Travelling in Comfort

by

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G. Kichenside, writing in *150 Years of Railway Carriages*, states:[26]

> Railway history is bound up with social history, by reflecting changing trends—carriage provision being forced on unwilling managements by public opinion or by legislation. It took nearly 70 years for railways to accept that passengers on long-distance journeys might need to use a lavatory, eat or even feel warm. Many railways resisted such developments because the provision of toilets, dining cars, of heating and of good lighting all added to the weight of the train.

HEATING OF TRAINS

In *Locomotive Railway Carriage and Wagon Review* one reads:[6]

> Although the desirability of heating railway carriages was recognised from the beginning, it was long before any effective system was devised; indeed it may be said that a thoroughly efficient method is a comparatively recent development. For many years, heating was commonly performed by means of portable containers filled with hot water, which were pushed, with much clatter and disturbance, into the carriage and were supposed to impart some warmth to its interior, but more especially to the feet of the semi-frozen passenger. As a means of producing chilblains, it would be impossible to improve on this primitive contrivance, but as it lacked every desirable feature, and was besides most troublesome and uneconomical, requiring quite elaborate plant for charging, heating, handling and maintenance, it gradually gave way on progressive railways to more scientific and satisfactory arrangements.
>
> It is remarkable that the use of steam from the locomotive, though this might be supposed to be the obvious solution of the problem and was in fact tentatively used in Germany as far back as 1865, was neglected in favour of stoves, either alone or in conjunction with hot air circulation or thermo-syphonic water apparatus in bewildering variety. The most complete account of such systems, to the writer's knowledge, is to be found in Moreau's monumental '*Traité des chemins de fer*', vol. IV, Sec. 590–713 (written about 1897).

The hot-water tin was introduced to Britain by the Great Northern Railway in 1852, though it had been used previously in France and North America. The tins were hired by passengers and placed in a floor recess. Findlay, describing the working of the LNWR,[19] states:

> . . . from November 1 to March 31, every compartment (of all classes) was provided with at least two foot-warmers. The ordinary warmer is an oblong tin filled with water and sealed: it is then placed in a boiler until the water is hot. The present soda-acetate warmer is now (1899) in use on all main lines of the LNWR—a comparatively recent introduction. The heat is retained nearly three times as long as the water tins, viz, about 8 hours. The heaters are charged thus—7 quarts of liquid soda-acetate are placed in each, 7 oz of water added, and 2 cast-iron balls 2 in. dia. and weighing 20 oz are placed inside. The entire heater is warmed to boiling point and then sealed.

Ellis[7] says the soda-acetate warmer was introduced by the LNWR in Webb's time and it was later adopted by other railways. The foot-warmer went out of general use about 1901 though it was still available until c1914 and later on slip coaches owing to the difficulty of arranging steam hose-couplings for these.[3] A Midland Railway working timetable of June 1911 gives detailed instruction as to the supply and distribution of foot-warmers to the public. Similar soda-acetate heaters were brought into use in Australia in 1891 and not finally phased out until 1976. They may still be found on certain sections of South African Railways.[9]

Fuel-burning stoves do not seem to have been used in passenger vehicles in Britain, though they were employed in Europe at least until the end of the 19th century. In Britian, however, stoves were regularly used in guard's brake vans where there were no passenger seats; they remained in use well into BR days.[25] Gautier (*Voyage en Russie*, 1873) commented that the foot-warmer would soon freeze in Russia. Wood-burning stoves were used to warm the carriages to a temperature of 19 or 20°C. All classes had the same mode of heating: 'The peasants and the seigneurs are equal in the face of the thermometer; it is a question of life or death'. The drawing room of the coach for the President of Argentina (1892) had an open fire and overmantel. The open fire was used also in a later train (1910).[28]

Hot-water heating. Hot-water heating was used for the Royal Saloon built by the London and Birmingham Railway in 1843.[1] It was designed by Jacob Perkins and consisted of a boiler fired by four oil burners, with a ring of pipes within the double floor of the coach. The pipes were covered by a brass grating. The boiler and water tank were mounted beneath the coach. The carriage itself was provided with quilted furniture for sound and heat insulation.

The Baker system of hot-water heating seems to have been introduced in USA by Nason. It employed a boiler with a conical fire-pot containing a spiral coil filled with brine—in effect a Perkins' high-pressure system with expansion vessel and safety valve.[5] There was a draught regulator of the aneroid type, working on the pressure in the flow pipe. The first Pullmans, in America in 1858, employed a coke-fired boiler.[8] An improved version was supposed to be fire-proof, that is, the coals were contained even in the event of a crash. In a later version of the system, locomotive steam was used to heat the brine or water. A shell-and-tube calorifier consisting of four $\frac{3}{4}$ in copper pipes in a 3 in wrought iron cylinder $3\frac{1}{2}$ ft long was fitted in the pipe leading to the expansion drum.

The system was introduced to Britain in the American-built Pullmans for the Midland Railway (1874). These were oil-fired; so too were a GNR Pullman of 1880 (the expansion vessel was placed on the roof), Bore's first LNWR sleeper of 1881 and a dining-car for the Harwich boat train of 1891. Gas firing was used in some LNWR dining-cars of c1893.

Another experiment in the latter part of the 19th century was carried out by the Glasgow and South Western Railway, but it came to naught. Small boilers on top of the gas lamps served a closed-circuit heating pipe in the compartment below.[7]

A luxury sleeping car for the Chemin de Fer de l'Est of France, intended for use on international trains, was exhibited in Brussels in 1897. A boiler (probably solid fuel) was mounted on the buffer at one end of the coach and hot water circulated by gravity through heating panels in the floor. The expansion vessel in the roof contained a small coil which served to prevent freezing of the water for flushing the toilets.[10]

Steam heating. Steam heating was tried on the West Lancashire Railway between 1878 and 1897. A small boiler placed in the guard's van supplied steam via a train pipe to radiators in the adjoining 4-wheel clerestory coaches.[7] A train for Franz Josef of Austria (1891) included a coach with a boiler and vertical steam engine to provide heat and electricity.[28] In 1885, the Cheshire Lines used Laycock's system, with steam from the locomotive, while the first GWR train with steam heating throughout was a Birkenhead corridor set of c1890, the heat being controlled by the guard.[3]

Moreau commented in 1897 that steam heating had but one drawback, namely the continuity of the piping. This objection was more apparent than real: 'we believe that this system will become almost universal in the future, above all when improvements render it more controllable and practicable'.[6] Steam heating became standard on the GWR from 1901 onwards. In the Dreadnought stock of 1904–7, the heating in the dining cars could be regulated by the passengers. Graduated controls were introduced in the 1920's.

Claypool, writing in 1903, noted that steam heating was common on British trains. A section of steam pipe was placed beneath the seats, supplied with steam from the train pipe suspended beneath the coaches. Flexible couplings were used between the carriages and included a device for draining the loop formed by the hose. The pressure in the steam pipe was controlled by a reducing valve on the locomotive. (On the Midland Railway, exceptionally, a two-pipe system was used, to return condensate to the tender. The steam was at a higher pressure than in the open system, giving 'a higher temperature than is necessary to produce healthful heating'.) A very small amount of heating surface was provided—about 4 ft^2 per compartment.

> The carriages have this heating surface at the sides; the pipes are continuous and of equal size throughout. Beneath the seats and at the sides will be noticed a series of copper fins bolted directly to the pipe and pointing upward.[24]

Claypool advocated placing the heating units in the centre of the floor, forming a portion of the flooring; Naylor commented that this was quite common in Europe. Yates preferred a plenum system to ensure both heating and ventilation. He recounts that on a journey from Manchester to London, the temperature at the start was 40°F, rising finally to 55° on arrival. A radiator under each carriage would, he said, supply a sufficient quantity of heated air to the whole coach. Claypool mentions a scheme with a nest of pipes at each end of the coach, air being diverted through it as the train travelled by a sheet iron duct: 'air is bound to get into the compartment, and the passengers get fresh heated air, although at the same time it may be dust-laden'.[24]

A novel steam system was used in 1905 in the Caledonian Railway's Grampian coach. The steam was used to heat soda acetate in a storage vessel, thus providing some heating while standing unattached to a locomotive.

Gresham and Craven made a direct storage system:

> There is a continuous heating pipe inside the entire length of the train; in each carriage and between each compartment there is a cylinder placed round the service pipe. These cylinders are so constructed that they will continue to give off heat when steam has been shut off the train. The service pipe connecting these cylinders takes the form of a foot-warmer in the centre of each compartment and, as this particular space can only be reached by persons occupying the centre of the compartment, this principle does not produce uniformity of heating effect.[24]

In G. D. Peters' variant, exhaust steam was used either directly or via storage heaters containing soda acetate. The steam pipe was the inner pipe of the heater and was enclosed by another pipe containing the chemical. The GNR also used a storage system until 1906, when it ran a series of trials to compare it with the low-pressure system used by the North Eastern. As result, the low-pressure system was adopted for future stock.[11]

The use of exhaust steam from the engine had been suggested, but 'unless the Locomotive Superintendent will permit some radical departure in the construction of his locomotive I fear we shall never attain this desired end'.[24] As an alternative, Claypool proposed the use of an air pump on the tender to maintain a vacuum in the return pipe of a two-pipe system and to assist condensate return. Such a plan would ensure that each radiator would be uniformly supplied with steam over the whole length of the train; moreover the steam temperature would be reduced. Vacuum heating of this kind was in use on the Pennsylvania Railroad, steam at 10 lb gauge pressure being employed. For ventilation of the car, fresh air was admitted through pipes at each end of the carriage and passed through the radiator casing to be warmed before entering the car. Vitiated air escaped through ventilators in the roof.

A whole range of steam systems was in use in America in the early years of the 20th century. The 'Economy car heating system' made use of exhaust steam from the air pump used for providing brake power. Exhaust steam and water were discharged to a reservoir where the water flashed into steam and this was used in the train heating pipe. Live steam could be used to supplement this if required.[5] In Gold's storage system, live steam entered a vessel filled with bricks, the condensate being run to waste. The vessel was usually a 5 in boiler tube beneath the seats. In the vapour system, an automatic inlet valve admitted just enough steam to condense. The outlet temperature was maintained at 200°F by a thermostatic valve (a capsule containing fluid boiling at 180°F). This valve was placed at the condensate outlet beneath the coach, where it was subject to both the condensate and the outdoor air, providing some degree of weather compensation. When both steam and condensate reached the valve, it closed the steam inlet valve. In some cases standard steam radiators were used as the heating surface, in others a cylindrical emitter was used, consisting of a steam pipe with a surrounding air jacket. Differential expansion of the pipe and jacket provided thermostatic control of the steam admission (Westinghouse c1910). Finned tube heaters under the seats were in use in Britain also in the 1920's. The GWR used a calibrated inlet nozzle to ensure the correct quantity of steam.

By 1925 the vast majority of trains were heated exclusively by steam taken from the locomotive (or from external sources during prolonged periods of rest) distributed through radiators by piping, and more or less controllable by the passengers.[6] The writer of the *Review* mentions three systems namely, atmospheric (train pipe pressure less than 40 psi), pressure, and storage. The atmospheric system was regarded as the most economical.

Standard BR stock in 1951 used steam heating with tubular (annular) finned heaters, with thermostat and passenger controls. Ventilation was by sliding vents and roof extractors.[18] The annular heater was also used in America, though with some differences—steam was supplied at 250 psi at the locomotive, dropping to perhaps 5 or 10 psi at the last coach, either to finned tube heaters or to a steam/liquid heat exchanger (using anti-freeze). When steam was used direct, the outer tube carried the returning condensate and heat transfer between the steam and the condensate ensured a uniform distribution along the length of the car.[23]

Design. In an empirical approach to design in 1896, Churchward of the GWR stated the amount of steam heating surface required to be

1st class: 1 in of 2 in pipe per 3.6 ft^3 of compartment
2nd class: 1 in of 2 in pipe per 3.5 ft^3 of compartment
3rd class: 1 in of 2 in pipe per 3.0 ft^3 of compartment

The differences arose through consideration of the ability of the extra horsehair and trimmings in the higher classes to retain heat after the compartment had been initially warmed.[3] The usual temperature was 55–60°F; a thermometer was provided in the first class compartments. Just after the turn of the century, design was on a slightly more rational basis. Claypool[24] details this as

$$Q = S\ K\ (t_i - t_o),$$

where Q is the total heat requirement, K a coefficient representing the transmittance of window, roof, sides and floor of a compartment, S the corresponding area and t_i and t_o the assumed inside and outdoor temperatures. As an example, for a first-class compartment with 30 ft^2 of window ($K = 1.03$) and 150 ft^2 of sides, roof and floor ($K = 0.104$) and, taking the temperature difference as 23°F, Q becomes 1070 BThU/hr, requiring 4.27 ft^2 of heating surface with steam at 212°F; this was for a compartment 6 ft × 8 ft × 7 ft high. The formula is that for an exposed building and hence analogous to, and suitable for, a moving carriage. The coefficients K are those prescribed in Germany for public buildings. Ventilation losses were ignored since, Claypool said, 'no adequate means are provided for this without causing uncontrollable draughts'.

A later reference of 1925 [6] indicates that design had returned to an empirical basis—from 1.8 to 2.75 in^2 of heating surface should be allowed per cubic foot of compartment volume; no main pipe should be less than 1½ in i.d. for steam under pressure, while larger sizes would be needed for atmospheric systems; the maximum pressure in the train pipe was to be 60 psi and the temperature in the compartment should be not less that 55°F. It goes on:

> From a study of the tables, it is apparent that an economy in steam consumption is effected by using heaters of small diameter, the amount of heating surface being obtained by an increase in length. With small diameters, a carriage is warmed more quickly than with large diameter heaters, though the latter retain their heat longer after steam has been cut off. This, however, is of less importance than rapid initial heating.

The ASHAE Guide of 1956 describes the method then used in USA. The finned-tube convectors are rated at 90,000 BThU/hr to maintain a minimum car temperature of 60°F; a warm-air circulation supplies 100,000 BThU/hr to cope with ventilation loss and some 20% of the structure loss. 2400 ft^3/min are circulated, of which one-quarter is fresh air.[23]

The heating and cooling loads of passenger vehicles have received much attention in post-war years, notably with the establishment of the international vehicle testing station in Vienna.

Electric heating. Electric heating (a warm-air system, with electric blowers and extractor fans) was used in the GNR/NER Royal train built in 1908. Spiral-wire elements were in occasional use in America at about the same time. A saloon coach on the London, Tilbury and Southend Railway (c1913) had 'an electric fire in an apparent grate, all of which could be folded up and turned into a writing-desk'.[7]

Ceramic formers with spiral windings, by Belling, and Morganite graphite heaters were in use in Britain in the 1920's, the latter having been introduced c1923.[6] The Metropolitan Railway ran a Pullman service from London to Verney Junction in 1910, with coaches both steam and electrically heated (part of the journey was steam-hauled). Gresley mentions the use of electric heating on steam trains in about 1928. His first coaches dispensed with steam heat but in the late 1930's it was reintroduced since the batteries could not meet the electrical load at stations.[11] With the advent of electric traction, electric heating has become much more usual. The Southern Region of BR used 300 W 60 v heaters, ten in series, on 600 v lines. Until 1950 these were placed under the seats and controlled by the guard. A maximum temperature of 13°C was thought adequate, partly because journey times on commuter services were short and partly because the passengers would be wearing outdoor clothing. After that date, the increase in domestic central heating and the adoption of lighter clothing pushed the required temperature to 23°C and the load per car to 25 kW. An experimental system using the heat generated by rheostatic braking has been tried.[17]

On British Railways stock, a modified pressure heating and ventilating system was being tested in about 1967. It comprised a 20 kW 800 v fan and heater assembly, with automatic recirculation control designed to change over from fresh air to recirculated air whenever the temperature in the toilet fell to 18°C. The design requirements were set down as:[21]

Outdoor temperature °C	Internal temperature toilet °C	Internal temperature compartment °C	Air flow to compartment smoking m^3/h per passenger	Air flow to compartment non-smoking m^3/h per passenger
−5	10–18	21–22	24	16
0–20	10–18	21–22	30	20

The opportunity was taken in the modification to alter the air distribution pattern to assist in pre-heating the coaches. The Mark I composite coach had fourteen 0.75 kW heaters in 7 compartments, plus six 0.4 kW heaters in the corridor and toilets.[26] 1960-pattern sleepers were provided with an 8 kW duct air heater, supplemented by 0.5 kW convection heaters in each compartment.[20]

Koffmann has estimated that in Britain, for a train of 300 to 500 tonnes hauled by an electric locomotive, the heating power is 72% of the traction power at a speed of 75 km/h, falling to 15% at 150 km/h. For normal BR coaching stock the heater loading is from 1 to $1\frac{1}{4}$ kW per metre length of coach.

On the London Underground, the 'spraymat' heaters in use in 1969 were vertical panels beneath the front of the seats and provided a large area of low-temperature heating surface under thermostatic control. As an alternative, a roof-mounted fan heater was used on surface and sub-surface stock, though it could not be used in tube stock on account of the smaller clearances and of air pressure variations.[18]

VENTILATION AND AIR CONDITIONING

Ventilation. When, shortly after the beginnings of the railway, first class coaches were enclosed, ventilation was obtained, as in the sedan chair and the stage coach, by drop-lights in the doors and by quarter-lights. The earliest carriages of the Liverpool and Manchester Railway (*Queen Adelaide* and *Wellington*) built about 1830 were so provided. But on the Newcastle and Carlisle Railway (c1835) there was no provision of any kind; ventilation could only be effected by opening the door when the train was stationary.[7] An open second class carriage (late 1830s) of this railway is shown in Fig. 1.

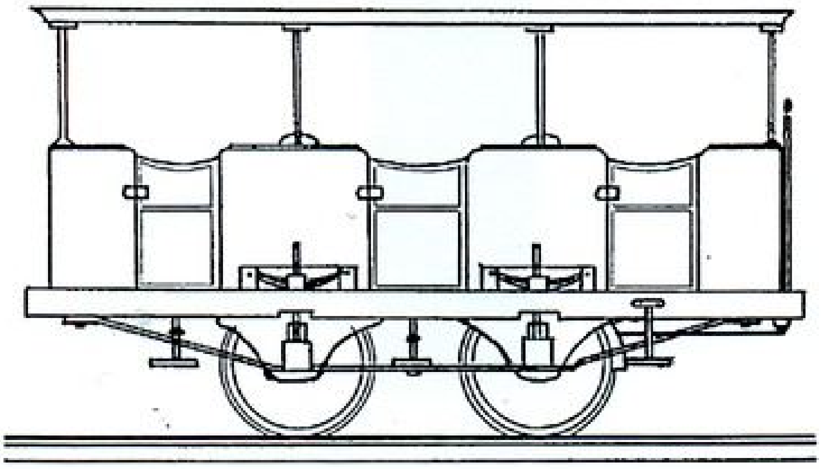

Fig. 1. Open second class carriage of the Newcastle and Carlisle Railway (late 1830s).

Top-hung opening lights above the windows were used on the Camden and Amboy RR in USA in the 1830's. Early second class carriages of the Manchester and Leeds Railway (c1850) had sliding panels of wood instead of glass in the doors for ventilation; these were also used in Austria. On the GWR broad-gauge trains the first class carriages had louvred ventilation openings in the top quarter-lights (1838); a similar arrangment was used in second class coaches in 1840 and for Queen Adelaide's saloon on the London and Birmingham Railway in 1842.[7] Louvred vents, with sliding hit-and-miss panels inside plus drop-lights in the doors, became fairly standard practice for many years. (Fig. 2)

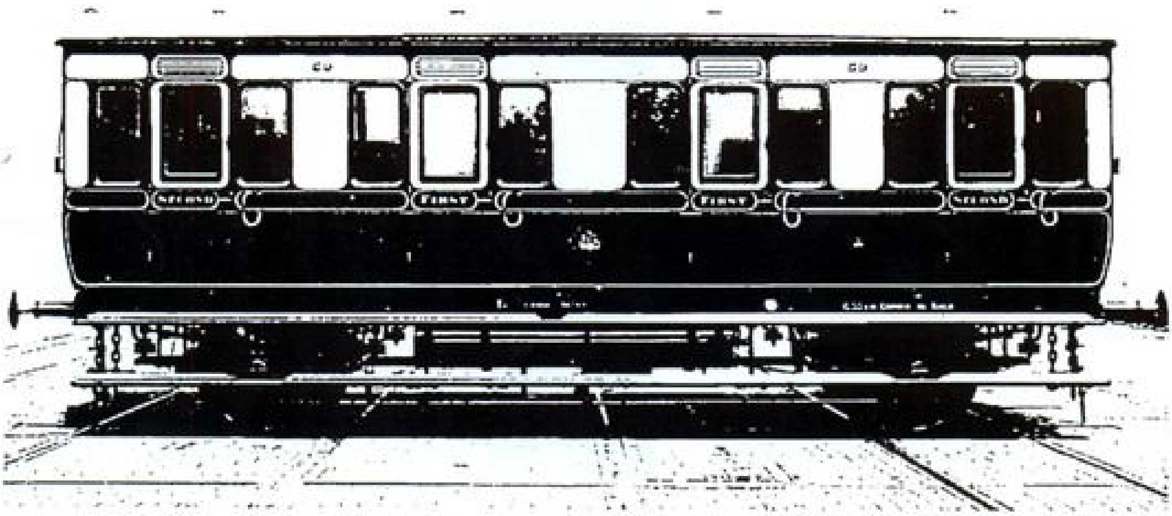

Fig. 2. GWR composite coach with drop-lights and louvred vents over doors (built 1879).
By Courtesy of British Rail and OPC Railprint

The clerestory roof was used in America in 1834 on the Philadelphia and Columbia RR and was introduced into UK by the GWR in about 1840. Its purpose was partly to improve daylighting and partly for ventilation. In some clerestories louvred vents were mounted on the sides; in more advanced forms hinged lights were provided. In the Dean stock (GWR 1877–1902) condensation was something of a problem and the hinged lights alleviated this.[3] The Pullman cars *Columba* and *Iona* built for GNR in 1880 had pivoted clerestory lights, with external gauze screens. On the Midland expresses of 1897 ventilation was effected by bottom-hung hoppers which directed incoming air into the clerestory, which also had opening lights.[16] Hit-and-miss vents in the sides of the clerestory were in use on LNWR in the 1890's; sometimes cowls were provided on the outside. Few clerestory coaches were built by British Railways after 1917, but the stock remained in common use until the 1950's and did not vanish until 1979.[25]

A roof ventilator in the form of a crown was provided on the Royal saloon of 1843 (London and Birmingham Railway).[7] Roof ventilators were in use abroad (e.g. Denver and Rio Grande 1850–1890; Jura-Simpson 1889). Laycock's 'Torpedo' extract ventilator was used on the roofs of coaches of the Midland and North British Railways in the late 1890's and it soon became common.[16] At first, these ventilators were placed only above smoking compartments. It was used on both top and sides of the clerestory on a batch of over 80 carriages built by LNWR in the period 1892–1903. This extractor was a static device, double-ended, so that it was effective in either direction of travel.

Limited trials of wind-vane cowls were made in about 1890 by GWR and GER but presumably they were unsuccessful, since they were not adopted. Rotating cowls do not seem to have been used on trains in Britain, though Russian trains of the 1870's had them on tall pipes above the roof to extract foul air.

Some attempts were made to improve the drop-light. Surrey Warner of the London and South Western used gauze dust-screens which came down on top of the light as it was lowered. Frameless lights were tried by the North Eastern in conjunction with Laycock's lazy tongs window lift; they could be adjusted to any desired height without the need for the usual strap and knob. They were, however, not absolutely watertight.

In the 1930's LMSR introduced the sliding ventilator above the principal fixed windows of corridor stock;[26] wind deflector vanes were fixed outside the coach. Inside, arrows indicated limits of movement of the slides; within the arrows, the opening was supposed to extract air while if the panels were withdrawn beyond the arrows the ventilator would admit air from outside. (Fig. 3)

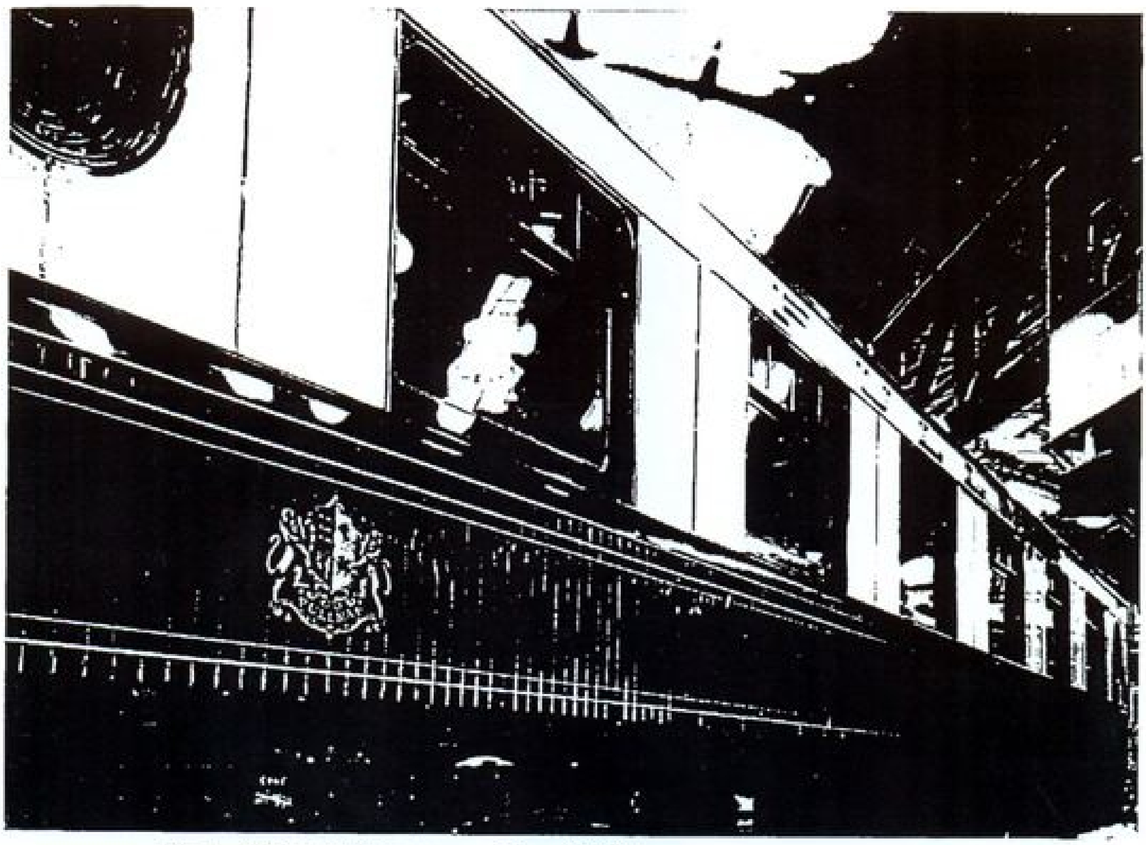

Fig. 3. Sliding ventilators over windows (1930s).
By Courtesy of the National Railway Museum, York

Mechanical ventilation. Electric desk and ceiling fans were used to promote air movement in a Royal saloon (LNWR 1902) and in a GWR *Dreadnought* dining-car in 1904. In the King's saloon of the 1908 Royal train warm air was supplied to the saloon from ducts in the ceiling void; extraction was through ceiling vents and an electric fan. Additional heating was provided by electric radiators.[11]

The Thermotank system of warm-air heating and ventilation was introduced for public use on first class sleepers of the LNER in 1930. Punkah louvres were fitted above each bed and supplied with warm air from a duct above the corridor. Stone's pressure ventilation was used c1934 in LMS sleepers and LNER dining cars and Gresley's *Silver Jubilee* train of 1935 was equipped with it throughout. The system as described in Stone's literature of 1934 comprised a heater, filter, fan and motor, a damper with reversing motor and a thermostat. The pre-filter of horsehair was followed by a viscous-coated filter. The heater battery was of finned-tube heated by steam; it had a bypass. The volume of air flowing in the bypass was controlled by the thermostat and damper. The thermostat was set to maintain 65°F, but in sleeping cars a night set-back of 5 to 15°F was provided. The sensing phial of the thermostat was in contact with the heater battery; when steam was supplied in winter, the thermostat switched the equipment on, and off again when steam was turned off. In summer, with the steam supply off, the equipment started when the dynamo generated current. The thermostat compensated for varying heat losses due to different vehicle construction or traffic conditions. There was no recirculation with this system.[29] It is doubtful if any serious design calculations were made—the openable windows would make nonsense of any ventilation assumptions. In any case, plenty of locomotive steam was available, so that ample margins could be provided. By 1964, pressure heating and ventilation was standard for new BR stock.

Cooling and air conditioning. The Great Indian Peninsula Railway first class carriages of c1871 had primitive cooling by R. D. Sanders' patent process.[1] A model of the coach is in the Science Museum in London. (Fig. 4) The two long first class compartments were separated by lavatories. Air for ventilation was drawn in via a double-ended scoop having an automatic flap valve which opened toward the direction of travel. The air then passed through layers of wetted cloth before entering the compartment through floor gratings. A large water tank in the double roof of the coach fed an automatic tumbler in an iron tank at one end of the carriage, whence pipes ran down to sprinkler pipes over the cloths. The flow of water from the main tank was regulated by a cock inside the coach. The carriage had double windows, the inner panes being side-hung to serve as air extractors, while the outer panes slid up and down in grooves. About 50 coaches of this kind were built. Coaches on many railways in the tropics around this period had deep hooded sunshades over the top part of the windows.

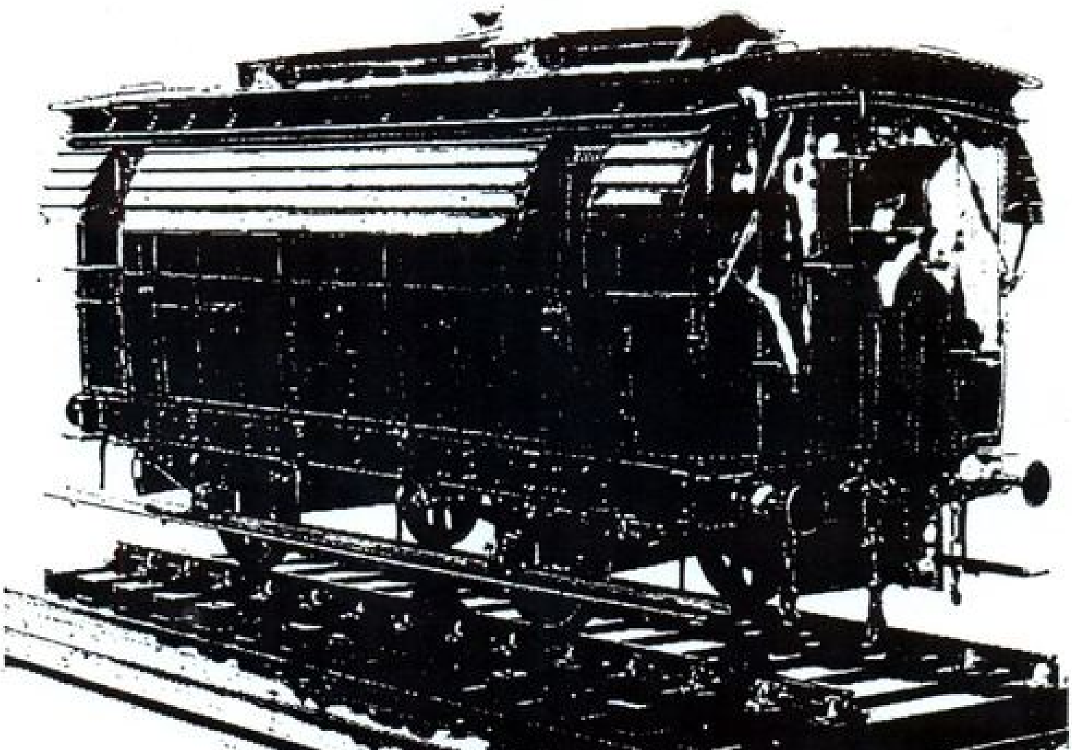

Fig. 4. Model of Col. Sanders' carriage for the Great Indian Peninsular Railway (1871).
By Courtesy of the Trustees of the Science Museum

Douane took a patent in 1903 and installed equipment containing 500 kg of ice in restaurant cars of the Wagon-Lits Co. running on Egyptian Railways. Ice blocks on the floor were used to cool the Maharajah of Jodhpur's private coach in the early years of the 20th century; later, fans driven by cup anemometers on the roof were added. An early attempt at evaporative cooling was on the *Southern Belle* in 1908, followed by equipment for the Sudan, Egyptian and Sao Paolo Railways. There is little evidence as to the degree of success.[27] In India, circulating fans with spray-type evaporative cooling were used up to 1939, though the Nizam of Hyderabad had a fully air-conditioned coach.[2]

About 1928, Carrier experimented with specially designed air conditioning equipment for a dining saloon on the Baltimore and Ohio Railroad. It was apparently successful and in 1930 the first diner in the world to have mechanical refrigeration (the *Yankee Clipper*) entered service on the New Hudson RR. A complete train ran from New York to Washington in 1931. Stone and Carrier came together and the Stone-Carrier system was introduced in 1935.

The first air-conditioned coach on British Railways was a GWR restaurant car pair of 1935 [3] and the LMS Royal saloon of c1941 had pressure ventilation and heating, with ice-block cooling.[25] These were isolated examples; air-conditioned coaches were not widely used on British Rail until many years later.

Stone installed air conditioning in a diner and first-class coach for the Melbourne-Sydney Mail in 1936 and orders for 61 air-conditioned sets, including the *Spirit of Progress,* followed. Air-conditioned trains were put into service in South Africa and Argentina in 1938. In 1947 Stone supplied 36 air conditioning sets for the Gandhi trains of Indian Railways. Each train consisted of a sleeping car, three club cars and a diner, carrying 260 passengers in all. Power equipment was carried in two brake vans and, for the first time in India, cooling was by electricity.

In about 1935 there were some 1000 air-conditioned cars on American railways. C. L. Smythe[13] gives the following details:

Type of system	Number	Capital cost per car	Operating cost per 1000 car-miles
Electro-mechanical compression	274	$6484	$0.99
Direct mechanical compression	133	$8515	$0.93
Steam jet	152	$8475	$1.02
Ice-block	363	$3982	$5.29

Taken overall, there was little difference in the owning and operating costs for the four systems.

In the Sturtevant ice system, ice was carried below the car. Water was pumped from the ice store to a cooler battery in the car roof; alongside this was a heater battery supplied by loco steam. The heated or cooled air was distributed throughout the car via a roof duct and exhaust air was voided through grilles in the clerestory. The plant included an ultra-violet air sterilisation unit.

With direct mechanical refrigeration the compressor was belt-driven from the axle; some cold storage was usually provided. Where electro-mechanical compression was employed thermostats in the return-air duct controlled the operation of the heating or cooling plant. The usual refrigerant was Freon.

The Union Pacific *City of Los Angeles* cars had double windows of polarising glass, so that by rotating the inner glass through 90° the window became non-transparent. In another case a motorised venetian blind was placed between the panes; this was under passenger control.

Design was based on standard air conditioning methods, using the ASHVE comfort zones. A typical load (in 1939) would be 72,000 BThU/h (6 tons refrigeration).

Similar systems were still in use in 1956.[23] Activated charcoal was sometimes used to reduce fresh air needs. Separate thermostats were provided for heating and cooling, though on/off control could be exercised by the guard. Sometimes a diesel generator was used to provide power for the whole train. More recently, there were separate diesel generators on each car which could give supplementary electric heating, the waste heat being used to supply hot water in the lavatories in the car.

The Stone-Platt system of air conditioning in use from 1968 on British Rail is described as follows:[22]

Cool air is admitted to the compartment via a roof duct and perforated ceiling. Warm air is supplied through a sub-floor duct to a nozzle bar beneath the seats. Separate fans are used for cool and warm air supply. A 3-cylinder reciprocating compressor, mounted on the sub-frame, is worked from 450 ampère hour 30 v dynamo-charged batteries (a sufficient capacity for 2½ hours' running whilst the train is standing). The electric heaters for both ceiling and floor warm-air supply are each rated at 9 kW. The refrigeration capacity is 4.5 t.r. Air from the compartment is vented to the corridor; some leaves the coach via grilles in the toilet door. Filters are provided for both the fresh and recirculated air. Passenger control of the warm-air supply, over the range 18 to 23°C, is provided. Each coach has its own generator and the system can be used with any form of traction. Fixed windows, double-glazed, are standard on BR air-conditioned stock. (Fig. 5)

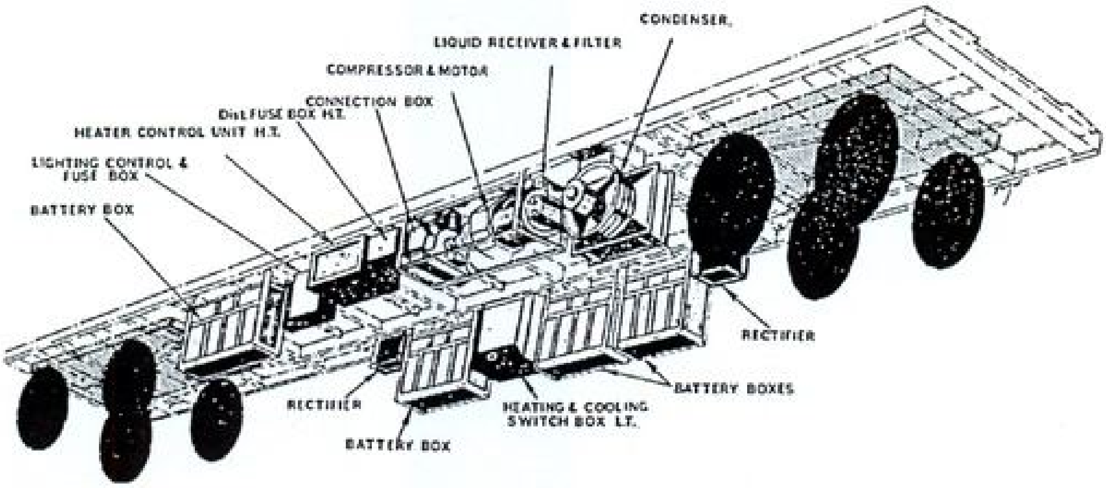

Fig. 5. Underfloor equipment on BR air-conditioned stock (1968). (*IHVE Journal*, Vol. 37, p. 112).
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The design conditions for the carriages are:[22]

20–22°C inside when the outdoor temperature is below 20°C,
rising by 0.5 deg for each deg above 20°C outside;
RH: 35 to 60%;
Fresh air: 30 (smoker) to 20 (non-smoker) m^3/h up to 26° outside
23 to 15 above 26° outside
Air speed in compartment 0.14 to 0.5 m/sec (depending on temperature)

The heating and cooling loads are calculated in accordance with normal building practice, the heat loss coefficients being experimentally determined, e.g. at the Vienna Testing Station.

For the Advanced Passenger Train, the design specification is broadly similar, save that a greater quantity of air is to be circulated and a maximum noise level of NC 65 is required. The equipment will provide 24 kW heating and 9 t.r. cooling per coach. The conditioned air is admitted to the coach at floor level; vitiated air is extracted via a ceiling duct, to be discharged or recirculated.[18]

BR diesel trains were provided with steam boilers which could be used as the source of energy for pressure heating. Air conditioning requires electric power; BR did not like the use of one or two axle generators on each coach, as being heavy and inefficient, nor did they like special vans for generator sets. Technically, the best solution is to provide power supply from the diesel locomotive. British Rail seems likely to adopt either power from the locomotive or from a separate power plant on the engine. Supply to the coaches will be at 800 to 1000 v transformed down for lighting and power.[22]

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DISCUSSION

Mr. L. R. Day, opening the discussion, asked whether Mr. N. S. Billington could say how much fuel was used in steam heating. The author replied that he had no direct knowledge but he thought that it would have used a considerable proportion of the locomotive's fuel. **Mr. E. F. Clark** challenged the estimate that heating used about 75% of the traction load; French railway authorities put the figure about 10%. [*Further information is given below—Ed.*]

Mr. D. H. W. Hayton asked whether the Author knew when the British railways segregated smokers from non-smokers. The Author replied that he had not a particular date in his mind but he thought that it had occurred in the early days of railway development.

Regarding the costs arising from the practice of smoking, Mr. Clark said that he had read a London Transport analysis which showed that during a coach's life a smoking compartment cost £5000 more than a non-smoking compartment, this sum being spent on burn repairs and redecorating.

Mr. Clark said that Indian railways had supplied ice to cool carriages and went on to report that in the 1940s electric trams were running in Toronto with stove heating for the colder weather.

Dr. A. Darling said that one of the first applications of the electrode boiler was for heating in electrically-propelled trains; he would have thought that it would have been much simpler to have used resistance elements instead of an indirect system.

Replying to **Mr. D. H. Tew**, the Author reported that the *Queen Adelaide* coach was preserved in the National Railway Museum at York.

There being no further questions, the **President** thanked Mr. N. S. Billington for having presented a most interesting paper and proposed that the audience should give him a hearty vote of thanks; this was passed with acclamation.

CORRESPONDENCE

Traction load required for heating. In a further written communication, Mr. Clark referred to a paper "Some considerations on the problem of the heating of British Railways Coaches" (F. J. Pepper, *Journal of the Institution of Locomotive Engineers*, Vol. 47, part 1, 1957). This gave a requirement of between 60 and 100 lbs of steam per hour per coach for British conditions, increasing to 250 lbs per hour per coach or even more for larger coaches in colder conditions in North America. Steam pressure should not exceed about 50 lbs/in^2 so that the temperature on flexible hoses was not excessive. Such a steam consumption gives, on condensation, a work equivalent closely approximating to the 25–35 kW per coach given in the paper as required for electrical heating or air conditioning.

To express the heating load as a percentage of the traction load is somewhat misleading. What matters is the average *increment* over the total power consumption purely for traction, due to the heating load; a contributor to the Institution of Locomotive Engineers paper mentioned above gave 6% as this increment. 10% seems more likely with modern standards and in line with the 15% figure quoted by Koffman at more realistic speeds when the heating is actually working.

In reply, Mr. Billington writes:

I would like to thank Mr. Clark for his comments of Koffman's figures. The clue lies in the fact (as Mr. Clark points out) that whereas the heating power remains constant (or nearly so) at all speeds, the necessary traction power rises steeply with speed. Also Koffman's figures for heating power relate to cold, not average, weather. In the same paper, Koffman does in fact indicate that the yearly energy consumption for heating is of the order of 10 per cent of the traction energy. I regret that I omitted to make this clear in the original text.