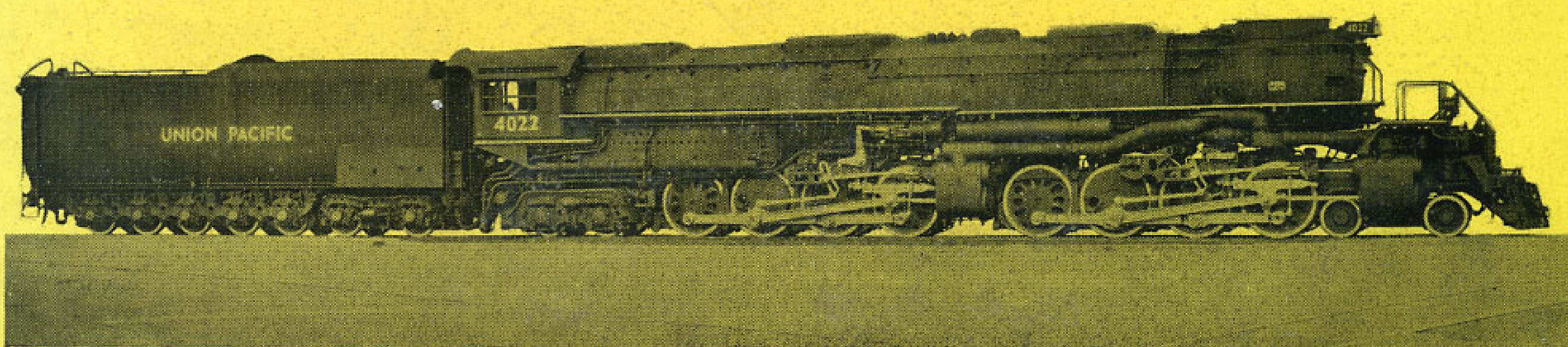
THE MALLET LOCOMOTIVE



A.E. DURRANT

The last mainline Mallets in the world are in Indonesia. Here compound 2–8–8–0 DD 5202 brews up at Tjitjalengka with a mixed train in October 1970

THE MALLET LOCOMOTIVE

A. E. DURRANT

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INTRODUCTION

THE MALLET must count as the most successful articulated steam locomotive ever designed, for the quantities built (over 5,000) and period of construction (1887–1961) greatly exceeded those of all other articulated types. Nevertheless, as correctly classified by Wiener, the Mallet, strictly speaking, is only semi-articulated for the rear set of driving wheels is rigidly mounted to the same centre line as the boiler, and only the leading power unit is designed to move radially in accordance with track curvature. There seems to be some doubt in certain people's minds as to how the Mallet adapts itself to track curvature, and this has been expanded upon in the book's initial technical chapter.

Due to the Mallet's immense popularity and widespread application, it has been found impossible within the compass of a single volume to cover the subject as fully as were the Garratt and Fairlie types in earlier volumes in this series, in which every engine built received attention. Indeed, the American Mallet alone is a vast subject, enough to fill two or three books, and a more selective approach has perforce been adopted. Nevertheless, this is less restrictive than might at first seem the case for most of the small European Mallet tank engines tended to fall within a few categories, and, gauge for gauge, within limited ranges of dimensions, so that typical case histories must suffice for most. At the other end of the scale, many of the huge American Mallets differed surprisingly little between builder and builder and between railroad and railroad, so that a similarly selective approach may be adopted for that part of the world also.

In selecting the treatment of the various Mallets included the author has been constantly aware of the extensive literature available on the subject, reference to which has been made in the bibliography. This has made the task of selection easier, for the availability of a reasonably recent work for reference eliminates the need for full coverage, as for example in Frank Holland's two-part history of South African steam locomotives (David & Charles, 1971 and 1972), wherein every class of SAR Mallet has been covered, and illustrated with photographs and dimensioned diagrams. Following this policy, more space has remained for dealing with lesser known Mallets and for describing in greater detail those of particular technical, operational, or historical interest. Such information as dimensions has been tabulated throughout in an effort to avoid a book which reads like a telephone directory!

So far as current operation is concerned the Mallet is to a great extent history, unlike the Garratt, of which hundreds remain at work. Nonetheless the Mallet has suffered less than the Fairlie and small Mallet tank engines are to be found at work in various parts of the world, whilst the Indonesian State Railways still operate what are almost certainly the last mainline Mallets to be found anywhere in the world. For those to whom the Mallet is a fascinating item of motive power, an early visit to Indonesia is high on the list of priorities.

A. E. DURRANT

Selcourt, Springs,
Transvaal, South Africa

NOTES ON QUANTITIES: Wherever the information is available the author has given the quantities built of each Mallet type, and where the information is at variance with such authorities as Bruce or Vilain chapter and verse in the way of running numbers have been quoted where possible. Bruce, a mainly technical man, seems particularly unreliable on quantities, a small blemish which detracts little from the value of his work. It has been impossible to quote all the engine numbers of Mallets built, still less to quote detailed builder's numbers, dates and renumberings, since over 5,000 engines have had to be covered in the one book.

NOTES ON DIMENSIONS: Dimensions have been quoted either in imperial or metric measures, but not both together. The criterion chosen was the design standard; in other words, wherever conveniently possible dimensions have been quoted in the units designed in: imperial for American railways and metric for continental etc, although inevitably there are odd locomotives which do not fit in. This method has reduced to a minimum the quoting of round figures as awkward fractions of the opposing system and should prove acceptable to all.

CHAPTER 1

DEVELOPMENT

THE ORIGIN of the Mallet type makes unusual reading, for the engine now so well known by its inventor's name was not exactly that which he originally set out to produce at all! Anatole Mallet (pronounced Malley), was a French engineer born in 1837 when railways and the steam engine were in their infancy. After graduating as a civil engineer he became interested in the theory of compound expansion as a means of increasing the steam engine's thermal efficiency and made studies of the unsuccessful trials of double expansion carried out earlier on in France and Britain. Convinced that there was something worthwhile to it, he developed his own system, using two cylinders, and patented it in 1874. The first practical application was in 1877 when the little Bayonne to Biarritz railway, way south on France's Atlantic seaboard, applied Mallet's system to an 0–4–2T and in the following year extended the trial to a similar 0–6–0T. Apparently satisfied with the results, Mallet then had to find wider fields of application than this little railway could provide and one may imagine, with a strong degree of likelihood, that he approached the various mainline railways and was rebuffed by them. Not to be daunted, he saw further opportunities in the little Decauville narrow-gauge light railways then beginning to proliferate throughout the country's *departements*, railways whose light and crooked tracks demanded articulated power if they were to carry worthwhile loads.

Lionel Wiener, writing in his classic book *Articulated Locomotives,* states that Mallet proposed in 1877 the application of his compound system to Meyer and Fairlie articulateds, but that 'first attempts led to . . . inconclusive results'. The wording of this phrase would indicate that actual physical trials were carried out but no evidence of the existence of a compound Fairlie can be found in Abbott's work on the subject, whilst the only actual compound Meyers mentioned by Wiener are the Saxon locomotives of the 1890s. One is left to conclude that Mallet never got further than his drawing-board with these proposals and that engineers were reluctant to add the unknown complications of compounding to the known hazards of high-pressure flexible steam pipe joints. Evidently Mallet then set to with thinking cap, set square and compasses, and, applying the *logique* which all Frenchmen regard as their national characteristic, deduced that the successful compound articulated would dispense with high-pressure flexible steam pipe joints, becoming in the process a semi-articulated with one fixed and one mobile power unit. Determination of which would be which needed little thought—the fixed frames naturally set themselves around the narrow firebox of contemporary practice and the mobile low-pressure cylinders, equally naturally, needed to be in proximity to the smokebox to simplify exhaust piping. The supremely simple concept of the unsuperheated compound Mallet is shown in Figure 2, with short, direct steam pipes from the dome to the high-pressure cylinders, and flexibly-jointed low-pressure pipe along the frames to the low-pressure cylinders, themselves just where they ought to be, ie, under the smokebox. The other two diagrams on the same page show how, with the improvement of superheating, the main high-pressure steam piping was of necessity longer and less direct, whilst the plumbing on a superheated simple Mallet reached further into the realms of complexity and potential maintenance headaches.

Regarded as a vehicle, the Mallet was unlike other articulated types in *not* being a double-bogie engine. On page 13 of *The Garratt Locomotive* is a diagram showing the main feature of all principal articulated types—Fairlie, Meyer, Kitson-Meyer, Mallet and Garratt. From this it will be seen that all but the Mallet are mounted on two centrally pivoting bogies. The exception, the Mallet, has a set of wheels at the rear, mounted in a rigid frame, and a forward mobile set which,

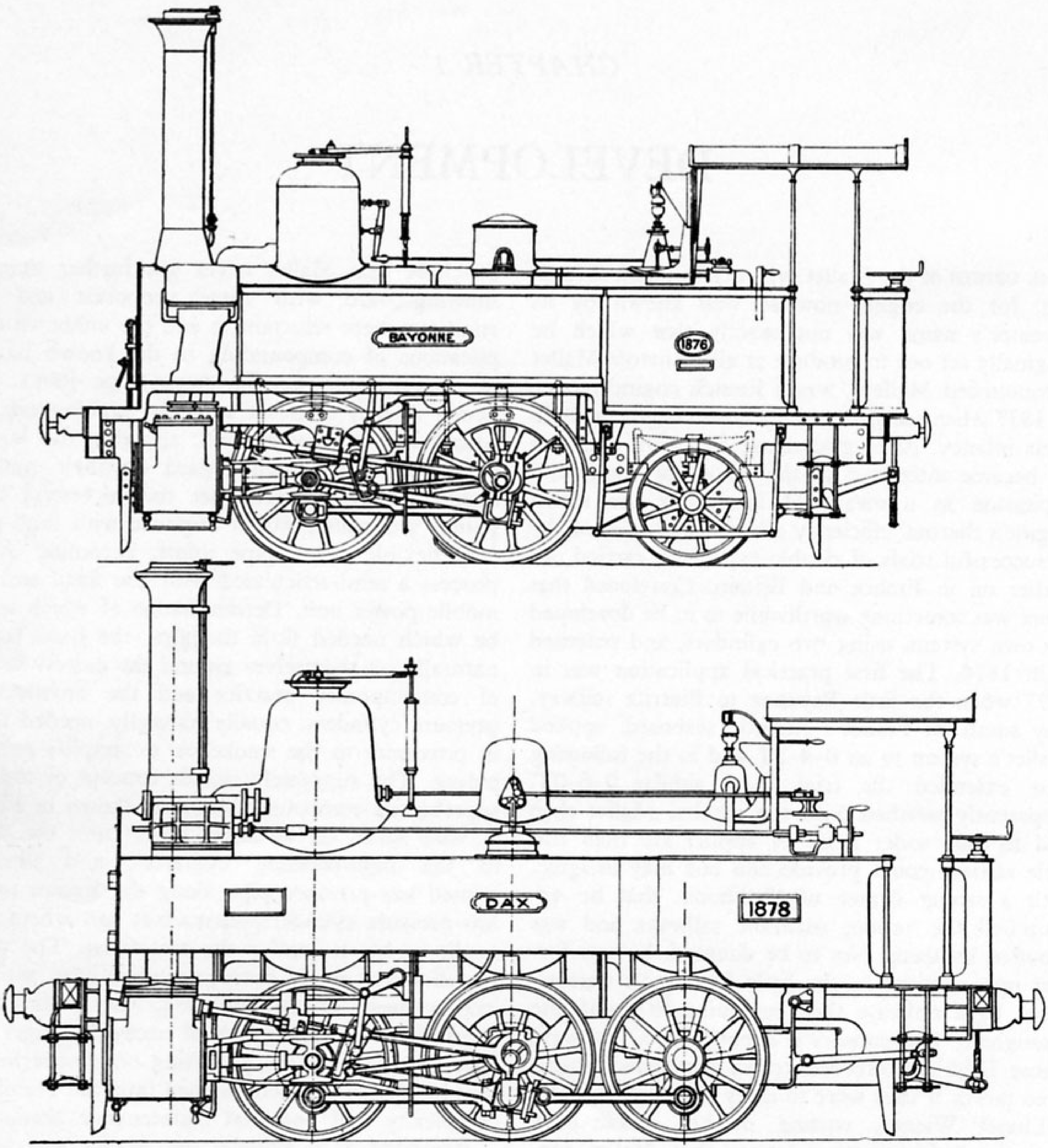


Fig 1 *The embryonic form—Anatole Mallet's two-cylinder compound non-articulated tank engines 0–4–2T and 0–6–0T, for the Bayonne to Biarritz railway in France*

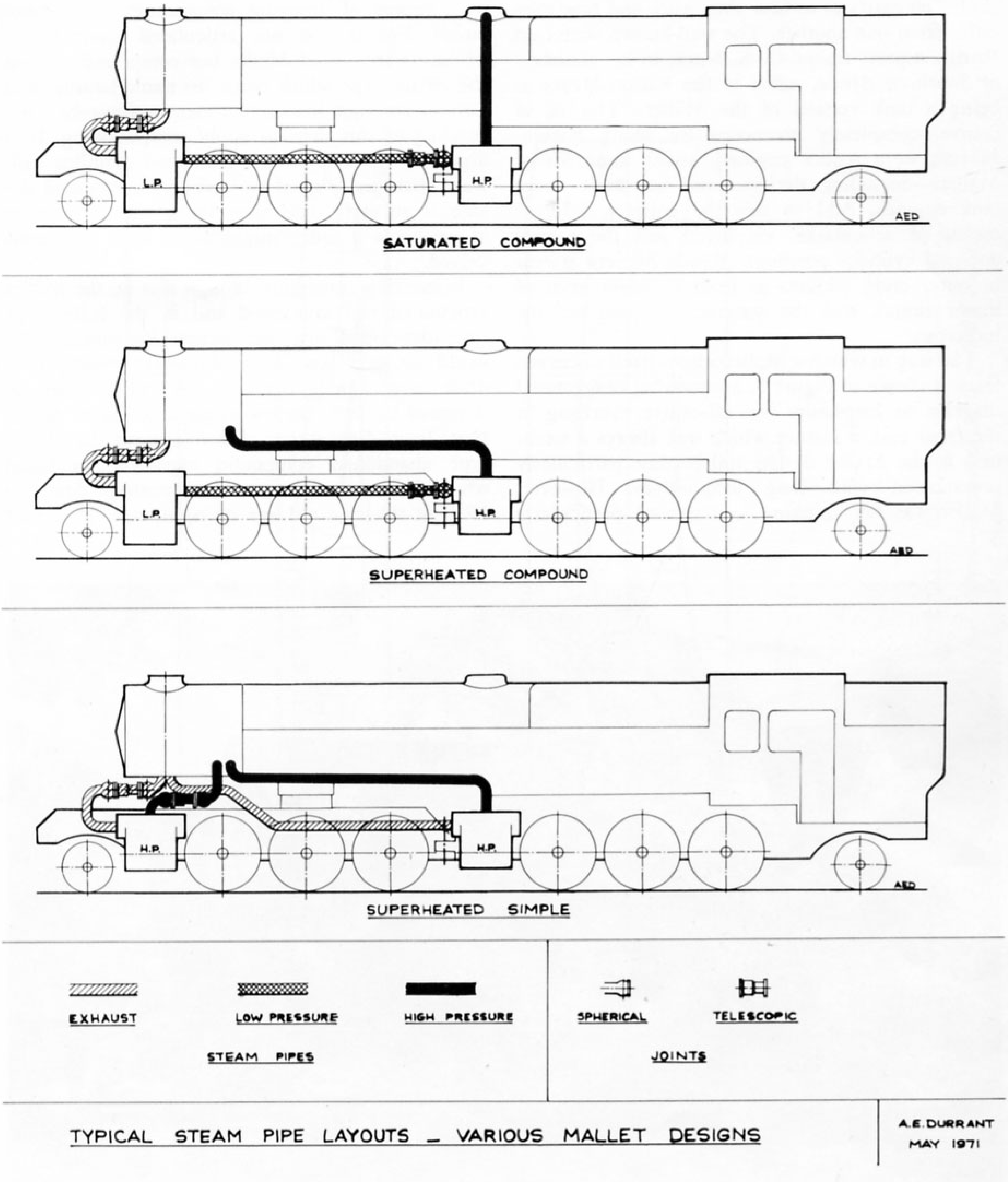

L.P.
H.P.
AED
SATURATED COMPOUND
L.P.
H.P.
AED
SUPERHEATED COMPOUND
H.P.
H.P.
AED
SUPERHEATED SIMPLE
EXHAUST
LOW PRESSURE
HIGH PRESSURE
STEAM PIPES
SPHERICAL
TELESCOPIC
JOINTS
TYPICAL STEAM PIPE LAYOUTS _ VARIOUS MALLET DESIGNS
A.E. DURRANT
MAY 1971

Fig 2

pivoting behind the wheels, is in effect a motorised pony truck. These differences have been described rather carefully for it seems that, amongst those unfamiliar with the Mallet and other articulateds, confusion exists as to how they work and how they differ from one another. The well-known writer on British express trains, O. S. Nock, in his *Railways of Southern Africa,* refers to the Kitson-Meyer as being a tank version of the Mallet. This is, of course, completely erroneous for many Kitson-Meyers were tender engines, whilst hundreds of Mallets—including the first and last built—were tank engines. Add to this the entirely different means of articulation employed and the utterly opposed cylinder positions (Kitson-Meyers at rear or outer ends, Mallets at front or inner ends of motor units), and the statement approaches the ludicrous.

The way in which a Mallet adapts itself to curved track is shown in Figure 3, a somewhat exaggerated diagram to emphasise the off-centre overhang at the front end, a feature which was always a weakness in the Mallet design and became particularly pronounced with long locomotives. However, Mallet was not thinking in terms of particularly long locomotives when, in 1884, he took out French provisional patent no 162,876 and, on 12 June of the following year, was granted full patent rights covering his system of locomotive designed purely as a means of applying compounding to articulateds. For it was not articulated steam which primarily interested Mallet but compounding, and the engine type which made his name familiar and famous amongst locomotive men was purely a by-product of this urge to apply compounding. It is arguable that had Mallet interested mainline railways with his original two-cylinder compound design at an early date, then the Mallet locomotive as we know it today might never have been conceived.

Interesting conjecture though this is, the Mallet articulated *was* conceived and in the fullness of time developed into the largest locomotives the world has ever seen, an evolutionary result which must have been far from Mallet's mind when he designed his little narrow-gauge tank engine prototype. In its later stages of development the Mallet type abandoned compound expansion, a trend which had started before the inventor's death in 1918 at the ripe old age of eighty-one. It is said

Not the first Mallet, but differing little in size or detail, a narrow-gauge 0-4-4-0T compound at Redjo Agung Sugar Mill in Java, Indonesia

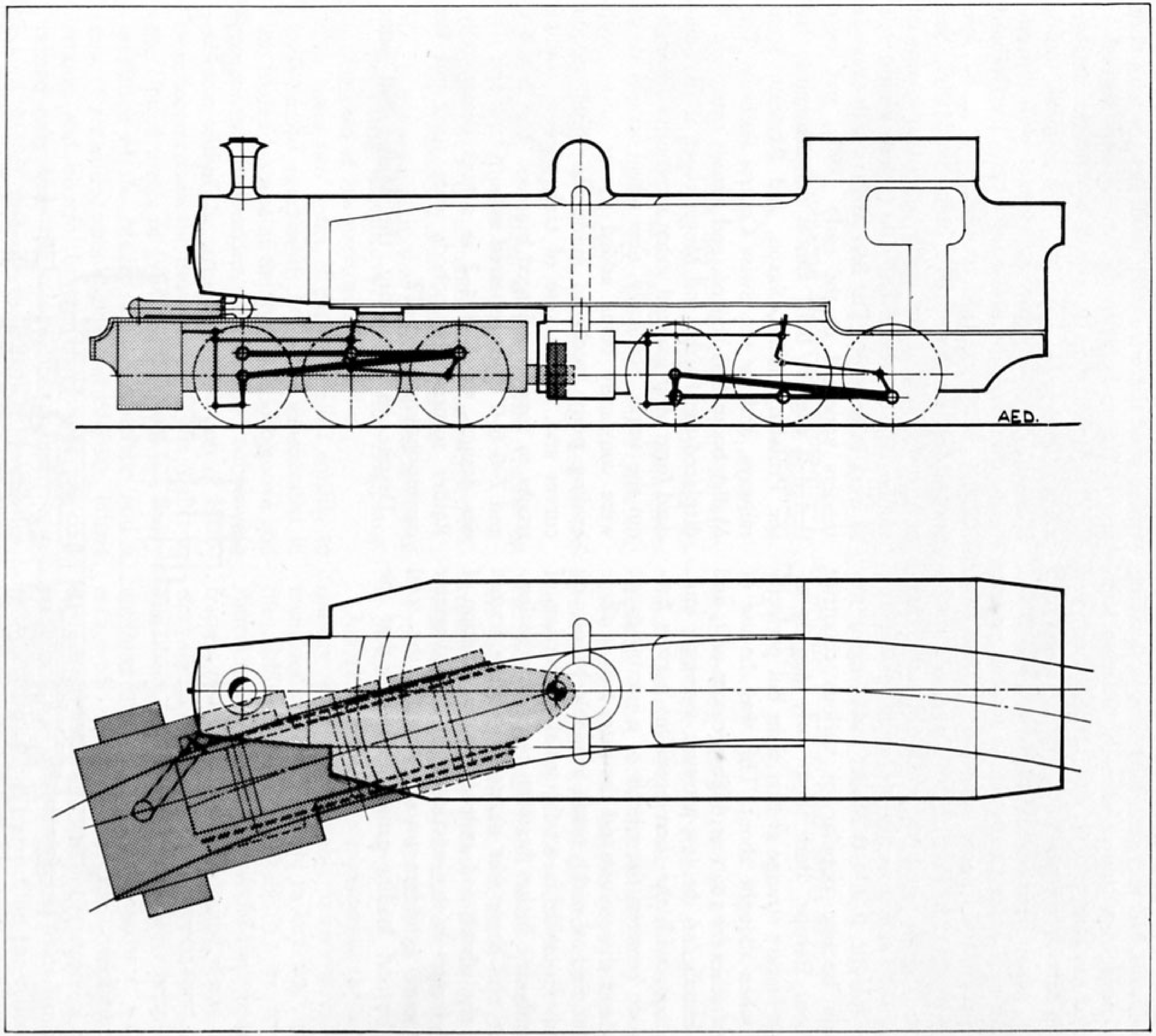


Fig 3 *How the Mallet negotiates curves—a view of an 0–6–6–0T on an exaggerated curve*

that these non-compound Mallets induced great anger in the old man, furious that the by-product of his articulated system had proved more popular than the compounding which had sired it!

Mallet's initial design for a specific interested party was an 0–4–4–0T for the metre-gauge Corsican Railways, but they took their time in deciding on the courageous step of actually ordering such an untried machine and the first actually built and placed in service was another 0–4–4–0T, this time of 60cm gauge. The Corsican project was dated 1885, the year Mallet was granted his full patent, and the prototype engine appeared in 1888 from the Tubize works in Belgium for Decauville tracks. This little engine ran at the Paris Universal Exhibition of 1889 and must have attracted considerable interest for the 0–4–4–0 Mallet tank engine immediately became popular in various countries throughout Europe. Both these early designs included a feature strange at first sight but perfectly logical when thought about. This was the use of outside frames for the rear, high-pressure unit, and inside frames for the low-pressure swinging unit. At the rear, with the then prevalent narrow firebox, space between the wheels of a narrow-gauge engine is at a premium and the extra two or three inches of firebox width made available by placing the frames outside is a substantial proportion of the twenty-one inches between tyres. At the low-pressure end there was no need to place frames outside the wheels and, indeed, the combination of outside frames in conjunction with large-diameter low-pressure cylinders usually brought the total width beyond loading-gauge limits, so that the mixed inside/outside frame design became quite a standard feature on narrow-gauge Mallets. Where a generous loading-gauge prevailed, narrow-gauge Mallets were constructed with outside frames throughout, with advantages in standardisation and riding stability, and for the broader gauges, or where wide fireboxes were used, designs with both sets of frames between the wheels were normal.

The Mallet soon developed beyond the narrow-gauge 0–4–4–0T concept. Six-coupled units, standard-gauge designs, and engines with separate tenders were rapidly evolved. By 1890, the Gothard Railway in Switzerland was running an 87 ton, standard-gauge 0–6–6–0T, built by Maffei, and before the turn of the century, another engine of similar type but exceeding 100 tons in weight was at work in Belgium. The first Mallets with separate tenders appeared in the early 1890s, and were 0–4–4–0 engines built almost simultaneously for the Prussian, Baden, Saxon, and Bavarian State railways, and for the Swiss Central Railway. The Mallet boom had started, and almost overnight it displaced the Fairlie and Meyer types as the standard form of articulated steam locomotive throughout the world. Naturally, new wheel arrangements were constantly being added to the range, with leading pony trucks to guide the thing around curves and, in the case of tank engines, trailing trucks to support enlarged bunkers. The 2–4–4–0 and 2–6–6–0 types appeared as both tank and tender designs, the 0–4–4–2 as a tank design only. Rather surprisingly, nobody ever tried out the corresponding 0–6–6–2T.

Despite its popularity, the Mallet had some

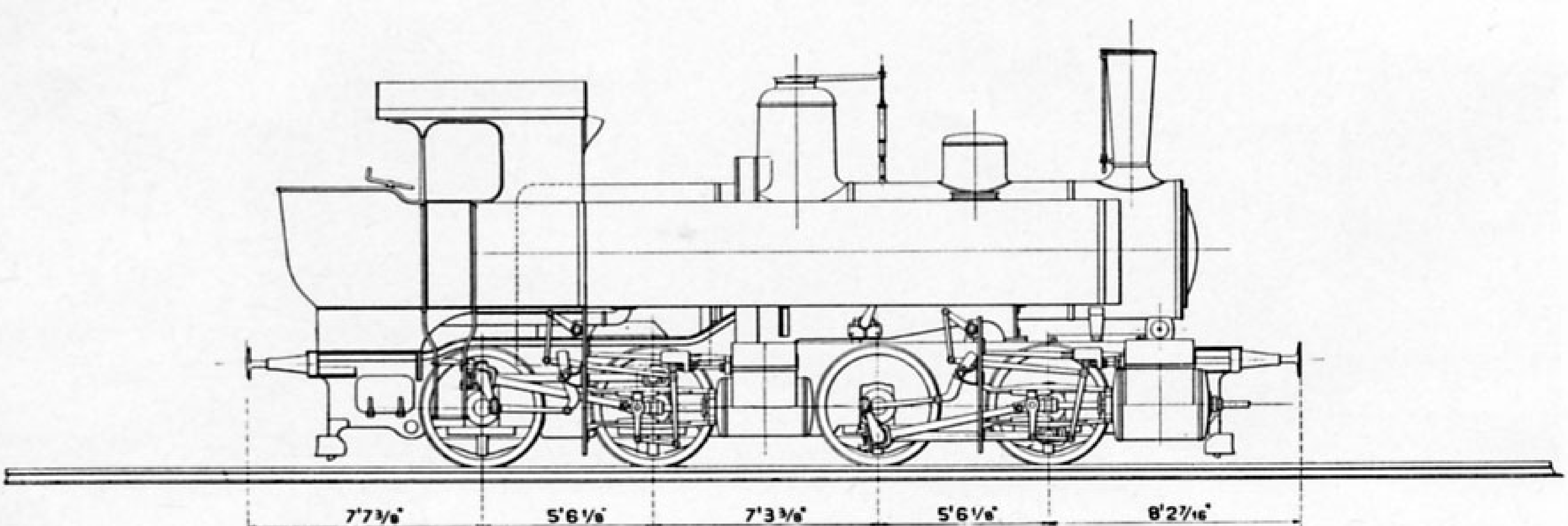
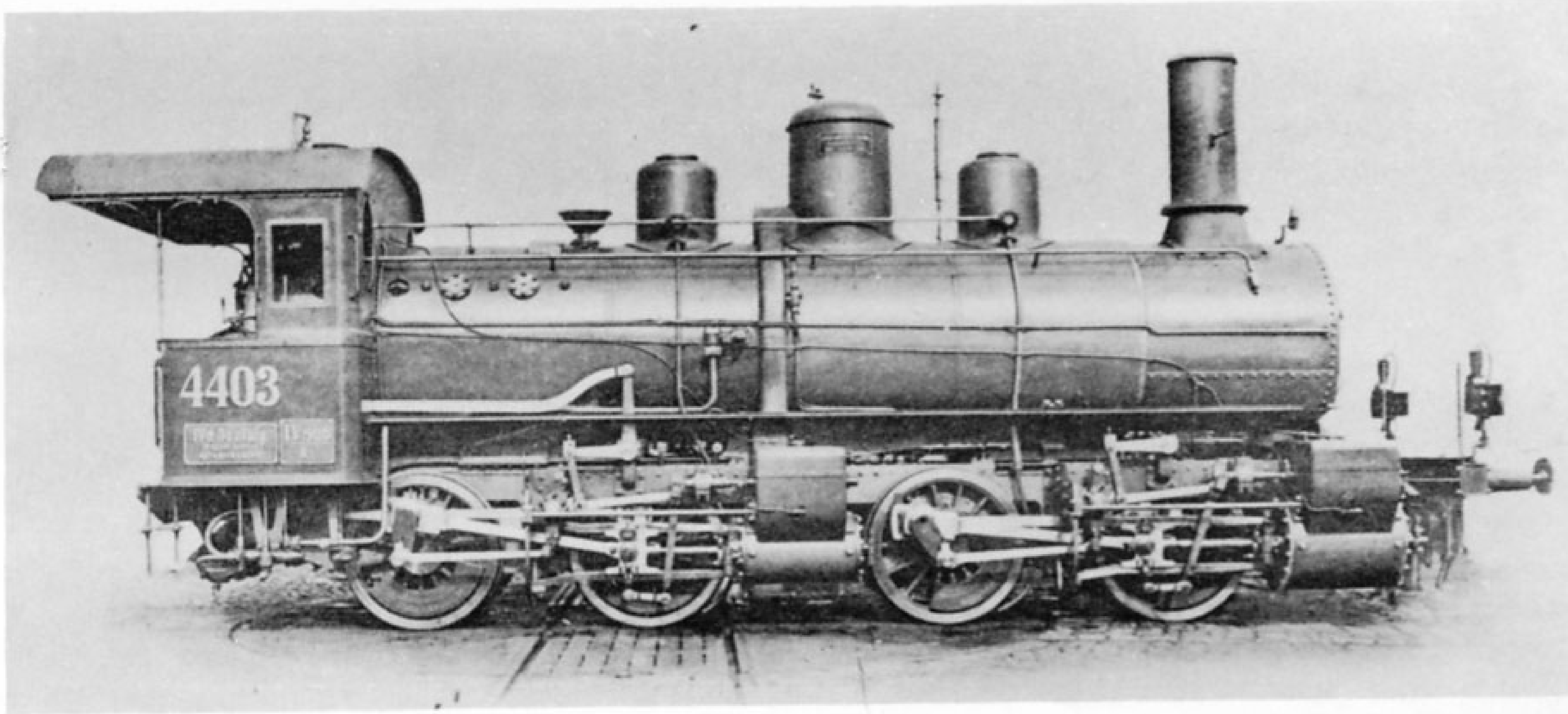


Fig 4 *Mallet's compounding as applied to articulated power: a basic 0–4–4–0T for the Swiss Central Railway, built by Maffei in 1890*



Hungarian Mallet development—1, the original 0–4–4–0 class, series 422, Budapest-built in 1898

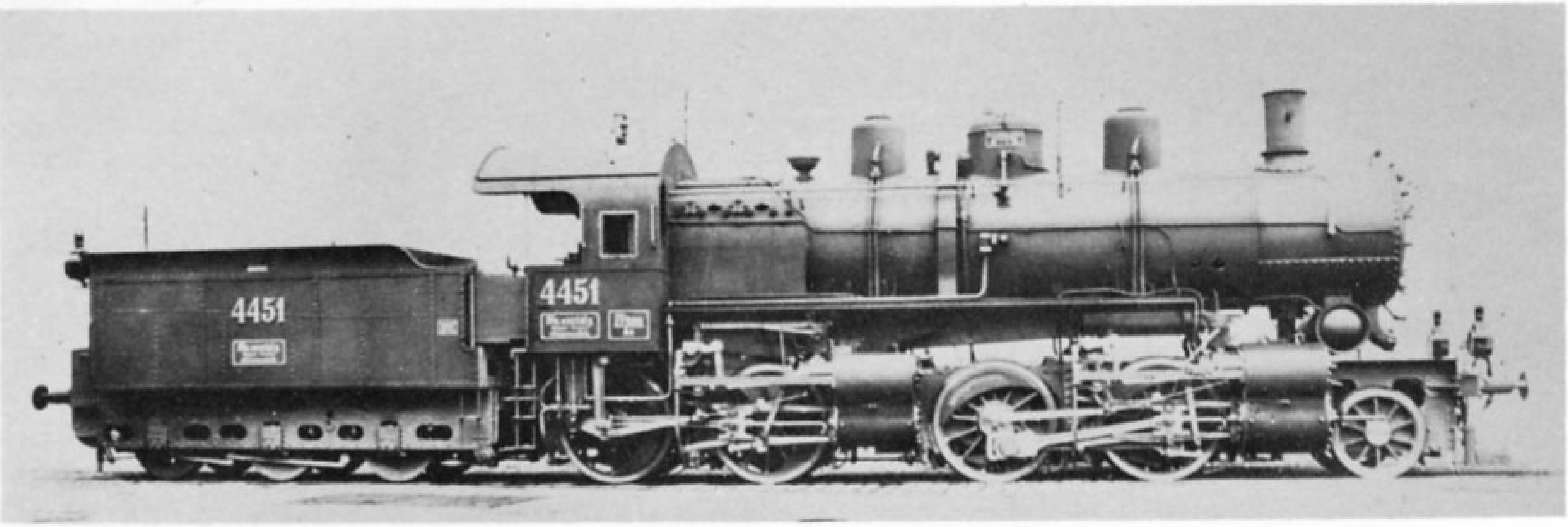
definite drawbacks and these were such that they increased with the size of the locomotive—increased, in fact, more rapidly as the locomotives themselves grew in size. These problems came into four broad categories:

1. Instability of the low-pressure unit, due to low inherent mass.
2. Overhang of boiler at front, with engine on curved track.
3. Difficulties of accommodating large low-pressure cylinders within loading-gauges.
4. Sluggish running, due to the impracticability of providing adequate valves for handling large volumes of low-pressure steam.

The latter two items, 3 and 4, applied equally to rigid-framed compounds but were exaggerated in the Mallet because of the increased locomotive and component dimensions. Never an outstanding problem within the sizes and proportion of European locomotives, the introduction of the Mallet to the United States in 1904 brought with it a heavy escalation of the Mallet's inherent defects and a host of remedies, some logical and effective, others strange and bizarre. In this chapter we are concerned only with the classic, four-cylinder compound Mallet and all variations and deviations from the basic theme, other than normal fire tube superheating, will be expounded upon in the succeeding chapter, 'Mallet Variations'.

The introduction of the Mallet to North America was an interesting phenomenon, posing a question or two not easily answered even now, some seventy years after the event. Historians of the day were usually content to record a rather stilted factual report on *what* happened—the equally, if not more interesting story of *how* and *why* things came to pass was regarded as a private matter, the end justifying, and obliterating, the means. There was in those day no E. S. Cox to chronicle the struggles and failures which preceded the successes, or if there were he would have been regarded as a nosey parker and not to be trusted with such information, an attitude this author encountered in his early years with the Great Western at Swindon.

American locomotive engineers at the turn of the century were a remarkably conservative body of men, not wont to innovate in any way other than the addition of more wheels. To be respectably American, the locomotive would have built-up bar frames, two outside cylinders, and inside Stephenson valve gear. Strange all-American exotica such as camelback cabs atop the boiler were permitted, but anything smacking of the transatlantic was rigidly eschewed. However, as the twentieth century dawned a rapidly industrialising America absorbed large numbers of immigrants from Europe, and many of these went to work on the railroads. For the technically qualified and the skilled, opportunities for rapid promotion presented themselves and senior positions on the railroads, or within the locomotive builders' establishments, began to be filled with first and second generation immigrants. With them came foreign features, Belpaire fire-



Hungarian Mallet development—2, the larger, mixed traffic 2–4–4–0 of 1905, for the Fiume line

boxes, Walschaerts valve gear, piston valves, Schmidt superheaters and, of course, the Mallet.

It was on the Baltimore & Ohio Railroad that America's first Mallet appeared, and the company's superintendent of motive power was one J. E. Muhlfeld, a name indicating an obviously Teutonic ancestry. It is interesting to surmise that Muhlfeld had close connections with Europe which had led, either before emigration or on subsequent visits to his fatherland, to direct personal contact with Mallet engines. The author has no evidence to support or disprove this hypothesis, but the fact remains that Muhlfeld was responsible for introducing the Mallet to the New World, an act which was to have far-reaching consequences. Muhlfeld's problem was Sand Patch gradient, an obstacle which heavy freight trains had to surmount in order to cross the Alleghenies. Trains of 2,000 tons weight needed three 2–8–0s (one hauling and two banking) to heave them over the summit, the American 2–8–0 of those days being little more powerful than was being built in Britain and Europe. For replacing two bankers with a single engine and to reap the thermal benefits of compounding, Muhlfeld ordered from the American Locomotive Co the stupendous, 150-ton 0–6–6–0, No 2400, which was to become, briefly, the world's largest locomotive. The Mallet system was new to America and so was the Walschaerts gear which actuated its valves, but in all other details it was a thoroughly American design. No superheater was fitted and 78 sq ft of grate area were hand-fired, a killing task for a single fireman, although with two firehole doors two firemen must have been employed, leaving a nett personnel saving of one driver. Nevertheless, Wiener states that between 1905 and 1910 economies of 38 per cent were realised with the Mallet, and other railroads were quick to exploit the machine's potential.

Mallets were soon hard at work all over the USA, from East to West, and by 1911 over 500 had been built by Alco and, of course, Baldwin. The 0–6–6–0 type was soon eclipsed in size and power by greater behemoths and, apart from the 0–8–8–0 banking type, most had pony trucks at the front for guidance and often at the rear, too. Hence the 2–6–6–0 was built, soon superseded by the 2–6–6–2, and large numbers of 2–8–8–0s and 2–8–8–2s were also built. Two developments which made these huge engines possible were the superheater and, more particularly, a reliable mechanical stoker, without which the insatiable appetites of these steam dinosaurs could never have been appeased. Fourteen years after Muhlfeld's 0–6–6–0, Alco delivered to the Virginian Railway ten 2–10–10–2 Mallets, the largest ever built to the original four-cylinder compound concept. These engines were unexcelled in detail, too, for they boasted larger cylinder diameters (48in low pressure), and larger boiler diameters (9ft 10½in) than any steam locomotive ever built before or since. Truly the Mallet had made North America its habitat, just as later on the Garratt was to adopt Africa.

Meanwhile, elsewhere in the world the Mallet was being accepted with less enthusiasm, especially for mainline duties, although there continued to be a steady demand for small tank engines, 0–4–4–0T and the like, for secondary systems. In Europe, only Hungary developed the Mallet to any extent, and built over one hundred examples for mainline work. In Asia, the Dutch adopted the Mallet for their 3ft 6in-gauge lines in Java, and again had over one hundred built. Only South Africa, on that continent, had any large quantity of mainline Mallet tender engines, but even these totalled less than the century score. South America had a fair number of small batches amongst its numerous railway systems, but the type was all but unknown in Australasia. Some of the examples quoted above were direct results from the Mallet's American successes, as for example South Africa whose first Mallets, for the Natal Government and the Central South African Railways, were American built, as were the earlier SAR examples. Even in metropolitan France, the Mallet's birthplace, the Chemins de Fer de l'Est ordered two Alco 2–6–6–0 Mallets for heavy mineral work, probably on the grounds that Alco had built more mainline Mallets than any French builder! South America was of course, a natural outlet for American power, Mallet or otherwise.

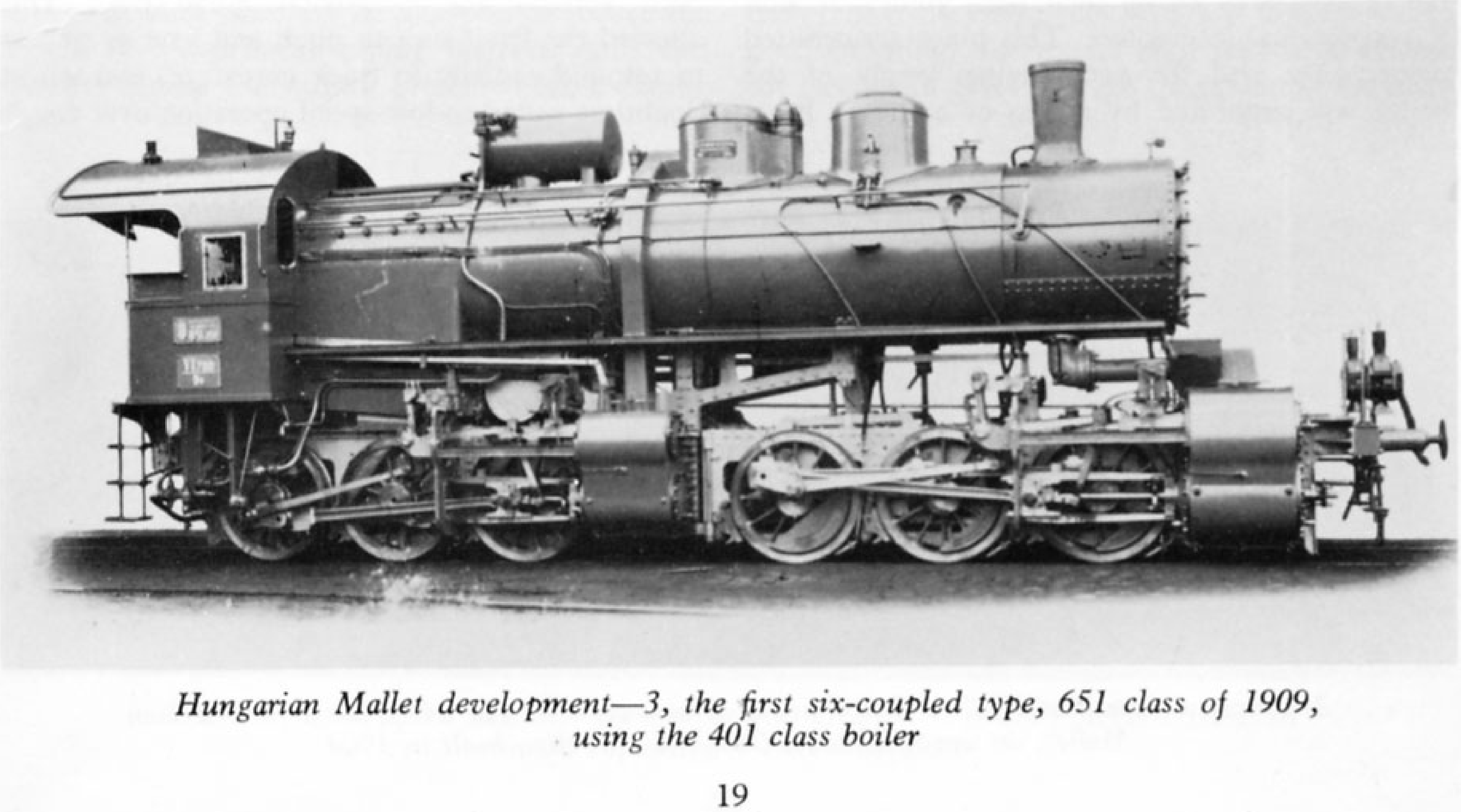
However, the weaknesses of the basic Mallet type, as previously enumerated, were beginning to count more and more against it, especially after the first World War when the pace of life began to accelerate and the slow and sluggish Mallet was found wanting in speed. Where slow, heavy haulage was required and nothing more, the Mallet remained popular and compounds were built for the lines serving the USA's eastern coalfields right up to the early 1950s. Elsewhere, compounding was slowly abandoned, and outside the USA and a few other small pockets of resistance the Mallet was replaced by the newer and more versatile Garratt. Within the United States of America the Mallet system of articulation remained favoured and, after going through some quite extraordinary development phases, the non-compound or simple Mallet became the accepted form for heavy haulage. These developments are outlined in the next chapter.

Constructional features of the Mallet

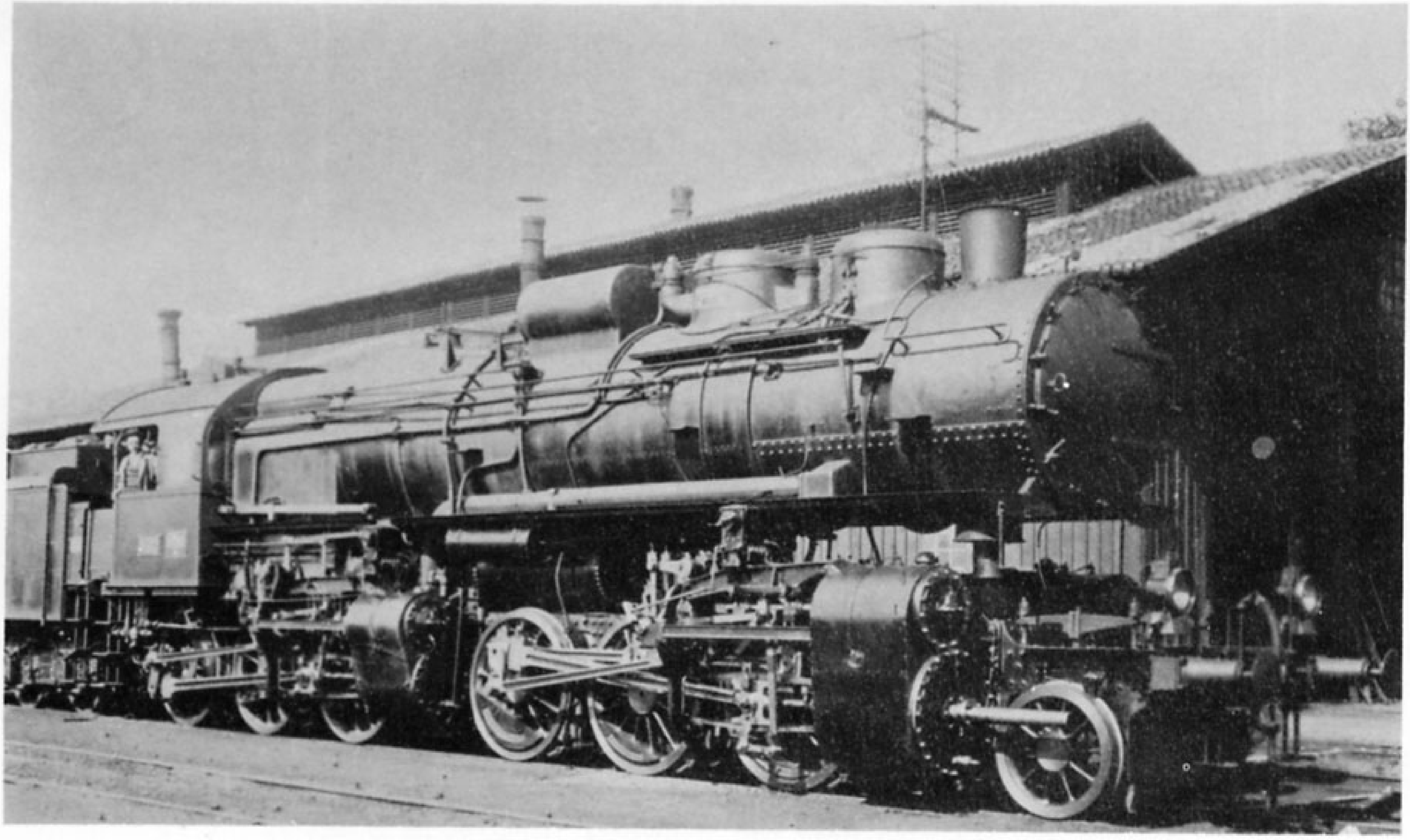
The Mallet locomotive was designed and built within the normal Stephensonian concept of the steam locomotive, in other words with a fire-tube boiler supplying high-pressure steam to reciprocating engines. There were thus no special peculiarities, such as the Fairlie's double-ended boiler, inherent in the system, although some unconventional components were applied from time to time. The main organs of the Mallet are considered below and their application to the locomotive's design are also discussed.

Frames

Apart from the articulated joint, framing was to normal design, plate, bar, or cast steel bed, either outside or inside the wheels to suit the railway's conditions. The use of inside frames on one unit and outside on the other was peculiar to the Mallet, and the reasons for this construction were given earlier in this chapter.



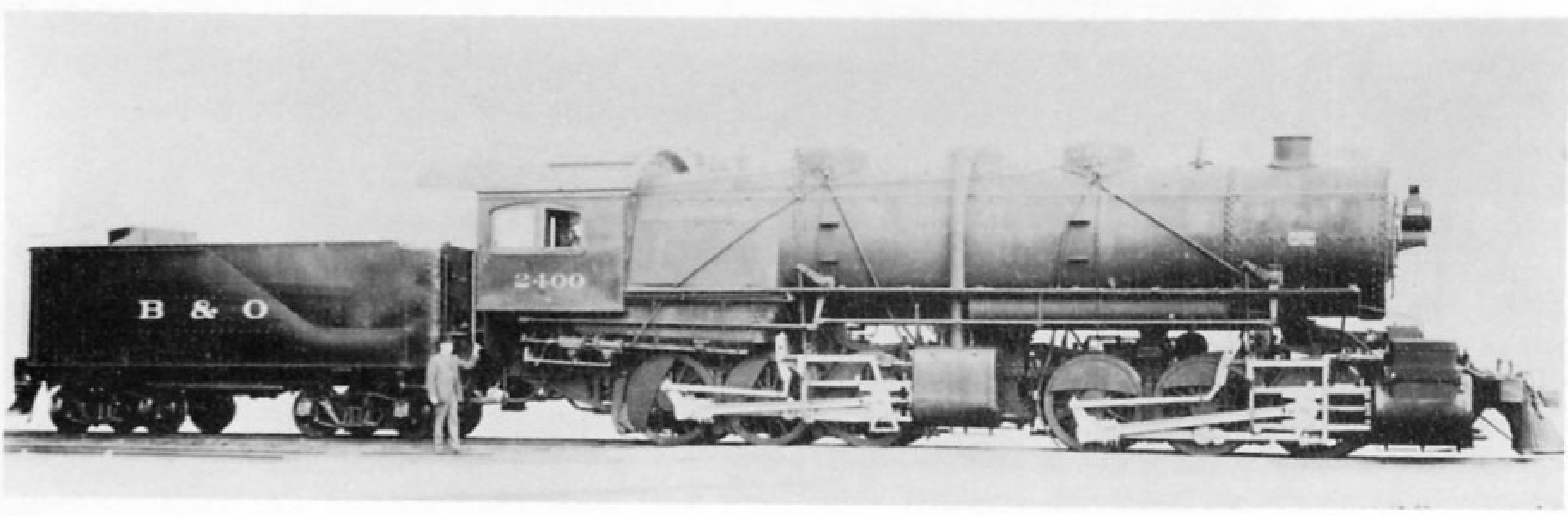
Hungarian Mallet development—3, the first six-coupled type, 651 class of 1909, using the 401 class boiler



Hungarian Mallet development—4, the massive, superheated and Brotan-boilered 601 class 2–6–6–0 introduced in 1914

Articulated joint

The basic Mallet concept included a vertically hinged joint between the two units, giving lateral radial movement to the front unit and leaving all vertical adjustment to be taken up by the rise and fall of axleboxes within their horn guides, as with a conventional locomotive. This hinge transmitted power only, and the overhanging weight of the boiler was supported by means of a sliding bearing situated approximately over the centre of gravity of the leading unit. Control springs to check the sideways movement were placed within or near to this sliding bearing. An early American development was a radius bar between units, with both vertical and horizontal hinge pins. This allowed the front unit to pitch and yaw as well as to respond radially to track curvature, and whilst doubtless suited to low-speed operation over rough



American six-coupled Mallets. Baltimore & Ohio's class 'O' No 2400, the first American Mallet, an unsuperheated 0–6–6–0 and Alco built in 1904 track, gave a very sloppy and undisciplined ride to the front unit. In the final flowering of American (simple expansion) design, this feature was completely eliminated and frame sets designed especially to combat vertical movement were developed.

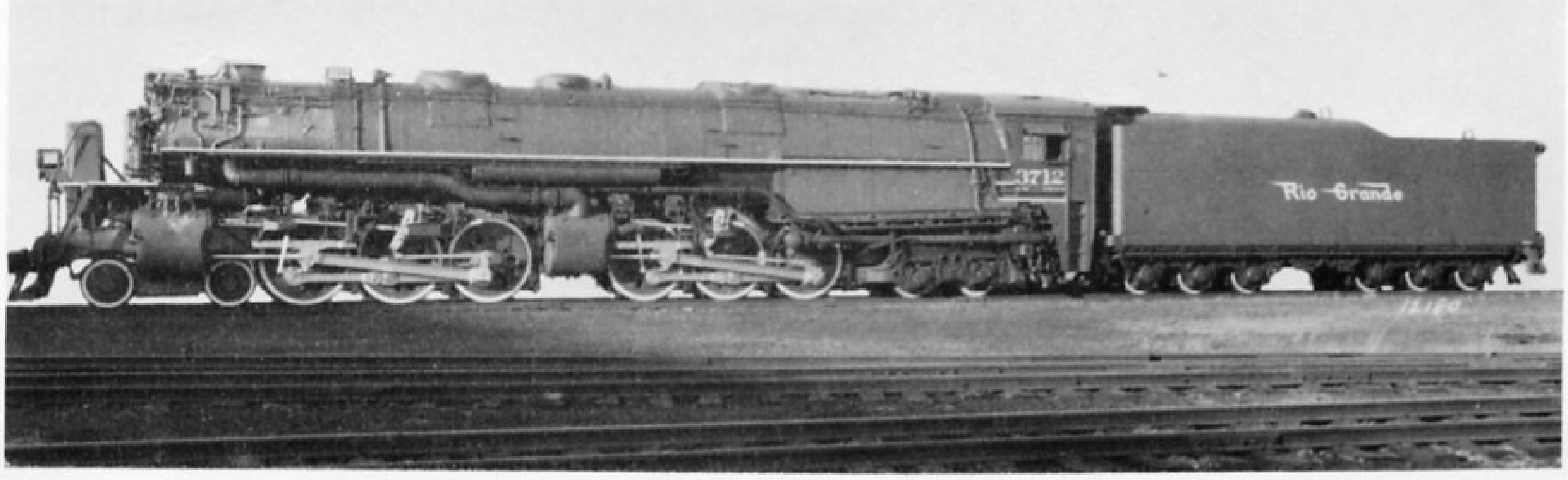
Cylinders, valves, and valve gear

With one exception, all Mallets built had each engine unit driven by two outside cylinders. Older non-superheated engines usually had slide valves for all cylinders, but with the general adoption of superheating, piston valves became normal, firstly for the high pressure and later for all cylinders. Poppet valves on Mallets were an extreme rarity. On all new Mallets valves were situated above the cylinders, although on a few conversions from conventional engines the valves were between the frames. Walschaerts valve gear was used on most Mallets, a few conversions had Stephenson link motion, and Maffei produced some with their local speciality—Helmholz gear, a straight link variation on Walschaerts. Quite a number of little 0–4–4–0Ts for the very narrow gauges had Orenstein & Koppel's version of Hackworth's radial gear.

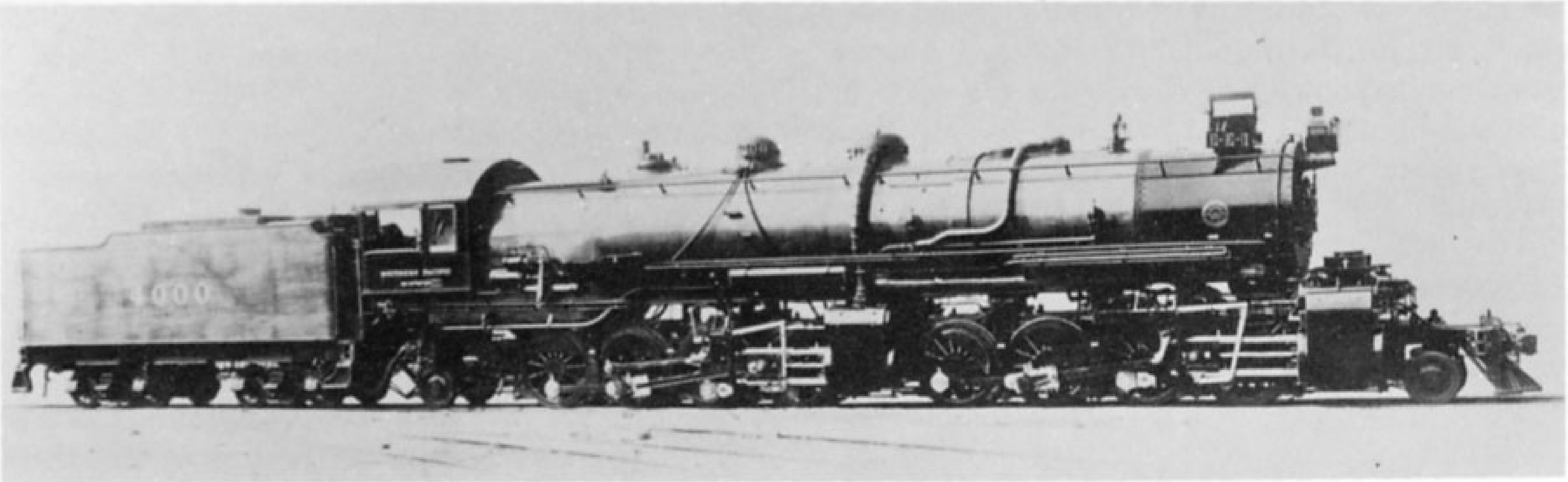
As regards the cylinder position, the standard form, which were the overwhelming majority, had cylinders at the leading end of each unit, positions which came naturally as the most suitable. For ultra-cold weather conditions in Russia and Canada, Mallets were built with all four cylinders grouped together in the centre, between the two sets of driving wheels. The idea was to reduce the length of low-pressure piping between units and thereby reduce the surface presented for radiating heat to the atmosphere, for condensation problems were severe in Arctic conditions. The advent of superheating eliminated the need for this construction, which had as disadvantages the inaccessibility of the cylinder heads, especially should a piston need removing, while the longish exhaust piping led to a woolly exhaust. A pair of little 0–4–4–0Ts built by Orenstein & Koppel for Tasmania seem to have been unique in having the high-pressure cylinders at the very rear, under the bunkers. No rhyme nor reason can be deduced for this design which increased the steam and exhaust pipe lengths on the high-pressure unit, besides introducing the complication of having to lead these pipes round the firebox and causing discomfort to the crew from hot pipes under the cab floor. They remained freaks, marsupial-Mallets, each a duck-billed platypus in the world of articulated steam locomotives.

Boilers

No deviation from normal locomotive boiler practice was necessary for application to the Mallet, and narrow or wide firebox designs were used as deemed most suitable. Brotan water tube fireboxes were applied to a number of Hungarian-built Mallets, and the similar Emerson design at a later date to a Baltimore & Ohio simple expansion 2–6–6–2. In neither case was the application to a Mallet any more difficult than to a standard engine. The length of boiler possible, even dictated by, the Mallet arrangement brought with it the problem of what on earth to do with all that space ahead of the firebox. Excessive tube length is detrimental to good steaming, due to the high resistance against the passage of gases through them, and in the early



American six-coupled Mallets. Denver & Rio Grande Western's superb Baldwin simple expansion 4–6–6–4 of 1938



American 2-8-8-2 Mallets: Southern Pacific's long thin compound No 4000 of 1909

days of Mallets American engineers introduced multiple-stage boilers in an attempt to utilise the space available for a power-station type, high-efficiency steam generator. The story of these unconventional boilers, however, belongs to the next chapter.

Controls

In theory, the controls on a Mallet are the same as those of any other compound engine—regulator, reverser, and a starting valve for admitting live steam to the low-pressure cylinders, the latter automatic or manual to suit the designer's or operator's ideas. However, in one respect the Mallet was like Webb's extraordinary compounds on the London & North Western—the high- and low-pressure units were not coupled. This meant careful driving if a successful start was to be made. The high-pressure cylinders were proportioned to deliver full tractive effort against the back pressure required to drive the low-pressure unit, and the application of full boiler pressure at starting, with the low-pressure unit empty, encouraged violent slipping. A slip of the high-pressure unit immediately exhausted a great gob of high-pressure steam into the low-pressure steam chest, and as these cylinders were proportioned to function on very little pressure the resulting tractive effort produced would then cause *that* unit to slip as well. Whilst self-generating, Mallet slips were self-controlling too, for the high-pressure unit would choke itself to death provided the low-pressure unit kept its feet, and a slipping low-pressure unit would peter out from lack of steam so long as the high-pressure wheels gripped. Considerable skill was thus needed to regulate the amount of high-pressure steam admitted to the low-pressure cylinders although the Mallet had one great advantage over the Webb—when the wheels slipped they all rotated in the same direction! There were, of course, automatic safeguards in the shape of low-pressure safety valves on the receivers, but these could not cope

American 2-8-8-2 Mallets: Western Pacific's massive simple expansion engines of 1938 were among the largest of this type ever built effectively with a violent slip. Apart from the above notes about slipping, the controls and handling of a Mallet are the same as with a conventional engine.

Flexible steam pipes

The Mallet needed two types of flexible joint in its steam piping to the mobile unit. Firstly, there is the obvious ball joint to allow for the radial movement of the pipes at the joints and, secondly, there are telescopic slip joints to take up the changes in length, partly due to thermal expansion but mainly to the pivoting of the pipes at different centres to the main frame joint. The actual joint construction in each case comprised packing and screw-down glands, and followed the same general design as other articulateds.

CHAPTER 2

MALLET VARIATIONS

FEW, IF ANY, inventions are perfect as originally conceived and the Mallet was no exception. True, it was a very good first effort and was little changed in principle or practice for engines built for the original conditions, ie, small tank engines for low-speed, narrow-gauge railways. However, as the scope of the Mallet's operation increased to larger and more powerful engines, and to engines for faster services, the inherent disadvantages became obvious, even acute, and engineers battled to reduce or eliminate these unwanted features. Some of the modifications won wide acclaim, others were unsuccessful, while further ideas hovered on the brink of success but lost out either due to faulty application, to being overtaken by better ideas, or to changes in the operating requirements. Basically, variations from the original Mallet concept may be classified as under:

(a) To provide increased power
(b) To provide increased speed
(c) To improve tracking and riding qualities
(d) To provide increased efficiency
(e) For special service conditions
(f) Miscellaneous reasons

Some designs, of course, were produced in an attempt to provide for more than one of the above. Dealing with the above in order, we have the following.

Increased power

There are two ways in which the power of a locomotive is referred to—the tractive effort and the horsepower. Of these, the first and the one most commonly used for steam locomotives is not a unit of power at all, but a unit of force which must be combined with a speed factor to produce *power*. Nevertheless, tractive effort is an oft-quoted statistic and determines the load an engine can start, or haul up a gradient at low speed. No matter what the type of traction, maximum tractive effort must be backed up by an adequate amount of adhesion weight, and for reciprocating steam

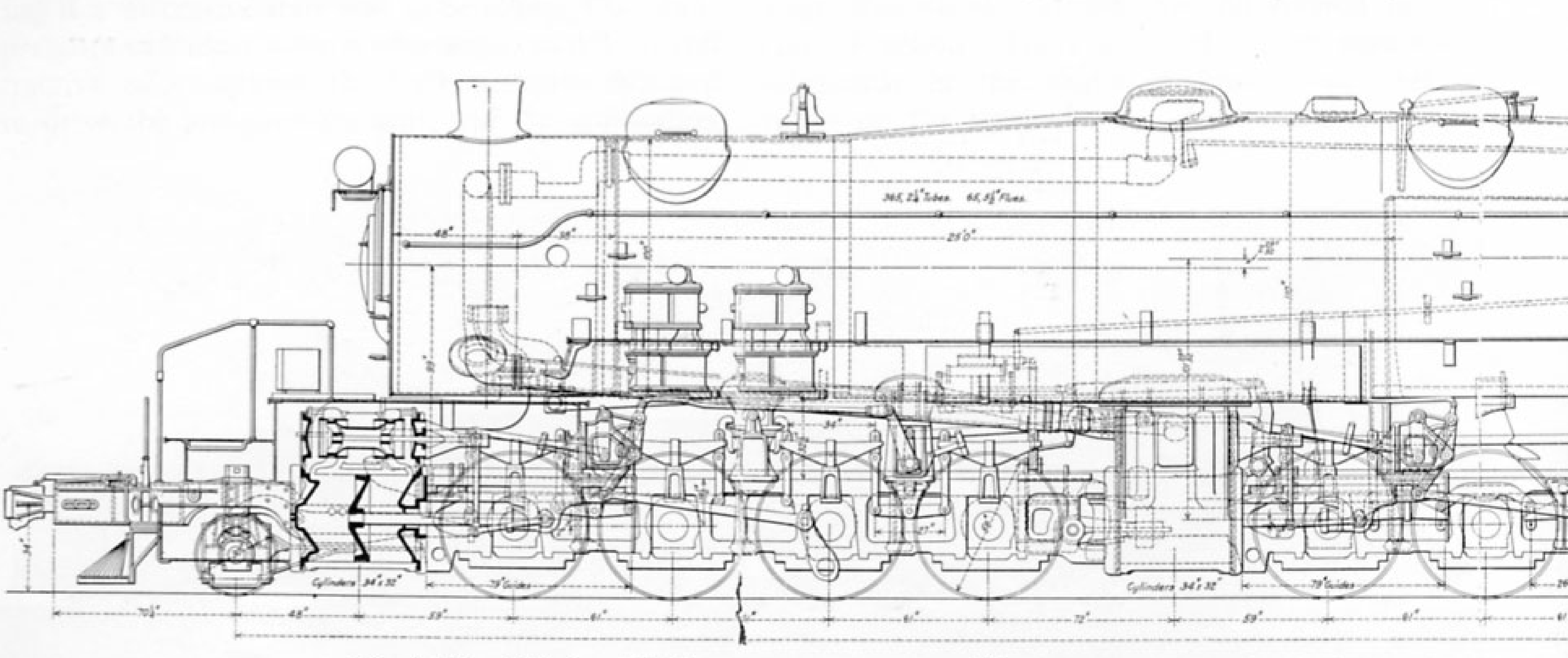
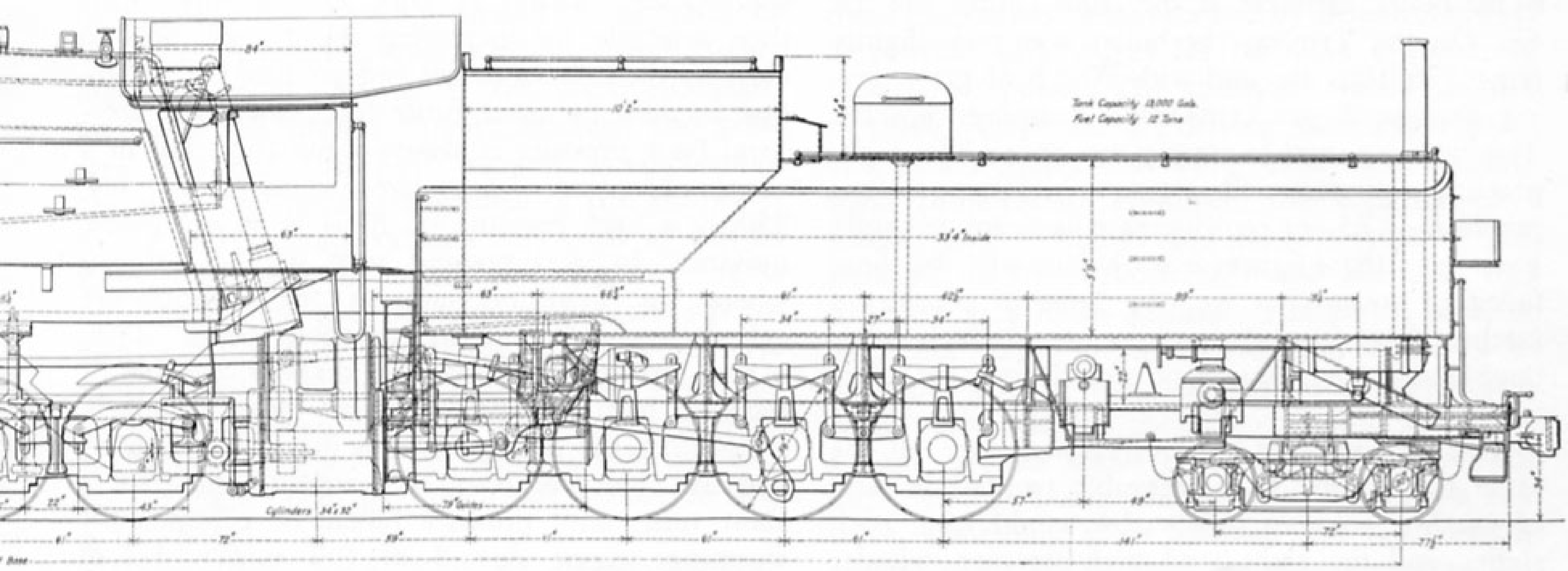


Fig 5 *The Triplex Mallet concept, as exemplified by the Virginian Railways 2–8–8–8–4*
while each outer unit was jointed

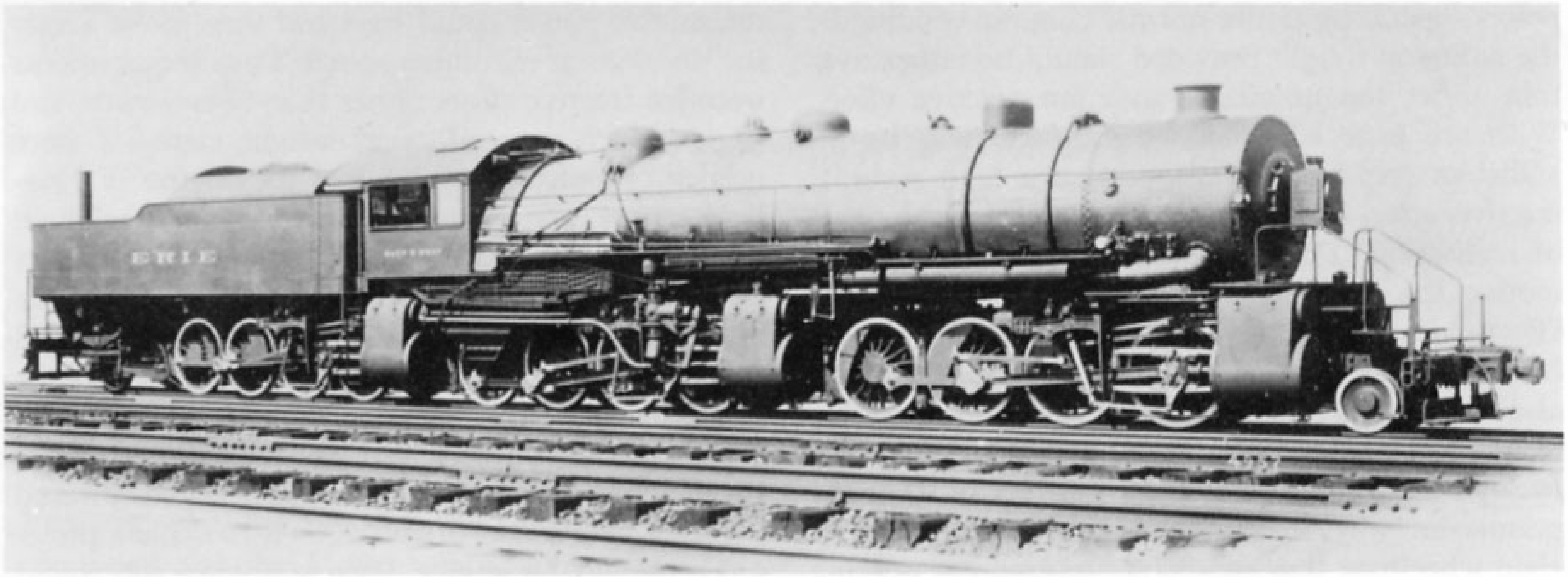
power, operating under normal climatic conditions, the adhesion weight provided should be rather over four times the nominal maximum tractive effort. With too little adhesion weight there will be insufficient grip on the rails, so that a high nominal tractive effort would be ineffective and incapable of realisation. Throughout the history of the locomotive the demand for more and more tractive effort, with correspondingly more adhesion weight, has been met by increasing the axle loadings and also by coupling together more and more driving axles. Each method has its limitations, the former because of the built-in strength (or lack of it) in the permanent way, and the latter in the amount of rigid wheelbase that can be got around the existing curvature. Articulated power was an answer to the second limitation, and in the USA the Mallet was speedily developed from engines with six-coupled units to bigger machines having eight coupled wheels per unit. When traffic outgrew these, a couple of ten-coupled designs were introduced to give a total of twenty driving wheels per locomotive. First of these was on the Santa Fé system, but later on, in 1916, when the Erie Railroad decided that it needed a banking engine capable of replacing three 2–8–0s, the obvious and logical double-twelve-coupled Mallet was ruled out, probably due to track curvature.

Meanwhile, in 1912, George Henderson of the Baldwin Locomotive Works had foreseen the future outclassing of the normal Mallet and had sought to find a solution to the provision of yet more tractive effort, for American operating procedure in those days was to assemble trains of the maximum weight the motive power could start and then move across the divisions at minimum speed. Thus requirements were for tractive effort rather than horsepower, and engines with vast adhesion weight statistics were needed. Henderson's idea had its origins in England, some sixty years earlier, when Archibald Sturrock, on the Great Northern, fitted cylinders and driving gear to the tenders of his 0–6–0 goods engines in order to increase the starting force and give a boost on gradients. These steam tenders worked after a fashion, but in the long run were not considered satisfactory. Nevertheless, the germ of an idea was there and Henderson's patent covered a Mallet with steam-driven tender, to make a three-unit, six-cylinder engine. The reasoning was sound —use the otherwise idle tender weight to provide added adhesion, and by using a double-jointed, double-ended Mallet chassis with the high-pressure cylinders built on to the centre section, upon which the boiler was rigidly mounted, joints to the leading and trailing (tender) power units had only to pass low-pressure steam.

Sound though the reasoning was, the detailing of Henderson's Triplex Mallet turned out to be defective. Bear in mind that here was an engine with 50 per cent more tractive effort, and therefore 50 per cent more cylinder volume than a standard Mallet, and it should be fairly obvious to a trained locomotive engineer that a commensurate increment in steam generating capacity was obligatory. Admittedly, she was for banking service and possibly the need for a high sustained steaming rate was less than for a mainline engine, but one would certainly expect a higher capacity, even by 25 per cent, than



The centre unit was mounted rigidly under the boiler and used high-pressure steam,
and consumed low-pressure steam



Henderson's original Triplex, a 2–8–8–8–2 built for the Erie Railroad in 1916, was an unsuccessful attempt to use the Mallet's tender weight to increase adhesion and tractive effort

the straight Mallet. Henderson's first Triplex, a 2–8–8–8–2, was built in 1916 for the Erie's banking service in the Susquehanna division, and it replaced either three 2–8–0s, or a 2–8–0 and a 'Camelback' 0–8–8–0 Mallet, or would have done had it been able to steam adequately.

Steaming troubles were inherent both in the design and proportions of the Erie Triplex. Viewed at first from the principal dimensions, and comparing it with a contemporary 2–8–8–0 Mallet such as the Baldwin engines for the Baltimore & Ohio, we find at first that the Triplex is clearly a 2–8–8–0 with an 0–8–2 tender. The B&O straight Mallet had a boiler with 88·2sq ft of grate area to supply two 28in x 32in high-pressure cylinders, driving 4ft 10in wheels, the boiler pressure being 210lb/sq in. Boiler diameter at the front course was 7ft 6in. On the Triplex, the boiler was very slightly larger, 7ft 10in dia, and with 90sq ft of grate, giving perhaps 5 per cent more steaming capacity. This was expected to supply two 36in x 32in high-pressure cylinders with steam at the same 210psi pressure—a 65 per cent increase in steam demand! Even from these figures it is obvious why the thing failed to steam, but we now have to consider a further factor, a design curiosity which made doubly sure that the engine would never be effective.

The six cylinders of the Triplex were all the same size, giving an undesirable two-to-one ratio of l-p/h-p volumes (about 2·4 would have been right), and the right-hand high-pressure cylinder exhausted into the front group of low-pressure cylinders. The left-hand high-pressure fed back into the rear set of low-pressures, situated just under the cab but of course attached to the tender frame, and the whole engine was thus effectively a pair of three-cylinder compounds. Steam exhausting from the rear set of low-pressure cylinders was not fed forwards into the blast pipe as it should have been, but was directed through a tubular feed water heater placed under the tender tank, and from this exhausted to atmosphere via a separate stove-pipe chimney right at the rear of the tender. No doubt a few per cent heat recovery was thus effected, but the price paid was in depriving the blast pipe of exactly half the exhaust steam so badly needed for inducing draught through the tubes of a pathetically undersized boiler. This was long before the days of the Giesl or Kylchap sophisticated exhaust systems, and the only means then available for increasing the draught was to close up the exhaust orifice and produce the smokebox vacuum by sheer brute force and back pressure. Back pressure is always a nuisance, but in a simple-expansion locomotive working at, say, 250psi, a back pressure of 20psi is an acceptable nuisance. In a compound such as the Triplex, where the inlet pressure to the low-pressure cylinders would be down to about 60 or 70psi, a back pressure of 20psi is a disaster, capable of sapping half the power from these cylinders. Thus, with the arrangement as it was, the Triplex had the choice of being a powerful engine for a short time, until pressure failed, or a reasonably steaming engine devoid of full power due to excessive back pressure, neither of which was an acceptable alternative.

On trial with a dynamometer car, the original Triplex managed to haul a load of 250 bogie wagons, weighing 16,025 long tons, at 13·5mph over the twenty-three miles from Binghamton to Susquehanna, a line with a gradually rising profile and a maximum gradient of 1 in 111. The maximum drawbar pull registered was 130,000lb, considerably less than the 160,000lb nominal rated tractive effort, and indicative of steaming troubles even under the carefully nursed conditions of a new locomotive under test. The Erie Triplex was built with a 'Gaines' combustion chamber (simply the forward section of the grate bricked off) and after a short while in service this was removed in two subsequent locomotives to give a substantial increase in grate area, to 121·5sq ft. Naturally, no increase in firebox volume accompanied this larger grate, and because of this, together with the other weak features of the design, she still failed to steam.

Meanwhile, the Virginian Railway was also faced with a problem in providing banking engines for the 14-mile section from Elsmore to Clark's Gap, the last eleven miles of which were on a solid 1 in 50. Coal was the main traffic, and in the booming years of the early twentieth century the railway was hard pressed to find suitable motive power—2–8–0s gave way to 2–6–6–0 Mallets and these to 2–8–8–2s, but still the insatiable demand for more power continued. The smaller Mallets were used as train engines and the larger as bankers, yet something bigger again was needed. Having sold a Triplex to the Erie, Baldwin then contracted to supply one to the Virginian. This was built a scant two years after the first Erie engine and any difficulties with this would have been put down to teething troubles, possibly curable. At any rate, the Virginian Triplex had smaller cylinders and a larger diameter boiler (8ft 4in at the front tubeplate, 9ft 2in at the firebox throat) although the grate area was but 108·2sq ft without a combustion chamber. The same arrangement of rear feedwater heater and separate exhaust was used as on the Erie engine and, all in all, the Virginian engine was slightly smaller although with more wheels, being a 2–8–8–8–4. Exactly the same troubles were experienced as with the Erie type, and two years later the Virginian had built for them ten gigantic 2–10–10–2 straight Mallets which successfully conquered Clark's Gap and which will be covered later in this book.

Henderson's patent (No 1,013,771) was worded so as not to preclude expansion to four or even five-unit engines, but with the failure of the Triplex there was no case for trying out such machines. One is left to conjecture whether the Triplex, properly designed, could have been more of a success. A higher ratio of boiler to cylinder size, normal proportions and ratios of high- to low-pressure cylinders and suppression of the rear exhaust system, could well have ensured success but, of course, today such arguments are academic.

Increased horsepower

Increased horsepower of the Mallet was always effected by simply enlarging on the basic theme, compound or simple, and no strange subforms emerged for this purpose.

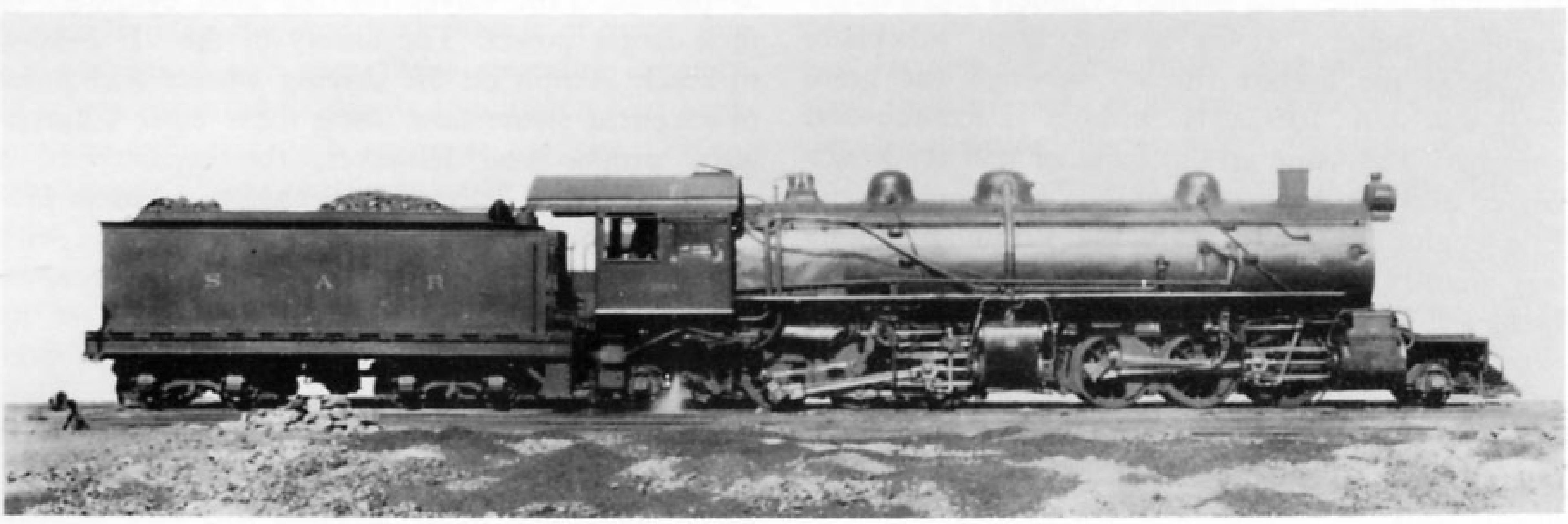
Increased speed

A basic defect in the compound Mallet was its sluggishness and rough riding at anything approaching a fast operating speed. This was particularly acute in the USA where, due to the very large sizes involved, the basic problems were accentuated. Dealing first with sluggishness, the reasons behind the defect boiled down to the sheer inability of practical sized valves to handle the vast quantities of soggy, wet, low-pressure steam exhausted by the high-pressure cylinders. The same problem was inherent in all compounds, but worse in the Mallet due to the much larger sizes involved. The earlier Mallets had slide valves, which must have had extremely strangulating tendencies, but even with piston valves it proved impossible to provide the size necessary for a reasonably snappy performance. Consider a modern British steam locomotive with long lap valves and modern cylinder design—Churchward's 10in valves with 18in or 19in cylinders gave very brisk performances and later on these proportions were retained by British Railways to provide 11in valves for the 20in cylinders of their larger power. The ability of the 9F 2–10–0 to reach 90mph on 5ft driving wheels was proof of excellent steam flow using these basic Churchward proportions. However, the capacity of a piston valve to deliver and exhaust steam is proportional to its circumference and increases with diameter in a linear manner. The piston area, on the other hand, increases with the square of its diameter, and to maintain the optimum proportions, valve diameter should increase to suit. Thus a 25in cylinder needs a 15in or 16in valve, still quite feasible, but a 30in cylinder demands a 22in valve, something never attained and very difficult to find room for. Extrapolate these functions and one finds that, around 40in, the cylinder needs a valve as big as itself, which is quite impracticable and almost ludicrous. As a result, these huge American Mallets oozed around with low-pressure valves of half the capacity needed, and the choking effect of these resulted in a sluggish engine. So long as the Mallets were kept on heavy, low speed work this was of no consequence, but attempts to run them at higher speeds resulted in constipation at the front end.

Similarly, the size of the low-pressure pistons caused rough running. With the Mallet, the low-pressure unit has no integral boiler or other heavy unit to impose an inertia and damp out the dynamic forces produced by the reciprocating pistons and crossheads, and the flailing rods. There is only the comparatively light main frame and cylinder assembly, and these are at a low centre of gravity where their stabilising influence is minimal. Thus the whole low-pressure unit rocked and vibrated from the tremendous forces produced by the pistons, causing heavy wear to track, wheel flanges, and the articulated joint. Clearly something had to be done to improve matters and a number of variations were introduced to this end.

An interesting experiment tried out once, on an American-built locomotive for South Africa, was in the use of differential driving wheel diameters—larger on the low-pressure unit than on the high. However, the amount of difference possible in practice was too small to be of significance and was partly counteracted by providing a longer piston stroke for the low-pressure unit, so the experiment was never repeated. The Santa Fé Railroad took things a step further by building Mallets with large wheels on each unit (2–6–6–2 with 5ft 9in and 4–4–6–2 with 6ft 1in wheels) but as the larger wheels needed larger cylinders to maintain tractive capacity, conditions were, if anything, worsened. Two of the 2–6–6–2s were the objects of a further experiment involving jointed, flexible, boilers, and these will be dealt with in greater detail later.

As for improving speed and riding by mechanical means concerning the driving mechanism, the abandonment of compounding was eventually hailed as the answer, but there *was* another method which, surprisingly, was never applied nor even, to the author's knowledge, proposed. This possible improvement for compound Mallets would have been the use of multiple low-pressure cylinders. Using three or four low-pressure cylinders, the valve situation would be vastly improved for each could have a valve of the same maximum practicable size as for a two-cylinder low-pressure unit—in other words three or four valves instead of two. Also, the self-balancing effect of multiple cylinders would greatly reduce the disturbing effects of the reciprocating motion and, at the same time, the slightly heavier construction inherent in multiple cylinders would assist in holding the front unit down on the track. A side effect of this, by reducing the size of the low-pressure cylinders, would be the greater ease by which a compound Mallet could be fitted into a restricted loading gauge, and Figure 6 shows how a fair-sized 2–8–8–0 could be squeezed into even British clearances. Baldwins produced their 'Duplex', rigid-framed four-cylinder design for the same purpose of improving the valve/cylinder capacity ratio, and to reduce the piston forces for a given output, and later on Chapelon was to come up with his 2–12–0, No 160-A1. This latter, apart from being a rigid engine was, cylinderwise, very similar to a multi-low-pressure Mallet in having two high-pressure



South African Railways MG class 2–6–6–2, a compound in which the driving wheels of the low-pressure unit were slightly larger than on the high pressure in an attempt to combat sluggish running

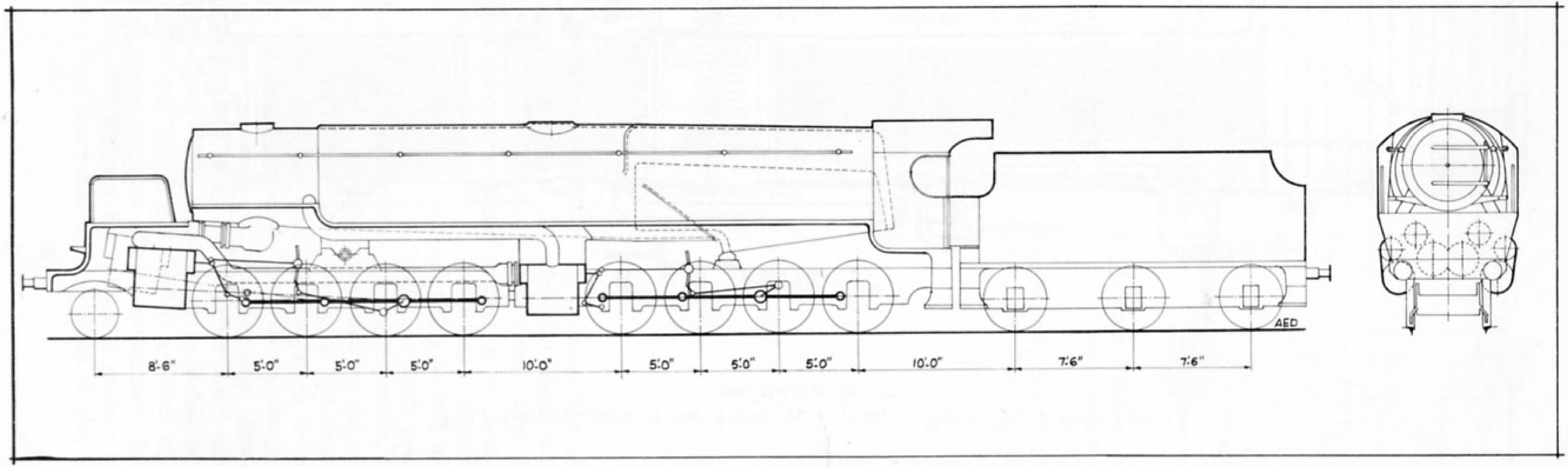


Fig 6 *A compound Mallet proposal suitable for the British loading gauge—two high-pressure cylinders 18¾ x 32in, four low-pressure 20½ x 32in, 300psi pressure and only 72,500lb tractive effort—equivalent to the LNER six-cylinder Garratt with the same sized wheels, the Mallet needing extremes in dimensions to achieve the same result*

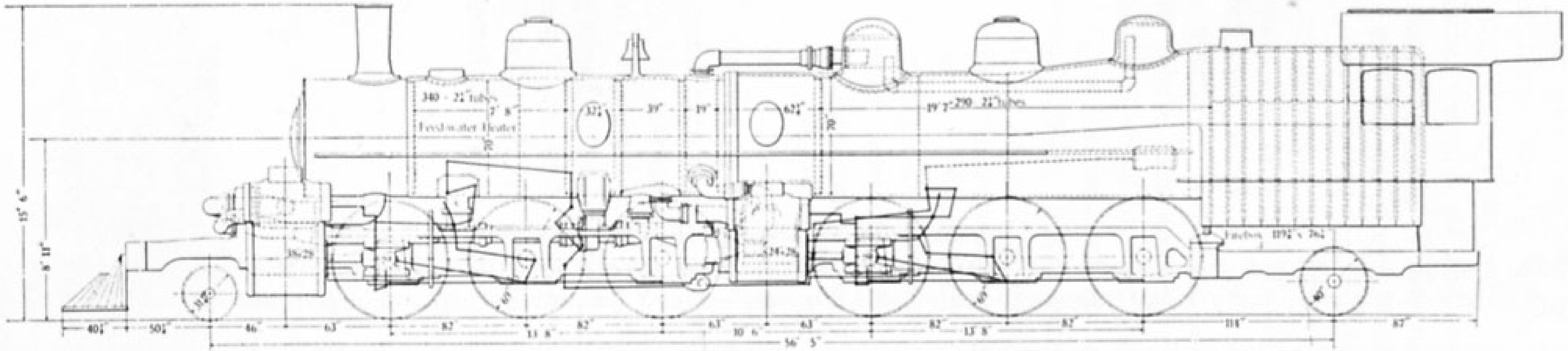


Fig 7 *General view of the Atchison, Topeka & Sante Fé's 2–6–6–2 with multi-stage boiler*

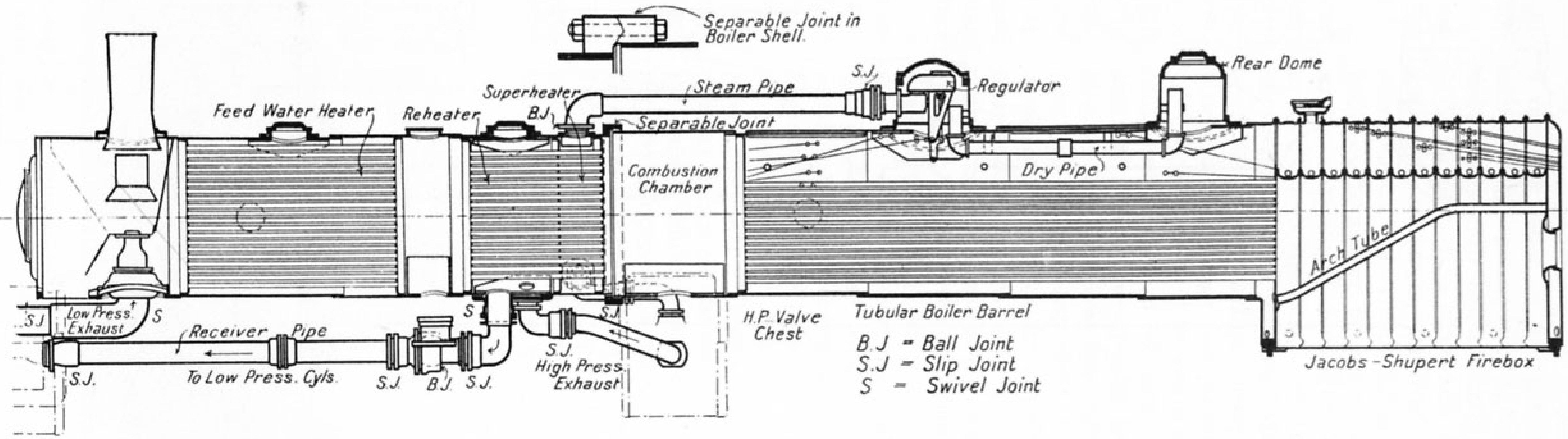
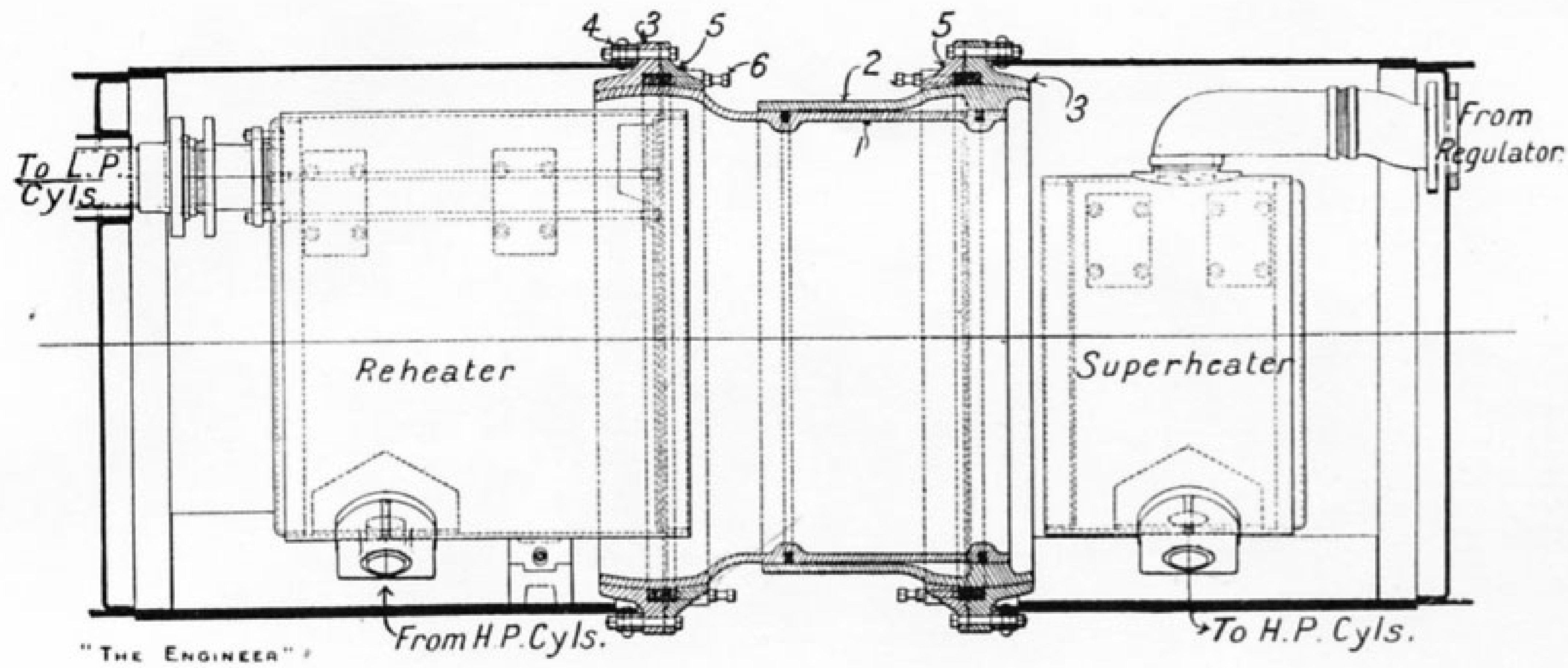


Fig 8 *Section through the multi-stage boiler, with organs from front to rear: smokebox, feed water heater, access chamber, low-pressure steam reheater, high-pressure superheater, 'combustion chamber' (in effect, a further access chamber), steam generating tubes, Jacobs–Shupert firebox*



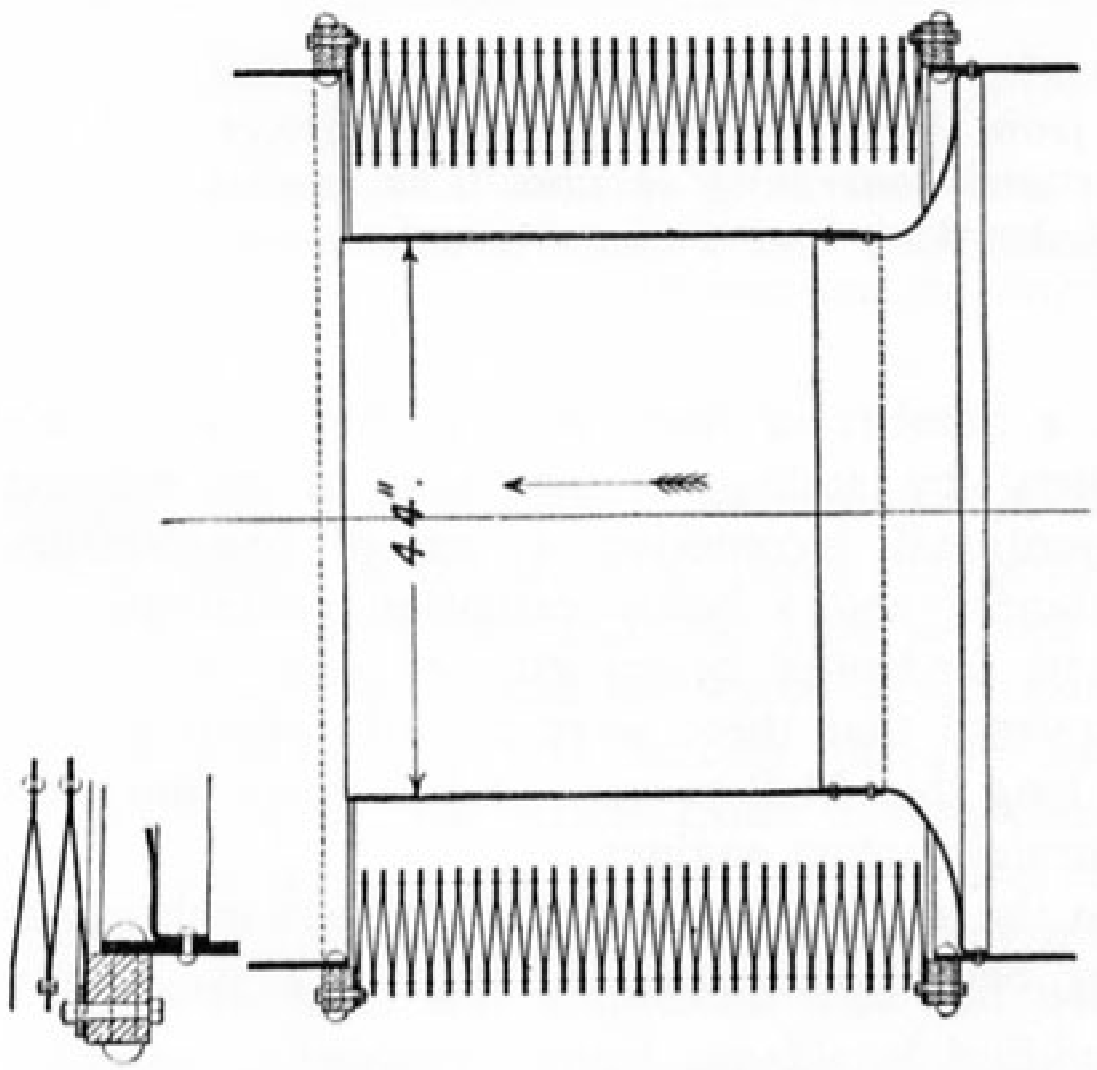


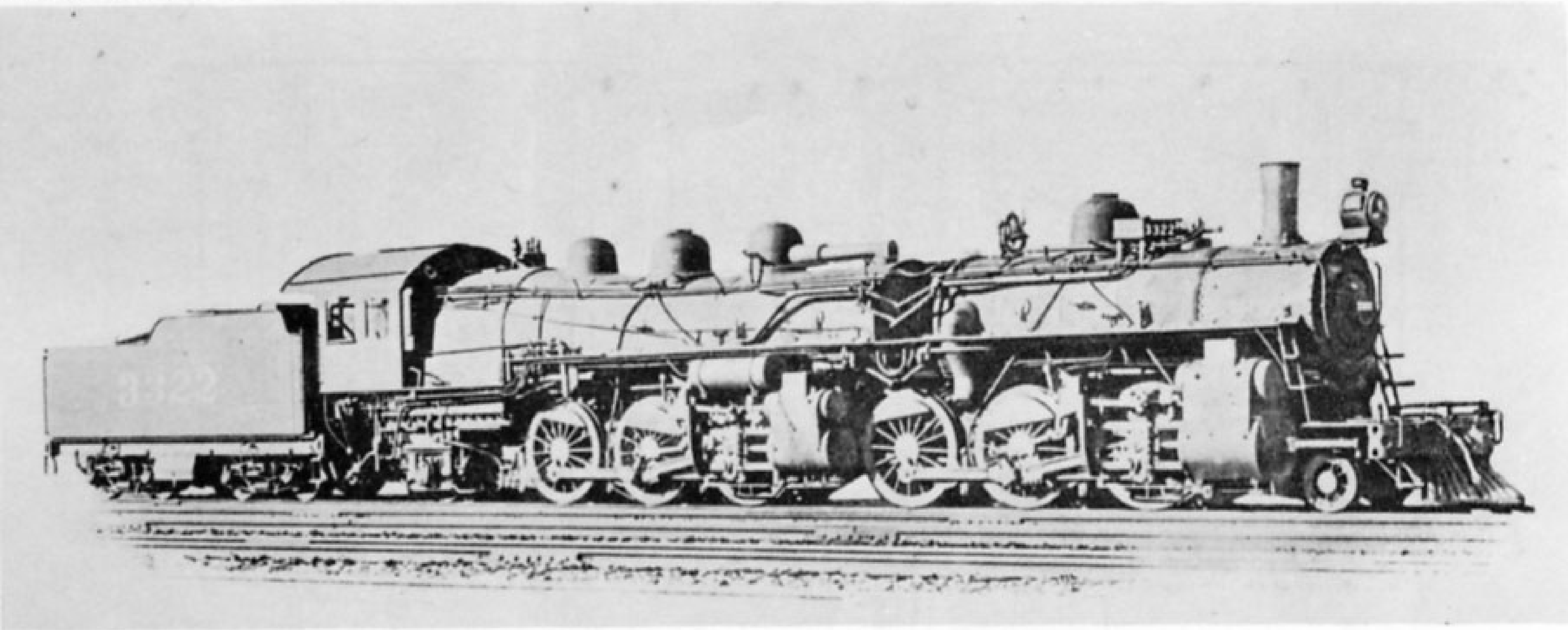
Fig 9 (above) *Ball-and-socket joint for flexible, multi-stage boiler, A.T. & S.F. 2–6–6–2*

Fig 10 (left) *Accordion, or concertina-type diaphragm joint, for flexible, multi-stage boiler, A.T. & S.F. 2–6–6–2*

cylinders aft, just ahead of the firebox, and four low-pressure cylinders in line across the front. However, with typical Gallic delight in complication, the high-pressure cylinders were between the frames, and the thing had two cranked axles.

Increased efficiency

The only successful way found to increase the thermal efficiency of the Mallet was no different from that applied to all other types of steam locomotive—the application of a Schmidt fire tube superheater. However, whilst the sound commonsense of this was sinking in, American engineers, faced with an apparent problem of how to fill in the space above the driving wheels of a long 2–6–6–2 and knowing that tubes 40ft long would severely inhibit steaming, hit upon the idea of adding a high-pressure superheater, reheater for the low-pressure steam, and a feed water heater, all in multi-tubular sections strung out one after the other ahead of the main bank of steam generating tubes. The theory was sound enough—the hottest gases nearest the firebox evaporate the water and superheat the high-pressure steam, and in doing so lose some of their heat content. The slightly cooled gases then pass through the low-pressure reheater, and in doing so impart some superheat to the steam in its second stage. Then finally, at the very front end, some residual heat was imparted to the incoming feed water. Apart from theory, the idea was tried and tested in practice for large stationary boilers such as are to be found in power stations. The difference lay in the space available per unit output—power station boilers are vast affairs relying on natural draught for combustion, but the steam locomotive is expected to produce an equivalent evaporation within a fraction of the total volume and within a par-

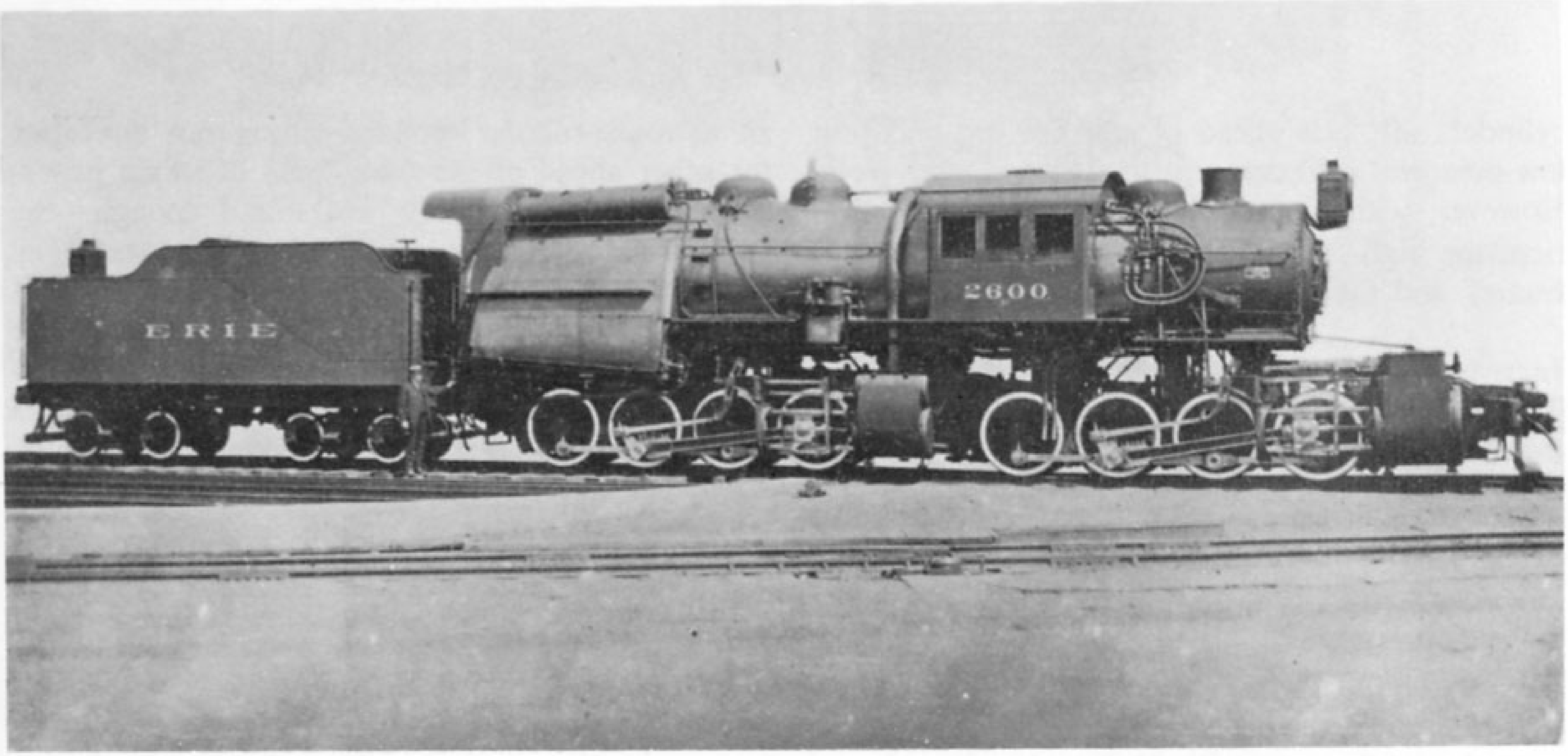


Probably the most outlandish Mallets ever built, Santa Fé's early large-wheeled 2–6–6–2s featured a four-stage flexible boiler; from front to rear: feedwater heater, low-pressure reheater, superheater, flexible joint and generating section. The firebox was Jacob–Schupert's type and No 3322 shown here had a concertina joint

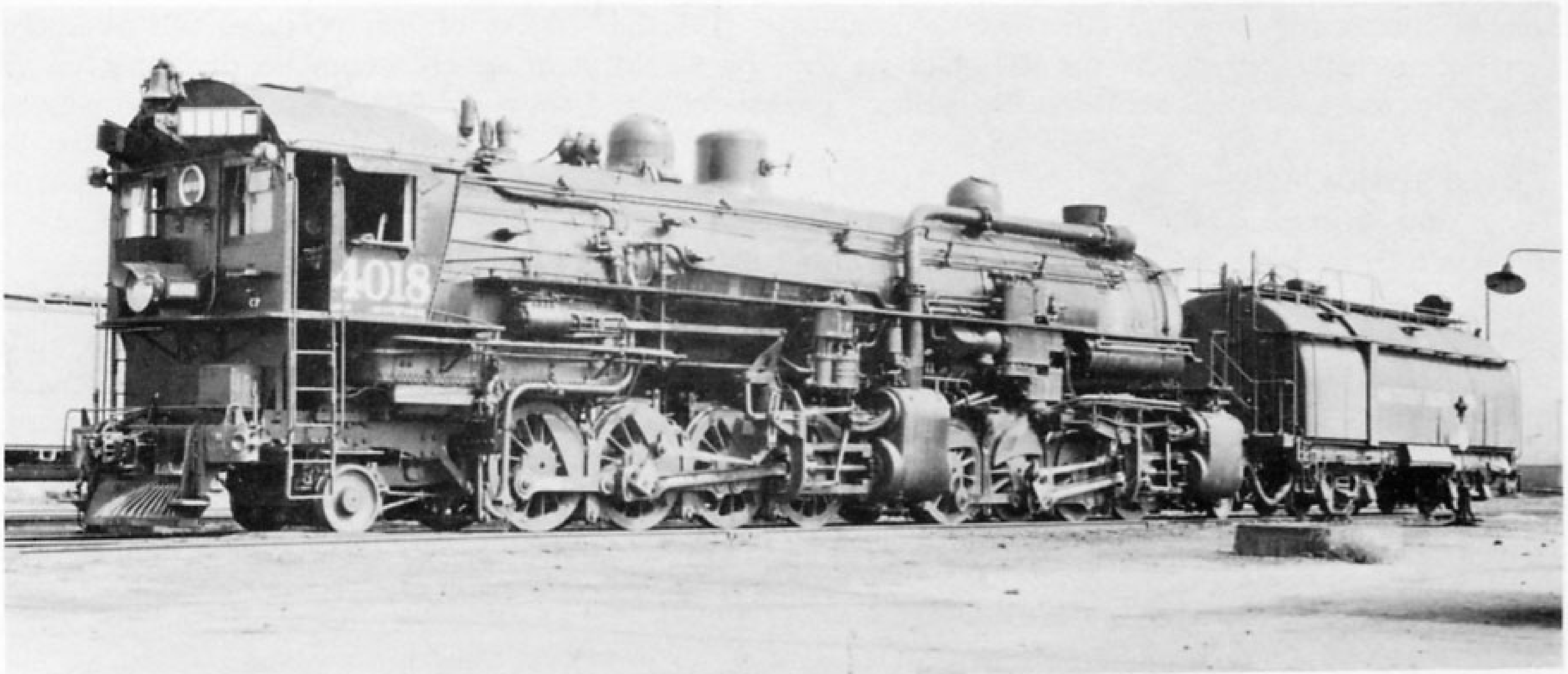
ticularly severely restricted cross-sectional area. Hence a high induced draught is needed at the smokebox end of even a normal engine with a relatively short, fat, boiler. These old Mallets with their multi-stage boilers needed far more smokebox vacuum, and with only low-pressure steam to provide the inductive power they suffered from the same constipatory ailments as the later Triplex designs previously described.

While these multi-stage boilers were being tried out, a number of lines went in for 'Poor Man's Mallets' by adding to the front of an existing conventional locomotive a set of low-pressure machinery and a boiler extension containing reheater, feedwater heater etc. As soon as it was discovered that these were of little practical use, the long thin Mallets were broken down into pairs of straight steam engines.

In the short boom period of Mallets with multi-stage boilers, the Santa Fé made a brave experi-



Erie Railroad 'camelback' 0–8–8–0 compound, with cab (for driver) astride the boiler. The fireman sweated under the brief canopy behind the firebox



Southern Pacific's Sierra Nevada mountain division, with its numerous tunnels and snow sheds, bred the cab-forward Mallet. No 4018, shown here, is as rebuilt from compound to simple expansion. Los Angeles, 1939

ment with flexible boilers. Reasoning that as the front stages were divorced from the generative section of the boiler and had only to cope with low-pressure steam and hot water, easily conveyed from and to the rear section through flexibly jointed piping, the whole front section could be mounted directly on to the low-pressure engine frame, and thus assist materially in holding it down to the track. It was a splendid idea and had the current technology proved capable of building an effective boiler joint, then the potentialities were enormous. However, it is one thing to produce a flexible joint eight or ten inches in diameter to convey steam—even highly superheated steam—but when it comes to a joint seven or eight *feet* in diameter, through which has to pass the even hotter combustion gases from the firebox, liberally polluted with incandescent cinders and unburnt fuel, then the problem becomes a nightmare sufficient to daunt the bravest of design engineers. Nevertheless, the Santa Fé had a go, although they were wise enough to try two engines only, one each of two designs. The engines concerned were a couple of large-wheeled 2–6–6–2s, Nos 3321 and 3322, and apart from their flexible boilers they were similar to other engines of the same type operated by the Santa Fé. No 3321 had a ball-and-socket joint, with two spherical joints, one on each boiler section, connected by a huge telescopic unit. Each moving section had a packed gland and the whole ensemble was similar to, but much larger than, a flexible steam pipe. The second engine, No 3322, had a vast bellows, or concertina-type joint, made from numerous rings of steel riveted together, and a central flue fixed at one end to deflect most (hopefully all) of the hot gases away from the rather delicate bellows diaphragms. In practice, neither worked successfully for reasons which take little imagination to deduce. The ball-and-socket joint probably seized up and burnt the packing material, whilst despite the deflecting chute, ash and cinders were bound to accumulate in the bellows of the other engine where they would speedily corrode, jam up the diaphragms, and cause holes to appear. It is a moot point whether with today's materials—stainless steel, improved lubricants and synthetic packing materials—such flexible boilers might be practicable, but certainly nobody was ever tempted to try them out again!

The principle of using superstructure weight to improve the riding on articulated locomotives became well known with the Garratt type, with front and rear tanks mounted directly upon the engine units, but before the Santa Fé flexible boiler engines there was an earlier and little known example of this idea, used on some 2–6–6–0Ts built for Java. In these, the side tanks were in two sections, the rear half mounted on the high-pressure main frame in the usual manner, and the front half mounted on and swinging with the low-pressure frames. A wide clearance between tanks and boiler was, of course, required, but otherwise the engines were of normal appearance, for the joint in the tank sides was concealed behind a flap plate.

Special Service Mallets

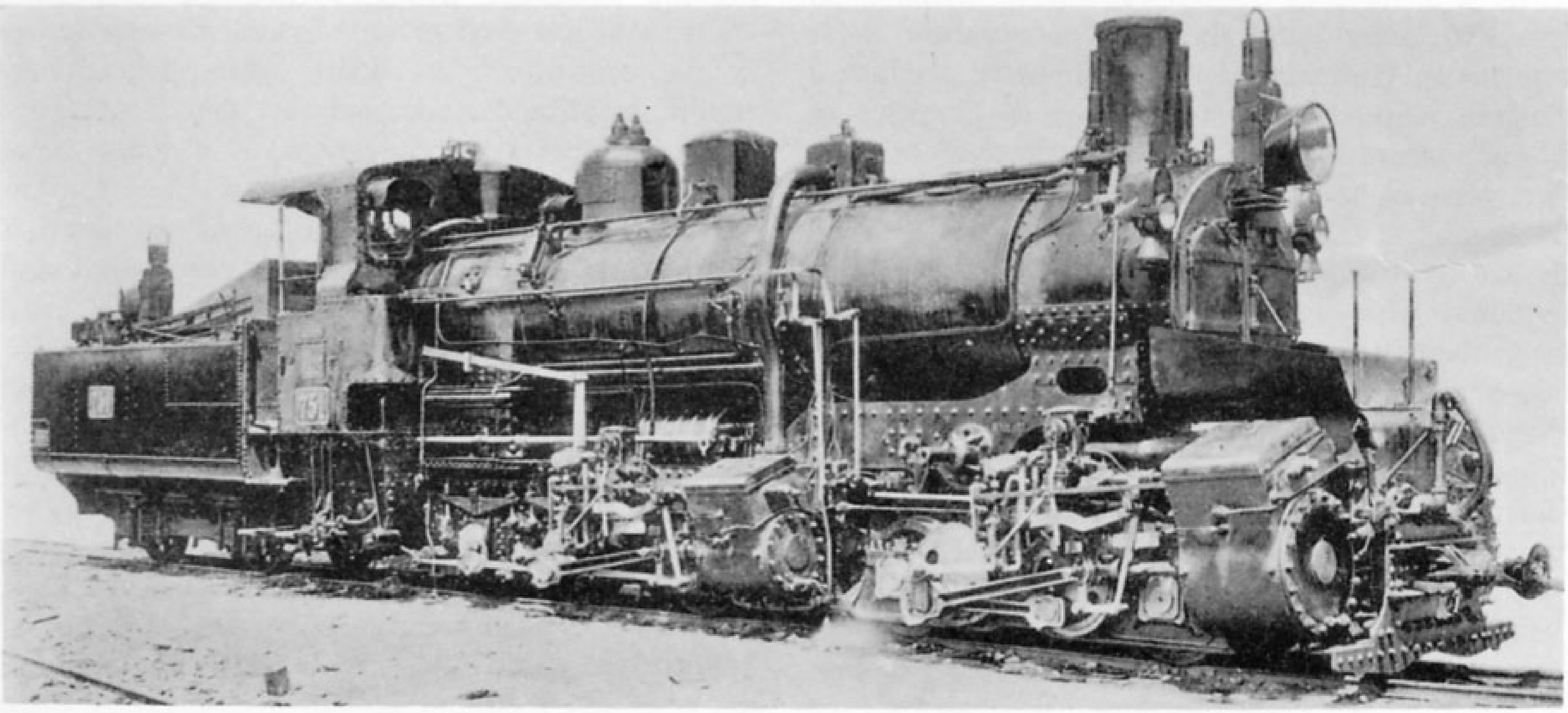
From time to time, Mallets were built for special duties which necessitated changes from the normal modes of construction to a greater or lesser degree, and one of the earlier examples was the 4–4–6–2 built for the Santa Fé for express duties. This was the only Mallet design, or for that matter the only articulated design ever built with driving wheels over six feet in diameter, and the only compound Mallet type with a four-wheeled leading bogie for high speed work. Other features of interest were the multi-stage boiler, already commented upon, and the assymmetrical number of coupled wheels on the two units, although this latter feature was not uncommon on Mallets. Hardly an outstanding success, the 4–4–6–2s were converted to straight Pacifics, after which they gave good service.

Another USA peculiarity, built into but one Mallet series was the 'camel-back' cab, astride the centre of the boiler. Quite common at one time on anthracite-burning engines with outsize fireboxes, it was eventually abandoned as being unsafe, due to the driver and fireman being separated, but not before the Erie Railroad had taken delivery of some 0–8–8–0 camelback Mallets.

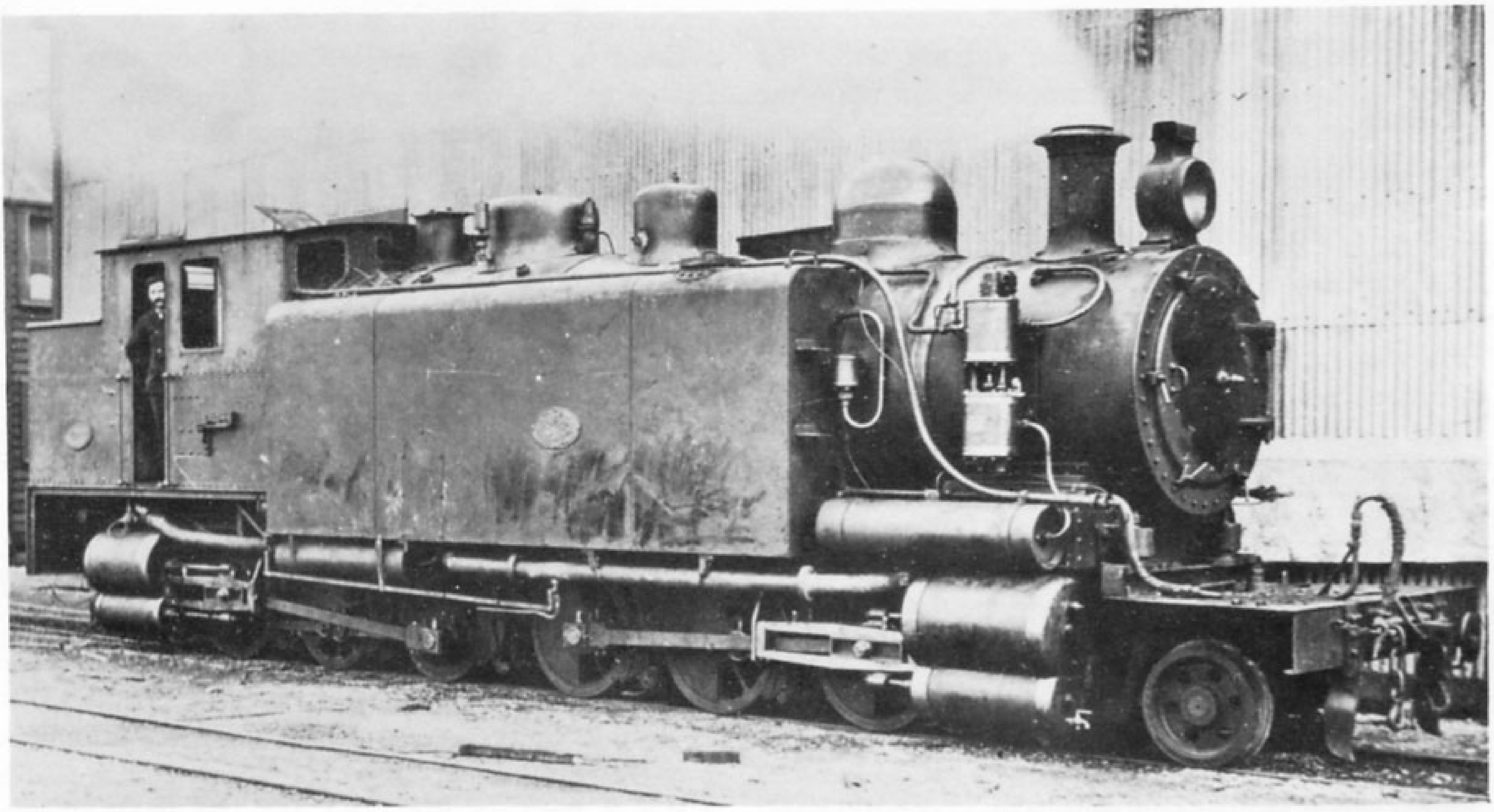
On the subject of cab position, the Southern Pacific, with its severe mountain divisions full of tunnels and snow sheds, were forced eventually to build their Mallets, compound and simple alike, to run cab forward, with the engine unit backwards and tender behind the smokebox. Large numbers of these engines saw service over many years and they became a kind of trademark for the SP. The arrangement was, of course, only feasible with oilfired power, except perhaps by fitting a tank engine type bunker ahead of the cab and leaving the tender purely as a water cart, as was done with the back-to-front 4–6–0s used in Italy. No other railroad adopted SP's cab-in-front design and that system did not extend the idea to conventional engines, even where they operated over the same routes. Apart from the unconventional cabs, neither the camelback nor the cab-forward engines differed from normal Mallets in their running gear and so call for no further comment at this stage.

Rack and Adhesion Mallets

In view of the comprehensiveness of Wiener's *Articulated Locomotives*, there are a couple of surprising omissions, and one of these concerns the rack Mallets which were built. Wiener illustrates a *design* for a rack Mallet, but states that none was built, which is incorrect as the Florisdorf locomotive works, Vienna, designed and built for Bosnia



The Bosnia–Hercegovina Railway used two Florisdorf-built 0–4–6–0 rack and adhesion compounds on its 760mm gauge system. Front (low pressure) cylinders drive the rack wheels and rear (high pressure) the adhesion



Another strange Mallet ran in New Zealand, Pearson's 2–6–6–0T with Vauclain cylinders on each unit—superimposed and driving a common crosshead—the only eight-cylinder Mallet. Rear cylinders faced backwards and a Vanderbilt firebox was another unique feature

two 0–4–6–0 rack and adhesion tender engines in 1906, long before Wiener's work was published. On these engines, the high-pressure cylinders drove the rear six wheels, forming the adhesion unit, while the low-pressure cylinders drove two shafts, coupled by cranks and rods, upon which were mounted the cog-wheels for engaging the rack. This front unit was mounted on four, undriven wheels and the frames on both units were outside the wheels. As may be deduced, the engine was only a part-time Mallet and when running on rackless track the low-pressure cylinders were inoperative and the engine functioned as a two-cylinder simple 4–6–0. As soon as the rack was reached, the leading pair of cylinders were fed with the high-pressure exhaust and the thing became a rack and adhesion Mallet. It is difficult to see any real advantages of this design as compared with the standard 0–6–4T rack engines operated in Bosnia—there was the additional weight of a tender to drag upgrade and no more adhesion to be gained. At any rate, they were not repeated and were scrapped many years before the well-known tank engines which worked the final 760mm gauge rack sections in what had by then become Jugoslavia.

The Fell Mallet

In New Zealand, a strange Mallet form developed, purely through accident of circumstances. On the Rimutaka incline, built on a 1 in 15 gradient, trains were handled by four-cylinder 0–4–2Ts. These had two cylinders driving the normal adhesion wheels and two driving horizontal wheels gripping a central rail, on the Fell system, rather analagous to a rack railway but less positive in application, as the centre wheels could and did slip at times. The condition of these Fell engines was allowed to deteriorate and, as a stop-gap measure, a large new powerful adhesion engine was hastily assembled from spare parts to ease the motive power situation. The story is well told in W. W. Stewart's *When Steam was King*, and the resulting engine was an eight-cylinder 2–6–6–0T using Vauclain superimposed compound cylinders. These cylinders being already in stock, cast with half saddles in the usual American fashion, the rear cylinders were positioned right at the very back of the engine under the bunker, as they would otherwise have fouled the boiler and firebox, incidentally of the cylindrical Vanderbilt type. As such, the engine was a most interesting sub-form of the genus

Mallet, for each unit was a self-contained compound and the slipping of one did not affect the other in any way, a distinct improvement upon the standard form, albeit accidentally achieved. High-pressure steam to the front unit needed routeing via flexible joints, of course, as in a non-compound Mallet, and presumably had normal cylinders been in stock, instead of the Vauclains, she would have been a four-cylinder simple. For further details of her work, and downfall, the author recommends Stewart's book. Sufficient here to say that she fulfilled the stop-gap conditions she was built for, but no more, and was never repeated in New Zealand or anywhere else.

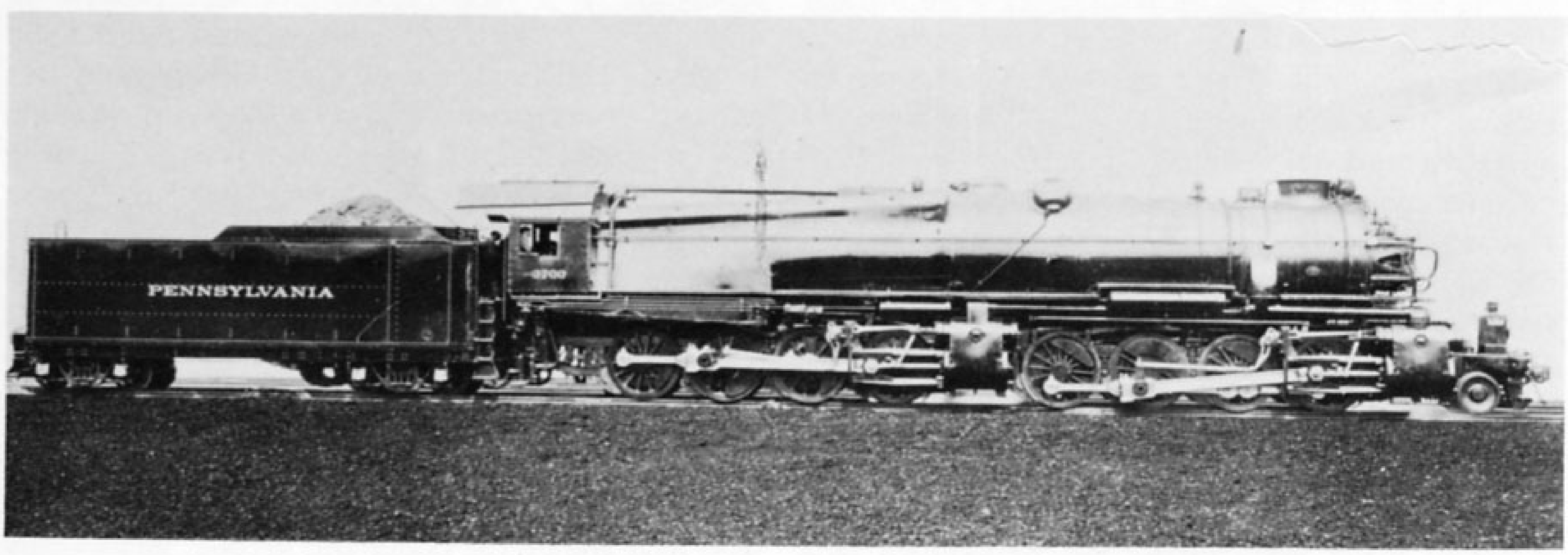
Simple Expansion Mallets

The form in which the Mallet reached its peak of development was in the non-compound, or simple expansion form. In this, old Anatole Mallet's original intentions of double expansion were cast aside, but his *form of articulated chassis was retained.* This is given with special emphasis as some Americans aver that in this form it is not a Mallet at all. A vague and unsatisfactory term, 'simple expansion articulated', has been coined to describe the non-compound Mallet, but as most Garratts, Fairlies, Kitson-Meyers and other like forms were also 'simple expansion articulateds', the term cannot be appropriated to cover the Mallet form only. The use of the term seems to go back to depression days, to an article in the Baldwin Locomotives house journal, when frantic efforts were being made to convince railroads that they would save money by investing in new locomotives. The article propounded the virtues of the new 'simple expansion articulated' as though it were just invented and nothing to do with the old compound version at all—rather on the theory that if you plug a new soap power sufficiently hard someone will be dim enough to buy it!

In all fairness, however, it *was* a good thing, and here we will refer to it correctly as a simple expansion Mallet, or, more succinctly, as a simple Mallet. The simple Mallet originated in Russia in 1902 on some 2–4–4–0s built for the Trans-Siberian Railway. Exactly why they were not compounded has not been recorded but it was presumably due to fears of condensation in the low-pressure pipe between units during the severe Siberian winters. A few 0–6–6–0s were also built non-compound, but eventually the ubiquitous 'E' class superheated 0–10–0 replaced all the Mallets on mainline duties.

Ten years were to elapse before the simple Mallet was to reappear and this time, in 1912, it came out simultaneously and independently in a 2–6–6–2 built in Scotland for South Africa and a 2–8–8–2 built in the USA for the Pennsylvania Railroad. The SAR engine remained the only one of its breed, although it *did* have some effect on future practice. World War I intervened while SAR's class ME simple Mallet was being evaluated, and afterwards there was a newcomer, the Garratt, to consider. Events favoured the Garratt, but presumably the overall performance of the Mallet, in terms of power and speed, was considered satisfactory, for new Garratts and 'modified Fairlies' of classes GC, GCA, and FC were built with the same nominal cylinder and wheel sizes as the ME.

It was in the USA that the simple Mallet was really developed and its potentialities thoroughly



The only successful variation from Anatole Mallet's original concept featured the suppression of compounding, using four high-pressure cylinders and, almost invariably, superheated steam. Pennsylvania's HC 1s 2–8–8–0 was an early example of the breed exploited. In the same year, 1912, as North British built the solitary ME for South Africa, Alco built for the Pennsylvania a 2–8–8–2 simple Mallet equal approximately to two of that company's standard 2–8–0s and suitable for either road work or banking. Some compound 0–8–8–0s for banking and hump shunting followed, and then Altoona works built, in 1919, a stupendous 2–8–8–0 simple Mallet for experimental purposes. The dimensions of this machine exceeded many later 2–8–8–2 and even 2–8–8–4 engines, but it was rather ahead of its time and not repeated. In fact, it is rather ironic that the PRR, having initiated the type of locomotive which was to become a national standard for heavy, high-speed haulage, had no more to do with the concept and for most of its steam-worked period relied upon engines which were, by American standards, rather small.

However, the seed had been sown, but the first shoot appeared more by force of circumstance than by any particular desire to invest in simple Mallet power. The Chesapeake & Ohio had, by 1923, been users of 2–6–6–2 compounds for over a dozen years, but traffic had grown to the point where Mallets with six-coupled units were becoming inadequate. Unfortunately for Anatole Mallet's original conception, restricted clearances, especially in tunnels, prevented the application of an eight-coupled compound with its low-pressure cylinders of at least forty inches diameter, and the American Locomotive Co co-operated with the railway's own design engineers to produce forty really notable simple expansion 2–8–8–2s. The problems of fitting both high-pressure and exhaust pipes to and from the four cylinders within the restricted space between wheels and huge boiler were successfully overcome, and the resulting locomotive was massively good-looking—far more so than some of the earlier long, thin and gawky compound Mallets. The performance of these C&O engines excited interest. Here was an engine with the haulage capacity of a compound Mallet, plus the free running of a conventional two-cylinder engine —an obvious development whose earlier acceptance had been delayed by residual opinions that the compound's double expansion must somehow be more economical and that high-pressure flexible steampipe joints must be troublesome to maintain. The former proved false and careful detailing in the drawing office prevented the latter, so that the engines were an immediate and immense success.

Following the success of the C&O simple 2–8–8–2, simple expansion Mallets were built for large numbers of American railroads. This was the era of 'Super Power', a term coined to embrace engines built with large fireboxes supported over four-wheel trailing trucks, initiated by Gölsdorf in Austria in 1908 and taken up with gusto by Lima in the mid-1920s. 'Super Power' meant engines having a high horsepower relative to tractive effort, in other words an engine to haul the same loads at much higher speeds. Just as with rigid engines the 2–8–2 gave way to the 2–8–4, the latter often with larger driving wheels, so in the field of articulateds there began to appear some 2–6–6–4 simples in place of the old 2–6–6–2 compounds. With the bigger eight-coupled power, the simple substitution of a four-wheel truck had little effect on improved firebox proportions for the firebox was *still* above the coupled wheels, these latter being often of larger size than hitherto, and ultra shallow fireboxes were used as a matter of no other choice.

Lima produced a notable 2–6–6–6 design for the C&O, giving a deep, wide firebox sufficient to provide 7,500hp, but no eight-coupled extensions to this concept were ever built, although a 2–8–8–6 design, or even a 2–8–8–8, would have been highly effective.

Alco, working in conjunction with Otto Jabelman of the Union Pacific, applied a four-wheel leading truck and improved articulation with vertically rigid construction to produce the 4–6–6–4 Challenger type, a high-powered design suitable for 80mph speeds and often used on mountain express work. Deservedly popular, the Challenger type spread to many roads but only the Union Pacific itself built the logical 4–8–8–4 development, the 'Big Boys', whose fame completely eclipsed their relatively small numbers. Both the 4–6–6–4 and 4–8–8–4 types had fireboxes above the coupled wheels, and had steam development been persisted with, someone would have presumably combined Alco's leading bogie with Lima's deep firebox and trailing truck to produce a 4–6–6–6, or even a 4–8–8–8 capable of generating outputs well into the five figure horsepower range. As it was, American railroads succumbed with incredible rapidity to the great diesel confidence trick and any such great engines which might have been envisaged were destined to remain stillborn.

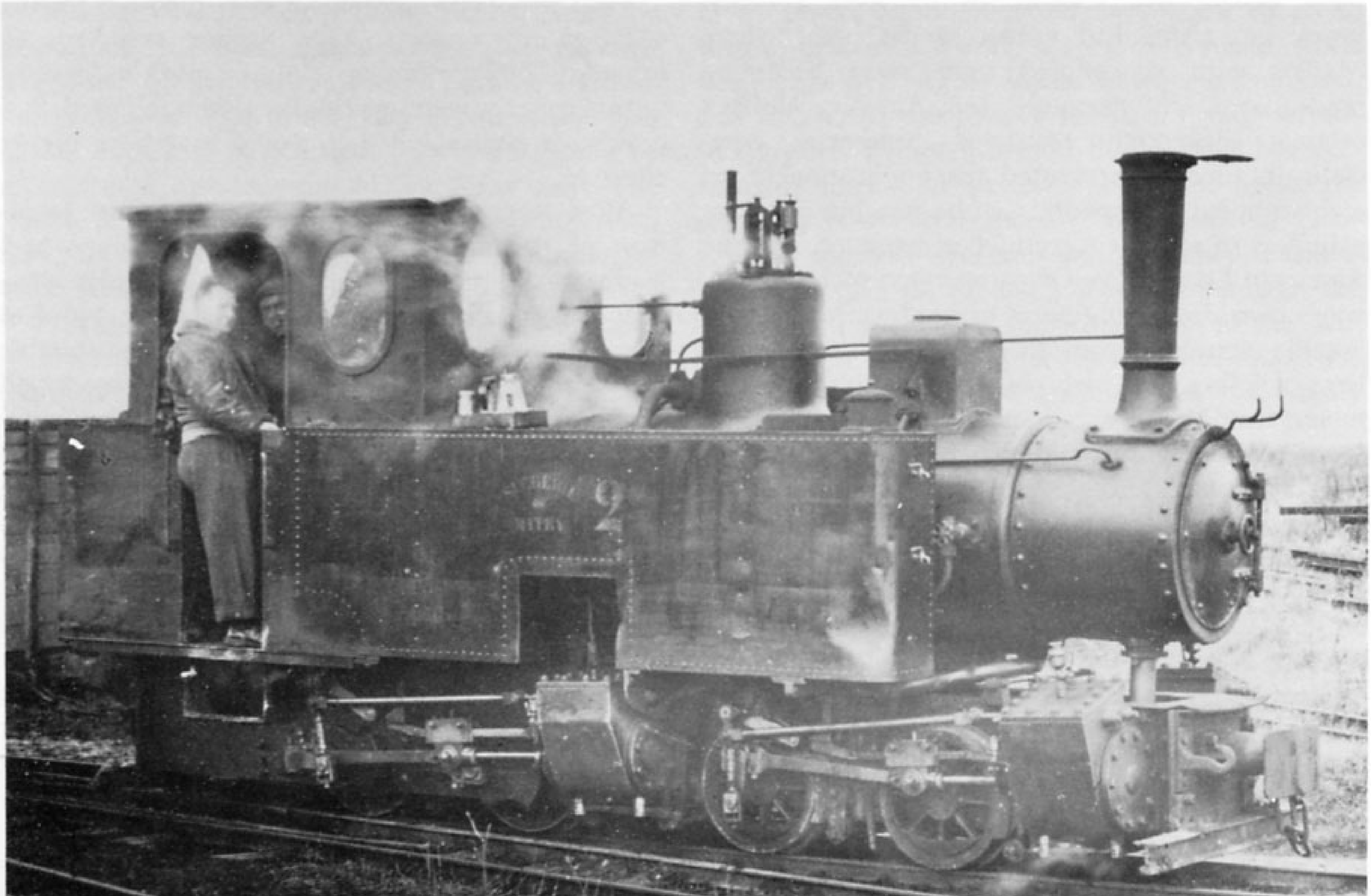
CHAPTER 3

THE MALLET IN EUROPE

EUROPE was the scene of the Mallet's conception and birth, and France the land of its inventor and of its initial trials, although the pioneer Mallet was built just over the border at Tubize, in Belgium. It is logical, then, that our geographical survey of the breed should commence with Europe in general and France in particular, after which it is proposed to head east round the world, finishing up in the United States where the Mallet reached its peak of development. In each country the Mallet will be dealt with in descending order of importance—main line, secondary lines, industrial and agricultural.

FRANCE

Although the homeland of the Mallet, French



Typical of the many 60cm gauge 0–4–4–0Ts used in France and elsewhere, Sucrerie de Mitry's little compound brings a load of sugar beet to the mill

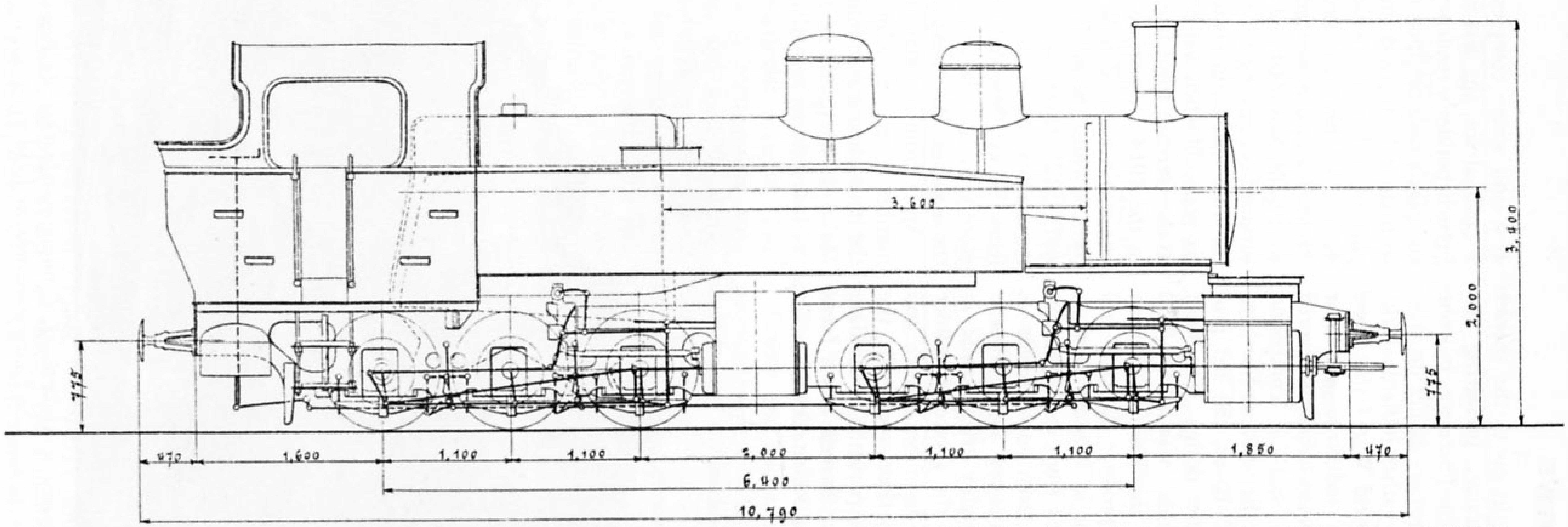


Fig 11 *French departmental railways, Vivarais section, 0–6–6–0T built by the Société Alsacienne de Constructions Mécaniques (SACM)*

mainline railways never caught on to the species for heavy duty freight service, preferring the smaller 2–8–0 or 2–10–0 types. There was but one exception to this rule, the Chemins de Fer de l'Est, or Eastern Railways, always rather individualistic, who decided just before World War I that their heavy mineral traffic in the industrial area near Alsace-Lorraine (then in Prussian hands) warranted something more than the smallish compound 2–8–0s in general use. Whilst the adjacent Northern Railway went in for large 2–10–0s, the Est proceeded with a 2–6–6–0 Mallet design. The most remarkable thing about this was that local builders were ignored and the land of Anatole Mallet's great idea did not produce the only real mainline Mallets ever to run in France! Instead, the two engines were ordered from the American Locomotive Co and, apart from such details as buffing and draw gear necessary for European operation, they were thoroughly transatlantic in concept. The reasons behind the choice of builder are obscure—it may simply have been price and delivery, but by 1908, when they were built, the USA already had far more experience in building mainline Mallets than France herself and a feedback of this was a useful acquisition. Additionally, in a land where complexity was never considered a cardinal sin, the Est may have been wary of a French builder's tendency to exhibit his virtuosity and play a *cadenza* upon the Mallet theme complete with three high-, and four low-pressure cylinders, plus any other frill which Gallic ingenuity could devise. All this was ruled out by buying a simple straightforward American design, and two engines were built, Nos 6001 and 6002. Little seems to have survived concerning their performance; allocated to the industrial basin visited by few, they were only six years old when war broke out and, working near to the German front line, both were soon engulfed in the 1914–18 warfare. At the end of hostilities one was a battered hulk and the other had disappeared, whilst the influx of numerous Prussian G12 and G12[1] three-cylinder 2–10–0s as armistice reparations solved the Est's heavy haulage problems. So excellent did the G12s prove to be that more were built in France to the same design and the mainline Mallet experiment died for ever.

Apart from the main lines proper, there were a number of secondary lines absorbed or operated by the mainline companies and a number of these used Mallet tank engines of the same general style as the independent secondary railways. The Est itself,

French simple expansion Mallets—1, Compagnie du Gaz de Paris' 0–6–6–0T at St Denis gasworks in 1954

FRENCH MALLETS

Railway	*Gauge*	*Type*	*Builder*	*Date*	*Quantity*	*Lit. Ref*
Paris exhibition	60cm	0–4–4–0T	Tubize	1887	1	V.43
Tramway de Royan	60cm	0–4–4–0T	Decauville	various	?	V.43–4
Tramways du Calvados						
Tramway de Pithiviers á Toury, etc						
Mines de Blanzy	80cm	0–4–4–0T	SACM	1891		V.44
CF Departmentaux	metre	0–4–4–0T	SACM	1888–91	10	V.45–6
Reseau d'Allier	"	0–4–4–0T				V.48
CF d'Herault	"	0–4–4–0T	Cail.	1891	4	V.48
Réseau Breton	"	0–4–4–0T	SACM	1894	7	V.51
Sud de France	"	0–4–4–0T	SACM	1895	8	V.52
Tramways á vapeur d'Ille-et-Vilaine	"	0–4–4–0T	Corpet L	1897	4	V.54
PO Correze	"	0–4–4–0T	Tubize, Blanc-Misseron	1906	4	V.70
Pyrenées–Orientales	standard	0–4–4–0T	Henschel	1910	2	V.74
Avricourt–Blamont–Cirey	"	0–4–4–0T	Henschel	1911	2	V.76
CFD	metre	2–4–4–0T	SACM	1909	5	V.94
CFD	"	0–6–6–0T	SLM	1905	1	V.105
CFD	"	0–6–6–0T	SACM	1927–32	6	V.114
Réseau Breton	"	0–6–6–0T	SACM	1913	9	V.110
Cie Gaz du Paris	standard	0–6–6–0T	Corpet L	1928	1	V.116
Cie de Somain-Anzin	"	0–6–6–0T	La Meuse	1930	3	V.117
" " " "	"	0–6–6–0ST	" "	1940	2	V.118
CF de l'Est	"	2–6–6–0T	Alco	1908	2	V.252

apart from the 2–6–6–0 mainliners just dealt with, had a subsidiary, the Avricourt-Blamont-Cirey, of standard gauge, with two Henschel 0–4–4–0Ts lacking any features of particular interest. The Paris–Orleans railway had a metre-gauge subsidiary, the P. O. Correze, and in 1906 Blanc-Misseron built four 0–4–4–0Ts of the classic metre-gauge Mallet type for operation on this scenic railway near Clermont Ferrand. This line and its Mallets deserve special mention as, surviving into the early 1970s and being by this time part of the SNCF, PO-C 0–4–4–0T Nos 101–4 were the only Mallets operated by the French National system, and one has been preserved working.

Next to the main companies came the *departmentaux* railways, owned and operated by the provinces through which they ran. Invariably lightly laid, these lines used featherweight track winding over and around natural obstructions, and many used Mallet locomotives, particularly of the 0–4–4–0T variety. The growth of road transport in rural areas spelt doom for most of these lines, the majority of which were metre gauge, and attempts to ape the opposition by using a variety of outlandish diesel railcars proved but a temporary palliative. Steam often survived for the *mixte* trains and for heavy traffic on *jours de fête*, but since World War II such trains have become a pleasant and nostalgic memory in the byways of France. The CFD bought a number of Mallets for its various lines and used the 0–4–4–0T, 2–4–4–0T and 0–6–6–0T types, the best known, because of their recent survival, being the 0–6–6–0Ts used on the Vivarais and Reseau Breton lines.

France also had a number of heavy simple expansion 0–6–6–0Ts for heavy industrial use. These included a low-loading-gauge side tank for the Compagnie du Gaz de Paris (Paris Gas Company) at their St Denis gasworks, and five huge machines, three side and two side plus saddle tanks, at the Compagnie de Somain á Anzin, a large coal and steel combine near Valenciennes in northern France. All these engines have now been scrapped.

Agricultural tramways, especially for the *betterave* (sugar beet) crop once played an important part in France's rural economy and most of these were of 60cm gauge, on Decauville portable tracks of very light weight indeed. Mallets were quite common on these, many being built by the Decauville company more or less to the same design as the original Mallet. Like today's farm tractor which has replaced them, some were built for stock and just taken off the shelf when a buyer appeared, and it would be a difficult task to trace the fate of all these minute Mallets. One of the largest and best known *betterave* railways, by virtue of its reasonable proximity to Paris and its public passenger service, was the Tramway de Pithiviers á Toury, which ran a number of 60cm gauge 0–4–4–0Ts and an 0–6–6–0T, the latter acquired from a military line in French Morocco.

The table above gives basic details of the Mallets

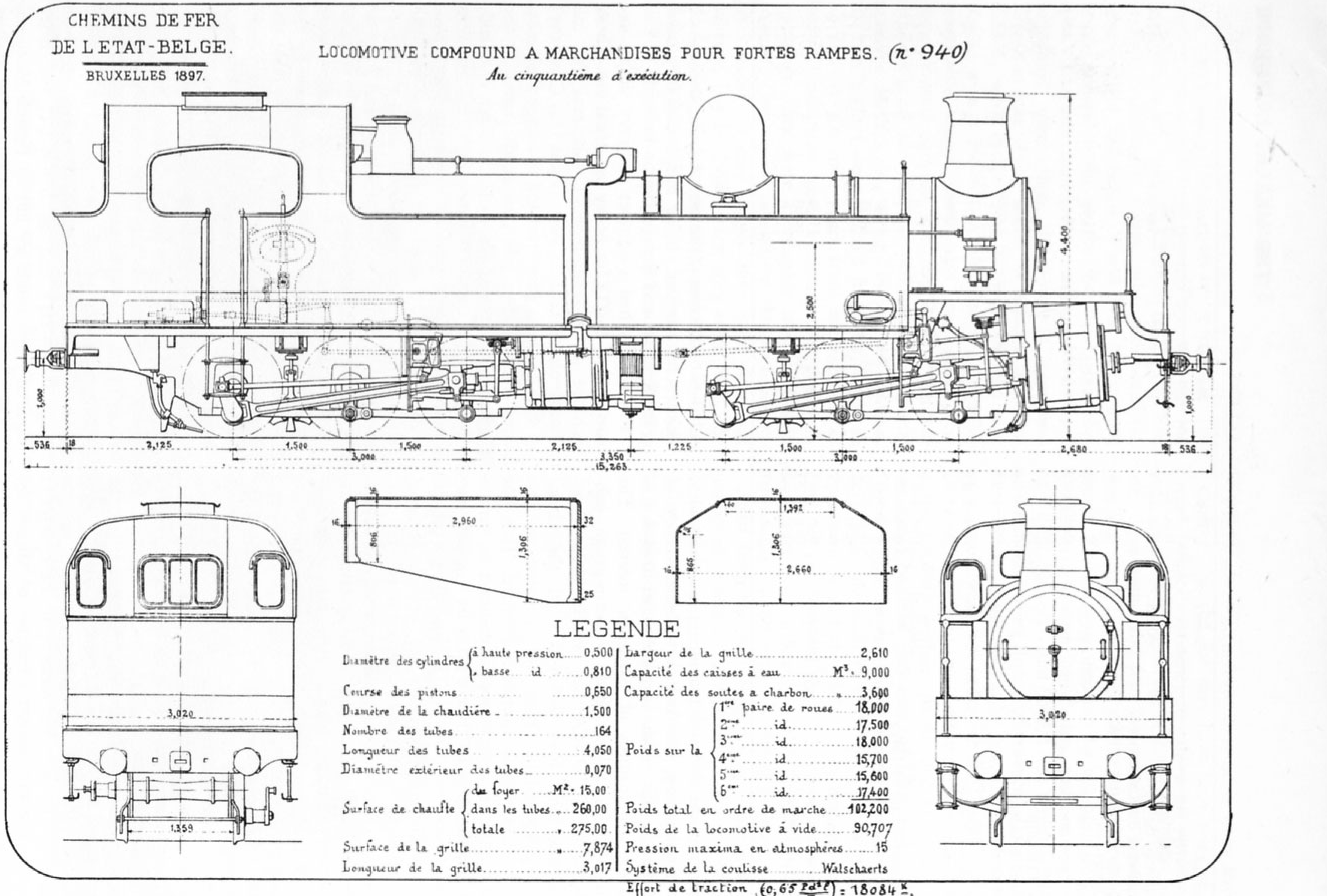
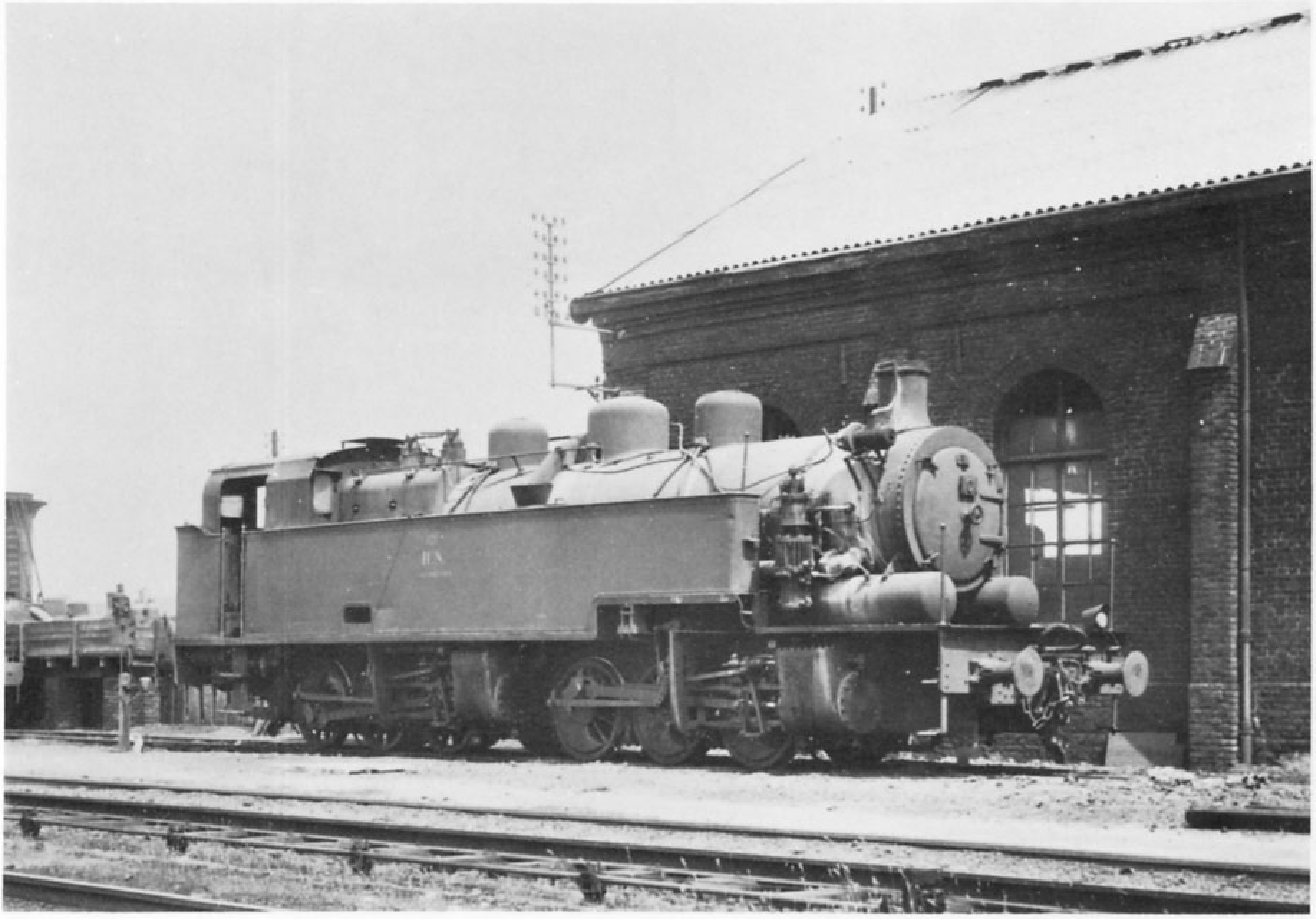


Fig 12 *Belgian State Railways: the ungainly 0–6–6–0T banking engine, No 940, for the Liége–Ans incline*



French simple expansion Mallets—2, original 1930 0–6–6–0T No 101 of the Houillères du Bassin du Nord et du Pas-de-Calais (HN) *at Valenciennes in 1952*

used in France, and another on page 61 provides selected principal dimensions for comparison.

Mallets preserved operable

Although all the regular services for Mallets have been discontinued, visitors to France will be able to see a few of these narrow-gauge tanks at work on preserved lines, usually operated at weekends only during the tourist season. Those known to the writer are:—

CF Forestier d'Abreschviller. In eastern France (department de la Moselle), 70cm gauge, with an 0–4–4–0T of German build.

CF Regioneaux. This has reopened 37km of the former Vivarais system, between St Agrève and Dunieres, on metre gauge. Engines include ex-PO Correze 0–4–4–0T No 101, and ex-Reseau Breton 0–6–6–0T No 413, plus, it is believed, a Vivarais 0–6–6–0T.

Toury Pithiviers museum line has preserved a section of this 60cm-gauge system, including steam power. It seems probable that one of the Mallets will operate at some time or other.

BELGIUM

The Belgians only ever had one Mallet on their state railways, but it was a most remarkable machine for its day. Built by the Societé St Leonard, of Liége, in 1897, No 940 was an immense 0–6–6–0T for banking on the severe incline right from the platform end at Liége Guillemins station to a summit at Ans, with maximum gradients a solid 1 in 30. Weighing just over one hundred tons, she was one of the largest engines built in the nineteenth century and included a number of unusual constructional features. The boiler was of the shallow Belpaire type then used in Belgium, with over 80sq ft of grate area. These oversize grates were apparently used to obtain a high boiler efficiency, as the smokebox arrangements were such as to prevent 'thrashing'—and probably adequate steaming as well! Cylinders were of incredibly modern design with outside admission piston valves controlling events through large straight ports. The low-pressure exhaust

French simple expansion Mallets—3, HN *No 105, built in 1940 with combined saddle and side tanks. Valenciennes, 1952*

escaped to atmosphere through a giant tapered chimney, rather like an old-fashioned milk churn. The side tanks were split, the forward sections fixed to and moving with the low-pressure main frames, the first example of this type of construction. In service, it was apparently not a success. Wiener attributes this to 'new (and defective) system of valve gear', but this is hardly likely as ordinary Walschaerts gear, the local speciality, was provided. It seems more probable that it was the valves themselves which were at fault, most early applications of piston valves running into trouble due to leakage or seizing up. Incidentally, both Wiener and Vilain quote a grate area of 7·30sq m for this engine whereas the official Belgian diagram in the author's possession gives 7·874sq m and is presumably correct. It might be added that the Etat Belge Mallet supplemented two equally strange-looking 0–8–2Ts, and no adequate banker was available for the incline until after World War I, when a number of the competent Prussian T16^{1} 0–10–0Ts, acquired as reparations, took over the duties, continuing to the end of steam in the mid-1950s.

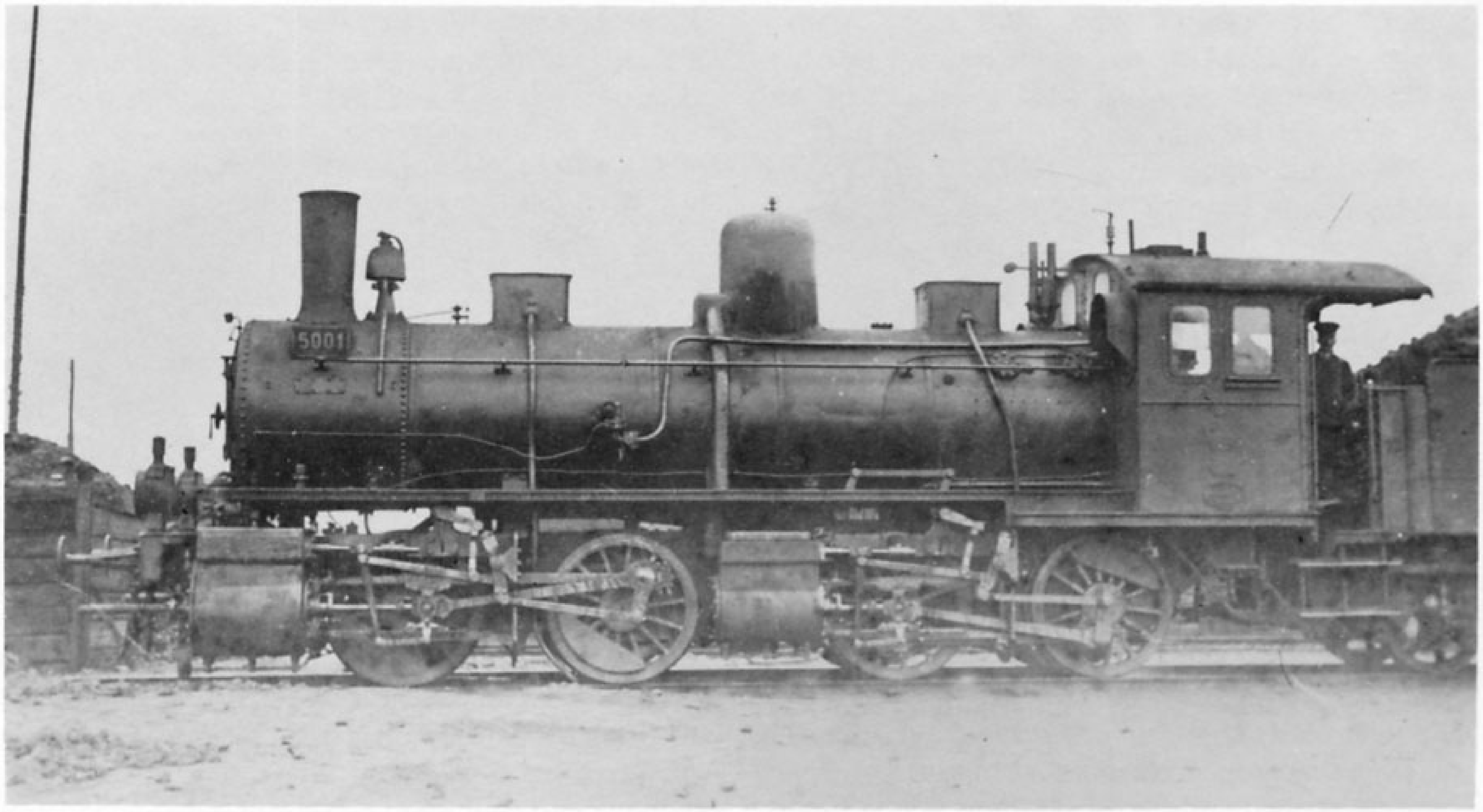
Although operating but the one Mallet, Belgian builders supplied a number of the type for use in other countries, including, of course, the first Mallet ever built.

HOLLAND

Mallets were hardly the type of engine needed for the flat lines in the Netherlands, but Dutch builders were active in their manufacture, particularly for the East Indies (now Indonesia). Both Werkspoor of Amsterdam and Ducroo & Brauns built Mallets for Java and Sumatra. Weiner mentions the former, but Vilain omits all mention of engines built by the colonial power for their overseas possessions.

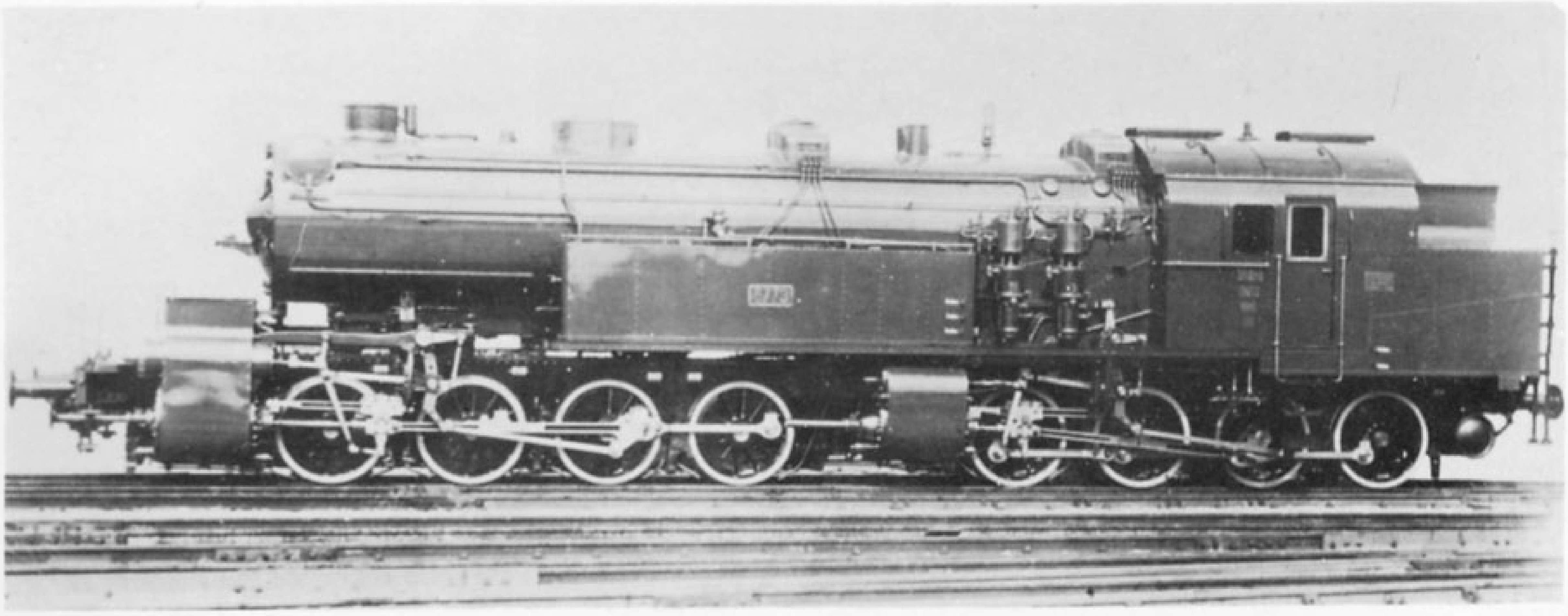
LUXEMBOURG

The sole Mallets used in Luxembourg were a class of metre-gauge 0–4–4–0Ts for the Luxembourg–Echternach line.



Prussian State Railways class G9 0–4–4–0, built by SACM at Grafenstaden in 1899 and allocated to the Kattowitz division

German Federal Railways 0–4–4–0T No 99.637, a 750mm gauge Mallet built for the former Württemburg State Railways, seen at Buchau in 1963



Massive and handsome, the Bavarian 0–8–8–0T compound banking engines were Europe's only eight-coupled Mallets

DENMARK

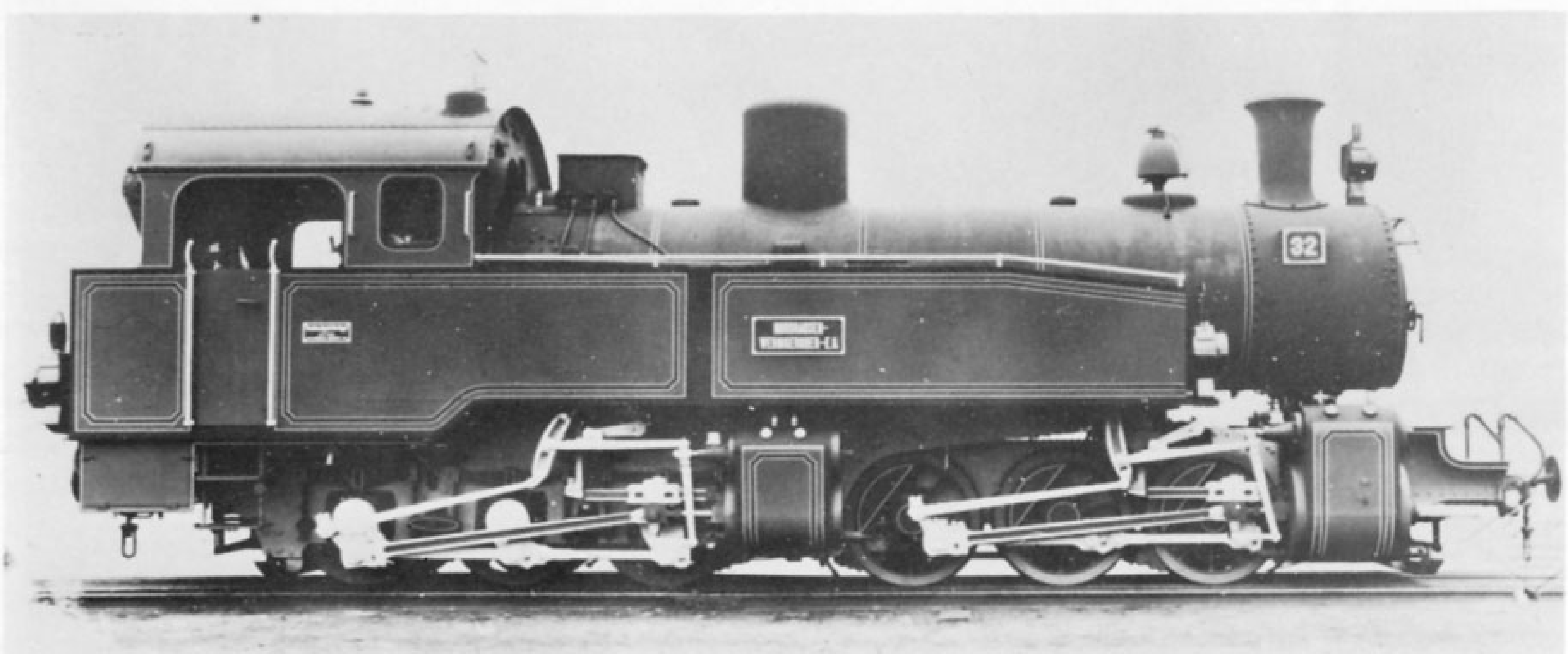
There were two groups of Mallets in Denmark, both on private railways. First were a couple of Jung 0–4–4–0Ts of standard type, delivered to the Horsens-Bryrup-Silkeborg Jernbane, but more interesting was a 2–4–4–2T engine with large wheels for passenger work, for the Sud Funen Jernbaner, incorporating components from ancient 0–4–2 engines.

SWEDEN

Sweden's only Mallets seem to have been three neat 0–6–6–0 tender engines for the 891mm-gauge Dala–Ockelbo–Norrsundet railway, built by the Atlas works at Stockholm in 1910. Fitted with four-wheel tenders, they were in use until recently and it is understood that one may be preserved in working order.

GERMANY

The major user of Mallets in Europe, in terms of sheer quantity, Germany's Mallets were for the most part tank engines for use on secondary railways. There were, however, a number of early mainline tender engines on various state systems

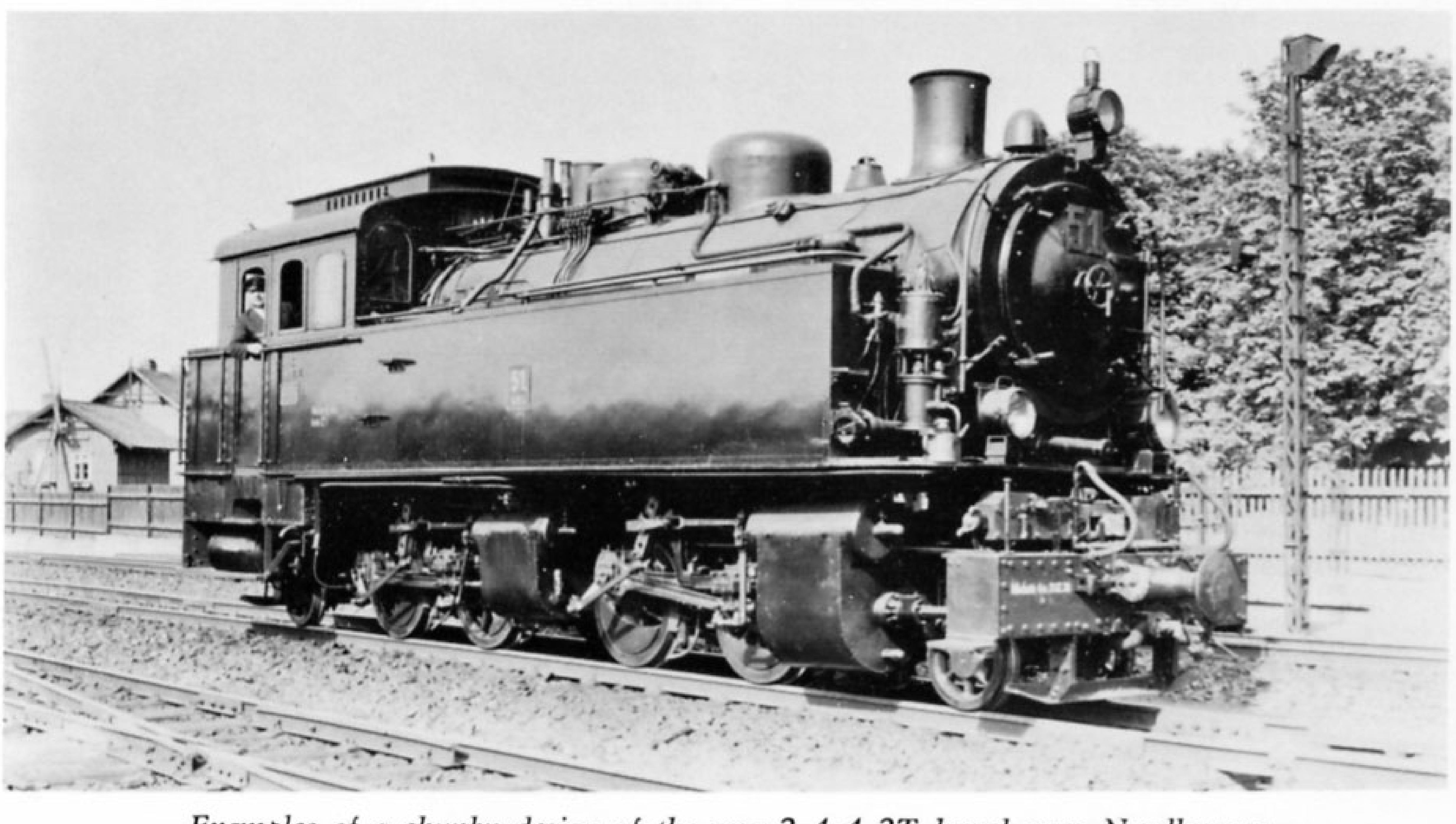


Nordhausen–Wernigeroder Eisenbahn's metre-gauge 0–6–6–0T featured superheaters and piston valves and the Bavarian State railways introduced the most powerful Mallets to be used in Europe, and the only eight-coupled type used on the continent.

Germany was the pioneer in the use of the Mallet for mainline work and, following the successful use of Mallet tank engines elsewhere, the Alsatian firm, SACM, conveniently situated within the French/German province of Alsace-Lorraine (or Elsass-Lothringen), persuaded the neighbouring Baden and Prussian State Railways to try out 0–4–4–0 Mallet tender engines for the heaviest freight duties. The first were supplied in 1892, and between then and the end of the century, 91 were supplied to these railways, plus the Bavarian State Railways, its subsidiary the Pfältzbahn (Palatinate Railway), and the Saxon State Railways. The complications of a compound Mallet for work more economically performed by 0–8–0 and 2–8–0 types soon led to their building being discontinued, but a number lasted until the early 1920s and were taken into stock by the Reichbahn, who numbered them into the 55 series, tagged onto the end of the numerous 0–8–0s which supplanted them. Thus ended a brief excursion by Germany into mainline Mallet haulage, but the Bavarian 0–4–4–0 has been preserved in the museum at Nürnberg and has been sectioned to show the internal workings.

Apart from the tender engines, the German mainline systems made use of Mallets for branch line and banking work and the biggest user was the Royal Bavarian State Railways, who built thirty-one 0–4–4–0Ts for the numerous Lokalbahnen, or local railways, which fed the mainlines. Apart from their state ownership, these were of much the same type as the private railways used elsewhere in Germany, and one engine, sold to the VÖEST steelworks at Linz in Austria, seems likely to be preserved workable. The Württemburg State Railways also built a class of 0–4–4–0Ts for branch lines, this time of 750mm gauge, and these have but recently been withdrawn from service by the Bundesbahn.

Of all the German Mallets, the 0–8–8–0T designed by Maffei, of München, for the Bavarian State Railways, were the most impressive and magnificent. Apart from their sheer size, they were of handsome appearance, in line with most of that company's products, and it is greatly to be regretted that not one has been preserved for posterity. When built they were the largest and most powerful locomotives in Europe and the only class of eight-coupled Mallet used on the continent. Indeed, they were almost the only eight-coupled articulateds of any sort, far exceeding in number the three 2–8–8–0T Kitson-Meyers on the



Examples of a chunky design of the rare 2–4–4–2T breed were Nordhausen–Wernigeroder Eisenbahn's passenger Mallets. The line is now in East Germany

GERMAN MALLETS

Mainline Mallets

Railway	*Gauge*	*Type*	*Builder*	*Quantity*	*Date*	*Numbers*
Prussian State	standard	0–4–4–0	SACM	27	1893–98	various
Baden State	"	0–4–4–0	SACM	32	1893–00	various
Saxon State	"	0–4–4–0	Hartmann	30	1898–03	1251–80
Bavarian State	"	0–4–4–0	Maffei	1	1896	2100
Bavarian Pfälz	"	0–4–4–0	Maffei	1	1896	199
Bavarian State	"	0–4–4–0T	Maffei	31	1899–1900	2501–31
Bavarian State	"	0–8–8–0T	Maffei	15	1913–14	5751–65
Reichbahn	"	0–8–8–0T	Maffei	10	1922–3	5766–75
Württemburg State	750mm	0–4–4–0T	Esslingen	9	1899–1913	641–9

NOTE: Reichbahn/Bundesbahn numbers of the above were as follows:

55.6001–13	ex-Saxon	0–4–4–0
55.6101–19	ex-Baden	0–4–4–0
55.7101–02	ex-Bav/Pf	0–4–4–0
96.001–15	ex-Bav	0–8–8–0T
96.016–25	Reichbahn	0–8–8–0T
98.701–31	ex-Bav	0–4–4–0T
99.631–30	ex-Württ	0–4–4–0T

Private Railways

Railway	*Gauge*	*Type*	*Builder*	*Quantity*	*Date*	*Numbers*
Gartetal–Gottingen	750mm	0–4–4–0T	Jung/O&K	2	1899	4–5
Osterode–Kreiensen	750mm	0–4–4–0T	O&K	2	1907	2, 6
Steinhelle–Medebach	750mm	0–4–4–0T	Henschel	4	1901	1–4
Rugensche Kleinbahn	750mm	0–4–4–0T	Vulkan	5	1902–8	241–5
Rhein–Sieg Eisenbahn	785mm	0–4–4–0T	Jung/O&K	4	1901–14	misc
Albtal Verkehrs Gmbh	metre	0–4–4–0T	Karlsruhe	4	1897–8	5–8
Bremen–Tarmstadt	"	0–4–4–0T	Hohenzollern	1	1899	1
Bichtal Eisenbahn	"	0–4–4–0T	Humboldt	3	1904	
Brohltal Eisenbahn	"	0–4–4–0T	Humboldt	3	1904–9	10–12
Franzburger B. Nord	"	0–4–4–0T	Vulkan	2	1902–10	165–6
Gera–Meuselwitz–Wuitzer	"	0–4–4–0T	Borsig	4	1900–21	misc
Geilenkirchener Kreisbahn	"	0–4–4–0T	Hohenzollern	2	1900	3–4
Mittelbadische Eisenbahn	"	0–4–4–0T	SACM/Karlsruhe	2	1896–1918	misc
Nordhausen–Wernigeroder	"	0–4–4–0T	Jung	9	1897–1901	11–22
Ruhr–Lippe Kleinbahn	"	0–4–4–0T	Jung/Hohenz	9	1897–1904	1–14
Arnstadt–Ichterhausen	standard	0–4–4–0T	Jung	1	1908	352
Filderbahn	"	0–4–4–0T	Hohenzollern	2	1902	1–2
Halle–Hettestedter	"	0–4–4–0T	Vulkan	4	1903–6	
Hohenebra–Eheleben	"	0–4–4–0T	Jung	2	1901–4	82, 85
Moselbahn	"	0–4–4–0T	Hohenzollern	2	1902	1–2
Süddeutscher Eisenbahn	"	0–4–4–0T	SACM/Jung/Vulk	8	1900–12	misc
Weimar–Berka–Blankenheim	"	0–4–4–0T	Jung	1	1901	980084
Südharz Eisenbahn	metre	0–4–4–2T	Henschel	2	1925	56–7
Nordhausen Wernigeroder	"	2–4–4–2T	Borsig	2	1926	51–2
" "	"	0–6–6–0T	Orenstein & K	2	1910	31–2
Brohltal Eisenbahn	"	0–6–6–0T	Hanomag	1	1928	II
Mittelbadische Eisenbahn	"	0–6–6–0T	Hanomag	1	1925	104

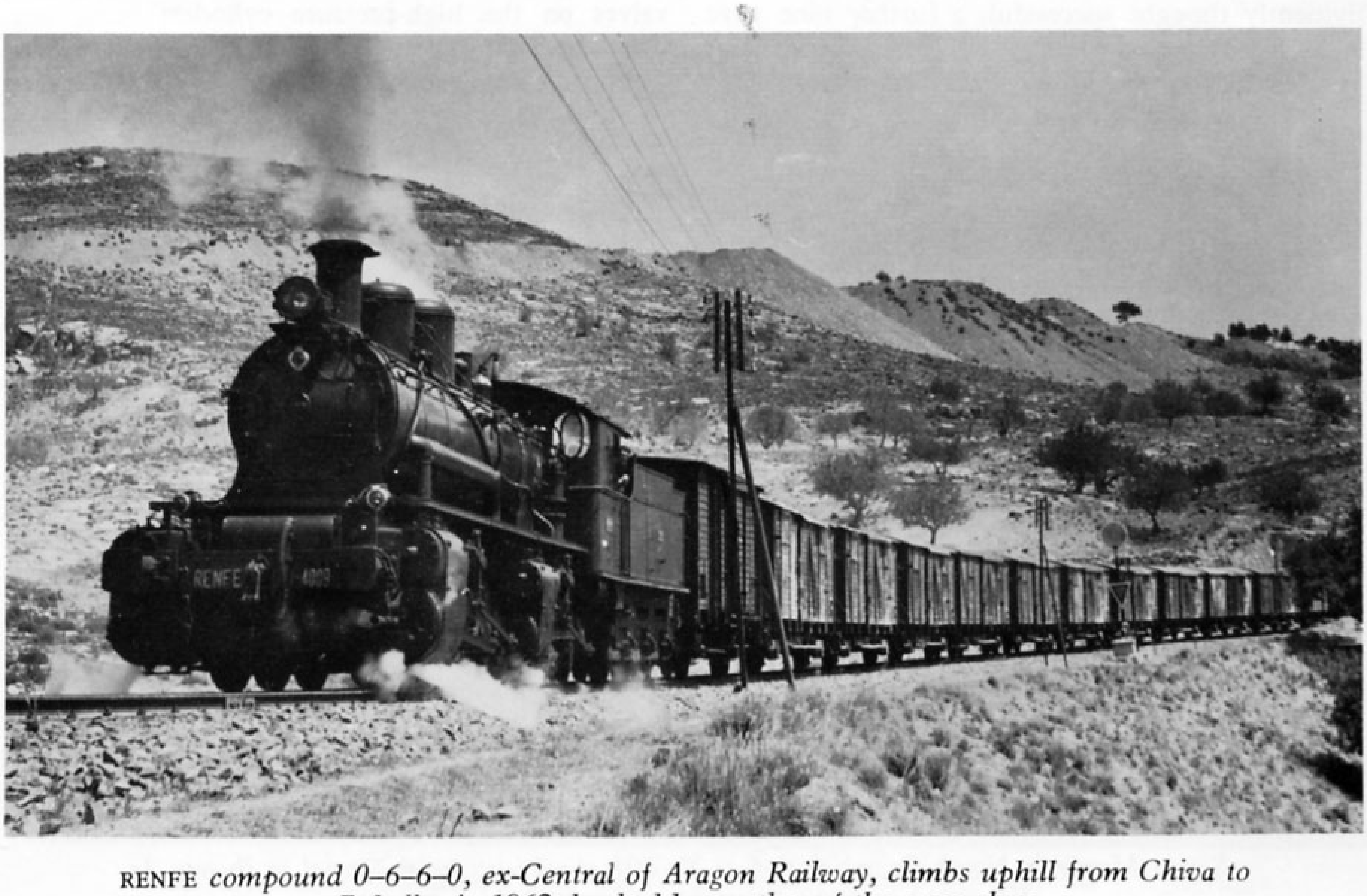
Additionally, in World War I, the German Army had built seven 0–4–4–0Ts by Karlsruhe, in 1917. These were of the standard metre-gauge form and were dispersed after the war to the

Euskirchener Kreisbahn	loco no 7	
Nordhausen Wernigeroder	" " 41	later DR 99.5906
Mittelbadische Eisenbahn	" " 105	
Albtal Verkhers Gmbh	" " 6	
Ruhr-Lippe Kleinbahn	" " 10–12	

More interesting were twenty 0–6–6–0Ts by Henschel, with piston valves all round although not superheated. Their disposal seems less well recorded, and is confused by new engines built new to the same design, by Hanomag. One of these handsome engines, with a corresponding 0–4–4–0T, both ex-Mittelbadische Eisenbahn (Zell-Todtnau), is preserved working on Switzerland's Blonay–Chamby line.

Great Southern of Spain, plus the solitary LNER Garratt. Fifteen Bavarian 0–8–8–0Ts were supplied in the first batch in 1913–14 and, after formation of the Deutsches Reichbahn, another ten were delivered in 1922–3. The earlier batch suffered from slipping of the low-pressure unit, hence the second series had larger high-pressure cylinders, thus extracting more energy from the steam and leaving a smaller residue to power the second stage. The first batch were never brought into line with the second, as this would have meant new cylinders and the troubles were evidently insufficient to warrant this. The main spheres of operation of these engines, which spent most of their lives as the DR 96° class, was the Aschaffenburg–Laufach section on the main Frankfurt–Nürnberg line, and from Hof on the Nürnberg–Berlin line. After formation of the DR it was found that the Prussian T20 2–10–2T (DR class 95°) were equally as effective as the larger Mallets as well as being cheaper to maintain, and in the years after World War II the Mallets were gradually phased out, the last working from Hof about 1951.

In the realm of private railways, the Mallet had a much longer innings, but most were of the usual saturated, slide-valved 0–4–4–0T type so common throughout Europe and are adequately dealt with in tabulated form below. Of the many Mallets listed (probably not all that were built), only a few need special mention. The two 0–4–4–2Ts built by Henschel in 1925 for the Südharz Eisenbahn are an interesting essay into upgrading the old 0–4–4–0T and providing it with a superheater, piston valves, a larger boiler and an attractively modern appearance. The following year, 1926, Borsig expanded upon the theme and built for the Nordhausen–Wernigeroder Eisenbahn a pair of 2–4–4–2Ts having similarly modern features and appearance. Both these types were on metre gauge and the Südharz design is little known, being mentioned in neither Weiner's nor Vilain's works. The Nordhausen line, prior to the acquisition of their 2–4–4–2Ts, had a number of the standard form 0–4–4–0Ts and also a couple of interesting 0–6–6–0Ts which might be considered as the ultimate form of mixed-frame Mallet, with outside rear and inside leading frames. Built by Orenstein & Koppel in 1910, they featured superheaters and had piston valves on all four cylinders—the only mixed-frame Mallets developed thus. After eleven years service, both engines were sold to Bolivia, after which they have been lost trace of. Tabulated



RENFE *compound 0–6–6–0, ex-Central of Aragon Railway, climbs uphill from Chiva to Rebollar in 1962, banked by another of the same class* details of the German Mallets are on page 48.

SPAIN

Conditions on the Spanish railways often favoured articulated locomotives and when the major independent lines were amalgamated to form the RENFE (Spanish National Railways), this concern found itself in the undoubtedly unique position of owning four different types of articulated steam locomotives! These were the du Bousquet, Kitson-Meyer, Garratt and, of course, the Mallet. These latter, which concern us here, amounted to twenty locomotives of four different classes and were from two railways. Principal contributor was the Central of Aragon Railway, later famous for its express Garratts, and this line's first venture into articulated power was with four large, heavy 0–6–6–0Ts built by Borsig in 1902. Possessing no frills, these unsuperheated slide-valve engines were found too heavy for the track and were converted from an impressive-looking tank to a clumsy 2–6–6–0 tender class, thereby reducing the axle load from over eighteen tons to thirteen. They were scrapped in 1952. The C of A's next attempt was a further four Mallets, 0–6–6–0 tender engines built by SLM at Winterthur, Switzerland, in 1906. These were much smaller, lighter and more elegant, and had larger wheels as well. Evidently thought successful, a further nine were built by Henschel during 1912–28, these latter being to an improved design with superheaters and piston valves, increasing their rating from the 950hp of the Swiss saturated slide-valve version, to 1,210hp. These were the last new Mallets to be built for Spain, which then turned to the Garratt type.

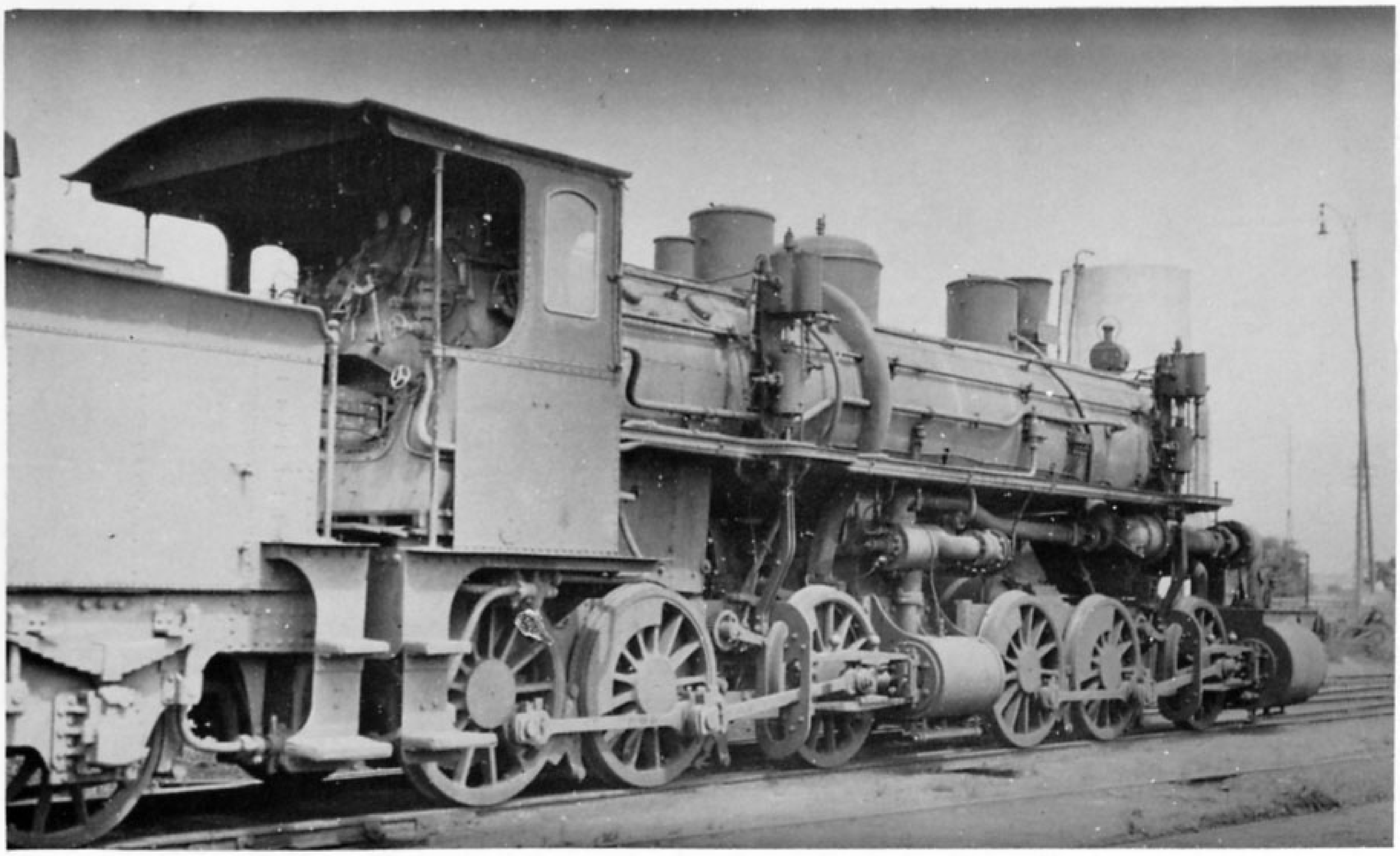
The latterday workings of the final superheated batch were of interest. Displaced from their original stamping ground, the Valencia–Teruel line, these 0–6–6–0s were transferred from the C of A shed at Valencia to the main *Termino* roundhouse and deployed on freight turns along the Valencia–Utiel line, the most direct route to Madrid, although not the main line. The main freight left Valencia in the early hours behind an 0–6–6–0, banked by another of the same class, and was overtaken (usually at Cheste), by the *Correo*, or mail train, double-headed by two old 4–6–0s. The following day they returned downhill double-headed, and there was usually a light freight or two with single Mallets as well. When the Utiel route went diesel in 1965–6, the Mallets were transferred for a short time to Alicante, where they saw passenger work, but were very soon withdrawn altogether. One other Spanish broad-gauge line, the Zafra–Huelva, had Mallets, three 0–6–6–0 tender engines by Maffei, in 1913 and 1922. These were unsuperheated, but had piston valves on the high-pressure cylinders only, and were scrapped in 1954.

Tabulated data on the RENFE Mallets follows:

Sierra Menera's North British 0–6–6–0 No 401 climbs up from Teruel to Puerto de Escandon in 1962, assisting a Garratt-hauled ore train

Madrid–Aragon Railways 2–6–6–0 leaks steam into a cool March morning in Madrid, hauling empty cement wagons to the workings

F. C. Utrillas' ex-Tunisian 2–6–6–0T No 204 eases ore hoppers over the weighbridge at Zaragoza in 1962



Archaic wheel and motion design betray the ancestry of this Portuguese 0–6–6–0 No 500, rebuilt from a pair of venerable 0–6–0 engines and seen at Entroncamento in 1932

RENFE *Nos*	*Type*	*Builder*	*Date*	*Former Railway and Nos*
060.4001–09	0–6–6–0	Henschel	1912–28	C of A 61–69
060.4011–14	0–6–6–0	Winterthur	1906	C of A 51–54
060.4021–23	0–6–6–0	Maffei	1913–22	ZH 101–03
160.4001–04	2–6–6–0	Borsig	1902	C of A 41–44

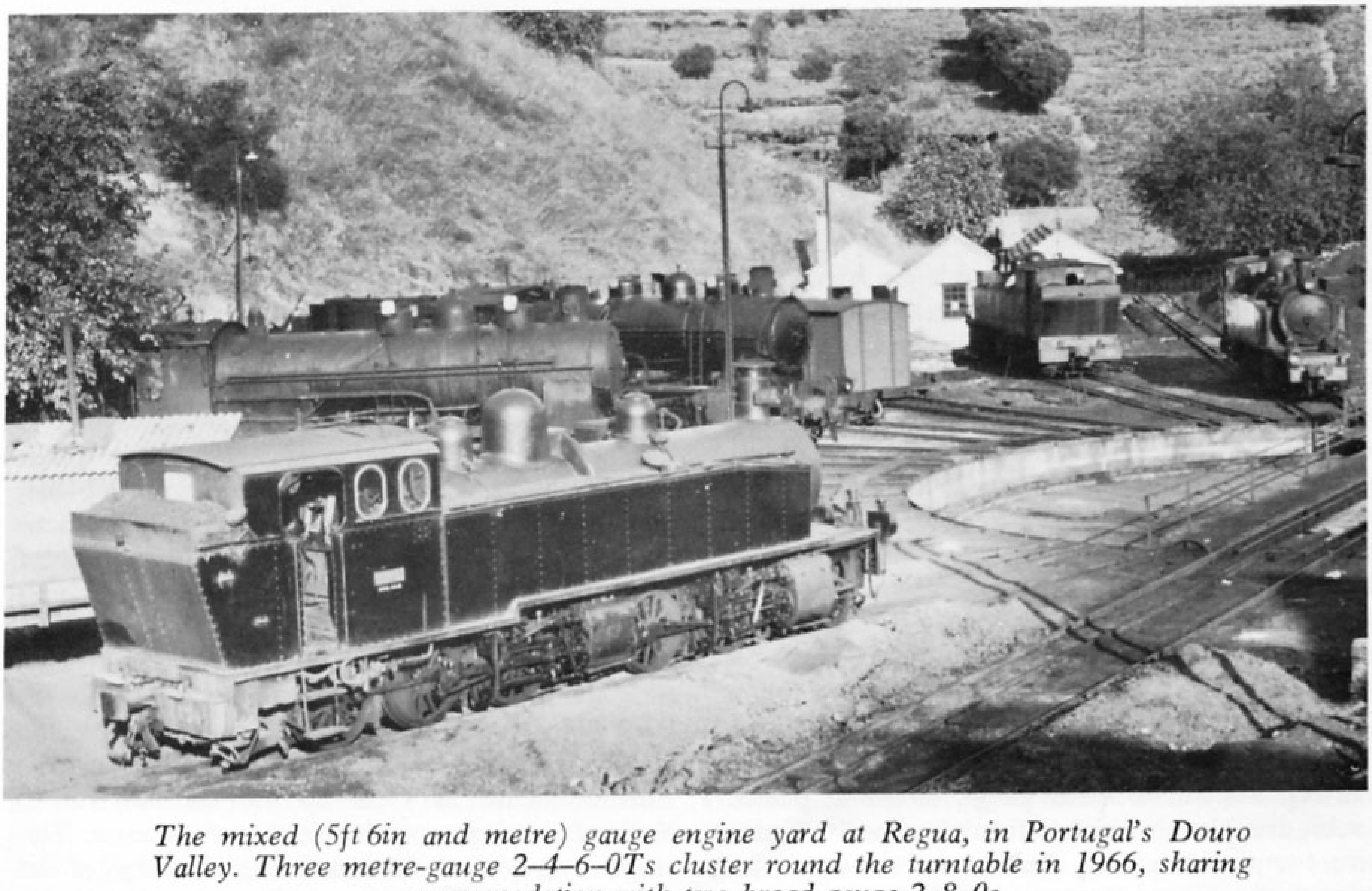
Narrow-gauge railways

The RENFE did not embrace railways of sub-broad gauge and thus these lines with their Mallets (if any), remained independent until either closed, taken into the ESTADO narrow-gauge network or, occasionally, remaining in operation. Of the once numerous metre-gauge lines, a number used Mallets and their variety exceeded that of the RENFE engines. Two of the lines used tender engines, one being the Ferrocarril Sierra Menera, a metre-gauge line used to transport iron ore from the Ojos Negros mines, near Teruel, to the Altos Hornos steelworks at Sagunto. For the section uphill against the load, North British built in 1909–11 four 0–6–6–0 Mallet tender engines of a new metre-gauge design, supplied later to various lines in India, Burma and Kenya. These remained in service until the mid-1960s having been latterly supplemented by a pair of Garratts.

Another 'narrow-gauge main line' was the Madrid–Aragon, which never reached the mountainous province of Aragon itself but remained a comparatively unimportant local line running from Niño Jesus in Madrid. Apart from its usual collection of narrow-gauge tank engines, the railway bought, for its long-distance aspirations, three superheated 2–6–6–0s with bar frames and piston valves all round. Looking rather like some of the Alco Mallets built for Africa, they were nevertheless of Belgian build, from the Societé St Léonard, of Liége, in 1916–17. These, working in the mid-1960s, are now believed replaced by diesels.

All other Spanish Mallets were tank engines although some were of more than usual interest. The Utrillas Railway, at Zaragoza, had a long association with the type, starting with a couple of standard metre-gauge 0–4–4–0Ts by Orenstein & Koppel in 1901. The company's staple iron ore traffic soon demanded something more powerful and in 1917 Baldwin built an 0–6–6–0T of generally American appearance but sporting such

Portuguese metre-gauge 0–4–4–0T No 167 handles a typical suburban working from Oporto (Trinidade) to Señora da Hora in 1966



The mixed (5ft 6in and metre) gauge engine yard at Regua, in Portugal's Douro Valley. Three metre-gauge 2–4–6–0Ts cluster round the turntable in 1966, sharing accommodation with two broad-gauge 2–8–0s

Zell–Todtnau's metre-gauge 0–4–4–0T, No 105, at work in pastoral Baden. This locomotive is now on Switzerland's Blonay–Chamby line

completely European features as plate frames, outside at the rear and inside at the front. Saturated steam was distributed to the high-pressure cylinders by piston valves and to the low-pressure by slide valves. After World War II, the Utrillas needed more six-coupled Mallets and was able to strike a bargain in the shape of eleven 2–6–6–0Ts purchased from Tunisia. Ten of these entered traffic from 1952 to 1956, the other presumably being retained as a spare parts reservoir, and these kept the traffic moving until the ore deposits ran out and the railway closed in the mid-1960s.

SACM built a chunky 0–4–4–0T design for the 75cm-gauge lines of the Queiros mines, and in 1895 Couillet built for the Durango-Zumaragua railway a pair of metre-gauge 0–4–4–0 pannier tanks, complete with that firm's curiously distinctive rounded cab. The Penarroya-Puertollano had one of the German wartime 0–6–6–0Ts and the Catalan Railways had two 2–4–4–0Ts built by SLM in 1902, for the Swiss Rhätische Bahn, reaching Spain, third hand, in 1947.

PORTUGAL

The Mallet in Portugal is mainly a metre-gauge phenomenon but there *was* a broad-gauge 0–6–6–0 tender engine, most details of which remain a complete mystery to the author. All that can be gleaned from the photograph available is that it was rebuilt from two of the ancient long-boiler 0–6–0s, so long a feature of the Portuguese railway scene, joined together and surmounted by a second-hand boiler from some suitable source. The number on the engine is 501 and the photograph was taken at Entroncamento in 1932 by the late W. H. C. Kelland, a pioneer globe-trotting enthusiast. The engine is a compound and the detail design of the massive steampipe joints indicates a familiarity

Zell–Todtnau's larger 0–6–6–0T, from the same German Army source, is also today on the Blonay–Chamby line

with American practice. Also to be noted are the separate power reverse cylinders, one for each unit (what troubles could such complexity bring forth?). The Companhia Portugese denied all knowledge of the thing when questioned by the author and it was probably a skeletal white elephant best left firmly locked in its cupboard. Vilain gives the rebuilding date as 1910, and adds cylinder dimensions. However, the author would be pleased to hear from anybody with further information on this interesting engine.

Turning now to the metre gauge, the CP has three classes of Mallet tank engine, all of which are in service today. Two classes are 0–4–4–0T, with two of a smaller and ten of a larger class, all by Henschel in 1905–10. The two lighter engines were built for the 900mm-gauge Porto a Pavoa–Famalicao line, and, with the line, were converted to metre gauge in 1930. They are to be found today on the Livracao–Celorico line. The larger engines are usually very busy around Oporto, sharing a busy suburban service with 2–6–0Ts and modern 2–8–2Ts—probably the last Mallets in the world in intensive passenger service.

The third series of Portuguese Mallet tank is also the most interesting and was delivered by Henschel between 1911 and 1923. Numbering eighteen engines, they were of the unusual 2–4–6–0T wheel arrangement, unsuperheated but with piston valves all round. Apart from the assymmetrical groups of coupled wheels, they have no unusual constructional features, but they have been most successful, showing that odd numbers of coupled wheels are little or no disadvantage on a compound Mallet. Other such Mallets have been used elsewhere in the world, but so far as is known these Portuguese engines are the last of their species left in service. They are distributed amongst the country branches of the CP system and may be seen particularly on the branches from Regua and Pocinho, in the Douro valley, and from Sernada do Vougo, south of Oporto. E216 was fitted with a Giesl ejector, later, transferred to E209 when boilers were changed, and although it gave beneficial results the future of these narrow-gauge branches is 'under consideration' and no more capital is being expended upon them. Presumably the outcome is predictable—the clean, quiet Mallets and metre-gauge trackage will be replaced by road-wrecking lorries, spewing noxious diesel fumes into the clean air of the wine-growing valleys, costs will escalate, and all will go under the euphemism of 'progress'.

SWITZERLAND

The gradients encountered by the Swiss railways along their Alpine routes presented a natural challenge to a type of locomotive such as the Mallet. What is more, the Swiss were quick to see the machine's potential, for in 1890, only a year after the original eleven-ton 0–4–4–0T had been exhibited at Paris, Maffei built for the Gotthard railway what was then a monstrous engine, an 85-ton standard-gauge 0–6–6–0T. It remained the sole example of its class and was presumably not considered a complete success, although it was retained until 1917 when it was reputedly sold to Poland, although no trace of such an engine has so far emerged from that country. Nevertheless, Maffei's monster Mallet took the type straight out of the secondary narrow-gauge bracket and placed it firmly on the mainline route which was to end with Union Pacific's 'Big Boy' 4–8–8–4. No other Swiss line went in for such large articulated power —the Swiss Central railway had Maffei build them twenty-six 0–4–4–0Ts in 1891–4, and then SLM followed on with twelve 0–4–4–0 tender engines during 1897–1900. That, as far as standard gauge went, was the end of the Mallet's reign among the Swiss Alps; electric traction prevented further steam development, although it is interesting to speculate on the type of steam the Swiss might have been using today had they not electrified.

On the metre gauge, the foremost user of Mallets was the Landquart–Davos railway, much better known by its German title, the Rhätische Bahn. The ten Mallet tanks owned by this railway were fairly unusual for metre-gauge Mallets in having outside frames on both engine units. First built were a pair of Maffei 0–4–4–0Ts, in 1890–1, and these were followed in 1896 by a couple of SLM 0–4–4–2Ts. The two original engines were converted to 2–4–4–0T in 1910–11, following the success of eight new engines of that type supplied by SLM in 1902–3. The Rhätische Bahn, in common with so many Swiss lines, electrified, and most of the Mallets were sold, the two originals to Brazil, three of the main class to the Yverdon–St Croix, and another three to Madagascar. The Yverdon–St Croix, in addition to its three ex-Rhätische engines, had three inside framed 0–4–4–0Ts of the standard type, built by SACM in 1893. All six of this line's Mallets were eventually superheated and fitted with piston valves on the high-pressure cylinders, but no sooner had the ex-RhB engines appeared on the scene than the originals were sold to the Lausanne–Echalens–Bercher. Later, in 1947, the 2–4–4–0Ts were sold to the Catalan railways, in Spain, although only two seem to be listed as arriving there—perhaps one was in pieces for spares. Two standard 0–4–4–0Ts were supplied by Jung in 1897 to the Saignelegier a la Chaux-de-Fonds line, also of metre gauge.

Of greater interest today is the Blonay–Chamby tourist railway which, in its collection of metre-gauge power, includes two Mallet tank engines, both ex-Mittelbadische Eisenbahn in Germany and both originally German Army engines of World War I. One, No 105, is the classic 0–4–4–0T, and the other the impressive-looking 0–6–6–0T with piston valves all round. Thus Switzerland, never a major user of Mallets, is today one of the few countries in Europe where they are still in service.

ITALY

The Alpine and Appenine backbone of Italy might have made it an obvious Mallet country, but with fairly light trains the type remained in a subordinate position serving the country's secondary railways. The SNFT, or National Railway & Tramway Co, had a number of standard gauge 0–4–4–0Ts for their line from Brescia to Edolo, these being of the standard form with slide valves and no superheater. The author well remembers seeing one of these leaving Brescia in 1951 (his first remembered sighting of a Mallet), and was so intrigued watching it go by that he almost failed to notice one of the line's smaller Mallets banking the lengthy train out of the station. Other Mallets in Italy were on the distinctive 950mm gauge of that country, of which only those built in 1913 by Borsig for the Adriatico–Sangranista line need comment as having piston valves on all cylinders. There were Mallets on the Italian islands of Sicily and Sardinia, all narrow gauge, and a perusal of the appropriate books by Vilain and Kalla-Bishop will provide any further required information. Italy also featured as a builder of Mallets, mainly for her colonies in North Africa and Eritrea, and these engines will be dealt with in Chapter 4.

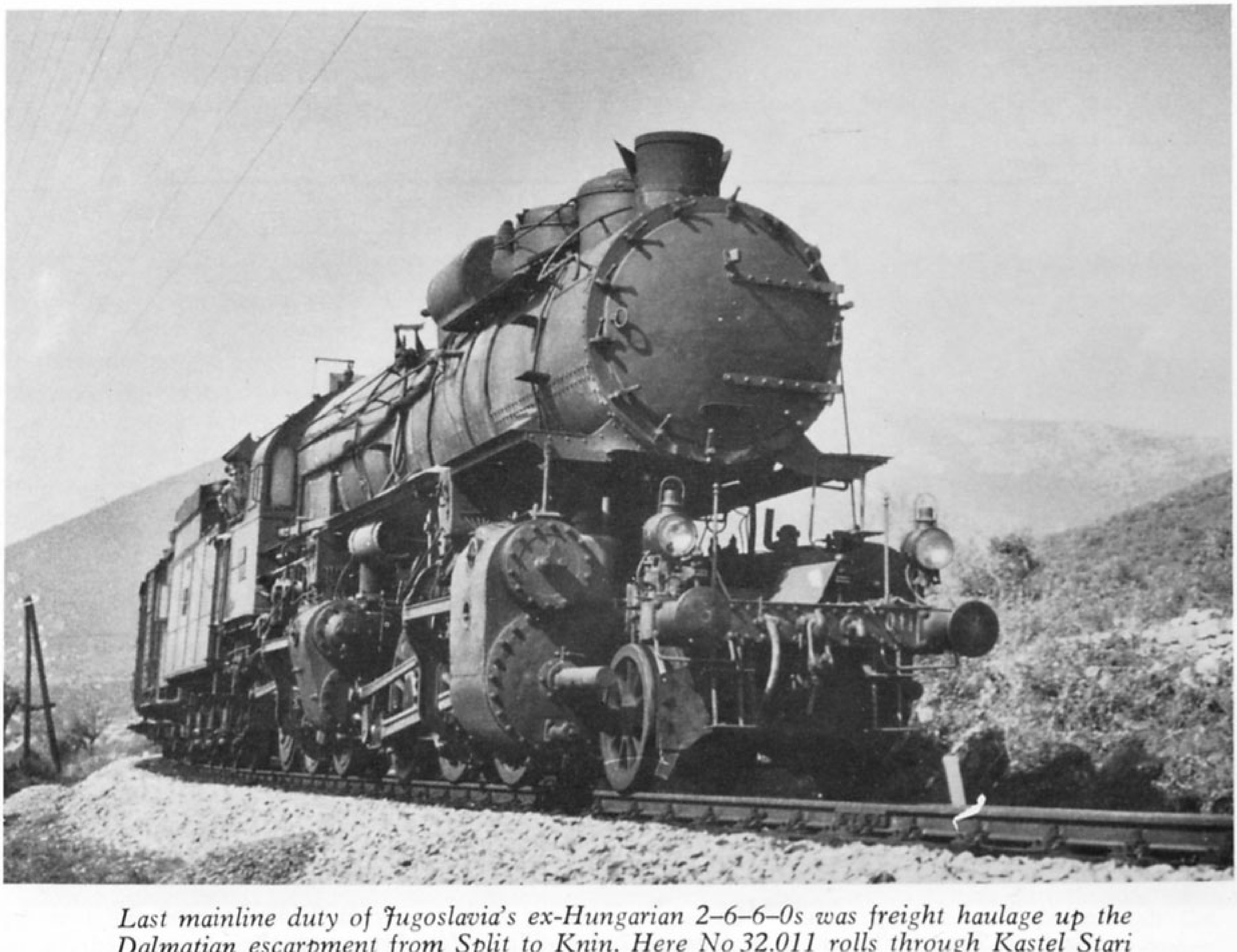
EASTERN EUROPE

Locomotives in Eastern Europe, including of course the Mallets, have already been covered in this author's book, *The Steam Locomotives of Eastern Europe*, so that it may be sufficient here briefly to recapitulate the quantities and principal features of the Eastern European Mallets.

HUNGARY

Hungary was by far the most important Mallet user in the whole of Europe, no less than 163 mainline Mallets having been built for the Hungarian State Railways over a period of twenty-three years, plus others for the international Kaschau–Oderberger Railway. Each design was an advancement upon its predecessor and all except the original 0–4–4–0 class had piston valves all round. The largest of all, the imposing-looking 601 class 2–6–6–0, had Brotan boilers with water tube fireboxes, as did a few of the two preceding classes. After World War I, Hungary lost most of its mountain territories to Jugoslavia, Rumania, and Czechoslovakia and, with them, most of its Mallets briefly detailed below.

Class Nos	*Type*	*Dates built*	*Old Class nos*		*Features*
422.001–30	0–4–4–0	1898-02	IVd	4401-30	Sat, slide valves
401.001–15	2–4–4–0	1905-08	IVe	4451-65	Sat, piston valves
651.001–58	0–6–6–0	1909-14	VIm	4501-30	" " "
601.001–60	2–6–6–0	1914-21	—	—	Sup, p.v., Brotan



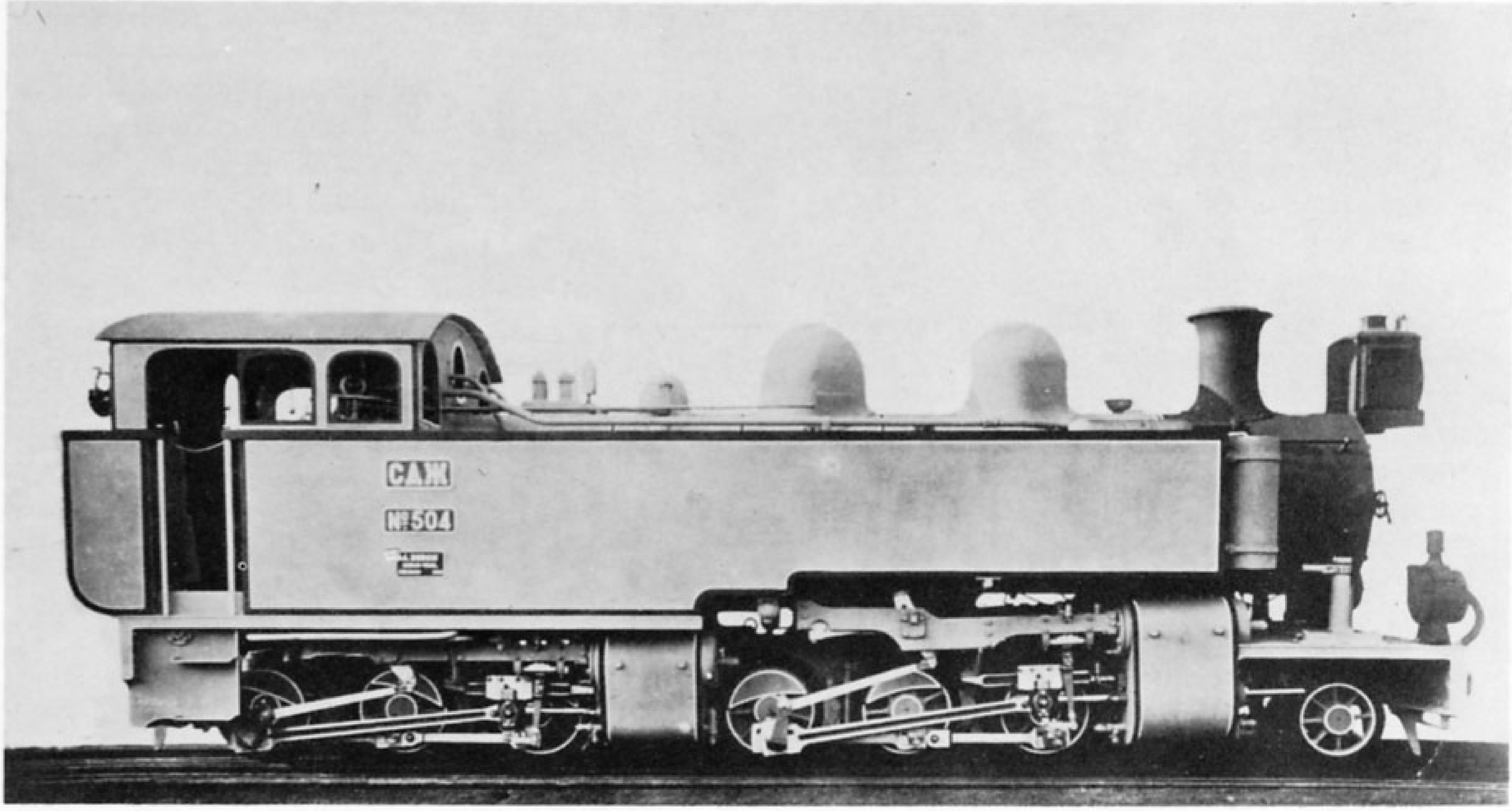
Last mainline duty of Jugoslavia's ex-Hungarian 2–6–6–0s was freight haulage up the Dalmatian escarpment from Split to Knin. Here No 32.011 rolls through Kastel Stari in 1957, the year before diesels

JUGOSLAVIA

This country rates as having the largest number of Mallets in Europe—the author has traced 194, and there might well have been a few more industrial engines to bring the number past the two hundred mark. It is not that the Jugoslavs were conscious protagonists of the Mallet type, for only thirty were actually ordered by them after the country's formation out of the dismembered Austro-Hungarian empire. Their mainline Mallets were inherited from Hungary and the narrow-gauge engines gleaned from assorted sources in Serbia, Bosnia, Hercegovina, Montenegro and the Austrian Army. Nevertheless, there were some interesting engines, plus one unique type found nowhere else in the world.

The list of locomotives detailed below constitutes as diverse a collection of Mallets as ever ran on any railway in the world, and comprises five tender and five tank wheel arrangements on three gauges. Apart from that, there were other items of note. The ex-Hungarian 2-6-6-0s were the largest and heaviest Mallet tender engines to run in Europe and spent their last days in Jugoslavia, hauling freight up the coastal escarpment from the port of Split, on the Dalmatian coast, until displaced by diesels in 1958. Thereafter they spent their final couple of years banking from Volinj to

JDZ *Class & Nos*	*Gauge*	*Type*	*Source*
27.001–15	Standard	2–4–4–0	Hungary (401 class)
31.001–09	”	0–6–6–0	Hungary (651 class)
32.001–36	”	2–6–6–0	Hungary (601 class)
90.001–09	760mm	0–4–4–0T	Serbia
91.001–38	”	2–6–6–0T	Serbia, Austrian Army
92.001–50	”	2–6–6–0	Austrian Army, new
93.001–10	”	2–6–6–2	Serbia
192.001	750mm	2–4–4–0T	Antivari Railway, Montenegro
196.001–02	760mm	0–4–6–0	Bosnia-Hercegovina, rack and adhesion
206.96–97	”	0–4–4–0T	Ressau Colliery
(14 misc locos)	”	0–4–4–0T	Steinbeis forestry railway, Bosnia
(5 ” ”)	”	0–4–4–2T	” ” ” ”
(3 locos)	”	0–6–6–0T	” ” ” ”



Serbian State Railways 760mm gauge 2–6–6–0T, a class later multiplied for the Jugoslavian Railways

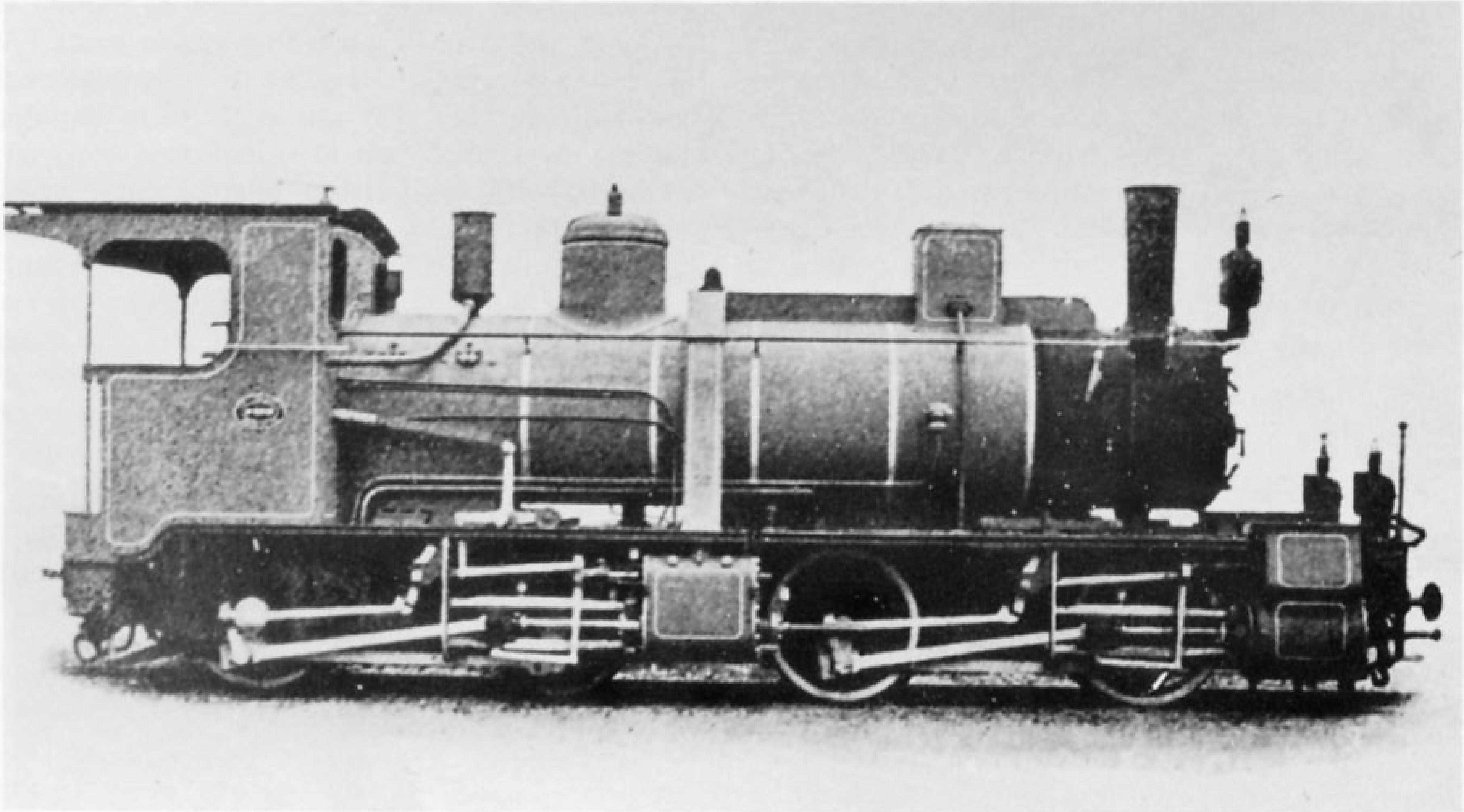
Two Jugoslavian 760mm gauge 2–6–6–0s, one fore and one aft, lift a mixed train out of Metovnica, in Eastern Serbia

Kostajnica, further inland towards Zagreb.

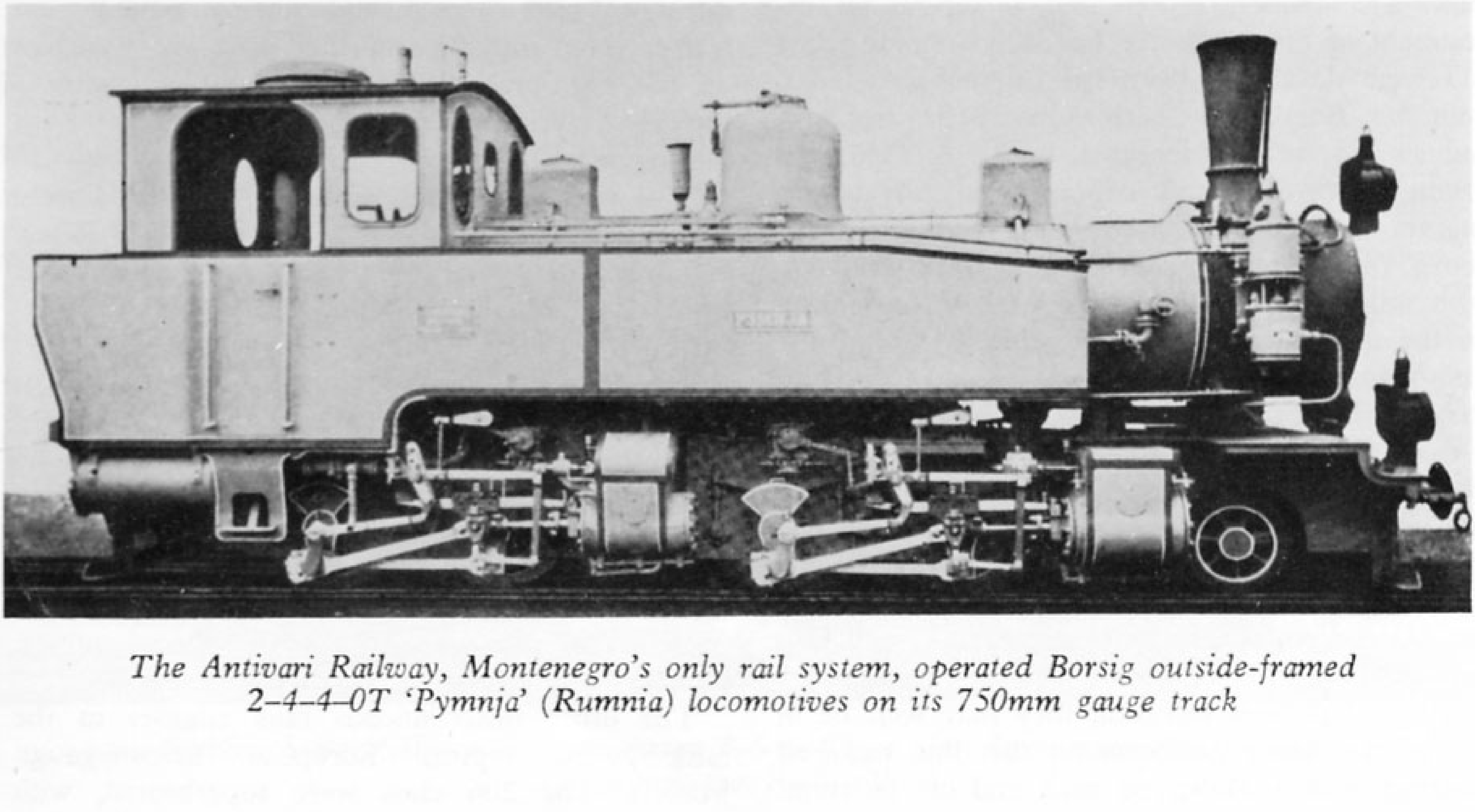
Of the narrow-gauge engines, the 2–6–6–0, tank and tender, represented a substantial investment of motive power for such a small gauge and were developed from the original 2–6–6–0T built by Borsig for Serbia in 1916, the later engines all being Henschel built. All featured piston valves all round, although only the tender engines were superheated. With wide fireboxes above the wheels, inside frames were used on both units. The bulk of these Mallets were used on the main Beograd-Sarajevo line, and over the tremendous mountain section out of Visegrad freights hauled by 2–6–6–0s and banked by 2–6–6–0Ts were the order of the day, until completion of the standard-gauge extension to Sarajevo in the early 1950s robbed the narrow gauge of its heavy freight and the Mallets of their jobs. Some of the 92 class tender engines survived on the Metovnica line, in northeast Serbia, well into the late 1960s, and although no recent news from this area has been received, they may well be in use as the heavy gradients on this line required banking with a Mallet on each end of the train.

The ten 2–6–6–2s from Serbia were an interesting type, being of Alco design and manufactured during World War I and having outside bar frames. Non-superheated, they had piston valves on the high-pressure cylinders only and were a typical American narrow-gauge Mallet, as built for logging lines in the USA. The most remarkable of the Mallets to operate in Jugoslavia were the 196 class, rack-and-adhesion engines, already mentioned on page 35, which featured outside frames and non-superheated steam for the slide-valved cylinders. Although the author, together with Vilain, has classified them as 0–4–6–0, this is not fully accurate or satisfactory, as the leading unit, although running on four wheels, has no adhesion power, the cylinders driving two coupled axles upon each of which is mounted a driving cogwheel. For those who understand it, the German classification of 2zz+C would be applicable. Attached to four-wheeled tenders, these engines, built in 1906, lasted for about thirty years.

The other miscellaneous tank engines in the table were typical European narrow-gauge Mallets. The 206 class were superheated, with



Greece's only Mallets were metre-gauge 0–4–4–0s such as this, on the Peloponnesus Railway



The Antivari Railway, Montenegro's only rail system, operated Borsig outside-framed 2–4–4–0T 'Pymnja' (Rumnia) locomotives on its 750mm gauge track

EUROPEAN MALLET TENDER ENGINES

Typical dimensions of selected classes (metric units)

Railway	Gauge mm	Type	Cylinders mm × mm	Coupled wheel dia mm	Boiler pressure kg/cm²	Grate area m²	Total heating surface m²	Super-heating surface m²	Weights (loco only) Adhn t	Total t
Peloponnesus	1000	0–4–4–0	340/500×540	1100	12	1·51	106·6	—	39·2	39·2
Prussian State	1435	,,	420/630×600	1270	12	2·0	142·2	—	55·2	55·2
Baden State	,,	,,	390/600×600	1260	12	2·0	137·8	—	55·3	55·3
Saxon State	,,	,,	450/650×600	1240	12	2·0	141·1	—	59·6	59·6
Hungarian State	,,	,,	385/580×610	1220	13	2·6	166·9	—	56·9	56·9
Swiss Central	,,	,,	355/550×640	1280	14	2·0	131·5	—	57·2	57·2
Bavarian State	,,	,,	420/640×630	1340	12	2·1	122·4	—	56·2	56·2
Hungarian State	,,	2–4–4–0	390/635×650	1440	16	3·55	234·8	—	65·3	75·3
Bulgarian State	,,	,,	400/640×630	1340	15	2·7	157·5	—	57·2	67·1
Bosnian–HLB	760	0–4–6–0	370×400 Adhn 570×360 Rack	800 A 688 R	13	2·0	115·8	—	—	39·5
Hungarian State	1435	0–6–6–0	400/620×610	1220	16	3·6	235·2	—	71·5	71·5
Central Aragon	1676	,,	400/600×600	1200	13	2·5	156·0	—	68·2	68·2
,, ,,	,,	,,	400/600×600	1200	13	2·42	113·0	37·3	73·1	73·1
Zafra Huelva	,,	,,	450/700×640	1230	14	2·82	182·1	—	75·5	75·5
Jugoslavian State	760	2–6–6–0	360/560×400	800	14	3·0	99·7	40·0	48·6	55·0
Madrid Aragon	1000	,,	400/600×560	1110	14	2·8	136·2	35·2	60·0	66·0
Eastern, France	1435	,,	440/710×660	1270	14	4·2	236·2	—	82·6	93·5
Hungarian State	,,	,,	520/850×660	1440	15	5·5	275·3	66·5	96·9	109·4
Central Aragon	1676	,,	470/710×600	1100	12	4·3	219·0	—	78·0	90·0
Serbian State	760	2–6–6–2	330/520×510	910	14	2·6	123·8	—	46·8	57·2

EUROPEAN MALLET TANK ENGINES

Typical dimensions of selected classes

Railway	Gauge mm	Type	Cylinders mm × mm	Coupled wheel dia mm	Boiler pressure kg/cm²	Grate area m²	Total heating surface m²	Super-heating surface m²	Weights (loco only) Adhn t	Total t
(Original Mallet)	600	0–4–4–0T	187/280×260	600	13	0·5	22·3	—	11·7	11·7
Querios Mines	750	,,	210/370×320	700	12	0·6	28·0	—	15·8	15·8
Steinbeis Wald B	760	,,	210/340×400	750	12	1·3	39·3	—	21·0	21·0
Amando Adriatico	950	,,	290/450×420	900	12	1·2	60·7	—	32·0	32·0
C.F. Departmentaux	1000	,,	250/380×460	900	12	1·4	42·0	—	24·7	24·7
Süd Deutsche EB	,,	,,	300/460×550	1080	12	1·5	71·6	—	43·6	43·6
Brohltal EB	,,	,,	330/500×500	1000	14	1·5	80·0	—	48·0	48·0
Central Swiss	1435	,,	360/550×640	1200	12	1·8	109·0	—	59·5	59·5
Bavarian State	,,	,,	310/490×530	1006	12	1·4	67·7	—	42·2	42·2
Rhätische Bahn	1000	0–4–4–2T	320/490×550	1050	14	1·3	79·0	—	42·0	46·3
Südharz EB	,,	,,	330/520×500	1000	14	1·8	76·7	25·5	46·3	53·4
Antivari	750	2–4–4–0T	230/360×400	800	12	0·9	50·0	—	25·0	29·0
Rhätische Bahn	1000	,,	320/490×550	1050	14	1·3	80·0	—	42·5	45·0
C.F. Departmentaux	,,	,,	280/430×500	1030	13	1·2	66·8	—	32·0	38·0
Nordhausen-W.EB	,,	2–4–4–2T	360/560×400	850	14	2·0	86·0	22·0	38·0	53·0
Comp. Portugese	,,	2–4–6–0T	350/500×550	1000	14	2·0	137·0	—	52·2	59·5
Steinbeis Wald B.	760	0–6–6–0T	260/420×400	750	14	1·7	57·0	—	31·5	31·5
German Army	1000	,,	400/620×450	900	15	1·85	130·0	—	56·4	56·4
C.F. Departmentaux	,,	,,	310/480×550	1010	14	1·44	78·8	—	45·4	45·4
Nordhausen-W.EB	,,	,,	380/600×500	1000	12	1·9	110·5	20·5	54·0	54·0
Gotthard	1435	,,	400/580×640	1230	12	2·2	155·6	—	87·0	87·0
Etat Belge	,,	,,	500/810×650	1300	15	7·87	275·0	—	102·2	102·2
Gaz de Paris	,,	,,	(4)460×650	1200	12	3·30	165·0	—	72·0	72·0
Somain á Anzin	,,	,,	(4)480×680	—	13	3·90	—	—	103·0 112·0	103·0 112·0
Central Aragon	1676	,,	470/710×600	1110	12	4·3	219·3	—	108·0	108·0
Serbian State	760	2–6–6–0T	330/520×400	800	13	1·9	108·8	—	45·1	50·9
Jugoslavian State	,,	,,	330/520×400	800	13	2·2	110	—	48·0	55·0
Bavarian State	1435	0–8–8–0T	520/800×640	1216	15	4·25	195·6	65·4	123·2	123·2
German State	,,	,,	600/800×640	1216	15	4·25	195·6	65·4	131·1	131·1

piston valves throughout, and the Steinbeis 0–6–6–0Ts, built saturated with slide valves, later had superheaters with piston valves on the high-pressure cylinders. Differing accounts occur as to which Steinbeis engines were 0–4–4–0T and which were 0–4–4–2T, and possibly some were rebuilt during their career—at any rate, all were jolly little forestry engines with an assortment of spark-arresting chimneys, but they are now believed to be out of service.

CZECHOSLOVAKIA AND RUMANIA

Both these countries inherited some of the Hungarian Mallets and, in addition, Czechoslovakia took over from the Kaschau–Oderberger Railway that line's 0–6–6–0 Mallets, thirty-seven in number, generally to the Hungarian design. There were also two narrow-gauge 0–4–4–0Ts of standard features.

EAST GERMANY AND POLAND

The assorted Mallet tanks in East Germany have been covered under the main German heading and the only Polish Mallets seem to have been three 600mm-gauge superheated 0–6-6–0Ts, built in 1939. The author has never seen a description or illustration of these latter, nor knows exactly where they work or worked.

GREECE

Only three Mallets are known to have worked in Greece and these were built by Krauss in 1908 for the Piraeus–Athens–Peloponnesus railway. Detailing was generally as the normal 0–4–4–0T, but these were 0–4–4–0 tender engines, with mixed frames and high-pressure piston valves. The wheelbase on each unit was longer than on similar tank engines, presumably for better lateral stability, and they were superceded by straighforward 2–8–0 and 2–8–2 engines.

BULGARIA

Bulgaria's sole Mallet was a 2–4–4–0 tender built by Maffei and exhibited at Paris in 1900. It seems that Maffei built it as an exhibition engine and then sold it to Bulgaria, and this has given rise to a myth that there were two Maffei Mallets, one of which has been quoted as being for the Bavarian State Railways. Weiner was caught by this one and quotes 'both' engines, and even stretches the imagination by tabulating the 'Bavarian' engine as an 0–4–4–2, although describing it correctly as a 2–4–4–0!

AUSTRIA

No Mallets were ever built for the Austrian Railways proper, although the Royal and Imperial Army had 2–6–6–0s and 2–6–6–0Ts built for the narrow gauge during World War I. All the tender engines and most of the tanks went to Jugoslavia and have been mentioned; the remaining tanks found their way to Italy and from there to Sardinia, ending up converted to 950mm gauge. As a small feedback, the former Antivari Railway 2–4–4–0T found its way during World War II into Austria and became No 4 on the Tschagguns–Parthenen railway in the Vorarlberg. It was scrapped in 1956 and seems to have been the only Mallet ever used on a public railway in Austria proper.

MEDITERRANEAN ISLANDS

A number of islands in the Mediterranean Sea had railways and, serving mountainous terrain, those in Corsica and Sardinia operated Mallets. In fact, the Corsican Railways were actually the first to seriously *consider* the use of a Mallet, but not, as it turned out, the first to put one into service. With no outstanding features, it is sufficient to refer readers to Kalla-Bishop's *Mediterranean Island Railways* for details of the Mallets which ran thereon, amounting to eight 0–4–4–0Ts and nine 2–6–6–0Ts in Sardinia, plus thirty 0–4–4–0Ts in Corsica.

TURKEY and RUSSIA are dealt with in Chapter 5.

CHAPTER 4

THE MALLET IN AFRICA

THE OMNIPRESENCE of the Garratt throughout the 'Dark Continent' tends to overshadow the fact it was preceded by about 350 Mallets, tank and tender of various wheel arrangements and including a few simple expansion engines. As might be expected, a large proportion of these Mallets were to be found on the metre-gauge lines in North Africa, in those countries having French rule, and one such country, Tunisia, had the only Mallet collection in Africa to exceed one hundred engines. At the other extremity, South Africa was one of the few countries in the world outside the United States of America to make any serious attempt at developing the Mallet as a mainline engine. There are, thus, some interesting facets of the type's reign in that continent.

NORTH AFRICA

ALGERIA

Five 0–6–6–0Ts were built in 1909 by SACM for the 1,055mm-gauge lines in Algeria, these being similar to the standard *Departmentaux* engines used in metropolitan France. The Chemins de Fer de Bône-Guelma, centred in Algeria, also owned extensive metre-gauge mileage in Tunisia upon which ran many Mallets, and these will be dealt with under the next heading, although a few of the smaller 0–4–4–0Ts ran in Algeria. The Algerian 0–6–6–0Ts were superceded by 4–8–2 + 2–8–4 Garratts, themselves eventually supplanted by diesels.

TUNISIA

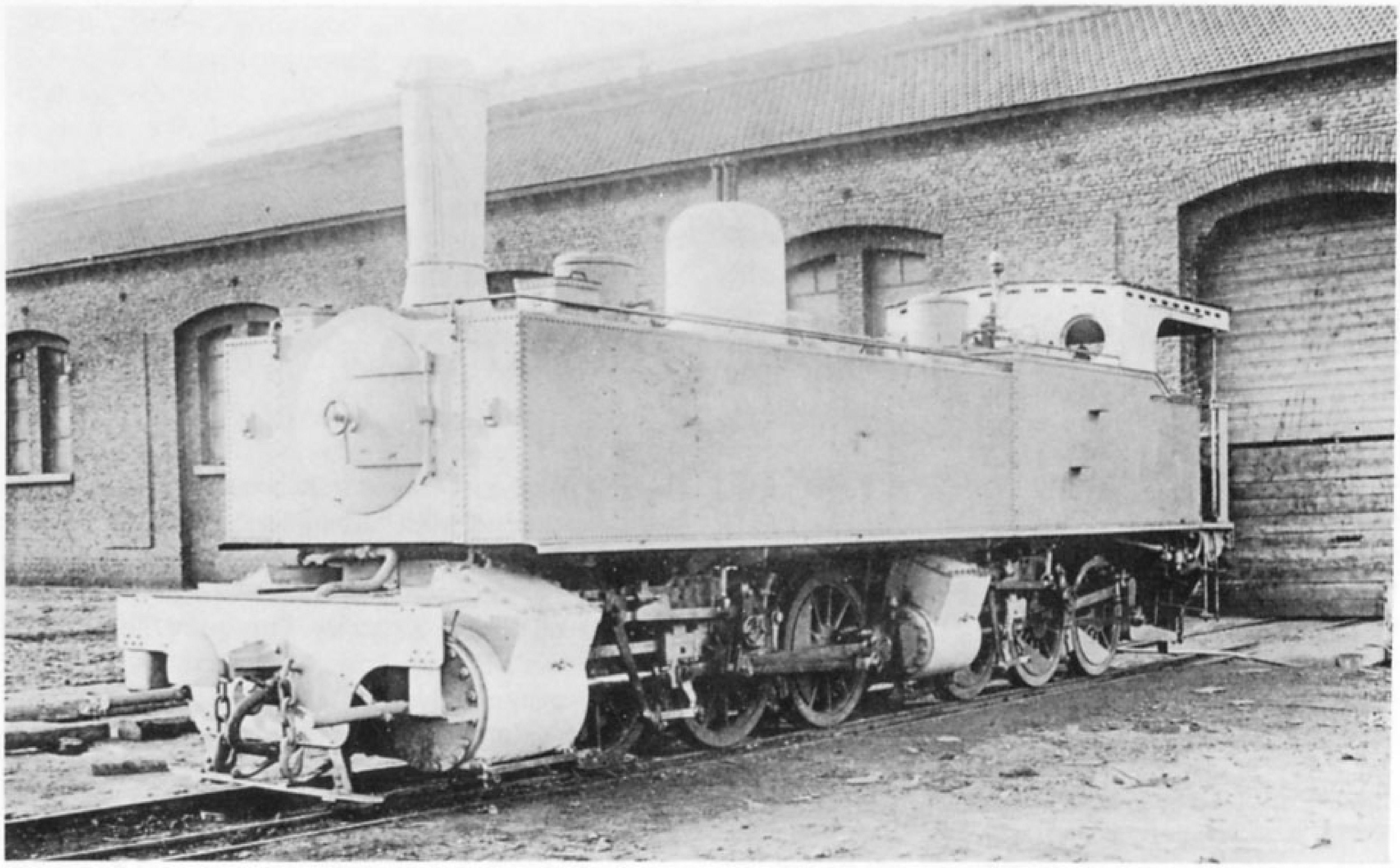
Africa's major Mallet user, the Bône–Guelma railway, commenced Mallet operation with seven Batignolles 0–4–4–0Ts, built in 1897, and followed on with thirty-two similar engines dated 1903–6, all being the usual French compound type. To handle the heavy phosphate traffic to the port of Sousse, no less than sixty-five 0–6–6–0Ts were supplied in 1907 by Batignolles, Franco-Belge, Henschel and Schwartzkopf, these again being saturated slide-valve engines of the classic Mallet type. When, in 1920, these needed supplementing, Baldwin received the order for thirty engines of similar capacity but quite different in appearance. These American versions had bar frames, piston valves on the high-pressure cylinders and split side tanks, the forward section presumably articulating with the frames. With the acquisition of this batch, the railway possessed 134 Mallet tank engines of four different classes. Starting in 1926, the company's works at Sidi Fathallah rebuilt thirty-four of the European 0–6–6–0Ts with larger boilers and tanks, mostly with a leading truck, making them 2–6–6–0T, and with the onset of dieselisation eleven of these redundant 2–6–6–0Ts were sold to the Utrillas railway in Spain. Briefly listed, the Bône–Guelma Mallets were:—

Nos	*Type*	*Builder*	*Date*	*Notes*
251–57	0–4–4–0T	Batignoles	1895	
451–82	0–4–4–0T	Batignoles	1903–6	
551–615	0–6–6–0T	Various	1907	
616–26	0–6–6–0T	Sidi Fathallah	1931–2	Rebuilt from 551-615
658–80	2–6–6–0T	Sidi Fathallah	1926–30	Rebuilt from 551-615
681–90	0–6–6–0T	Baldwin	1920	

In 1922, the Tunisian lines of the Bône-Guelma became the Chemins de Fer Tunisiens and, following the PLM tradition, the wheel arrangement was added to the engine numbers, becoming 22,251 etc, and 33.555 etc. Some of the smaller Mallets later found their way to Corsica.

MOROCCO

The only Mallets traceable in this country are of unusual interest as being 0–6–6–0 tender engines, simple expansion, on the narrow gauge of 60cm. These were built by Decauville for the Ministry



A Tunisian Railways 0–6–6–0T ex-works in photographic grey

of War and used on a strategic line from Marnia to Taouirt. Mixed inside/outside frames were used and all cylinders had slide valves, actuated by Walschaerts gear, distributing saturated steam. The author has been unable to establish the exact quantities or building dates of these engines, nor their ultimate fate, except that one was sold to the Pithiviers–Toury tramway in France, converted to a tank engine, and lasted until well after the second world war.

WEST AFRICA

The French and German possessions in West Africa made use of the familiar Mallet for their narrow-gauge lines, but France later followed the British lead and introduced Garratts.

FRENCH GUINEA

The Konakry-Niger railway had 0–6–6–0T Mallets built by Batignolles in 1909 and similar to those built by the same firm for Tunis. These were later supplemented with a further batch of eighteen 0–6–6–0Ts built by Corpet-Louvet in 1914 and shared between the Konakry-Niger and Abidjan-Niger railways. Garratts of striking design replaced the Mallets, but the railways are now dieselised.

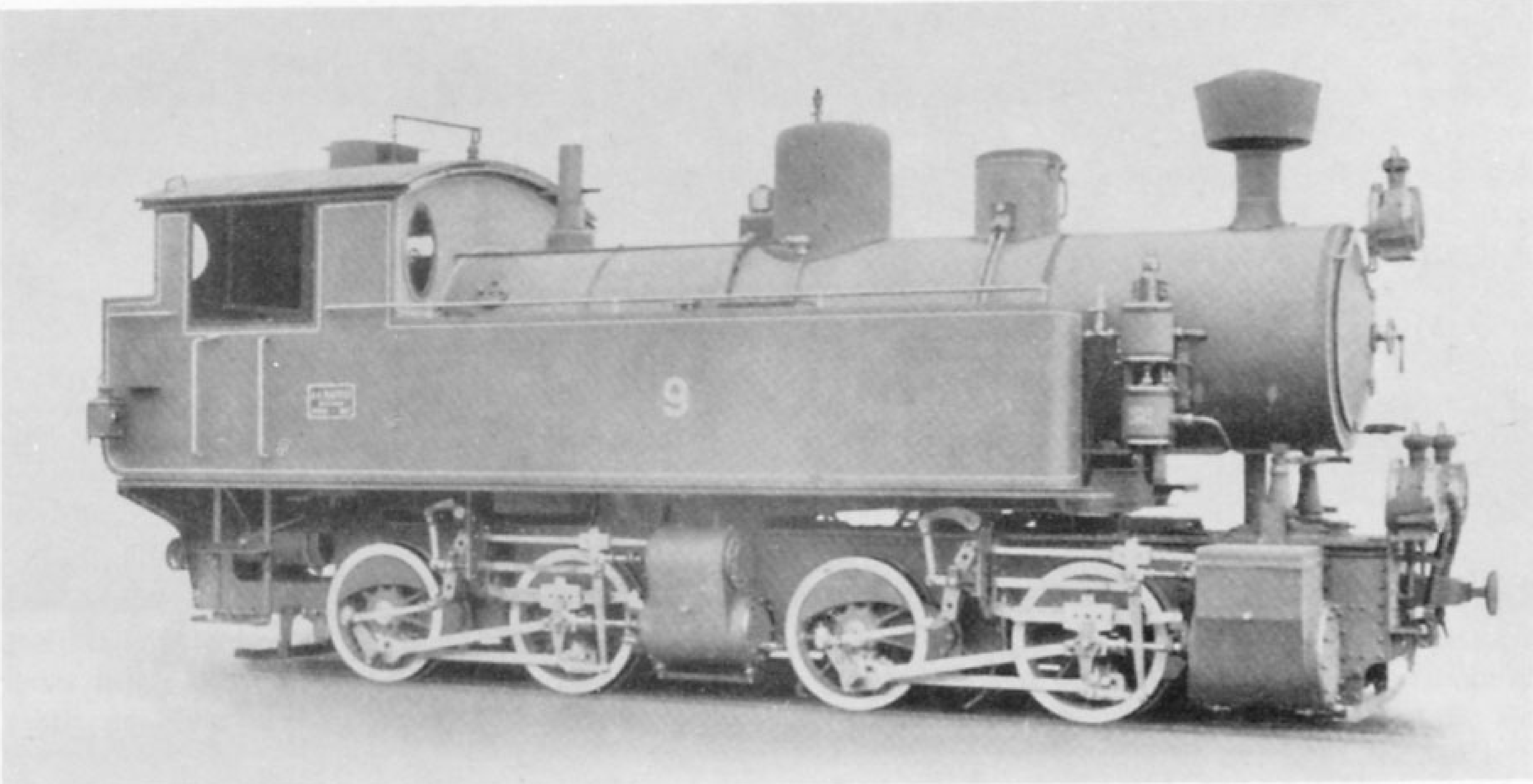
TOGOLAND

This former German possession in the Cameroons at one time had six Mallets on the colony's Togoland Eisenbahn. Built by Orenstein & Koppel in 1905, these were typical of that firm's 0–4–4–0T type, with mixed inside/outside framing, and the Orenstein version of Hackworth gear driving slide valves. The line is now dieselised.

EAST AFRICA

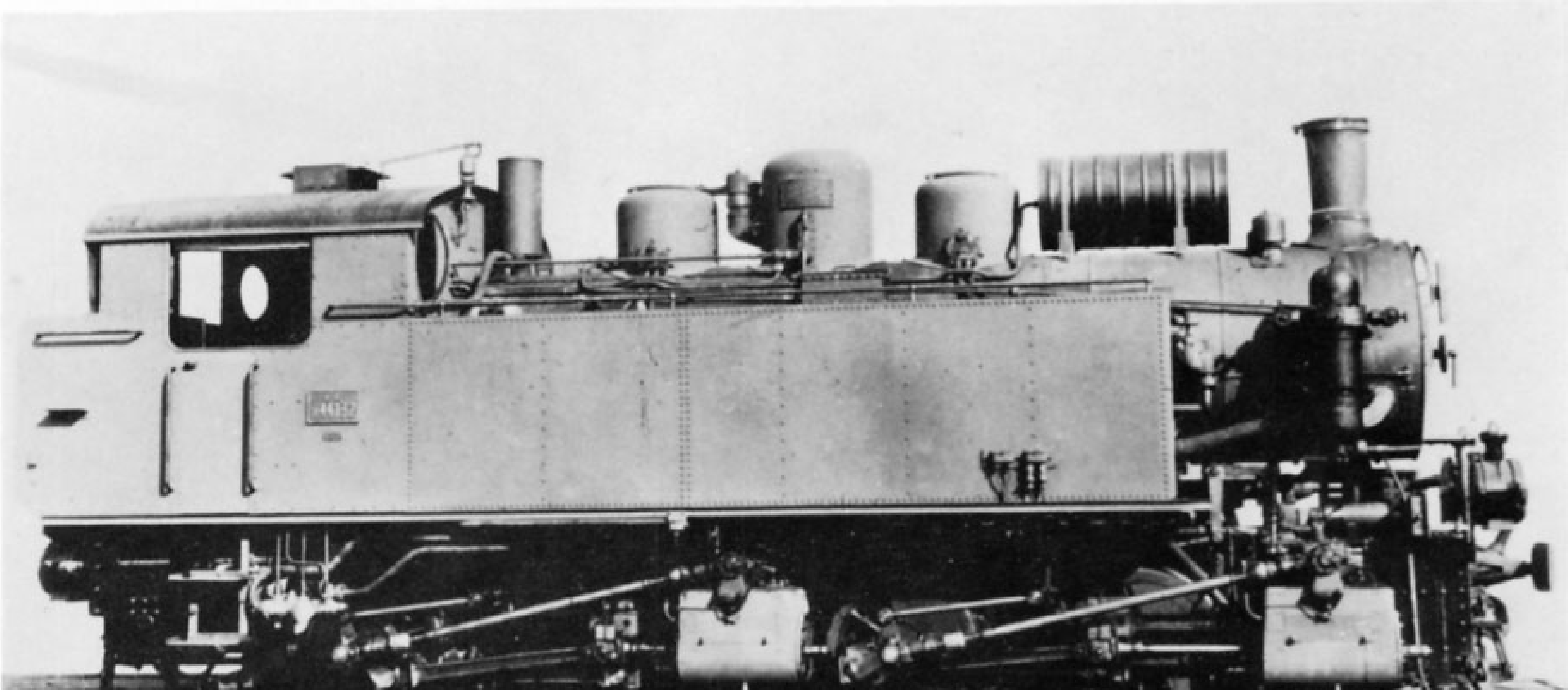
ERITREA

A thriving colony of Mallets was to be found on the out-of-the-way metre-gauge line from Djibouti to Addis Ababa, off the Gulf of Aden. For fearsome gradients through wild, inhospitable and downright dangerous country Maffei built in 1907 the first three 0–4–4–0Ts, which were to become the railway's staple motive power before dieselisation. Ansaldo followed suit and supplied twenty-five further engines of the same class between 1911 and 1915, and in 1931 and 1939 Asmara shops assembled a nominal three new engines from components of earlier withdrawn engines. All these were standard European narrow-gauge Mallet tanks, saturated, slide-valved and with inside frames. In 1933–6 fifteen larger 0–4–4–0Ts were

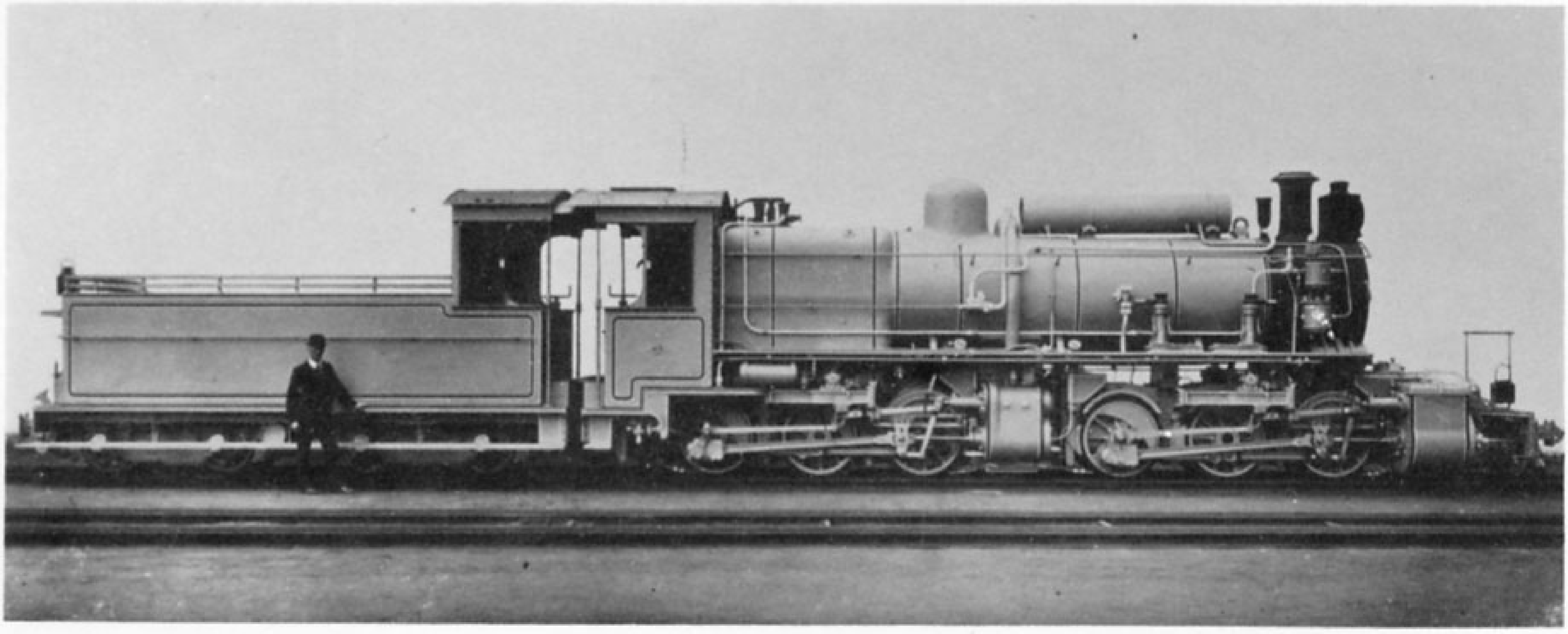


Eritrean Railways original type of small 0–4–4–0T, built by Maffei for the 950mm gauge line, and later class R440

built to a superheated, simple expansion design, of which ten had piston valves and Walschaerts gear and the other five Caprotti poppet valves driven from outside cardan shafts. These latter appear to have been the only Mallets ever built with poppet valves. Evidently the simples were not a complete success for a further eight engines built by Ansaldo in 1938 were of generally similar design, but reverted to compound expansion, retaining the superheater and piston valves features. Charles Small's *Far Wheels* has the best account ever published of this fascinating railway.



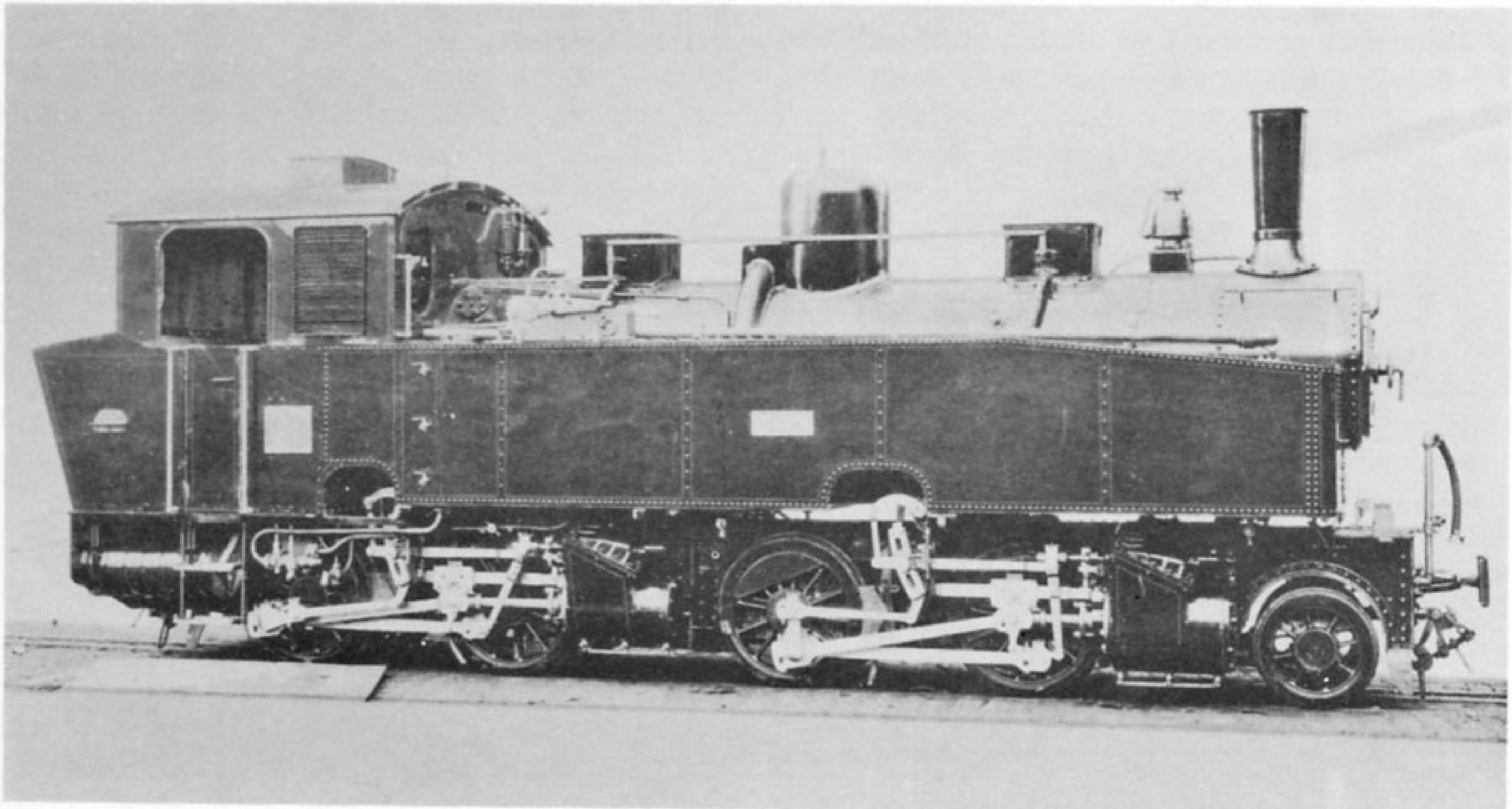
A unique Mallet species—superheated, simple expansion and with poppet valves. *As Eritrea's class R441, she was similar in size to the later R442 compounds*



Uganda Railways metre-gauge North British 0–6–6–0, used over the Great Rift Valley between Nairobi and Nakuru until superseded by Garratts about 1930

KENYA-UGANDA

The first articulated power of the Uganda Railway (which operated mainly in Kenya, and later became the Kenya-Uganda Railway) was a batch of eighteen 0–6–6–0 compound Mallets to what was the North British Locomotive Co's standard metre-gauge design, as supplied also to India, Burma, and Spain. They had wide Belpaire fireboxes, inside frames and piston valves for the high-pressure cylinders only. Built at Queens Park works in 1912–13, these locomotives entered service in 1913–14 and remained at work until 1929–30, when they were then replaced by the EC1 and EC2 Garratts.



O.A.E.G., in German Tanganyika, operated this neat Henschel 2–4–4–0T on the main Dar-es-Salaam to Morogoro line of East Africa's Central Line

TANGANYIKA

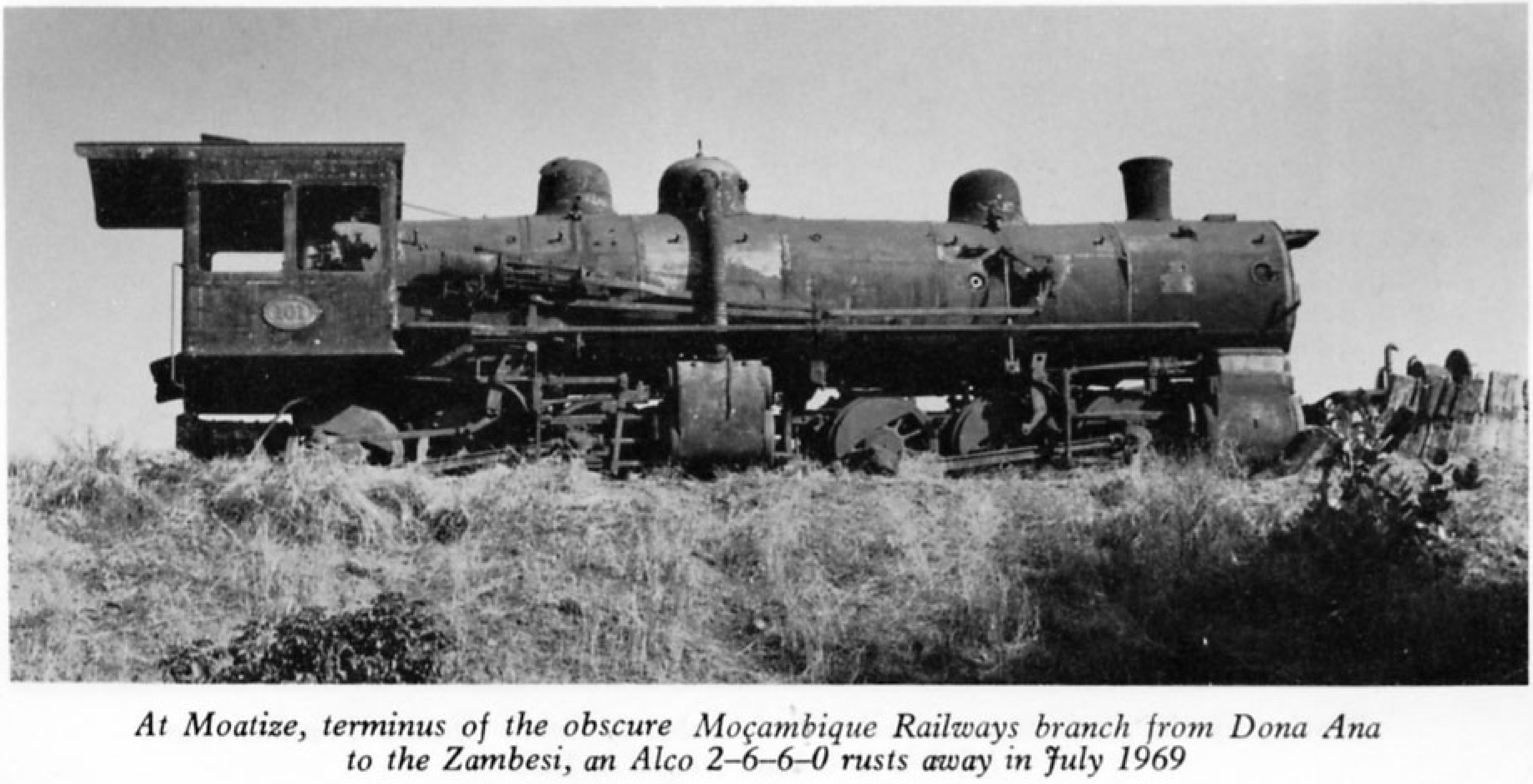
In the days when Tanganyika was a German colony, a metre-gauge line inland from Dar es Salaam was built by the Ost Afrika Eisenbahn Gesellschaft, or East African Railway Co, and apart from the early 0–4–0T used to build the line, its first 'main line' power was a class of typical German *lokalbahn* 0–4–4–0T Mallets, built by Henschel in 1905–7. These were supplemented in 1908 by four larger 2–4–4–0Ts from the same builder, after which the railway turned to straight eight-coupled tank and tender engines for further additions. The Usambarabahn from Tanga to Neu Moschi also had five 0–4–4–0Ts built by Jung in 1900. Exactly how many of the Mallets survived World War I (when a number of engines were dismantled and buried to prevent the British from using them) seems now unknown, but certainly none survived to World War II.

MOÇAMBIQUE

Before World War I, experiences with American-built Mallets in South Africa, on both the Natal Government and Central South African Railways, led the Portuguese authorities to purchase two 2–6–6–0 compound Mallets from the American Locomotive Co to much the same design as the Natal engines. Built in 1912, these became C. F. Lorenco Marques, and later C. F. Moçambique Nos 100–1. Their full history seems obscure, but both eventually left the L.M. system and were noted derelict at Moatize, terminus of the branch just north of the Zambesi, in 1969. Presumably they had worked coal traffic on that line until sometime in the 1960s, and the foreman's office at Gondola on the main Beira-Umtali line contained a faded photograph of a coal train double-headed by both the Mallets, although he did not know where or when it was taken. However, these two engines do seem to have been amongst the last mainline Mallets to work on the continent of Africa and were certainly the last of the breed in existence.

SOUTH AFRICA

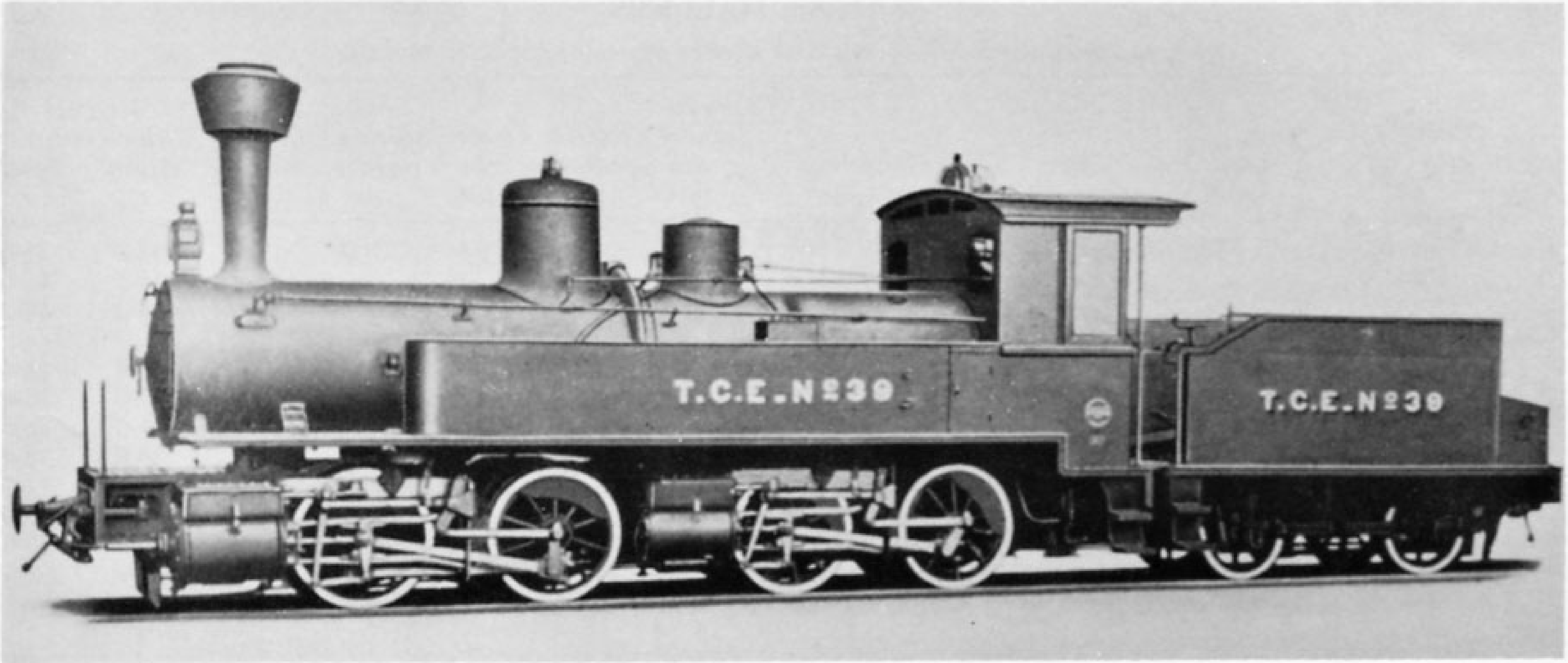
The main African user of mainline Mallets was the South African Railways who, inheriting a number of 2–6–6–0 and 2–6–6–2 tender engines from the Natal and Central South African Railways in 1910, persevered with the type and experimented with various features in brave attempts to cure the beast's inherent faults. The arrival of the Garratt, with its superior performance, spelt the end for the Mallet, only the final MJ and MJ1 classes surviving World War II. Photographs, diagrams, dimensions and building data are detailed fully in D. F. Holland's *The Steam Locomotives of the South African Railways* (2 vols, David & Charles, 1971–2), so it is enough here to list only the Mallets and comment briefly on features of particular interest. Of the engines tabulated below, the ME was interesting as being a pioneer simple expansion Mallet with superheater, while the MG endeavoured to correct the compound Mallet's



At Moatize, terminus of the obscure Moçambique Railways branch from Dona Ana to the Zambesi, an Alco 2–6–6–0 rusts away in July 1969 sluggishness by fitting larger wheels to the low-pressure unit than to the high-pressure. Largest of all were the MH, built for the Witbank–Germiston coal traffic, one of which was sent down to Natal for testing against the pioneer GA class Garratt, trials which showed up the Garratt's superiority in performance and economy, and effectively sealed the Mallet's fate. Details of these Mallet *v* Garratt trials are to be found in *The Garratt Locomotive* (p 87), and an interesting document which has recently come to light is a graph of the speeds of the two engines over the trial section, showing that the uphill performances of the two engines, so far as power output was concerned, was comparable but that the free-running and smooth-riding Garratt was much faster downhill. Some of the Garratt's economy must have been due to this speedier downhill performance—the sluggish Mallet probably needed steam in the cylinders downgrade, whilst the twenty minutes time saved by the Garratt would affect the fuel and water used over a given mileage. The SAR Mallets' main spheres of operation were the Natal main line (classes MA, MB, MC & MC1), Witbank-Germiston (classed MD, MF, MG, and MH), and the Cape Eastern division, particularly the Umtata line (classes MJ & MJ1). The engines concerned were:

Class	*Type*	*Nos*	*Builder*	*Dates built*	*Withdrawn*	*Notes*
MA	2–6–6–0	1601	Alco	1909	1926	Ex-Natal
MB	2–6–6–0	1602–6	Alco	1910	1921–4	Ex-Natal
MC	2–6–6–0	1607–16	NBL	1912	1921–33	
MC1	2–6–6–0	1634–48	NBL	1914	1932–8	
MD	2–6–6–2	1617	Alco	1910	1926	Ex-CSAR
ME	2–6–6–2	1618	NBL	1912	1937	CSAR, simple
MF	2–6–6–2	1619-33	Alco	1911–12	1930–9	CSAR
MG	2–6–6–2	1628	Alco	1911	1927	CSAR, odd wheels
MH	2–6–6–2	1661–5	NBL	1914	1938–41	
MJ	2–6–6–0	{ 1651–60 { 1674–81	Maffei/NBL Maffei	1914–18 } 1920 }	1947–62	
MJ1	2–6–6–0	1666–73	Montreal	1918	1948–61	

Blasting up the gradient from Bashee to Mamba, on South Africa's Transkei route, MJ 2–6–6–0 hauls freight in 1955



Madagascar's unique island evolution in Mallet types was the 0–4–4–0 tank + tender compound. One of Baldwin's batch is shown here

Five engines of classes MA, MB, MC & MC1 were sold, when withdrawn, to the Transvaal and Delagoa Bay collieries, near Witbank, and in 1970 there were some remnants existing in the form of tenders and a boiler at Dunn's Witbank locomotive works.

MADAGASCAR

From 1906 until the end of steam, the classic and unique form of traction on Madagascar's metre-gauge railways was the 0–4–4–0 tank-tender compound Mallet—virtually the standard French 0–4–4–0T shorn of its bunker and fitted with a four-wheeled tender. There were a lot of these engines, although there is an element of uncertainty as to the exact number. Vilain, who ought to be reliable on such a Gallic institution as the Madagascar Railways, states that SACM supplied thirty-six saturated and eighteen superheated engines, yet makes no mention of the Baldwin batch. A list in the author's possession detailing engine and builders' numbers adds up to forty-seven locomotives, made up of an initial Batignolles engine dated 1906, fourteen SACM engines of 1907–16, and six 1916 Baldwins making, with eight 1923 SACMs, twenty-nine saturated Mallets, plus the eighteen superheaters. Weiner states that the Madagascar Mallets were built by Schwartz-kopf and Baldwin, but the German entry can, one thinks, be ignored. The superheated Mallets comprised eight engines built in 1925, the year before two Garratts were introduced, and it is interesting to note that a further ten superheated Mallets were built in 1927–30, making a rare case of a railway returning to Mallets after trying out the Garratt. Three 2–4–4–0Ts were acquired from the Rhätische Bahn in Switzerland, after that line electrified in 1922. Altogether, whichever version is correct, there were about fifty Mallets on the island of Madagascar.

AFRICAN MALLETS

Typical dimensions of selected classes (metric/imperial units)

Railway	*Gauge* *mm*	*Type*	*Cylinders* *mm × mm*	*Coupled wheel dia* *mm*	*Boiler pressure* *kg/cm²*	*Grate area* *m²*	*Total heating surface* *m²*	*Super-heating surface* *m²*	*Weights (loco only)* *Adhn* *t*	*Total* *t*
Eritrea (R440)	950	0–4–4–0T	265/430 × 500	900	12	1·34	70·0	—	35·0	35·0
„ (R441)	„	„	(4)330 × 500	900					46·0	46·0
„ (R442)	„	„	330/485 × 500	900					48·2	48·2
Usambara (Tanganyika)	1000	„	250/380 × 400	820	12	1·04	43·3	—	26·4	26·4
O.A.E.G. (Tanganyika)	„	„	260/390 × 500	950	12	1·15	53·7	—	30·0	30·0
Togoland EB	„	„	270/425 × 450	1000	12	1·03	54·9	—	31·0	31·0
St Charles (Algeria)	„	„	280/425 × 500	1000	12	1·05	67·0	—	33·0	33·0
Madagascar	„	0–4–4–0T + T	280/425 × 500	1000	12	1·19	71·4	—	32·0	32·0
O.A.E.G.	„	2–4–4–0T	290/445 × 500	950	14	1·33	68·2	—		45·0
Bone Guelma (Tunis)	„	0–6–6–0T	380/580 × 560	1100	15	1·55	96·3	—	60·9	60·9
„ „ (Baldwin)	„	„	343/533 × 559	1098	14·8	1·51	101·0	—	63·9	63·9
C.F. Moçambique	1067	2–6–6–0	445/711 × 660	1156	14·1	3·72	236·9	—	79·8	88·3
Railways using imperial units										
	ft in		*in × in*	*ft in*	*psi*	*ft²*	*ft²*	*ft²*	*T*	*T*
Uganda Railway	3 3⅜	0–6–6–0	15½/24¼ × 20	3 3	180	32	1513	—	60·3	60·3
South Africa (MA)	3 6	2–6–6–0	17½/28 × 26	3 10	200	40	2547	—	79·8	86·6
„ „ (MB)	„	„	17½/28 × 26	3 10	200	42·5	2701	—	82·8	90·0
„ „ (MC)	„	„	17½/28 × 26	3 10	200	42·5	2616	—	86·6	95·3
„ „ (MCI)	„	„	18/28½ × 26	3 10	200	42·5	2214	488	90·0	97·8
„ „ (MD)	„	2–6–6–2	18/28½ × 26	3 10	200	49·5	3325	—	86·6	100·7
„ „ (ME)	„	„	(4)14 × 23	3 6¼	180	32	1455	346	59·3	72·2
„ „ (MF)	„	„	18/28½ × 26	3 10	200	49·5	2616	559	87·5	102·7
„ „ (MG)	„	„	HP 18 × 26 LP 28½ × 28	3 10 4 3	200	49·5	2616	559	88·4	103·1
„ „ (MH)	„	„	20/31½ × 26	4 0	180	53	3211	684	105·6	128·3
„ „ (MJ)	„	„	16½/26 × 24	3 6¼	200	40	1913	343	76·2	84·0
„ „ (MJI)	„	„	16½/26 × 24	3 6¼	200	40	2042	413	81·0	88·5

CHAPTER 5

THE MALLET IN ASIA

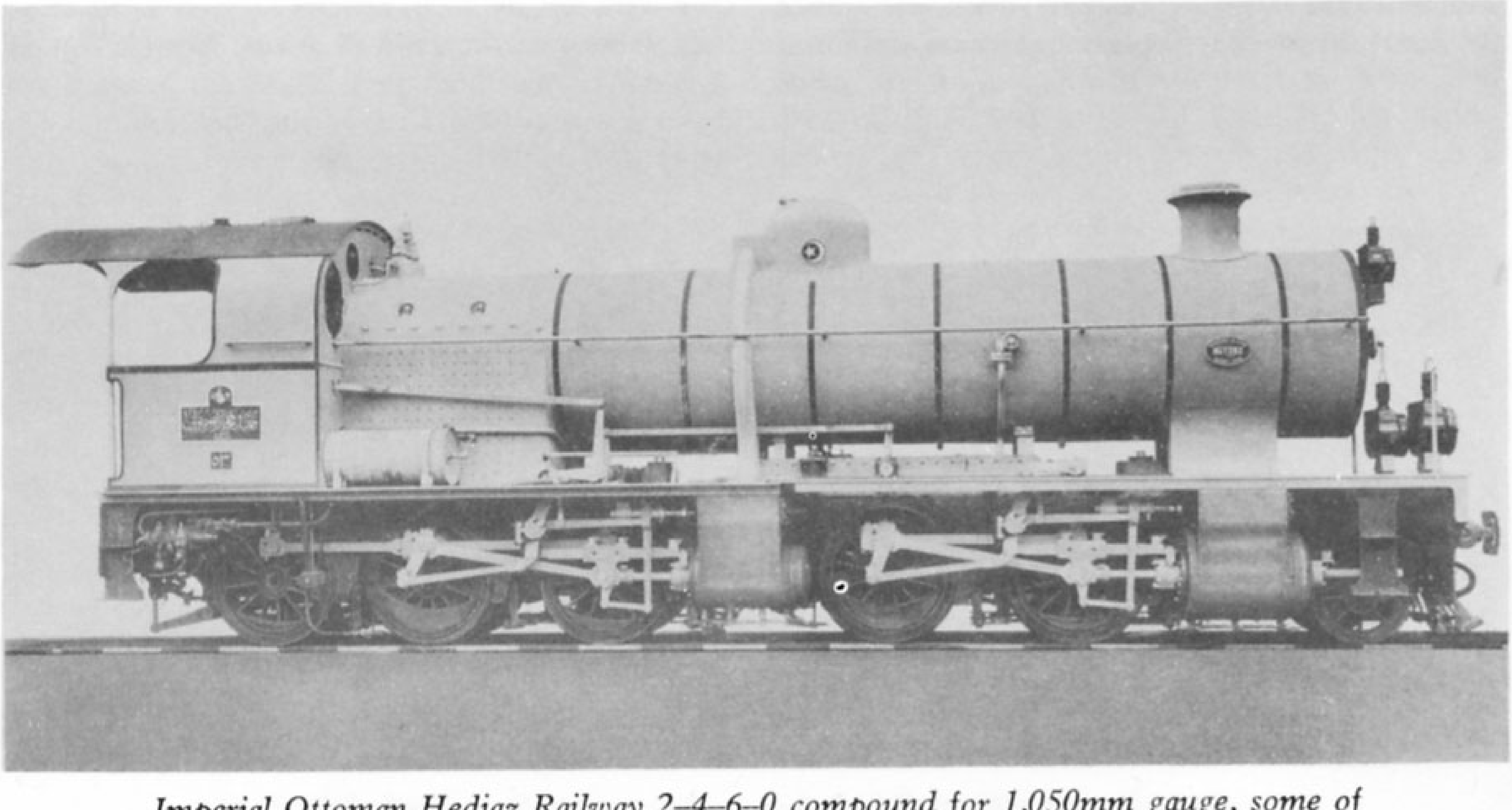
ASIA today is an important country for students of the Mallet type, for within that continent lies Indonesia, wherein runs the largest remaining pocket of Mallets left in the world today. In fact, Indonesia is to the Mallet what South Africa is to the Garratt—a 3ft 6in-gauge system with mainline Mallets, plus smaller engines on narrow gauge. Altogether there were less than one thousand Mallets in Asia, but of these, about two hundred were in Indonesia, a substantial proportion being in existence today. Within Asia, the author has included Turkey and Russia, those intercontinental Euro-Asian countries which may be classified as either continent as convenient. As however, the majority of their Mallets ran in their Asian divisions, they are classified accordingly.

TURKEY

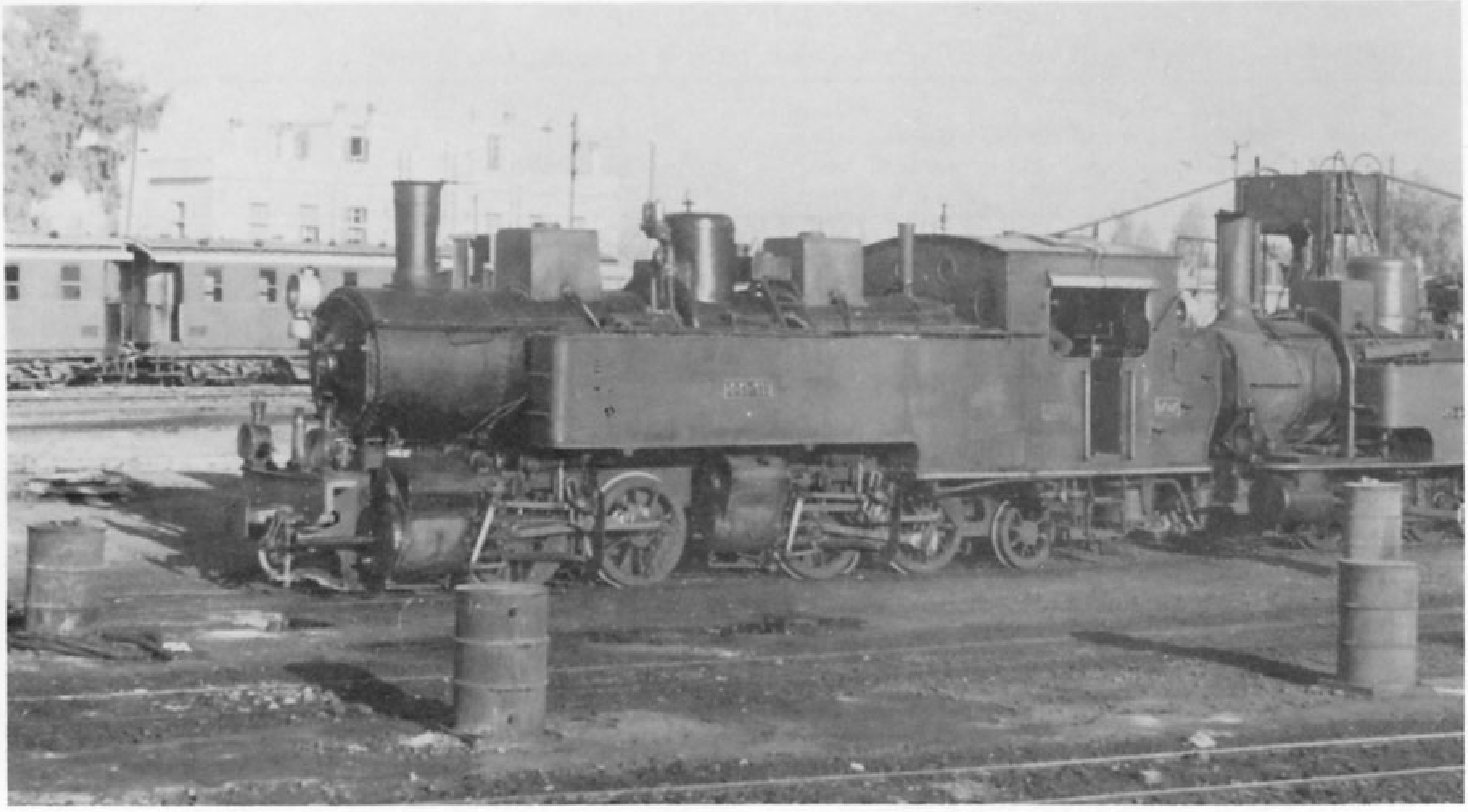
In the days when Mallets were being supplied, there were a number of independent railways in Turkey, a country which was then the centre of the Ottoman Empire, stretching well into Eastern Europe on the one hand and down into Asia minor and the Middle East on the other.

Chemins de Fer Ottoman Anatolie: As its title implies, this railway served Anatolia and in 1895–6 Maffei supplied six 0–4–4–0 tender engines generally similar to those built by the same firm for home use. Numbered 101–6, they did not last to be taken over by the Turkish State Railways. Of standard gauge, they were non-superheated compounds.

Compagnie Oriental: This railway served European Turkey and in 1918 took delivery of three



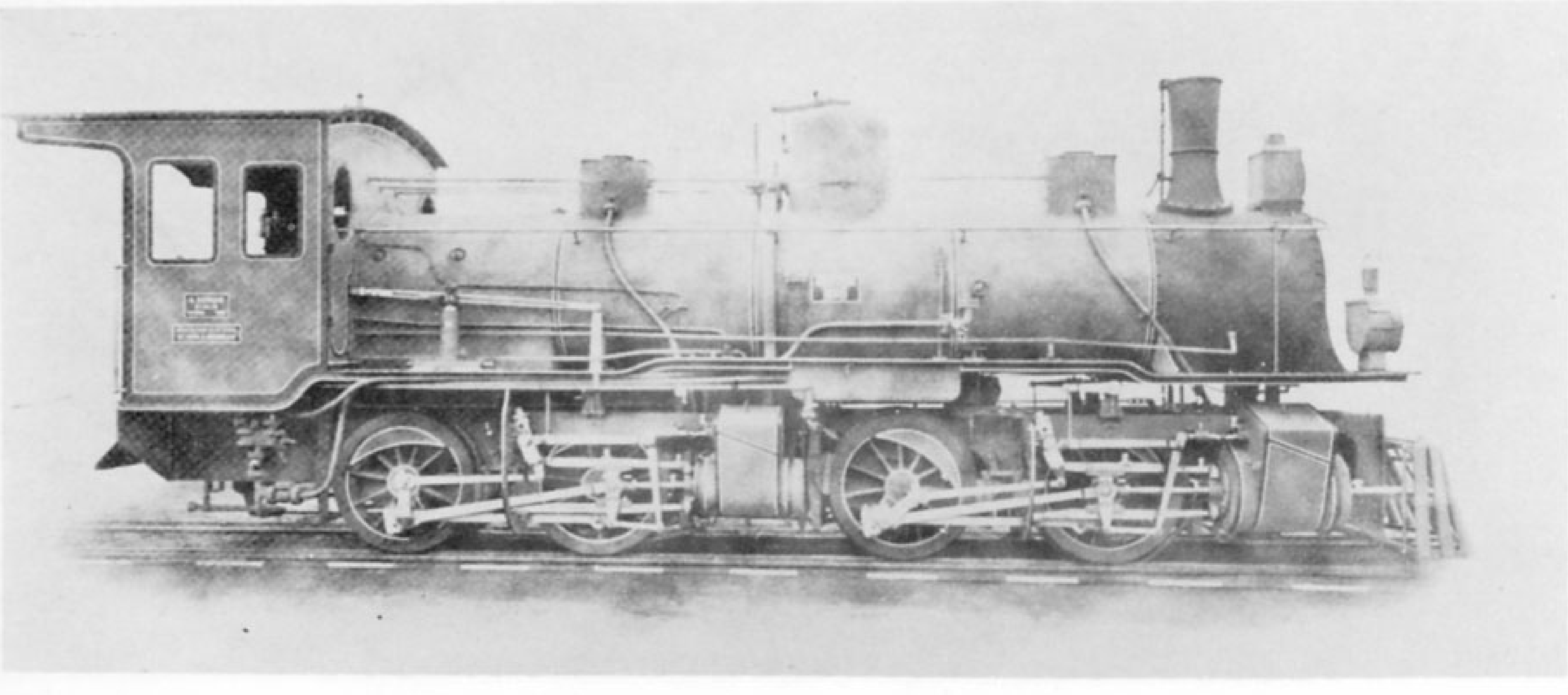
Imperial Ottoman Hedjaz Railway 2–4–6–0 compound for 1,050mm gauge, some of which may still be lying derailed in the Arabian Desert



Syrian Hedjaz Railway 0–4–4–2T No 961 at Damascus in November 1966

large 2–6–6–0 superheated compounds to Hungary's 601 class. Coincidentally, they were numbered 601–3 by the CO and like the CFOA Mallets, did not survive nationalisation.

Hedjaz Railway: This railway, built to the unusual gauge of 1,050mm, reached south from Anatolian Turkey to the Islam holy city of Mecca and served the dual purpose of transporting pilgrims and forming a supply link for the Turkish Army, which tried to maintain law and order in that ever turbulent part of the world. No part of the Hedjaz Railway survives in today's Turkey, but there are still remnants of it in Lebanon, Syria and Jordan, much of them in the same shattered state in which they were left by T. E. Lawrence, who so successfully sabotaged the railway during World War I.



Borsig's unsuperheated 0–4–4–0 tender engine for the now defunct Jaffa–Jerusalem Railway

The Hedjaz Railway owned ten Mallets, of which the first were four unusual 2–4–6–0 compound tender engines built by Henschel in 1907, Nos 52–5, later 200–3. These were followed after the war by 210–15, six 0–6–6–0Ts from the German Army batch of piston-valve engines built in 1917 by Henschel. It is believed that one or two of each type are still rusting away at Beirut, in the Lebanon, and have not been steamed for many years.

Damas Haman et Prolonguements: Built to the Hedjaz gauge of 1,050mm, the DHP, which connected Damascus and Homs with the main Hedjaz system, had two 0–4–4–2Ts, Nos 61–2, built by Hartmann in 1906 for the Beirut–Damascus section of the line. As Syrian Railways nos 961–2, they were noted in 1966.

Jaffa–Jerusalem Railway: This metre-gauge line seems now to have disappeared entirely, and with it the four compound 0–4–4–0 tender engines, Nos 6–9, built by Borsig in 1904–14.

IRAQ

For its extensive metre-gauge system, the Iraqi Railways purchased from the USA no less than forty 0–6–6–0 compound Mallets built by Baldwin in 1917 and originally destined for Russia. They seem to have long disappeared and visitors since World War II have not reported seeing any, not even in Baghdad dump.

RUSSIA

The railways of Russia in Tzarist days were extensive users of the Mallet type, and right at the end of steam development in the USSR it was revived in two experimental designs which did not, however, go into production. In the western world there seem to be no precise figures as to the number of engines built to each class—mainly because most Russian Mallets were built locally, and foreign enthusiasts are not exactly welcomed to poke around the archives today! Rakov's book describes and illustrates most, possibly all, of the 5ft gauge Mallets, but only deals vaguely in quantities and does not cover the narrow-gauge engines at all. Other western publications dealing with Russian steam have, like this author, to lean heavily on Rakov, and it seems doubtful now whether we shall ever know the full story. The two main railways using Mallets in early days seem to have been the Moscow–Kasan, and the Trans-Siberian, which were largely the western and principal sections of the same route. The Moscow–Kasan (or Kazan) seems to have been the main user of the 0–6–6–0 type, of which about 350 are reputed to have been built, by Putilov, Briansk, and Kolomna works, and possibly elsewhere, from 1897 to about 1910.

The earliest 0–6–6–0s were compounds with slide valves all round, fed with saturated steam from a round top boiler. These were class Θ, and there seem to have been thirty-five built to this design. Kolomna built a version, with Belpaire fireboxes and piston valves on the high-pressure cylinders, and then another series in 1903 featuring a wide Belpaire firebox above the frames and piston valves all round. These latter were classed ΘTT. At an early date, this latter series was superheated, and there seem to have been thirty of class Θy, dated 1904–7, followed by classes Θyc and Θye of 1907 and 1910, all three having superheaters and piston valves all round. Rakov gives

Typical of the early Russian Mallets, Moscow–Kazan Railways 0–6–6–0 on 5ft 0in gauge in Tsarist days

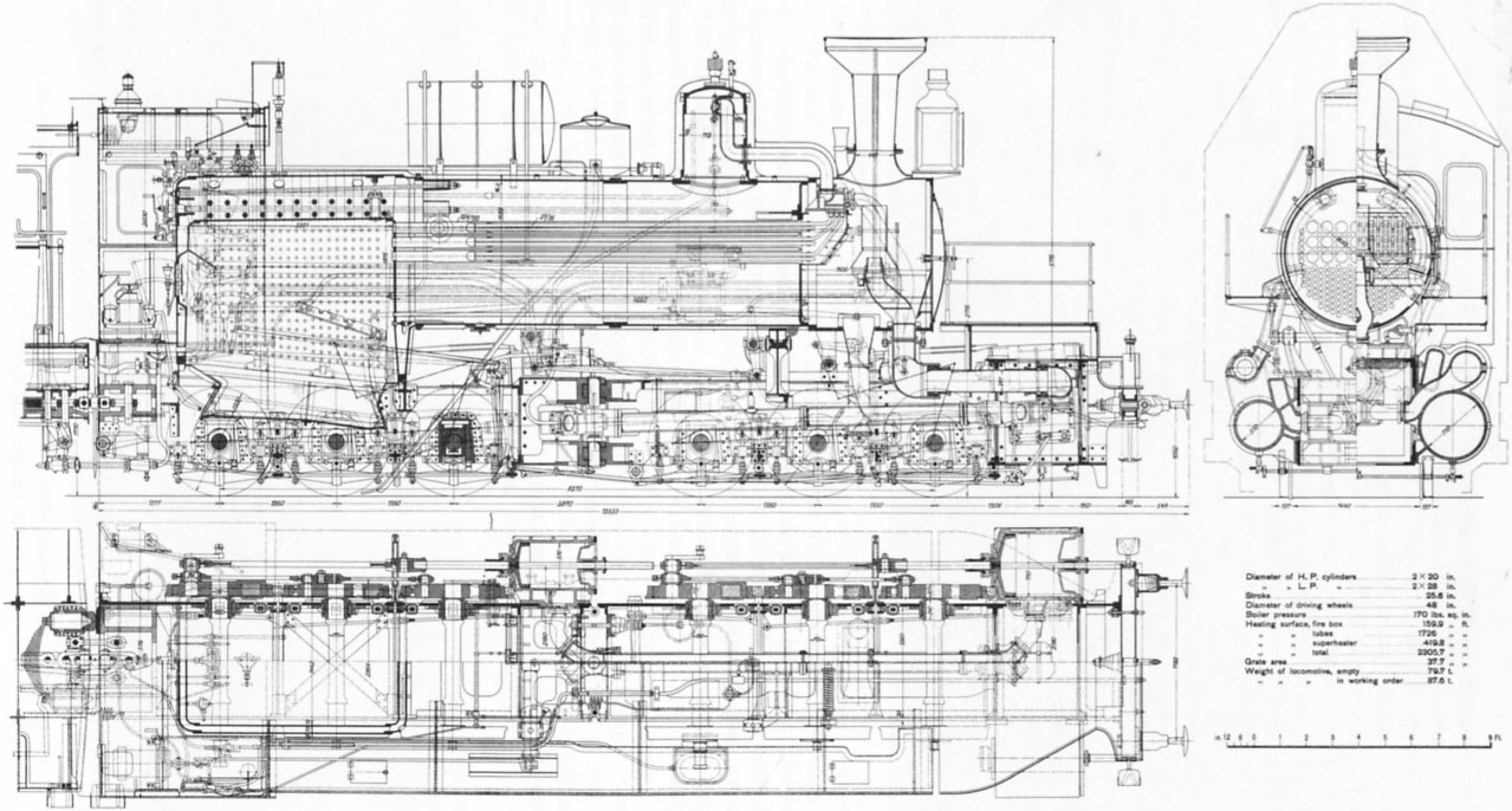


Fig 13 *General arrangement drawing of Moscow–Kazan Railway superheated 0–6–6–0, built at Kolomna and Putilov works, showing chassis joint, steam pipes, etc*

in each case the quantities built of the first batch but does not follow through with the detailed class totals. There was also a batch of peculiar Mallets with four cylinders grouped together in the centre, and these have been referred to both as simples and as compounds. The construction seems more logical for a compound, but perhaps some were of each type. Rakov gives no class letter for these, nor, of course, any quantities, but mentions a date of 1910. It seems that these 0–6–6–0s were introduced on the Moscow-Kazan Railway and further batches of each improved version put to work on the Trans-Siberian.

For mixed traffic work there was a series of 2–4–4–0 tender engines with larger wheels, and an article in *Die Lokomotive,* in 1925, gave a total of 112 such engines built by Kolomna for the Trans-Siberian in 1903–5. These were saturated slide-valve engines with spark-arresting chimneys of diamond pattern. Vilain gives the dates as 1900–3 and adds that four engines were converted to simple expansion in 1902, a move which brought a protest from M. Mallet to the Russian minister of transport. The only conflict in these two reports concerns the dates, and in view of the number of engines built they may well have extended over the whole period from 1900 to 1905.

All these 2–4–4–0 and 0–6–6–0 Mallets were replaced eventually by the standard 0–10–0 superheated E class, the Mallets, it is believed, being downgraded first to branch lines and then to forestry and similar railways. The type was ignored for half a century until the 1950s, when two superheated simple expansion designs were built for experimental purposes as a step towards the higher power outputs eventually realised by electrification. Like most modern Russian steam power, these simple expansion Mallets were unashamedly patterned on USA practice, with Boxpok wheels and even the 'Skyline' casings used on such prototypes as the Southern Pacific AC9 2–8–8–4. So far as is known, two each were built of the P34 2–6–6–2 and the P38 2–8–8–4, the latter at Kolomna in 1954 and the former in 1948. The 2–8–8–4 engines were amongst the most powerful ever used outside North America and were recorded as producing over six thousand indicated horsepower at fifty miles per hour. In the present run-down state of Russian steam, it seems most unlikely that either of the modern Mallet classes exists.

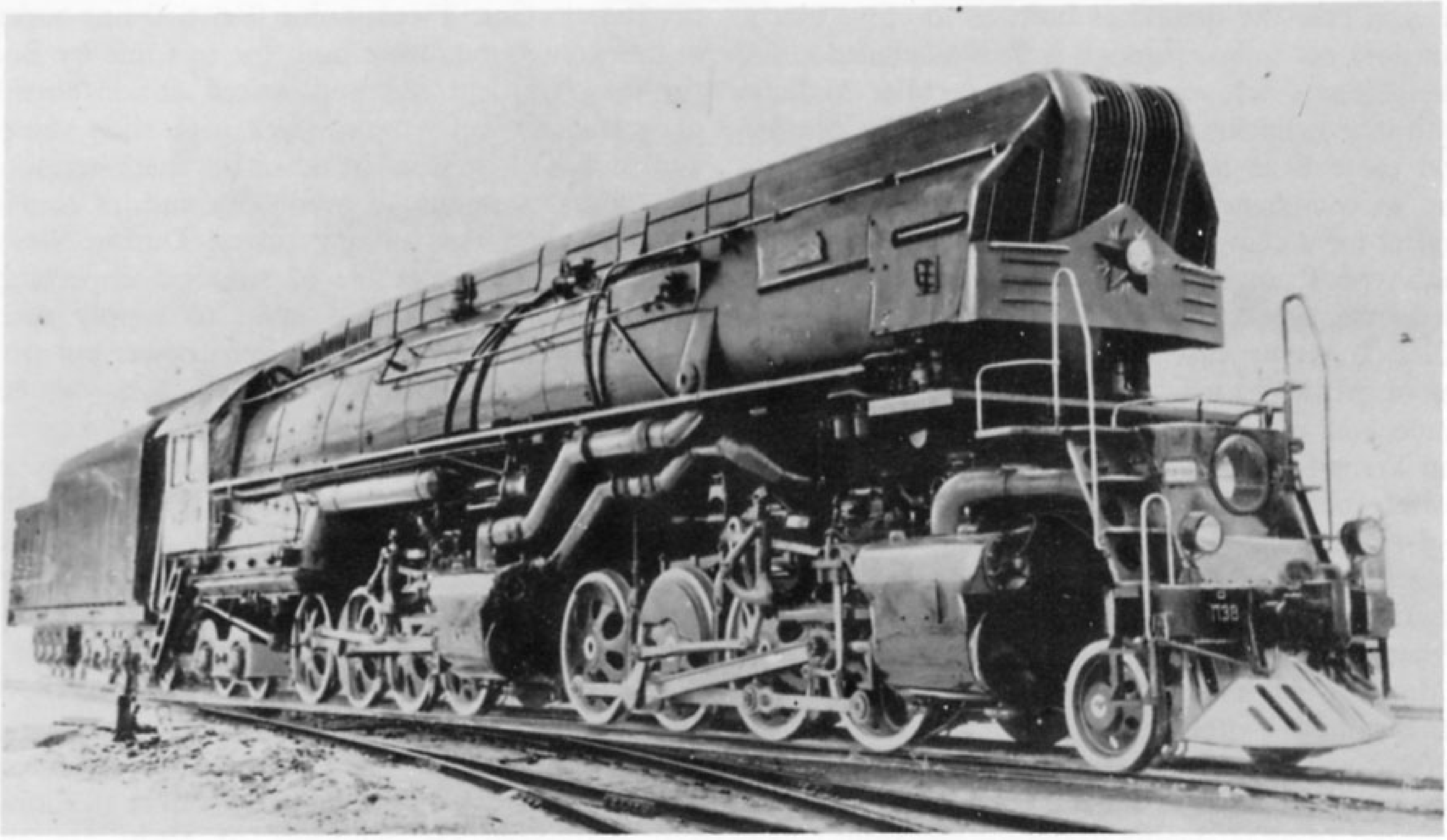
Apart from the mainline 5ft gauge Mallets, Russia also had a number of narrow-gauge examples, chief of which were those built for the 3ft 6in-gauge Archangel Railway, reaching up to the Barents Sea. Twenty-nine 0–6–6–0 non-superheated compounds were built for this line by Borsig in 1895 and featured mixed inside/outside plate frames, inclined cylinders with slide valves, and such Tzarist Russian details as spark-arresting chimneys, enormous oil headlamps and, of course, railings round the running plates. During World War I this route became of strategic importance and Baldwin were called upon to supply more 0–6–6–0 Mallets of much the same power but with American constructional features such as bar frames, inside the wheels on each unit, and piston valves on the high-pressure cylinders. Many of these engines, built in 1917, never reached Russia, because of the revolution, and forty went to Iraq, plus two to Malaya.

Russian Mallets also included some for the smaller gauges, including five 0–4–4–0Ts for a 75cm-gauge mining line, built by SACM in 1896–1901, and some unusual 0–4–4–0 tender engines from Henschel for the same gauge, featuring superheaters, mixed frames, piston valves all round, and spark-arresting chimneys. If there are any Mallets still in existence in Russia, they are likely to be of this latter batch, for use on secondary light railways.

INDIA

Railways in India, superbly built under the British Raj to the extravagant 5ft 6in gauge, were generally engineered to exclude heavy gradients, and with them the need for heavy power. There were exceptions, of course, and amongst these were the frontier lines in the North West, bordering Afghanistan, now within West Pakistan. For heavy service on these lines Baldwin built for the NWR an experimental 2–6–6–2 superheated compound in 1925. An unusually handsome machine, it had a wide Belpaire firebox, piston valves all round, and the usual Indian-style cab with sliding louvre panels. Not the equal of two 2–8–0s, she was joined by a Garratt of similar power, neither of which were repeated. Some further details of the two types running are to be found in *The Garratt Locomotive* and *Couplings to the Khyber.*

On the metre gauge, the Madras & Southern Mahratta Railway had six of the North British standard 0–6–6–0 tender engines for their subsidiary line, the West of India Portuguese Railway, serving the colony of Goa. Three each were built in 1911 and 1921, and it is possible that one or two may still be rusting away at the depot there. Engine numbers were 315–17, and 500–2.



Soviet Russia's two ventures into Mallets culminated in the immense TT38, 2–8–8–4, Kolomna-built in 1954 and spoilt in appearance by the jukebox front end treatment. It has probably been scrapped, though this is uncertain

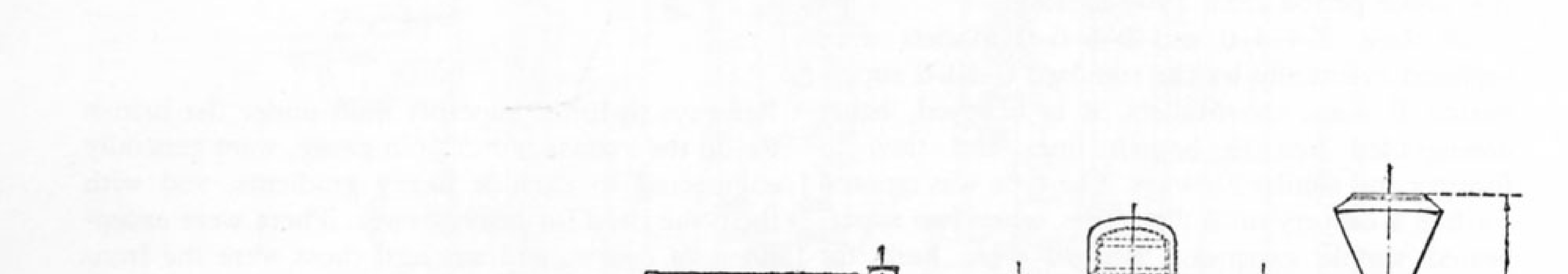
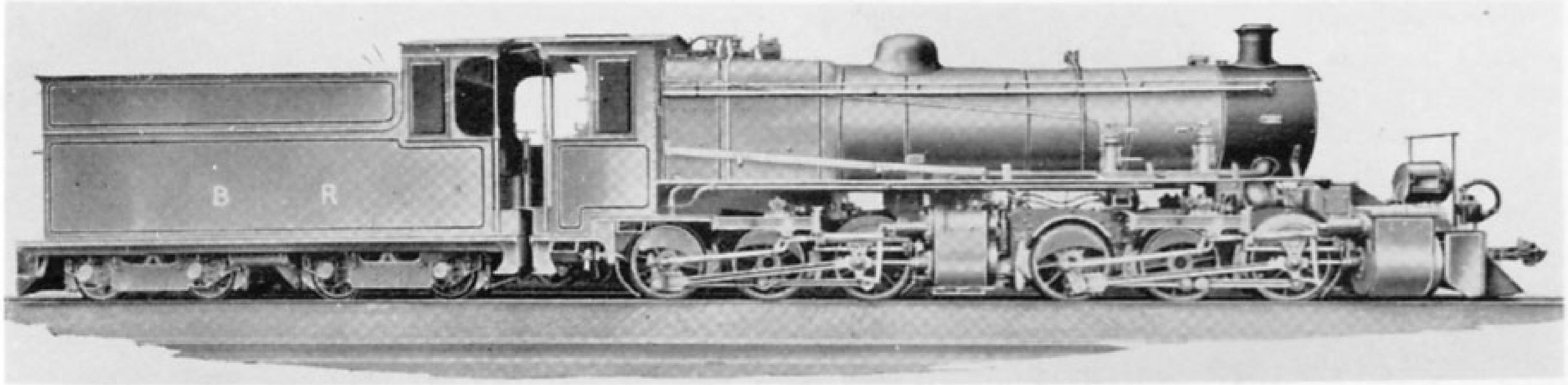


Fig 14 *Trans–Siberian Railway 2–4–4–0 compound passenger Mallet, built at Kolomna works in 1903*



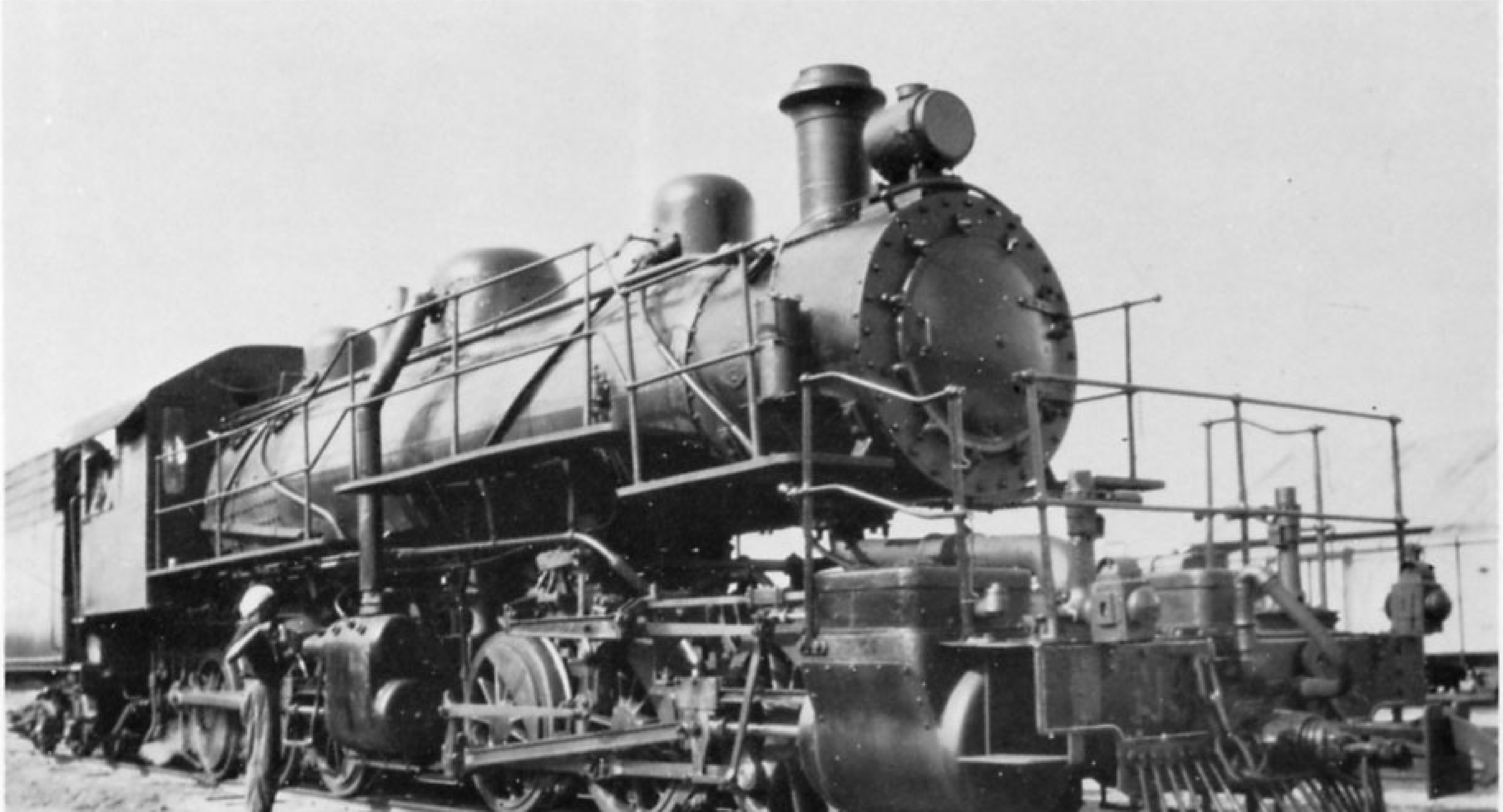
Burma Railway's version of North British's metre-gauge 0–6–6–0; this example was one of Beardmore's superheated batch

BURMA

The Burma Railways were the second to introduce North British's metre-gauge 0–6–6–0 and their first batch of four engines was built in 1910, a year after NBL introduced the type on the Sierra Menera Railway, in Spain. Altogether, twenty-two of these Mallets were built for Burma, where they supplanted the Fairlie as the principal form of articulated power until themselves rendered obsolescent by the Garratt. The total was made up of five batches, the later having superheaters, as listed below:

Engines	342–45	North British	1910
	381–81	,, ,,	1913
	1– 4	,, ,,	1915
	11–15	,, ,,	1921
	16–20	Wm Beardmore	1923

These Burmese Mallets were used on the mountain lines from Mandalay to Lashio and from Thazi Jc. to Shwenyaung, each having miles of



A Malay Mallet—one of two FMSR *0–6–6–0s built by Baldwin for the 3ft 6in gauge Archangel Railway, diverted because of the 1917 revolution and converted to metre gauge for Malaya*

1 in 25 gradients with zig-zag reversing stations to gain height. As at January 1972, all had been out of service many years, probably since the war, but the remains of at least one, derailed during the war, were still visible beside the track on the Shwenyaung branch!

MALAYA

Only two Mallets ever worked on the Malayan Railways, and these were a pair of the Baldwin 0–6–6–0s built for the Archangel Railway and rendered surplus by the Russian revolution. No doubt the FMSR picked them up at a bargain price, but they seem to have had little real use for them and ran them mainly on the branch from Kuala Lumpur to Port Swettenham. The original Russian 'onion' style spark-arrester was soon replaced by a British-type capped chimney, but they retained their all-round handrails (intended to prevent crews slipping off the engine in icy weather, and hardly necessary in Malaya's tropical climate!) to the end.

INDONESIA

In this country is to be found the world's last major Mallet colony. Over one hundred Mallets were built for the mainline public railways, plus many more, possibly as many again, for the numerous sugar and oil palm plantations which abound on the two main islands of Java and Sumatra. Hence the Mallets of Indonesia deserve a fuller coverage than those Mallets in operation elsewhere in the world, despite the production of another work *PNKA Power Parade,* which illustrates and lists all the Indonesian mainline engines including, of course, the Mallets.

First batch of Mallets for Java's Staats Spoorwegen, a Hartmann 0–4–4–2T, now Indonesian Railways (PNKA) class BB10. Here BB1009 poses on the turntable at Bandjar in October 1970

PNKA's *massive 2–8–8–0 No DD5202, one of the world's last few eight-coupled Mallets, seen at Tjitjalengka, Java, in October 1970, heading a mixed in stormy weather*

Although the Dutch East Indies, as they were before World War I, operated a number of private railways and tramways, it was the Staats Spoorwegan, or State Railways, who were responsible for operating all the mainline Mallets. First built were sixteen 0–4–4–2Ts, saturated slide-valve engines of typical European aspect built by Hartmann and Schwartzkopf in 1899–1907. They assured the success of the Mallet in Indonesia and no other type of articulated was ever introduced to this tropical archipelago. Under Japanese occupation the stock was renumbered in the JNR style, with letters indicating the numbers of coupled wheels, and these 0–4–4–2Ts became class BB10, the PNKA, or Indonesian State Railways, retaining the convenient Japanese classification system. Only six of the BB10s remain active today, mainly at Bandjar, from where they work to Tjidjulang, with one each at Ambarawa and Rangkasbetung.

The next type introduced was a 2–6–6–0T, Indonesia's most numerous Mallet class, and thirty-four were built in 1904–11 by Hartmann, Schwartzkopf, and Werkspoor. All were saturated slide-valve engines, and an unusual feature included was the split side tank, with the forward half mounted on the low-pressure frame, articulating with it. The final eleven engines built by Werkspoor in 1910–11 were of modified design, with higher pitched boilers, shorter chimneys etc, and tanks with sloping tops at the front. As class CC10, twenty remain active, mainly at Tjibatu and Klakah, with others at Rangkasbetung, Purwakarta, and Djember.

Mallet tender engines for mainline work appeared in Java in 1916, when eight Alco 2–8–8–0s were built. Thorough American mainline Mallets scaled down to 3ft 6in gauge, they were bar-framed compounds, superheated, and had piston valves on the high-pressure cylinders. Their sphere of operation was the mainline between Batavia (now Djakarta) and Bandoeng (Bandung), the two principal cities in West Java, between which ran a heavy passenger and freight traffic. From Batavia to Purwakarta the line is fairly level and conventional engines sufficed, but from Purwakarta to Bandoeng the Preanger mountain range is climbed by means of a most spectacular railway winding around the jumbled ridges and crossing deep ravines by means of awesomely high bridges. It was for this line that the Alco 2–8–8–0s were built and these became class DD50, but all are now scrapped. A further twelve similar engines, later class DD51, followed in 1919, and although these were taken out of service about 1968–9, some still exist at Purwakarta, Madiun works, and Surabaja. The latter engines are very derelict; the Purwakarta engines include a couple which could, perhaps be steamed up if traffic warranted it.

After World War I, the Dutch continued the 2–8–8–0 type with another batch of ten engines built in Europe by Hanomag, Hartmann, and Werkspoor, having plate frames, piston valves on all four cylinders, although generally of the same size and proportion as their Alco predecessors. These were put to work further east, on the Tjitjalengka–Tjibatu–Tasikmalaja section of the Bandung to Surabaja main line, where they remain today. Only four are now serviceable and the others are stored at Tjibatu and Tasikmalaja. These are the only eight-coupled Mallets known at work in the world today, and anyone who has never seen a large Mallet in action is advised to visit the area as soon as possible for they may not last many more years. As class DD52, these impressive engines were last reported working in August 1973.

Following the eight-coupled engines, the SS had built in 1927–8 thirty compound 2–6–6–0s by Werkspoor and SLM, as a lighter version of the final 2–8–8–0 but sharing the same technical features. These are now class CC50, and twenty-five are still listed in service at Purwakarta, Tjibatu, Purwokerto, Ambarawa, Bandjar, Madiun, and Surabaja (Sidotopo).

All the larger Mallets were the subject of improvements to the exhaust arrangements in the 1930s—the 2–8–8–0 classes all had double chimneys fitted, whilst many of the 2–6–6–0 tender engines received new, large diameter chimneys, although some still retain their original blastpipes and capped chimneys.

Last tender Mallets for Java, the 2–6–6–0s, now PNKA class CC50, totalled thirty engines, most of which are in stock today. Here No CC5004 prepares to depart from Surabaja (Sidotopo) on a freight in October 1970

Tjibatu—a Mallet mecca

In the foregoing historical account, the name Tjibatu crops up a few times and this little country junction, about forty miles east of Bandung, is the place to visit if one wishes to see Mallets in action. Although the through passenger trains are diesel-hauled, everything else is steam—and handled by Tjibatu's allocation of CC10 2–6–6–0Ts, CC50 2–6–6–0s and DD52 2–8–8–0s. Every engine stationed at Tjibatu is a Mallet—almost certainly the only depot in the world today with a 100 per cent Mallet roster. The tank engines work mainly on the three or four return trips to Garut and Tjikadjang, a branch climbing high into the volcanic mountains to the south, but they also appear on the main lines. The 2–6–6–0 tender engines operate principally on the main line east to Tasikmalaja and west to Tjitjalengka, but are light enough to take occasional turns over the branch. Most imposing of all, the big 2–8–8–0s are confined to the mainline working. The mainline turns are not frequent and usually comprise two trains, each with a 'figure eight' roster, departing Tjibatu east and west in the small hours, returning from Tasikmalaja and Tjitjalengka about dawn, crossing at or near Tjibatu about midday, each proceeding to the extreme terminus before returning home again late at night. The turns are arranged cyclicly, and one can sample the same train three days running and have a different Mallet each day—with a good chance of a different class of Mallet each day and, if loading is heavy, double-headed Mallets!

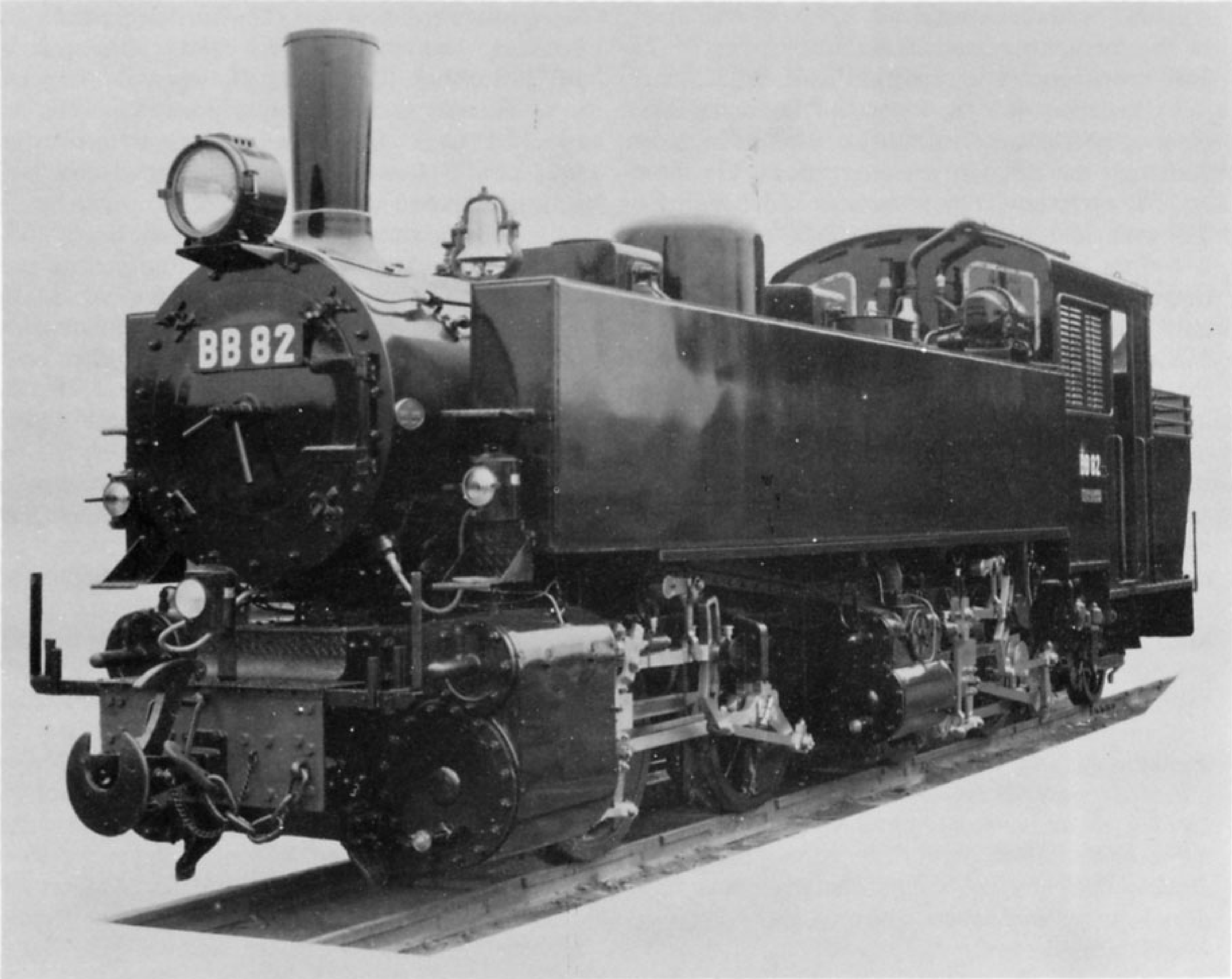
The mainline turns from Tjibatu are mixeds—usually an old wooden coach at the head end, followed by a string of freight wagons. There is no hotel at Tjibatu itself, but Bandung itself makes a good centre for either riding the Mallet-hauled trains or for chasing them by taxi to obtain action photographs, according to one's tastes. Action photographs can be quite spectacular, with plenty of black oil smoke and a splendid backdrop of jumbled volcanic hills and mountains.

The Atjeh Tramway, Sumatra

In the far north of Sumatra, serving the province to Atjeh, runs the three hundred mile Atjeh Tramway, a roadside light railway of 750mm gauge. For the northern section, between Banda Atjeh and Sigli, which encounters severe gradients, Esslingen built in 1904 six 0–4–4–0T Mallets of the usual European light railway type, with mixed inside/outside frames, and slide-valve cylinders using saturated steam. At some time in their career they were converted to 0–4–4–2T with larger cabs and bunkers, and their current PNKA numbers are BB71–6. After World War II, when the line was in a derelict condition, new motive power was supplied from Japan, and amongst these were four new 0–4–4–2T Mallets, designed and built as a modernised version of the Esslingen rebuilds, with superheaters, and piston valves on all four cylinders. Technically they are nothing remarkable but they do have an important place in the Mallet story as being the last Mallets ever built and the only Mallets ever built in Asia, the builders being Nippon Sharyo and the date 1961. Thus, like the Garratt, the Mallet began and ended with a small narrow-gauge engine, in between which it had developed into machines of epoch-marking proportions. Sad to relate, these final Mallets do not have a particularly healthy future ahead of them, and during the author's visit to the line in September 1971 all were out of service and only one (BB84, the very last) was actually steamable. Apparently the line was very uneconomical and the local officers were awaiting a subsidy from PNKA head office, without which they were unable even to pay for the wood fuel needed to run the engines! Nevertheless, BB84 was kindly lit up for photography—an act typical of the generous hospitality extended by the Indonesian railwaymen wherever we went. It can only be hoped that these last Mallets can be revived somehow or other, for the bone-jarring, two-day, Jeep ride which we suffered from Banda Atjeh to Medan, is no acceptable alternative!

Plantation Mallets

In the two main islands of Java and Sumatra there are large numbers of plantation railways serving the oil palm and sugar cane industries. Most of these are of 700mm gauge, plus others of 600mm, and a few on the 3ft 6in main line. There are about fifty sugar cane railways in Java alone, and one oil palm organisation in North Sumatra operates over one hundred steam locomotives. It can be estimated that there must be at least five hundred steam plantation locomotives in Indonesia today, and as twenty-four of the eighty-four engines positively identified are 0–4–4–0T Mallets, one may extrapolate this random sample to arrive at about one hundred Mallets. All those so far noted have been of the 0–4–4–0T variety, but Henschel built a number of delightful 0–4–4–0 tender Mallets for the 600mm gauge, probably the smallest Mallet tender engines ever built. These were destined for Java, but their exact whereabouts have yet to be discovered. Of the tank



One of the final batch of Mallets built in the whole world—Nippon Sharyo's 0–4–4–2T of 1961, for the 750mm gauge Atjeh Tramway in Northern Sumatra

engines so far noted, all have been either by Orenstein & Koppel, and feature their Hackworth-type valve gear, or by the Dutch firm of Ducroo & Brauns, at Weesp, and have the more usual Walschaerts gear.

PHILIPPINES

The mainline railways in the Philippines have not, to the author's knowledge, ever operated any Mallets, but there still exists, working as at September 1971, a Baldwin compound 0–6–6–0 tender engine on the railway owned by the Insular Lumber Company.

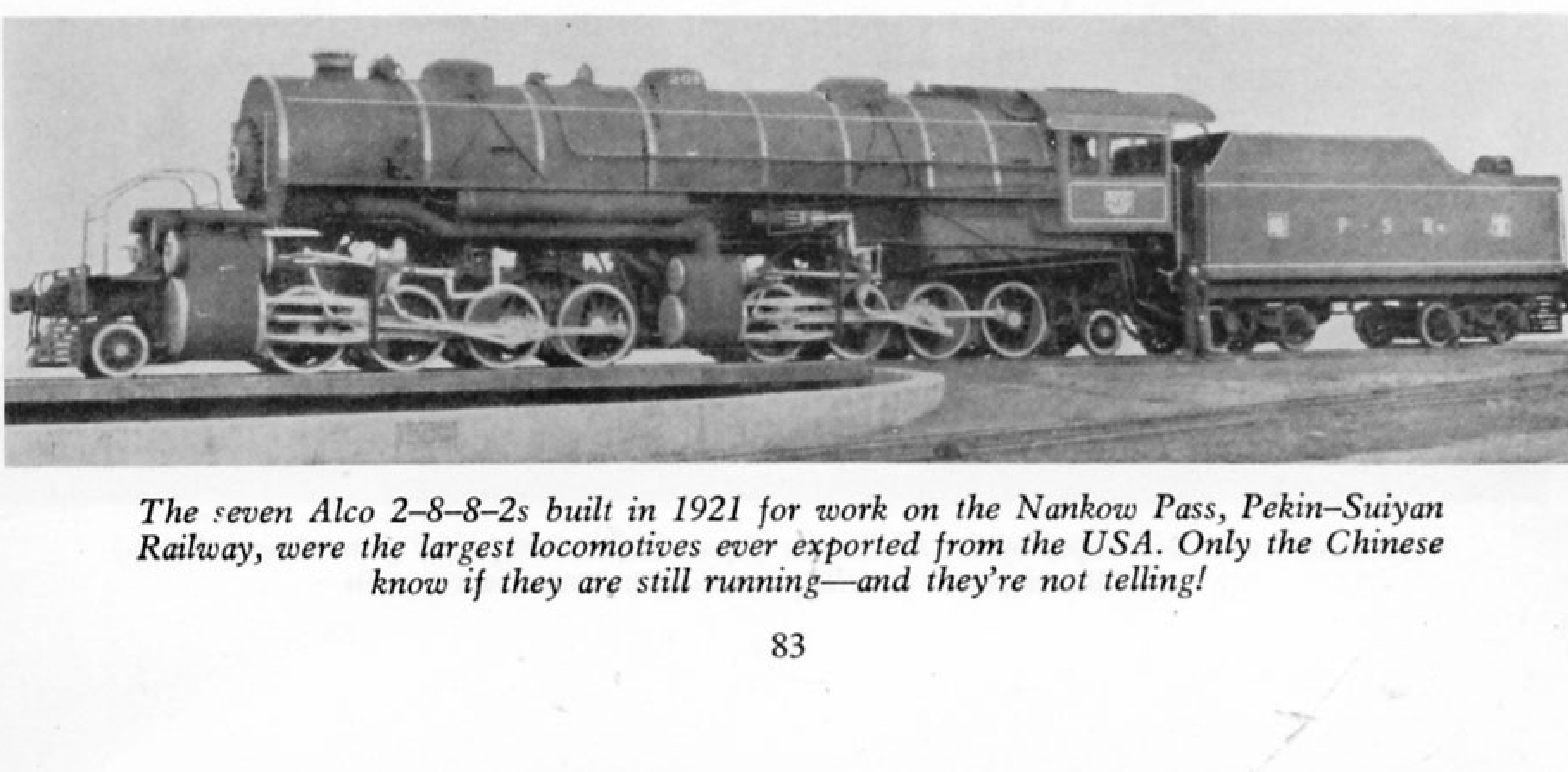
CHINA

In the centre of China, when railways in that land were in their infancy, a route from Pekin was struck westwards through the mountains and through the Great Wall of China, up the Nankow Pass (from Nankow to Kangchwang), to Kalgan. In 1910, two batches of compound Mallet tender engines were built for this line, four light 2–4–4–2s from Baldwin, presumably for passenger work, and four heavier 0–6–6–0s from North British with smaller wheels for freight. Traffic evidently grew rapidly for in 1913 Alco supplied a further four engines, this time much larger 2–8–8–2s, light by American standards but very big engines for anywhere else in the world. The line was then extended to Suiyan, and in 1921 Alco built a batch of seven much larger 2–8–8–2s, little inferior in size to those used in the USA and, in fact, the largest locomotives ever exported from the States. Little has been seen or heard of these engines for thirty or forty years and it now seems too much to expect them to have survived, although Indonesia has

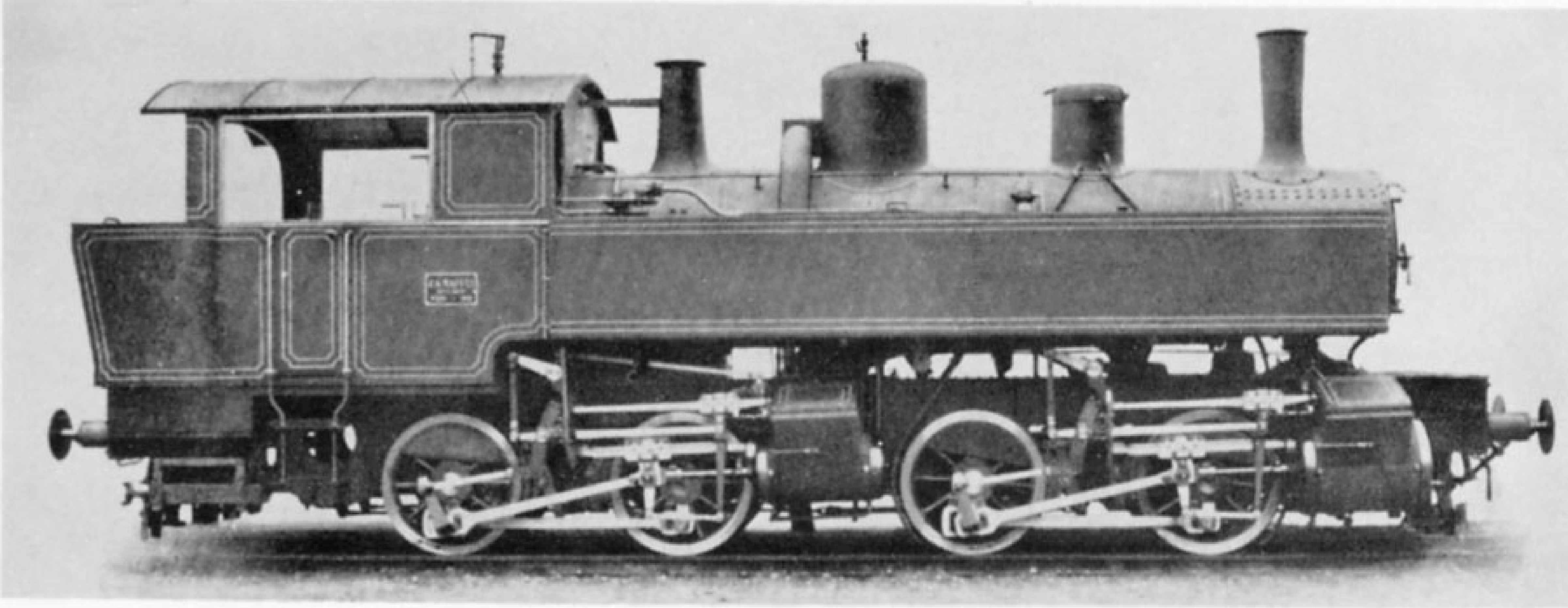
A 1971 shot of the Baldwin 0–6–6–0 on the Insular Lumber Co's line in the Phillipine Islands

shown that it is not an impossibility. The Pekin–Kalgan–Suiyan line is now part of the international route from Pekin through Outer Mongolia to Ulan Ude, in Russia, and with heavy traffic the Mallets may have been retained for banking purposes over the heavy sections. It is by no means impossible that the Chinese may have built further *new* Mallets for such work, but this is purely a hypothesis based on the fact that they have built modernised versions of other pre-war classes where these were found useful, so that a batch of Mallets is by no means to be discounted. One day, we hope, the Chinese will ease travel restrictions sufficiently to enable enthusiasts and historians to probe around and unravel the mystery of the big Chinese 2–8–8–2s. Twenty-five metre-gauge 2–8–8–2s were built in 1941 by Alco for the Yunnan–Burma railway in Southern China, and these may well be in operation today.

In addition to the mainline engines, there were four metre-gauge 0–4–4–0Ts, built by Tubize in 1892, which are of no particular interest.



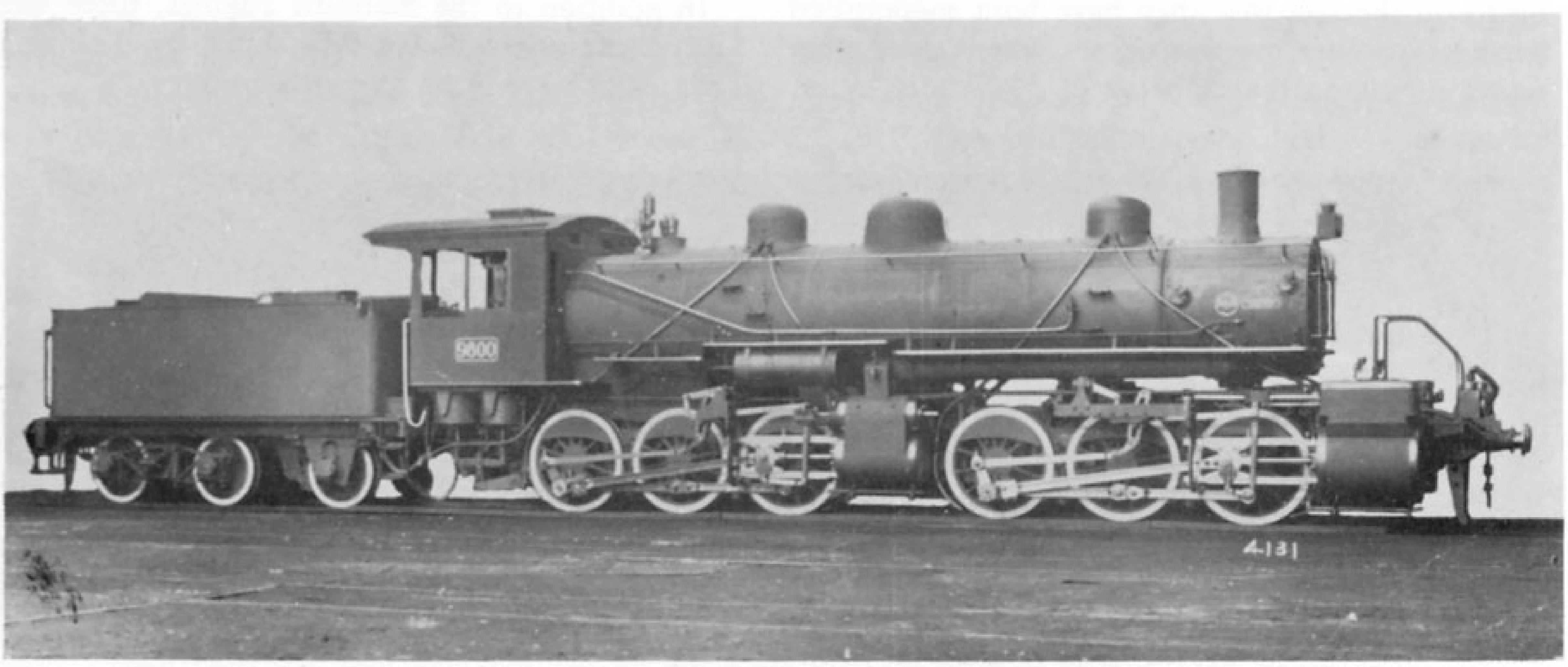
The seven Alco 2–8–8–2s built in 1921 for work on the Nankow Pass, Pekin–Suiyan Railway, were the largest locomotives ever exported from the USA. Only the Chinese know if they are still running—and they're not telling!



Maffei's 0–4–4–0T for the Japanese Railways—a standard European Mallet tank transported to the Land of the Rising Sun

JAPAN

From 1902 to 1912 the Japanese National Railways invested in a variety of Mallets for the mountainous sections of their 3ft 6in system. First came one each of typical European 0–4–4–0T engines, classes 4500 and 4510, built by Maffei in 1902 and 1904. After an extended period of trial, Alco supplied six 4600 class of 0–4–4–0 tender engines in 1911, these being typical light American Mallets with bar frames and slide valves, as might be expected. Proving unsteady at speed, they were soon converted to 2–4–4–0 by adding a leading pony truck and were reclassified 9020. There were then three batches of 0–6–6–0s, all built in 1912, 24 9750 class by Alco, 18 9800 class by Baldwin and 12 9850 class by Henschel. All were superheated, the American engines having piston valves on the high-pressure cylinders only, and the German on both high- and low-pressure sets. With these engines the development of the Mallet in Japan came to an abrupt halt and none was ever built there for home consumption, although nearly half a century later, in 1961, four Mallets were built for Indonesia. The Japanese Mallets seem to have been scrapped at a fairly early date and all available photographs of them are posed 'sitting duck shots', it being thus evident that they missed the keen action photographers of post-1945.



Baldwin's 0–6–6–0 superheated Mallet for Japan did not inspire a general adoption of articulated power for the prevailing mountainous terrain

ASIAN MALLETS

Typical dimensions of selected classes (metric units)

Railway (Country or Class)	*Gauge mm*	*Type*	*Cylinders mm×mm*	*Coupled wheel dia mm*	*Boiler pressure kg/cm²*	*Grate area m²*	*Total heating surface m²*	*Super-heating surface m²*	*Weights (loco only) Adhn t*	*Total t*
Plantation (Java)	600	0–4–4–0	160/240×300	610	12	0·42	18·5	—	10·0	10·0
Jaffa–Jerusalem	1000	„	290/450×550	1100	12	1·6	89·0	—	35·0	35·0
Japanese Nat (4600)	1067	„	394/622×610	1245	12·7	1·96	155	—	58·8	58·8
Atjeh (Sumatra)	750	0–4–4–0T	275/420×450	875	12	1·1	62·1	—	29·3	29·3
Japanese Nat (4500)	1067	„	310/490×540	1000	12·4	1·35	76·9	—	43·1	43·1
„ „ (4510)	„	„	300/490×530	1143	12·7	—	—	—	43·7	43·7
Kebao–Tonkin	1000	„	230/350×360	800	12	0·93	39·0	—	23·0	23·0
Atjeh (BB71)	750	0–4–4–2T	275/420×450	875	12	1·1	62·1	—	28·8	31·3
„ (BB81)	„	„	275/420×450	875	12	1·2	52·2	15·1	28·4	31·1
Damas–Hamah & P	1050	„	340/520×510	1070	12	1·3	111·1	—	46·1	54·1
SS Java (BB10)	1067	„	300/460×510	1106	12	1·5	101·4	—	36·9	44·1
Japanese Nat (9020)	„	2–4–4–0	394/622×610	1245	12·7	1·96	155	—	—	62·4
Trans Siberian (I)	1524	„	420/630×600	1350	12	2·7	176·2	—	54·8	65·8
Pekin–Suiyan	1435	2–4–4–2	381/584×559	1450	—	—	—	—	—	—
Hedjaz	1050	2–4–6–0	320/510×560	1070	12	2·66	162·3	—	45·0	53·0
Malaya; Iraq	1000	0–6–6–0	330/483×559	1119	12·7	1·79	130·8	—	49·0	49·0
Burma (final batch)	„	„	406/622×508	990	12·7	3·06	130·3	20·8	61·0	61·0
W India PR	„	„	394/615×508	990	12·7	3·06	140·5	—	60·0	60·0
Japanese Nat (9750)	1067	„	394/622×610	1245	14	1·98	120·8	31·3	65·3	65·3
„ „ (9800)	„	„	406/635×610	1245	14	1·97	165·1	30·0	65·5	65·5
„ „ (9850)	„	„	419/648×610	1245	14	2·1	124·9	35·5	69·2	69·2
Jaroslav–Archangel	„	„	350/450×550	1110	12	1·79	—	—	47·5	47·5
„ – „ (Baldwin)	„	„	330/483×559	1118	12·7	1·79	121·5	—	49·9	49·9
Insular Lumber	1067	0–6–6–0	381/584×610	1118	14	1.81	108.7	230.0	66.0	66.0
Pekin–Kalgan	1435	„	483/730×711	1300	14	4·2	241	—	96	96
Trans Siberian (Θ)	1524	„	475/710×650	1220	12	2·48	201	—	83·1	83·1
„ „ (Θɤ)	„	„	510/710×650	1220	12	3·5	179·1	24·1	80·1	80·1
SS Java (CC50)	1067	2–6–6–0	420/650×610	1106	14	3·4	150·8	50·0	66·0	73·5
„ „ (CC10)	„	2–6–6–0T	340/570×510	1106	12	2·0	136·2	—	54·0	62·3
USSR П34	1524	2–6–6–2	(4)500×800	1500	14	7·8	281·5	155·6	117·5	147·8
NWR India	1676	„	483/749×762	1320	14·7	5·23	295·0	65·7	107	124
SS Java (DD50)	1067	2–8–8–0	445/711×610	1106	14	4·2	213·4	64·4	84·0	93·5
„ „ (DD51)	„	„	445/673×610	1106	14	4·2	213·4	64·4	88·0	96·9
„ „ (DD52)	„	„	450/700×610	1106	14	4·2	212·4	64·6	88·0	96·6
Pekin–Kalgan	1435	2–8–8–2	508/813×660	1270	14	5·53	244	52·5	106·5	129·5
„ – „	„	„	610/965×711	1270	14	8·82	514	133·0	172·0	199·1
USSR П38	1524	2–8–8–4	(4)575×800	1500	15	10·7	396·3	236·7	179	215

CHAPTER 6

THE MALLET IN AUSTRALASIA

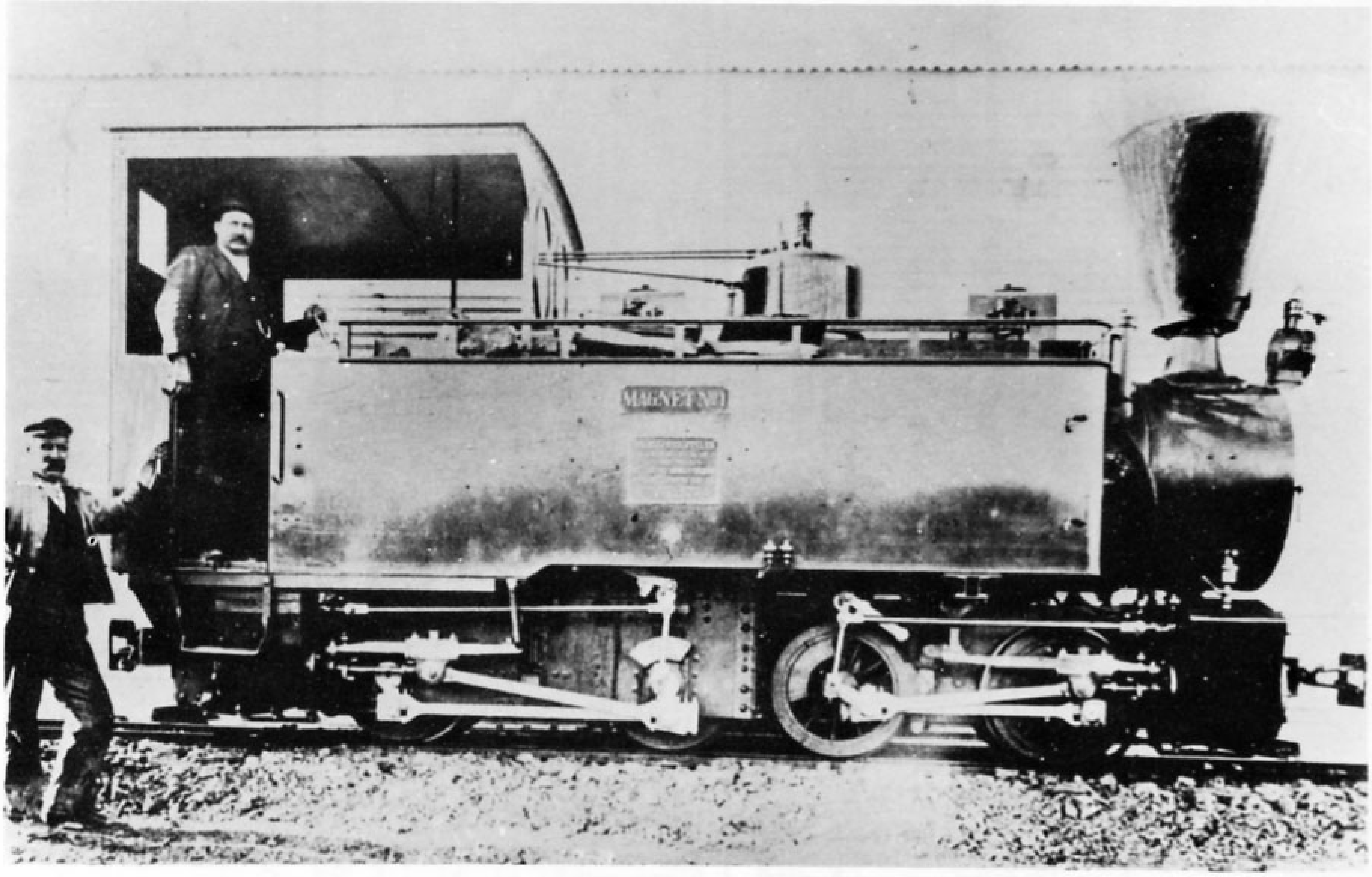
COVERING the Mallet continent by continent, each with its own chapter, we are left with nothing more than a mini-chapter for Australasia, whose Mallets were few in number although they tended to compensate for this by assuming strange marsupial forms quite unlike those found elsewhere in the world. The number of Mallets actually to run in Australasia may be counted on the fingers of just one hand, yet their spheres of operation extended from one end of Australia to the other, to the island State of Tasmania, and to New Zealand!

AUSTRALIA

Only three Mallets ever ran in Australia, and these were 2ft-gauge 0–4–4–0Ts built by Orenstein & Koppel, although nobody seems to know exactly when. In most respects they were a perfectly normal O & K light compound Mallet, complete with that firm's form of Hackworth valve gear, outside frames aft, and inside fore. However, the one feature which places them firmly into the marsupial Mallet category is that the rear unit is back to front, with the high-pressure cylinders right at the rear under the bunker! It is hard to find a logical reason for this peculiar form of construction which has nothing to its advantage and creates various problems in running the steam piping. One is tempted to imagine the things delivered in 'knocked down' condition and assembled incorrectly, but this is too unlikely to consider seriously. Whatever the reasons behind them, two of these little engines were delivered to the Mount Magnet Mining Co's railway, numbered 1 & 2, and spent their early lives on the island of Tasmania. After the railway closed, both were disposed of to a gold mine at Kalgoorlie, Western Australia. Fortunately, one engine was not to suffer the oblivion of the oxyacetelyne torch, and is now 'preserved', after a fashion, in a strange museum at Mussel Pool, in the Upper Swan valley, near Perth, W.A. It is the only railway exhibit there and stands forlornly, minus cab and chimney, in a park devoted mainly to old farm tractors, threshing machines, horse wagons and other agricultural machinery of the past. However, the main thing is that one of these unique Mallets *has* been saved, and one can only hope that it will one day be restored and found a better home, perhaps in the Railway Museum at Bassendean. The third engine worked on the Port Douglas Shire Tramway, Queensland, and now lies buried under a breakwater.

NEW ZEALAND

The New Zealand Government Railways also ran a version of Tasmania's marsupial Mallet, with cylinders at each extremity, but this time it was even more bizarre in execution. Born out of necessity, as ably told by W. W. Stewart in *When Steam was King*, the engine was hurriedly assembled out of spare parts to hand when the Fell centre-rail engines used on the Rimutaka incline fell into disrepair and further power was urgently needed. To equal the Fell engines by adhesion alone, an articulated was required, and as spare Vauclain compound cylinders were available these were worked into the engine. For those not familiar with the system, the Vauclain system of compounding comprises, on each side of the engine, superimposed high- and low-pressure cylinders driving a common crosshead, and from that a common connecting rod. American in conception, it enabled four cylinders to be used without recourse to a crank axle, introducing a certain amount of simplicity at the expense of heavy reciprocating masses, plus wracking stresses on the crosshead. Tried and found wanting in New Zealand as elsewhere, sets of Vauclain cylinders had been ordered to convert simples to compounds, and wisely set aside unused. Good enough for what was intended as a stopgap, G. A. Pearson decided to use them up, and as half saddles were cast integrally, in the usual American



'Magnet No 1' of the Mount Magnet Mining Railway, Tasmania, one of the only three Australian Mallets. Note the reversed position of the rear high-pressure cylinders

manner, the rear cylinders were positioned backwards so that the saddles did not clash with the Vanderbuilt boiler fitted. As such, with two units, each having four compound cylinders, the engine became the only eight-cylinder Mallet ever built, which, coupled with its other curious features, made 'E' class No 66 quite unique. Built in 1905, she worked until 1917, but after transfer from her original duties to work demanding higher speeds, of which she was not capable, she earned an unenviable reputation for herself and her designer. After scrapping, the boiler lasted until 1932 for washout duties.

After the experiences with No 66, it is surprising to find the NZGR toying again with the Mallet, but by 1920 something of greater power was needed than the 'X' class 4–8–2 for the middle section of the North Island main line. S. H. Jenkinson, under Chief Mechanical Engineer H. H. Jackson, designed a handsome 2–6–6–0 compound tender Mallet, but this never got off the drawing board and the big engines eventually built were the ill-fated 'G' class Garratts.

Meanwhile, the Wellington & Manawatu Railway, an independent line competing with the government railways with a shorter but more difficult route, were looking into the possibilities of more power than their existing conventional engines provided. Baldwins were usually favoured with the Manawatu line's locomotive orders and it is not surprising to find that the two Mallet designs prepared by J. Marchbanks, the locomotive superintendent, had a strong Philadelphia flavour. One was a 2–6–6–2T engine and the other a slightly larger 0–6–6–0 tender locomotive, both featuring bar frames, Belpaire unsuperheated boilers, and slide valves all round. Dated 1907, the proposals remained stillborn, as the Government Railways absorbed the Manawatu line in 1908 and no Baldwin Mallet ever assaulted the 1 in 36 gradients between Wellington and Paekakariki.

New Zealand's other Mallet story belongs to the Taupo Totara Timber Co which, in 1907, ordered two Mallets, an 0–4–4–0T from Orenstein & Koppel and a 2–4–4–2 tender engine from Alco. Due to a period of financial embarrassment, both

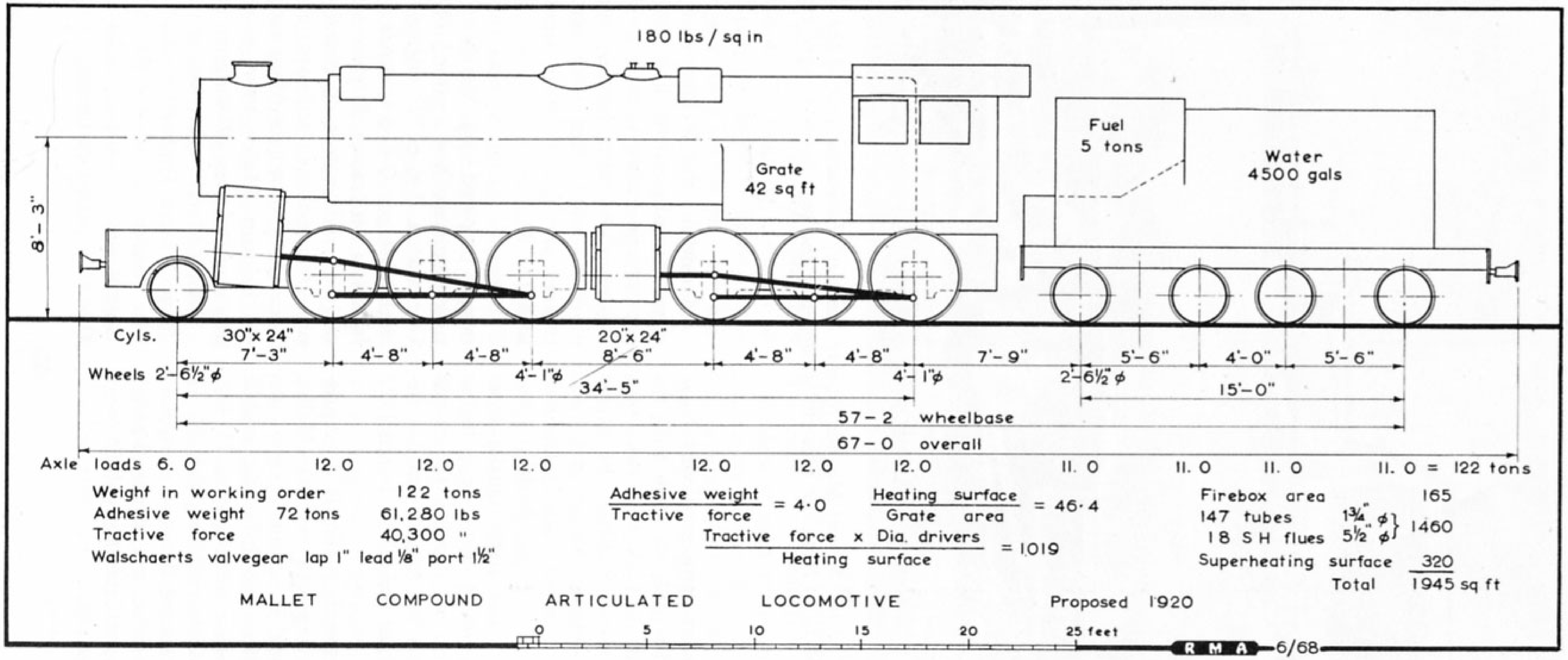


Fig 15 *New Zealand Government Railways Mallet proposal of 1920*

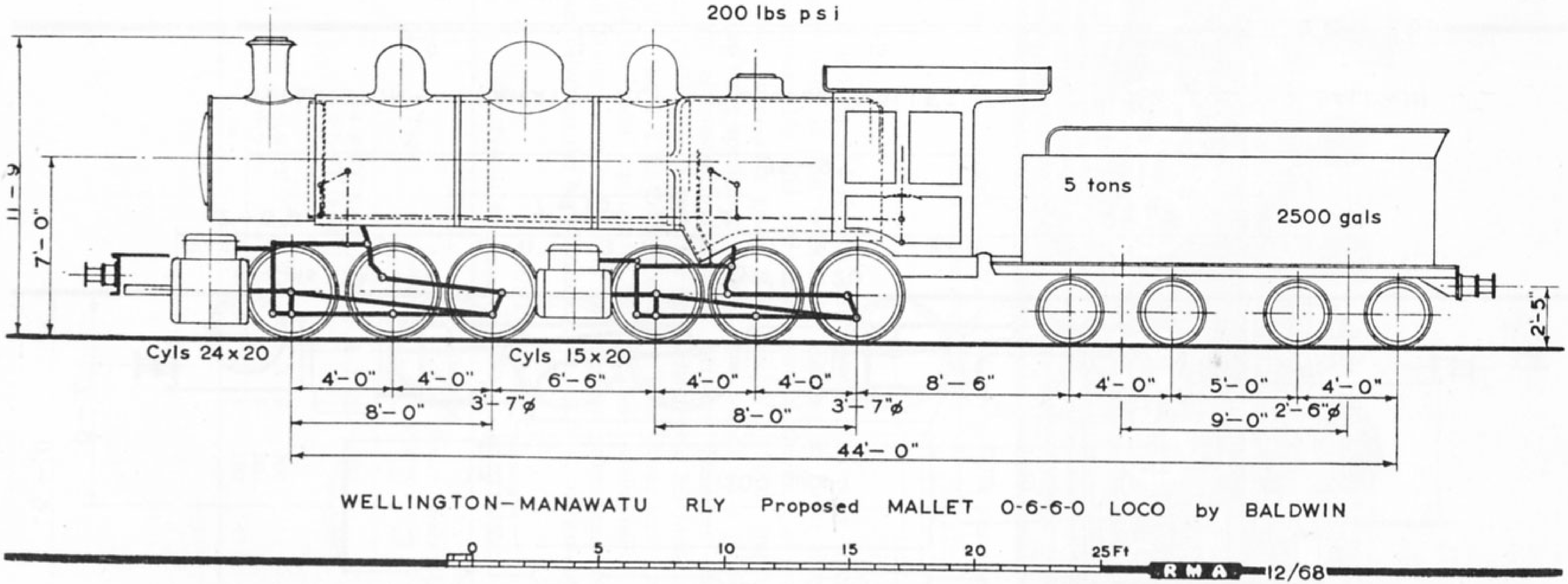


Fig 16 *Wellington & Manawatu Railways 0–6–6–0 Mallet proposal*

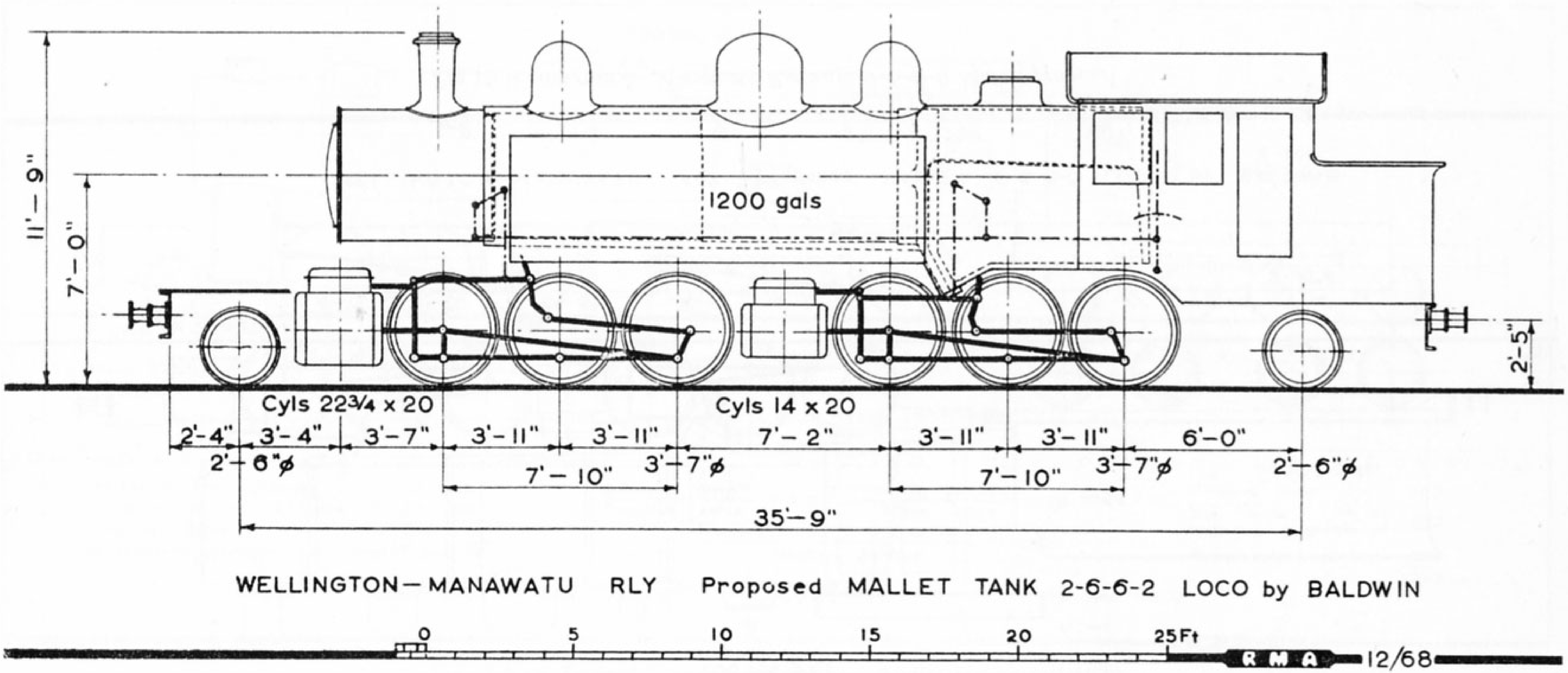
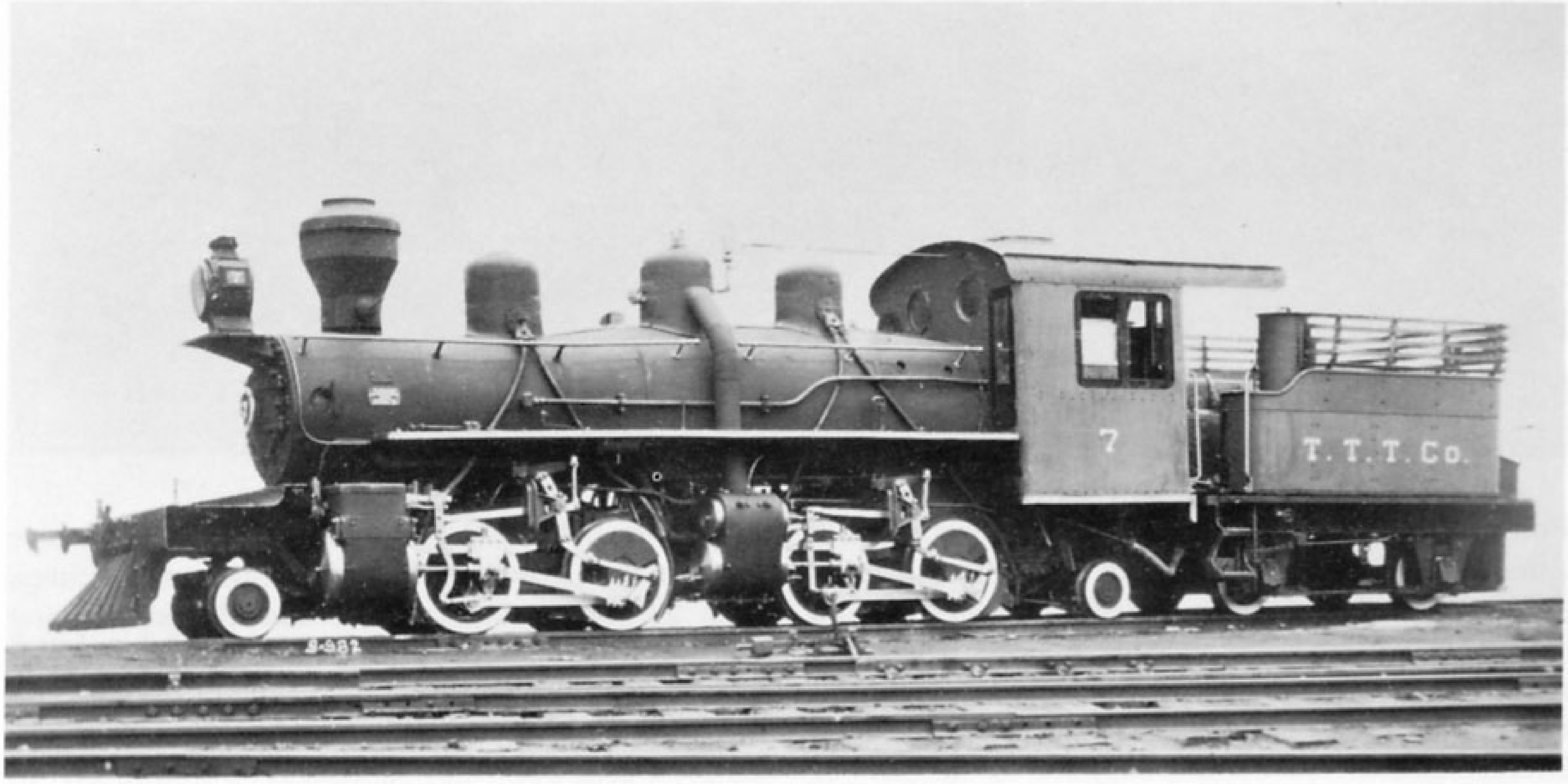


Fig 17 *Wellington & Manawatu Railways 2–6–6–2T Mallet proposal*



The Taupo Totara Timber Co in New Zealand operated this neat Alco 2–4–4–2 which is now preserved at Putaruru

engines were cancelled and the O & K tank was never heard of again—being of that company's stock design it was presumably sold elsewhere, probably after conversion to another gauge. The Alco engine was a rather more specialised engine, and as its American type of construction made it less amenable to gauge conversion, it hung fire for six years until, in 1913, the T.T.T. Co was able to afford delivery. As No 7, she was one of the most delightful small Mallets ever built, with inside bar frames, piston valves on the high-pressure cylinders, a pony truck at each end to facilitate running in either direction, and a four-wheeled tender, the fuel, of course, being wood. Fortunately, this little engine, too, has been preserved and stands on a plinth outside Putaruru station, between Hamilton and Rotorua in the North Island, near her former place of work.

Thus Australasia may have been the world's smallest Mallet-using continent, but it has the highest proportion of them still in existence—40 per cent, or two out of five.

AUSTRALASIA

Typical dimension of Mallets (imperial units)

Railway	*Type*	*Cylinders in×in*	*Coupled wheel dia ft in*	*Boiler pressure psi*	*Grate area ft²*	*Heating surface ft²*	*Super-heating surface ft²*	*Weights (loco only) Adhn T*	*Total T*
Magnet Mines	0–4–4–0T	8¼/12 × 12	2 1 3 0½	200					
NZGR	2–6–6–0T	(8)9½/16 × 18			26	1540	—	61·1	65·9
Proposals									
Wellington & Manawatu	2–6–6–2T	14/22¾ × 20	3 8	200					
„ „	2–6–6–0	15/24 × 20	3 8	200					
NZGR	„	20/30 × 24	4 1	180	42	1625	320	72	80

CHAPTER 7

THE MALLET IN SOUTH AMERICA

FOR THE purpose of this chapter, the term 'South America' includes all countries south of the USA or, in other words, Latin America. There were no really big Mallet users in this part of the world and the type amounted only to about two hundred engines, but they were divided into numerous small batches of assorted designs supplied to railways of diverse gauge in many countries.

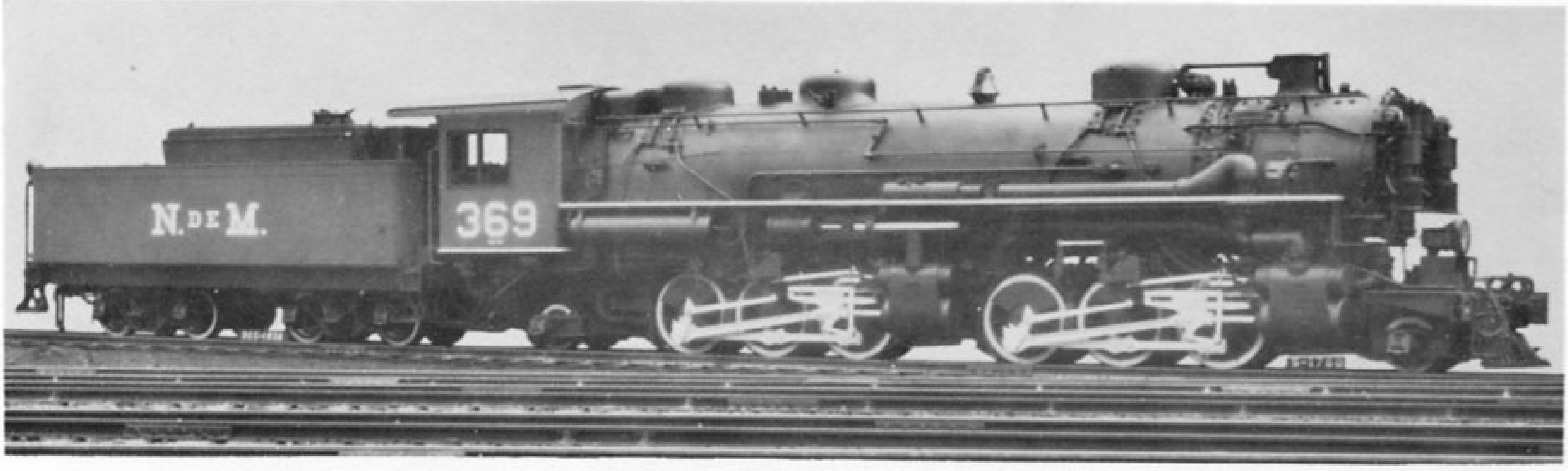
MEXICO

Mexican locomotive practice generally followed that of her northern neighbour, except that the engines were of somewhat smaller dimensions to suit the lighter track. Nevertheless, by world standards they were big engines and in 1911 Baldwin supplied twenty-two compound 2–6–6–2s, with slide valves all round and using saturated steam. These were used on the main line from Vera Cruz to Mexico City for the climb up the Sierras to Bocca del Monte. Restricted to mountain train and banking duties, they lasted well towards the end of steam and in 1938 were supplemented with eight superheated simple expansion 2–6–6–2s, designed and built by Alco, of handsome and impressive proportions. The usual modern American features, such as Delta trailing truck and Boxpok driving wheels, were incorporated into this design which would have been just light enough to run on selected European main lines. The mainline simples followed the successful introduction in 1930–6 of four smaller 2–6–6–2s for the 3ft gauge sections, where heavy haulage through the Sierras was also a problem. These engines were also of modern design and had Baker valve gear as opposed to the Walschaerts on their later standard-gauge sisters. All the Mexican Mallets are now scrapped.

SALVADOR

The 3ft-gauge International Railways of Central America (which are not international at all!) had two most interesting Mallets—superheated simple expansion 2–6–6–2 tender engines which started life as 2–6–6–2Ts built by Baldwin for the Uintah Railway in the northern USA. By the time they reached the IRCA, each of the two engines was third

Nacionales de Mexico used eight of these handsome standard-gauge Alco simple expansion 2–6–6–2s, built in 1938

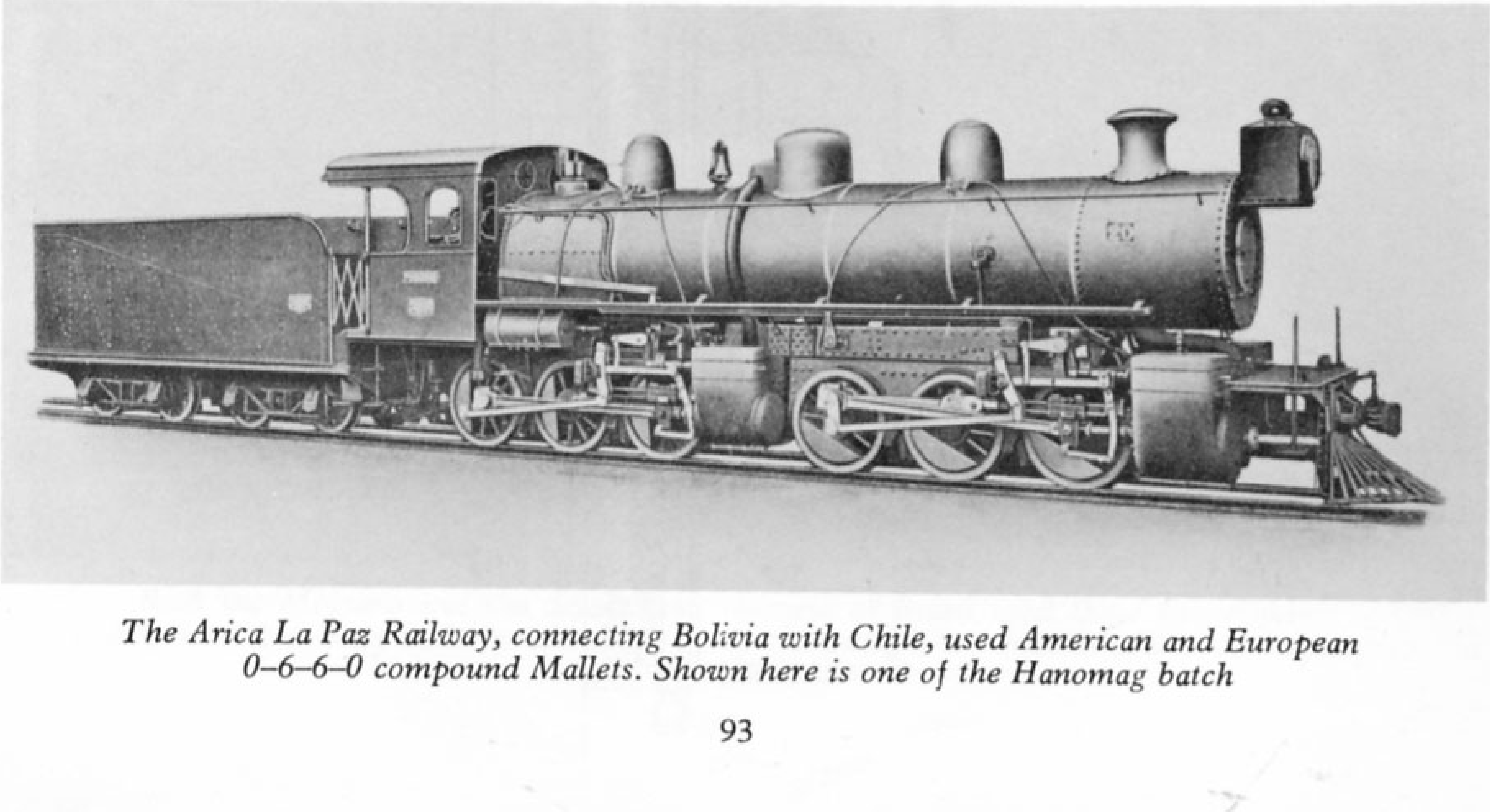


Modern Mallet power on the 3ft gauge: Mexico's Alco simple expansion 2–6–6–2, outshopped by the builders in 1930

hand and had been converted from tank to tender. So far as is known, they may still be in service. Running numbers 250 and 251 belie the handful of locomotives operated by this little railway.

COLOMBIA

The mountainous regions of this republic, situated at the neck of the Panama isthmus, have necessitated the use of many articulated locomotives. Perhaps the largest user of the Kitson-Meyer, the various railways also used a few Garratts, a strange, double-bogie Sentinel and assorted Mallets, all of them tank engines. First were some 0–6–6–0Ts built by Alco in 1910 for the 3ft-gauge F. C. de Tolima, and these had inside bar frames, piston valves on the high-pressure cylinders only, and were not superheated. Doubtless, they are long since defunct. The metre-gauge F. C. del Sur (Southern Railway) had a superheated 2–6–6–2T built by Baldwin and this, too, had piston valves on the high-pressure cylinders with slide valves for the low pressure. Finally come the most interesting of all, two superheated simple expansion 2–8–8–2Ts, built by Baldwin in 1935 for the Ferrocarriles Nacionales, presumably to try out the features of a large Mallet against the Kitson-Meyers of similar size and wheel arrangement supplied by Robert Stephenson's that same year. These were the only eight-coupled Mallet tank engines used outside Bavaria, and thus the only simple expansion eight-coupled Mallet tanks in the world. Apart from this, they featured inside frames, Walschaerts-operated piston valves and double chimneys, plus an unusual arrangement of steam pipes emerging from the top of the smokebox beside the chimneys before splitting at a



The Arica La Paz Railway, connecting Bolivia with Chile, used American and European 0–6–6–0 compound Mallets. Shown here is one of the Hanomag batch

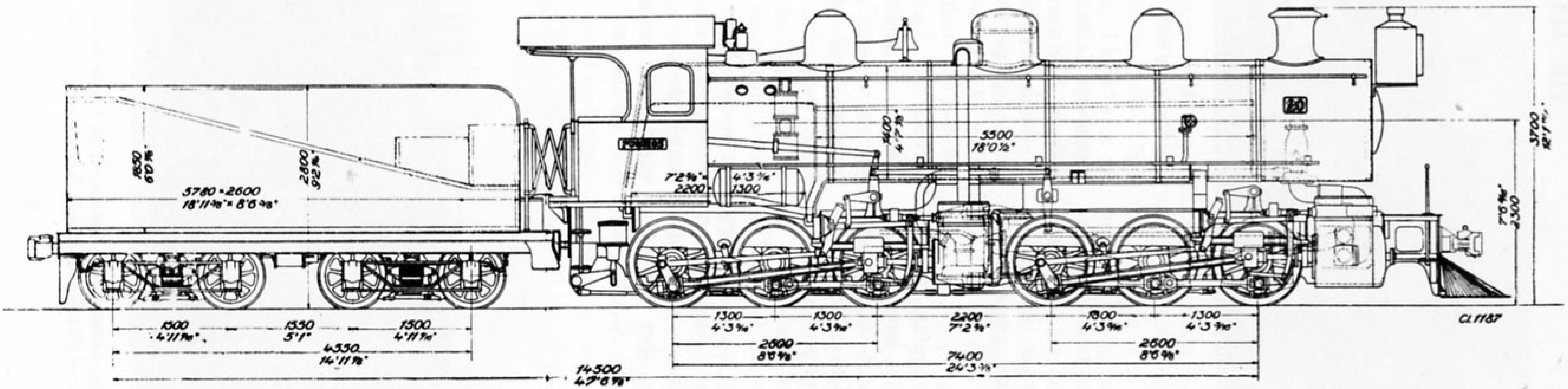
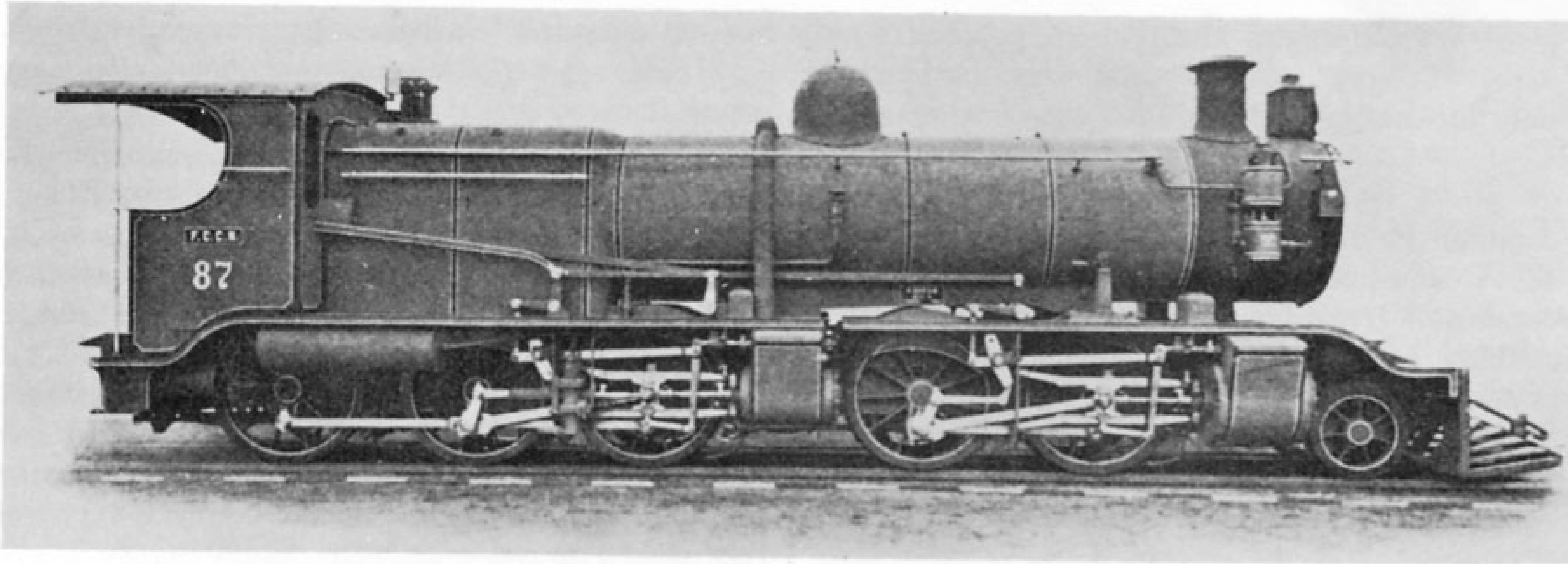


Fig 18 *Arica La Paz Railway, Hanomag 0–6–6–0*



Unusual Mallet power for Argentine's F.C. Central Norte were these English-looking Borsig 2–4–6–0 passenger engines on metre gauge

T-piece to the two sets of cylinders. At the last known report, Colombia had largely dieselised and neither the Mallets nor any other articulateds were among the last steam survivors.

BOLIVIA—CHILE

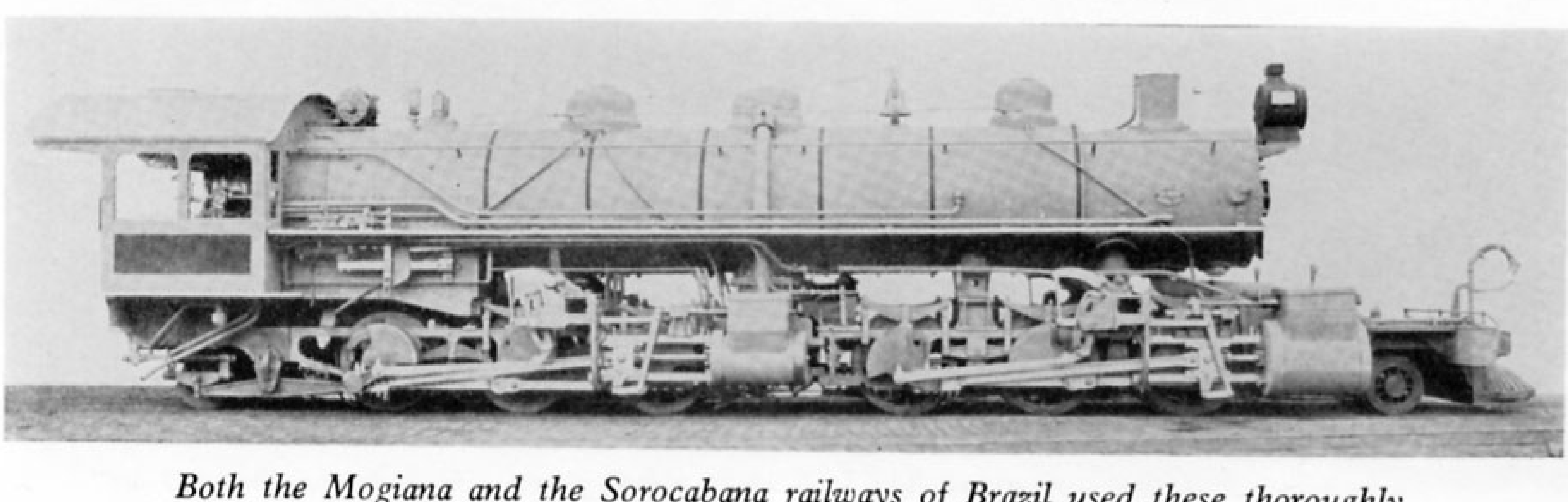
The Arica–La Paz Railway, connecting the former town on the Chilean coast with the latter high up in the Bolivian Andes, encountered long and steep gradients in its climb inland and was a natural candidate for articulated power. Both Baldwin and Hanomag built metre-gauge 0–6-6–0 tender engines of similar design in 1913-18, unsuperheated compounds with inside frames, the Baldwins having piston valves on all cylinders and the Hanomags slide valves throughout. Other differences were plate frames on the German and bar on the American, which also had power reverse.

CHILE

Baldwin built, in 1915, two superheated compound 2–6–6–2s with piston valves on all cylinders for the Andes Copper Mining Co of Chile, for use on their F. C. de Potrerillos, a line dieselised today but still retaining steam in reserve, although whether this includes the Mallets is unknown. Later, Henschel supplied similar locomotives, also of metre gauge, for the Chilean State Railways, but again, with the country in the usual state of Latin-American revolution and upheaval, it is impossible to glean any current information.

PUERTO RICO

For the American Railway of Puerto Rico, a metre-gauge sugar cane railway, Baldwin built in 1904 the first Mallet constructed in the USA, an unsuperheated 0–6–6–0 tender engine whose



Both the Mogiana and the Sorocabana railways of Brazil used these thoroughly American 2–6–6–2s built by Henschel. Note the outside bar frames which were rare on Mallets pioneer position has always been eclipsed by the massive engine of the same wheel arrangement built for the Baltimore & Ohio the same year.

ECUADOR

Another Baldwin 0–6–6–0, similar to the engine above, was built by Baldwin for the 3ft 6in-gauge Guayaquil & Quito Railway for use on their incredible 1 in 18 gradients from the coast to the interior. This line later introduced a pair of Garratts and had rack sections as well, but no recent report of operations or locomotive stock is to hand. The Mallets were Nos 17 and 18, also of 1904.

PERU

The Ferrocarril del Sur, or Southern Railway, one of the lines owned and operated by the Peruvian Corporation in London, had two Baldwin superheated compound 2–6–6–2Ts built in 1921. Typically American, they had bar frames and piston valves on all cylinders and were used on the steepest gradient, 1 in 33, to Crucero-Alto until they were replaced by diesels and scrapped. The line is, of course, of standard gauge.

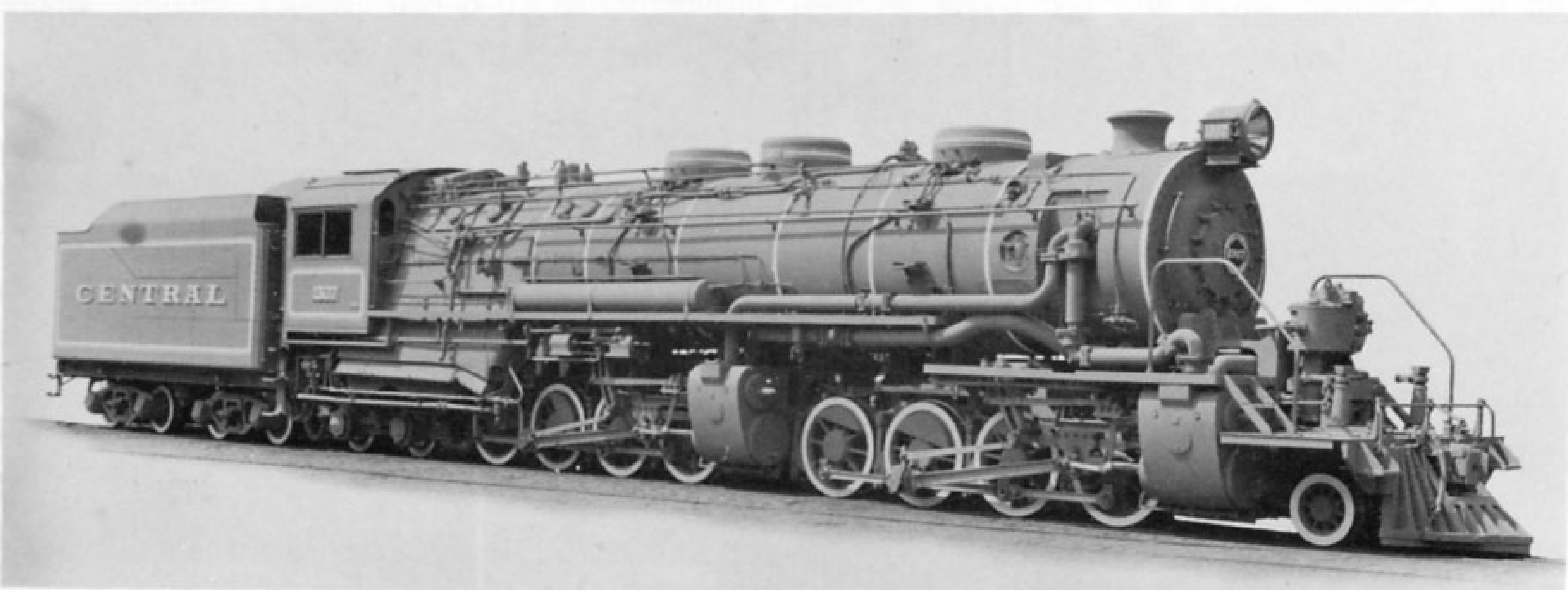
ARGENTINE

The Ferrocarril Central Norte, now the major component of the metre-gauge General Belgrano system, was the only railway in this vast country to use Mallets, and there were but two classes, introduced in 1904 and having identical boilers and other components. For freight work, engines 166–71 were of the 0–6–6–0 type and were unsuperheated, with Walschaerts-actuated slide valves on all cylinders. For passenger duties the unusual 2–4–6–0 type was selected with, for metre gauge, quite large wheels. Both classes were designed in Borsig's 'English period' and had suitable cabs, domes and capped chimneys, the passenger engine sporting a running plate gracefully curved at each end, with splashers for the coupled wheels, the only such Mallets built. In fact, had Marsh or Billinton ever encountered the unlikely necessity of building a 2–4–6–0 Mallet for the London, Brighton & South Coast Railway, it would have looked exactly like Borsig's FCCN engine! Presumably, but not definitely, these engines are now defunct. The 2–4–6–0s were nos 86–9.

BRAZIL

Unlike its southern neighbour Argentine, which with its strong British railway traditions favoured the Garratt, Brazil followed USA practice in adopting the Mallet for performing heavy duties, and unfortunately followed America, too, in becoming an early victim of the great diesel confidence trick.

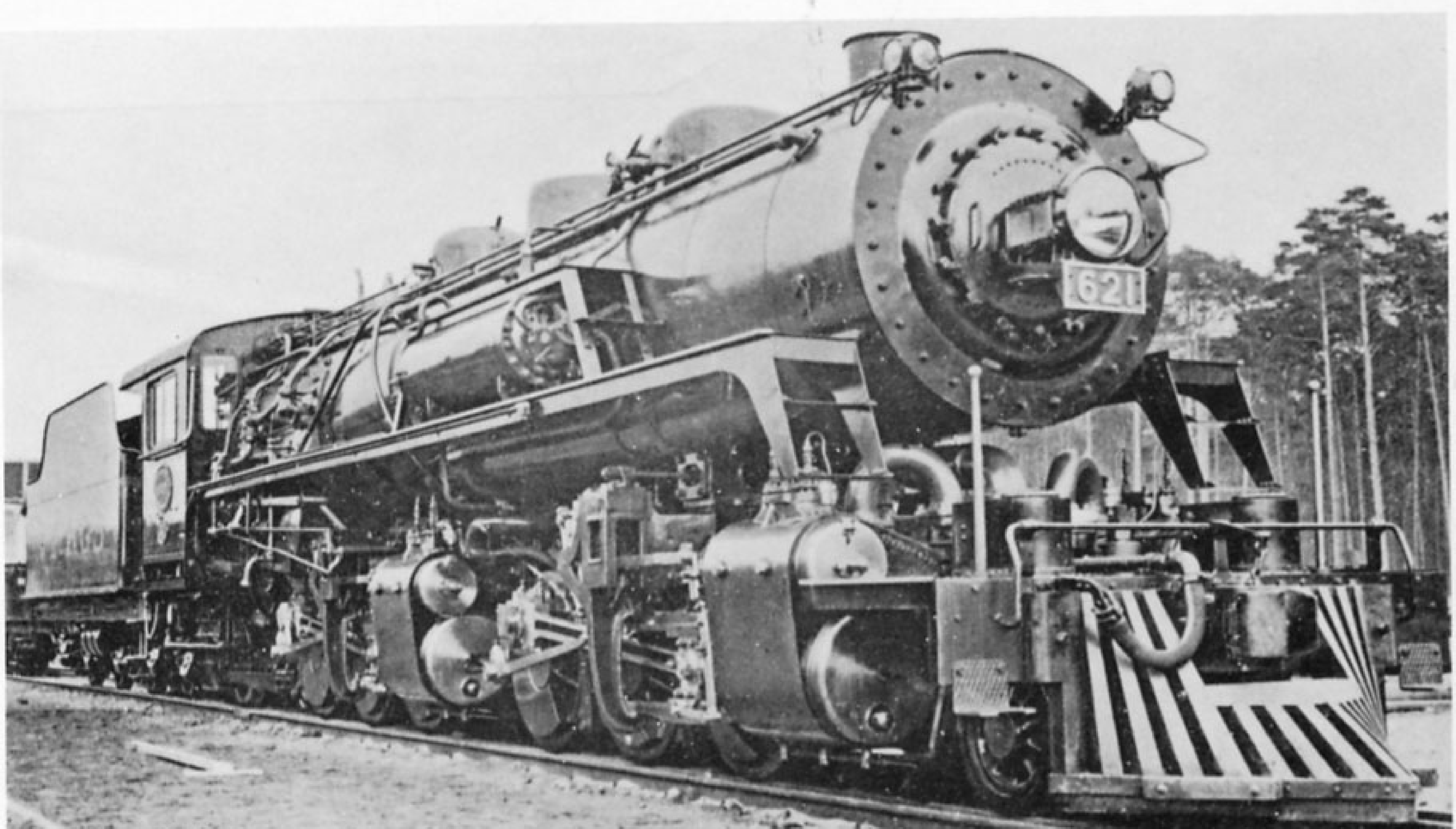
Estrado de Ferro Sorocabana: This metre-gauge line was the first Brazilian railway to adopt the Mallet and its initial four engines, built by Baldwin in 1907–9, were unsuperheated 2–6–6–2s with outside bar frames on each unit. Engine numbers were 40–3 and these slide-valve machines had disappeared by 1950. Next were a batch of six engines, Nos 701–6, by Baldwin and Henschel in 1909–11, believed to have been similar. There were also twelve engines, Nos 601–12, by Alco and Henschel, smaller and with inside frames, of which



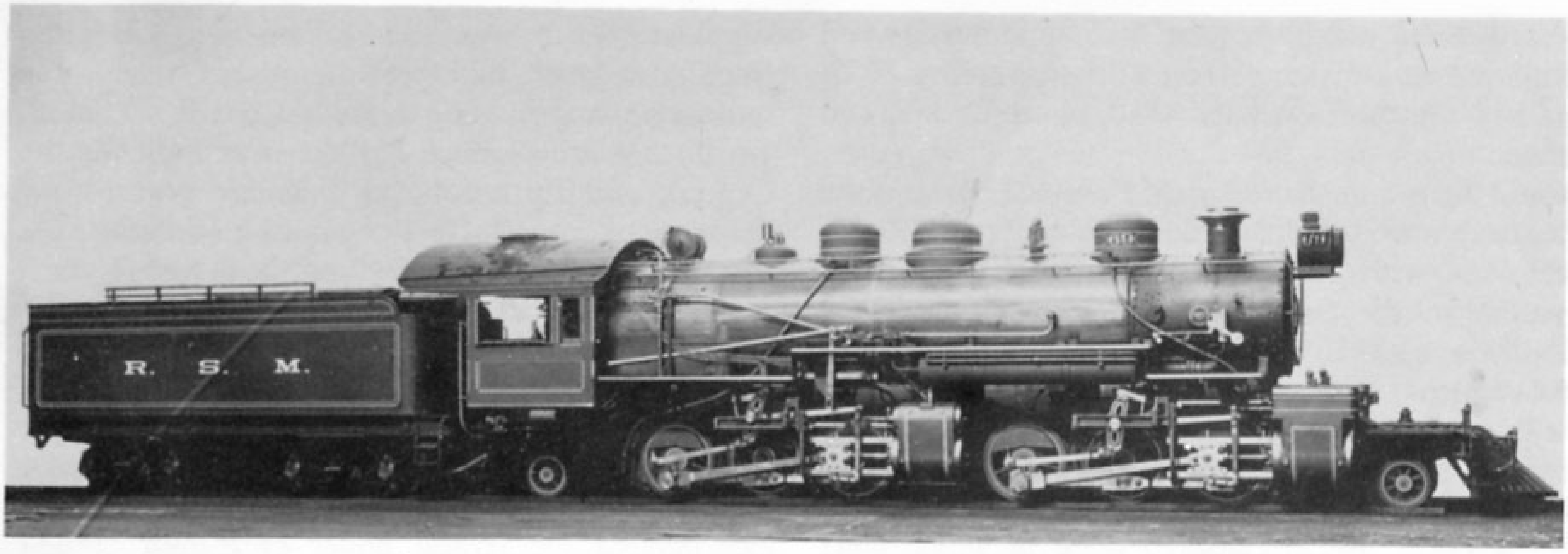
The Central Railway of Brazil had four large metre-gauge 2–8–8–4s, outshopped by Henschel in 1937. The world's only narrow-gauge 2–8–8–4s, they had the largest boilers ever used on a narrow-gauge Mallet the German batch, at least, had superheaters and high-pressure piston valves. All had gone by 1957, as had the three-cylinder 4–10–2s which followed them.

Cia Mogiana de Estradas de Ferro: The Mogiana Railway introduced the Mallet just after the Sorocabana, with four outside-framed 2–6–6–2s, similar to the Sorocabana's first batch, built by Baldwin in 1910–12. There was also a batch of four Alco superheated 2–6–6–2s, built in 1919 with high-pressure piston valves, plus a batch of twenty-three outside-framed 2–6–6–2s of the early Baldwin design, built by Henschel and destined for a vague 'Brazil railway', some of which were believed to have been the Sorocabana engines, and others the Mogiana.

Estrada de Ferro Central do Brazil: The Central Railway was Brazil's largest Mallet user and used them both on its broad (5ft 3in) and metre-gauge lines. The first broad-gauge engines were three Alco 0–6–6–0s, built in 1907, saturated compounds based on but smaller than that builder's prototype Baltimore & Ohio engine. These were followed by three slightly enlarged engines from Baldwin in 1911. Used in haulage and banking on the main line, traffic grew rapidly and in 1911 they were supplemented by ten superheated 0–8–8–0s, also from Alco, with high-pressure piston valves, the same builder providing a further ten in 1912–19. No further broad-gauge Mallets were built for the Central, and further heavy mainline power took the form of large 2–10–4 engines by Henschel. On the metre gauge, Baldwin built a 2–6–6–2 compound in 1919, after which the type seemed moribund. However, in 1937, Henschel built four superheated simple expansion 2–8–8–4 tender engines of distinctive design, quite unlike the thoroughly American Mallets which had preceded them. Of no great weight or tractive effort, they nevertheless incorporated the largest boiler ever built onto a 12-ton axle load, a boiler comparable in size with the East African Railway's 59-class Garratt, on the same rail gauge but with a 21-ton axle load! Henschel were, naturally, rather proud of their achievement within such tight limitations and provided substantial write-ups both for their house journal *Henschel Hefte*, and for *Die Lokomotive*, comparing the Brazilian Mallet with a Reichbahn 44-class, three-cylinder 2–10–0, in many ways the smaller engine. Burning mechanically-fired, low-grade Brazilian San Jeronimo coal of 4,500 kcal/kg calorific value, the engines were conservatively



Brazil's VFRGS *ran two types of simple expansion 2–6–6–2s, American and German. No 621, shown here, is one of the Henschel batch*



Brazil's metre-gauge Rio Sul do Mineras operated this Baldwin-built, and thoroughly American, compound 2–6–6–2 on metre-gauge track

Almost certainly the last simple expansion Mallets in operation today are the Baldwin 2–6–6–2s of the Donna Thereza Christina Railway in Brazil. Here No 204 is seen hauling coal in 1972

SOUTH AMERICAN MALLETS

Typical dimension of selected classes (imperial units)

Railway	Gauge ft	Gauge in	Type	Cylinders in×in	Coupled wheel dia ft	Coupled wheel dia in	Boiler pressure psi	Grate area ft²	Total heating surface ft²	Super-heating surface ft²	Weights (loco only) Adhn T	Weights (loco only) Total T
F.C.C.N. Argentine	3	3⅜	2–4–6–0	13/20½×21⅝	4	3	171	35·5	1820	—	42·1	47·6
„ „		„	0–6–6–0	13/20½×21⅝	3	7⅛	171	32·3	1770	—	46·2	46·2
American, Puerto Rico		„	„	12½/19×20	3	1	200	18·3	1355	—	48·4	48·4
Arica La Paz (Hanomag)	3	3⅜	„	16/25×22	3	7½	200	31·3	1469	363	68·0	68·0
„ „ „		„	„	15¾/24×21⅝	3	7½	200	30·1	1955	—	62·6	62·6
Central of Brazil	5	3	„	17½/28×26	4	2	200	41·0	2317	—	92·0	92·0
Giradot, Columbia	3	3⅜	0–6–6–0T	13/20½×20	3	2	200	24·0	1160	—	56·9	56·9
Nacionales, Mexico	3	0	2–6–6–2	(4)15×22	3	7	210	52·5	2449	680	77·0	96·4
Sorocabana, Brazil	3	3⅜	„	16/25×20	3	6	200	31·5	1881	—	59·9	71·2
Mogiana, Brazil (Henschel)		„	„	16½/26½×24	3	9	200	36·9	1934	506	69·7	82·7
VFRGS, Brazil		„	„	(4)16½×22	3	6	171	53·8	1355	505	62·5	78·9
„ „ (Baldwin)		„	„	(4)16×22	3	6	170	53·7	1694	432	59·0	74·3
Goyaz, Brazil		„	„	(4)14×22	3	7	180	26·4	1255	337	54·7	64·5
Rio Sul, Mineras		„	„	16/25×20	3	6	200	31·5	1566	321	58·5	70·0
Nacionales, Mexico	4	8½	„	21½/33×32	4	8	220		4700		134	151
„ „		„	„	(4)18×30	4	9	250	70·3	3801	1080	142	176
F.C. Sur, Columbia	3	3⅜	2–6–6–2T	13/20½×20	3	2	190	24·0	797	212	55·3	64·7
Central, Brazil	5	3	0–8–8–0	20/32×26	4	2½	220	51·8	3860	—	125	125
Paulista, Brazil	3	3⅜	2–8–8–2	18½/29×22	4	2	200				85·7	100·3
Giradot, Columbia	3	0	2–8–8–2T	(4)17×22	3	4	205	51·6	2584	656	111·3	128·8
Central Brazil	3	3⅜	2–8–8–4	(4)17×22	3	6	210	75·4	2346	915	96	117·5

rated at 1,750ihp, running at 60 km/h, with 25 per cent cut-off in the cylinders. These Brazilian Central engines vie with the South African MH in being the largest narrow-gauge Mallets ever built —the MH was the heavier engine, but the Brazilian locomotive had more horsepower and tractive effort and the larger boiler, probably thus having the edge over its African rival.

Companhia Paulista de Estradas de Ferro: The metre-gauge Paulista Railway was unusual in starting off with two quite large Mallets, and then at a later date buying a pair of much smaller engines. The big engines, 2–8–8–2 Nos 89 & 90, were built in 1913 by Baldwin and Alco respectively and were similar in size. Presumably purchased as a trial of the Mallet type and of the two builders' ability to provide a satisfactory example, they were, at about 100 tons apiece without tender, very big engines for the metre gauge. The repeat order went to Alco after an extended trial and was not delivered until 1916–17, Baldwin getting a consolation prize in the shape of two smaller 0–6–6–0s, built in 1919. The Paulista Railway is now fully dieselised.

Viaçao Ferrea do Rio Grande do Sul: Apart from finding yet another way of saying 'railway' in Portuguese, the VFRGS was unusual in that both its excursions into the Mallet type have been with simple expansion superheated engines. The first, 2–6–6–2s, were among the earliest of this species built and came from Baldwin in 1924. A batch of similar but larger engines was built by Henschel a little later, and when further articulateds of the lighter type were required, Henschel also provided them, but this time they were Garratts.

Miscellaneous Baldwin 2–6–6–2 compounds: Odd engines of this popular type were built for the Rio Sul do Minas, Vitoria & Minas, and Vitoria–Diamatina lines, all being of metre gauge.

Miscellaneous Baldwin 2–6–6–2 superheated simples: Five lightweight engines of this type were built for the metre-gauge Goyaz Railway, a line which no longer seems to exist, at least under that name. Neat, modern little engines by Baldwin in 1935–40, they burned wood and had spark-arresting chimneys. Evidently a successful design, a further six were built in 1941–9 for the Donna Thereza Christina Railway, Nos 200–5, to a modified design with a Delta trailing truck instead of the original pony truck and without the spark-arresting chimney. There were also ten further 2–6–6–2s, closer to the original design but with larger boilers, built for the Brazilian Ministry of Communications in 1945. The Donna Thereza engines were last reported running in 1973, and are probably the world's last operating simple expansion Mallets.

CHAPTER 8

THE MALLET IN NORTH AMERICA

IN THIS final and longest chapter the author has had the difficult task of reviewing more than half the world's Mallets—a task worthy of a substantial tome of its own! In very round figures, the world had rather over five thousand Mallets at one time or another, and more than three thousand of these operated within the USA, comprising a score of wheel arrangements divided amongst fifty main-line railroads and a further assortment of logging and similar lines. Exactly how many American Mallets there were is difficult to compute—Alfred W. Bruce, in *The Steam Locomotive in America in the Twentieth Century*, tabulates them under wheel arrangements, as simples or compounds, and totals them up neatly to 3,096 (2,395 compound plus 701 simples) which, together with the four Triplexes, makes a grand total of 3,100. This figure is, however, suspect for Bruce was a locomotive industry man, an employee of the American Locomotive Co, and tends to ignore engines built or rebuilt by the railroads in their own workshops, probably regarding this as some form of unethical practice entered into deliberately to deprive his firm of its rightful business! As such, the 2–6–8–0 type is disregarded altogether, only ten of the twenty 2–10–10–2s appear in his table, and one is left wondering whether the large numbers of Roanoke-built N&W 2–8–8–2s and 2–6–6–4s have been accounted for, although the total for the latter indicates that they have. There could thus be from fifty to a hundred or more engines than Bruce indicates, but cross-checking railroad for railroad is indecisive due to some engines being sold from one to another.

There is, fortunately, a steadily growing library of books covering the railroads of the USA and their steam power, very often detailing the motive power engine by engine, with building, rebuilding and scrapping dates, dimensions, diagrams and other technical data, plus operating information illustrated by good action photographs. In this book's bibliography will be found those known to the author, and the remaining railroads, if not yet included, probably will be in good time. There remained the decision as to whether USA Mallets should be dealt with type-by-type, which has many advantages, or railroad-by-railroad, which has others, and after much thought it was decided to first of all enumerate the types and operators of the various Mallets and then deal in rather more detail with a few selected railroads, chosen as being users of Mallets of particular importance or unusual interest. It is hoped that readers will find this treatment satisfying—at least until some American author comes up with a 500-page magnum opus on the American Mallet!

DEVELOPMENT OF THE MALLET IN NORTH AMERICA

The early years of the twentieth century saw the United States of America emerge from being a pioneer and agricultural country and head towards becoming the industrial power it is today. Previously, in the mid-nineteenth century, the world's main industry had been concentrated in little 'two-by-four' Great Britain and the slightly larger countries of Western Europe, particularly Germany. Thus the pattern of railway traffic was cut to suit the prevailing conditions. Britain's railways tended to be short and thick-set—the Taff Vale Railway in South Wales moved immense coal tonnages over a line whose main trunk, from Pontypridd to Cardiff, was only a dozen miles long and whose longest haul about double that figure. The biggest engine was a moderately proportioned 0–6–2T and there was a continual stream of coal trains, nose to tail, down the main line. In America, when the industrial revolution started to mature, conditions were very different—places of production and consumption, and sources of raw materials, were hundreds, even thousands of miles apart and connected by long skinny railroads, often but a pioneer single track connecting distant horizons. There was no way of running British style short-and-frequent trains; once the track capacity between telegraph points had been allocated to a train it had to be of maximum tonnage, and so that the line might be cleared for the next train to pass that tonnage had to move fast. Thus locomotives of immense power were needed and whereas in 1900 the eight-coupled engine of about 30,000lb tractive effort was more or less a world standard for the heaviest work and took many years to double elsewhere, in the USA the 100,000lb engine was soon commonplace and often exceeded. What enabled such giant strides to be taken was the Mallet, and the Baltimore & Ohio's 0–6–6–0 No 2400, introduced in 1904, was 'the world's largest locomotive'—but not for long. Bigger and bigger engines appeared, each holding the 'world's biggest' title for a short while until replaced by something bigger again. But all the time, from that fateful appearance in 1904 until today—and possibly for ever—the world's biggest locomotive has always been a Mallet. For fifty years the Mallet held sway, until the 1950s saw them all swept away as though decimated by a disease, and that disease was the diesel.

In that brief decade of the fifties, American railroads went from being a predominantly steam-operated institution to almost full dieselisation, and numerous powerful and modern steam locomotives were laid aside and scrapped almost before they had been run in. With them, of course, went the big modern Mallets, and the whole story is a sad one of how the large, powerful oil companies and diesel manufacturers either persuaded the railroads to buy diesels, using dubious comparisons between the best results of new diesels and average results from over-age steam, or by virtual blackmail in threatening to divert traffic from railroads not investing in their diesels. Thus administrations which had rejected three-cylinder, or poppet-valved steam as 'too complicated' found themselves saddled with highly complex diesel power, plus expensive equipment to service and repair it. What is more, they did not last. By the time a good steam engine would have been decently run in the diesel needed a new engine, or even completely renewing, and the initial few cents saving on fuel became a constant drain on capital for costly new components, assemblies, or complete diesel locomotives. The result was as planned—railroads made less profit on their main lines, and losses on the secondary services which they had to close. Eventually, even the main lines may disappear and this is just what the oil and diesel interests want. A hundred-car freight hauled by a Mallet offers no profit to the diesel builder, nor to the oil purveyor. A three- or four-unit diesel to do the same work reverses the situation, but what the manufacturers *really* want is to see the train replaced by a hundred road leviathans—a hundred road diesels each of 250hp represent more profit to the manufacturer than the 8,000hp set of diesel locomotives needed to perform the same transportation job. And, of course, for the oil supplier 25,000 horsepower's worth of oil to cart the load is better than 8,000 horsepower's worth by diesel locomotive, and infinitely superior (to them) than 8,000hp of steam locomotive, burning either coal or low grade (and low profit!) residual oil. To speed the change-over, railroad mergers were opposed (as large, strong railroads might prove less tractable than smaller concerns frightened by cut-throat competition), and pressures maintained at Federal and State Government levels to subsidise the roads and tax the railroads. One man in the USA, just too late, saw what was happening and wrote a learned paper on the subject. He was not allowed to read it in America, nor to the Institute of Locomotive Engineers in Britain, although Britain's Institute of Mechanical Engineers did permit him to read his paper in 1958. Unfortunately, the lessons were not learnt and the same commercial pressures which killed the American Mallets were allowed to swarm across the Atlantic and decimate half of Britain's railway system, together with its rolling-stock and coal industries, thus reducing exports, increasing imports and throwing people out of work—all to enable more diesel lorries to wreck the roads and pollute the atmosphere.

That, then, was the sorry background to the incredible extinction of the amazing locomotives now about to be described.

SECTION A

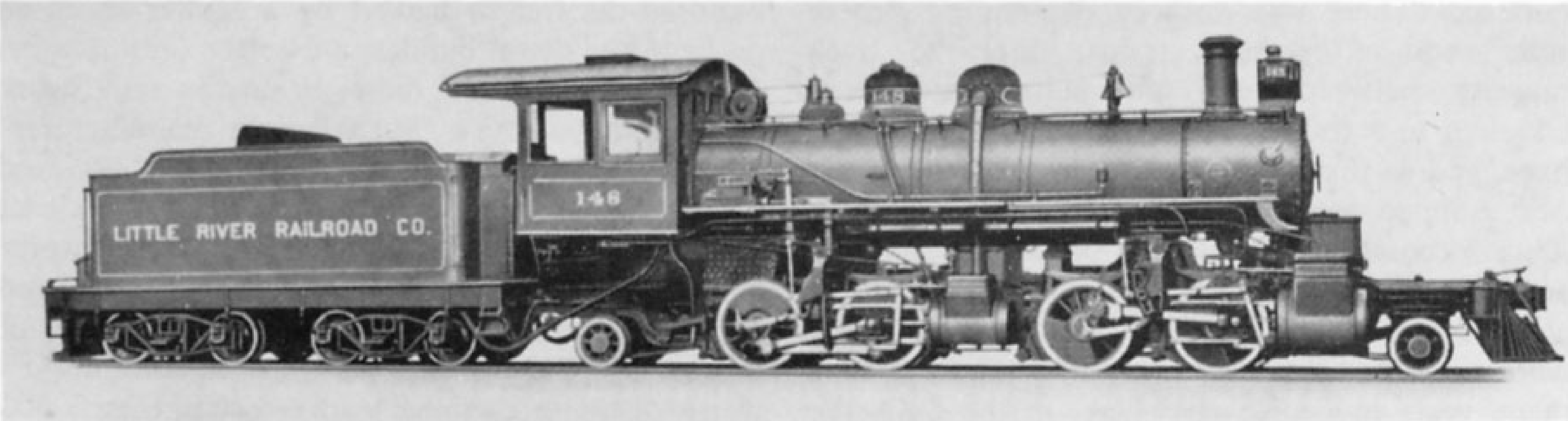
DEVELOPMENT OF THE AMERICAN MALLET BY TYPE

The 2–4–4–2

This type never attained any importance, and was built in both tank and tender forms, mostly the latter, from about 1910 to 1913. All were non-superheated compounds, some with high-pressure piston valves, and were used purely for logging service.

The 4–4–6–2

Only three engines of this unusual type ever ran; the first pair were experimental express passenger Mallets. Nos 1300–1, (later 1398–9) built by



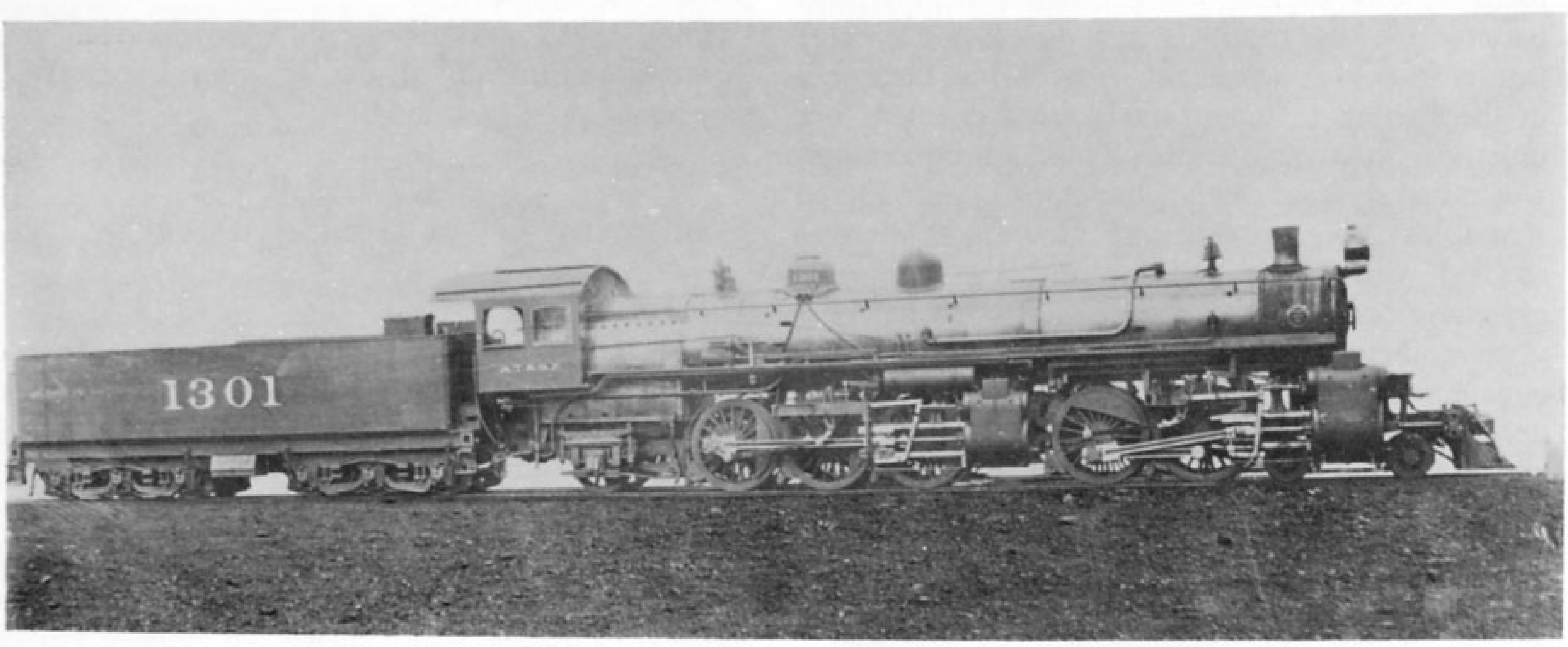
A far cry from the gigantic machines associated with the term 'American Mallet' is this Little River Railroad Co's small compound 2–4–4–2 by Baldwin

Baldwin for the Atchison, Topeka & Santa Fé Railroad in 1909. Their 6ft 1in diameter driving wheels were the largest ever applied to any form of articulated, and they featured the multi-stage boilers then often applied to American Mallets, together with the Jacobs–Schupert firebox, a construction made from U-shaped rolled sections riveted together with slotted diaphragm plates in place of the usual troublesome screwed staybolts. As a structure, the firebox worked well and successfully stood up to a degree of overheating and abuse sufficient to explode a normal stay-bolted firebox, but the diaphragm plates inhibited water circulation and steaming, and the Jacobs–Schupert firebox disappeared together with the multi-stage boiler. The two express Mallets were not considered a success and in 1915 their components were re-assembled into conventional 4–6–2 engines, in which form they lasted well.

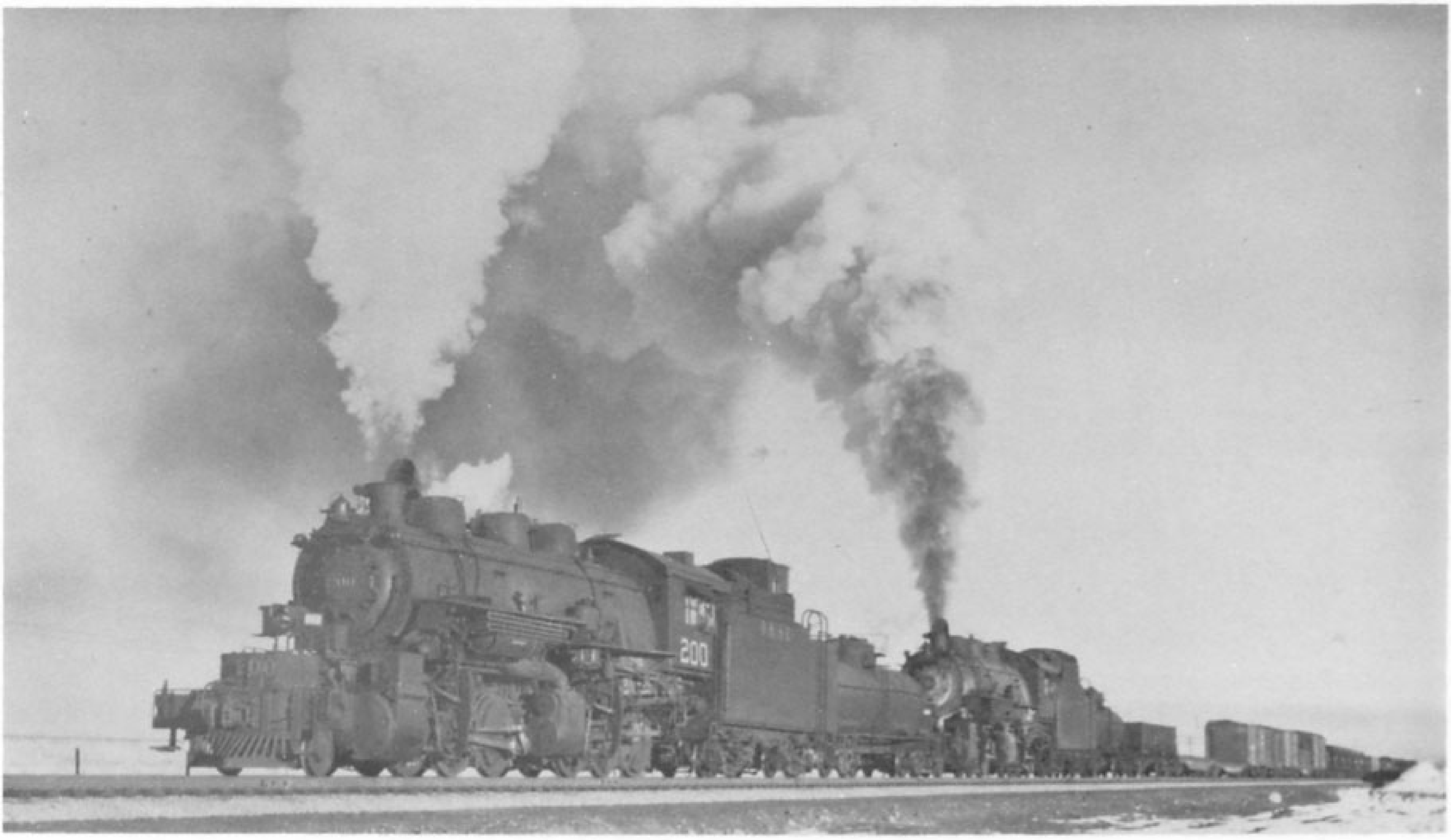
The third 4–4–6–2 was quite a different machine from the Santa Fé's compounds although it enjoyed no greater measure of success. In 1932 Baldwin delivered two experimental high-speed simple 2–6–6–2s to the Baltimore & Ohio, and in October of that same year No 7400 was converted to a 4–4–6–2 for mountain passenger work. She ran in that condition for just over a year, until January 1934, and was then reconverted to her original 2–6–6–2 form, evidently not having given full satisfaction as an express engine.

The 0–6–6–0

America's first Mallet was Baltimore & Ohio's 0–6–6–0 No 2400, delivered in 1904 by Alco for



The Atchison, Topeka & Santa Fé's early venture into express passenger Mallets —a compound 4–4–6–2 with 6ft 1in driving wheels. She functioned better as a Pacific, following amputation of the low-pressure unit



Two 2–6–6–0s on the Denver & Salt Lake Railroad, No 200 (rebuilt from 0–6–6–0) and No 216, storm up a 1 in 50 gradient near Leyden Junction, Colorado, in November 1947 hauling sixty-one bogie cars

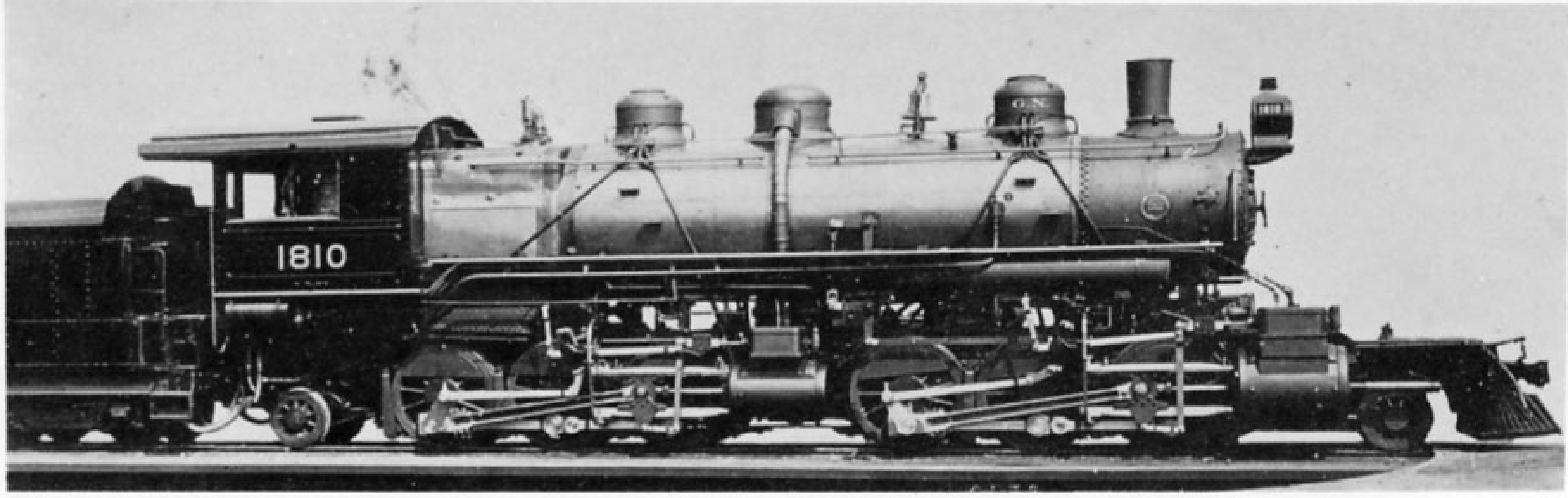
banking duties. Bruce mentions eighty of this type as having been built between then and 1913, but this is believed to include a number of export orders for various countries. All the American engines were compounds, mostly with piston valves on the high-pressure cylinders, some having superheaters. Banking, heavy shunting and hump work were their main spheres of operation, although the ten engines for the Denver & Salt Lake RR were for road service, and were soon converted to 2–6–6–0 to improve their tracking. A number of 0–6–6–0 Mallets were built also for the B & O, Denver & Salt Lake, Denver & N.W., Kansas City Southern, Lake Terminal, New York Central, and Virginian railroads.

The 2–6–6–0

Popular elsewhere, the 2–6–6–0 was rapidly superseded by the 2–6–6–2 type in the USA, where Bruce mentions twenty as being used. Twelve of these were Baldwin engines for the Virginian Railway, and the other traceable engines were for the Denver & Salt Lake, ten rebuilt from the foregoing 0–6–6–0 and six new to the modified design by Alco in 1913–16. All the D & SL engines were taken over by the D & RGW, who renumbered them 3360–75, by which time they had been superheated and fitted with 'Universal valve chests', converting the low-pressure cylinders from slide valves to minimum sized piston valves. Lasting until the early 1950s, they were America's last 2–6–6–0s. The Virginian engines were much larger, built with piston valves all round and, although originally saturated, were later fitted with superheaters. It will be noticed that this author cannot agree with Bruce's total for the type.

The 2–6–6–2

Easily the most numerous species of Mallet used in the United States, or for that matter in the world, Bruce gives the USA total as 1,295 compounds plus twenty simples, making a grand total of 1,315. Again, one suspects that export figures have been included here, as of the twenty simple 2–6–6–2s used in the USA, eighteen were rebuilds from compounds and would normally have been ignored by Bruce. It is difficult to dismiss such a large body of motive power in a few paragraphs, but fortunately many of the 2–6–6–2s were so similar that this may be attempted without too

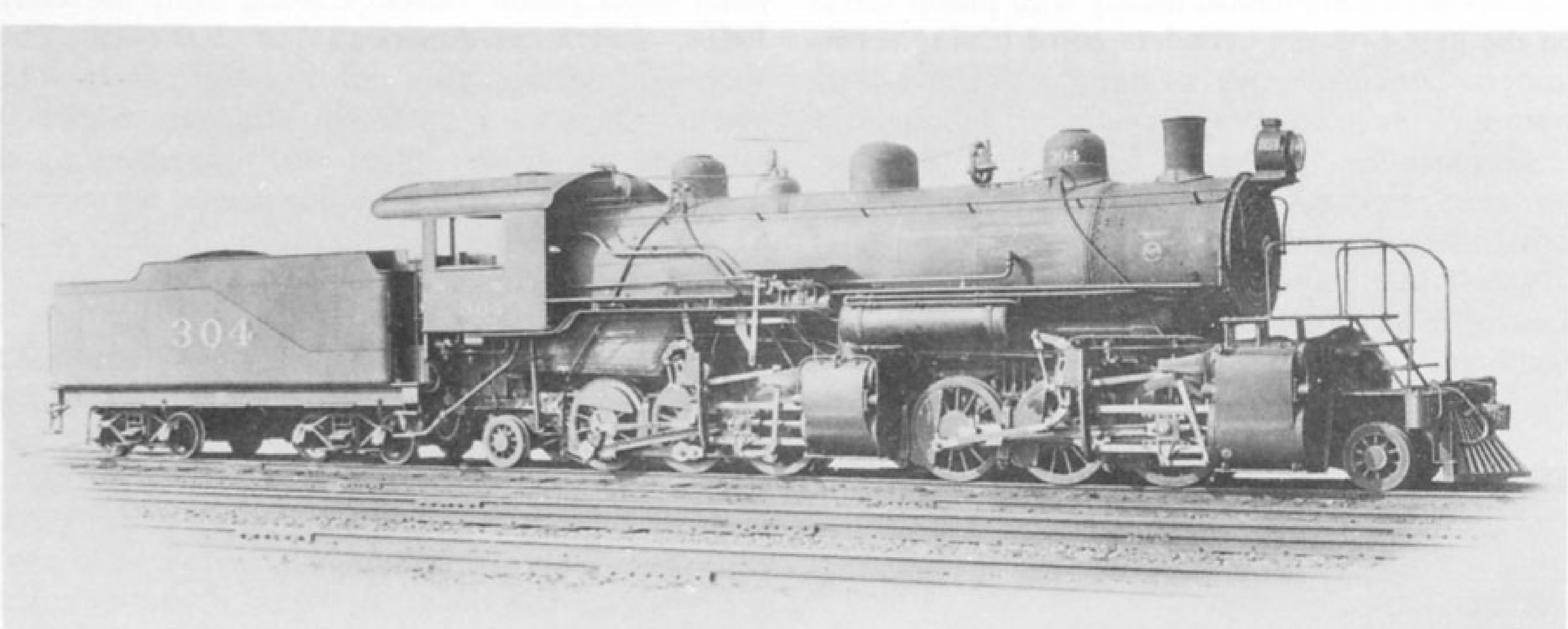


The Great Northern was the United States' pioneer of mainline Mallets, with two 2–6–6–2 types built by Baldwin in 1906. No 1810, above, was of the lighter batch

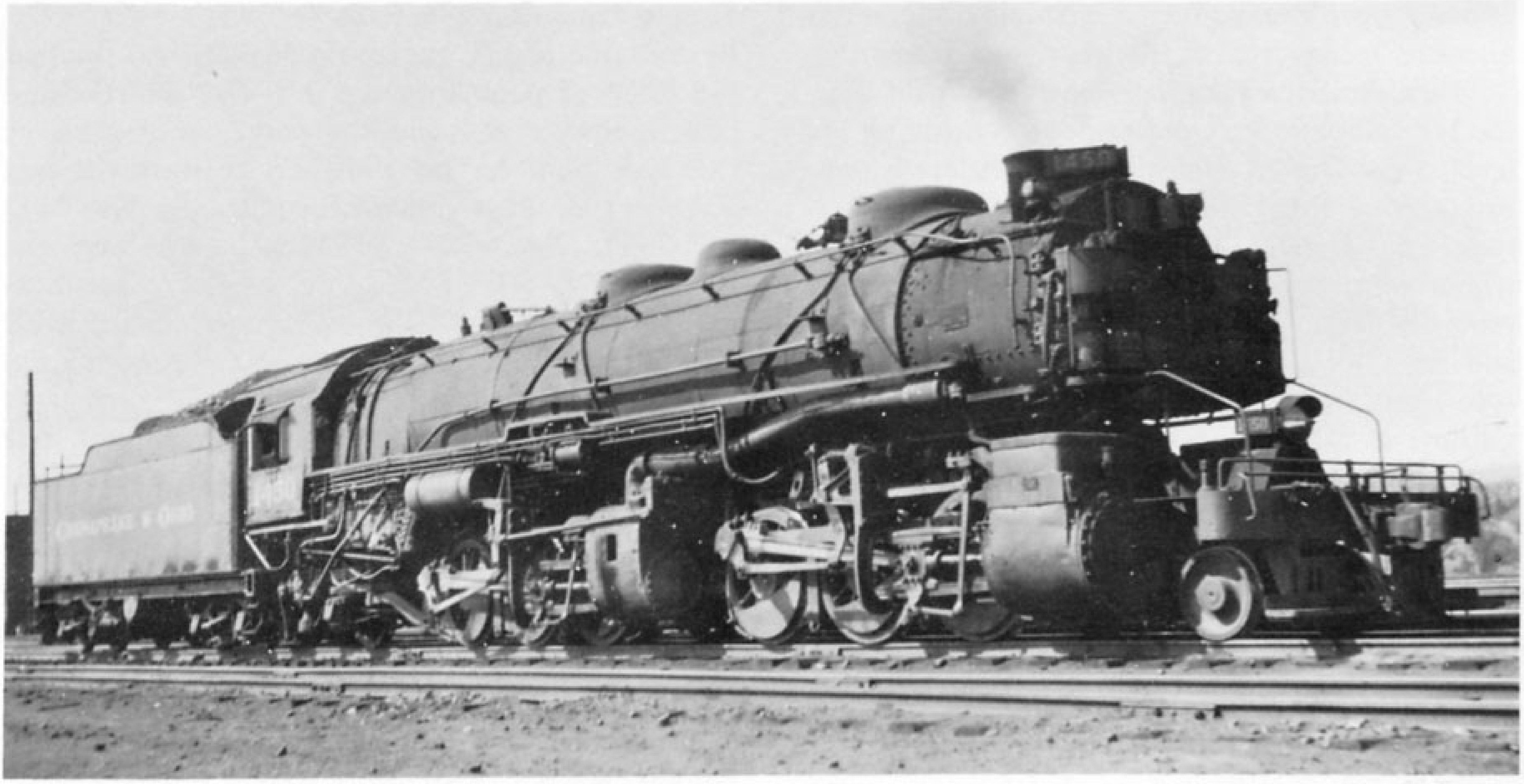
much loss, provided that the more notable engines receive fuller treatment. There were two broad categories into which all the 2–6–6–2s fell, those clearly developed from the earlier 0–6–6–0 and 2–6–6–0 types and having the firebox over the rear coupled wheels, with a trailing pony truck added almost as an afterthought, and those designed from the start as a 2–6–6–2 with a firebox over the trailing truck, giving better combustion and ash disposal conditions.

The first 2–6–6–2s built were for the Great Northern's Cascade division, through the Rockies, and were of the more primitive type with firebox over the drivers, unsuperheated and with slide valves on all four cylinders. Other railroads such as the Western Maryland, and Chicago Great Western followed suit with this basic type, which was later developed to include superheaters and high-pressure piston valves (for example, engines on the New York Central, Boston & Maine, Alton, and other lines), and finally piston valves were applied to all cylinders, as on the Wheeling and Lake Erie class 1–2, the Northern Pacific engines 3101–4, for branch work, and the rather similar lightweight engines for the Missouri, Oklahoma & Gulf Railroad.

The best conditions for achieving an adequate deep, wide firebox came with positioning it behind the driving wheels, as in a 'Pacific', a form of construction also enabling wheels of large diameter to



Another Baldwin 'light' (by American standards) Mallet for the Missouri Oklahoma & Gulf Railroad, with firebox over the driving wheels. This type of 2–6–6–2 was an obvious development of the 0–6–6–0 and 2–6–6–0 types with an 'afterthought' trailing truck to improve riding



A large, deep firebox behind the coupled wheels was needed to gain full advantage of the 2–6–6–2 arrangement. Chesapeake & Ohio's H4 No 1450, seen at Russell, Kentucky, in 1949, is characteristic of this type

be used without cramping the design. First to realise this potential was the Atchison Topeka & Santa Fé who, in 1909, had built by Baldwin some forty large 2–6–6–2s with the unprecedented wheel size of 5ft 9in, only four inches smaller than the contemporary 4–4–6–2 for the same road. These 2–6–6–2s were the first stage in developing a large Mallet to combine high speed with heavy haulage and they pointed the way for such later developments as the Challenger 4–6–6–4s, and Lima's 2–6–6–6. Rather before their time, peculiar details such as the multi-stage boiler and Jacobs-Schupert firebox were unfortunately included, and two of the engines were the guinea pigs for the brave but impracticable excursion into the realm of flexible boilers. The forty engines saw but short service as Mallets and were divided up into pairs of conventional power.

In 1911 the Southern Pacific, following the successful venture into cab-forward operation for freight service using 2–8–8–2s, took delivery of twelve Baldwin 2–6–6–2s with larger wheels for passenger service, but also featuring cabs in front. With a tendency to derail, they were soon converted to 4–6–6–2 and later to simple expansion, and will be referred to again later.

The main form of the 2–6–6–2 was that of a heavy, small-wheeled engine for mineral traffic, and in 1912–14 notable and very similar designs were supplied to the three Allegheny coal roads, the Norfolk & Western, Baltimore & Ohio, and the Chesapeake & Ohio, all for coal haulage. The earlier examples had slide valves on the low-pressure cylinders but later developments progressed to piston valves all round. The C&O became the biggest user of this type, with 150 of the earlier and sixty-five of the later versions built between 1912 and 1921, plus ten more surprisingly built at the end of steam, in 1949!

Whilst on the subject of compound 2–6–6–2s, it is convenient to mention here the efforts made to convert conventional engines into Mallets. In the days when the long, thin, multi-stage boiler was being tried out, a number of lines tried to 'get-something-for-nothing' by backing a low-pressure unit onto the front of the old loco, plus the superheater/reheater/feed water heater stages added to the front of the existing boiler. At least two railroads rebuilt 2–6–2s into 2–6–6–2s in this manner. The AT&SF used the chassis of engines 1051 and 1125 to produce Mallet No 1157, whilst the Chicago Great Western added entirely new front ends to produce Mallets 650–2. In both cases the resulting Mallet conversions had large wheels and the unusual feature (for a Mallet) of inside Stephenson valve gear. In both cases, also, the engines were not adjudged a roaring success and all were reconverted to their original forms.

When America eventually entered World War I, the US railroads were put under a controlling body termed the United States Railroad Administration, and one of the USRA's tasks was to produce a range of standard locomotive designs, included in which were two Mallets. All the USRA designs were particularly efficient and handsome engines and the 2–6–6–2 Mallet, based on the 'Allegheny type', was no exception. They were supplied to a number of railroads, none of which regretted their acquisition.

Summing up, the compound 2–6–6–2 Mallet, in its various forms, was used by the following American railroads:—

Atchison Topeka & Santa Fé
Boston & Albany
Buffalo, Rochester & Pittsburg
Baltimore & Ohio
Chicago & Alton
Chicago, Burlington & Quincy
Carolina, Clinchfield & Ohio
Chicago Great Western
Chesapeake & Ohio
Chicago, Milwaukee, St Paul & Pacific
Central of Georgia
Denver & Rio Grande Western
Great Northern
Maine Central
Missouri, Oklahoma & Gulf
Northern Pacific
Norfolk & Western
New York Central
Southern Pacific
Wheeling & Lake Erie
Western Maryland
Western Pacific

Simple expansion 2–6–6–2s

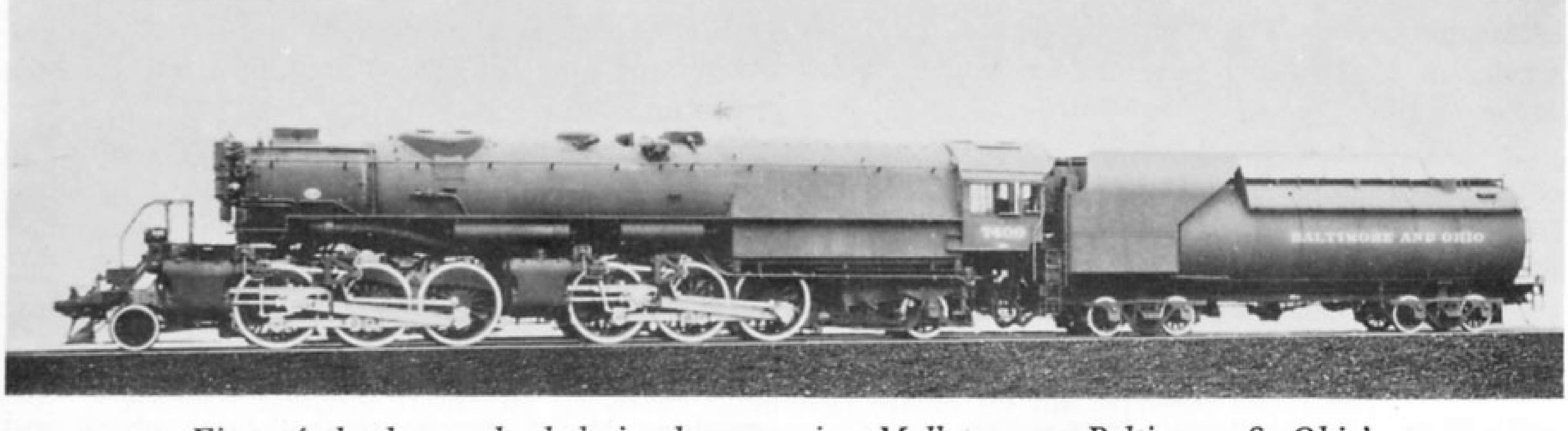
By the time simple expansion Mallets had reached the stage of popularity the 2–6–6–2 had become largely obsolescent, and the only new engines of this type built for mainline service were the two Baltimore & Ohio experimental engines Nos 7400 and 7450, classes KK1 and KK2. These were the heaviest 2–6–6–2s ever built and were identical except that 7400 sported an Emerson boiler with water tube firebox—a transatlantic version of the Brotan boiler—while 7450 retained the usual stay-bolted firebox. Each seemed to perform well but their appearance in 1932, during the depression, prevented any multiplication and the B&O only bought one further large batch of steam power before the end of World War II and subsequent dieselisation. The KK1, as previously recorded, ran for a short period as a 4–4–6–2.

The C&O, following the success of its simple expansion 2–8–8–2, rebuilt one of the older compounds, H4 No 1470, into a simple 2–6–6–2, class H4a, in 1927. She had a double chimney, but with the faster mainline freights being handled by the larger power there was no case for rebuilding the older compound 2–6–6–2, used on the mine runs, and the H4a was retired in the 1940s.

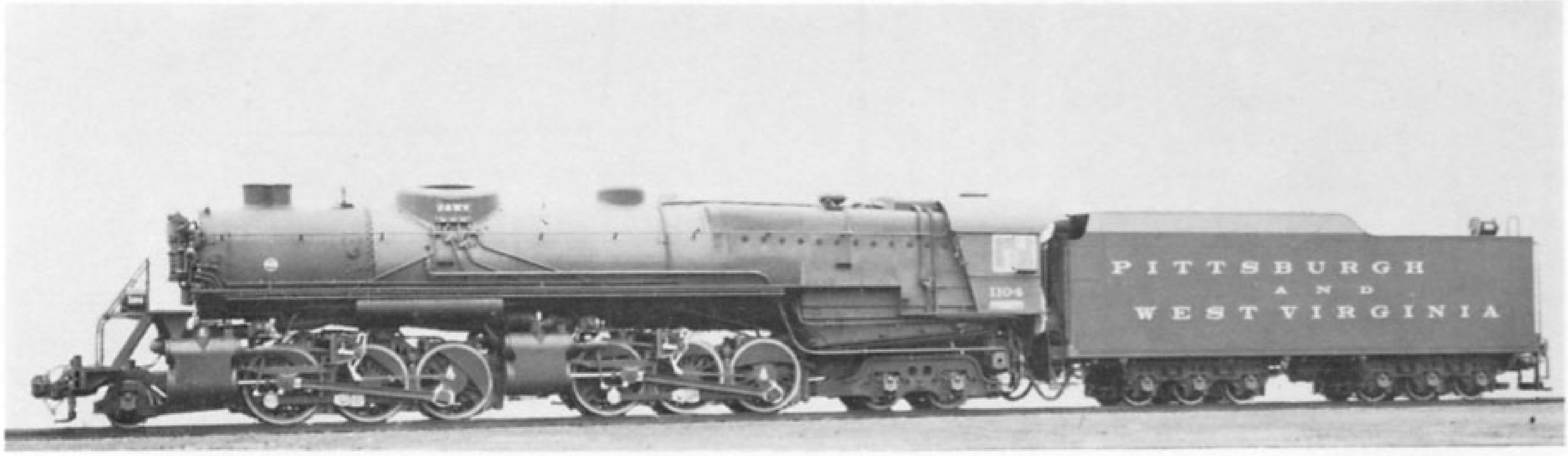
The biggest pocket of simple 2–6–6–2s was to be found on the Chicago, Burlington & Quincy, where eighteen compound engines were given a new lease of life by rebuilding as simples, class N-3, enabling them to cover a useful range of work on secondary routes.

Logging 2–6–6–2

The 2–6–6–2 Mallet proved a very popular type on logging roads as it combined adequate power with sufficient flexibility for the tracks used. There were probably over a dozen built, all in ones or twos and



First of the large-wheeled simple expansion Mallets were Baltimore & Ohio's experimental KK classes of 1932. KK1, No 7400, above, features an Emerson water tube firebox



The little known Pittsburg & West Virginia Railroad originated this simple expansion class of the 2–6–6–4 type with double-chimneys and Belpaire boiler

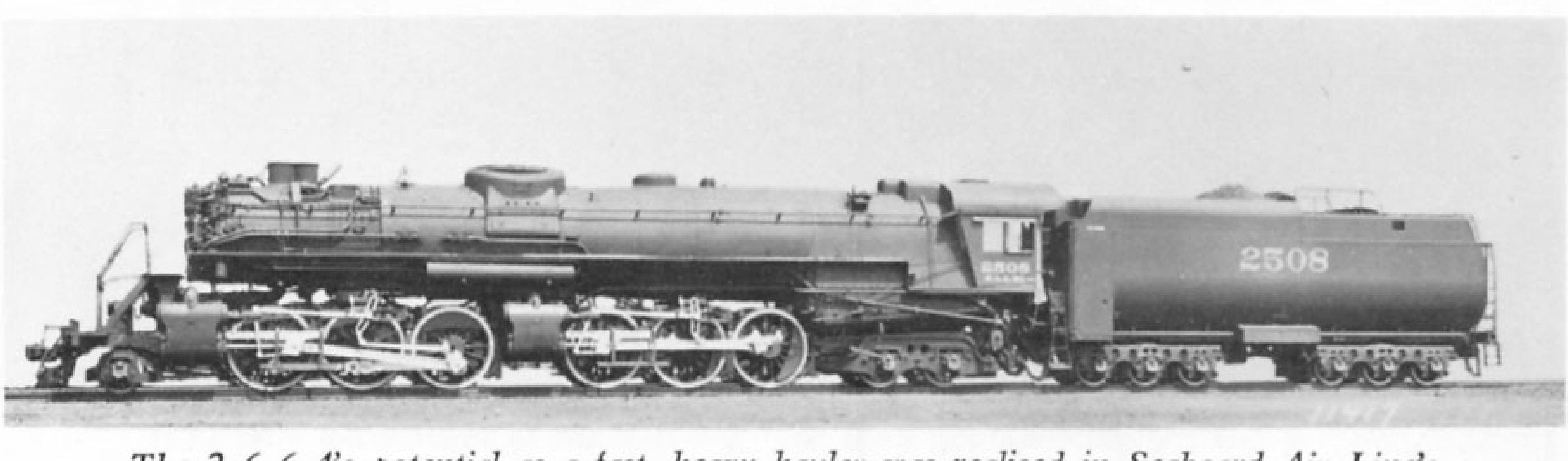
all different in one way or another. Some had tenders, others were tanks of either the saddle or side variety, and while most were compounds, there were simple engines too. Probably the most unlikely form of saddle tank engine (usually associated with small, four- or six-wheeled engines) would be a superheated, simple expansion 2–6–6–2 Mallet with double chimney, but the Weyerhauser Timber Co's No 111 was such a collector's item.

The 2–6–6–4

This was a comparatively unusual type of Mallet, although familiar to most people due to the fame of Norfolk & Western's 'A' class, the most numerous built. All were simple expansion engines and Bruce gives a total of sixty-three built, although the total would seem to be sixty-five. First to appear were the seven engines by Baldwin for the Pittsburg & West Virginia, a little known railroad even with such attractive machines as these Belpaire-boilered, double-chimneyed engines on its freight roster. The first batch of three engines, Nos 1101–3, incorporated a booster operating all six wheels of the rear tender bogie, but in the second batch, Nos 1104–7, this was suppressed, presumably as being more trouble than it was worth.

The second batch of 2–6–6–4s, again Baldwin built, were for the Seaboard Air Line which, despite its name, *was* a railroad. Class R1, Nos 2500–4, these were lighter engines with larger wheels and were built in 1935 with fast freight of the parcels or perishables type in mind. Five more almost identical engines, class R2, Nos 2505–9 with Walschaerts instead of Baker gear, followed in 1937, and after being displaced by diesels about 1950 the Baltimore & Ohio, with a good nose for a bargain, bought these useful and scarcely worn engines and put them to work as classes KB1 and KB1a, engines 7700–9. With a light axle load, a good turn of speed, and 6,000hp at their command, they equalled three or four diesels and deserved to last far longer than they were allowed to.

The *Locomotive Cyclopedia* of 1947 records an order of five 2–6–6–4s for the Minneapolis & St



The 2–6–6–4's potential as a fast, heavy hauler was realised in Seaboard Air Line's Baldwins, introduced in 1935. No 2508 here is from a 1937 batch with Walschaerts gear, and all ten engines were later bought by the Baltimore & Ohio

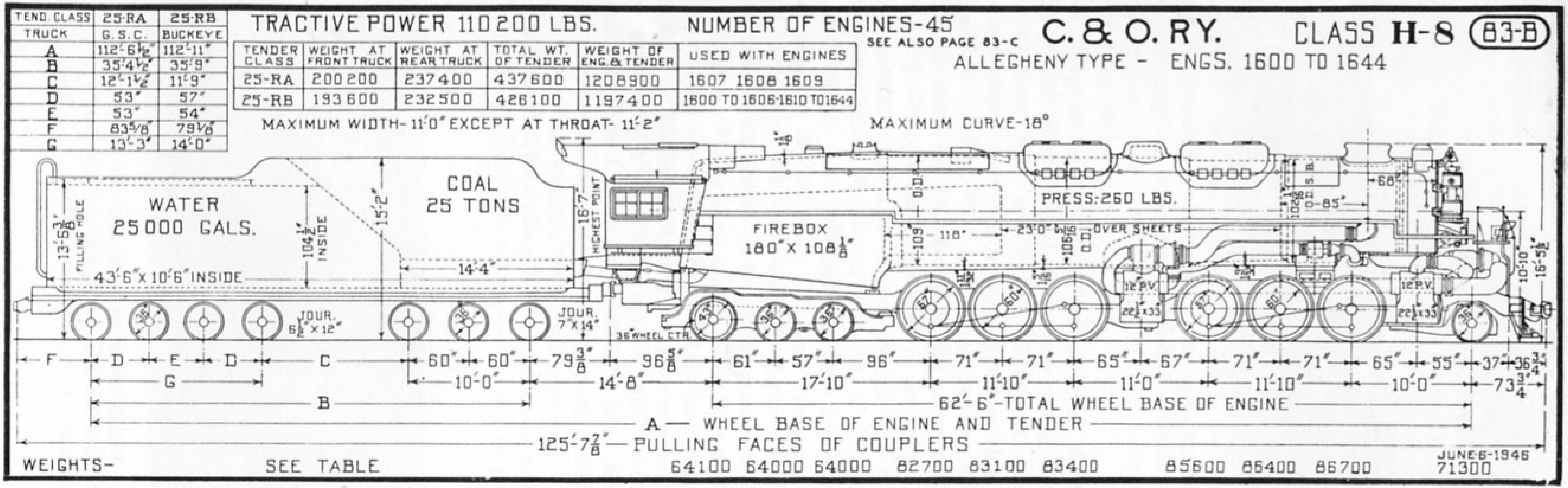


Fig 19 *Chesapeake & Ohio class H8 2–6–6–6, the heaviest six-coupled Mallets built*

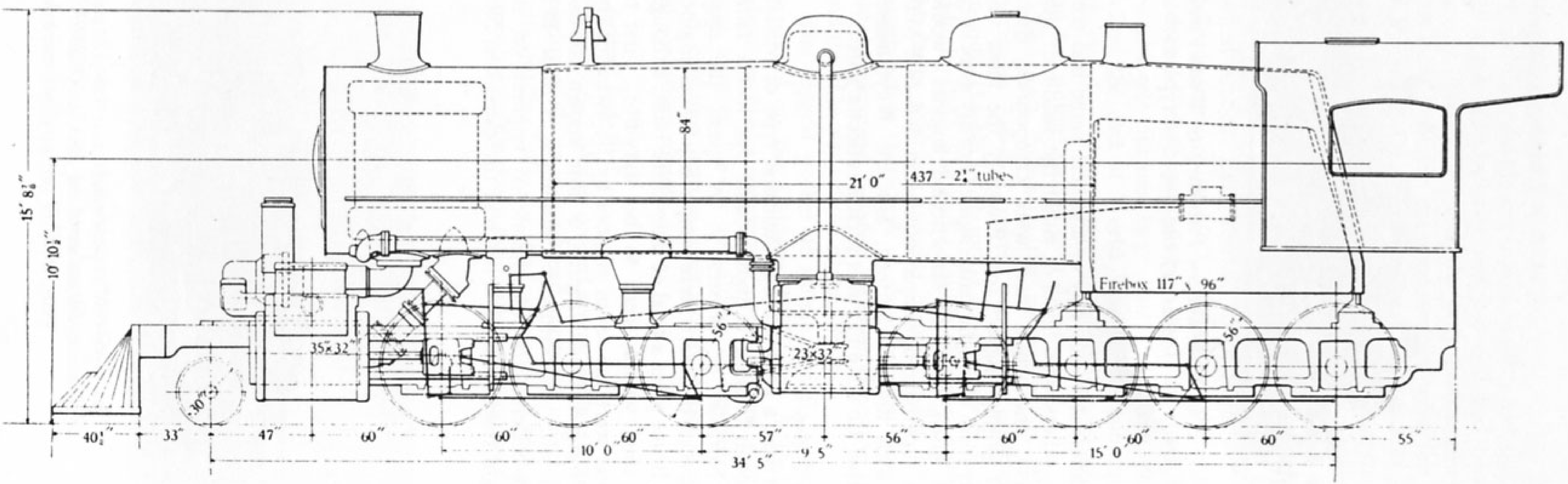
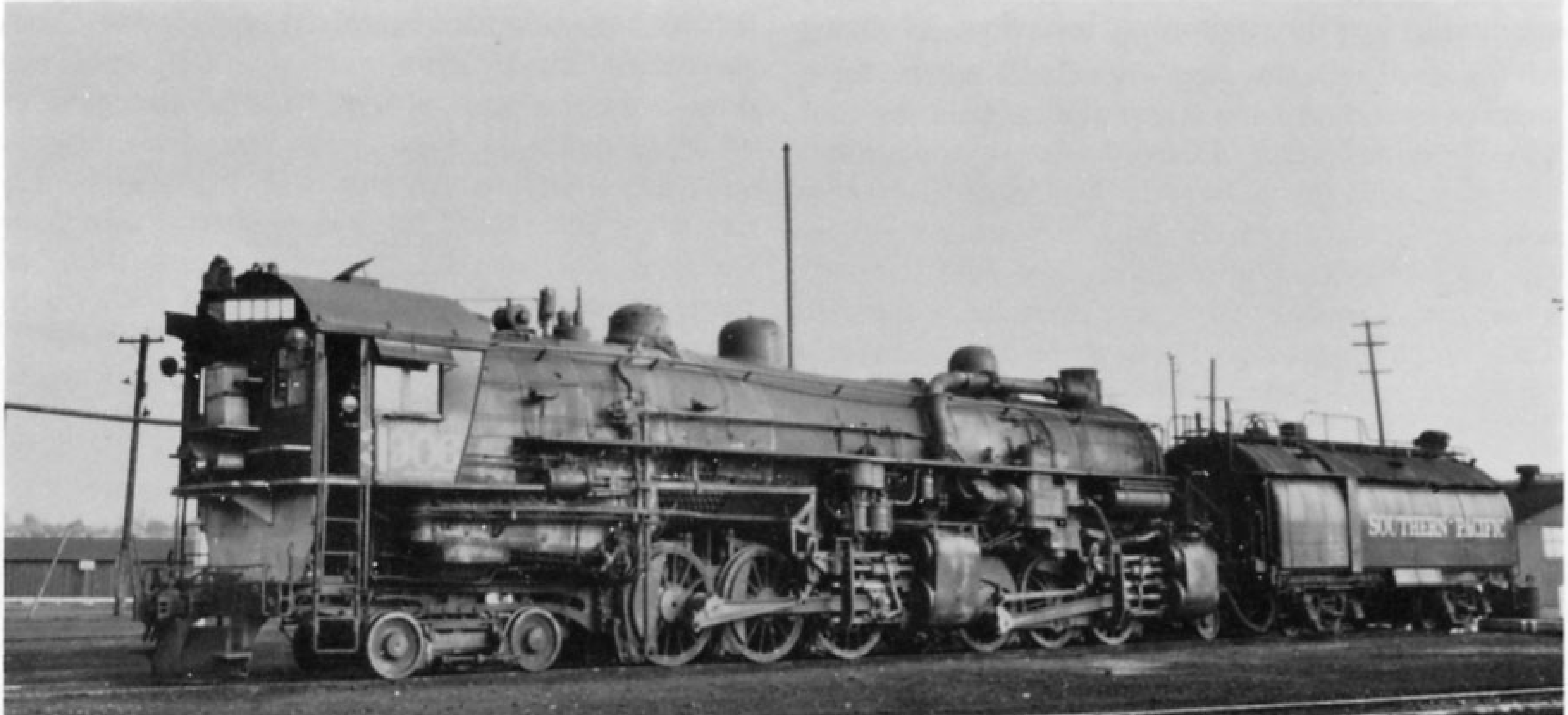
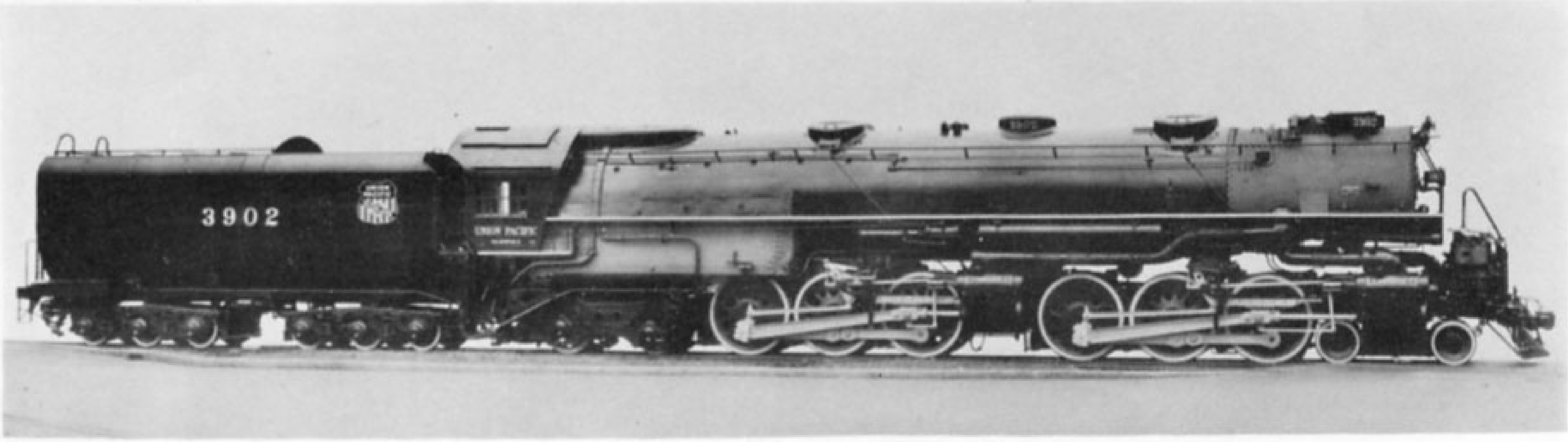


Fig 20 *Diagram of Southern Railway 2–6–8–0 compound Mallet, Baldwin built, with smokebox reheater*

Final development of the six-coupled Mallet was Lima's 2–6–6–6 for the Chesapeake & Ohio, only marginally lighter than Union Pacific's 'Big Boys'. No 1633 of class 'H' stands in the yard at Fulton, Virginia, in September 1940



The only locomotives of the 4–6–6–2 type were Southern Pacific's cab-forward passenger engines built as 2–6–6–2 compounds, rebuilt with four-wheel leading bogies and finally converted to simple expansion. No 3906 is seen above in final condition at Portland, Oregon, in November 1947



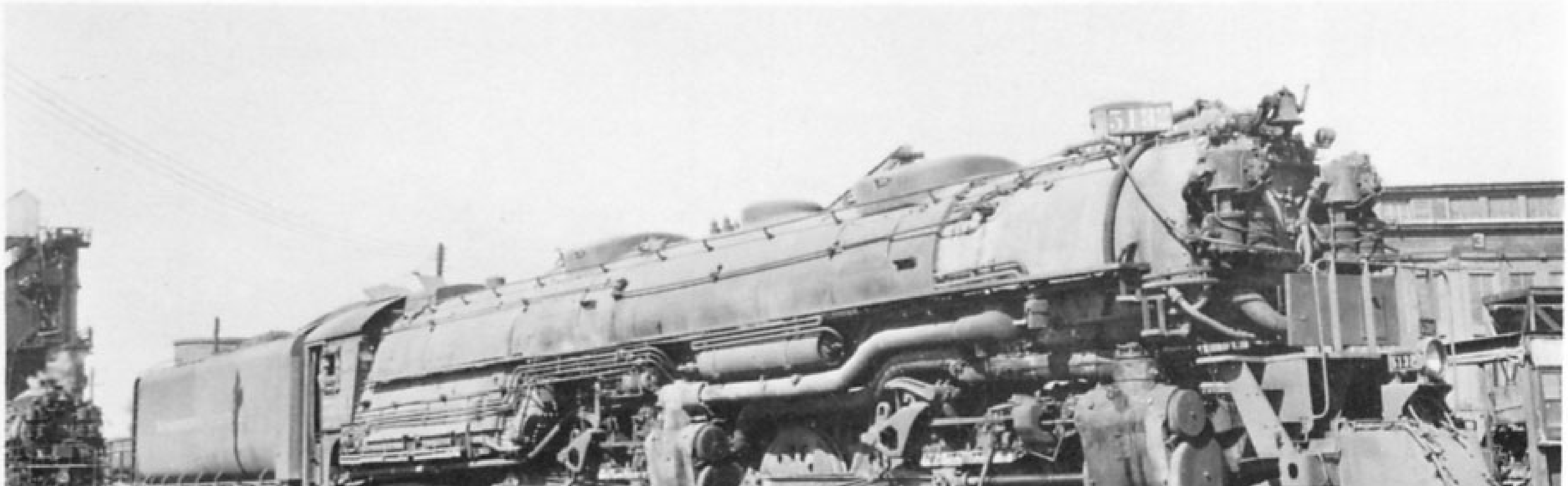
The splendid 4–6–6–4 Challenger type was pioneered by Union Pacific and Alco in 1936. Capable of 80mph in passenger service, yet equally at home on heavy freight, the 4–6–6–4 was a tremendous concept. UP *No 3902, above, was one of the first series*

Louis RR, but the author has never been able to trace any further information on these.

The engines which really put the 2–6–6–4 type on the map were Norfolk & Western's 'A' class, built in the company's Roanoke shops between 1936 and 1950. They were the largest, heaviest, most powerful and most numerous of the 2–6–6–4s, with enough tractive effort to start a 7,500-ton coal train and enough horsepower to bowl it along at over 60 mph. In fact, at 45 mph, some 6,300hp has been recorded at the *drawbar,* which would make one 'A' class the equal of at least *four* 2,000hp diesels! The story of their summary execution, for the traitorous behaviour of being more efficient than diesels, will be told in the next section of this chapter. Altogether forty-three were built, all with Baker valve gear, the later examples having roller bearings throughout, including crankpins, while all other features of advanced steam technology, such as cast steel bed frames were, of course, included.

The 2–6–6–6

There was really only one class of 2–6–6–6, but this was built with minute variations for two adjacent railroads. They were a straight development of the 2–6–6–4 type, with a larger boiler and firebox to provide increased horsepower and,



Northern Pacific followed close behind UP *with the 4–6–6–4, using giant grates to burn 'Rosebud' lignite. Above, No 5132 from the second series simmers at Missoula, Montana, in September 1952* rather than accept the cramped conditions of a large firebox placed over the trailing coupled wheels, a six-wheeled truck was provided to support a deep, wide and long firebox. Apart from a few odd experimental engines, these were the only locomotives to use a six-wheeled truck. Something of their performance will be covered in the second section of this chapter but, so far as mechanical matters go, the 2–6–6–6, (of which sixty were built for the Chesapeake & Ohio in 1941–8, class H8, engines 1600–59) was an outstandingly proportioned machine containing no strange, untried features—sound and solid mechanical engineering from one end to the other. The neighbouring Virginian Railway bought eight, Nos 900–7, from the same builders, Lima, in 1945. Their boiler size and tractive effort will bear comparison with many an eight-coupled Mallet design, and this was made possible by the immense axle loads permitted, amounting to nearly 39 long tons on the front axle of C&O's first batch and averaging about 38 long tons for the whole set of driving axles! By comparison, Union Pacific's 'Big Boys' were a branch-line engine, with a little over 30 tons per axle! The total of 2–6–6–6s was, of course, sixty-eight.

The 4–6–6–2

This type comprised twelve engines only, operated by the Southern Pacific Railroad and rebuilt from the 2–6–6–2 type. Originally numbered 4200–11, and later 3900–11, they were of the backwards running, cab-forward type so long associated with that railroad, and were built as compounds by Baldwin in 1911. Due to a tendency to derail, they were rebuilt with four-wheel bogies under the cab end after a short period in the passenger work for which they had been built, and then when about twenty years old were given a new lease of life by rebuilding into simple expansion engines. Mechanically, they were a backwards-running 2–6–6–4, but since they were designed to run that way they may correctly be classified as a 4–6–6–2. As rebuilds, they were ignored by Bruce.

The 4–6–6–4

This type, known as the 'Challenger', was one of the most magnificent conceptions evolved during America's steam age. Adding a four-wheel leading bogie to the 2–6–6–4 chassis, providing adequate sized driving wheels and a specially designed joint, and limiting movement of the front unit to controlled, laterally radial directions, produced a Mallet steady enough to run at 80mph with no ill effects to itself or the track, and at once railroad managements had a new and highly versatile tool capable of hauling heavy freight at near-express speeds. To the Union Pacific goes the credit for inspiring the Challenger's creation, for in the mid-1930s traffic conditions were such as to require further engines comparable in output to the 9000 class, three-cylinder 4–12–2s having 67in driving wheels for fast freight. Although the 4–12–2s were multiplied up to a total of eighty-eight engines and lasted thirty years, the road's superintendent of motive power, Otto Jabelmann, thought that something better could be evolved and, in conjuction with the American Locomotive Co, developed the high-speed simple expansion Mallet which was to bear the name of one of Union Pacific's trans-mountain expresses. The first fifteen Challengers came out in 1936 and won immediate acclaim. No other railroad had followed UP's lead into three-cylinder 4–12–2s, but a further eight lines were to buy Challengers, which, with UP's lion's share of 105 engines, were to total 254 locomotives. All the 4–6–6–4s were of much the same size and power. Driving wheels varied only from 67in to 70in and, apart from the Northern Pacific batch with oversize grates to burn their local Rosebud, semi-lignite coal, boilers were much of a muchness. A standard 4–6–6–4 for the whole of the USA could easily have been evolved, and its difference in performance from the various custom-built engines would have been imperceptible. The only weak point in the Challenger type was the firebox—the four-wheeled trailing truck was insufficient to carry the firebox required, which thus was positioned with its leading end across the top of the driving wheels, resulting in a loss of depth and combustion volume. This con was greatly outweighed by the machine's assorted pros; the 4–6–6–4 became a standard for fast, heavy freight, and on at least three roads was regularly scheduled for mountain express passenger duties. Details of the Challengers built are given in the accompanying table.

This totals some 254 locomotives, rather more than the 215 quoted by Bruce, and makes the type even more popular than that authority, from its principal builder's works, was prepared to admit. All were simple expansion engines.

The 2–6–8–0

This assymetrical type was not common, as may be expected, and probably amounted to less than forty examples, none of which are included in Bruce's list. All appeared about 1910 and the most numerous were the thirty Belpaire-boilered

Union Pacific	3800–39	Built Alco	1936–37	40 locos	(ex-3900–39)
,, ,,	3950–69	,, ,,	1942	20 ,,	
,, ,,	3975–99	,, ,,	1943	25 ,,	
,, ,,	3930–49	,, ,,	1944	20 ,,	
Northern Pacific	5100–26	,, ,,	1936–41	27 ,,	
,, ,,	5130–49	,, ,,	1943–44	20 ,,	
Clinchfield	650–57	,, ,,	1943	8 ,,	(to D & H design)
,,	660–63	,, ,,	1947	4 ,,	
DRGW	3700–14	,, BLW	1938–41	15 ,,	
,,	3800–05	,, Alco	1943	6 ,,	(to UP design)
D & H	1500–39	,, Alco	1942–46	40 ,,	
W Maryland	1201–12	,, BLW	1940–41	12 ,,	
SP & Seattle	900–10	,, Alco	1944	10 ,,	(to NP design)
Gt Northern	4000–01	,, ,,		— ,,	(ex-SP & S)
W Pacific	401–07	,, ,,	1938	7 ,,	
Clinchfield	671–6	,, ,,	1943	6 ,,	(ex-DRGW 3800–05)

engines, Nos 1930–59, built by Baldwin for the Great Northern. Piston valve compounds, they were later rebuilt as simple expansion engines and survived in that form until after World War II. The original compound design had a low-pressure reheater in the smokebox and slide valves on the low-pressure cylinders, while the second version included a multi-stage superheated boiler with piston valves all round as first described.

Other 2–6–8–0 engines were mostly odd engines, some being rebuilt from conventional 2–8–0s. For example, Erie No 2900 comprised the bulk of 2–8–0 No 1830, a Stephenson geared engine as its high-pressure unit, with a new 2–6–0 low-pressure unit attached ahead of this. All cylinders had piston valves. Like most of these makeshift Mallets, she was no great success and was later converted to an 0–8–0 switcher. Baltimore & Ohio's No 2421 was a similar conversion, but with Walschearts gear and slide valves all round, reconverted in 1918, whilst the Southern Railways and the Alabama Great Southern each had one of the type, by Baldwin, similar to the Great Northern engines. There may have been one or two more which have so far escaped this author's attention, but they certainly had no great influence on future Mallets.

The 0–8–8–0

A straight development of the 0–6–6–0 for heavy shunting and banking, but with more power and weight, Bruce states that 150 of this type were built between 1907 and 1920, this figure probably including the engines exported to Brazil. First of this type were three engines built in 1907 for the Erie Railroad, saturated compounds sporting 'camelback' central cabs and the only Mallets so fitted. They were eventually fitted with superheaters, mechanical stokers, conventional cabs and pony trucks at either end, in which form they became rather undistinguished 2–8–8–2s.

The Baltimore & Ohio had a batch of twenty-seven engines, Nos 8021–47, built by Alco in 1910–12, and these supplanted the original 0–6–6–0 design on banking duties over the Alleghenies and survived until World War II. The Delaware & Hudson had a batch of fourteen similar engines from the same builder at the same time and these, Nos 1600–13, were the subject, just before World War II, of 'de-Americanisation', in other words cleaning up the engine's outline by concealing all piping etc, as inspired by the visits of the British 4–6–0 *King George V* (GWR) and *The Royal Scot* (LMSR) to the United States.

The only other 0–8–8–0 of any note was the only Belpaire-boilered engine of this type built, predictably, for the Pennsylvania, class CCIs, engine No 3397. This had piston valves on all cylinders whereas most other 0–8–8–0s, including the same railroad's later CC2s and other engines for the Norfolk & Western, New York Central, Lake Shore & Michigan Southern (a NYC subsidiary), Birmingham & Garfield, and the Boston & Maine

The 2–8–8–0

This type is the logical development of the 0–8–8–0, with a leading pony truck to make it more suitable for road work. Bruce gives a total of 200 compounds and a solitary simple of this type, but this is clearly a substantial underestimate, ignoring rebuilds from compound to simple. The first of the type appear to be the B&O class EL–1, Baldwin built in 1916, and by 1919 this line had eighty-six of the type in heavy freight (mainly coal) service, especially over the Alleghenies. All were superheated compounds, the earlier classes with slide, and the later with piston valves on the high-pressure cylinders. Details of building are:

Classes	*Engines*			
EL–1	7100–14	Baldwin	1916	
EL–2	7200–14	Alco	1916	
EL–3	7115–44	Baldwin	1917	
EL–5	7145–70	Baldwin	1919	
EL–6	7300–15	Alco	1917–18	Rebuilt ex 2–8–8–2
EL–4	7020–49	(9 locos)		Rebuilt ex 0–8–8–0

Mallets for heavy switching, particularly hump work, were a feature of the Eastern American scene. Pennsylvania CC–2S No 8183, a compound 0–8–8–0, is seen above at Columbus, Ohio, in April 1938

Favourite articulated type on the Baltimore & Ohio was the 2–8–8–0. EL–5A was a simple expansion rebuild, with double chimney, from a Baldwin compound

The EL–6 class had larger driving wheels than the others and were ex-SAL. In the 1930s, the railroad started rebuilding them as simple expansion engines, using new leading cylinders of the same size but of slightly different design to the existing high-pressure cylinders. Double chimneys were fitted to ensure free exhaust and the engines were reclassified EL–1a, EL–2a, etc.

The other large user of 2–8–8–0s was the Union Pacific which had fifty-five engines, Nos 3600–54, these being superheated compounds with piston valves, very similar to the B&O engines. Like their eastern sisters, they were converted to simple expansion and renumbered into the 3500 series, and free exhaust was ensured by the application of the UP's large-diameter single chimney and multiple-jet blastpipe. Some of the UP subsidiaries such as the Utah RR also had similar engines.

Twenty-five notable 2–8–8–0s were built for the Great Northern Railway in 1913 by Baldwin and these were superheated compounds with piston valves all round, fed with steam from large Belpaire boilers. They were eventually converted to simple expansion and a further twenty-five simple 2–8–8–0s with larger boilers were built in the company's own workshops in 1940–1. The original compounds were classed N–1, the rebuilds N–2, and the new engines N–3.

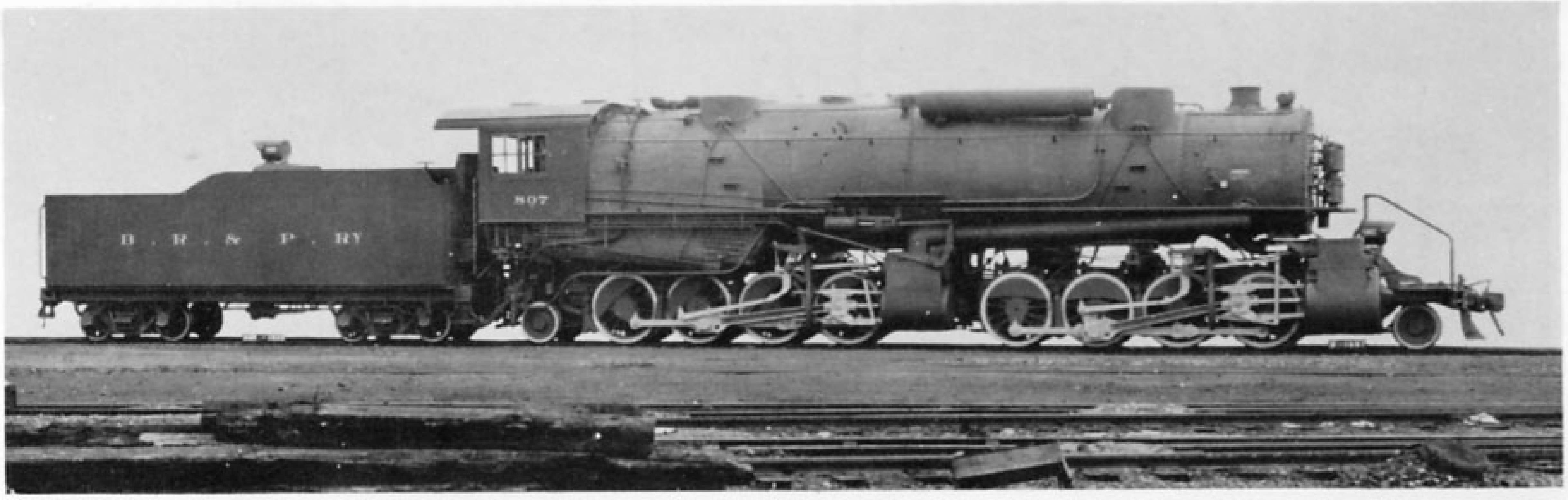
The Pennsylvania RR built itself a vast expansion 2–8–8–0 at Altoona works in 1919, with Belpaire boiler featuring an extra long combustion chamber and oversize cylinders having restricted maximum cut-off. Apparently she was too powerful for hauling trains, having a tendency to snap drawbars like rotten carrots, and consequently spent most of her short life banking from Altoona up to Gallitzin via the famous Horseshoe Curve.

There were a few other odd 2–8–8–0s, including a 1924 Alco batch for the Kansas City Southern and an odd engine on the Virginian Railway, No 610, which was the front two-thirds of the former Triplex engine fitted with new cylinders (slide valve low-pressure, evidently similar to the 800 class 2–10–10–2), and a normal tender.

The 2–8–8–2

Here we come to the most popular eight-coupled Mallet type in the United States, and indeed of all Mallets, second only to the 2–6–6–2. Bruce gives the type as totalling 624 compounds and 86 simples, totalling 710 as built, although many of the compounds were later simpled. Bruce's figure ignores the company-built Great Northern engines, and probably others. The type represents a development of the 2–8–8–0 species, with a trailing truck to improve riding, especially when proceeding tender first as often happened when these engines were returning downhill after banking duties. Although mechanically a 'development' of the 2–8–8–0, the 2–8–8–2 actually preceded the more primitive type and the first were a pair of remarkable engines built for the AT & SF in 1909, a period when sectional boilers with multitubular superheaters and reheaters were all the rage. These details were included in Nos 1700–1 and probably played a big part in ensuring the engines' non-repetition. Considering that they appeared only five years after the United States' first Mallet, these Santa Fé engines showed that tremendous strides had been made in the Mallet concept, although the Santa Fé line was the most forceful system at that time in pressing the Mallet's case. Whilst the rest of the USA thought of the Mallet as a low-speed freight and banking engine, with wheels about 4ft 9in diameter, the ATSF had, as we have already seen, applied the principle to a 4–4–6–2 express engine with 6ft 1in drivers, a 2–6–6–2 mixed traffic with 5ft 9in drivers, and the third of their 1909 trio of designs was the 5ft 3in wheel 2–8–8–2, already pointing the way to the 'Big Boy' in combining great pulling power with adequate speed potential. Nos 1700–1 were no more successful than their smaller sisters and it is ironic that the Santa Fé, after initiating the really great line of Mallet development, should have become so fed up with the quite unnecessary and troublesome details of multi-stage and flexible boilers, and Jacobs–Schupert fireboxes, that it could never again be persuaded to give the beast a second chance, despite the prevalence of exceptionally severe gradients. Instead, it eventually limited tractive effort to that attainable with maximum sized 2–10–4s—engines which, with 6ft 2in driving wheels, almost 100,000lb of tractive effort, and a suitably beefy boiler, were more than a match for some of the 4–6–6–4 simple Mallets.

The second 2–8–8–2 type to appear was Baldwin-built, also in 1909, for the Associated Harriman lines and comprised eight compounds, three each for the Union Pacific and Oregon Railroad & Navigation systems, plus a pair for the Southern Pacific. Neither of the first two lines thought much of their examples, which suffered undistinguished lives and premature retirement, but the SP found in theirs just the engine they needed for their mountain division eastbound up the Sierras out of Roseville, California. Just the engine, that is, for the haulage specified, but a severe problem in



A massive compound 2–8–8–2, Alco-built for the Buffalo, Rochester & Pittsburg Railroad in 1923. Superheated but with slide valves on the 44in low-pressure cylinders

terms of smoke, fumes and heat while running through the tunnels and snow sheds in which the line abounded. How these and subsequent Mallets came to be operated cab forwards, with tender behind the smokebox, is a story to be dealt with in this chapter's next section, but repeat orders delivered from 1910 to 1913, until the class numbered forty-nine engines, showed that the SP at least, received satisfaction from Baldwin's design.

Other railroads soon caught on to the 2–8–8–2's potential. The Virginian and the Duluth, Missabe & Northern each took delivery of some in 1910, and the Chicago, Burlington & Quincy in 1911, after which the type became too widespread and popular to need much detailed treatment other than a list of users. Perhaps it should be mentioned now that the compound 2–8–8–2 was the last compound steam engine of any form built in that country and, apart from the two Russian experimental 2–8–8–4s, the last mainline Mallets built anywhere in the world. The engines concerned were, of course, Norfolk & Western's Y6b class, built in the company's Roanoke shops, in 1950.

Technically, the 2–8–8–2 was a straight development of the earlier type of 2–6–6–2, having firebox over rather than behind the rear driving wheels. With the larger 2–8–8–2, there was never any possibility of placing the firebox behind the drivers, like the later 2–6–6–2, as there was just too much firebox to be positioned over a single pair of trailing wheels. One or two early designs, such as those on the Virginian and the Santa Fé, had fireboxes supported over the trailing driving axle and widespread pony truck, but the standard form had firebox over two coupled axles, with pony truck tucked into the confined space underneath the cab. All 2–8–8–2s were superheated, a few early designs with multi-stage boilers but mostly with normal fire tube elements, and apart from a handful with low-pressure slide valves all were equipped with piston valves throughout. It is hardly necessary to add that with an engine the size of a 2–8–8–2, a mechanical stoker was obligatory, and indeed, the prior development of a reliable stoker was a necessary prelude to the introduction of such large engines. A fair number of 2–8–8–2s were converted to simple expansion in the 1920s and '30s, thus giving them a new lease of life. Users of compound 2–8–8–2s were:

Atchison, Topeka & Santa Fé
Baltimore & Ohio
Buffalo, Rochester & Pittsburg
Chicago, Burlington & Quincy
Carolina, Clinchfield & Ohio
Denver & Rio Grande Western
Duluth, Missabe & Northern
(later D M & Iron Range)
Great Northern
Interstate
Missouri Pacific
Nashville, Chattanooga & St Louis
Norfolk & Western
Northern Pacific
Philadelphia & Reading
Pennsylvania
Seaboard Air Line
Southern
Southern Pacific
St Louis Iron Mountain
St Louis San Francisco
Western Maryland
Western Pacific
Union Pacific
Virginian

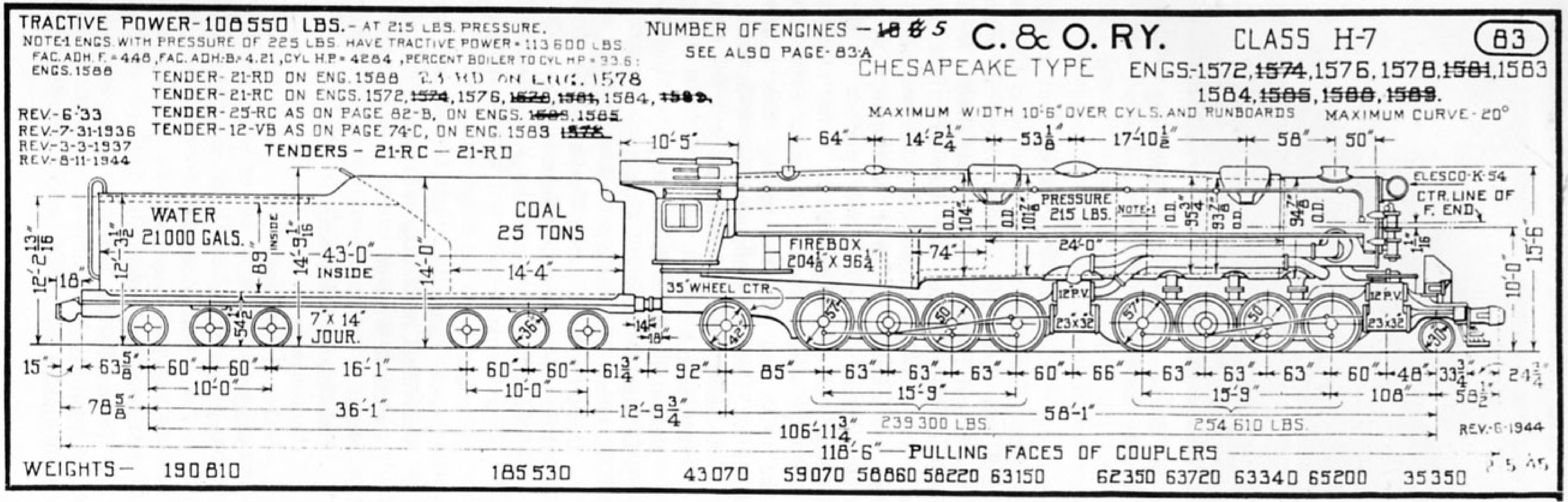


Fig 21 *Chesapeake & Ohio class H7 2–8–8–2, the first major application of simple expansion to the Mallet type*

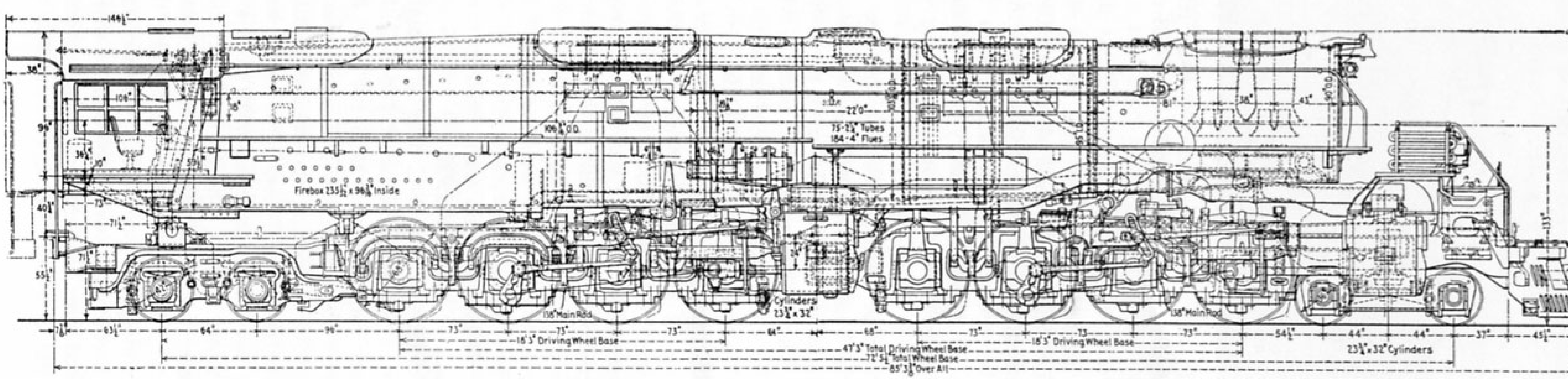
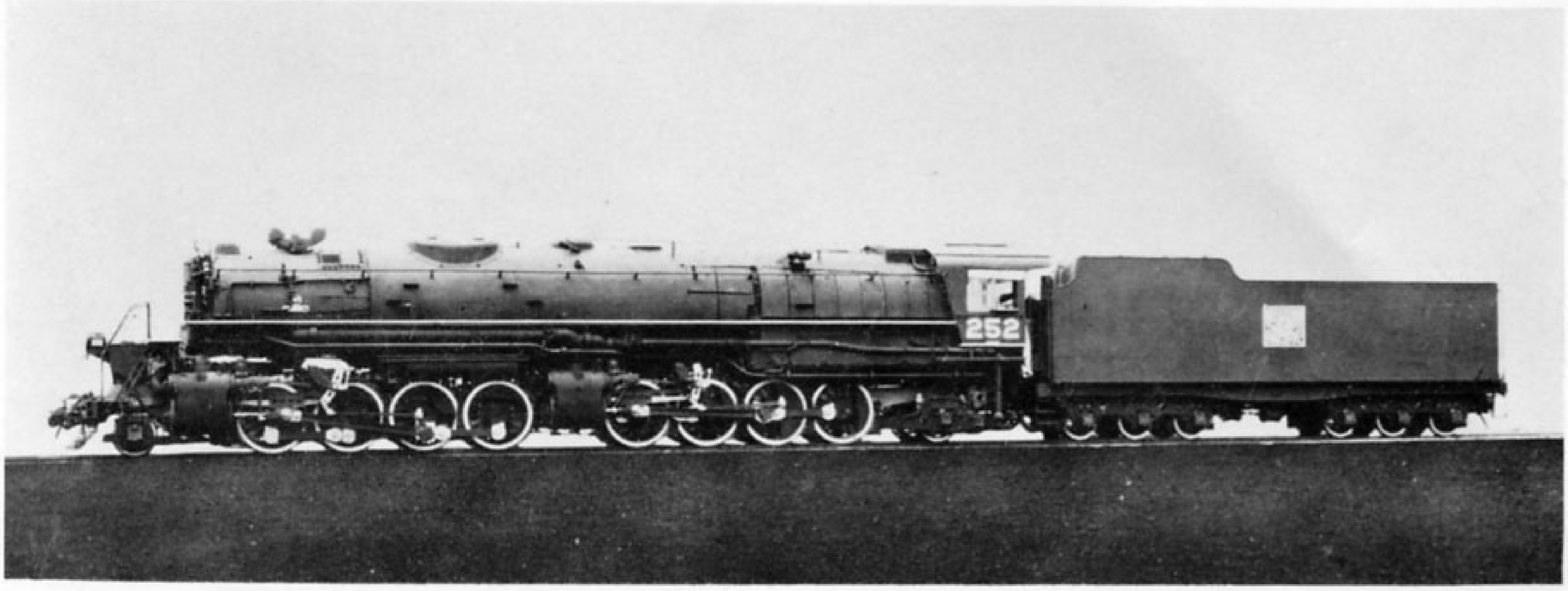


Fig 22 *Union Pacific Railway: diagram of 'Big Boy' 4–8–8–4, generally conceded as the world's largest locomotives*

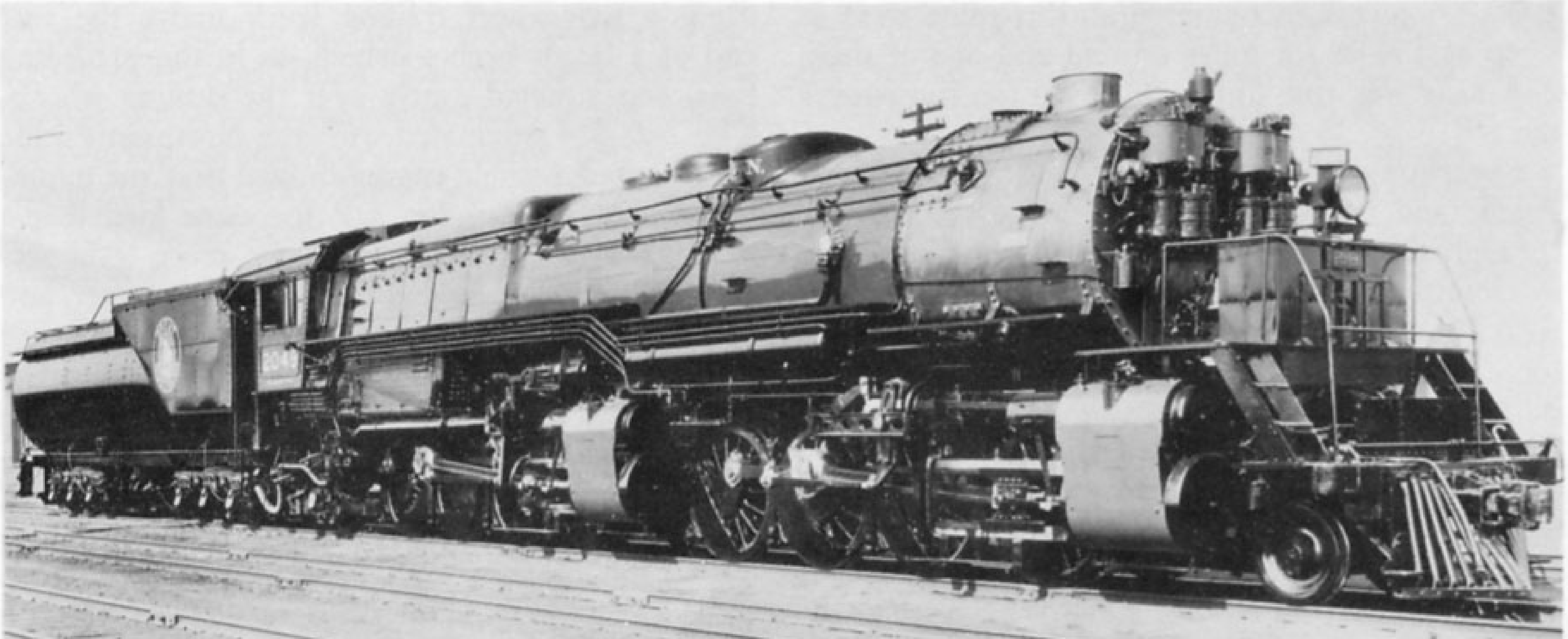


Western Pacific's massive simple expansion 2–8–8–2, weighing nearly 300 tons without tender, was among the largest of its type

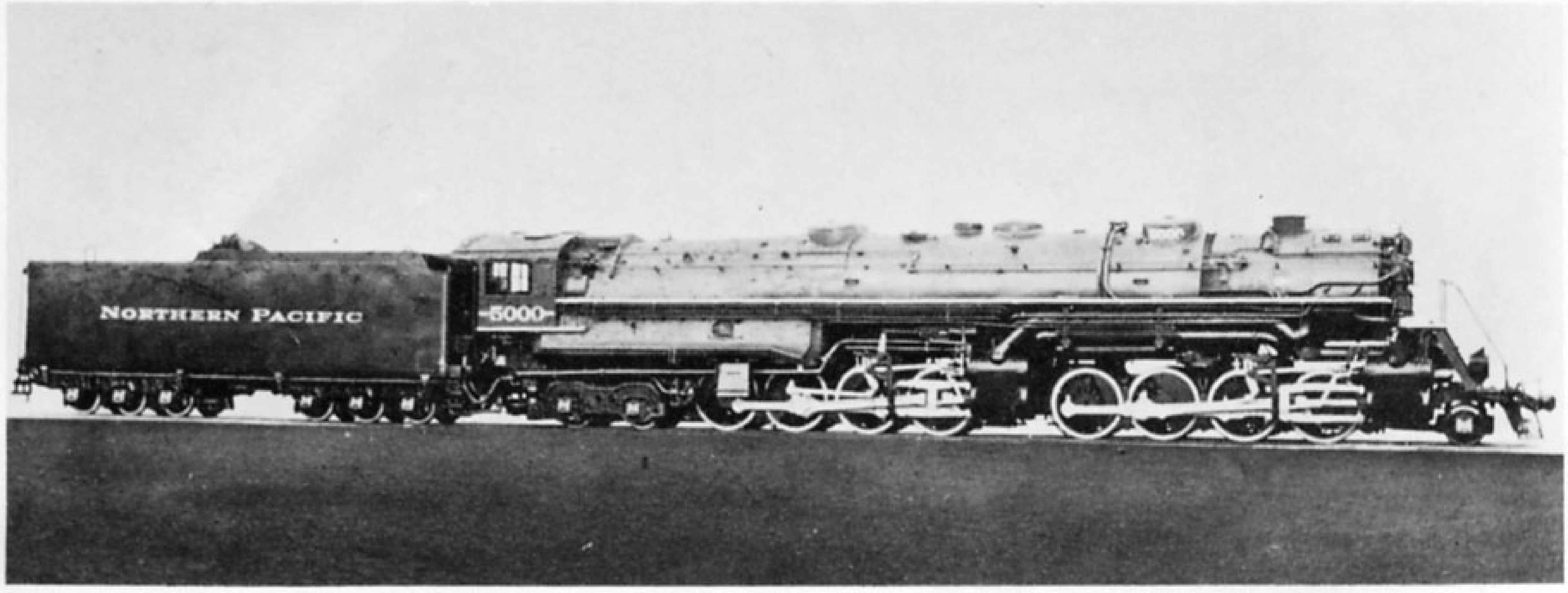
Simple expansion 2–8–8–2s

Less numerous than their compound sisters, the simple expansion versions were nevertheless an extremely important item in USA steam power. Bruce gives their total as only eighty-six, but the author can account for over one hundred and Bruce probably ignored those built by the Great Northern in its own shops.

Being a modern type, the development story is simple—Pennsylvania had the very first example, an experimental engine, No 3388, class HH1s, built by Alco in 1912. Evidently they saw no particular virtue in the engine as she was never repeated and spent most of her days banking out of Altoona, where her capacity was equal to two standard eight-coupled engines. The Chesapeake & Ohio was the first line to invest heavily in the type and, as has already been explained on page 37, this was due to force of circumstances rather than any particular desire to initiate a movement towards



The Great Northern Railway showed its individuality by using Belpaire fireboxes and green livery. No 2049 bears witness to the rugged good looks of class R2, home-made in the company's shops



First 2–8–8–4s were Northern Pacific's monster Z–5 class, in certain dimensions, particularly grate area, the world's largest. Prototype engine No 5000, above, is by Alco

non-compound Mallets. So successful were the C&O's forty-five H7 and H7A engines that other lines soon followed suit, starting with the Great Northern whose ten engines of class R1s came from Alco in 1925, and were followed by the fifteen R2 class from the company's shops in 1929–30. As was the GN's practice, these engines had Belpaire boilers.

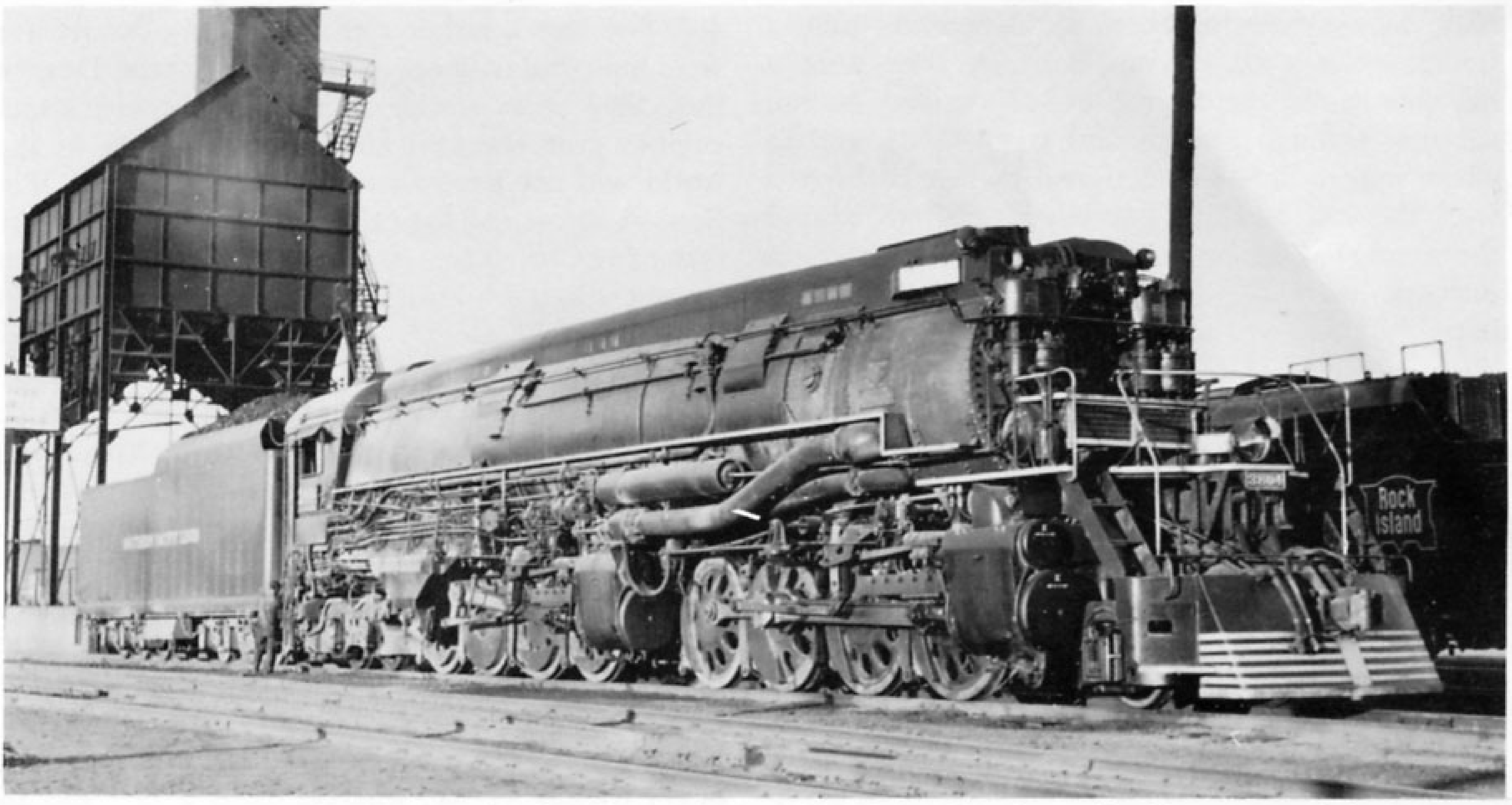
For its tremendous main line through the Tennessee Pass, over Soldier Summit, the Denver & Rio Grande Western took delivery of ten massive L131 class engines from Alco in 1927–8, and a further ten of improved design, class L132, in 1930. Gradients encountered on this route were as steep as 1 in 30 for miles on end and one of these 2–8–8–2s was able to handle 1,200 ton trains over the hill.

Competing with the DRGW was the Western Pacific and its main line through the Rockies cut through the precipitous Feather River Canyon in awesome scenery. In climbing from the West Coast with fast fruit trains the line was faced with a solid forty miles of 1 in 40, and to cope with this Baldwin built two batches of 2–8–8–2s similar to but slightly larger than the Rio Grande's engines, WP Nos 251–6 in 1930–1 and 257–62 in 1938. These latter, with all mod cons such as Boxpok wheels, cast steel beds etc, were the last simple expansion 2–8–8–2s built, so ending a fairly short reign of construction.

There were a number of railroads who converted some of their compound 2–8–8–2s to simple expansion engines, adding about seventy-five engines to the type which thus reached almost two hundred examples. Chief among these was the Southern Pacific who converted their forty-nine cab-forward 2–8–8–2s from compound to simple. The Southern Railway and the DM&IR lines each carried out similar conversions. Most unusual was the Reading line, which owned thirty large anthracite-burning compound 2–8–8–2s and rebuilt twenty of these to simples, and the other ten to conventional 2–10–2 engines, using little more than the original Mallet's boiler.

The 2–8–8–4

This type was a straight development of the 2–8–8–2 using a four-wheel trailing truck under the rear end of a larger firebox which, as in the preceding type, was situated partly over the driving wheels. The 2–8–8–4 originated with the Northern Pacific who wanted a single engine to haul over the mountain section of its main line the same load that a heavy 2–8–2 could handle on the more level sections. This meant double the 'Mikado's' power, and under normal conditions the line would have opted for a 2–8–8–2. However, this line, from Glendive in Montana to Mandan in North Dakota, tapped a source of low-grade fuel, Rosebud coal, a semi-lignite, which the NP wished to use (as they owned the coal mine!), and the 2–8–8–4 was evolved to enable the immense grate needed to burn this stuff to be incorporated. This grate, 182sq ft in area and the largest ever fitted to any steam locomotive, was 18ft 6in long and evidently there was some doubt at first as to whether a mechanical stoker could distribute coal across such a distance, as only a prototype locomotive was built by Alco in 1928.



To burn coal and run in the New Mexico divisions, Southern Pacific reversed its standard cab-forward 4–8–8–2 into a conventional 2–8–8–4. Above is Lima-built AC–9 3804 at Tucumcari, New Mexico, in May 1940

Following a trial period, a further eleven engines were supplied, this time by Baldwin in 1930. One wonders why Alco, who developed the original design, did not receive the main repeat order and possibly this story may one day be told. Apart from their enormous fireboxes and grates, these NP 'Yellowstones', a name given to the type due to the railroad serving the Yellowstone National Park, contained no particular features of mechanical interest but are strong contenders for the title of the world's largest locomotive, for they exceed Union Pacific's 'Big Boys' (normally considered the biggest, in terms of overall weight) in grate area, tractive effort and adhesion weight.

The 2–8–8–4 type was built for only three other North American railroads, the Southern Pacific, who had twelve Lima-built engines, Nos 3800–11, in 1939, class AC–9, as a version of their well known 'cab forward' 4–8–8–2, but built in the conventional manner, to burn coal, for heavy freight and passenger service between El Paso, Texas, and Tucumcari, New Mexico.

The years 1941–3 saw the introduction of eighteen class M3 and M4 2–8–8–4s on the Duluth, Missabe & Iron Range Railway, an ore carrier from the Mesabi range in Minnesota to Duluth, on the shores of Lake Minnesota. These were of similar basic dimensions to the NP engines, except in having normal-sized grates, and were built by Baldwin. Their chief claim to fame lies in their performance and this will be covered in this chapter's next section.

Last, lightest and most numerous of the 2–8–8–4s were the thirty engines of class EM–1, numbers 7600–29, built by Baldwin for the Baltimore & Ohio in 1944–5. These were not purchased for any special service but supplemented the older 2–8–8–0 classes on general heavy coal traffic over the Alleghenies. With their larger wheels and boilers, they were capable of faster speeds for general freight duties and even for passenger work if required. With these engines in service the total of 2–8–8–4s came to seventy-two examples, although Bruce quotes a figure of 213. Exactly how this figure was arrived at is unknown, for if the Southern Pacific's 4–8–8–2s (mechanically a 2–8–8–4 running backwards) are included the total becomes 267. As all the 2–8–8–4s (all, of course, simple expansion) are well known modern locomotives and fully documented, there can be no case of a large batch of engines are unaccounted for and Bruce must have miscalculated quite substantially here.

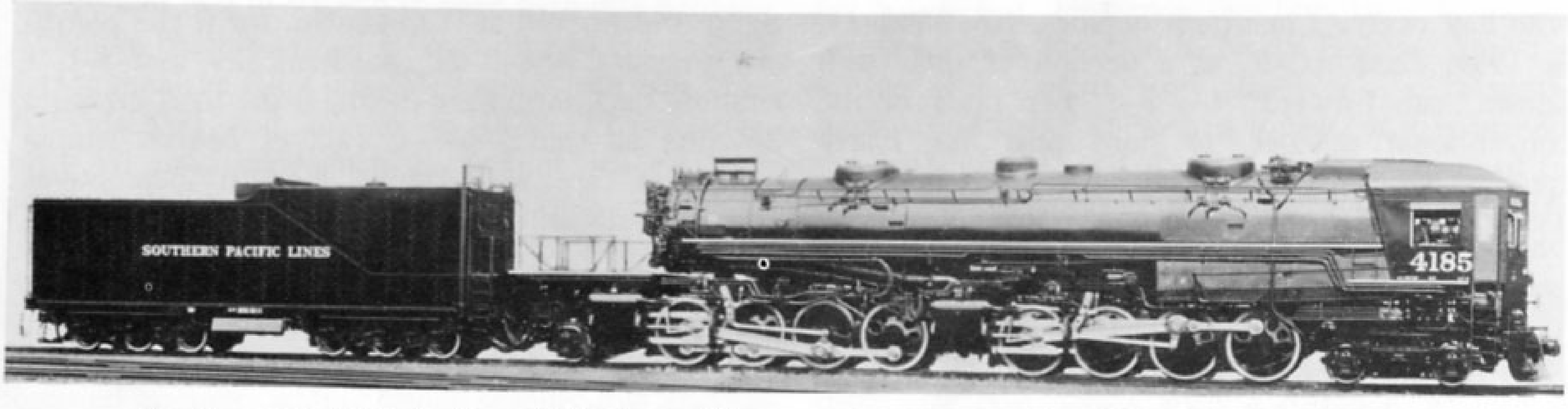
The 4–8–8–2

This type of Mallet was built for one railroad only, but in such numbers as to become quite a trademark for the system. Basically they were a development of the older 2–8–8–2, designed to run cab-first through tunnels and snow sheds, and in effect were a 2–8–8–4 designed to run backwards with the cab leading, but tender trailing behind the smokebox. The engines were, of course, oil burners, without which the system would have been impossible, and the leading bogies were of the normal centre-pin type, rather than the 'Delta' type usually found under a large Mallet's firebox, for better running at high speeds. Apart from these special features, they were built, all by Baldwin, with the usual features of American simple expansion Mallets and were first introduced in 1928. Sixteen years later there were 195 of this type running on the Southern Pacific, classes AC–4 to AC–8, and AC–10 to AC–12, the AC–9s being conventional 2–8–8–4s as already described. Engine numbers ran through in a solid block from 4100 to 4294 and they were the most numerous group of Mallets ever built, as well as being fairly high up amongst the ranks of largest and heaviest. Despite the proliferation of class numbers, there were but two main varieties, the classes AC–4 to 6 with 235lb pressure and spoked wheels, plus the later engines having 250lb pressure, Boxpok wheels, and a more rounded design of cab. The breakdown of classes and numbers is:

Class	*Numbers*	*Date built*
AC–4	4100–09	1928–29
AC–5	4110–25	1929
AC–6	4126–50	1930–31
AC–7	4151–76	1937
AC–8	4177–204	1939
AC–10	4205–44	1942
AC–11	4245–74	1942–43
AC–12	4275–94	1943–44

The 4–8–8–4

So far as wheel arrangements are concerned, the 4–8–8–4 was a rather rare type—only twenty-five were built and only one railroad used them. Despite this, they were amongst the most famous steam engines ever operated and few enthusiasts in the world will not have heard of a Union Pacific 'Big Boy'. A direct and logical development of the same system's 'Challenger' type 4–6–6–4, the Big Boy, considered basically, is but a 'Challenger' with an extra driving axle on each unit and a suitably enlarged boiler mounted on top. This is, of course, an over simplification of the splendid design work performed in the drawing offices of both the railroad and Alco, the builders, for the co-designers created the largest and heaviest steam locomotives ever to run on the world's railways. Not the largest in every single statistic, as a perusal of this book's tabular pages will reveal, for the Big Boys were exceeded in grate area, tractive effort and adhesion weight by other heavy Mallets in North America. However, these were all designed and built for slow, heavy freight service, whereas the 4–8–8–4 was an express engine, designed to run up to 80mph so that correspondingly larger driving wheels had to be fitted under the enormous boiler. Despite its size, the Big Boy was a superbly proportioned machine, with the massive yet clean outline which characterised the latest and best of American steam power. Here was no freak, like the Henderson Triplex, or the Santa Fé 2–10–10–2, but a magnum opus in the world of steam locomotion—in fact it is no exaggeration to say that the Big Boy occupied the same place in the world of steam locomotives as does Beethoven's ninth symphony in the world of music: a supreme concept whose awesome size was skilfully blended with beauty in a manner never likely to be equalled or surpassed in today's plastic age. The saddest note lies in the impermanence of a revenue-earning piece of machinery, for whereas Beethoven's ninth may still be



Southern Pacific's trademark in the golden age of steam was the oil-burning, cab-forward 4–8–8–2, 195 of which ran on the system at one time. No 4185 is a 1939-built AC–8

Final Mallet development was Union Pacific's class of gigantic yet superbly proportioned 'Big Boy' 4–8–8–4s. A straight enlargement of the Challenger 4–6–6–4, they combined 80mph speed potential with the highest haulage capacities

experienced in all its glory in concert halls throughout the world, the rostrum of Sherman Hill, set in the auditorium of Nebraska's prairies, will never again resound to the syncopated, unsynchronised music from a Big Boy's double, multiple-jet chimneys as it battles upgrade with a hundred or so bogie wagons in tow.

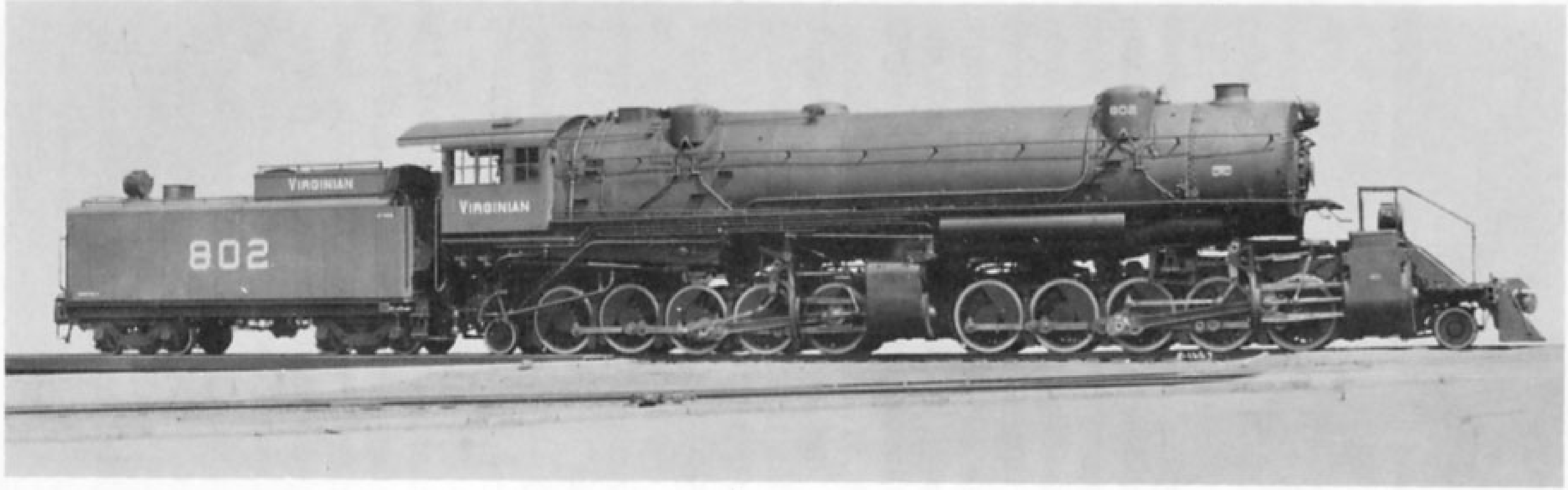
Mechanically, the twenty-five Big Boys Nos 4000–24 (Alco, 1941–4), were a direct enlargement of the later 3930–99 Challengers and had all the features expected of a modern American steam locomotive—cast steel beds, roller bearings, high pressure, largely welded boiler, fed with a mechanical stoker, piston valves actuated by Walschaerts gear and Boxpok driving wheels. They were very fully covered in the technical press when built and, having won wide acclaim, have revelled in a substantial coverage in American railroad magazines, in books on the Union Pacific, and have even gained that rare distinction, a book to themselves, as will be seen in the bibliography on p000.

The 2–10–10–2

Most articulated types never developed beyond the size and power realisable with six-coupled engine units. Apart from the Mallet, only the Garratt was built in large numbers with eight-coupled units, and the Mallet alone was built with ten-coupled wheels on each power unit.

The first ten of the ten-coupled Mallets were 2–10–10–2s, rebuilt by the Santa Fé from earlier 2–10–2 tandem compound engines, the rebuilds having multi-stage boilers with Jacobs–Schupert fireboxes and Walschaerts actuated piston valves on each cylinder. Despite their great size, grate areas were small at 82sq ft and they were very much the long, thin, Mallet, over-cylindered or under-boilered depending upon one's point of view. As a direct enlargement of the Santa Fé's other strange Mallet classes, they were no more successful and in 1917–18 they were, amoeba-like, divided into two, each half becoming a superheated simple expansion 2–10–2 of straightforward rugged design, in which form they lasted well as helper engines.

The second and last ten-coupled Mallets were also 2–10–10–2s, this time built new by Alco in 1918, the same year as the Santa Fé was dismantling their predecessors. Virginian Railway's Nos 800–9 were a vastly different conception to the Santa Fé engines and were so well proportioned that one has to count the wheels before realising how many there are! A direct enlargement of the 2–8–8–2 type, the Virginian engines, like the Santa Fé, were compounds, but had a normal fire tube superheater and slide valves for the low-pressure cylinders. In a number of dimensions they were unsurpassed at any time: the low-pressure cylinder's 48in diameter was the greatest ever applied to a steam locomotive, as was the boiler's 9ft 10½in diameter at the rear course, whilst their tractive effort and adhesion weights were only exceeded, and not by much, in the Triplex three-unit Mallets built for the same railway and the Erie. In fact, the Virginian 2–10–10–2 came about as a direct result of the Triplex's failure to perform adequately. So huge were the 2–10–10–2s, due to the Virginian's generous loading gauge, that cabs and low-pressure cylinders had to be removed to allow them to be railed over other lines in course of delivery, and even then a special route had to be arranged. Details of their



Count the wheels! Alco's 2–10–10–2 for the Virginian Railway was so superbly proportioned that its immensity tends to be lost. Its 48in low-pressure cylinders were the largest ever applied to a steam locomotive

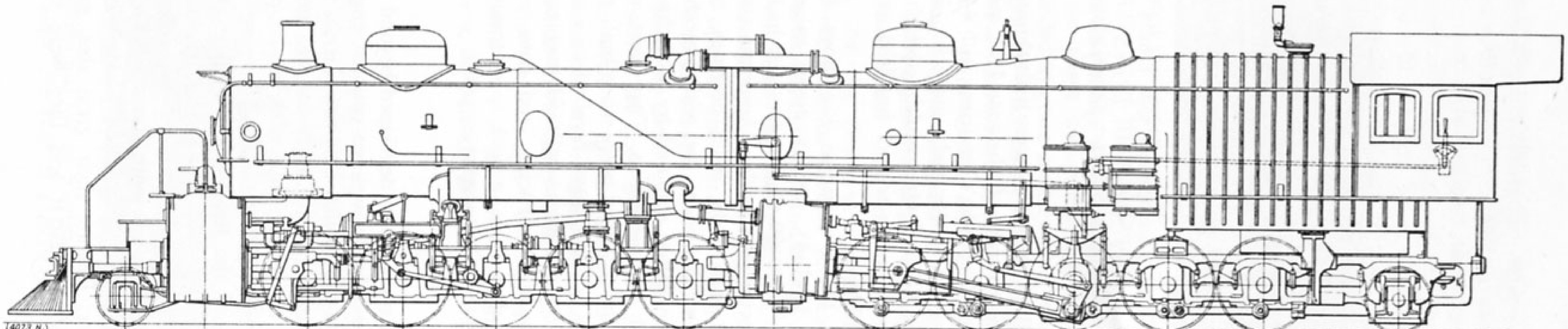


Fig 23 *The largest and most awkward of Santa Fé Mallet experiments were the 2–10–10–2s, soon to be broken down into pairs of 2–10–2 conventional engines. Compare these engines with Alco's handsome design of the same wheel arrangement above*

work will follow in this chapter's second section. With the Virginian engines, the 2–10–10–2 type numbered twenty, Bruce quoting only ten.

The 2–8–8–8–2T

Some considerable space has already been devoted to the technical aspects of the Henderson Triplex development of the Mallet principle and it is here necessary only to record the numbers built of the type, their variations and fates. The first Erie 2–8–8–8–2 was outshopped by Baldwin in 1914, and named *Matt H. Shay* after one of the road's veteran engineers (drivers). Numbered 5014 and classed 'P', she had a Gaines combustion chamber, as often fitted to American Mallets and other large power where large fireboxes were positioned over the driving wheels. The Gaines system was not a true combustion chamber at all but consisted simply of bricking off the forward section of the grate and continuing this baffle upwards to form the brick arch. The Gaines system simplified the firebox shape and reduced manufacturing costs, but of course any leakage of cold air through the brick baffle would adversely affect steaming, as well as thermally stressing the tubeplate. The sheer brute force of the initial Triplex persuaded the Erie to try out another two, despite the steaming troubles of the prototype, and a rather feeble attempt to provide more steaming capacity was made by removing the Gaines baffle to increase the grate area. With no increase in firebox volume, and without suppressing the tender feed water heater as already described (p 000), there was little improvement and P1 Nos 5015–16, built in 1916, in no way justified any further investigation into the Triplex's potential. All three were withdrawn in 1927 and cut up 1930–3.

The 2–8–8–8–4T

In the same year, 1916, that the Erie took delivery of its second Triplex batch, the Virginian Railway, faced with ever increasing traffic over its severely graded main line, also opted to experiment with this apparently promising development. The Virginian mechanical men evidently sensed that Erie's engine was not correctly proportioned or, more likely, sent someone over to look at the thing, for the second customer chose a decidedly larger boiler and two inches off the diameter of each cylinder. This gave an engine which might have worked, except that the draught-depriving feed-water heater was still tucked away under the tender section, and Virginian No 700 proved no more use than had her contemporaries. She did, however, enjoy a longer life, or at least her components did, for she was, in 1921, after supercession by Alco's 2–10–10–2s, divided into two engines; the front unit, including the boiler, was fitted with new cylinders and became a compound 2–8–8–0 No 610, whilst the tender section was made into a 2–8–2 tender engine. The Mallet half of the rebuild used cylinders cast from the same patterns as the 2–10–10–2s and, like these, the high-pressure cylinders were horizontal with piston valves and the low-pressure slightly inclined, with slide valves. In this form the converted Triplex lasted into the early 1950s, latterly acquiring a trailing pony truck to make it a 2–8–8–2—probably the only Mallet to have three wheel arrangements.

CANADA

Canadian Pacific Railroad

Railroads in Canada closely followed US locomotive practice, although Canadian engines were generally somewhat smaller. In Western Canada, both the Canadian National and the Canadian Pacific had to cross the Rocky Mountains and, not surprisingly, the CPR in 1909 decided to try out the Mallet. The half-dozen Mallets built were 0–6–6–0s, strange machines with the front unit reversed so that all four cylinders were grouped together between the two sets of driving wheels, apparently in an attempt to reduce condensation in the receiver pipe. Although superheated, they were not considered a success and suffered two experimental forms—one being converted to simple expansion and another fitted with a strange boiler having a superheating chamber mid-way along the barrel between two tube banks. The superheater was of the stationary boiler type, with the vertical elements suspended from an overhead header. Neither experiment brought success to the Mallets, whose recoverable components were then incorporated into a class of 2–10–0 engines, nominally 'rebuilt' from the Mallets. No other Mallets were ever supplied to Canada.

NORTH AMERICA—MAIN LINES

Typical dimensions of selected compound Mallets (imperial units)
All 4ft 8½in gauge

Railway	*Class*	*Type*	*Cylinders* in×in	*Coupled wheel dia* *ft in*	*Boiler pressure* *psi*	*Grate area* *ft²*	*Total heating surface* *ft²*	*Super-heating surface* *ft²*	*Weights (loco only)* *Adhn* *L Tn*	*Total* *L Tn*
Little River	—	2–4–4–2	14/21×22	3 10	200	21·5	1517	—	49·7	63·2
ATSF	1300	4–4–6–2	24/38×28	6 1	200	52·5	4756	798·R 323·S	119·7	168·1
Baltimore & Ohio	0	0–6–6–0	22/32×32	4 8	235	72·2	5586	—	149·6	149·6
Kansas City Southn		,,	22/35×32	4 8	225	72·3	4374	858	157	157
New York Central		,,	21½/34×30	4 3	220	53·6	4246	948	155	155
Denver & Salt Lake		,,	21/33½×32	4 7	225	72·2	5241	—	150	150
Lake Terminal		,,	24/37×32	4 7	205	78·3	5640	—	156	156
Canadian Pacific		,,	23¼/34×26	4 10	200	59·0	2950	548	117	117
Virginian		2–6–6–0	22/35×30	4 6	200	57·0	5046	—		148
Norfolk & Western		2–6–6–2	22/35×32	4 8	200	72·0	4771	1022	152	184
Great Northern	1800	,,	21½/33×32	4 7	200	78·0	5658	—	141	159
USRA		,,	23/35×32	4 9	225	76·3	5443	1292	160	200
Chesapeake & Ohio	H6	,,	22/35×32	4 8	210	72·2	4830	991	164	200
Missouri, Oklahoma & Gulf		,,	21/32×30	4 7	210	53·4	3407	685	124	141
New York Central		,,	21½/34×32	4 9	200	56·5	4481	1082	135	158
Chicago Gt. Western		,,	23/35×32	4 9	205	78·0	5766	—	137	158
Southern Pacific	MM-1	,,	25/38×28	5 3	200	70·0	7117	—	143	172
ATSF	1170	,,	24/38×28	5 9	200	52·5	5503	719·R 390·S	142	175
Southern		2–6–8–0	23/35×32	4 8	200	78·0	5601	638·R	148	162
Great Northern		,,	23/35×32	4 7	200	78·0	5060	480	160	169
Pennsylvania	CC1s	0–8–8–0	25/39×30	4 8	205	78·0	4936	1020	200	200
,,	CC2s	,,	26/40×28	4 3	225	96·3	5030	1406	205	205
Erie		,,	25/39×28	4 3	215	100	5314	—	183	183
Delaware & Hudson		,,	26/41×28	4 3	220	100	6629	—	199	199
New York Central	N1	,,	26/40×28	4 3	220	81	5289	1265	208	208
Baltimore & Ohio	EL-1	2–8–8–0	26/41×32	4 10	210	88	5821	1400	210	220
Kansas City Southern		,,	26/41×32	4 9	225	88	5170	1459	212	225
Great Northern		,,	28/42×32	5 3	210	78·4	6446	1368	188	201
Union Pacific		,,	26/41×32	4 9	210	81·1	5412	1397	208	222
Virginian (Baldwin)		2–8–8–2	26/40×32	4 8	215	84	6926	—	181	200
,, (Alco)		,,	28/44×32	4 8	185	99	6830	1310	213	241
ATSF		,,	26/38×34	5 3	220		6621	1201·R 544·S	184	206
DRGW	L-107	,,	25/39×32	4 9	240	96	6119	1582	215	238
Philadelphia & Reading		,,	26/40×32	4 7½	210	108	5747	1436	195	214
Seaboard Air Lines		,,	26½/42×32	5 3	210	88	5913	1458	187	222
NC & St L		,,	27/41×30	4 8	210	85·5	5433	1262	192	209
Southern Pacific	MC-1	,,	26/40×30	4 9	200	68·4	6393	—	176	190
Buffalo, Rochester, Pittsburgh		,,	28/44×32	4 9	200	99·2	6625	1632	224	256
Norfolk & Western	Y6b	,,	25/39×32	4 10	300	106·2	4915	1478	245	273
ATSF		2–10–10–2	28/38×32	4 9	225	82	6580	2330	245	275
Virginian		,,	30/48×32	4 8	215	108·7	8606	2120	276	306
Erie	5014	2–8–8–8–2	(6)36×32	5 3	210	90	6886	1584	336	377
,,	5015	,,	(6)36×32	5 3	210	121·5	6851	1584	342	384
Virginian		2–8–8–8–4	(6)34×32	4 8	215	108·2	8120	2059	324	377

USA SIMPLE EXPANSION MALLETS

Typical dimensions of selected classes (imperial units)
All 4ft 8½in gauge

Railways	*Class*	*Type*	*Cylinders* (4)in × in	*Coupled wheel dia* *ft in*	*Boiler pressure* *psi*	*Grate area* *ft²*	*Total heating surface* *ft²*	*Super-heating surface* *ft²*	*Weights (loco only)* *Adhn* *L Tn*	*Total* *L Tn*
Baltimore & Ohio	KK1	2–6–6–2	23 × 30	5 10	250	92	6543	1666	166	208
” ”	KK2	”	23 × 30	5 10	250	92	6409	2900	166	209
P & WV		2–6–6–4	23 × 32	5 3	225	102·3	5914	1873	177	236
Seaboard Air Lines	R-2	”	22 × 30	5 9	230	96·3	5429	2397	147	214
Norfolk & Western	1st-type A	”	24 × 30	5 10	275	122	6650	2703	192	255
” ”	2nd-type A	”	24 × 30	5 10	300	122	6639	2703	193	256
Chesapeake & Ohio	H-8	2–6–6–6	22½ × 33	5 7	260	135	7240	3186	227	344
Union Pacific	3800	4–6–6–4	22 × 32	5 9	255	108·2	5381	1650	180	260
” ”	3950	”	21 × 32	5 9	280	132·2	4795	1741	181	283
Northern Pacific	Z-8	”	23 × 32	5 9	260	152·3	5832	2114	198	288
Western Pacific	401	”	22 × 32	5 10	265	108·2	5666	1724	177	263
Delaware & Hudson	J95	”	20½ × 32	5 9	285	108	5389	1681	181	267
D & RGW	L105	”	23 × 32	5 10	255	136·5	6341	2628	194	286
Western Maryland	M-2	”	22 × 32	5 9	250	118·8	5770	1735	180	268
Clinchfield	651	”	22 × 32	5 9	265	108	5392	1680	188	271
Pennsylvania	HC-1s	2–8–8–0	30½ × 32	5 2	205	112	6656	3136	234	257
Great Northern	N3	”	22 × 32	4 8	265	95	5805	2188	240	256
Baltimore & Ohio	EL3A	”	24 × 32	4 10	220					216
Pennsylvania	HH-1s	2–8–8–2	27 × 28	4 8	160	96·5	6125	1257		216
Chesapeake & Ohio	H7A	”	23 × 32	4 9	215	113	6428	1885	188	252
Western Pacific	M137	”	26 × 32	5 3	235	145	6811	2152	246	297
Great Northern	R3	”	28 × 32	5 3	210	108	7142	1896	238	290
D & RGW	L131	”	27 × 32	5 3	240	136·5	7265	2295	250	290
Great Northern	R2	”	28 × 32	5 3	240	126	7834	3515	264	306
Northern Pacific	Z5	2–8–8–4	26 × 32	5 3	250	182	7673	3219	249	322
DMIR	M4	”	26 × 32	5 3	240	125	6758	2770	252	312
Southern Pacific	AC-9	”	24 × 32	5 3½	250	139·3	6918	2281	237	308
Baltimore & Ohio	EM-1	”	24 × 32	5 4	235	117·6	5298	2118	217	280
Southern Pacific	AC-4	4–8–8–2	24 × 32	5 3½	235	139	6505	2988	212	274
” ”	AC-10	”	24 × 32	5 3½	250	139	6470	2616	238	294
Union Pacific	4000	4–8–8–4	23¼ × 32	5 8	300	150·3	5889	2466	241	340
” ”	4020	”	23¼ × 32	5 8	300	150·3	5755	2043	243	345

USA MALLETS FOR LOGGING LINES

Typical dimensions of selected locomotives (imperial units)
4ft 8½in gauge unless otherwise stated

Railways	*Type*	*Cylinders* in × in	*Coupled wheel dia* *ft in*	*Boiler pressure* *psi*	*Grate area* *ft²*	*Total heating surface* *ft²*	*Super-heating surface* *ft²*	*Weights (loco only)* *Adhn* *T*	*Total* *T*
Various	2–4–4–2	14/21 × 22	3 8	200	26			50	64
Columbia River	”	15/23 × 22	4 0	200	28·2	1959	—	58	72·5
Caspar Lumber Co	2–6–6–2	13/19 × 20	3 1	200	18·2	1193	—	47·3	55·3
” ” ”	”	13/20 × 20	3 1	200	17·6	1016	218	50·8	60·0
Booth Kelly Lumber Co	2–6–6–2T	17/26 × 24	3 8	200	26·2	2089	—	79	92
St Paul & Tacoma Lumber Co	”	17/26 × 24	3 8	200	26·2	2089	—	81·5	99
Hammond Lumber Co	”	17/26 × 24	3 8	200	26·2	1654	358	81·5	99
Clemons Logging Co	2–6–6–2ST	18/28 × 24	3 8	200				93·5	109·5
Weyerhauser Timber Co	”	17/26 × 24	3 8	200	26·2	1654	346		
” ” ”	”	(4)16 × 24	3 8	200	26·2	1654	346	95·0	112
Uintah Railway	2–6–6–2T	(4)15 × 22	3 8	200	26·2			50	64
Weyerhauser Timber Co	2–8–8–2	23/35 × 28	4 3	215	64·5			145	161

Baltimore & Ohio's coal moving operations over the West Virginian mountains were as spectacular as anywhere else in the world. Here EM–1 2–8–8–4 No 7625 climbs 'Cranberry Hill', near Amblersburg, with two 2–8–8–0s banking

SECTION B

SOME NOTABLE AMERICAN MALLET USERS

In the foregoing pages describing American Mallets type by type it will have been seen that some railroads' names have cropped up frequently and others only under some of the less usual Mallet types. Here, then, will be described some of these railroads which are notable for assorted reasons—either for having a lot of Mallets, a wild assortment of the breed, for pioneering, or for having developed units of particularly outstanding performance. For those elsewhere in the world who have not thought too deeply about American steam performance—perhaps only to the extent of asking 'What else do you expect from such a huge engine?'—some comparative figures have been given to help put the matter in perspective. The results will be found quite surprising. The selected railroads will be dealt with in alphabetical order, and the author apologises in advance to any American reader whose favourite railroad has been left out of the selection.

Atchison, Topeka & Santa Fé

This western railroad had but a brief and unhappy flirtation with the Mallet; it spoilt her by overindulgence in express-sized wheels, flexible boilers and other unnecessary extravagences, and then wondered why she behaved with devastating Gallic coquettishness and failed to perform her duties. It was not as though Santa Fé rushed in too soon—it waited on the sidelines whilst B&O tried out the very first in America, and again while Great Northern pioneered Madamoiselle Mallet in main-line service. But by 1909 Santa Fé could contain its passion no longer and fell headlong in love with her. An orgy of Malletisation followed, 4–4–6–2s with 73in drivers, 2–6–6–2s with 69in, 2–8–8–2s with 63in and finally, the 2–10–10–2 56in wheeled centipedes. All had peculiarities in their boilers, as already described, and Santa Fé hoped to economise on their French mistress's housekeeping by tightening up on her grate areas under the mistaken impression that this would reduce fuel consumption. Within the decade the affair was over and Mlle Mallet was sent packing one way or the other. After that the Santa Fé, once bitten twice shy, shied away from any thought of articulateds and remained faithful to the old American concept of two outside cylinders—and make them as big as you like! Even the sophisticated and later-day simple expansion types such as the Challenger 4–6–6–4 failed to seduce Santa Fé, whose final 2–10–4,, with 30 x 34in cylinders, 74in wheels, 310lb pressure and boiler to match steam demand, was capable of giving many a 4–6–6–4 a good run for its money, although not capable of outperforming the larger eight-coupled simples.

Blasting furiously with the stuttering exhaust from a simple articulated's unsynchronised units, EL–5A 7153 and EL–3A 7133, both 2–8–8–0s, bank EM–1 2–8–8–4 on coal through the wooded hills of West Virginia in July 1949

Baltimore & Ohio

This railroad features in the notable selection mainly by virtue of its pioneer position, but also because of its perseverance with the Mallet in slow but successful development, and only one slight peccadillo towards the realms of freak Mallets. The original 'O' class 0–6–6–0, No 2400 (later 7000), remained the only one of her class and the only Mallet on the system from 1904 to 1911. Adjudged a good girl after her long apprenticeship, 'Old Maud', as she was known, was then joined by numerous sisters. The ugly sister was O-odd No 2421, a 2–6–8–0 rebuilt from a 2–8–0 and a member of the long thin brigade. Later renumbered 7010, class KL1, she was not a success and was reconverted back to original form. The same year, 1911, as 2421 appeared, the first ten 0–8–8–0s arrived on the property, and by 1913 there were thirty of them, good hard-working compounds, with no frills class LL1, engines 7020–49. Then from 1916 to 1920 came the eighty-six 2–8–8–0s, classes EL1, 2, 3 and 5. The latter were to USRA design and details of builders and dates will be found on p 00. Finally came sixteen 2–8–8–2s, class EE1, second-hand from the Seaboard Air Lines, who had apparently found them rather too heavy for their tracks. These latter were larger wheeled engines and theoretically suited to faster service than the home design. The B & O found these eight-coupled Mallets very satisfactory for their coal drags over the Allegheny Mountains, and normal practice was to use three Mallets on a train of four thousand tons, one hauling and two banking, enabling gradients of 1 in 45 (2·2%) to be surmounted. In due course, a measure of standardisation was achieved by converting nine of the 0–8–8–0s to 2–8–8–0, in which form they became class EL4, and the ex-SAL 2–8–8–2s lost their trailing trucks to become the standard wheel arrangement as class EL6. The compounds pulled and pushed the never ending stream of coal over the mountains, and when simple expansion Mallets became popular, seventy-nine of the compounds were simplified with new high-pressure leading cylinders and double chimneys, each pair of cylinders exhausting into its own chimney, a curious arrangement which nevertheless appeared satisfactory. The conversions were

Class	EL1	12	locos	became	EL1a
,,	EL2	8	,,	,,	EL2a
,,	EL3	20	,,	,,	EL3a
,,	EL5	24	,,	,,	EL5a
,,	EL6	15	,,	,,	EL6a

After rebuilding so many engines to simple, the B&O eventually added to their numbers the thirty EMI class 2–8–8–4s used on the same duties, although of course favoured whenever a Mallet was called upon to handle one of the faster tasks. In the last days of steam even the EM1s were relegated to mine runs and spectacular photographs exist of them triple-heading on heavy coal trains —whether this was regular working, luck, or organisation on the photographer's part now seems lost in the mists of not-so-long-ago. Unfortunately, the B&O Mallets were displaced from their main duties by diesels before tape recording became a popular adjunct to railroad photography—probably even before the requisite equipment became available. Which is a pity, for the sound of three Mallets blasting through the heavily forested West Virginia hills, offbeat unsynchronised exhausts stuttering deafeningly, would have been music to a steam lover's ears today.

The B&O also made an excursion into the realms of high-speed simple Mallets as early as 1930. The KK1 and KK2 2–6–6–2 appeared in 1930, on the eve of the depression, and normally would have been the prototypes of a larger class. As it was, nobody seemed interested and it was left to the Union Pacific to invent the 4–6–6–4 before the high-speed simple Mallet pioneered by B&O became a popular and powerful force on American railroads. Ironically, B&O's only more numerous classes of this type were the ex-SAL 2–6–6–4s, acquired second-hand right at the end of steam operation to perform the fast freight tasks for which their second owners had pointed the way a generation before.

Chesapeake & Ohio

Another eastern states coal hauler like the B&O, the 'Chessie' line also used Mallets from an early date for similar duties through similar terrain, but developed its power along quite different lines. No Mallet pioneer, 'Chessie' waited until the Mallet was well established and then invested heavily in the popular and well tried 2–6–6–2 type. From 1912 to 1918 some 150 of this type, classed H4 were built, plus sixty-five H5 and H6 in 1919–21. With over two hundred Mallets, the line seemed well supplied with motive power to meet its requirements, but boom conditions soon demanded more power and if heavier trains were to be run to ease line congestion, each would have to be more powerful. An eight-coupled type was needed, but with close clearances in tunnels the loading gauge dictated a move to simple expansion, as has already been described on p 00, and the forty-five 2–8–8–2s of class H7 were the result.

We now come to a strange reversal of policy, for having replaced straight unarticulated power first with compound Mallets and then with the pioneer large-scale application of simple Mallets, the C&O went back to rigid-framed locomotives! The reason behind this was Lima's concept of 'super power' or, in other words, engines having a high horsepower in relationship to their nominal tractive effort. The end result of such proportions is the ability to haul the same loads at higher speeds, with a resulting quicker turnround of motive power and rolling stock, so reducing the number required to haul a given tonnage within a given time. In the case of the 'Chessie', the H7 2–8–8–2s with 108,550lb nominal tractive effort and about 4,000 rated horsepower, mounted on driving wheels 57in diameter, were replaced by 2–10–4s which, with booster and heavier axle load, exerted the same starting effort, and with 69in drivers were capable of substantially higher speeds. Furthermore, larger boilers were fitted, making these higher speeds a realistic proposition. The forty 2–10–4s of class T1 bumped the almost new simple Mallets off the mainline runs and made them largely redundant, so much so in fact, that during World War II, when motive power was at a premium, thirty could be spared for sale to the hard-pressed Union Pacific and three to the Richmond, Frederiksburg & Potomac. The remainder soldiered on as bankers and hump engines at such centres as Russel yard, Kentucky and Walbridge, until scrapped about 1952.

When, during the 1940s, further power of the heavy, high speed 'super power' type was needed to replace the H7 2–8–8–2s, C&O decided to opt for something bigger again than the 2–10–4 type, calculating that six-coupled axles would be required. Lima is known to have worked on a design for a 2–12–6 as the next logical evolutionary stage from the 2–10–4, and this may well have emanated from C&O's requirements. However, the old bugbear of tunnel clearances probably mitigated against a two-cylinder 2–12–6, needing cylinders of about 32in diameter, whilst a three-cylinder design by then was considered obsolete. The only solution, and the one taken, was to return to the simple expansion Mallet concept, outfitted with large wheels and vast firebox, and produce the 2–12–6 as a 2–6–6–6 Mallet. The resulting H8 class were one of steam's highlights, perhaps second only to the 'Big Boys' as a tremendous concept in steam power. Their rated nominal tractive effort, some 110,200lb, gives little idea of their performance, and sustained *drawbar* horsepowers little short of 7,000 have been recorded. In service, coal trains averaging about 12,000 long tons in 160 bogie wagons were the usual load, and the average

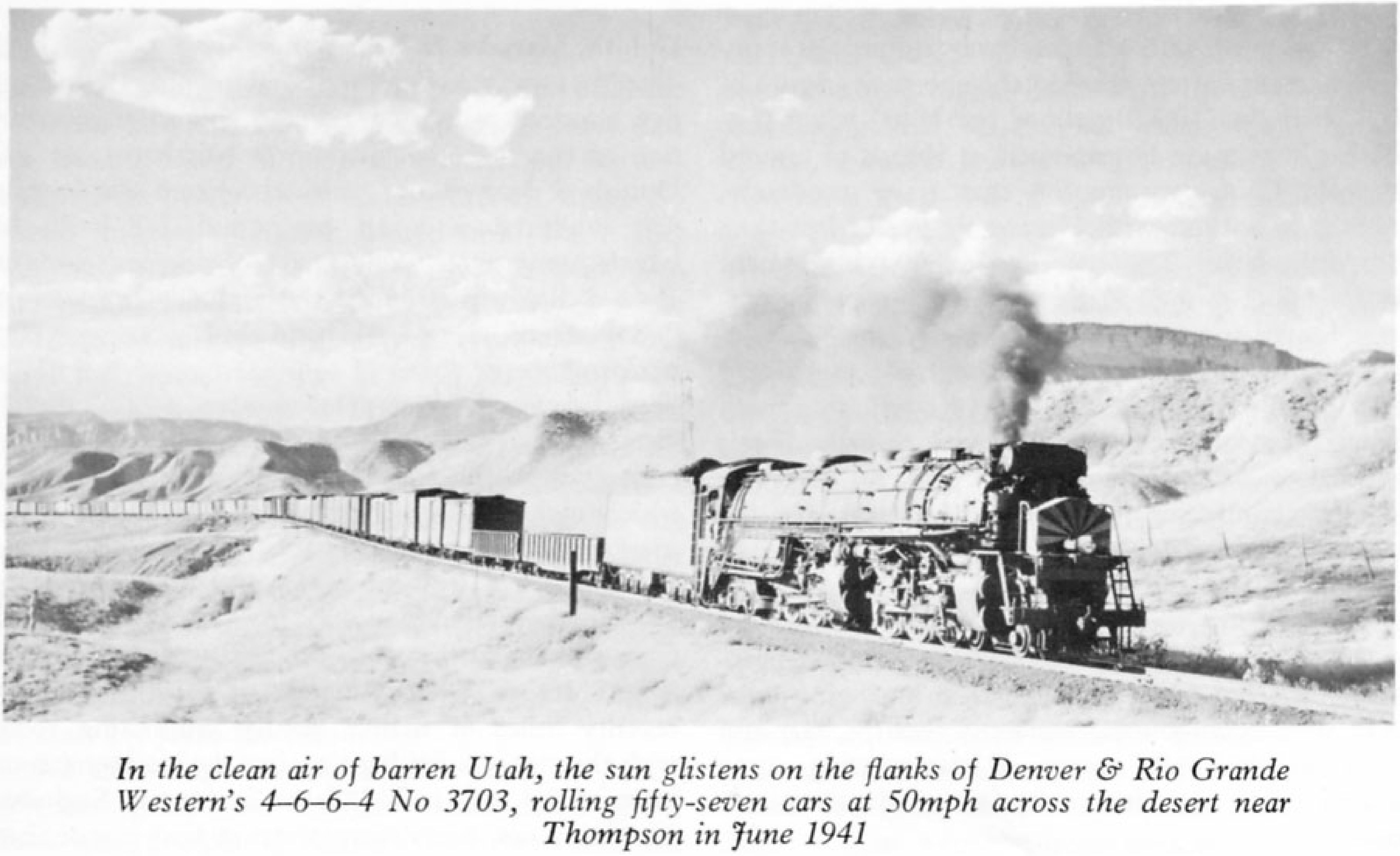
Delaware & Hudson's 4–6–6–4s, uncluttered and with shapely chimney, were Anglicised in style if not in size. Here No 1504 leaves Schenectady, NY, home of its builder Alco, with a 73-car westbound freight in 1950

speed attained with this load was around 30 mph. Evaporation on test reached the enormous figure of 108,200lb/hr (10,820 gallons per hour) when producing maximum horsepowers at speeds of around 45mph. Coal consumption was quite moderate, related to output, with average figures of less than 3lb/dbhp-hour. The C&O had a great investment in its H8 2–6–6–6 Mallets, which by 1948 numbered sixty engines. A few years later, the 'Chessie' abandoned all this splendid, profitable machinery and blindly followed the fashion, replacing each powerful steam unit with the three or four diesels needed to accomplish the same task. By 1956 the last H8, barely run in, had gone for scrap and the railroad was left with the burden of paying heavy interest on its enormous diesel investment, complex machinery which wore out rapidly and needed replacement before it was paid for. The Chesapeake & Ohio today is engaged in arranging mergers with neighbouring concerns such as B&O and N&W as the only means of maintaining some degree of profitability in the face of dieselisation's costs.

Duluth, Missabe & Iron Range

The DM&IR is a small railroad owning less than five hundred miles of track and was an amalgamation of the Duluth, Missabe & Northern and the Duluth & Iron Range railroads. From the former was inherited a dozen compound 2–8–8–2s, of which some were converted to simples, and in 1941–8 Baldwin supplied the eighteen remarkable 2–8–8–4s of classes M3 and M4 whose regular performance in terms of tonnage hauled has never been surpassed by any locomotive, steam, diesel, electric or gas turbine, used singly. They were huge engines by any standards but not the biggest, which makes their achievements all the more remarkable. Ordinary day-to-day operation called for the haulage of iron-ore trains weighing 18,000 to 19,000 short tons (16,000 to 17,000 long tons) from the ore workings to Proctor yard, Duluth, on the shores of Lake Superior. This meant about seventy miles of mainly gently undulating road, with the steepest gradient against the load some four miles of 0·3% (1 in 333) from Burnett to Saginaw. This may not sound very steep at first glance, but

171 bogie hoppers of iron ore, totalling about 15,000 long tons gross, represent an everyday assignment for Duluth, Missabe & Iron Range 2–8–8–4 No 227, seen here ascending Saginaw Hill, Minnesota, in 1959



In the clean air of barren Utah, the sun glistens on the flanks of Denver & Rio Grande Western's 4–6–6–4 No 3703, rolling fifty-seven cars at 50mph across the desert near Thompson in June 1941

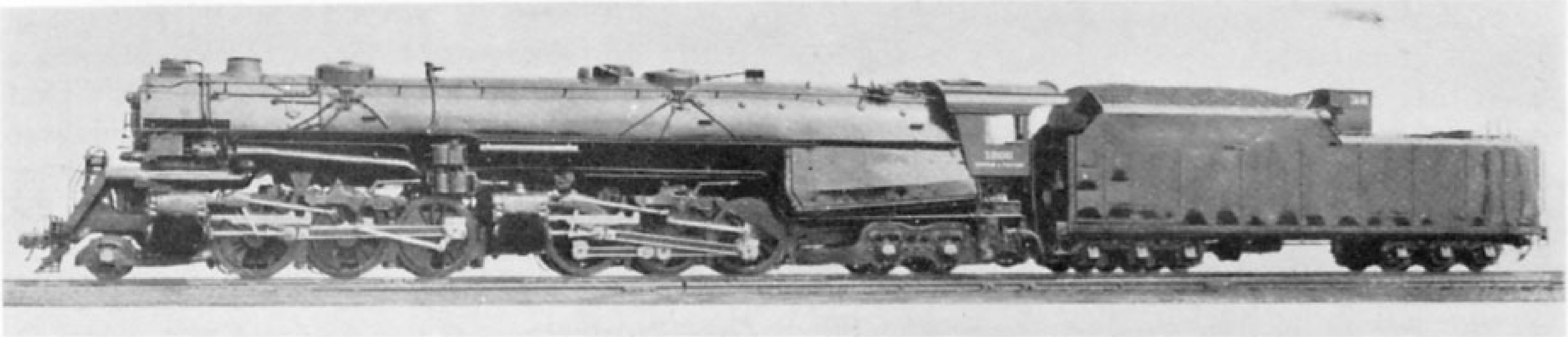


Fig 24 *Norfolk & Western 2–6–6–4, simple expansion, first series*

A rare old print of an Erie Triplex in action, probably No 5014 on its trial run with 250 cars of coal the gradient resistance alone of loco and train works out to about 125,000lb, leaving a mere 15,000lb of nominal tractive effort to cope with rolling resistance, alone likely to exceed 60,000lb. Even allowing for bored-out cylinders, turned-down tyres and a mean effective pressure of 90% instead of the usual 85% boiler pressure, they were overloaded, and without the momentum of a 30mph initial speed at the gradient's foot could never have reached the summit. However, they *did*, day in and day out, performing a task which *three* large diesels found difficult. For a vivid on-the-footplate account of such a run the author can recommend *Trains* magazine for November 1959, in which William D. Middleton describes a trip on the line in its last year of steam when the 2–8–8–4s were being used only when traffic was at its peak and were presumably not in the best of condition. To put these performances in perspective to people outside the USA, one may compare a DMIR 2–8–8–4 with, say, a British Railways 9F 2–10–0, and find that the Missabe engine equals 3½ 9Fs in tractive effort, 3·⅓ in adhesion weight, and three in grate area. Taking the most favourable ratio, tractive effort, at one Missabe equals 3½ 9Fs, then the regular performance expected from a BR 2–10–0 would be the haulage of 4,600-ton trains from Swindon Junction to Acton Yard, a figure enough to make any British Rail executive's hair stand on end. And just to complete the comparison, the Missabe 2–8–8-4s averaged about 27 mph with their gigantic loads, a figure BR finds hard to equal today with mineral trains one tenth the weight, plus the 'benefits' of diesel traction!

The Erie

This railroad, like the Santa Fé, forsook the Mallet after trying out a succession of the wrong types, almost like a man who becomes a misogynist after marrying, in quick succession, a gambler, a drug addict, and a prostitute! Erie's first venture into Mallets was not too outlandish, except that the three 0–8–8–0s, class L1, Nos 2600–02, were 'camelback' types with cab atop the boiler, affording commodious accommodation for the lordly driver but confining the wretched fireman to a brief canopy behind the boiler backhead. With 100 sq ft of grate area and 94,000lb of tractive effort, and lacking the economical benefits of superheating, they were hand-fired (!) and must have been a fireman's nightmare, although surely there must have been two shovellers to feed the brute. As later superheated, fitted with mechanical stokers and converted to 2–8–8–2, they were the Erie's only venture into normal Mallets. No 2900, class M1, was one of those peculiar conversions from 2–8–0 to 2–6–8–0 which we have encountered from time to time in this book, and the poor railroad's final and most disastrous essay into the world of Mallets was its affair with the Triplex type. Little may be added to the words already written on the Triplexes except to say that under test conditions the first 2–8–8–8–2 hauled a load of 250 wagons, probably the longest train ever run behind a single locomotive, although at about 16,000 short tons it was not so heavy as those the Missabe line operated in regular service.

Great Northern

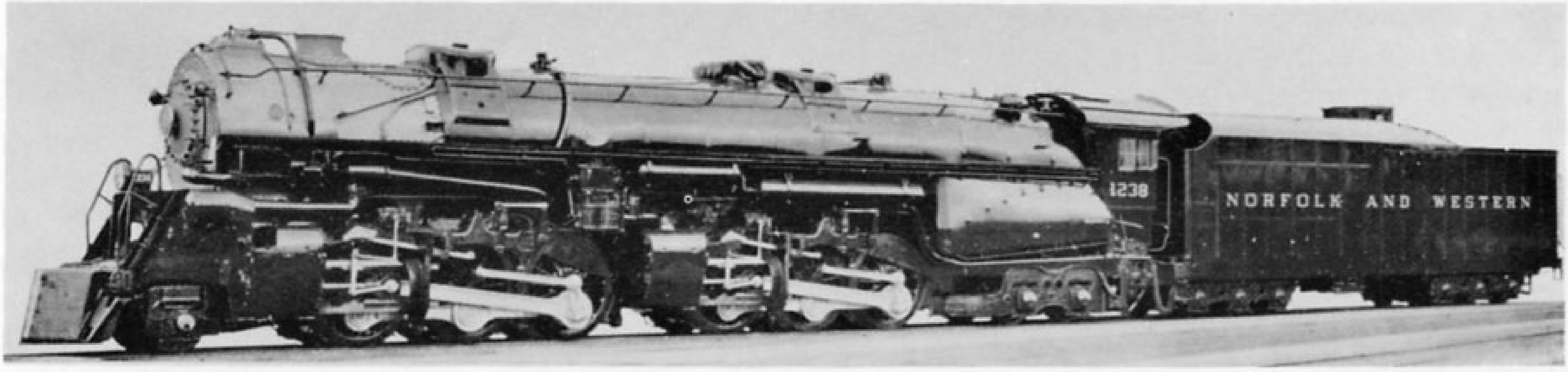
The 'Big G', as it is often referred to, comes under the notable railroads category as being the first US system to take the Mallet out of the banking-engine bracket and place it in road service. The engines, two classes of 2–6–6–2s supplied by Baldwin in 1906, were the first of that most popular type ever built, and the GN followed through with the only large-scale investment in the assymetrical 2–6–8–0 arrangement, then returned to normal with the large 2–8–8–0 and 2–8–8–2 types already mentioned. Its only venture into the more modern types was the acquisition of two Northern Pacific design 4–6–6–4s, second-hand from the jointly owned Spokane, Portland & Seattle.

Northern Pacific

Northern Pacific's main claim to fame was in its use of Mallets with the largest grate areas (182 sq ft) ever applied to steam locomotives, these being the 'Yellowstone' 2–8–8–4s already covered in the previous section. Even the smaller 4–6–6–4 engines, with 152 sq ft, exceeded all other grates in area, but of course the reason behind this was to lower the combustion rates for the low-quality lignite burnt and not to attain any exceptional power outputs.

Norfolk & Western

Here we had a Mallet user which made a determined effort to stay with steam power and was still building new steam locomotives in its own Roanoke workshops after other railroads had almost abandoned steam. Starting in a conventional way with a hundred and sixty 2–6–6–2s, Alco and Baldwin built in 1912–18 and all compounds, the road then increased its power in size to the 2–8–8–2,



Norfolk & Western's two Mallet designs evolved for high utilisation. An 'A' class 2–6–6–4 simple of the final batch with roller-bearing crankpins

of which two hundred and thirty were placed in service, the oldest in 1918 and the last in 1952. This basic type, developed and improved over the years from the Y2 through to the Y6b, all had the same cylinder and wheel dimensions but were improved in detail from batch to batch, the Y5 and Y6 series having 300lb pressure against the 270lb of the older series. Finally came the 'A' class, simple expansion 2–6–6–4s with larger wheels for fast freight and heavy passenger work, making but three basic types of Mallets in a roster amounting at one time or the other to 432 Mallets, not all of which were in service at one time. The list of engines was:—

Class Z1	2–6–6–2	compound	1330–79	Alco	1912–13
,, ,,	,,	,,	1380–419	Baldwin	1914
,, ,,	,,	,,	1420–89	Alco	1916–18
Class Y2	2–8–8–2	compound	1701–30	Roanoke	1918–24
,, Y3	,,	,,	2001–49	Alco	1919
,, Y3a	,,	,,	2050–79	,,	1923
,, Y4	,,	,,	2080–89	,,	1927
,, Y5	,,	,,	2101–19	Roanoke	1930–2
,, Y6	,,	,,	2120–54	,,	1936–40
,, Y6a	,,	,,	2155–70	,,	1942
,, Y6b	,,	,,	2171–200	,,	1952
Class A	2–6–6–4	simple	1200–42	Roanoke	1936–50

Apart from its sheer quantity of Mallets, most of which were home-made, N&W engines enjoyed the most modern servicing facilities applied to steam anywhere in the world. Coaling, watering, lubrication, ashing and other shed duties were carried out in an assembly-line manner, with gangs of men performing various operations simultaneously, and to such good effect that turn-round times and availability were competitive with the best that could be organised with diesels. On top of this, the engines had tremendous haulage capacities, the later 2–8–8–2s regularly handled 13,000 ton trains up 0·3% (1 in 333) gradients, and the 2–6–6–4s were able to produce 6,300 *drawbar* horsepower at 45mph and to attain over 60mph on level track with trains weighing 7,500 tons! All modern tried and tested improvements such as cast steel beds, roller bearings on axleboxes (and on all crankpins, in the final batch of 'A' class 2–6–6–4s), welded boilers etc, were incorporated successively to these engines, and by the late 1950s the result was a situation that completely and utterly shocked the American railroad world. Brainwashed into accepting the great diesel confidence trick, they sud-

Norfolk & Western's final heavy coal hauler, the Y6b compound 2–8–8–2, heaviest of its type built denly discovered that the only steam line remaining was also the most profitable! It was a traumatic experience and there seemed only two ways out of the dilemma—for everybody to admit they were wrong and return to steam operation, or to somehow dieselise the N&W and hope that time would erase memories of its intransigence. Of course, the diesel manufacturers, and the vendors of fuel for them, pressed hard for the expensive boxes of flatulent horsepower, whilst organisations mesmerised by public relations experts and their slick 'corporate image' phrases were too afraid to do anything but be good sheep and follow the leader. Luckily for the diesel interests, Norfolk & Western's castration operation was easy—Pennsylvania, already hooked on diesels, had a controlling interest in N&W and it was simply a matter of throwing out the old president, installing a suitably diesel-addicted replacement and rapidly ordering hundreds of diesels to replace the steam. In 1958 the railway was all steam bar a few switchers, and by 1960 it had all gone—old, new, large and small, in an act of vindictive anti-steam spite which makes Britain's Beeching regime appear almost benevolent by comparison. The official reason given for this sudden act of vandalism was that 'spare parts were not available', but since Roanoke built large numbers of complete new locomotives one cannot see that they would have had any difficulty in manufacturing a few spare parts.

Southern Pacific

The SP had a speciality in its application of the Mallet principle—cab-forward operation—dictated by the conditions of the Sierra Nevada main line, Forty miles of snowsheds and thirty-nine tunnels on a line which climbed to 7,000ft altitude in 140 miles with a ruling gradient of 1 in 42, increasing for short stretches to 1 in 38. Train haulage had always been a problem over this section, from Roseville, California inland to Nevada, and the original 'Wild West' 4–4–0s, used very much in multiple, gave way in the nineteenth century to 4–8–0s and even an experimental 4–10–0. By the early years of the present century increasing traffic was again becoming a problem and, with Southern Pacific by then part of the Harriman railroad empire, two of a batch of 2–8–8–2 Baldwin compounds were allocated to California. They hauled the loads splendidly but nearly choked the crews to death with exhaust smoke, and at such temperatures as to roast them as well. Breathing apparatus bled from the air brakes aided respiration, but the heat remained overpowering. A trial run made tender-first gave a clue to the final solution, which was to run cab-first with tender trailing behind the smokebox—a solution made possible only by the SP's use of oil as fuel. Accordingly, one of the two initial engines was converted as a trial guinea-pig and, once enginemen's prejudices had been overcome, the back-to-front Mallets became standard

Southern Pacific's cab-forward 4–8–8–2 No 4201 rolling through Santa Susana Pass, California, in 1950 with an Eastbound freight

Double-headed cab-forwards on express passenger work! 'The Owl' in Soledad Canyon, California, loaded to seventeen cars, behind Nos 4285 and 4274

power on 'The Hill'. Forty-nine 2–8–8–2s were built from 1909 to 1913 and twelve 2–6–6–2s (later 4–6–6–2) with larger wheels for passenger work. After World War I it seemed that the day of the Mallet was over—first came 150 large 2–10–2s, superheated simple expansion engines with two cylinders, which replaced the passenger Mallets, and to a large extent the freight engines also. Much faster than the sluggish compound Mallets, they were supplemented in 1925 by the first of another new concept the Alco Southern Pacific type, a three-cylinder 4–10–2. Strangely enough, none of these non-articulated engines ever ran cab forward, although used over the same route as the Mallets. Eventually, traffic began to press hard on the ten-coupled engines and, rather than follow Union Pacific into the realm of twelve-coupled operation, the SP first of all rebuilt a 2–8–8–2 into a simple expansion engine with fire tube superheater and then, finding it successful and versatile, ordered the first of the new 4–8–8–2 type which were to become the system's hallmark. With driving wheels of the same diameter as the 'passenger' 4–6–6–2, the 2–10–2, and the 4–10–2, the new AC–4 class were the equal of all predecessors in the matter of top speed and greatly superior in tonnage ratings—in other words, just what was wanted. Proof of the pudding was in the re-ordering of the same basic type until 195 had been built over a period of seventeen years.

Rated at 2,250 tons over 'The Hill', three ACs per train were needed when the fruit rush was on, and 6,000 ton fast freights from the California orchardlands followed each other at short intervals up the Sierras. Usually, one AC led the train and two banked, cut into the train about two-thirds down to the end. Photographs show it to have been a stirring sight but, unfortunately, no audio recordings seem to have been made or to have survived. The first 4–8–8–2 was withdrawn for scrap in 1953 and by the end of November 1956 all were out of service, although a few hung on, stored serviceable, for another couple of years in case they were needed. The very last run was in December 1957, when AC-12 No 4276 ran an excursion for the local railroad historical society, reliving the days when ACs regularly worked passenger trains at speeds up to 75mph. The last one built, No 4294, is stuffed and mounted outside Sacramento station.

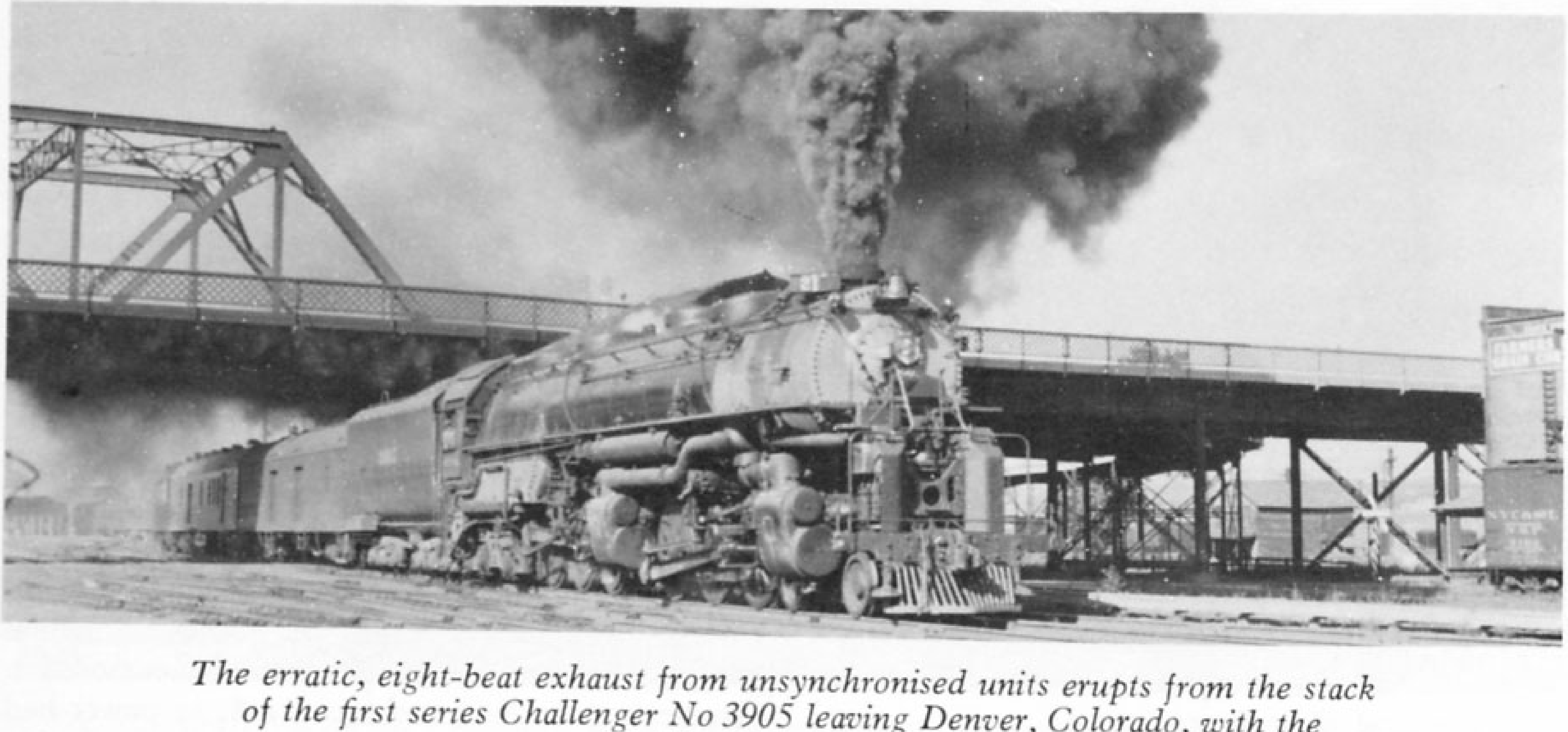
Union Pacific

This main line through the west, 'The Overland Route', was a tentative Mallet user in early days, buying three compound 2–8–8–2s in 1909 and fifty-five larger superheated compound 2–8–8–0s just after World War I. These low-speed, heavy haulers were not the ideal power for the UP, most of whose freight was run in fast, trans-continental block loads, often of perishable commodities. Gradients were long and fairly stiff, so power had to be amply proportioned resulting in a succession

Southern Pacific's coal-burning 2–8–8–4 heading west near Montoya, New Mexico, in May 1940 with 101 cars in tow

of designs—two-cylinder 2–10–2s, three-cylinder 4–10–2s (each with 63in drivers), and then the stupendous, three-cylinder 4–12–2 with 67in wheels, of which eighty-eight were built between 1926 and 1930. These latter, the Union Pacific type, seemed at one time to make the Mallet obsolescent for UP's type of traffic, and the more lumbering 2–8–8–0s, even after conversion to simple expansion, were normally used either on helper duties over the steeper gradients or on severely graded branches.

The 4–12–2, although giving excellent service, did have some drawbacks. The crank axle, inside motion, and Gresley valve gear all gave some form of trouble, as did the extraordinary long coupled wheelbase of 30ft 8in, and after the depression, when traffic began to look up again, UP started to investigate means of equalling or bettering the 4–12–2's performance, whilst eliminating its objectionable traits. Alco, the traditional supplier of heavy power, were consulted and with B&O's pioneer KK classes and Seaboard Air Lines'



The erratic, eight-beat exhaust from unsynchronised units erupts from the stack of the first series Challenger No 3905 leaving Denver, Colorado, with the 'Pacific Limited' in 1937

2–6–6–4s as a guide, a notable machine was evolved, the 4–6–6–4. All the troublesome features of the 4–12–2 were eliminated at the expense of having four instead of three cylinders, each with its own set of Walschaerts motion, whilst, of course, flexible high-pressure pipework needed inclusion. As with the 4–12–2, the firebox was above the trailing driving wheels, although this section was blocked off as a Gaines combustion chamber, leaving the actual grate behind the coupled wheels. It seems surprising that full advantage of the proportions was not taken to place a wide, deep firebox entirely over the trailing truck, even though this would have neccessitated moving the firebox about a foot further back, with possible problems in weight distribution. Some trouble was taken to redesign the Mallet articulation to give a less floppy movement and so ensure steadier riding at higher speeds on straight track. Union Pacific had sufficient confidence in Alco to buy forty 4–6–6–4s, labelled the Challenger type after one of the system's express trains, and fifteen were delivered in 1936, plus twenty-five the following year.

Though a magnificent conception, even the Challengers were capable of improvement and the second series, comprising sixty-five engines built in 1942–4, were completely redesigned. Cast steel beds replaced the built-up frames of the earlier series, with further stiffening up of the front unit's movement; the steam pressure was raised from 255 to 280psi and cylinders reduced in diameter from 22 to 21in, making the chassis, at least, capable of redesign into the British loading gauge! Free exhaust was ensured by fitting a double chimney, each handling steam and gases from a four-jet blastpipe, a substantial advance over the single blastpipe and chimney of the first series. Finally, a new concept of flexible piping was evolved, replacing the telescopic section with an elbow joint, with resultant improvements in maintenance and reduction of leakage. The engines' performance was as superb as their massive good looks, speeds up to 80mph were attained in passenger service, and in freight service a steady mile-a-minute could be maintained on the level with a 4,000-ton train. This was excellent work, and to place the engine in perspective for British and other readers unfamiliar with such large power, the Challenger dimensionally could be likened to three Gresley V2 2–6–2s designed for the same range of duties, yet it was capable of outperforming four V2s! The author well remembers working in the Swindon

Second series Union Pacific Challenger No 3936 leaves Denver in 1947 with a 52-car freight for Laramie, Wyoming

Double-headed Challengers Nos 3941 and 3997 assault Sherman Hill, near Burford, Wyoming, at 40mph, trailing fifty-nine cars, in May 1953

dynamometer car while testing V2 No 60845, hauling a 26-coach, 850-ton train from Stoke Gifford to Reading—60mph was really hard work for the 2–6–2 working at maximum steaming rate, and a maximum of 71mph was reached on the slight falling gradient through Didcot. Size for size, the Gresley engine would have had to reach the same speeds hauling about 1,200 tons to match a Challenger's horsepower-per-unit-size performance. Six thousand *drawbar* horsepower at 40mph was attainable with the Union Pacific 4–6–6–4s, corresponding to about 7,500hp in the cylinders.

Some Challengers were fitted with smoke deflector plates beside the smokebox, the only Mallets so equipped and indicative of the high-speed, short cut-off work they produced on passenger turns. Some, incidentally, were painted in Union Pacific's distinctive grey passenger livery, although most were freight black. Some ran for a while as oil-burners and were renumbered into a 3700 series but later reverted to normal form, burning the Wyoming coal mined in Union Pacific territory.

At the same time as Alco were producing the second series 4–6–6–4s, they were also working on the same design but next size up, in other words the 4–8–8–4 engines destined to become world famous as the 'Big Boys', the only articulated to combine eight-coupled slogging power with the 4–6–6–4's speed potential. Mechanically the two designs were identical, except, of course, in dimensions, and they were visibly from the same erecting shop and sired by the same drawing office. The operating plan which inspired the 'Big Boys' envisaged the same train hauled by a 4–6–6–4 over the easier sections of the main line and taken over by a 4–8–8–4 over the Wahsatch mountains, (from Cheyenne to Green River, Wyoming) with similar high speeds on the level and downhill sections. Reading between the lines of available test data, one senses that Union Pacific's dynamometer car was incapable of recording the full output of a 'Big Boy' and performance in service exceeded that on test, a reversal of the usual situation. Rated at 7,0000 drawbar horsepower for timetable computation, the 4–8–8–4s were probably capable of 8,000hp at the drawbar and 10,000 in the cylinders, a magic 'five figure' output which will remain unexcelled by any steam locomotive and has yet to be approached by any other selfcontained unit of more 'modern' motive power. In his frontispiece caption, Vilain mentions a figure of 12,000hp as a one-hour rating for a 'Big Boy', but this is hard to believe and well outside the outputs reached and recorded by other modern American power. The largest engine fully tested, on stationary plant and on the road, was the Pennsylvania 'Q2' non-articulated 4–4–6–4 with 7,998 indicated horsepower (say 8,000—no tests can be *that* accurate) and,

Union Pacific puts on its grandest show—two 'Big Boys', Nos 4014 and 4021, approach Granite Canyon, Wyoming, with 101 cars in tow. Something like 20,000hp is represented in the combination depicted here!

extrapolated to the 'Big Boy's' size, we again reach the 10,000 cylinder horsepower mark.

The Union Pacific ended its steam operations in the late 1950s with the two express articulated types, 4–6–6–4 and 4–8–8–4, supplemented by their equally superb high-wheeled 4–8–4 passenger engines, capable of racing at 100mph with trains of 1,000 tons (900 long tons). And, unlike many lines which relegated steam to secondary services, they kept them on mainline work right to the end, although by 1958 this meant during the seasonal peak only. Despite the size and power of these monstrous machines, the demand for faster and heavier trains eventually led to double-heading, using every available combination up to two 4–8–8–4s. The sight of this spectacular last stand of steam has fortunately been well recorded on film, but there seem to be few sound recordings of good quality available. Certainly nobody seems to have captured the incredible syncopated rhythm accompanying the progress of a Gresley-geared off-beat three-cylinder 4–12–2 piloting an unsynchonised simple expansion 4–6–6–4, or 4–8–8–4, as they teamed up to lift tonnage over the rise of Sherman Hill.

The Virginian

Unlike most, the Virginian Railway was a twentieth-century phenomenon, formed and expanded from a couple of short lines, the Deepwater and the Tidewater railways, becoming the Virginian in 1907. By that time the Mallet was already at large on the continent of North America and, following in the footsteps of Baltimore & Ohio, VGN took delivery in 1909 of four Alco 2–6–6–0s, class AA, Nos 500–3. The *raison d'etre* of such power on a new railway was its traffic and topography. Competing with neighbouring Norfolk & Western and Chesapeake & Ohio for coast-bound coal traffic, Virginian had a severe obstacle in its course to the seaboard—a fourteen mile ascent through the Allegheny mountains, from Elsmore to Clark's Gap, of which the final eleven miles was a solid 1 in 50 (2%), compensated for curvature of 12 degrees (485ft, or 7½ chains). As though that were not severe enough, there were five tunnels of the cramped cross section typical for single track railways.

Eight-coupled conventional engines were the standard power and the Mallets acted purely as helpers over the hill section. The four originals were soon joined by eight more powerful 2–6–6–0s with tractive effort raised from 70,000 to 90,000lb, engines 510–17 by Baldwin. Traffic was increasing at an incredible rate and these large engines soon found themselves so hard pressed that, in 1912–13, seven 2–8–8–2s were put into service—a multi-stage-boiler job from Baldwin with piston valves all round, and six larger Alcos with fire tube superheaters but slide valves on the inclined low-pressure cylinders. There were, by then, sufficient Mallets to use them as train engines and bankers, and standard procedure was to use one or two 2–6–6–0s at the head end with a pair of 2–8–8–2s banking. Even this was soon insufficient and the Virginian turned to Baldwin for a Triplex 2–8–8–8–4 which was delivered in 1916 and soon proved of little use. Shuttling back to Alco, a solution was found in the ten gigantic 2–10–10–2s already covered, and the final procedure in steam days was to run 6,000-ton trains headed by a 2–8–8–2 and banked by two 2–10–10–2, the total tractive effort, around 400,000 lb, leaving very little margin for contingencies. Steam operation through Clark's Gap lasted until 1925, when this section was electrified, not through any inability of the 2–10–10–2s to handle the loads offering but due to the sheer discomfort of working such mammoth engines flat out at walking pace through the narrow confines of the tunnels. No attempt was made to extend electric working and the Mallets, plus thirty-five further 2–8–8–2s of USRA design, Nos 701–35, Alco-built in 1919–23, handled traffic on the non-electrified sections. Former Triplex No 700 went into Baldwin's works in 1921 and emerged as 2–8–8–0 No 610 and 2–8–2 No 410, after which no further steam types appeared until after World War II, when eight 2–6–6–6s of C&O design were acquired, (Lima-built in 1945), for mainline haulage, and seven old 2–8–8–2s, ex-Santa Fé and originally N&W, came third-hand to assist the older versions on the mine runs. With such power, burning locally produced fuel, steam should have been safe for many years, but in 1955 the Virginian, like so many others, succumbed to the diesel epidemic and withdrew all its steam, including of course, the splendid 2–6–6–6s, executed with 75 per cent of their economical working lives still ahead of them.

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- † Technical information, drawings, etc.
- ‡ Historical matters, builders, dates, etc.
- § Action photographs.
- ¶ Current reports on locomotives' whereabouts, duties, etc.

LIST OF ABBREVIATIONS

AT & SF	Atchison, Topeka & Santa Fé Railroad
B & O	Baltimore & Ohio Railroad
C of A	Central of Aragon
CFD	Departmental Railways, France
CFOA	Ottoman Anatolian Railway
C & O	Chesapeake & Ohio Railroad
CP	Portuguese Railways
D & H	Delaware & Hudson Railroad
DM & IR	Duluth, Missabe & Iron Range Railroad
D & RGW	Denver & Rio Grande Western Railroad
D & SL	Denver & Salt Lake Railroad
FMSR	Federated Malay States Railways
GWR	Great Western Railway
JDŽ	Jugoslavian State Railways
JNR	Japanese National Railways
LNER	London & North Eastern Railway
LMSR	London, Midland & Scottish Railway
NBL	North British Locomotive Company
NP	Northern Pacific Railroad
N & W	Norfolk & Western Railroad
NWR	North Western Railway (India)
NYC	New York Central Railroad
NZGR	New Zealand Government Railways
O & K	Orenstein & Koppel
PLM	Paris, Lyons & Mediterranean Railway
PNKA	Indonesian State Railways
PRR	Pennsylvania Railroad
RENFE	Spanish National Railways
SACM	Societé Alsacien de Constructions Mechaniques
SAL	Seaboard Air Lines
SAR	South African Railways
SLM	Swiss Locomotive Company
SNET	National Railway & Tramway Co (Italy)
SP	Southern Pacific Railroad
SP & S	Spokane, Portland & Seattle Railroad
UP	Union Pacific Railroad
USRA	United States Railroad Administration
WP	Western Pacific Railroad
ZH	Zafra–Huelva Railway (Spain)

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