Why Did BR Give Up On Steam ?
– And Could It Have Been Avoided

Part 6 – Lessons Learned

Andrew Hartland
September 2025

Introduction

- BR built 999 new “standard” steam locomotives starting in 1951 (plus 1518 to Big 4 designs)
- BR then abruptly reversed policy in 1955 with the publication of it’s Modernisation Plan, which advocated the immediate replacement of steam with diesel and electric traction.
- Little doubt that BR got worst of all worlds – building 2500 new steam locomotives then rapid dieselisation– US railroads did better
- E.S.Cox wrote several books justifying the BR Standards, then conceded defeat to diesels at the end.
- Others since have shown that claims for diesels were optimistic/not justified (Brown, Porta, Wardale etc.)

Introduction (2)

- However diesel did replace steam – "winning the argument" later on does not change this

- Given the natural resistance to change of any large organisation, there must have been what were seen to be very powerful reasons for BR to abandon a form of motive power that was well understood by it's workforce in favour of a technology of which BR had little knowledge or experience

- This presentation seeks to answer two questions:

1. What were the reasons given at the time for the perceived superiority of diesel over steam traction ? – Part 1
2. Would it have been possible for different designs of steam locomotive to those actually built to have addressed these perceived weaknesses ? – Part 2 etc.

Introduction (3)

- In response to question 2 above I have considered:
  - Express Passenger locomotives
  - Freight Locomotives
  - Shunting Locomotives
  - Multiple Units

- Conclusions about the relative merits of steam vs. diesel in these categories are quite clear (and were known at the time!)

Contents – Part 6

1. Introduction
2. Recap – US Experience
    1. NYC
    2. PRR
3. Recap – Basis For UK Decision To Replace Steam
    1. 1951 RE Forms of Motive Power Report
    2. 1954 BTC Planning Committee
    3. 1955 BTC Modernisation Plan
    4. 1963 Bond Justification
4. Lessons Learned

Recap – US Experience

Kiefer – *Basis of Comparison*

Chief Engineer Motive Power NYC

(1) Availability and its dependent counterpart, utilization.
(2) Over-all costs of ownership and usage.
(3) Capacity for work
(4) Performance efficiency

Comparison based on :

(a) Locomotives of equivalent power and representing the latest state of the design art

(b) Equivalent through-line passenger schedules and freight operations and efficient use of potential availability

(c) Equivalent maintenance and servicing attention at all times

Motive Power Type	Efficiency (%)
Diesel-electric	22
Electric	17
Pulverized coal gas-turbo-electric (est.)	16
Pulverized coal steam-turbo-electric (est.)	10
Modern reciprocating steam	6

At full load in train service at a speed of about 65 m.p.h., with fuel of average quality

Kiefer – Performance, Availability and Utilization

- Appraisal of on-time passenger performance, actual operations, Harman-Buffalo, 403 miles, of 6 S-1 steam and 6 4,000 b.h.p. Diesel-electrics
- Average delay chargeable to the locomotive practically negligible for both classes of power.
- The relatively more stable performance of the Diesel was accomplished with the same size trains as with the steam although rated horse-power was about one-third less

No.Trains = 178	Steam	Diesel
Gross Delay (min)	21.1	16.1
Running Time Made Up	17.6	13.9
Net time Late	3.5	2.2
Gross Delay Due to Loco	1.2	1.3
On Time (%)	75	71
Annual Mileage	288,000	324,000
Avg. Miles/mth	24,000	27,000
Utilisation (%)	63.0	70.4
Availability (%)	69.0	74.2

Kiefer – Over-all costs of ownership and usage

	Steam	Diesel	
	S-1	2 unit	3 unit
	6600 hp	4000 hp	6000 hp
Relative Capex	100	147	214
Annual Mileage	288,000	324,000	324,000
Costs per Mile ($)			
Repairs	0.356	0.352	0.5
Fuel	0.41	0.28	0.42
Water	0.031	0.004	0.005
Lubrication + Other Supplies	0.016	0.032	0.047
Engine House	0.1	0.1	0.1
Crew Costs (2)	0.2177	0.2216	0.2291
Total per mile (operating)	1.1307	0.9896	1.3011
Total Annual operating Cost	325,642	320,630	421,556
Fixed Charges (Depreciation, Interest)	24,453	38,841	56,640
Total Annual Cost	350,095	359,471	478,196
Total Annual Cost per mile	1.2156	1.11	1.48

- Capex ratio diesel/steam = 1.47
- Fuel costs shown assume 6% STE
- At 9% STE fuel costs equal and Total Annual Costs lower for Steam

Conclusions from Kiefer

- Kiefer Rule – Steam requires 50% more horsepower (ihp) than equivalent diesel-electric
- Fairly heroic routine maintenance required to achieve equivalent steam availability as diesel (e.g. knocking down brick arch in hot boiler every round trip)
- Operating Costs 14% higher for S-1 steam than 4000hp diesel
- 9% efficiency steam would equal diesel operating costs with lower CAPEX charges
- Kiefer believed coal-burning gas-turbine loco with electrical transmission was way forward

Recap – UK Decision

1951 RE Forms of Motive Power Report – Steam Key Findings

- Public believe that the steam locomotive is rapidly being outmoded.
- Smoke and dirt are increasingly frowned upon and add substantially to cost of cleaning locos, rolling stock & structures
- The era of unlimited supplies of large coal at favourable prices has passed
- The transport and handling of loco coal is expensive and labour intensive
- Shortages of footplate crews and running shed staff is a serious problem
- The cab of an electric or diesel locomotive is a more pleasant environment than the footplate of a steam engine

1951 RE Forms of Motive Power Report – Diesel Key Findings

- Economics of DE depend on finding rosters which allow full advantage to be taken of the greater availability of the diesels compared with steam
- Unlikely that UK diesel/steam CAPEX ratio could match US (between 2 & 3)
- Considerable potential for use of diesel railcars on secondary and branch-line services – detailed investigation required
- 20 years' experience shows DE Shunters offer considerable advantages over steam

1951 RE Forms of Motive Power Report – Key Economic Conclusions

- The diesel-electric locomotive, by the very character of its design and equipment, cannot be other than high in first cost relative to the steam locomotive
- A round trip between London and Glasgow every 24 hours only represents a mileage of some 4,800 in six days, and with two round trips between Waterloo and Exeter every 24 hours the mileage in six days only amounts to about 4,122.
- if the 2,000-h.p. single-unit diesel-electric locomotive can be successfully developed and the first cost, by large-scale production, brought appreciably below that for the prototype 1,600-h.p. units, and the operating costs do not greatly exceed those experienced with the 1,600-h.p. units, then the extended use of diesel traction for main-line working in this country may be a sound economic proposition.
- Even so, the degree to which diesel traction will prove economic will still be dependent on the extent to which it will be possible to find rosters which will allow full advantage to be taken of the greater availability of the diesels compared with steam locomotives.
- In the light of the experience to date, the Committee is unable to recommend any changeover of this character.

BTC Planning Committee – Forms of Motive Power Report (1954)

- Key advantage of ML DE higher availability (12 hours on shed reqd per week)
  - Requires 24 hour diagrams to take advantage
- No detailed cost justification for replacing ML steam with diesel provided
- *2,500 diesel locomotives (plus 4,600 DMUs) to replace approx. 19,600 steam locomotives (1955 Modernisation Plan)*
- Advantages of DMUs and DE/DM shunters already accepted by regions, implementation ongoing

Bond 1963 I.Mech.E. Pres. Address

- "The price of coal in relation to oil increased substantially... whole national economy …dependent on oil removed any lingering doubts…allowing a large part of the railway system to become dependent on imported fuel"
- "the relation between the first costs of steam, diesel and electric locomotives of broadly comparable capacity was approximately 1: 3·5: 2·5"
- "With freedom from the limitations imposed on steam locomotives by fire and water, diesel and electric locomotives have a greater potential availability for traffic. They are not immobilized for quite long periods for fire cleaning, firebox inspections, boiler washing and steam raising."
- "Experience so far on British Railways has shown that one main line diesel locomotive can replace rather more than two steam locomotives of comparable capacity"
- "growing realization of the fact that there were very few services, passenger or freight, on which the greater potential availability of diesel locomotives could not be utilized sufficiently for the annual mileage per locomotive, compared with steam, to be increased by the amount necessary to establish an overall financial advantage."

Bond – 1963 I.Mech.E. Pres. Address

- "Contrary to experience in some overseas countries, there is so far no indication that, from a strictly technical point of view, the lives of diesel locomotives in Britain need be any less than the life of steam locomotives. Nor do we find that repair costs of individual locomotives, averaged over a number of years, exhibit a constantly rising trend in direct proportion to age."
- "Representative mileages between consecutive repairs at main works for medium-duty steam locomotives of modern design are about 90 000 miles, with 215 000 miles, between general repairs.
- With diesel locomotives of comparable type it is expected that between 200 000 and 300 000 miles, depending on the class of work, will be achieved between consecutive periods of main works attention, with at least 600 000 miles between general repairs."
- "In diesel and electric locomotives:

  (1) A higher proportion of total locomotive weight is available for adhesion;

  (2) The power available from the diesel engine (or the electricity supply network) is virtually independent of locomotive speed;

  (3) No limitation on output is imposed by the physical endurance of a member of the crew."

Requirements For Steam to Compete With Diesel

- Less Old Fashioned
- Cleaner
  - ➔ Less Pollution
  - ➔ Better combustion (with lower quality coal)
- Less Manual Labour
  - Cleaning/Servicing
  - Firing
  - ➔ machine washing, stoker firing & reduced service reqmts
- Higher Low Speed Performance
  - ➔ Better Acceleration & Hill Climbing
  - ➔ consistent higher power outputs (Kiefer Rule) ➔ mech. firing
  - ➔ better use of locomotive weight for adhesion
- Reduced OPEX
  - Reduce Fuel costs to Diesel levels ➔ Higher Efficiency
- Higher Availability/Utilisation ➔ match diesels
  - Increased Operating Range w/o refuelling/water/ash removal
  - Reduced terminal time (turn, water, coal, ash)
  - Reduced servicing
  - Increased major repair intervals

Lessons Learned

Design Drivers pre-WW2

- UK
  cheap coal + cheap labour
  ➔ simple locomotives, manual firing
- France
  expensive coal + cheap labour
  ➔ sophisticated locomotives, manual firing
- USA
  cheap coal + cheap labour + max performance
  ➔ simple (large) locomotives, stoker firing

Design Drivers post-WW2

- UK, France, USA
  expensive coal, expensive labour

➔ Steam design philosophies didn't change

- Diesels seemed to offer a way forward
  - High performance cf. manually fired steam
  - High availability
  - Lower labour requirements
  - Cleaner
  - Modern

Proposed 1950s Steam Loco Design Parameters

- Equal Performance to diesel
  - Remove manual firing limit
- Equal Crew Costs to diesel
  - Automatic firing
- Equal Fleet Cost to diesel
  - Fleet Cost = N locos reqd x Unit Capital Cost
  - N locos reqd = N traffic diagrams/ % Utilisation
- Equal Fuel Costs to diesel
  - Fuel Cost = Cost/MJ÷Thermal Efficiency
- Equal Repair Costs to Diesel
  - Over economic loco life

Equal Performance

- For main line locos, this is the easy one, once manual firing limit removed
  - Shunters and local passenger (MUs) less clear
  - See Parts 2-5 for examples

- But: Bruce: American 4-8-4
  - Ashpan capacity 100 ft3
  - Fuel 10% ash, 15,000 lb/hr ➔ 37.5 ft3 ash/hr
  - ➔ 3 hour max non-stop run (coincides with tender capacity)

- Need to find sweet spot between
  - BR7 3000 lb coal/hr ➔ 1575 ihp } Cox min steam
  - T1 13000 lb coal/hr ➔ 5500 ihp } consumption

Equal Fleet Costs (1)

- Fleet Cost = N locos reqd x Unit Capital Cost
- N locos reqd = N traffic diagrams / % Utilisation
- % Utilisation ≤ % Availability

- USA (Kiefer)

	Availability		Utilisation		Capital Cost	Fleet Cost
	Pass	Freight	Pass	Freight	2 Unit Diesel	
Steam	69	65.7	63	63.5	100	159
Diesel	74.2	73.5	70.4	70.1	147	209
Ratio	1.08	1.12	1.12	1.10	1.47	1.32

Fleet cost for diesel is 1/3 greater for diesel than steam

Equal Fleet Costs (2)

BR Modernisation Plan Justification

- Diesel Availability >> Steam Availability ➔ Smaller Fleet Size Reqd
- Diesel Availability = 93% (12 h on shed/week) – FoMP Rpt 1954
- Diesel Utilisation : London–Glasgow rtn in 24 hours
  - approx 6 hours each way, Utilisation = 12/24 = 50%

Steam Utilisation (Peter Townend "Top Shed")

- Availability = 6 days/7 = 86% (1 X day/wk for boiler w/o & planned maint.)
- "On lodge turns the loco generally worked down one day and up the next"
- Diagram 1 9.10 KX–Leeds, 5/15 Leeds–KX
  - approx 3 hours each way, Utilisation = 6/24 = 25%

Bond 1963 Paper

- UK Unit Capex Diesel/Steam = 3.5
- Diesel /Steam Utilisation ≈ 2.5

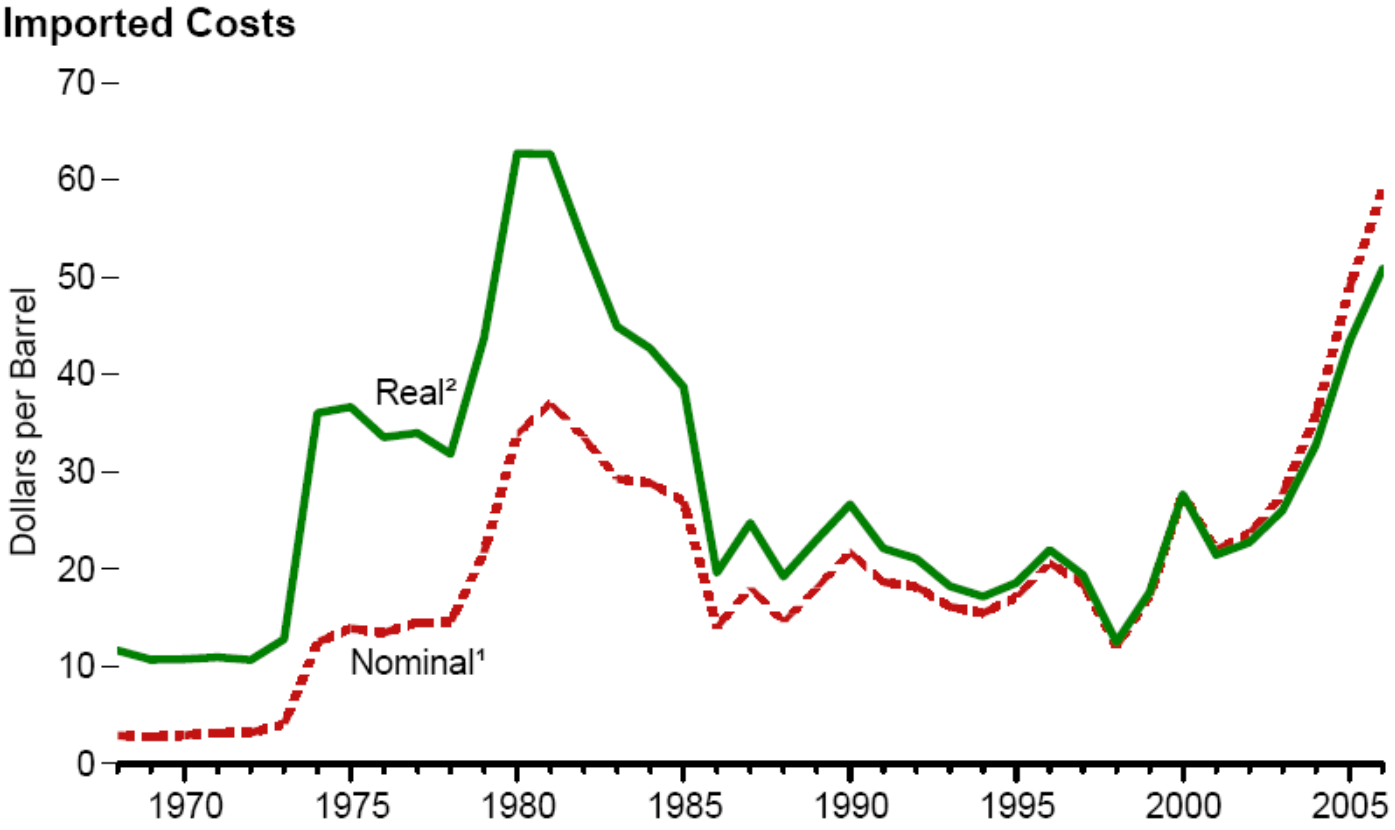
➔UK Diesel Fleet cost is 40% higher for diesel than steam

Equal Fleet Costs (3)

Ratio Diesel/Steam	Kiefer	Mod. Plan	Bond
Unit Cost	1.47	> 3	3.5
Availability	1.08	1.1	
Utilisation	1.12	2	2.5
Fleet Cost	1.34	1.5	1.4

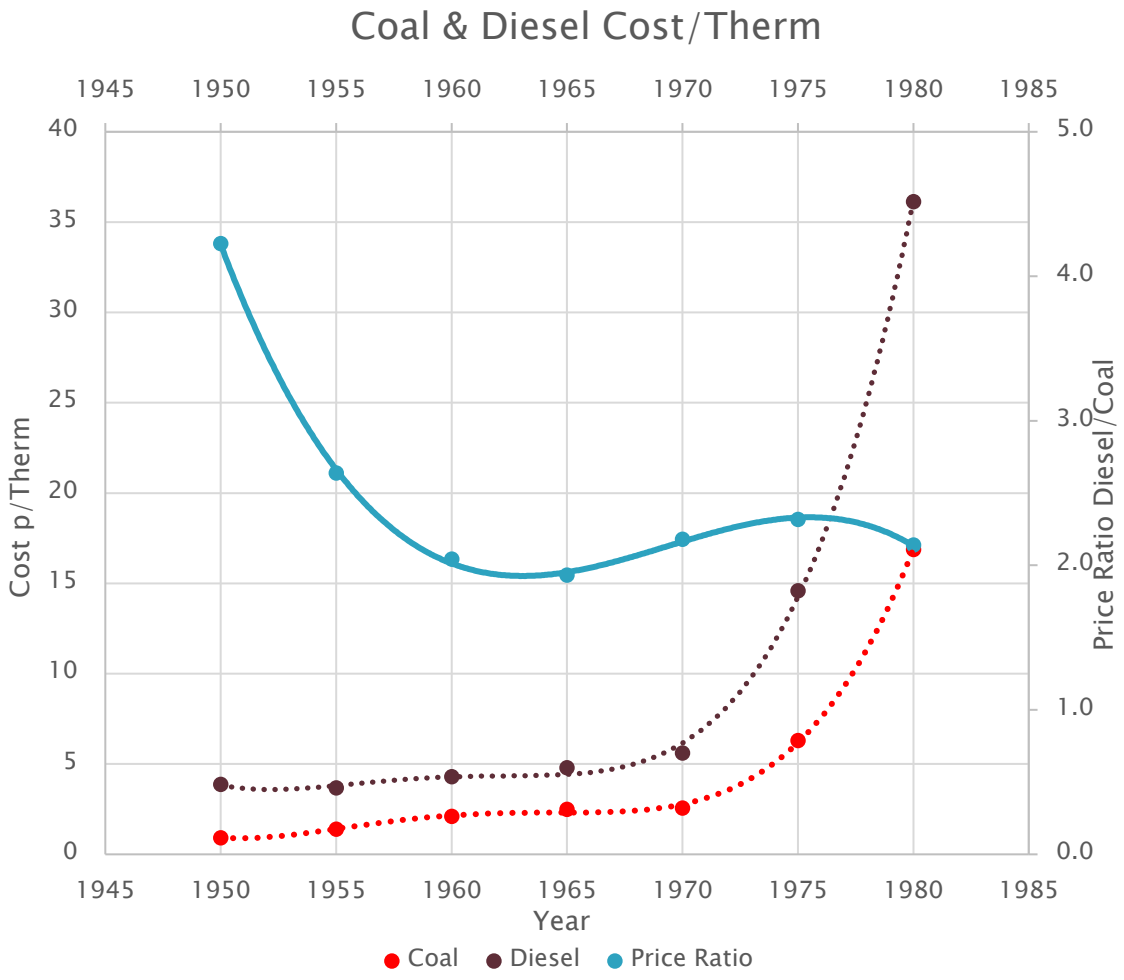
- Diesel fleet costs at least one third more than Steam in all 3 cases

Equal Fuel Costs (1) – The Bigger Picture



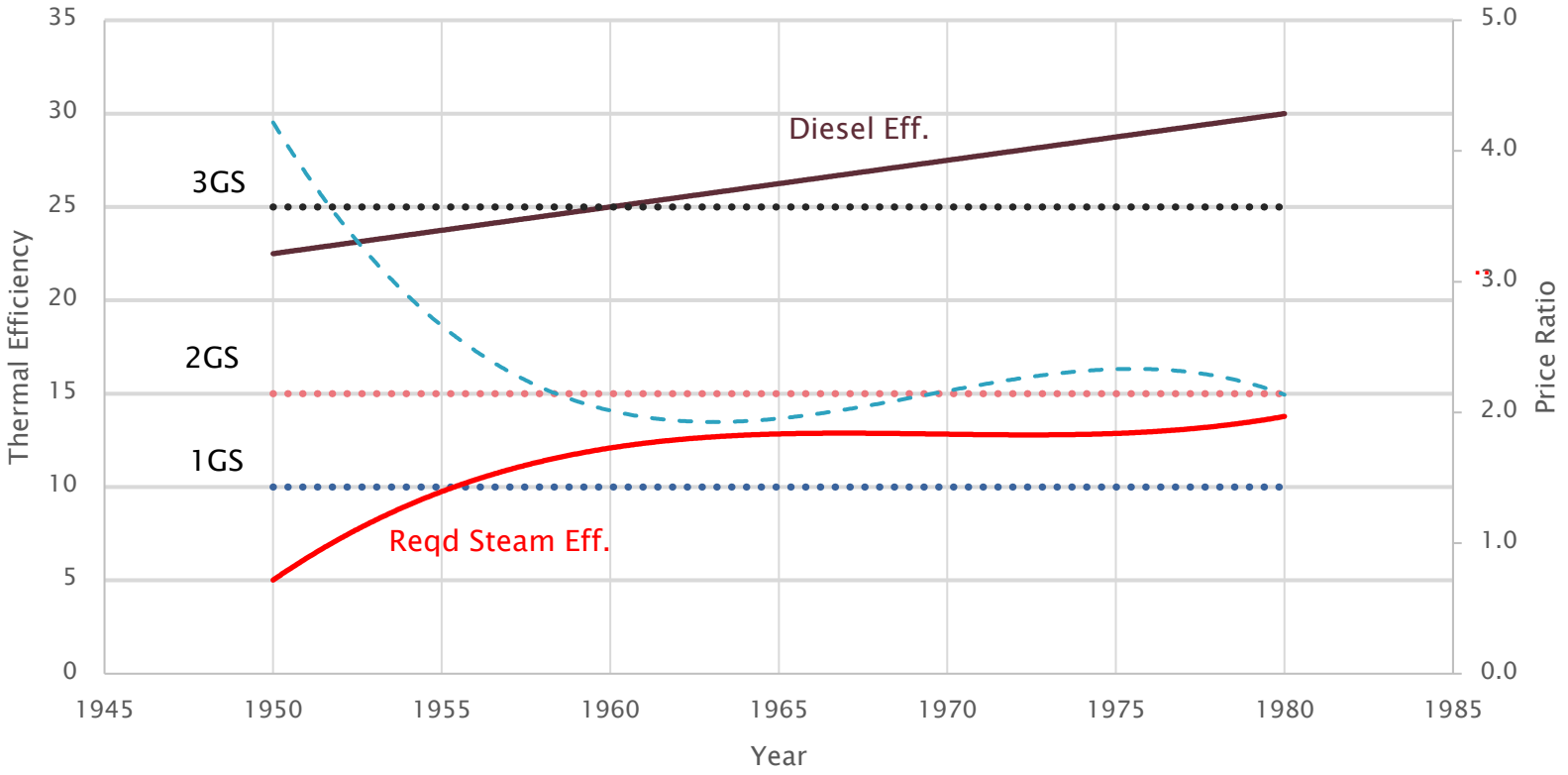
- Two “Oil Crises” in 1973 and 1979
- Price of oil tripled in 1973 and then doubled again in 1979

Equal Fuel Costs (2) – Cost per Unit Energy



- Coal Prices
  - 1950–1960 BR (Atkins)
  - 1965–1980 Power Stn Steam Coal
- Diesel Prices
  - 1950–1955 BR
  - 1960–1980 DoE Gas Oil

Equal Fuel Costs (3) – Thermal Efficiency



- Required steam thermal efficiency for equal fuel costs to diesel between 10% & 15% (< Porta 2GS)

Equal Repair Costs

Ratio Diesel/Steam	Kiefer	Bond	Brown
$/mile	0.99	0.33*	1.29

- BR anticipated lower repair costs for diesels
- International evidence showed otherwise

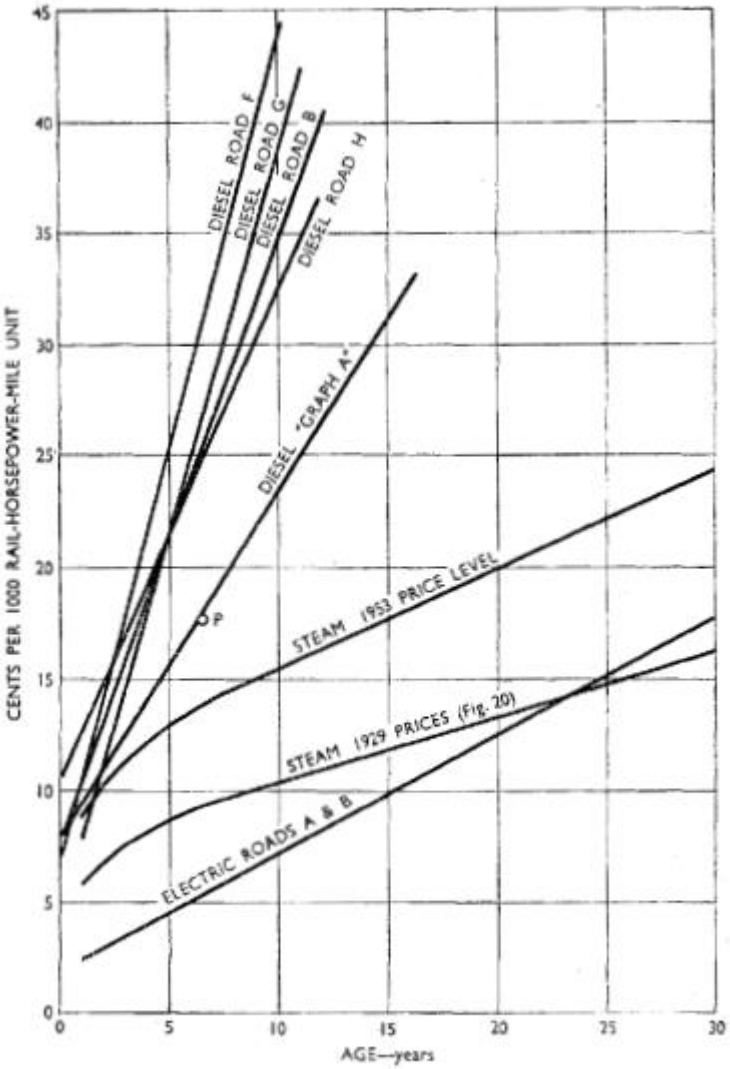


Fig. 21. Comparison of steam, diesel, and electric locomotive repair costs on basis of 1953 price level

Actual 1950s Steam vs. Diesel

	BR Standards	Chapelon SNCF	US Superpower
Equal Performance	X	✓	✓
Equal Crew Costs	✓	✓	✓
Equal Fuel Costs	X	?	X
Equal Fleet Cost	✓	✓	✓
Equal Repair Costs	?	?	?

- Chapelon SNCF comes closest
- Increasing coal prices favours compounding
  - Increased thermal efficiency also offsets stoker firing penalty

(My Personal) Conclusions

- Conventional Main Line Steam could (and should) have survived in the UK until the 1970s if world-wide best practice had been followed
  - What would Chapelon or Porta have achieved if they had been allowed to build 1000 new steam locomotives in the 1950s?
- The case for Steam Shunters and MUs is less clear
- After the 1973 and 1979 oil price shocks, further technical development could have kept coal-fired steam competitive for a further generation
  - E.g. Porta 3GS designs
- In today's net-zero world, coal-fired steam is a non-starter for main-line (non-heritage) use

End of Part 6 Presentation

Major Source Documents

- The Railway Executive
  - Forms of Motive Power Report 1951
  - Light Weight Trains Committee Report 1952
- British Transport Commission
  - Future of Diesel Traction letter 1948
  - Methods of Traction Sub-Committee Report 1954
  - Modernisation Plan 1955
- Cox
  - Locomotive Panorama 1966
  - BR Standard Steam Locomotives 1966
- Kiefer
  - Presentation to I Mech E 1947
  - Practical Evaluation of Railroad Motive Power 1948
- Bruce
  - The Steam Locomotive in America 1952
- Brown
  - Economic Results of Diesel Electric Motive Power on the Railways of the United States 1959
- Bond
  - I.Mech.E. Presidential Address 1963

Kiefer – *Capacity for work*