THE EVOLVING COAL WAGON

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Summary
Coal is one of the most widely traded mined commodities in the world and is one of Australia’s largest exports. Because of the large volumes of coal transported, the efficiency of the transport system of the coal chain is a critical factor for Australia’s export economy.

A significant component of the coal chain is the wagon used to carry the product and its evolution over the years has played a significant role in Australia’s economic development.

This paper presents the evolving developments and changing features of coal wagon design as used in the New South Wales Hunter Valley and also of two prototypes for use in Queensland.

As mining techniques improved over time, the amount of coal mined grew. The railways had to keep up with this in order to move the coal efficiently to port or power station, hence the wagon design also changed in order to improve efficiency.

Early Coal Wagons
Coal has historically been transported in many types of vehicles. The first purpose built coal wagons were constructed almost entirely from timber, and were four-wheel type wagons.

The four-wheel coal hopper leant heavily on the so-called ‘box’ coal wagon designs, which were employed en masse in Britain.

The build specifications for the BCH were:
- Composite welded and riveted steel construction
- Tare mass of 21 tonnes
- Capacity of 42 tonnes
- Riding on three piece bogies
- Fitted with automatic couplings
- Drawgear capacity rating 0.75 MN
- Roller bearings and solid disc wheels

Some of these are still in existence as sand carrying wagons. Many others were converted to wheat, cement, aggregate or fertiliser carrying wagons by fitting roof structures.

The BCH wagon was designed with a centre sill and three pairs of doors, with a door fitted each side of the centre sill (see Figure 3).

The three sets of doors are manually operated via a fixed transverse shafts mounted to the wagon hopper.

Door security is provided by an over-centre type operating mechanism. There is also a latching pawl and a locking cam, commonly referred to as belt braces and tie (see Figure 3).

(CH) NHAF Coal Wagon
The next change in coal wagon design was the (CH) NHAF wagon.

This was the first of the curve sided wagons, creating a major shift from the previous straight sided steel wagon designs. This monocoque style design continues to the present day.
The build specifications for the NHAF wagons were:

- Tare mass of 18 tonnes
- Capacity of 58 tonnes (which was a significant increase to the carrying capacity on the previous BCH coal wagons)
- Higher capacity bogies which allowed the wagon to operate at 80km/h
- The wagon body was built from aluminium with riveted steel draft gear stops
- Drawgear rating of 0.75 MN.

Wagons of this era were built without centre sills. NHAF wagons were fitted with four manually operated transverse single leaf steel doors.

The operating mechanism was the same as the older BCH wagon; consisting of a shaft attached to the wagon hopper. Door security was again provided by an over-centre mechanism, a latching pawl and a locking cam.

(CH) NHEF Coal Wagon

A variation to the CH design was the NHEF wagon. A hundred of these were built during 1969-70 by Tulloch, also in aluminium and without a centre sill.

NHEF’s had three pairs of manually operated transverse steel ‘Bomb Bay’ doors (see Figure 4), which was a significant variation from the earlier transverse door arrangements.

Another major difference with the door design on the NHEF wagons was that the door operating shaft is mounted on only one of the doors.

Security is provided by over-centre mechanism and a latch which operates through the main operating shaft (see Figure 5).

Rotation of the door crank is prevented by the latch acting against the stop on the connecting arm.

This wagon has the same tare (18 tonnes) and capacity (58 tonnes) as the NHAF wagon.

The drawgear rating was an increased 0.9 MN.

### 100 Tonne Coal Wagons

The next major development in coal wagon design occurred in 1976, which was to increase the gross mass at rail to 100 tonnes.

Other significant firsts at this time included:

- Pneumatically operated doors
- Drawgear capacity increased to 1.8MN (double the previous capacity and allowing for significantly longer train consists)
- A main reservoir air pipe added for the door operating mechanisms and brakes
- The use of stainless steel (301) as the build material in contact with the coal
- The tare mass of the stainless wagons was largely retained at 22 tonnes, mainly due to the thinner material used in their construction.
The pneumatically operated doors are arranged in pairs operated off a common shaft, security is provided by over-centre mechanism and a pneumatically operated latching cylinder.

Main reservoir air (at 700 kPa pressure) is supplied to the latching cylinder for de-latching prior to activating the larger ram which operates the main shaft and opens the doors.

The door levers have turnbuckles (see Figure 6) to adjust the position of the door panel relative to the hopper and hence ‘tune’ the door mechanism.

The first of these wagons with pneumatically operated doors (NHTF, NHVF, NHCF and NHGF) were fitted with antennae for remote automatic opening of the doors.

Unfortunately after a number of coal spills, either due to signal interference or because of unreliable system operation, the remote system was disconnected and later removed. Figure 7 shows the antennae at the side and end of the wagon.

**NHFF Coal Wagon**

The next major change in design was in 1982, with the NHFF 100 tonne gross coal wagon.

These wagons were stainless steel bodied (including the doors) with carbon steel end units and three pairs of pneumatically operated longitudinal ‘Bomb Bay’ style doors.

The advantage of longitudinal doors being that the coal was only dumped between the rails.

This door design was able to use a greater over-centre setting for security and also eliminated the need for a pneumatically operated latching cylinder (see Figure 8).

The NHFF wagon was the first to be fitted with a totally different bogie design, the DCA bogie.

This bogie was based on the Gloucester design with the following features:

- A single piece fabricated steel frame
- Constant contact side bearers
- Hemispherical centre-plate (non-metallic liner)
- The axleboxes were a “saddle” type carrying package unit bearings
- Primary springs fitted between the axleboxes and the bogie frame, fore/aft of the bearings
- A friction wedge system mounted over the primary springs to control axle movement

Previously built coal wagons were fitted with three (3) piece bogies with no significant bogie design change other than plain bearings being replaced with roller bearings in axle boxes or package units.

The main improvement to previous wagons with 3 piece bogies was that the NHFF could operate at 70km/h loaded.

The drawgear rating was also increased to 2.2 MN.

The Gloucester bogie didn’t really catch on due to its higher capital cost and no incentive was given by the track provider.
NHHF Coal Wagon
The other wagon of significance in 1982 was the NHHF wagon of 76 tonnes gross mass built in aluminium.

The ends structures had an aluminium shear plate Huck bolted to the steel shear plate.

The tare mass was much lighter at 16 tonnes compared to previous wagons.

This wagon has a plug in door design which eliminated the turnbuckles by allowing the door to travel inside the hopper.

NHRH Coal Wagon
Beginning in 1993, the first of a new generation of coal wagons was designed and built by Asea Brown Boveri (ABB).

The NHRH was the first 120 tonne gross mass wagon (see Figure 9).

This radically new design had an immediate impact on the coal supply chain in the Hunter Valley, with the gross mass of 120 tonnes per wagon significantly increasing through-put per train.
The differing design features of the NHRH wagon consisted of the following:

- Side wall height at tare increased to 4,130mm above rail height (previously 3,660mm)
- Top cant-rails were mounted inside the wagon
- The body was a centre sill design
- Shortened wagon spacing was achieved by reducing the dimension between the outer axles on adjacent vehicles
- The body material in contact with the coal was 3CR12 stainless steel
- The ‘Kwik Drop’ door system was introduced
- Steering bogies were introduced
- Wagons were permanently coupler in ‘packs’ of seven, which eliminated glad hands and end cocks at the intermediate connections
- Slack reduced drawgear was fitted at the six intermediate connections
- Standard couplers and draft gear were fitted at the outer ends of the seven packs
- Coal deflectors for the bogies assisted with ploughing whilst unloading

The tare mass of the wagons was 23 tonnes and the drawgear capacity was increased to 2.45 MN

Another advantage of the system is that a large over-centre is used for security and a latch is no longer required.

The most significant advantage is that there is no longer a need for a person to manipulate a handle to operate the door valve for unloading the wagon and also for closing the doors.

The 2nd generation of Kwik Drop doors eliminated the turnbuckles by using a plug-in door. For door security, two helical springs were added, one on each side of the hopper (see Figure 11). Maintaining a force on the doors by the helical springs is important to prevent the doors from changing from an over-centre to an unstable or under-centre position in service.

All modern bottom discharge door, coal wagons built for the Australian market utilise the ‘Kwik Drop’ door system with or without turnbuckles and with or without plug-in doors.

Other improvements to the doors were:

- Adding rubber bump stops to reduce noise
- Use of non-metallic bushes
- Use of aluminium doors
- Stainless steel support brackets and stiffeners

The ‘Kwik Drop’ Door System

The ‘Kwik Drop’ door system (see Figure 10) revolutionised unloading for coal wagons.

The doors reverted back to the transverse pair of leaves system operating off a common shaft, with security relying on only the over-centre mechanism.

Thus coal wagons with longitudinal ‘Bomb Bay’ doors, as had become the norm in NSW, were no longer being built.

The ‘Kwik Drop’ door system eliminated the need for pneumatic door cylinders, door valves, filters piping and also the latching cylinders thus saving capital and maintenance cost.

NHPH Wagon

The next change in wagon design was the NHPH wagon built in 1996.

This wagon was designed with ‘Y’ frame ends and no centre sill to reduce tare mass in order to avoid contractual penalties for excess tare mass. Unfortunately the wagon suffered early fatigue cracking.

This was very unfortunate because it had the opportunity to be a very good design; particularly for hauling sticky coals that tend to cause hang-up on wagons with centre sills (the NHFF 100 tonne coal wagon, which has no centre sill, has been operating since 1982).

All coal wagons in Australia have since been built with a centre sill.
Design Improvements to Improve Coal Discharge on Existing Wagons

The significant process change that the ‘Kwik Drop’ door system provided for discharging the coal was the catalyst to automate the discharge of coal on other existing wagons. However retrofitting of the ‘Kwik Drop’ system was not considered to be cost effective; as either the wagons were too old or there were difficulties for adapting the longitudinal doors. Hence two different discharge designs were developed.

The Leigh Creek to Port Augusta Train

In considering the design criteria for automating the door systems, three important conditions were required to be met, (1) low cost, (2) high reliability and (3) good maintainability. A simple basic concept was designed using the existing door valve because of its high reliability; it was relocated from underneath the centre of the wagon to the end wall. The valve was operated by a hinged flap on each side of the wagon connected by a shaft to the door valve.
A small pneumatic boat trailer wheel, mounted on a trackside pedestal, provided the initiating movement to the door valve as the wagon traversed past (see Figure 12).

The automation of the doors also meant that the wagons could only travel in one direction, with loops introduced at each end of the route rather than turn-backs to re-orientate the locomotives.

The Hands Free System in NSW
The trackside pedestal as used on the Leigh Creek operation was not suitable to use in NSW because of interference with the ‘Kwik Drop’ door system operating ramps, hence the development of the Hands Free unloading system.

A new solenoid activated valve was mounted on the end wall replacing the manually operated valve underneath the wagon.

This new valve was triggered by a trackside electrical signal which was delivered via contacts on a collector (Figure 14) mounted to the side of the wagon as the wagon moved past (see Figure 13 below).

ECP Braking
ECP (Electrically Controlled Pneumatic) braking was first introduced into Hunter Valley operation in 2005 by QR National on their QHAH 120 tonne wagon fleet.

ECP braking is now used on most modern wagons.

Two Queensland Prototypes
i. Close Coupled Wagon (CCW)
A concept for a close coupled wagon design was presented at the CORE 1998 Conference on Railway Engineering by Mr Vic Stevens. A prototype was then later built.

The CCW has a higher linear density advantage over existing wagon types where there are infrastructure constraints such as the shared Brisbane passenger corridors.

Figure 15 shows the extra capacity carried by the CCW compared to the existing wagons being used.

ii. The American Built Wagon
In 2009 two prototype wagons (see Figure 16) were imported from America in an attempt to obtain a standard North American design of wagon except for the tapered upper sides.

The rationale behind this thinking being that with a standard wagon, all problems would have already been designed out.

The wagon had an aluminium body, Huck bolted to a steel centre sill and end platforms.

It is fitted with five ‘Kwik Drop’ door sets with larger end doors to provide better discharge and resistance to coal hang-up.

The wagon is slightly longer (by 200mm) than current Australian typical monocoque designs and has a tare mass of approximately 20 tonnes.

The exchange rate and the manufacture of coal wagons in China have combined to prevent further builds.
Design Improvements Envisaged in the Future

1. **Side Sheet**

The use of a single piece side sheet, or else using wider plate, to eliminate the many vertical welds required during assembly will have a huge impact.

2. **Utilisation of Voids**

Within the spatial envelope of any wagon are a number of voids that are unutilised for the carried capacity (see Figure 18).

   i. **The Voids Behind the End Slope Sheets**

   The utilisation of the void behind the slope sheet is worth considering as this extra volume has the potential to shorten the wagon hopper whilst maintaining the current capacity. This may require a different door panel at the end hoppers (see concept shown in Figure 19).

   ii. **Recovery of Door and Non-Door Voids**

   The volume from the two non-door voids (formed by the slope sheets) and the ‘Kwik Drop’ door voids has the potential to be used. This could also be achieved by implementing transverse or longitudinal ‘bomb bay’ type doors (see the concept in Figure 20).

   Whilst this door design is currently pneumatically operated, it is considered that the transverse ‘Bomb Bay’ door design can be adapted to be used with the ‘Kwik Drop’ system.
iii. Voids at the Ends of the Wagon
The under-utilised voids at the ends of the wagon are worth exploring (see Figure 21), as there is significant potential volume available there (approx. 20% or more per wagon).
This would also make for a shorter wagon which may enable more wagons to be added to each train consist (provided that tractive effort is available).
However the size of the hopper openings either side of the stub sill may cause coal hang-up and there may be structural integrity issues to consider.

Figure 21: Use of void at ends of the wagon

3. Continuous Loading
Continuous loading is an area that could be investigated to prevent stop start loading or even changing to automatic loading.

Figure 22: Continuous loading

4. Reducing Tare Mass
A reduction in wagon tare mass can provide a significant operational and financial impact.
As a typical example: a 10kg saving in tare mass for 1,000 wagons at one trip per day for 350 days per year over 40 years, with a coal price of $80 per tonne, can increase through-life fleet revenue by approximately 11 million dollars.
Optimised wagon design should maximise the volumetric capacity of the hopper within the limits of the rolling stock profile, whilst also minimising the coupled length of the wagon.
In reviewing other areas where the mass could be reduced, the following options are presented for consideration.

i. Centre-Sill-Less Wagon
Using FEA tools, the design of a wagon with no centre sill and larger end doors should be considered especially for Queensland where coal hang up has been a constant problem.
Centre sill-less wagons have been used successfully in NSW for quite some time.
The NHFF wagon has been in service since 1982. It has been through a refurbishment program, but it also has not been designed to account for the increased train lengths or benefitted from sophisticated FEA design technique.
A wagon without a centre sill also has the potential to save mass.

ii. Twin Pack/Quick Pack draft gear
Use of Twin Pack/Quick Pack draft gear in lieu of a standard draft gear pack provides potential mass savings as shown in Table 1.

Figure 23 Twin Pack/Quick Pack draft gear

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<th>Qty</th>
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<th>Qty</th>
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<td><strong>596.8</strong></td>
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Table 1: Comparison of Standard Draft Pack to Twin Pack/Quick Pack unit
As can be seen from Table 1, a four wagon set using Twin Pack/Quick Pack draft gear would save 580kgs tare mass per wagon. For a train of eleven coupled eight packs this will increase the train capacity by approximately 50 tonnes.
The greater number of wagon sets (i.e. more multipacks per train consist) the greater the potential mass savings.
The Twin Pack is rated to M901G capacity and is a two stage unit (i.e. having a shorter draw travel and a longer buff travel).

iii. Drawbar
Further investigation could be carried out for implementation of a quick/easy connect drawbar and the subsequent shortening or optimising of drawbar lengths (see Figure 22)
This is co-dependent on the result of reducing the distance between end axles of adjacent wagons.
5. **Bogie Design Considerations**
A bogie designed specifically for mass saving that utilises minimum wheel base dimension (depending on results of bridge and track loading investigations) should be considered.

Other additional design features to consider follows:

i. **Wheels**
The wheel diameter could be minimised to one turn wheels as used in the USA.
Reduced diameter wheels also provide scope for increasing the hopper volume, due to likely changes in the relative spacing between end slope sheets, end platforms and cant rails.

ii. **Axles**
Use of hollow axles, as currently used on EMU rolling stock (which meet the allowable axle load), could provide a tare mass saving of approximately 50kgs per axle (or 200kgs per wagon).

iii. **Spring Parking Brake**
The use of spring parking brakes in lieu of standard body mounted cross shaft yard brakes is estimated to provide a saving of approximately 51kgs per wagon.

6. **Use Of Aluminium**

i. **Body**
The use of aluminium for hopper body fabrication could provide some potential for tare mass savings compared to use of materials such as corrosion resisting or stainless steels.

However from the perspectives of design, fatigue resistance, manufacturing and material costs, based on industry experience it is considered that the use of stainless steel material will likely be of lower risk than fabricating from aluminium.

ii. **Doors**
The use of aluminium door panels will also have potential mass saving.

7. **Coal Ploughing**

Ploughing through discharged coal causes the coal to be deposited on the bogies and onto the door operating equipment such as levers shafts support brackets, etc.

The problems caused by ploughing have been addressed to some extent on newer coal wagons by fitting shields to prevent coal being carried out of the unloading terminal on the bogies (see Figure 24).

8. **Noise**

Bogies selection/wagon design in regard to reducing noise has already been raised as a concern and will be required to be addressed for future wagons.
REFERENCES

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