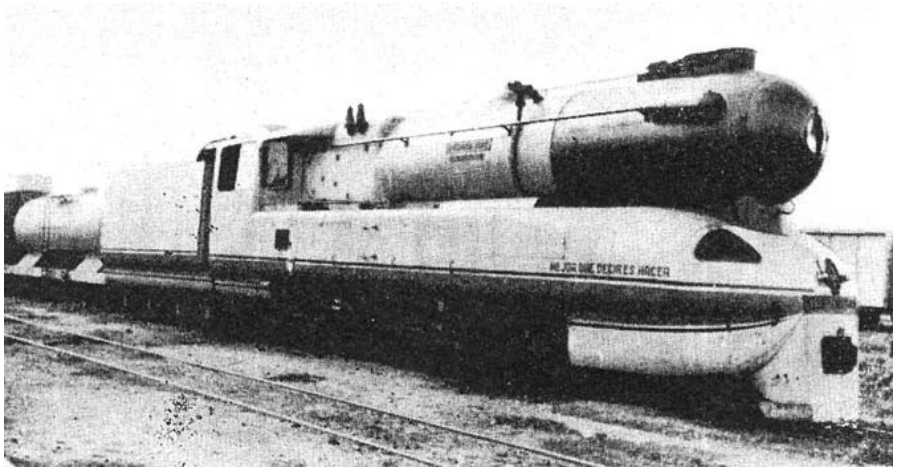
Chapelon

- Father of modern steam
- Created early principles of steam improvement
  - Internal streamlining
  - Improved exhausts
  - Compounding
- Pioneered locomotive as a thermodynamic whole
- A lot of his work damaged for political reasons



Porta

- Chapelon's Protégé
- Created, possibly, the most thermally efficient steam locomotive
- Modified locomotives on Rio Turbio railway – amazing feats of haulage
- Developed key Design improvements:
  - Lempor exhaust
  - Gas Producer Combustion System (GPCS)
  - Water treatment improvements



Wardale

- Application of Porta and Chapelon
- Almost managed to keep steam going in South Africa
- Worked on ACE program in USA
- Modified locomotives in China (last real opportunity for operational railway experience)
- Wrote a book - often-considered the modern steam bible
- 5AT calculations

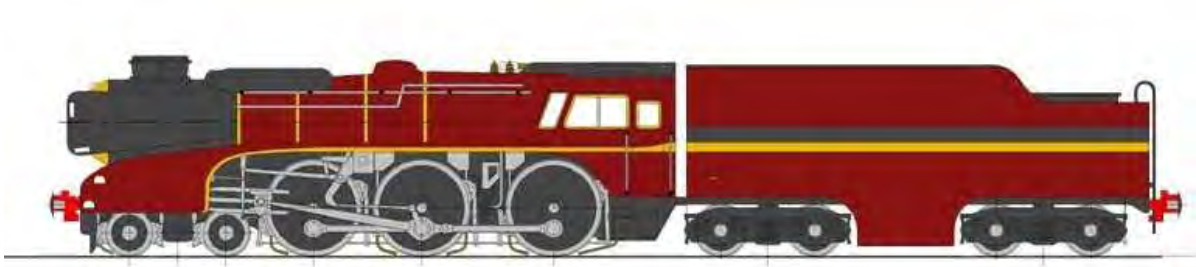
Waller

- Light oil firing
- 1 man operation
- Modern design used to replace diesels
- Boiler preheating

5AT Project

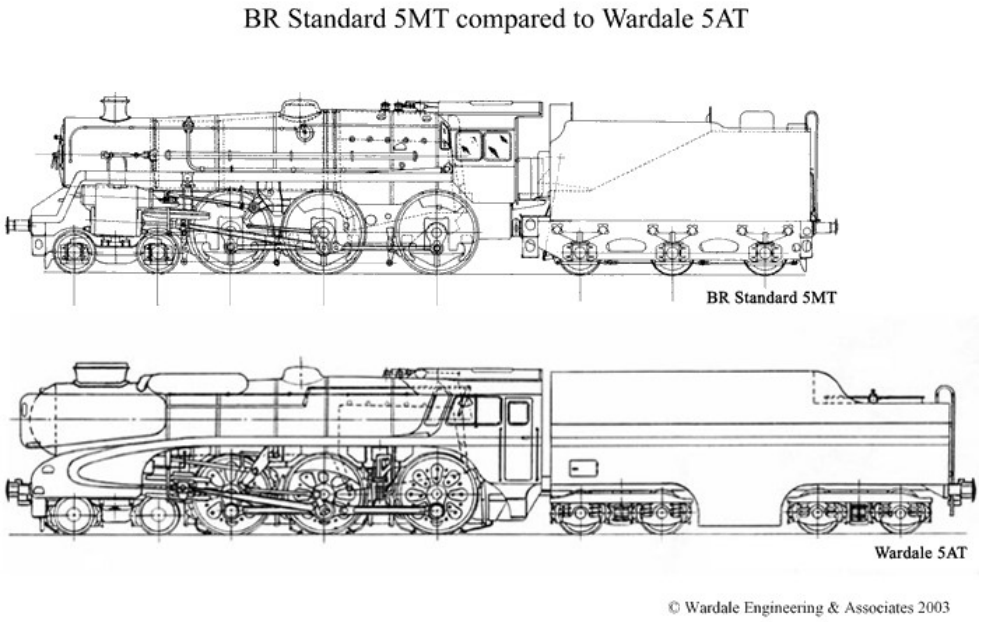
5AT Project

- Proposed in 1998
- Project setup in 2002
- Design calculations
- Feasibility study
- Early design work



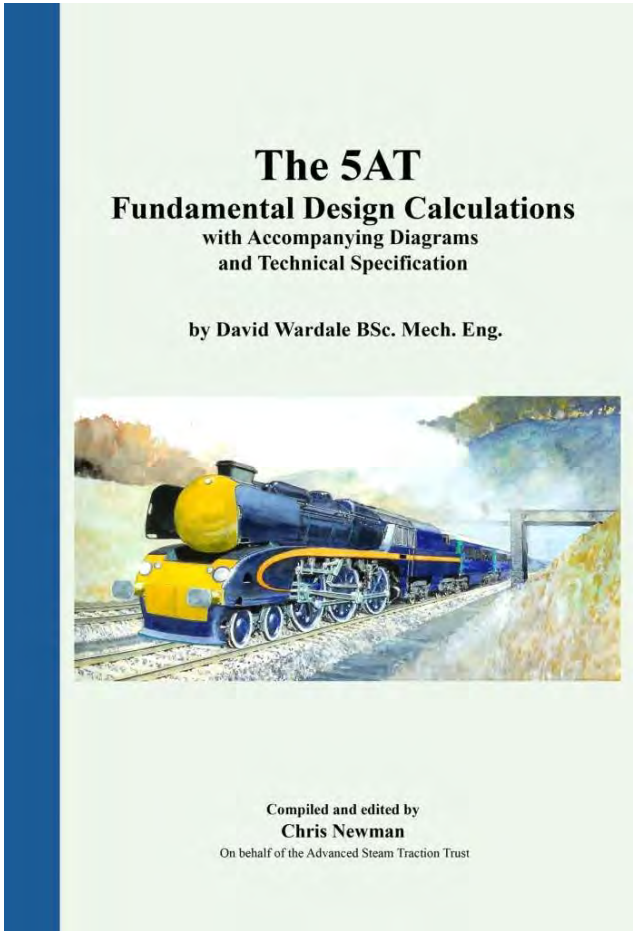
5AT Concept

- Modern design based on dimensions of BR 5MT
- Designed for Charter and Cruise trains
- 125mph design, 112.5mph max
- High power to weight
- High efficiency
- Long operating range
- High reliability
- Low maintenance costs



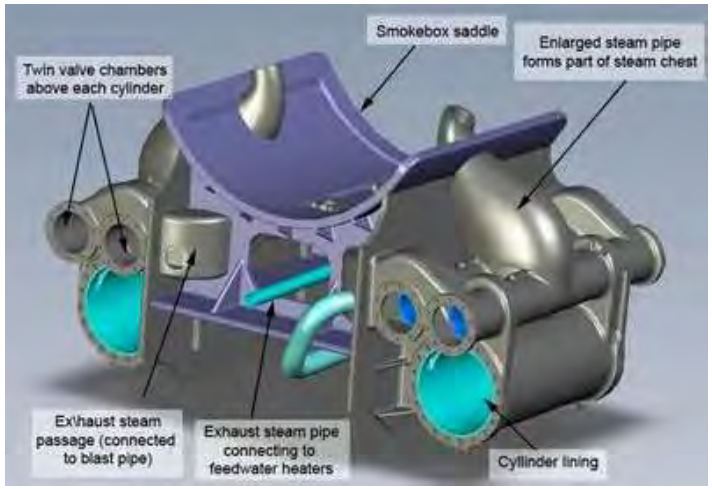
Fundamental Design Calculations

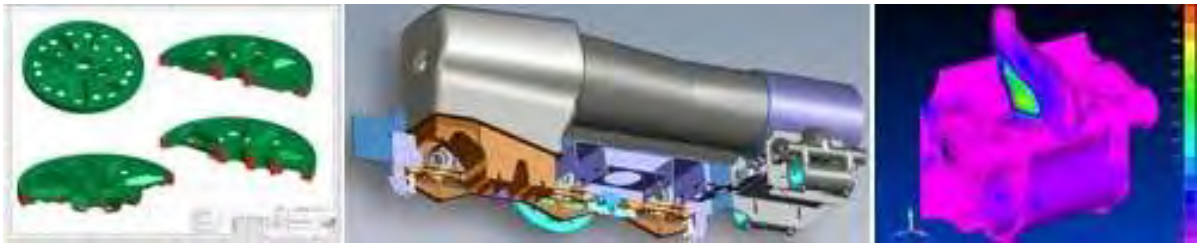
- Completed in 2005
- Done the traditional way to prove it was possible in the 1950s
- 556 pages of calculations, specifications and diagrams
- Proved performance was possible and achievable



Design Work

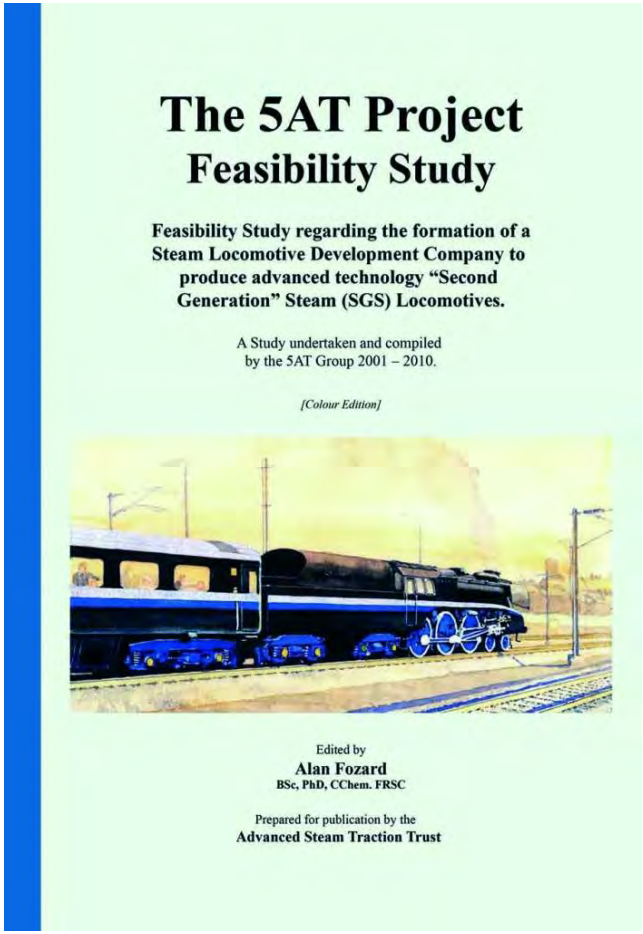
- Based off calculations and performance targets
- Used modern CAD techniques
- Taking best aspects from previous designs
- Improving and innovating where possible





Feasibility Study

- Completed and circulated in 2010
- Set out the plan for a fleet of 5AT locomotives and trains
- Also detailed what would be needed for design team
- ~£11M needed
- Failed to raise Capital
- Project shut down in 2012



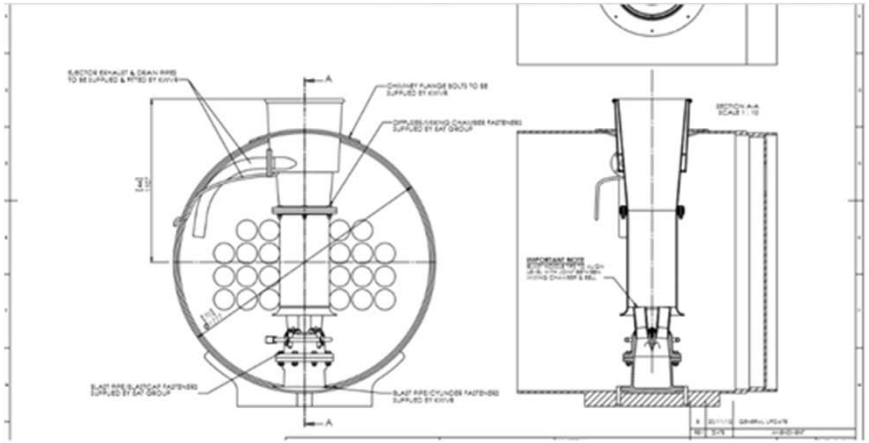
Advanced Steam Traction Trust (ASTT)

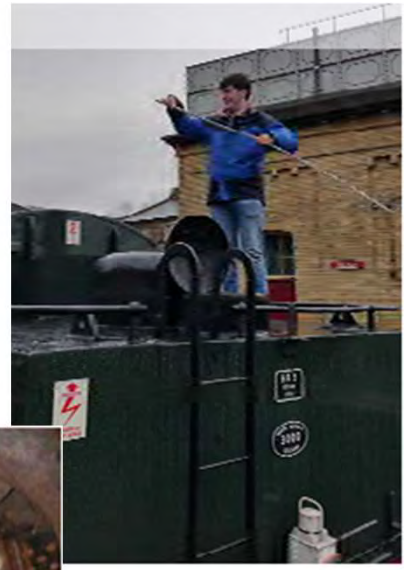
Objectives

- Formed by 5AT group to preserve knowledge
- Continue steam locomotive development for heritage and Mainline use
- Like old ILocoE (railway division)
- Annual conference
- Publishing of literature

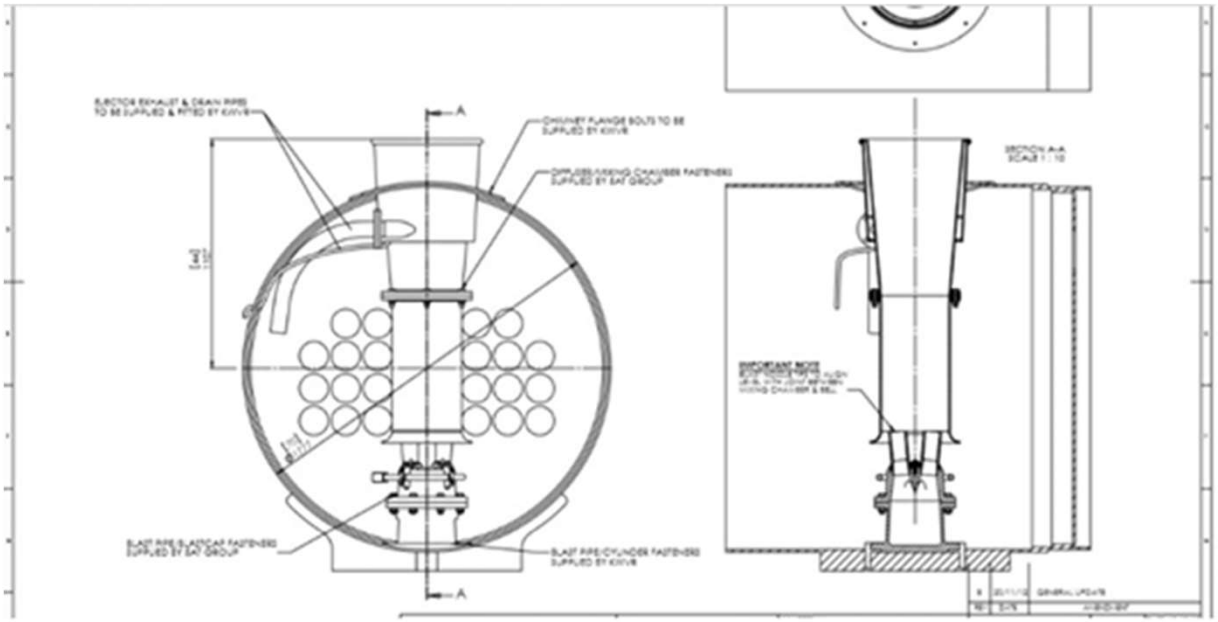
Projects

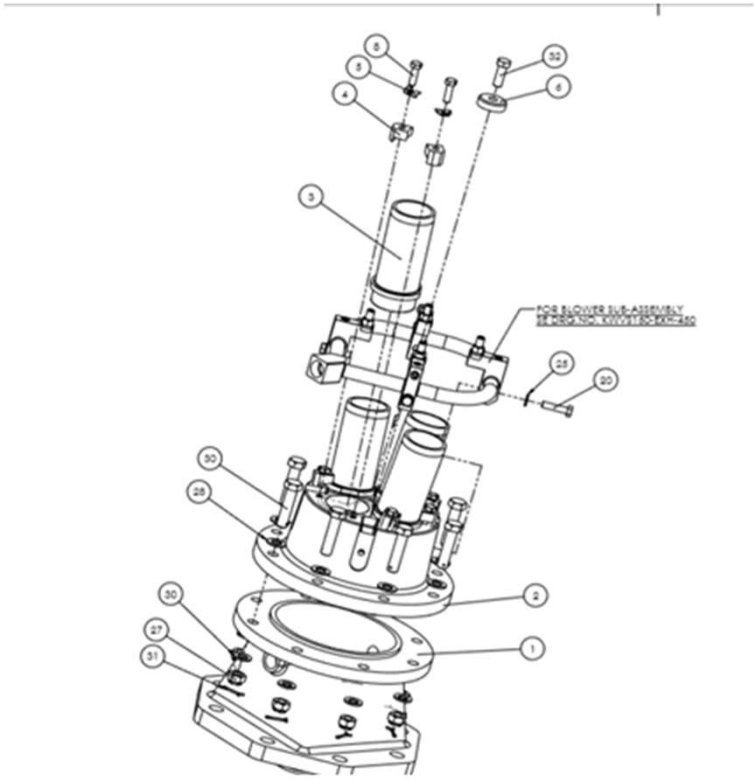
- Clan locomotive study
- S160 exhaust
- Performance monitoring
- Biofuel testing
- Revolution



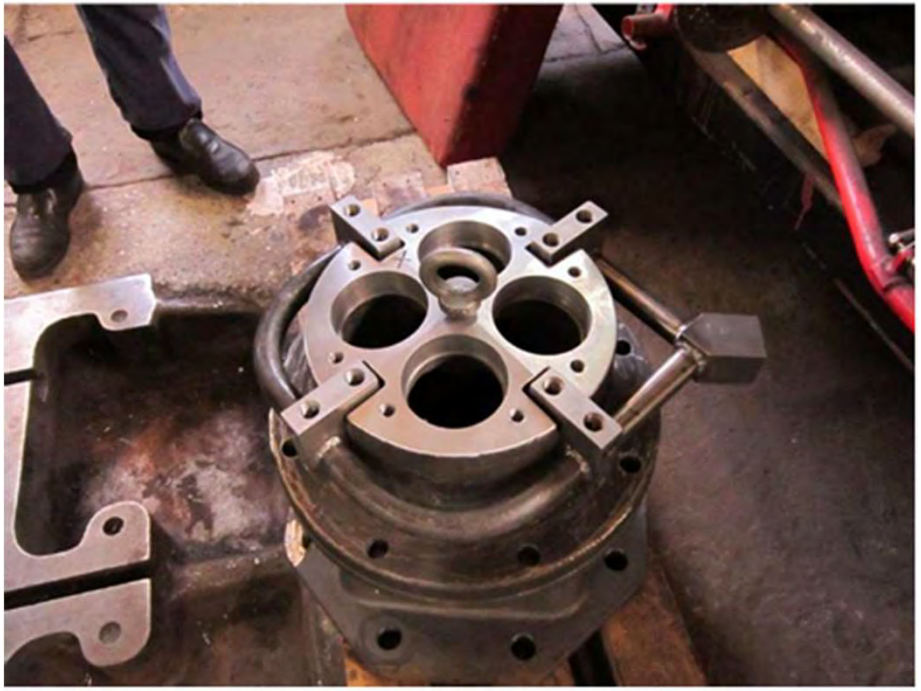


S160 Lempor Exhaust

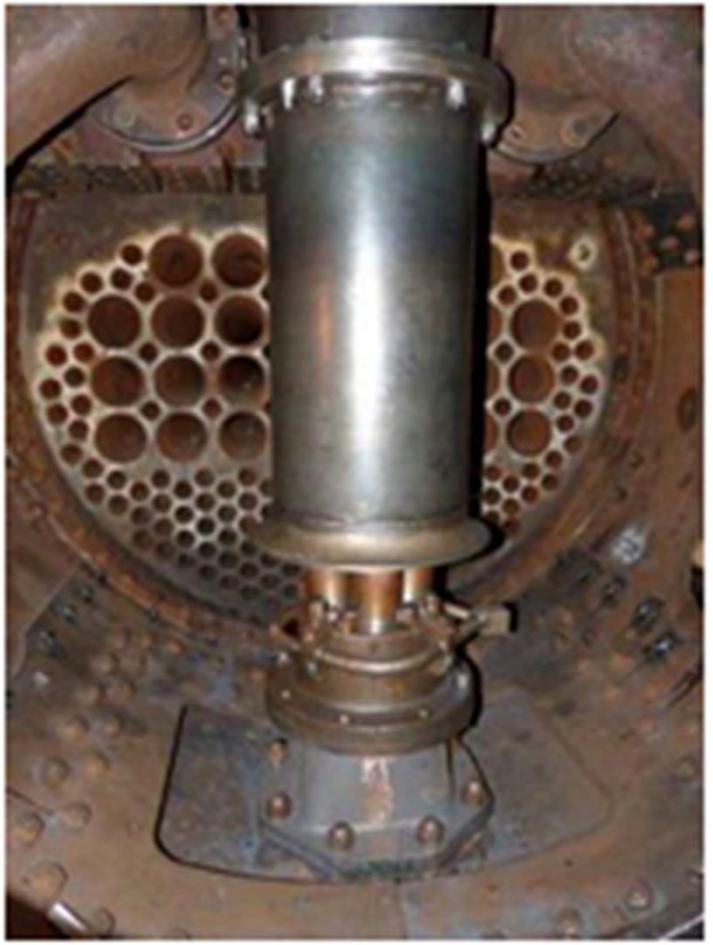




S160 Lempor Exhaust



S160 Lempor Exhaust

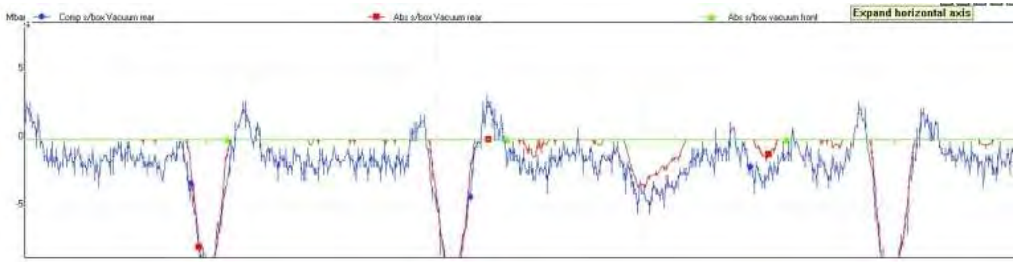


Clan Project Study

- Performance from Class 6 to 7
- Improve reliability
- Recommended:
  - increase in boiler pressure
  - Single Lempor exhaust
  - remove stress raisers from frames
  - Lightweight piston valves and narrow rings
  - improved lubrication
  - Undergrate steam
- Elements of the work could be applied to other BR standard locos

Performance Monitoring

- Known as indicating
- Huge number of measurements
- Using a Pico logger
- Can be used to diagnose faults or check performance and efficiency values
- Used for monitoring during fuel trials



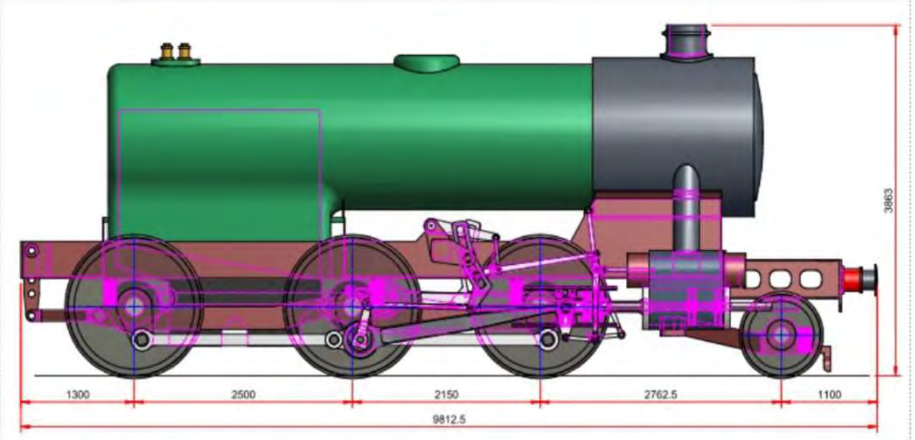
Biofuel Testing

- Started in 2012 - serious work from 2021
- Qualitative responses from as many railways as possible, in conjunction with manufacturers
- Quantitative testing on 15” gauge Bure valley and Standard gauge KWVR
- Reached a stable point, but further work needed

Revolution Project

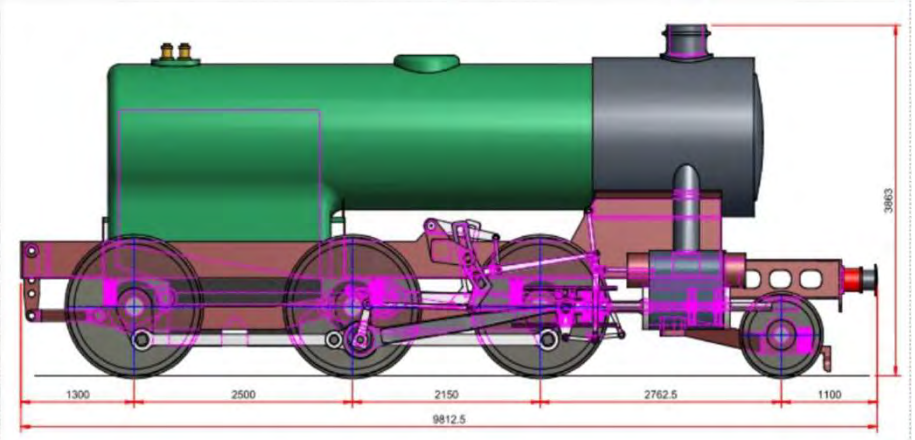
Revolution Concept

- New design for tourist routes and Heritage lines
- Even the youngest steam locos are 60+ years old
- Reduce cost of operation
- Increase reliability
- Reduce cost of servicing maintenance and overhaul



Revolution Concept

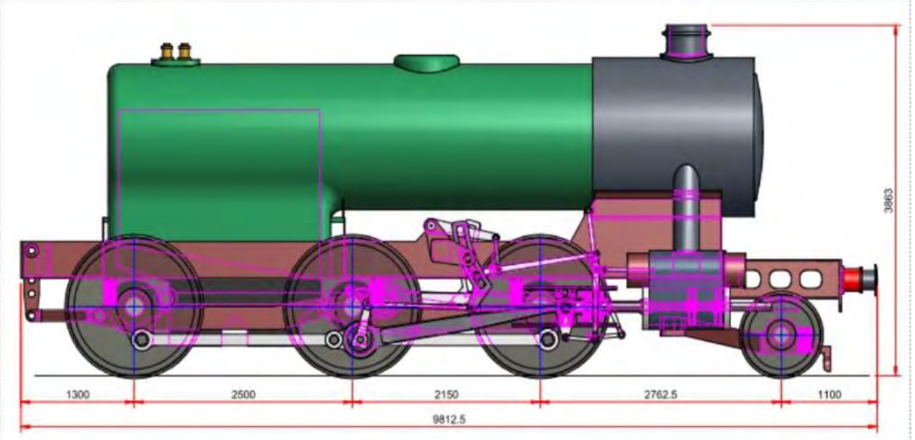
- Stephensonian Layout
- Embrace best practice
- Modern materials, parts and manufacturing



Revolution Concept

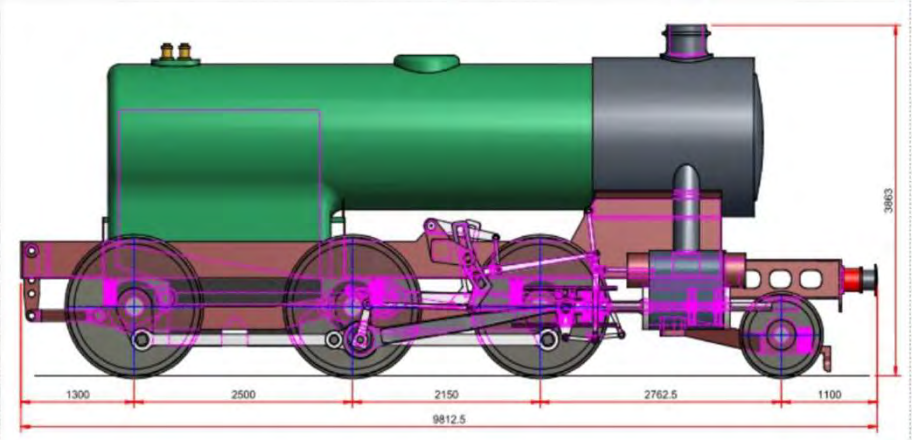
Aims

- High efficiency
- High reliability
- Very low maintenance
- Simplicity
- High level of standardisation
- Low cost
- Retain the sights and sounds of steam

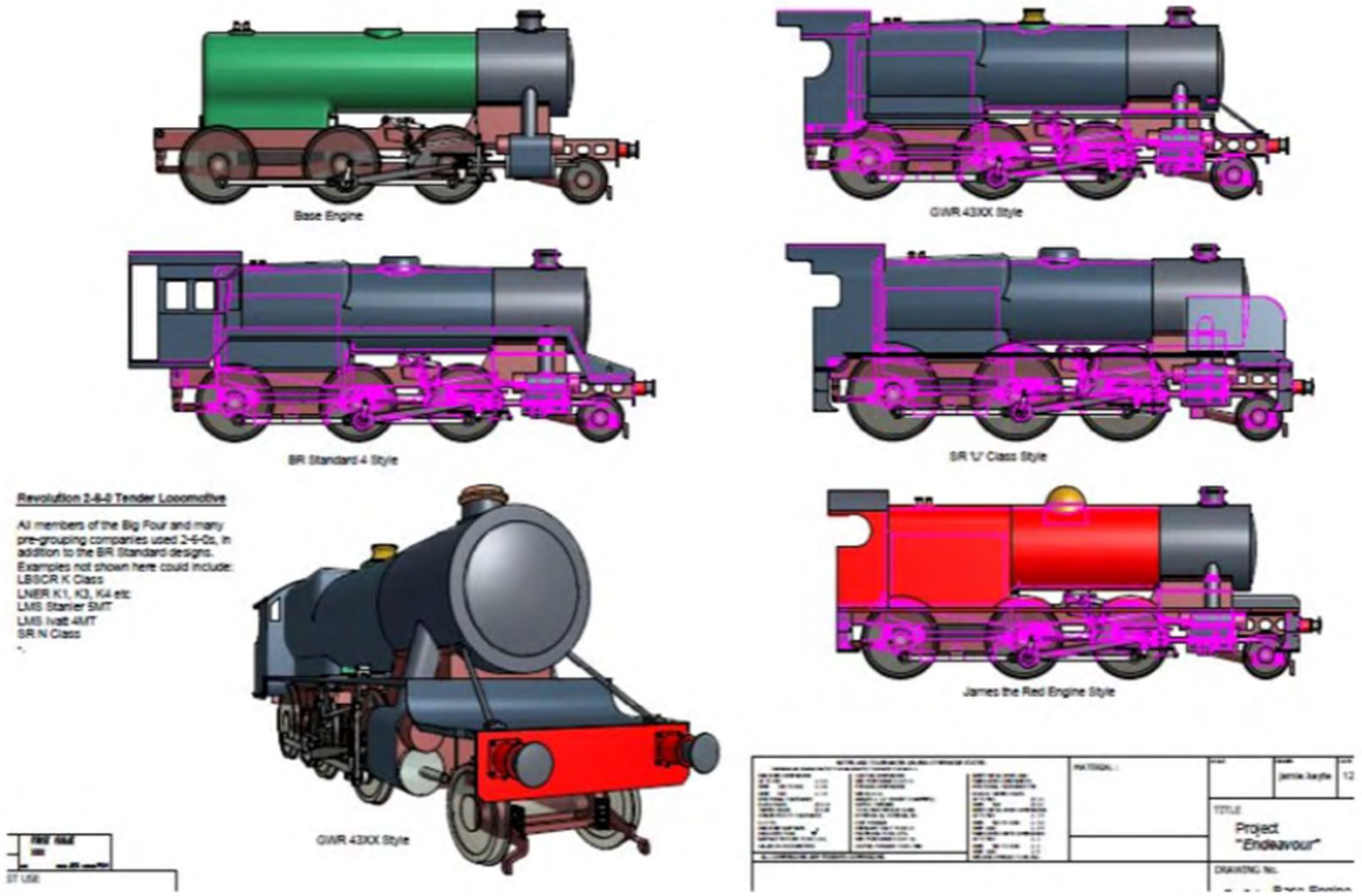


Revolution Final Concept

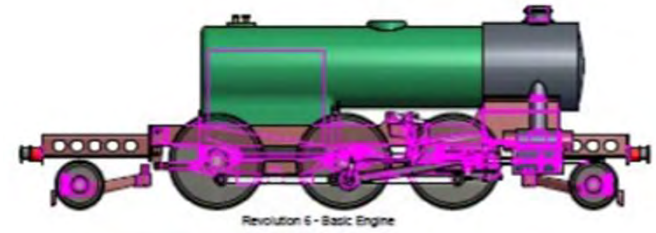
- A basic 2-6-x chassis comprising:
  - Boiler
  - Cylinders + motion
  - Wheels and running gear
- Specification can be altered by:
  - Cylinder bore
  - Ballasting
  - Draughting
- Adaptable to many configurations

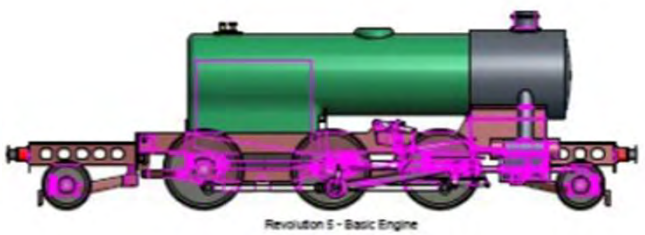


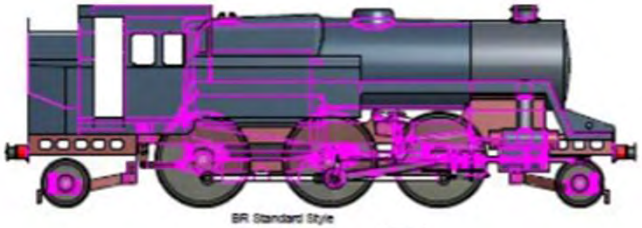
Revolution Final Concept- Tender variants

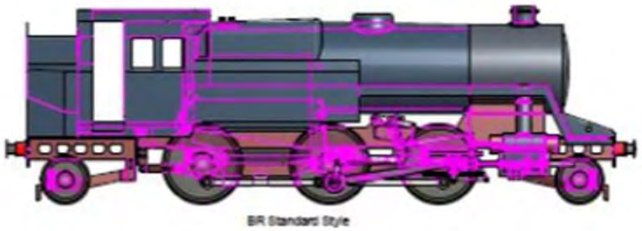


Revolution Final Concept- Tank variants









Revolution 2-6-2T / 2-6-4T Tank Locomotive

All members of the Big Four and many pre-grouping companies used 2-6-2Ts and 2-6-4Ts, in addition to the BR Standard designs. For extended range a bogie can be substituted under the trailing truck under longer frames. Examples not shown here could include:
SE&CR / SR "River"
LNER V1
LMS Stanier 4MT
GWR Prairies

Revolution 10.25” Gauge Demonstrator Locomotive

- Heritage movement very resistant to change
- A lot of novel design elements which are unproved – Learn lessons from 5AT
- 10.25” is the most cost-effective gauge that’s result will scale up
- Not a scale model, just a smaller revolution locomotive
- Also allows the ASTT a loco to test designs and ideas on without affecting other owner's locos or heritage railway services

Revolution Design

Revolution Specification

- Start a fully laden train on 1 in 40
  - Defines adhesion
  - Train resistance: 3208N
  - Adhesive weight: 1235kg ~400kg/axle
- Maintain line speed(10mph) on 1 in 60
  - Defines steaming requirements
  - Train resistance: 2252N
  - Tractive power: 10kW

Revolution Specification – Major Dimensions

- Driving wheel diameter: 330 mm (13”)
  - Standard SMR Practice
- Stroke: 150 mm
  - Longest stroke which permits Big End clearance.

Bore: 85mm

- After a great deal of messing about!

Boiler Pressure: 200 psi or 14.62 bar(a)

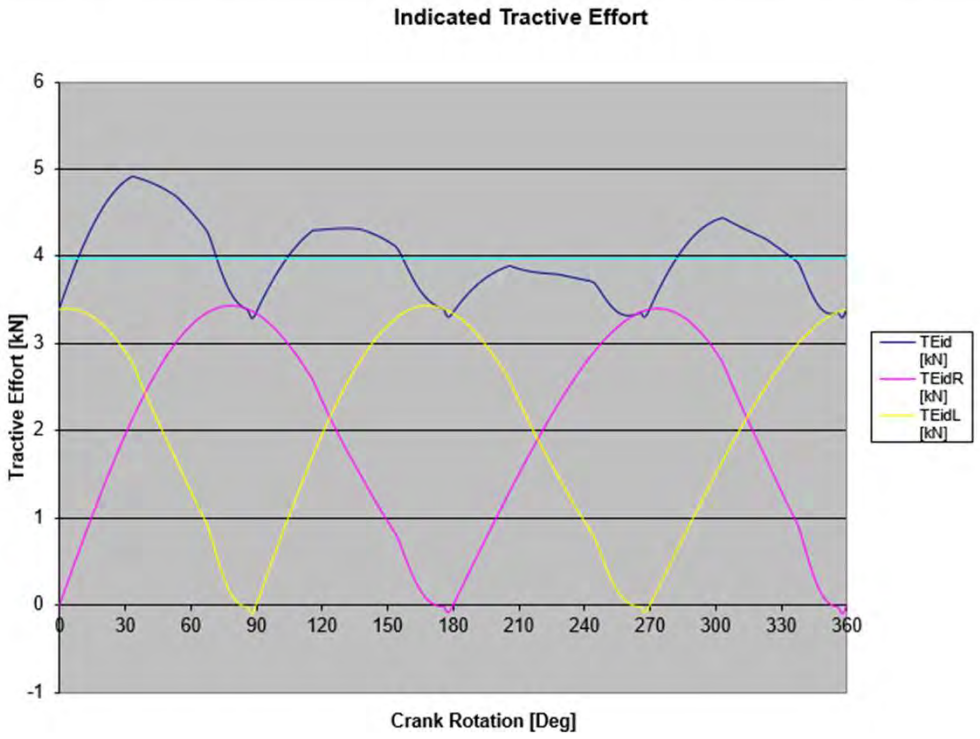
- Practical level - No point in it being too high.

Loading Gauge: 850 x 600 (sort of Continental 1/5 scale!)

Revolution Specification

Starting Tractive Effort (85 mm Bore, 75% C/O)

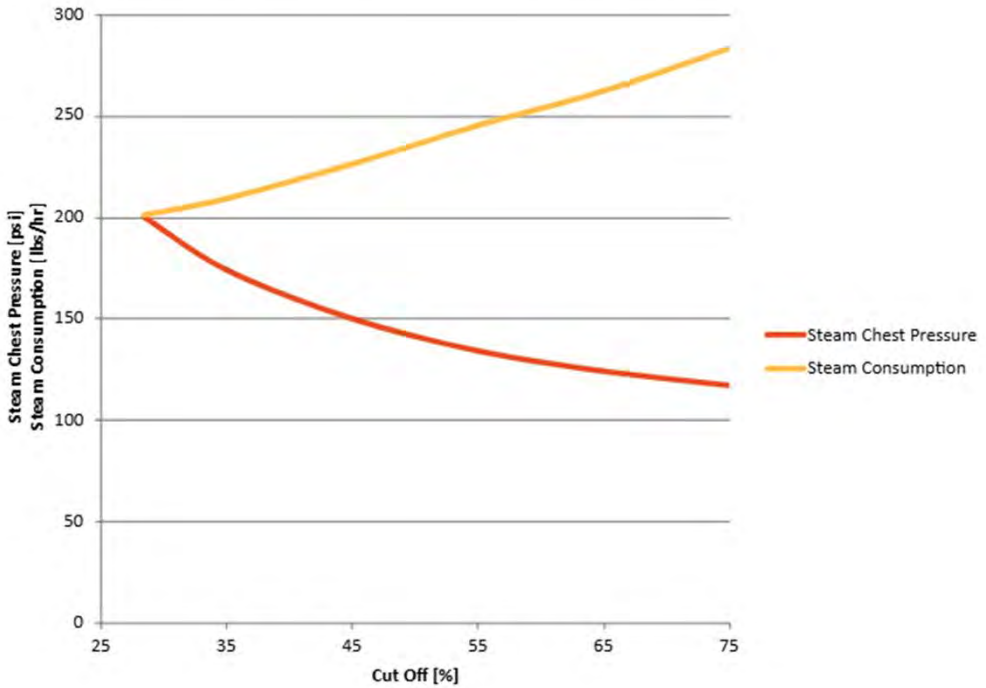
Steam Chest		Min TE	Mean TE
psi	bar (a)	kN	kN
60	5.08	0.96	1.2
70	5.76	1.13	1.4
80	6.44	1.31	1.62
90	7.12	1.46	1.81
100	7.8	1.63	2.01
110	8.49	1.8	2.22
120	9.17	1.96	2.42
130	9.85	2.13	2.63
140	10.53	2.29	2.83
150	11.21	2.46	**3.04**
160	11.89	2.62	3.24
170	12.57	2.78	3.44
180	13.26	2.95	3.65
190	13.94	**3.11**	3.85
200	14.62	3.28	4.06



Revolution Specification

Constant WR Power – 10 kW, 10 mph, 350°C S/H

Cut Off	Steam Chest Press		Steam Consumption	
%	bar(a)	psi	kg/s	lbs/hr
28.5	14.62	200	0.02541	201
35	13	174	0.02635	209
45	11.33	150	0.02844	226
55	10.24	134	0.03082	245
65	9.52	124	0.03304	262
75	9.04	117	0.0357	283



Revolution Specification – Steam consumption

At design point (10mph, 1 in 60, 45% Cut-Off):

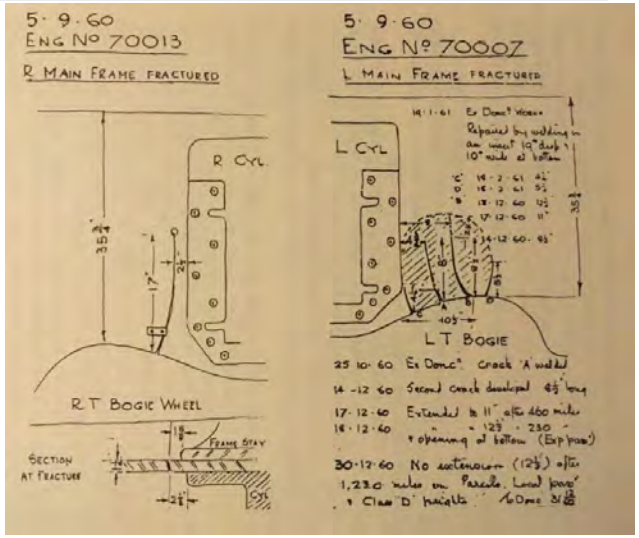
0.02844 kg/s (226 lbs/hr).

But……

- Assumes superheat of 350°C
- No leakage
- No condensation
- No thermal losses

Revolution Frame design – Traditional issues

- Frame cracking
- Poor alignment
- Spring failures
- Total loss lubrication
- Risk of contamination



Revolution Frame design – Traditional issues

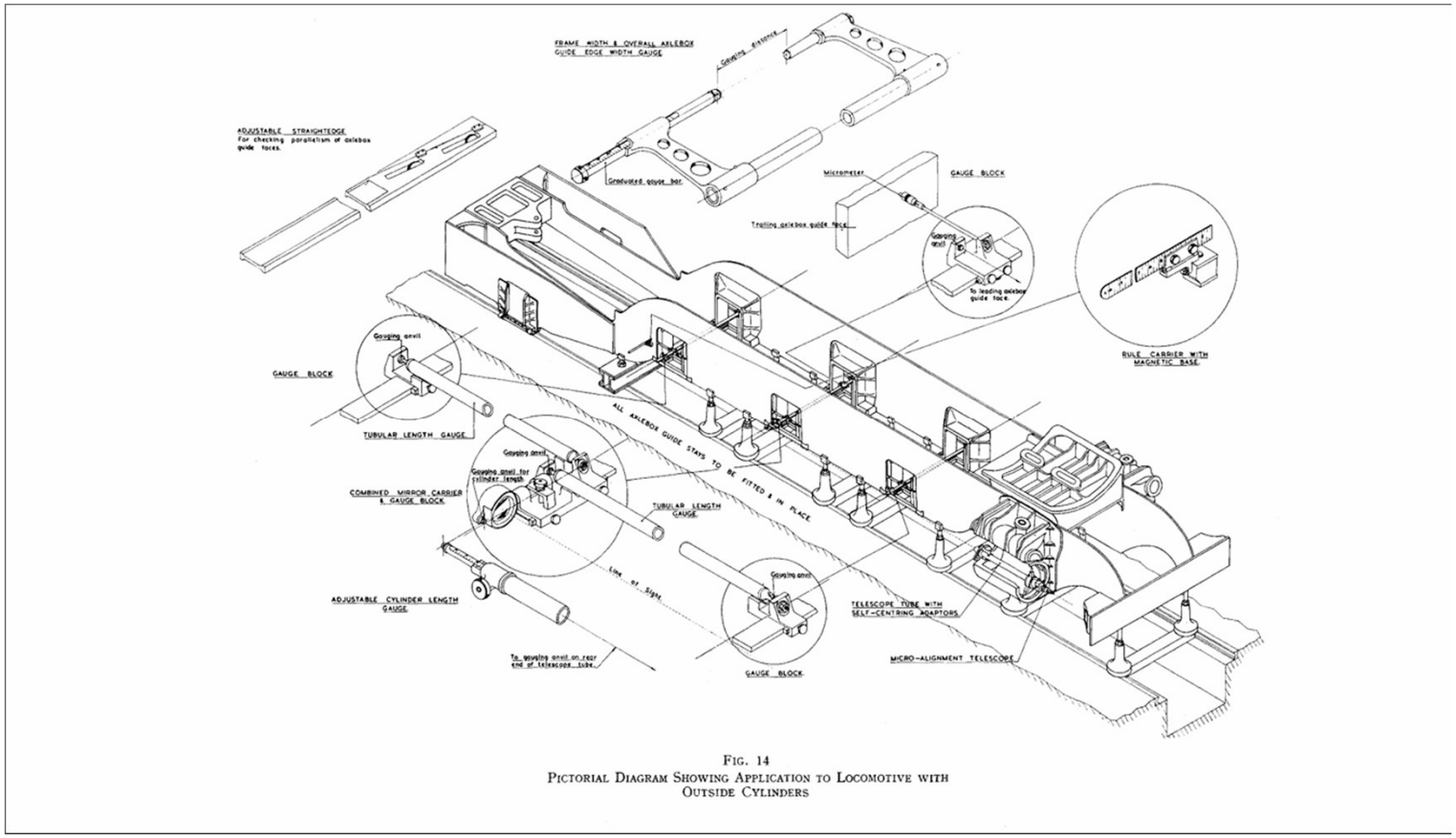
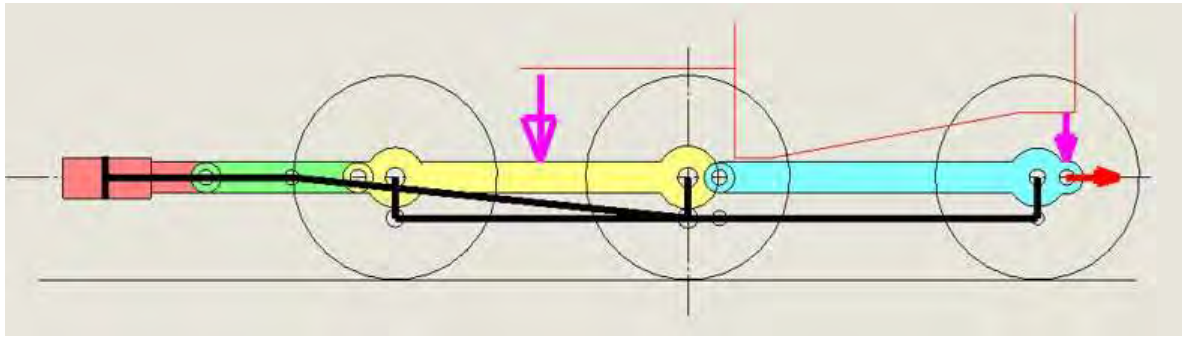


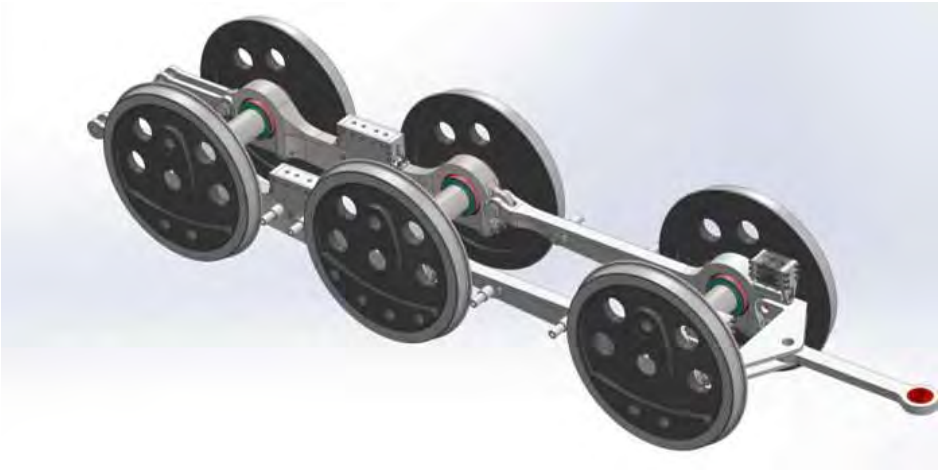
FIG. 14
PICTORIAL DIAGRAM SHOWING APPLICATION TO LOCOMOTIVE WITH OUTSIDE CYLINDERS

Revolution Frame design – Potential solutions

- Simple, direct load paths
- Avoid stress concentrations
- Remove the complexity of alignment

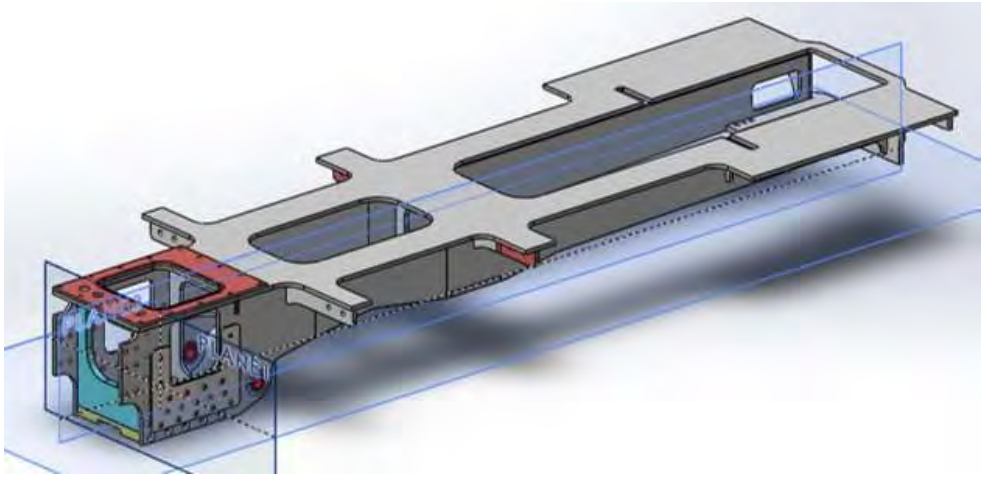


- Accuracy at the component level



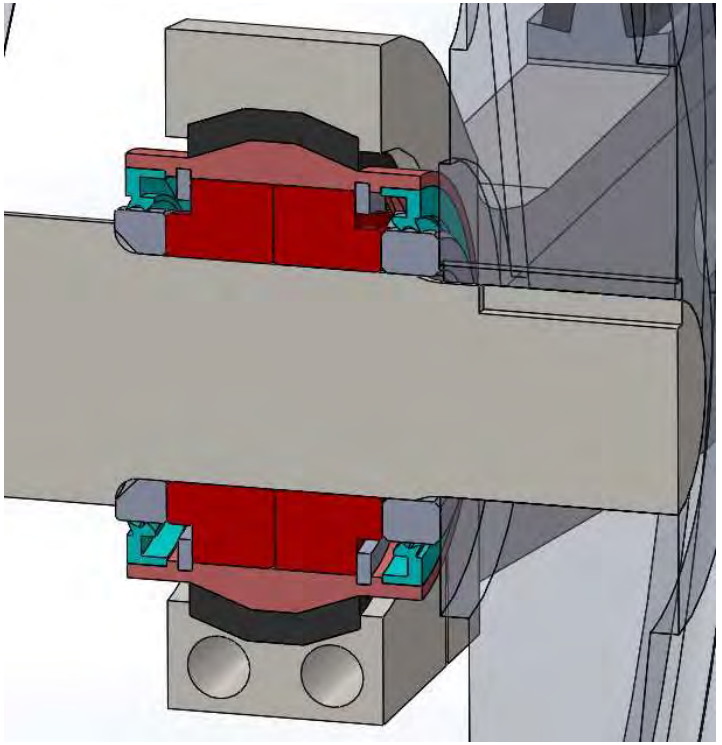
Revolution Frame design – Potential solutions

- Simple traditional plate frame for mounting components to
- No traction forces through it
- All mass completely sprung



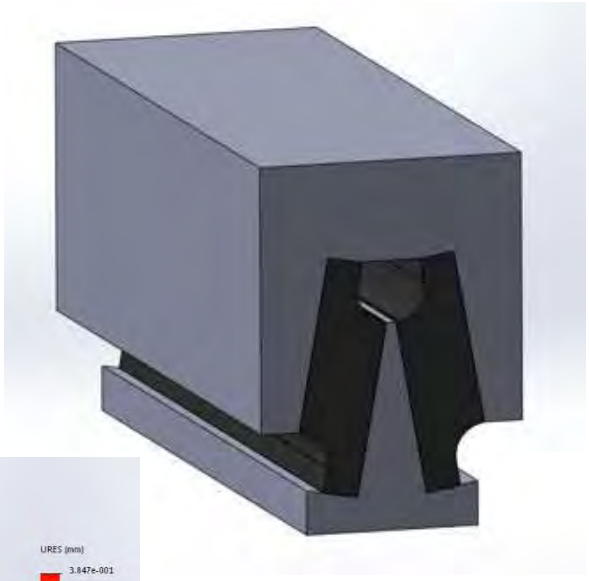
Revolution Frame design – Axle-boxes

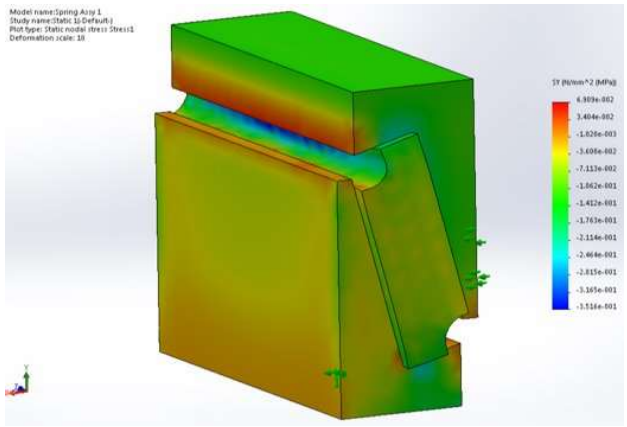
- Double taper rollers
- Contact shaft seals
- Retained by axle
- Clamped with tie bolts
- Spherical elastomer spring element - Gives primary suspension

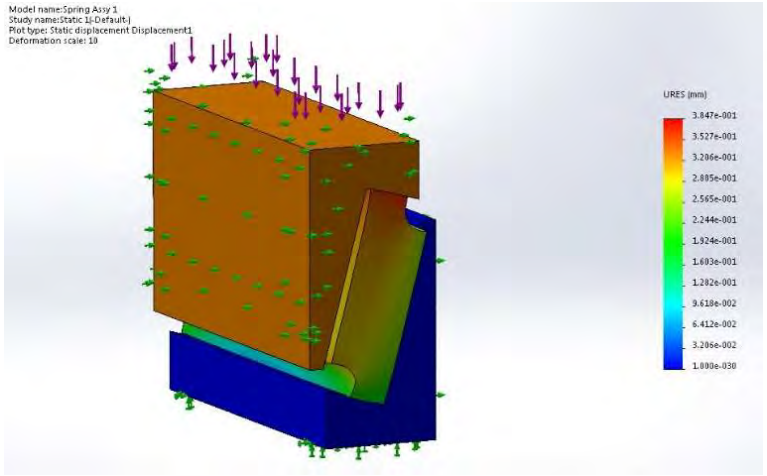


Revolution Frame design – Springs

- IHRD 65° shore A elastomer springs
- 75° inclination
- Length adjusted to support load
- FEA validated

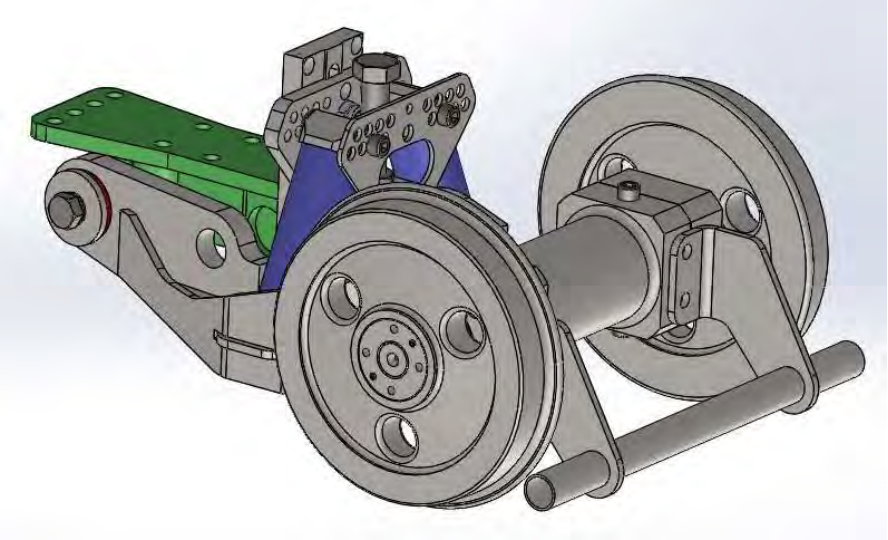






Revolution Frame design – Pony Truck

- Simple bolt on assembly
- Cannon axle-box
- Simple load adjustment
- Adjustable side control
- Ability to add:
  - Additional side springing
  - Lateral dampening

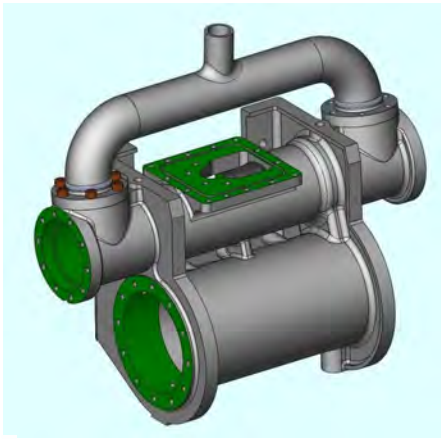


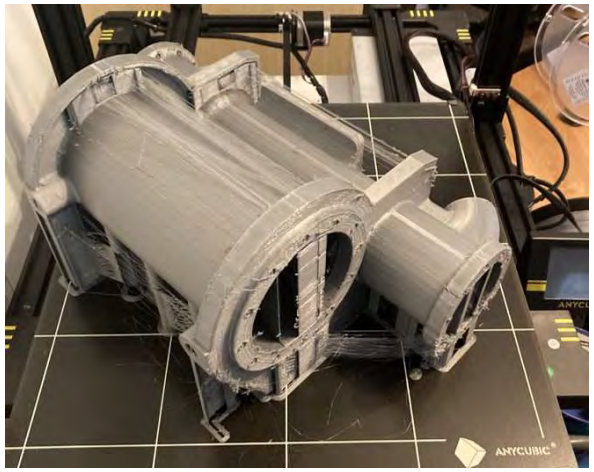
Revolution Wheel design

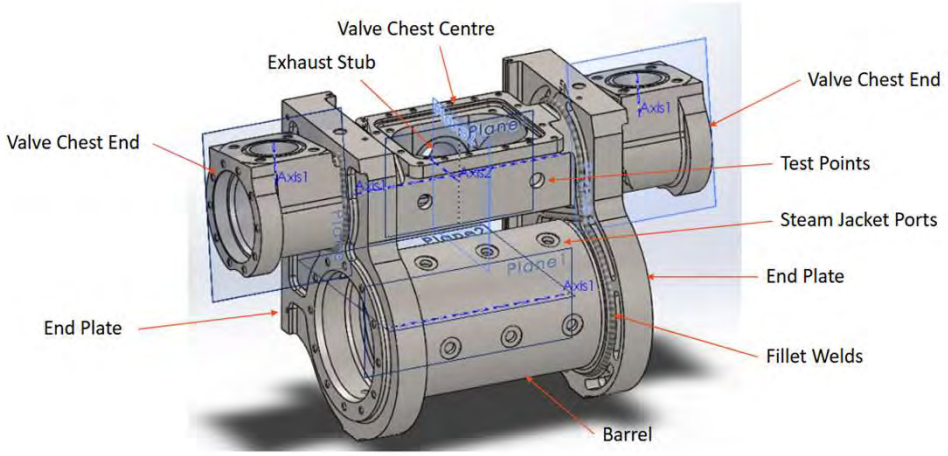
- Spoked wheels – traditional but have cracking issues
- Disc wheels - stiffer for same weight
- Disc wheels chosen

Revolution Cylinder design

- Various Concepts
  - Fabrication
  - Casting using 3D printed pattern
  - Welded fabrication chosen

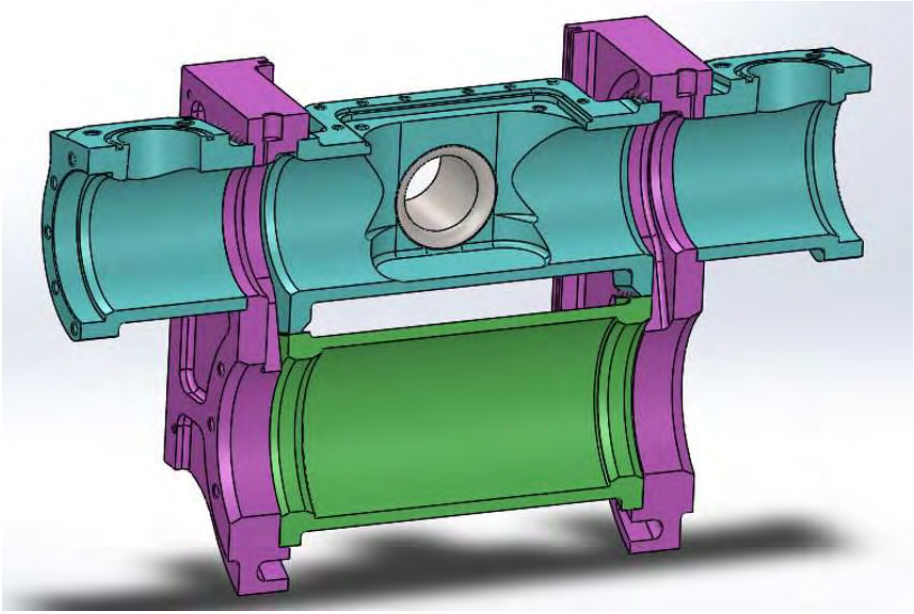






Revolution Cylinder design

- Welded Fabrication allows:
  - Accuracy
  - Self jigging
  - Features at a component level
  - Internal spaces to be machined accurately
  - Steam jacket to be easily incorporated
  - Reduction in cost

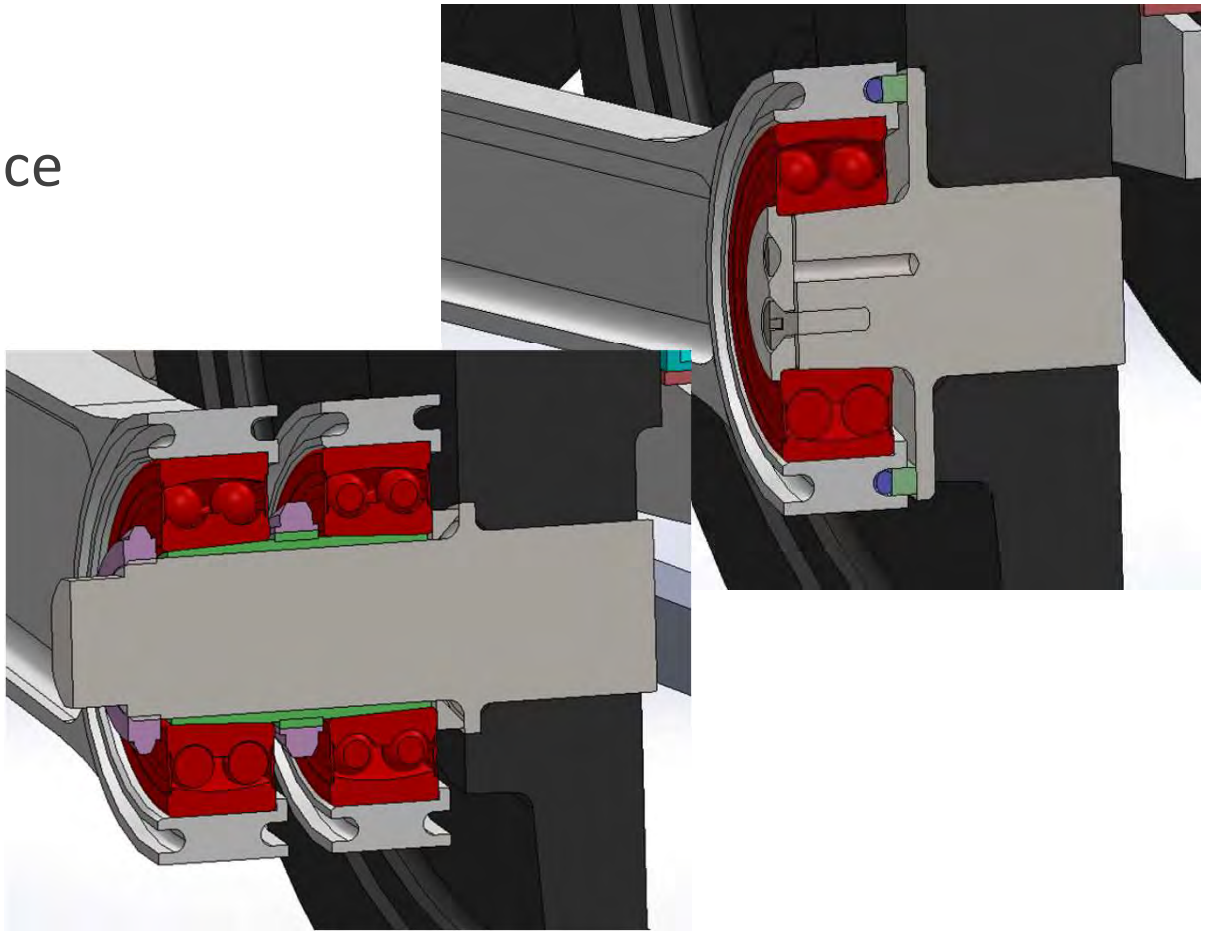


Revolution Cylinder design

- Kit of machined parts
- Fully welded fabrication
  - Stress relieved
  - Final boring done post welding

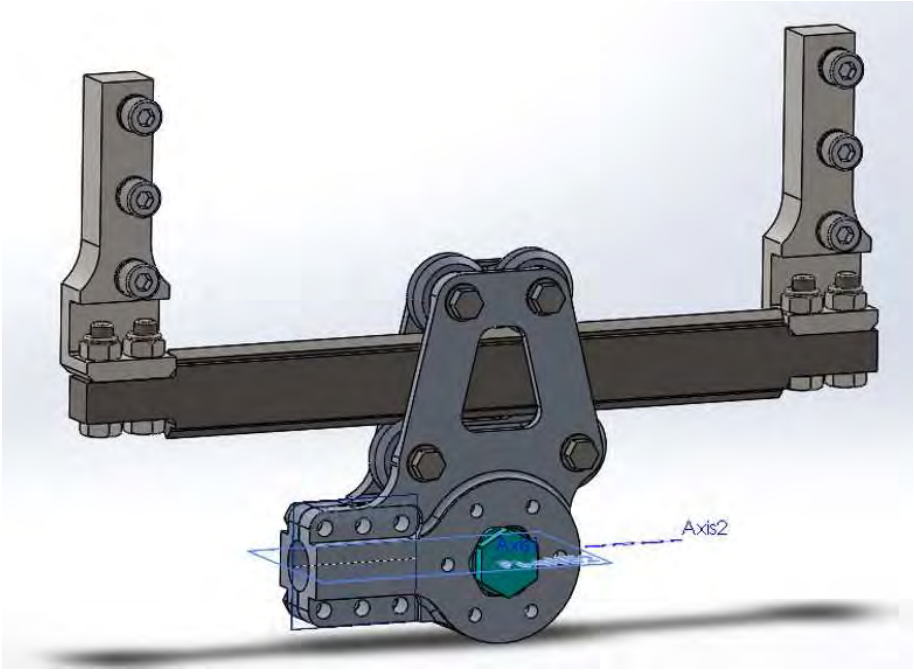
Revolution Running Gear Design

- Roller bearings throughout
- Rods from aluminium to reduce reciprocating mass



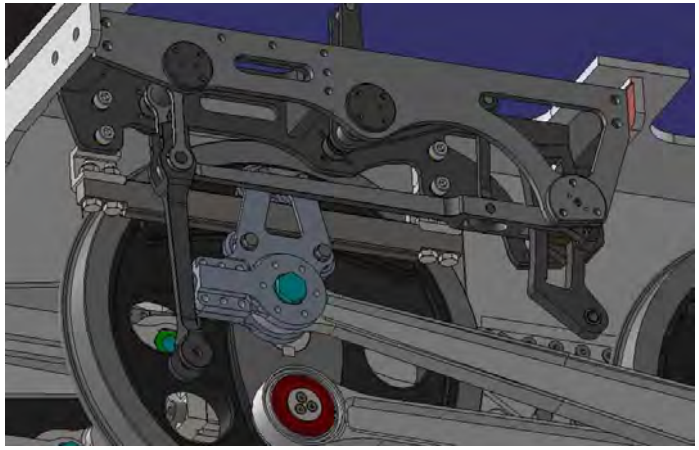
Revolution Running Gear Design

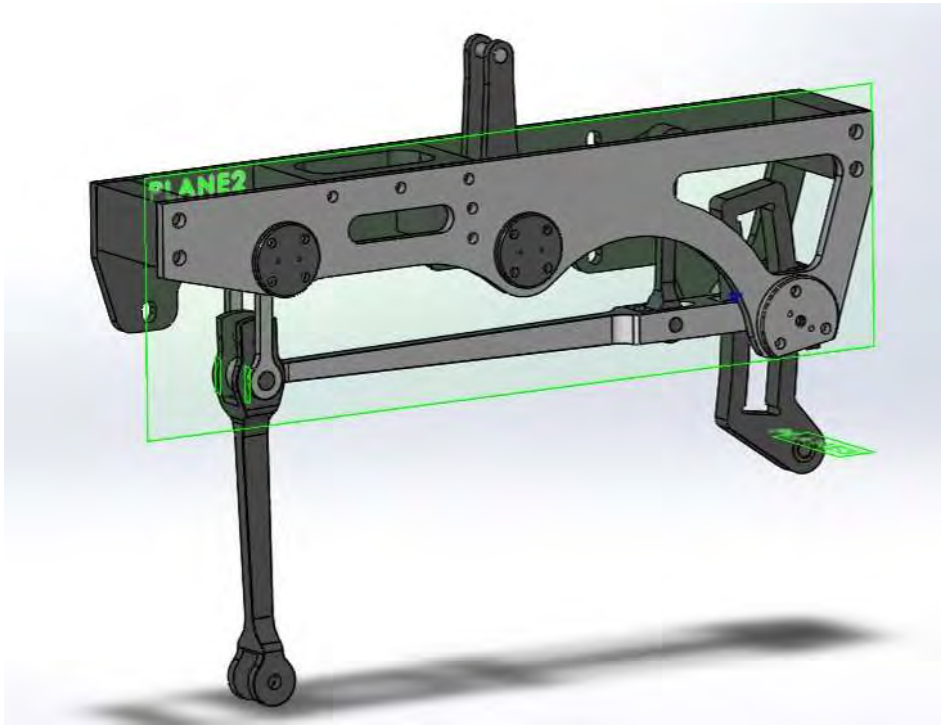
- Roller Slide bar
- Reduces friction
- Less wear
- Symmetrical
- V-Rollers



Revolution Valve Gear Design

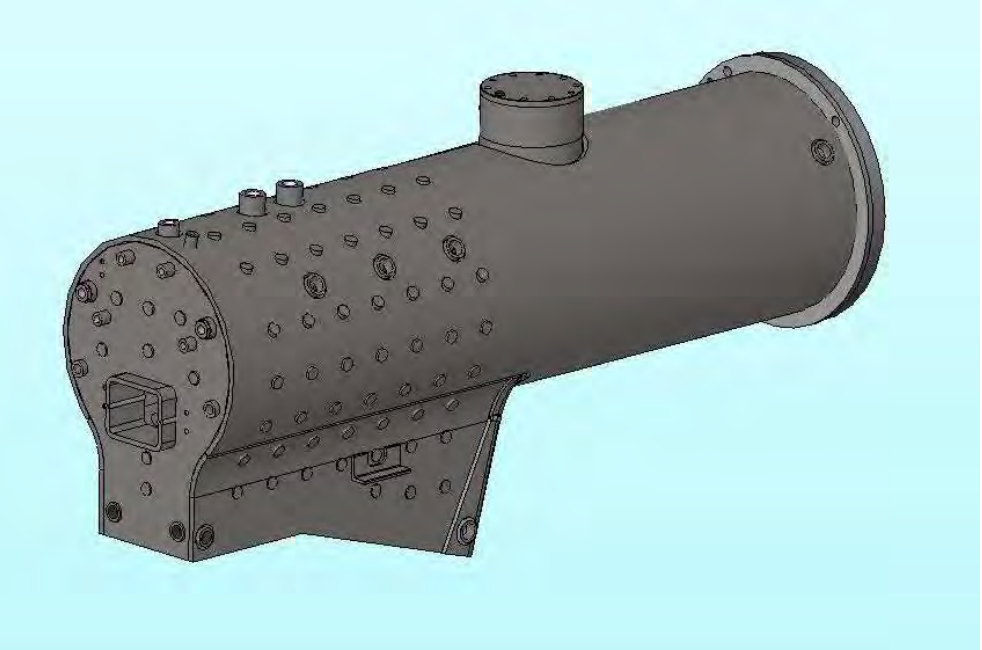
- Modular sub assembly – Not handed
- Machined mounts
- Slide bar support
- Needle rollers





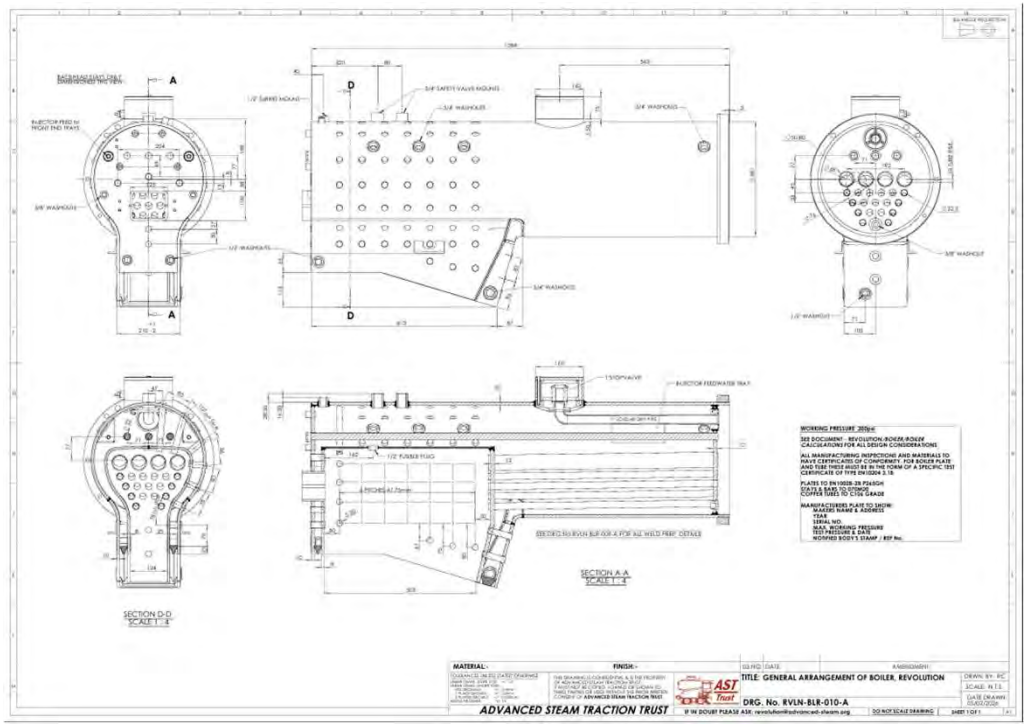
Revolution Boiler design

- Indebted to Martin Johnson for his work on boiler design spreadsheet
- Optimisation of design based around performance and ease of maintenance
- Target to meet the calculated consumption and 350°C



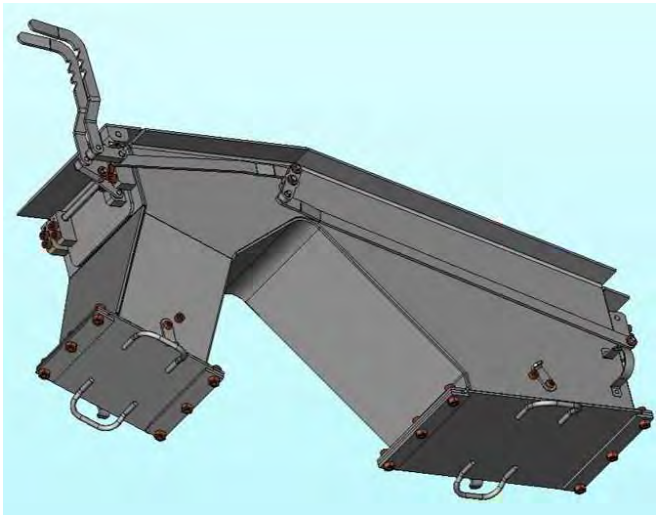
Revolution Boiler design

- 4 superheater flues with two elements each
- Auxiliary supply using superheated steam
- Dry side regulator (emergency shutoff valve)



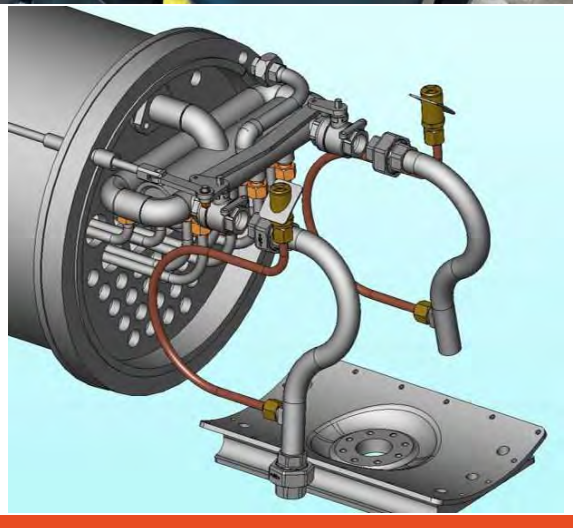
Revolution Boiler design - Ashpan

- Ashpan designed combining GPCS and 10.25” practice.
- Under-fire steam to reduce clinker and improve grate life



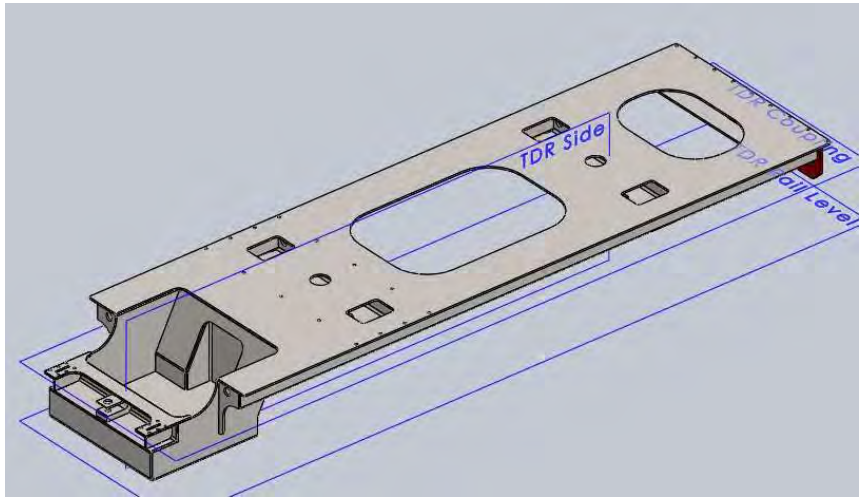
Revolution Front-end design

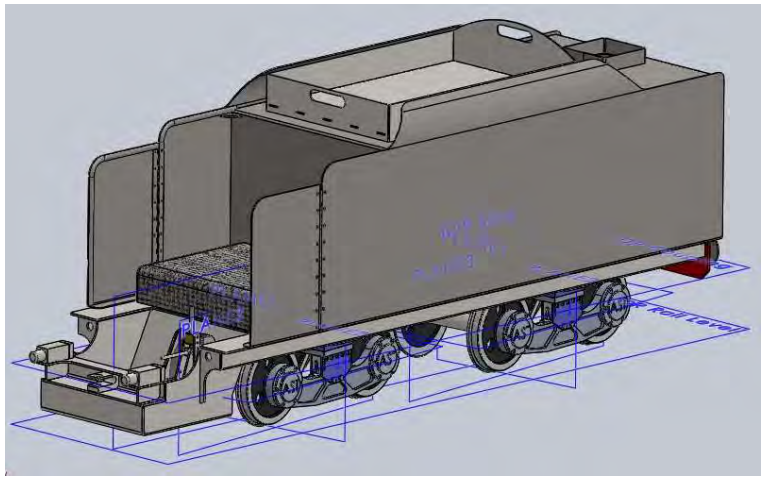
- Revolution an exhaust test bed
- Start with well designed simple exhaust
- Change exhaust regularly
- Designed for easy change
- Pipework designed for the best flowing and largest steam circuit as possible



Revolution Tender design

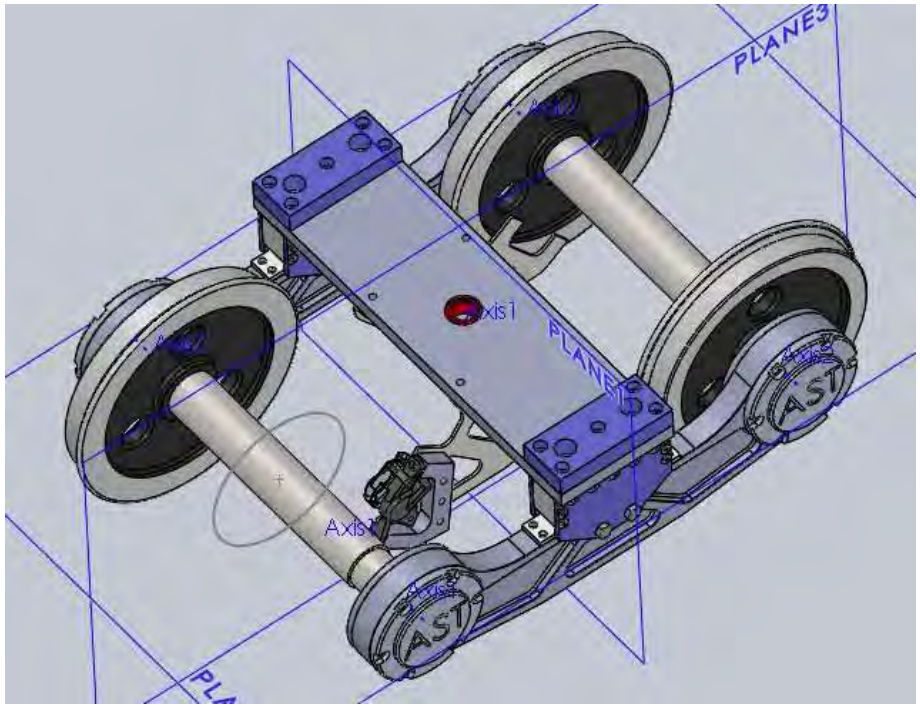
- Large water tank
- Potential for trying other fuels
- Unusual construction method





Revolution Tender design

- Same design principles as locomotive frames
- Spring beams as main frame
- Same design of elastomer springs as the locomotive



Revolution Construction Progress

Revolution Construction Progress

Revolution Construction Progress

Revolution Construction Progress

Revolution Construction Progress

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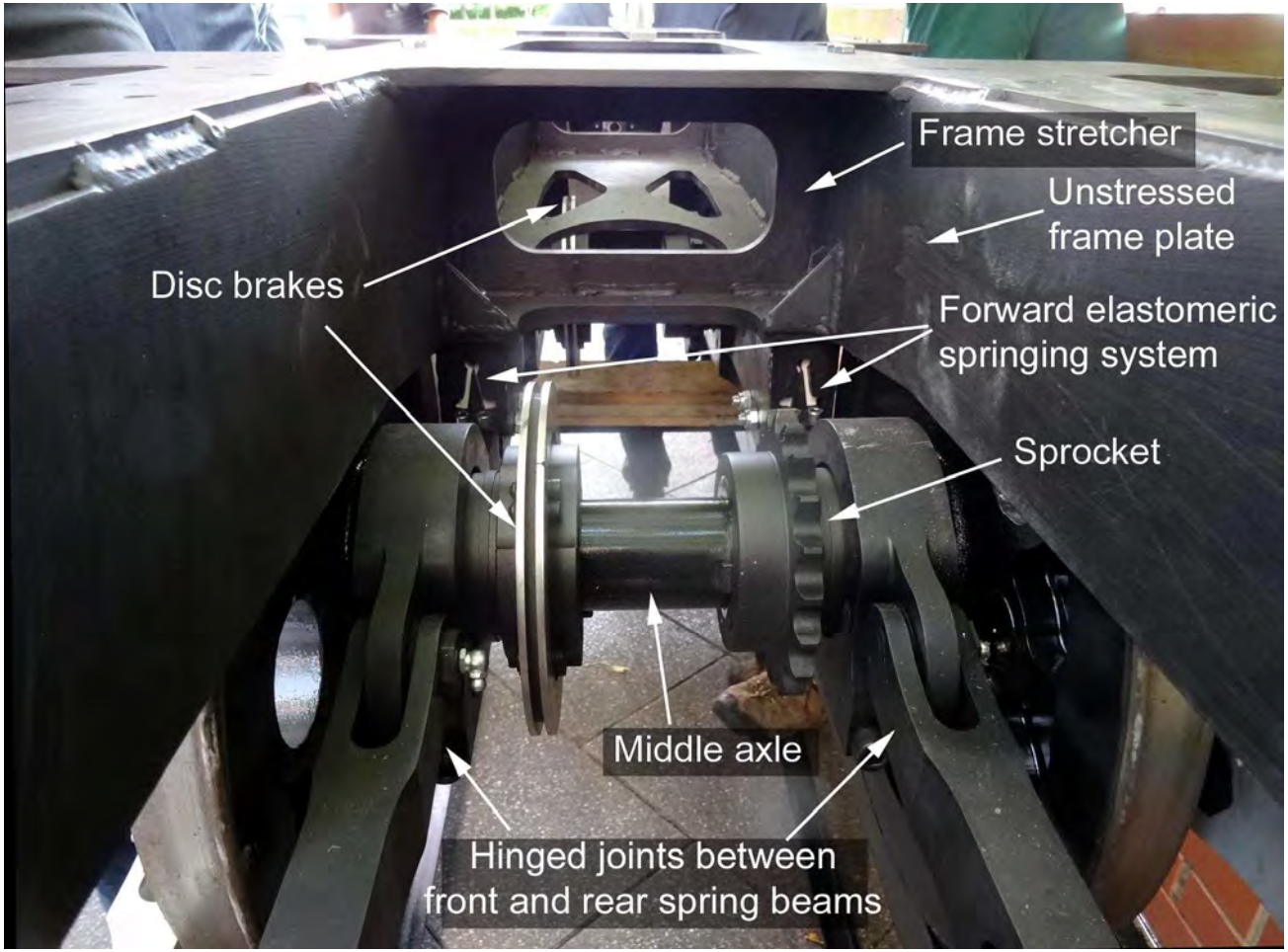
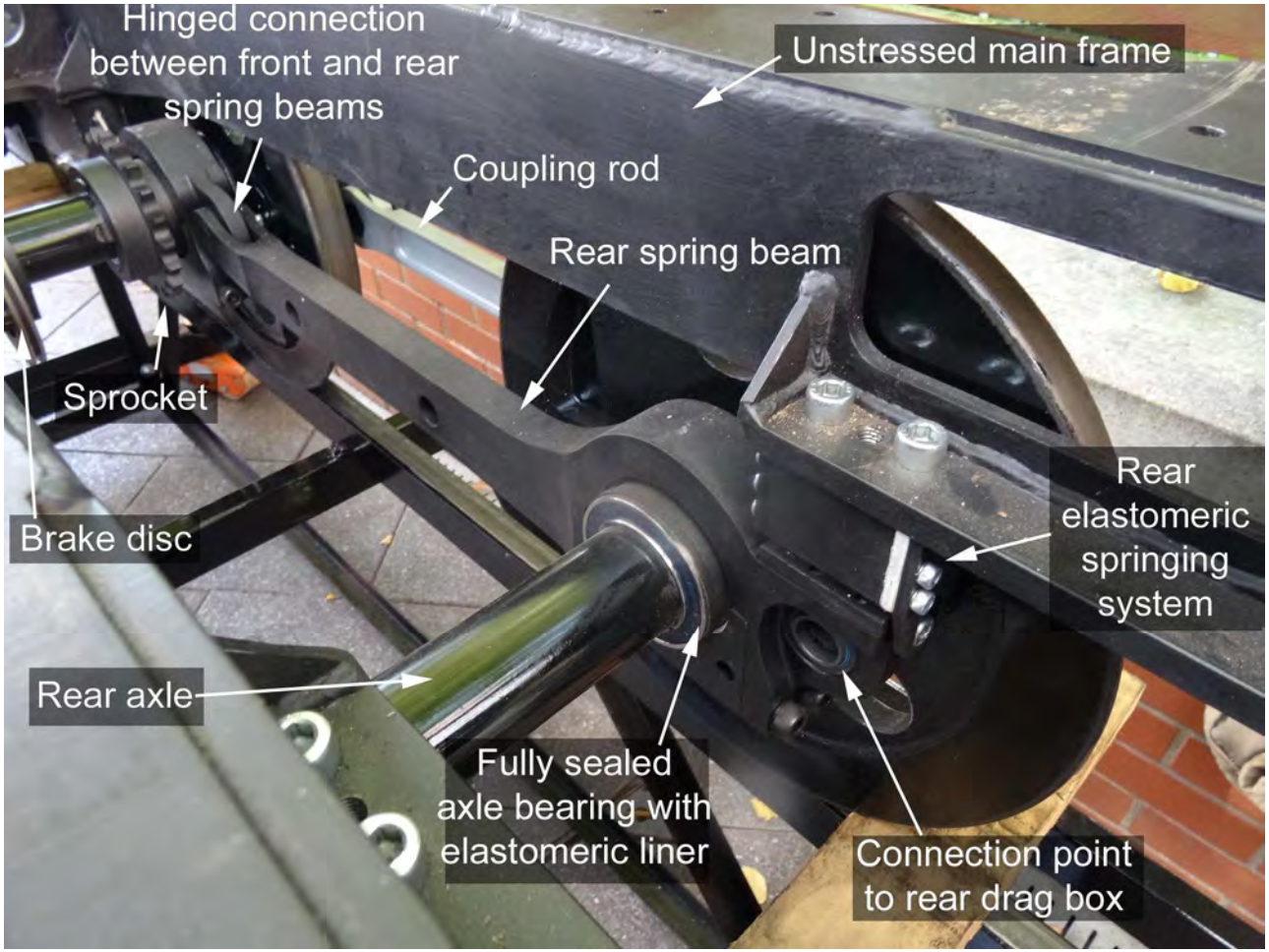
Revolution Construction Progress

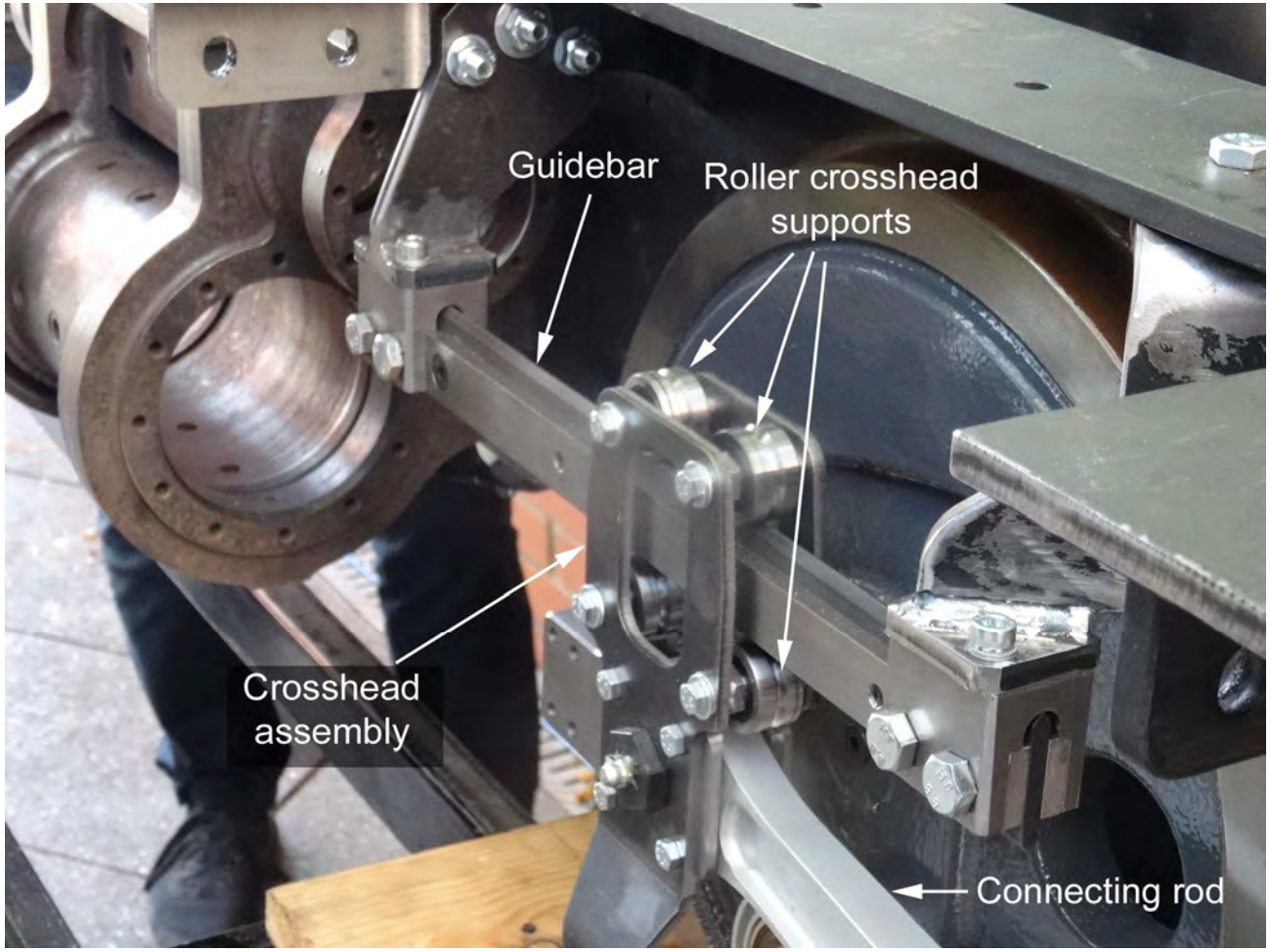
Revolution – Annotated Pictures



Revolution – Annotated Pictures



Revolution – Annotated Pictures



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- Opportunities to meet and get to know like-minded people and to learn from experts in the field

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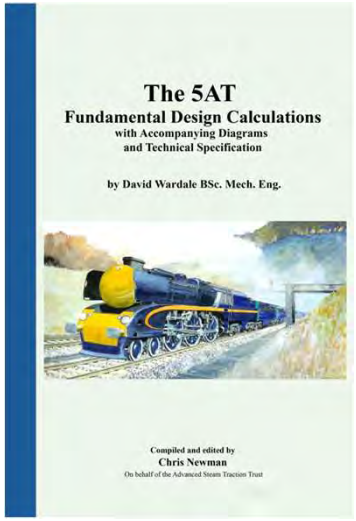
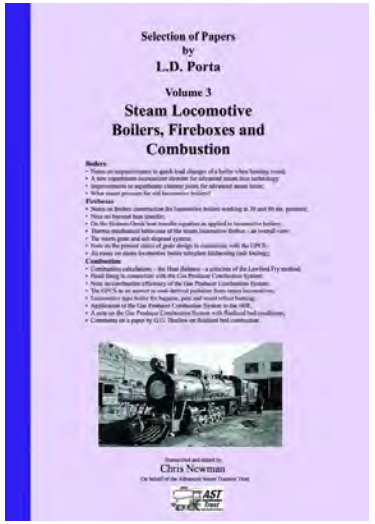
- Porta papers vol 1-5
- Porta compendium vol 1&2
- Lyn design specification and calculation





Any Questions?