J. N. Westwood

SOVIET LOCOMOTIVE TECHNOLOGY DURING INDUSTRIALIZATION 1928-1952

STUDIES IN SOVIET HISTORY & SOCIETY

General Editor R. W. Davies

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Preface

The author of this study is well aware, and sometimes penitently, that each chapter could easily be expanded to book-length. Nevertheless, the theme is narrow, which means that attention is concentrated on just one small sector of that wide front over which the struggle for Soviet industrialization took place. Essentially the book is about the choice of motive power for Soviet Railways; that is, what options were available, how and why they were chosen, and how successful the choices proved.

This volume is unlikely to interest all its readers all the time, but it may interest some readers for some of the time. This is because, having so narrow a theme, it frequently strays into adjacent topics. Such topics include the general railway situation in the USSR, problems of locomotive design, the transfer of technology between the USSR and other countries, the organization of research and design, relationships between ministries, and the interplay of engineering with economic and political factors in technical decision-making and in innovation. The examination of these related topics may not be exhaustive, but it does have the virtue of illuminating them from a hitherto unfamiliar angle.

Literature in English about Soviet Railways is more plentiful than is sometimes thought, and the opportunity offered by an expansive publisher would be squandered if used merely to recirculate material already available. For this reason, an occasional lack of balance has been accepted. This enables, for example, the Soviet dieselization programme of the 1920s to be treated in noticeably greater detail than the corresponding steam programme; the former is an important part of world technological history which has hitherto been only sketchily described, whereas the latter has neither of these justifications.

Although the kindness of two individuals has permitted reference to original sources, most of the narrative depends on printed works. Since discussion of technical choices was carried on very largely in specialized journals, it seems quite appropriate that great use has been made of these. Contemporary Soviet newspaper accounts have provided additional flavour; the author is aware that such accounts can be highly coloured, but assures the reader that, while those he has used or quoted may be embellished or polemical, the general picture they present does match the impression conveyed by other sources.

Among those other sources are conversations enjoyed with Soviet railwaymen and railwaywomen over the past quarter-century, and the author takes the opportunity to record his appreciation of those of them who gave their time to enlighten him. Substantial appreciation must also be expressed for the informed hospitality of the Centre for Russian and East European Studies of Birmingham University, and for a grant by the Social Science Research Council which considerably lightened the financial burden of the research incorporated in this volume.

Birmingham
February 1980

J. N. WESTWOOD

1 The Foundations, 1912–1922

Locomotive design and research

In the decade before 1914, when public discussion of Russian institutions was relatively free, the railways were a frequent target of abuse. They were said to be incapable of handling the traffic offered by the developing Russian economy and their losses were said to be the biggest drain on the Treasury. In reality the railways had been expanding their work continuously, although the standard of service was not high. Most of the railways, too, by 1914 were regaining the profitability they had lost in the first years of the century.

Most of the mileage was owned by the several state railways, but six large private companies still survived in 1914. The Ministry of Transport supervised both the state and private companies, although several non-operating matters were reserved to the Ministries of Finance and of State Control. In view of subsequent inter-ministerial difficulties concerning Soviet railway problems, the comment of a 1907 enquiry is interesting:

> . . . the Commission must point out that there is complete anarchy in the activity of the separate ministries, each pursuing in railway matters its own goal and often in circumstances of mutual hostility, where there ought to be agreement and mutual aid.[1]

In the second half of the nineteenth century the Russian railways began to buy their locomotives and other equipment from domestic producers. However, this break from foreign suppliers was accompanied by a continuing interchange of experience between Russian railway engineers and their western counterparts. In 1892 the young International Railway Congress Association held its second conference in Moscow, presided over by the Belgian locomotive designer Belpaire. Belpaire, and French engineers, helped with the design of certain Russian steam locomotives. A little earlier, the Russian railway engineer Borodin had presented a paper to the Institute of Mechanical Engineers in London.[2]

In tsarist Russia there was hardly a national school of locomotive design as there was in Britain, America, or France. Both in external appearance and in the chosen technical solutions, Russian locomotives were akin to those of Central Europe. But in certain fields Russian locomotive engineers and researchers had not been content to follow others; especially in the methodical testing of locomotives, and the adaptation of locomotives to burn unusual fuels, enough work had been done to attract the interest of foreign railways.

Aleksandr Borodin is regarded by Soviet historians as the greatest locomotive engineer of tsarist times. Among many other things, he founded the Russian tradition of locomotive testing when, in the early 1880s, he built the world's first stationary locomotive testing plant. As this plant could only absorb low power outputs he turned his attention to line testing, and found that the prevalence in Russia of long, flat and straight lengths of track presented ideal conditions for taking measurements at constant power outputs.[3] Borodin attracted several engineers to the technique of locomotive testing. Later, a younger man, Yuri (George) Lomonosov, of whom much would be heard later, developed locomotive testing still further so that it appeared to progress from a mere technique to a new, real, science. This scientific aura, the consciousness that the work really seemed to be extending the range of human knowledge, and its intrinsic interest, made it an alluring prospect for young railway engineers, especially for those who were ambitious and preferred the theoretical to the practical. It was not long before locomotive testing became a distinct discipline and its practitioners a self-confident élite. One mark of the distinction accorded to these researchers was that their special test trains were accorded the same line-clear privileges as the Imperial Train. Apart from one incident, when a prowling policeman convinced himself that a calorimeter glimpsed in the dynamometer car was an illicit vodka still, the researchers were more or less given the freedom of the railway network.[4]

The aim of testing, whether out on the line or in a stationary plant, was to discover what actually happened when a locomotive was at work, and with this knowledge to improve existing designs and build better new types. The enquiry was both thermodynamic and mechanical. Line testing techniques were far more advanced in

Russia than in other countries, where testing was small-scale and unsystematic.[5]

One of the ways in which Russian locomotive practice resembled that of Germany and Austria was the large role played by academic researchers in the design of locomotives and their components. In Germany locomotive designers held, typically, chairs in neighbouring universities or higher technical schools; professors designed and designers professed. This practice was even more marked in Russia, where new locomotive types were designed not so much by professors as by committees of professors. Lomonosov and his colleagues were employed by the Ministry of Transport, but they spent much of their time teaching or researching in higher educational institutes. The leading institute in locomotive design was the St Petersburg Institute of Transport Engineers, which trained engineers like Lomonosov and in due course received the best of its graduates back as teachers or researchers.[6]

Lomonosov himself had had a fairly varied life, and it would be an exaggeration to claim that he had little practical knowledge of what daily life on the railways was like. However, his approach was noticeably 'academic', by which is meant that he was more at home with theory than with practice. The same could be said, and will be said, about his colleagues and successors. This had its effect in the field of locomotive testing, where specialists seemed intent on creating a new pure science of traction computations (*tyagovye raschyoty*). The end-product of this new science was the so-called 'locomotive passport' compiled from test data and showing such parameters as the horsepower developed at different speeds by a given locomotive, how much tractive effort it could exert, how much steam it could produce at different rates of fuel consumption, how much steam it used for different outputs. These parameters were produced as tables or curves, and from the operating point of view the most important by-product was the curve showing a given locomotive type's rating in terms of permissible loads up various gradients.

As the years passed traction computations became ever more refined, until it could be said with only slight exaggeration that for whatever moved inside a locomotive the Russian engineers could produce an appropriate equation or curve. But it might also be said that eventually the practice of locomotive testing actually degenerated into the theory of traction computations; locomotive passports could not fulfil what they promised. A steam locomotive's performance did not depend on what its passport specified, but on such changeable factors as the wear of its cylinder linings, the amount of unwanted deposits in its boiler or firetubes, the size and other variables of its coal, the ambient temperature, local humidity, and what its driver and fireman had been doing the night before. The researchers did make what seemed to them appropriate assumptions to allow for such factors, but such assumptions were in no way 'scientific' or indisputable. The sally of a British locomotive engineer in conversation with Lomonosov seems quite understandable: 'Professor, you know that in this country trains are pulled by locomotives, not by differential equations'.[7] Locomotive passports were not adopted in other countries, except in Poland (where one of Lomonosov's colleagues, Czeczott, returned after the Revolution).

But in the pre-1914 decade the Russian locomotive testing programme, unmatched elsewhere in the world, seemed to mark a great step forward. Formal recognition came in 1912, when the Ministry of Transport established the State Locomotive Testing Office. This office may be regarded as the foundation from which subsequent Soviet railway research institutes developed. Its first director was Lomonosov. For those brought up in the Russian bureaucratic tradition and touched by the new respect for scientific method, the Office's locomotive passports were impressive documents. They were printed, issued by a state body, and were clearly scientific. They maintained their reputation after 1917, even though they were a momentary embarassment when the demands of the economy required more from locomotives than the passports promised. This problem, as will be seen, was solved in that spirit of compromise typical of the 1930s: a few heads rolled and the passports were altered 'to bring them closer to reality'.

Even in 1912 there were those who regarded the granting of credits to Lomonosov for his State Locomotive Testing Office as simply the subsidizing of a great folly.[8] Among these opponents were, apparently, N. L. Shchukin and M. V. Gololobov. Gololobov was a designer employed at the Putilov Works who had supervised the construction of a stationary testing plant in that factory. Professor Shchukin was a very influential locomotive specialist whose approval, by 1910, was almost a prerequisite for the adoption of any new locomotive design. This influence was derived not from personal experience of locomotive design or practice, but from his chairmanship of a key committee.

The influence of Shchukin was probably beneficial on the whole, but his reputation has been subject to severe criticism. Rakov, the author of a definitive work on Russian locomotives,[9] is fairly scathing in his attitude. However, supporters of Shchukin have pointed out[10] that the latter had made an enemy of Lomonosov, and Lomonosov used to spread all kinds of hostile stories about those whom he disliked. Shchukin's key post was his chairmanship of the Commission for Rolling Stock and Motive Power, which he held throughout its life (1901–17). This was a body established to coordinate the work of the locomotive and car-building companies with the requirements of the state and private railways. It came to be known as the 'Shchukin Commission', although its first title had been Commission for the Elimination of the Defects of the Standard Freight Locomotive.

The freight locomotive referred to was the type O (see Figure 1), destined to be the most numerous locomotive type on Soviet railways until the late 1930s, numbering about 9000 units. It was an 0–8–0 (that is, it had eight coupled 'driving' wheels, without small carrying wheels at front or rear). The design had originated with the Pole, V. I. Lopushinskii of the private Vladikavkaz Railway, and the design department of the Kolomna Locomotive Works. The first had been built in 1890 and in 1893 the Ministry of Transport had ordered the type for the different state railways, for which it became the 'normal' type. The advantage of having what became virtually a standard type became apparent in the war years of 1914–21, when units of this class

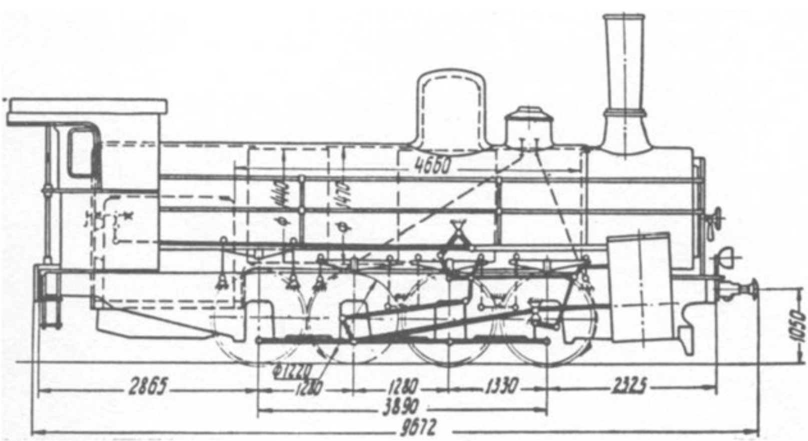


Figure 1 The type O freight locomotive. (Leading dimensions of steam locomotives may be found on p. 216.)

were easily transferred from one railway to another. However, by 1895 it had been realized that the design was a 'coal-eater', and had other defects too. It relied on the Central European principle of the 'cross-compound', in which steam went first to a small cylinder and then, having given up some of its pressure, passed to the larger, second cylinder. This was a very attractive theory, but practice showed that it was not possible to get good results except at certain speeds; one basic theoretical defect, which for long was regarded as only a practical problem, was that it was virtually impossible to guarantee that the first cylinder would produce exactly the same power as the second. Up to the mid-1930s there were successive attempts to improve this type, and the Shchukin Commission was the first such attempt.

The Shchukin Commission was especially condemned for its part in delaying the introduction of the E type locomotive. This freight design, destined to be not only the USSR's but also the world's most numerous locomotive type, first appeared in 1912, although Lopushinskii and the Vladikavkaz Railway had made their first proposals in 1909. But this was a ten-wheeler, with all wheels coupled (that is, an 0–10–0), and the technique chosen to enable such a long rigid wheelbase to conform to the ruling curves of Russian railways was modified during that gestation period. This and other modifications, requested by the Shchukin Commission, resulted in a better locomotive (see Figure 2).

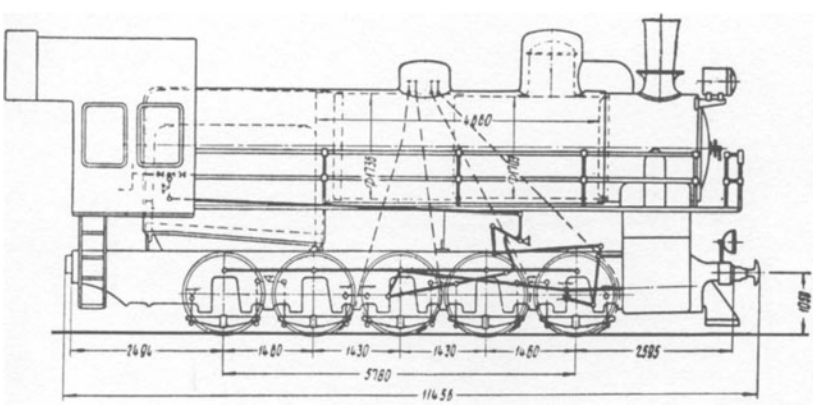


Figure 2 The class E 0–10–0, as supplied by Swedish and German builders.

Rakov alleges that Shchukin was against the E because it rivalled his own preferred replacement for the imperfect O type. This preferred solution was the type Shch 2–8–0, also a cross-compound. The class designation Shch was in honour of Shchukin, although the latter was in no sense the designer, having merely given the outline requirement to the Kharkov Locomotive Works, where the design was made by A. S. Raevskii. This type was built in relatively large numbers but was never as popular as the E.

Passenger locomotives of the time included several designs of 4–6–0, both simple and multi-cylinder compound, and a 2–6–0 version (type N) of the O type. The former tended to be favoured by the private railways and the latter by the state companies, but this was not a rigid distinction. Shchukin, Rakov implies, also opposed the introduction for the state railways of the highly successful type S 2–6–2. This was designed and built by the Sormovo Works from 1910 and became the basis of the standard Soviet passenger locomotive, type S. The S had the Central European feature of a pivoted arrangement for the leading carrying and leading coupled wheels (the Zara-Krauss truck), and proved to be a very fast and quite economical machine. On the fastest schedules offered in Russia in 1912, the trains of the state North Western Railway between St Petersburg and Luga, these locomotives brought the time for the 138km (88 miles) down to 1 hr 40 min, compared to the three hours required by the N type 2–6–0.

Both the E and the S types were delayed by the bureaucratic procedures of the Shchukin Commission, but the fact remains that both designs were finally approved by that body. A long period 'in committee' continued in Soviet times, as did the very thorough line testing of new designs before approval was given for series production. The type S, in particular, received very thorough line testing between Moscow and St Petersburg, in competition with a 4–6–0 design of completely contrary design philosophy; the former was a two-cylinder simple expansion machine with a larger firebox permitted by its trailing supporting axle, while the latter was a multi-cylinder compound with a smaller firebox. The reports of the tests were published at great length and favoured the S type, although supporters of the 4–6–0, like Raevskii, said that the type of 4–6–0 chosen for the test was in any case not designed for a dead-straight, dead-flat, main line like that between the two capitals.

Meanwhile, those who supported locomotive testing but distrusted line testing and the passport system were trying to get a large stationary testing plant built. Gololobov's plant at the Putilov Works had been used for testing a few standard designs but was intended more for testing the performance of new components and modifications, and also as a substitute for the test run (*obkatka*) of new locomotives. After Gololobov retired from full-time work at Putilov this plant was hardly used, and seems to have been dismantled in the First World War. Meanwhile, for years Russian locomotive engineers had been discussing the creation of a centralized, open-to-all testing plant. In 1921 the building of such a plant was given priority by the new Experimental Institute of Transport (EIPS) but nothing came of this. In the meantime Gololobov, before succumbing to typhus in 1919, had built a small testing plant, leaving room for later enlargement, for the Petrograd Institute of Transport Engineers. This was used only for small-scale research in the 1920s and eventually found its way to the Bryansk Locomotive Works, where it was allowed to fall into permanent disuse.

During the First World War locomotive testing and design continued, although locomotive output fell as the different manufacturers were caught up by the demands of war. To ease a motive power shortage, locomotives were ordered from American and Canadian builders. Their design was jointly worked out by engineers of the Russian Railway Mission (notably Lomonosov, and his erstwhile colleague on the Tashkent Railway, Alphonse Lipets), and the locomotive builders. These units, of which about 800 were delivered between 1915 and 1918, had small differences between batches, but were essentially American, not Russian. They were very successful, largely because the transition to a 2–10–0 wheel arrangement enabled a larger firebox to be used; the deteriorating quality of coal supplied to the railways had persuaded the Ministry that such large fireboxes were needed.

Domestic locomotive production never entirely ceased (see p. 210). The lowest outputs were a result of the Civil War, with a trough being reached in 1922 at 71 units; this compares with the best pre-war output of 1266 units in 1906. From 1921 to 1923 Swedish and German manufacturers built 1200 units of the well-tried E type 0–10–0 for Soviet railways. This import, together with an increasing Soviet production of this design, meant that there was no great locomotive shortage in the years of economic recovery from 1922 to 1928. Whatever shortage there was derived from the inability of locomotive repair shops to return inoperable locomotives promptly to service; at the end of the Civil War 12,000 of the 19,000 locomotives on the books were stored in locomotive 'cemetaries' waiting for rehabilitation. But in any case, the determining railway bottleneck was the supply of freightcars. Moreover, the E type was not only sufficient in terms of numbers, but also in terms of design. A more powerful locomotive would have been desirable, but the catastrophic state of the track meant that even the E had an axleloading too heavy for most secondary lines, and for some main lines too. At the same time, the non-automatic couplings used on freight cars would not have withstood tractive efforts greater than those exerted by this design. Largely because the economy was crucially short of steel, these two deficiencies seemed unlikely to be remedied in the immediate future.

With passenger locomotives the situation was more lively, as the contest between the two-cylinder machine with a trailing axle and large firebox, represented by the state railways' S class, and the multi-cylinder 4–6–0 favoured by many of the one-time private railways, was not settled. During the 1920s three types of passenger locomotives were built, one being of the former concept, one being of the latter, and one being somewhere in between. The two-cylinder candidate was a revised version of the 1910 S. In 1914 the chief draughtsman at Kolomna Works, the German Felix Meineke, had been entrusted with a top-priority requirement for a modified version of the S, type Sv, which was to be suitable for the Warsaw–Vienna Railway (Meineke later said this had convinced him that war was imminent, but apparently this prescience did not do him much good, for in August 1914, while holidaying on a Volga steamer, he was detained, and he spent the war in internment). It was Meineke's Sv which became the basis of the Soviet Su, which in turn became the workhorse of Soviet passenger services until the end of steam traction. Compared to the S, the Su was slightly more powerful and was better-suited for heavy trains than the former, although not so fast. It was designed under the supervision of K. Sushkin, who as chief designer at Kolomna had supervised Meineke's Sv. Being of moderate size, the new design was easily assimilated by five locomotive works (Kolomna, Sormovo, Lugansk, Bryansk, and Kharkov) although the first 38 units turned out by Bryansk and Sormovo emerged considerably heavier than the design anticipated; with a load on the trailing axle of 19–20 tons, instead of 17, they were seriously route-restricted. Excessive weight of cast components seems to have been the cause of this misfortune, but in the subsequent batch (1926) the boiler was raised and advanced to redistribute the weight.

As an alternative to the Su concept, Raevskii, who had moved from Kharkov to the Putilov Works in 1910, devised a three-cylinder compound locomotive of the 4–8–0 wheel arrangement. This was an enlarged version of the compound 4–6–0, but was intended to incorporate many new or improved features. Raevskii called it his 'swansong' and 'favourite child' but was destined never to see it built. However, an earlier Raevskii type, designed in collaboration with Lopushinskii and known as the 'Vladikavkaz Pacific' was built in the 1920s. Unlike the pre-war units, built as oil-burners for the Vladikavkaz Railway, the Soviet-built locomotives were coal-burners, and were used on the Moscow–Leningrad line of the October Railway. These were four-cylinder simple machines, with a trailing axle beneath the firebox. They incorporated several new features, including wide and streamlined steam passages, a feature which other Soviet designers were slow to appreciate. However, these machines, especially the Soviet-built units, were subject to frequent crank-axle fractures, and only 66 were built.

Both in daily service and in tests the Su seemed a better locomotive than the Vladikavkaz Pacific. As for the M 4–8–0, this was built after Raevskii's death, but it did not include several of the features envisaged by its designer. It was soon judged a failure, and the 100 units were from 1933 rebuilt as two-cylinder simple units, after which their work was adequate but not sparkling. Thus it was the Su which was built in hundreds of units, right up to 1950, and which represented the end of attempts to perpetuate the multi-cylinder compound locomotive.

The claimed advantage of multi-cylinder locomotives was that they caused less stress on the track, especially at high speeds. Professor M.E. Pravosudovich, a railway engineer, devised a method of measuring such stresses by measuring the deflections of bridge spans caused by passing locomotives. Such trials, held in the early 1920s on the October Railway, seemed to show no appreciable difference between two- and multi-cylinder locomotives in this respect, although the technique was not sufficiently developed to make such results unassailable. It was while attending tests at the Likhobor Bridge outside Moscow, in company with some of his students from the Leningrad Institute of Transport Engineers, that Raevskii was knocked down by a train; he died of blood poisoning in hospital a month later.

This death (1924) meant that of the most notable locomotive engineers of the pre-war decade, only one, Lomonosov, remained in Soviet service. Lopushinskii had returned to his native Poland and

Shchukin, too, died in 1924; the latter had played a leading part in the research and planning of the new People's Commissariat of Transport (NKPS) and regret at his death was expressed in a special edition of the journal of the Commissariat's Scientific Technical Committee, of which he had been a prominent member.[11] It had been Shchukin who had prompted the establishment of the Experimental Institute for Transport (EIPS) in 1918. The EIPS, which could be regarded as a partial successor of the old 'Shchukin Commission' was later (1919) merged into a new organization, the Technical Committee of the NKPS, which in turn (1922) became the NKPS's Scientific-Technical Committee (NTK). It was the NTK which, until the upheavals of the Five-Year Plans, would supervise equipment testing, design, and research. In locomotive matters it continued the pre-revolutionary tradition of locomotive testing and the compilation of passports, and was concerned with the specification and outline drawings of proposed new locomotive types. It relied heavily on engineers of the old school, 'bourgeois specialists', who passed on their design and research philosophies to the younger generation. Among that younger generation was Valentin Egorchenko who, while still in his mid-twenties, had taken an active part in the establishment of the EIPS and in the 1920s became a leading light among the traction computation specialists.[12] However, the old 'Shchukin Commission' had not been completely replaced; a gap was left which was probably not apparent at the time, the gap between the railways and the now-nationalized locomotive works. The railways and their locomotive researchers were represented by the NKPS, whereas the locomotive builders came under the Supreme Economic Council (VSNKh). Although the working drawings of new locomotives continued to be made by the factory designers, as before, with the outline drawings produced by the NKPS locomotive specialists, the extent to which the NKPS could influence design and construction beyond the outline drawing stage was not defined, and there was no longer a Shchukin Commission to regulate this. After the deaths of Raevskii and Shchukin, who each had a foot in both camps,[13] there was growing acrimony between the two sides.

Even before the deaths of Raevskii and Shchukin, Lomonosov was regarded as the most notable Russian locomotive specialist. Outside the USSR, he is still considered to be Russia's greatest locomotive engineer. This opinion is partly based on his gift for self-publicity and the opportunity that thirty years' residence in the West gave him for the exercise of that gift. Nevertheless, that he advertised his successes so freely should not be allowed to disguise the reality of his talent. The fullest biography is an article by his acquaintance Brian Reed,[14] an article which has all the advantages and some of the disadvantages of being based on material supplied by its subject. As will be seen, other commentators had some scathing remarks to make about Lomonosov, but there can be little doubt that his prominence in the history not only of Russian but of world locomotive history, was well-earned.

Lomonosov graduated from the St Petersburg Institute of Transport Engineers in 1898, and subsequently held, sometimes simultaneously, a succession of engineering posts for different railway administrations. In 1913 he received the Salov Prize for a work on locomotive testing and, according to his own testimony,[15] his work on wheel/rail reactions in 1912–16 enabled higher speeds to be accepted. During the First World War he led the Russian Railway Mission to the USA. His great enthusiasm was locomotive testing and the passport system; he had hoped to incorporate in locomotive passports the results of his researches on the dynamic interaction of locomotives and track, but this was not achieved until the 1930s, after he had left the USSR.

Those who knew Lomonosov in the West describe him as flamboyant, charming, and a born raconteur. Elsewhere, he has been described as brash, ingratiating, and a born liar. Since both his friends and his enemies agree on these points, differing only in their choice of language, there is little need to dwell on them except to observe that Lomonosov's tendency to make a good story even better means that opinions derived from him (especially about his colleagues and their work) are best digested with the aid of a pinch of salt. A Swede who worked with him in the early 1920s[16] records that Lomonosov treated his subordinates with scarcely-concealed contempt and his superiors with proper respect, and that his so-called charm consisted in the retailing of usually quite untruthful anecdotes. When Lomonosov was appointed to the Russian Railway Mission, says this Swede, he lost little time in adding his wife and friends to its payroll. But the sturdy and respected Academician A. N. Krylov recorded that Lomonosov was a good man to work for.[17] Again, contrary views are less conflicting than they might seem. To anyone brought up in the Russian bureaucratic tradition, a soft approach to those above, and a rough approach to those below, was unexceptional and may even have been the best tactic for anyone determined to get things done.

As a real expert, self-confident and able to express his ideas forcibly, Lomonosov was just the kind of man Lenin was looking for at this period. As a railway expert, he became a member of the presidium of the Supreme Economic Council (VSNKh) in 1919 and was also a member of the highest council of the NKPS, its collegium. In that year too, he was chairman of the technical committee of the NKPS. On several occasions he advised Lenin on railway matters and presumably made a good impression on the latter. In 1920, as the Civil War was coming to a close, he was sent by Lenin to inspect the condition of the railways in zones recently occupied by the Red Army. He had also discussed with Lenin the question of building a pipeline from the Emba oilfield. It was while on his tour of the rehabilitated railways that his leaning towards independent action seems to have led him into some difficulties. He contrived to get himself appointed by Smilga, the chairman of the Caucasian 'Army of Labour' as the latter's deputy. Lenin, and the central Council of Labour and Defence, took this amiss, and ruled that the chairman had no right to make such an appointment. A few days later Lomonosov was back in Moscow and discussing with Lenin the proposed order for locomotives from Sweden. It was at this period that Lenin envisaged the appointment of Lomonosov as People's Commissar of Transport. On 24 May 1920 he discussed this proposal with 19 colleagues and specialists but evidently could not gain their approval.[18] However, Lenin did not abandon his idea, although the term Technical Director of Transport was substituted, implying that Lomonosov, if appointed, would be effective director but supervised by a trusted political figure as People's Commissar. At the end of 1921 the People's Commissar of Transport (Dzerzhinskii) was writing to Lenin to explain why Lomonosov would not be suitable as Director of Railways:

> I asked his opinion about [Lomonosov]. He said he would not be able to work with him, and described him as an intriguer. So far I have not met a single railway worker who would speak out in favour of [Lomonosov]. And that alarms me. In these difficult times it is hardly possible to envisage him directing and uplifting transport, having relationships like these.[19]

In a documentary novel, N. Zarkhii portrays Lomonosov entering an office of the People's Commissariat and shaking hands only with the deputy commissar, not with the surrounding officials. The latter discuss him afterwards, showing respect for his ability but regarding him as something of a dark horse. The author gives an account which, though fictionalized, rings true. 'All students study his textbook *Traction Computations*, it's the best guide for engineers', says one character, while another continues '. . . he loves adventures, . . . he has a sort of passion for shocking his neighbours. Before the Revolution, in 1916 I think, he surprised his colleagues by declaring himself a socialist. And you know why? Just to surprise everybody with his original behaviour . . .'[20] One thing seems certain, and that is that Lomonosov made enemies among those below him, and at a period when yesterday's underdog could be tomorrow's top-dog this was perilous. Lomonosov was probably quite accurate when, some years later, he said he left the USSR because he felt he was no longer safe.

In May 1920, however, he seemed to have a very bright future in the USSR. In June, after discussion in the Politburo, it was decided to send Lomonosov to Sweden to arrange for the building there of locomotives for Soviet railways. Because of a mistrustful attitude on both sides, the negotiations were not smooth and eventually a large part of the order was transferred to German firms.[21] Meanwhile Lomonosov set himself up in Berlin with the Russian Railway Mission, renewing his acquaintance with German engineers (including Meineke), with whom he pursued his interest in locomotive testing and in diesel locomotives.

Lomonosov's work with diesel traction will be described later. In the 1920s it was in this new field that the most interesting Soviet progress was made. But most NKPS locomotive specialists still regarded the steam locomotive as the motive power of the future. With the continuing perfection of traction calculations and line testing the steam locomotive was expected to develop even further in power and efficiency. Nevertheless, political circumstances, namely the interest of the ruling Party in railway electrification and dieselization, caused the NKPS to devote more attention to new forms of traction than it would perhaps have wished.

Diesel and electric traction

As will be seen in the following chapter, in the late 1920s the USSR was the world leader in mainline diesel locomotives. Soviet historians regard 1922 as the key year, and rightly so, for it was then that the government allocated funds that ensured the building of the first mainline diesel locomotive prototypes. However, well before 1922 Soviet engineers had discussed, and even designed, such locomotives. Even before 1900 the Vladikavkaz Railway had produced a drawing of a locomotive in which an oil engine drove a pump producing compressed air which was to be fed, in place of steam, to the cylinders of a conventional locomotive. In 1905 the Russian Technical Society of St Petersburg heard a paper by two engineers proposing a diesel-electric locomotive which, with its swivelling powered trucks and tramway-style traction motors, came remarkably close to the diesel locomotive of modern times.[22] At the Kolomna Works, which apart from building steam locomotives and boats was a successful manufacturer of diesel engines, several diesel locomotive designs were worked out between 1909 and 1913. Felix Meineke was one of the participants in these projects, which were intended to widen the market for Kolomna's diesel engines. On the Tashkent Railway, which had problems of water supply with steam locomotives, Alphonse Lipets designed an ingenious pneumatic clutch intended to solve the fundamental problem of diesel locomotion, the successful transmission of high-speed diesel revolutions to the slow-moving locomotive wheels. With Lomonosov, who for a time was traction engineer of that Railway, Lipets designed a diesel locomotive incorporating this clutch and in 1913, after the proposal had passed through the various committees and councils of the MPS, government funds were granted to build two prototypes. However, August 1914 put an end to this project. Meanwhile, Professor V. I. Grinevetskii at the Moscow Higher Technical School (MVTU), was designing a diesel-type engine for railway use, in which the cycle took place in three successive cylinders. Grinevetskii, whose avowed hostility to the Bolshevik regime came to an end in 1919, when he died of typhus, is regarded almost as the Grand Old Man of Soviet diesel traction. His work *The Problem of the Diesel Locomotive*,[23] which envisaged 12,000 diesel locomotives at work on Soviet Railways by 1930, was published posthumously in 1923.

Among Grinevetskii's pupils at MVTU before the First World War was A. N. Shelest.[24] Shelest was one of those men, quite numerous in tsarist Russia, who took the opportunity of 'second-chance' education quite late in their careers. Shelest started his working life with a position as draughtsman in the main workshops of the Moscow–Kiev–Voronezh Railway. But after six years there he moved to an American railway brake company near Moscow (this company made the 'New York' air brake, then being fitted by the Vladikavkaz and certain other Russian railways). He stayed there five years, becoming manager of the technical department. It was when he was in his thirties that he became a student at MVTU, having first passed his school-leaving certificate 'Attestation of Maturity' by external examination. At MVTU he fell under the influence of Professor Grinevetskii and when, after five years, he began his diploma project, he chose a diesel locomotive theme. This was in 1912, just as the Sulzer Company in Switzerland was building an experimental mainline diesel locomotive for the Prussian Royal State Railways. Shelest's project was the design of a diesel locomotive which would be an improvement on the Swiss design. In preparation he worked a spell as student locomotive driver, and also spent some time at the Kolomna Works.

The first part of his work consisted of a critique of the Sulzer locomotive, showing that it could not possibly give economic results because it did not solve the transmission problem satisfactorily.[25] That is, the problem of transmitting the power of the diesel engine effectively at all speeds was far from solved. Instead, Shelest proposed in his project an entirely new system, having rejected the concepts of electric, mechanical, hydraulic and pneumatic transmissions. Shelest's own proposal, which he called a 'mechanical generator of compressed gases', is shown in Figure 3. Like other projects, it utilized the machine and valve gear of the conventional steam locomotive, but replaced compressed air with hot gas as the medium, thereby avoiding the sub-zero temperatures which air expansion entailed.

Shelest patented his idea promptly, applying to the British and Russian patent offices in 1913 (the London Patent Office evidently gave the best service, the British patent being granted in 1914 and the Russian only in 1915). In 1915 he successfully defended his dissertation and thereby gained the qualifying title of mechanical engineer. He then joined the staff of MVTU which, under its later name of the Baumann Moscow Higher Technical School, became the USSR's centre for research and training in diesel locomotive work. It was at this school that Shelest would do most of his research. This was concentrated on further refinements of his gas generator diesel locomotive, which was a pity because he never succeeded in developing his idea to a stage where it could be applied for railway use. Thus, in a sense, much of his talent was wasted. But apart from being a teacher as well as researcher, Shelest was also a great publicist

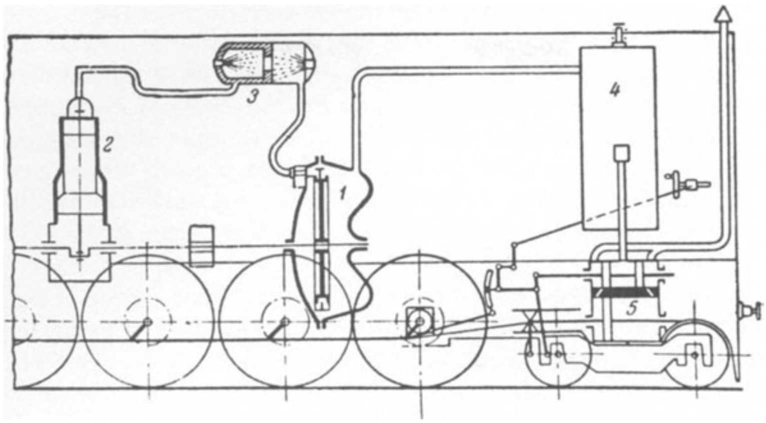


Figure 3 Shelest's gas-transmission system. In this, air is compressed by the pump (2), is ignited with injected fuel in the combustion chamber (3) and then in the second division of that chamber is mixed with cooling air or water. The gas then passes through the turbine (1) which powers the pump, to the pressure reservoir (4) from where it is supplied to the cylinders (5).

for the diesel cause. In his books and articles about diesel locomotive development he tended to give excessive space to the gas-generator concept but at the same time his preoccupation with this did enable him to view other developments in diesel traction with a critical eye; unlike other proponents of diesel traction in the inter-war period, he did not give an excessively rose-tinted view of Soviet progress with diesel-electric and diesel-mechanical locomotives. Partly this might be explained by his antipathy towards Lomonosov, but largely it was because he realized that the Soviet diesel locomotive was not economically competitive with the steam locomotive.

Lomonosov, one of the most forceful proponents of the diesel locomotive, seems to have been unconnected with the Moscow group centred around the MVTU. His primary allegiance was to the Ministry of Transport and his academic chair was at the St Petersburg Institute of Railway Transport Engineers. In mid-1920 he left to take charge of the Russian Railway Mission in Berlin, and seems to have lost little time in pushing the diesel issue. In his own words:

> In July 14 1920 a special meeting of 190 Russian experts with Trotzky [*sic*] in the chair unanimously expressed itself against my proposal to order some Diesel locomotive. Nevertheless owing to the support [*sic*] of Lenin this question was considered by the

> Soviet Government an [*sic*] on the January 4th 1922 the order of Diesel locomotives was found desirable, but the State Planning Commission (Gosplan) explained that their price must be not higher than that of steam locomotives of the same power. I applied to the Government and on October 31st 1922 the Cabinet decided to give me £100,000 in order to build abroad three Diesel locomotives and to give me a free hand for this work. This was the last meeting of the Cabinet with Lenin in the chair.[26]

This account is accurate as far as it goes, but the telescoping of 1920 and 1922 may give a false impression. It does not really provide any base for the claim that diesel locomotives were introduced 'against the wishes of Trotsky but with the blessing of Lenin'.[27] The special meeting of experts would have been an NKPS affair and Trotsky would have participated solely because at that time he was People's Commissar for Transport. The account is very much simplified; the process of obtaining the Party's and the government's backing for diesel traction was rather more complex, and some of the details are still unclear.

The arousal of Lenin's interest in, and support for, the diesel locomotive meant far more than the opportunity to at last build prototypes. Lenin's blessing implied the Party's blessing, and in later years, when the dieselizers were embattled against the steam and electric interests, this evidence of Party support was quoted again and again, and to some degree could compensate for the electrification protagonists' frequent references to the Party's support for the electric locomotive implied by its enthusiastic acceptance of the GOELRO plan. Those who have written of the history of the Soviet diesel locomotive (Shelest, Yakobson, Shishkin – all diesel engineers) agree about the broad picture of Lenin's 'conversion' in late 1921 and early 1922. The sequence of events that has been handed down over the years is that on 20 December 1921 Lenin read an article in *Izvestiya* about transport problems, in which the writer mentioned, among other things, that in America ordinary road trucks had been fitted with flanged wheels for service on industrial sidings and that in London the Russian engineer Kuznetsov's idea of using modified road trucks instead of locomotives had shown that a 30 hp truck could handle up to 10 freightcars. Lenin the following day telephoned a letter to *Izvestiya*, asking for more details and references to sources. Copies of this letter were sent to the Presidium of Gosplan, the scientific-technical organization of the Supreme Economic Council

(VSNKh) and to the NKPS,[28] with a request for the opinion of Soviet specialists. In this way Lenin discovered that Soviet engineers had already given much thought to the concept of the diesel locomotive and were ready to build prototypes which might revolutionize Soviet transport.

Although there is a wide gap between the concept of a motor truck hauling freightcars over industrial sidings and the idea of a mainline diesel locomotive, this sequence of events is plausible and acceptable. For some reason, however, it leaves out the fact that Lenin had shown interest in diesel traction well before this period. In 1919 he had read the comment of the Party's industrial expert Krasin on a Swedish newspaper article about diesel traction (it was a short private Swedish railway which in 1914 had bought what can be regarded as the world's first economically-viable diesel-electric motive power). Then on 16 March 1920 he had written to Krasin suggesting that foreign experts should be invited to participate in the design of a diesel locomotive for Soviet Railways.[29] Since in this period Lenin was in frequent contact with Lomonosov, who was not the kind of man to let slip opportunities for advancing his favourite projects, it seems reasonable to assume that Lenin was well informed about diesel traction rather earlier than the 'standard version' of these events implies. If indeed it was Lomonosov who was at work in the background, the reticence of later commentators is perhaps explicable.

But whatever Lenin had been thinking in 1919 and 1920, nothing seems to have been done until 1922 towards the building of prototypes. True, Lomonosov in his capacity as head of the Russian Railway Mission appears to have made some contact with German engineers interested in diesel traction, among them his old acquaintance Meineke, but this most likely would have been on his own initiative, even though oral encouragement might well have been given by Lenin in May 1920, when the pair discussed the Swedish steam locomotive order.

According to Shelest, who provides no documentary evidence,[30] what happened when Lenin's letter to *Izvestiya* was circulated was that he then heard that Russian scientists and engineers had already designed a new type of diesel locomotive. He posed the question of building diesel locomotives, but opponents of the diesel locomotive objected that the building of experimental machines would be expensive and that the attempt in Switzerland to build a powerful diesel locomotive, undertaken with the greatest talents, headed by Diesel himself, had been unsuccessful. Lenin replied that Russian engineers 'would do what foreign engineers had failed to do'.

Lenin by this time certainly regarded the diesel locomotive as an important matter, especially in view of the fuel and fuel transport problems currently experienced by the railways. At his initiative, the question was reviewed at a meeting of the Council of Labour and Defence (STO). As a result the STO issued an order which, in effect, launched the Soviet diesel locomotive.[31]

The preamble of this order referred to the importance diesel locomotives had for the rehabilitation of the railways and for the fuel problem. It then instructed the Institute of Power Engineering (*Teplotekhnicheskii institut*) to draft a preliminary proposal and technical prerequisites for diesel locomotives, making use of the Technical Committee of the NKPS and the work already done by Professor Grinevetskii and his colleagues. One month was stipulated as the deadline. The second instruction was to the relevant technical departments to place whatever materials about diesel traction they had at the disposal of the Institute of Power Engineering. Then, within a week of receiving the proposals from the Institute of Power Engineering, the State Planning Commission was to arrange the conditions for the placing of appropriate orders at home and abroad. The fourth and fifth points concerned the financing and administration of these tasks, but the sixth requested Professor Lomonosov to send, as a matter of urgency, a detailed technical report of what he and his colleagues had done in this field while abroad. The final two points allotted one million gold roubles as prizes in an international competition for the best diesel locomotive designs, with arrangements made to finance the diesels of the Institute of Power Engineering from a separate account (that is, the latter would be built independently of the competition, which meant that they could be started as soon as the designs were approved).

Three weeks after this decisive meeting, Lenin was writing to the NKPS and the State Planning Commission (Gosplan) to hurry things along.[32] He said that no time should be wasted in using up the sums which might be left over as the delivery of imported steam locomotives drew to an end, spending it on 'the much more suitable for us diesel locomotives'. At the same time Lenin wrote a note to Gorbunov, who was secretary of the Council of Ministers, asking him to take a special interest in the matter, and telling him there would be a meeting at Gosplan that Wednesday between Lomonosov, Krzhizhanovskii and others and that he should have a word with Lomonosov.[33] On Monday, 30 January, a conference chaired by Dzerzhinskii recommended that three diesel locomotives be built abroad in place of three imported steam locomotives, on condition that their technical characteristics conformed with the conditions which would be imposed on competitors in the forthcoming diesel design competition. Different sources describe this conference as an NKPS or a VSNKh affair; this does not seem to be a material discrepancy; in view of the close coordination of the two organizations subsequently, through the Diesel Locomotive Bureau, it seems most likely that the conference included representatives of both. The Wednesday conference between Krzhizhanovskii, Lomonosov and others presumably marked the acceptance by Gosplan of this recommendation, Krzhizhanovskii being chairman of Gosplan.

However, the precise route followed by the funds granted by the government is unclear. Lenin, as quoted above, believed that the money could be taken from the funds allotted as payment for steam locomotives imported from Sweden. So evidently did Lomonosov, but in the letter quoted above he gives 31 October 1922 as the date when the 'cabinet' allotted him £100,000 for diesel construction. It seems that the Soviet government (more likely, someone within the Soviet government) raised objections to this unauthorized diversion of funds. A German engineer working with Lomonosov at that time says that since the 1, 750, 000 kronor 'saved' by the Russian Railway Mission and salted away by Lomonosov could not be delivered, Lomonosov ordered on his own account the diesel locomotives which the Hohenzollern Company was to build. Despite the earlier dissension in the Council of People's Commissars about the spending of the 'Swedish' money, the government approval did arrive in time to save Lomonosov from embarassment.[34] The whole affair seems characteristic of Lomonosov.

Taken together, the decisions so rapidly made in January 1922 ensured that the attack on 'the diesel locomotive problem' would take place on a broad front. At that time, too, projects for electrification seemed bright, because it had been given a prominent place in the economic ambitions and slogans of the Soviet government right from the beginning. The State Electrification Commission (GOELRO) of 1920 was an early and attention-catching manifestation of this, and devoted much attention to the electrification of transport as a part of the scheme to electrify the USSR. GOELRO, however, was only a continuation of a longstanding tradition, for nineteenth century Russian scientists had been in the forefront of the quest for ways to exploit electrical energy. It was only the outbreak of the First World War which prevented the opening of the partially-completed electrified railway from the capital to Oranienbaum.[35] Electrification of the Russian economy had always attracted the Bolshevik Party, even before 1917. Five months after taking power Lenin addressed to the Academy of Sciences a sketch of desirable research which embraced electrification of industry and transport. While the Civil War was still raging the NKPS was studying the possibility of electrifying the Suram Pass line and also the busy Moscow–Kursk line. At the same time a state committee was studying the possibility of electrifying the Murmansk Railway; this was an interesting, if not unique, project, for the electrification was aimed at preserving this line, which was threatened with closure.[36] In a frequently-quoted letter to Krzhizhanovskii in 1920 Lenin wrote that Krasin, the Party's industrial expert, had said that railway electrification was impossible, and enquired whether this could really be true, and if so whether the situation might not change within five years.[37] The GOELRO plan for the electrification of the USSR as a whole naturally included a large section on railway electrification.[38] In principle, railway electrification was to be coordinated with general electrification; for example, a given power station might be built to supply railway, industrial, and social needs, and this principle was maintained in later decades. The main proposal for railway electrification concerned the creation of 'super mainlines'. These were to carry very heavy traffic (and hence permit very low costs per ton-km) and would be electrified. The concept of super mainlines was later adopted for steam-operated routes in the five-year plans, enabling scanty investment to be concentrated on a few key lines which only in part were the lines scheduled in the GOELRO Plan for super mainline standards. As will be seen, the first Soviet electrified railway was not opened until 1926, and in the inter-war period railway electrification would lag lamentably behind the plan targets.

2 From Recuperation to Reconstruction, 1922–1929

The Background

In Soviet economic history, the mid-1920s are regarded as years of elemental discussion, with economists and Party leaders debating the best route to follow after the relatively easy return to the 1913 levels of production had been achieved. The acceptance of the First Five-Year Plan, which confirmed the USSR on its course of rapid industrialization, did not occur until 1929. Until then, in all parts of the economy, there was an odour of uncertainty, if not of unreality, in policy-forming departments.

Until 1929 the central administration of Soviet Railways in many ways resembled those remote places of the USSR where, according to travellers' tales, the inhabitants believed that Nicholas II still reigned, and that 1917 was just a rumour. True, the Ministry had been transferred from Petrograd to Moscow soon after the Revolution, and was no longer known as the Ministry of Transport (MPS) but rather as the People's Commissariat of Transport (NKPS). Many faces had disappeared (but not many more than might have been expected from a decade of retirements), and successive political heads (People's Commissars) had included such notables as Trotsky and Dzerzhinskii. But it was still a highly-departmentalized beehive, with officials passing to each other reports and statistics that were inevitably required but not inevitably needed. Those officials, despite the elevation or insertion of trusted Party workers in key places, were still men of the pre-revolutionary generation; and even those who were counted as revolutionaries were quite conservative in their attitude to running a railway.

In the 1930s there would be frequent reorganizations and upheavals in the NKPS, but its basic structure survived. This rested on its several directorates (*upravleniya*) and departments (*otdely*). The supreme policy-making group inside the NKPS was its Collegium, whose meetings were chaired by the People's Commissar or his deputy. Some coordinating functions were performed by committees and, on a more temporary basis, by commissions. The NKPS and its directorates supervised the individual railway managements and the latters' own functional departments. The number of railway administrations into which the network was divided varied; at first the railways were merely the old tsarist railways, but there were periods when subdivision was favoured (1940, which was such a period, would witness a 54-railway system).

The NKPS office with which this book is mainly concerned, is the Traction Department (later a Directorate). As will be seen, the scope of this Department could be a matter of dispute, but there was no dissent over its role in organizing the distribution and proper utilization of the locomotive stock. Its claims in the field of locomotive design, however, were stoutly resisted by the locomotive industry. Before the Revolution the 'Shchukin Commission' had successfully regulated the disagreements which naturally occurred between the locomotive users (the traction specialists of the Transport Ministry and of the individual state and private railways) and the locomotive builders (the various private locomotive works). Perhaps because it was thought that the nationalization of the locomotive works would automatically assure angelic relationships between the railways and the locomotive industry, no true replacement had been sought for the peace-keeping role of the Shchukin Commission.

As in tsarist times, locomotives were only parts of the production of the major locomotive building works; Kolomna, for example, built bridges, diesel engines and boats as well as locomotives, while Putilov was better-known for its armaments than for its railway material. The Lugansk Works, a comparative newcomer to the business (1900) had sought to specialize in locomotives, but in Soviet times failed to preserve this distinction. As late as the 1950s Kolomna would, it seems, be building simultaneously diesel and steam locomotives, diesel engines, space rocket components, and potato-picking machines. In 1930 Putilov would cease locomotive production in favour of tractors, while in the mid-1930s the Sormovo Works on the Volga would move away from locomotives towards submarine production.

During the inter-war Five-year plans the locomotive works came under a succession of central supervisory bodies.[1] At first, they were a part of the industrial empire ruled by the Supreme Economic Council (VSNKh) but during the First Plan they were taken into the new Commissariat of Heavy Industry. In 1939 they were affected by the proliferation of commissariats, most going to the new Commissariat of Heavy Engineering, although Kolomna, because of its diesel engine interests, went to the Main Directorate of the Diesel Industry of that Commissariat, rather than to the Main Directorate of Transport Engineering. To further complicate the picture, the NKPS did in fact have one locomotive-building works under its own control. This was the Kaluga Works, whose main output was low-power internal-combustion industrial and yard locomotives (*motovozy*). Presumably Kaluga's subordination to the NKPS was due to its important role as producer of locomotive components and spare parts. The frequently-changing and unsystematic allocation of responsibility for locomotive works must have led to significant day-to-day inconveniences. More fundamentally, it should be noted that in the First Five-Year Plan, when the design of new locomotives would be a source of dispute between the NKPS and the locomotive industry, the latter was ultimately subordinated to Kuibyshev and then Ordzhonikidze, who were members of the Politburo. The latter could be regarded as the final court of appeal in important technical disputes, and it was not until Andreev (in 1931) and then Kaganovich (1935) became successive Commissars of Transport that the NKPS secured representation in this supreme decision-making body.

In general the Soviet railways regained their 1913 levels at the same time as industry; ton-km in 1926 and freight tonnage in 1927. For a few months in 1927/8 railway administrators could look forward to a future in which steadily-increasing traffic would be matched by slowly-growing technical resources as railway restoration gave way to railway reconstruction. But reconstruction, the re-equipment of the railways with more advanced technology, depended on how far the railways' requirements could be met by industry. General shortages, especially of skilled labour, high-quality metals, and factory equipment, meant that whatever the NKPS might plan, actual achievement would depend on whether the required resources were made available. Thus in October 1927, when the NKPS made a report on its plan to reconstruct the railways' rolling stock it could not forbear to point out, not for the first time:

> The technical planning of measures for the reconstruction of rolling stock is carried out by NKPS organs, in appropriate cases in cooperation with VSNKh factories, in good time and without

> delaying the putting of measures into effect, so long as means are allocated . . . The extremely limited allocation of funds on account of the new NKPS works in general and on reconstruction in particular has in actual fact almost halted the modernisation of rolling stock . . . The NKPS emphasises these two points concerning the reconstruction of rolling stock and decisively puts forward the necessity of their being once more considered in the highest government organs . . . the question of the general modernisation of rolling stock must have a more fixed and exact place in the NKPS budget.[2]

The assumption by railway administrators that railway investment would parallel traffic growth was not shared by the economists of the State Planning Commission (Gosplan). This was confirmed in the First Five-Year Plan, which emphasized heavy industry (that is, the industries most productive of freight tonnage) and minimized railway investment (in the First Plan, which lasted a little more than four years, freight traffic would almost double, passenger traffic treble, but railway route mileage would grow by only five per cent). Because the move towards rapid industrialization began even before the First Plan was approved, the railways were awash with traffic as early as 1929. In the circumstances, new attitudes in the NKPS were required, and if not new attitudes, then new men. This became apparent in 1929, when a leading NKPS administrator of the old school was arrested for 'wrecking', and subsequently executed. He was not the last to make this kind of exit, but his fate probably had a greater impact than that of subsequent victims. He was N. K. von Mekk, a railway specialist all his life and a member of one of the great tsarist railway families; one of his ancestors had been the power behind the construction of the Kursk–Kiev and Libau railways. Perhaps the main lesson imparted by the Mekk affair to his former colleagues was that the Party and the government this time would stop at nothing to ensure that what was planned for the railways would be achieved by the railways.

In 1929 it was the freightcar shortage which was the determining bottleneck, but this did not mean that the locomotive builders, designers, and operators could relax. Better freightcar utilization was stressed, and one way of achieving this was to operate faster trains; that is, to provide more horsepower. Better car utilization attained by this and other means meant that more car-km and train-km would be achieved, which in turn meant better utilization of motive power, given the refusal to allow the locomotive stock to grow in step with traffic growth.

The Sixteenth Party Conference of spring 1929 was not too busy with the other aspects of the Five-Year Plan to neglect the opportunity to pass a resolution noting that in America, Germany, and Japan a passenger locomotive spent 14 hours daily in traffic, compared to 6½–9 hours in the USSR.[3] One measure to increase locomotive utilization had already been taken on the eve of the Five-Year Plan; this was the progressive introduction of 'impersonal' (common-user) locomotive manning. No longer did one crew have responsibility for one locomotive (which meant that when the crew was resting, so was the locomotive). The danger of this change must have been well known, at least to older railwaymen, at the time. Impersonal manning had been occasionally tried in tsarist days and had resulted in locomotives falling into rapid disrepair because no particular crew was held responsible. Only the old Ryazan–Uralsk Railway had made a success of the system, using it in the summer and harvest peak season and returning to 'personal' manning for the rest of the year, during which time the locomotives could convalesce. It was this introduction of impersonal crewing which was held mainly responsible for the abrupt increase in locomotive failures in 1929 and 1930; by January 1931 the Party and government would be calling for the replacement of impersonal driving by a scheme in which two or three crews shared each locomotive.[4]

However, changes in operating practices were accompanied by a realization that radical decisions needed to be made in locomotive policy. But it would not be until June 1931 that a Party plenum would pass a resolution that, in effect, would cut short further discussion and impose long-needed decisions.

Steam traction

By 1922 the early restoration of the locomotive works seemed feasible, with the end of the Civil War. The large order for locomotives placed in Sweden and Germany began to be criticized in some quarters, and it was suggested that it might be curtailed, using the alleged faults found in some units as an excuse. Although it had been Krasin who had first proposed this order (partly as a first, and successful, attempt to make Bolshevik Russia seem a plausible trading partner), it was Lomonosov who was blamed by the critics. Later, Lomonosov would also be condemned because these locomotives, naturally enough, caused more wear on the track than smaller locomotives; evidently his enemies were seeking ways to 'fix' him. The Soviet locomotive industry in 1923 was anxious for large railway orders, but the Soviet Railways' administration, headed by Dzerzhinskii, was unenthusiastic. Neither the NKPS nor Gosplan envisaged a return to 1913 traffic levels before 1932 (some forecast 1941), and there was already a large stock of E type locomotives which could not be used to their full advantage because of weak bridges. VSNKh, however, wanted large orders in order to resurrect and preserve the pre-1914 locomotive building capacity, and the resulting dispute went as far as the Politburo. A kind of temporary compromise was reached, by which production in 1923/4 would be neither expanded nor reduced. After Dzerzhinskii left the NKPS, he changed his mind and, among other things, claimed that for strategic reasons a strong reserve of modern locomotives was necessary. However, the new Commissar, Rudzutak, expressed the NKPS consensus that it was more important to invest in stronger bridges. References were made to Trotsky's alleged blunder in 1920, when he thought a railway crisis could be overcome simply by ordering new rolling stock. In the end, production did increase enough to keep six of the seven locomotive works moderately busy.[5]

However, in the later 1920s the NKPS modernization proposals were modest, compared to what would follow in the 1930s. The NKPS still considered the introduction of new steam locomotive designs a secondary matter. As priorities, it wanted to fit superheaters and feedwater heaters to its locomotives, to fit automatic train brakes, and to replace the old couplings with automatic couplings. The locomotive modernizations were expected to recoup their costs in saved fuel within three to five years, while the automatic brake, because it increased train speeds and dispensed with the need for trains to carry a complement of brakemen, would also be quickly recouped. Thus there would be a good return on these three investments and this, said the NKPS, should be offset against the cost of fitting automatic couplings. The experience of other countries (Japan in particular) had shown that a railway system's entire freightcar stock could be fitted with such couplings in just eight to ten years. The coupling was the determinant of locomotive policy. Even the strengthened non-automatic couplings fitted to many freightcars could withstand a tractive force of only 20 tons, whereas an automatic coupling might be expected to accept 65 tons. There was no

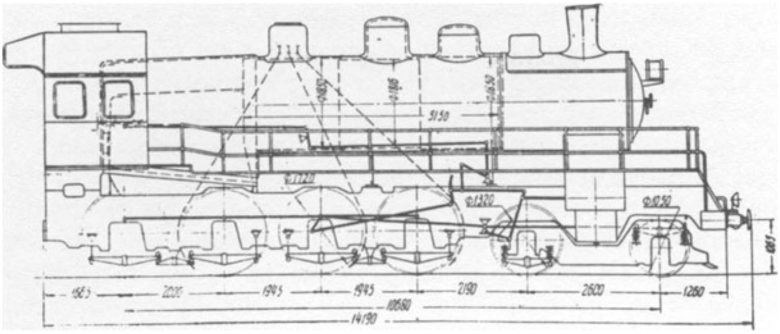


Figure 4 Raevskii's M type passenger locomotive, as rebuilt.

immediate point in introducing high-power freight locomotives if all they would achieve would be broken couplings. Nevertheless, if finance was forthcoming, the NKPS declared itself ready to introduce a locomotive just 25 per cent more powerful than the E type. This new type was already being designed and deliveries could start within about two years; it would be especially useful in increasing the line capacity of coal-carrying lines from the Donbas, provided that their track and bridges were strengthened. In the more distant future, said the NKPS, the perspective freight locomotive for around 1935–7 would be the type A, which would be twice as powerful as the E; American experience had shown the utility of such powerful machines. Passenger trains did not suffer from the coupling problem, and the NKPS praised itself for the introduction of the new M class 4–8–0 (see Figure 4), even though at the time (six months after its introduction) it must surely have had doubts about it. It also proposed a 4–6–4 tank locomotive to help solve the problem of the rapidly increasing commuter traffic; this design, a symbol of the NKPS's lack of faith in the plans for suburban electrification, was never built.[6]

From the tables on p. 210 it will be seen that locomotive production at this period was small. Moreover, the locomotives in production were of modest dimensions. Although these qualitative and quantitive limitations fitted the needs and constraints of the railways in the 1920s, they also represented the maximum that could be conveniently supplied by industry. Quite apart from the general supply difficulties affecting Soviet industry, there was the additional limit that the locomotive works were physically unable to build larger locomotives in series. Possibly Putilov, which had built the large M type, could have handled the production of large freight locomotives, but Putilov left the locomotive industry in 1930.

In the late 1920s, and the following decade, a particular bottleneck was the shortage of metals, and in particular of the higher grades of steel. Although in this book the emphasis is on the requirements and limitations of the users, the constraints imposed by the supply situation should not be ignored. As will be shown, the choice of steam locomotives for series production in the 1930s was very much influenced by material supply conditions and by the size and availability of factory space. With electric traction, heavily dependent on a metal in especially great demand and short supply (copper), supply constraints were exceptionally important.

Electrification

The State Electrification Commission (GOELRO) 1920 proposal for the electrification of the Russian Republic envisaged 3860 km (2400 miles) of electrified railway within 10–15 years. Being a herald of the good times ahead, the proposals were heavily publicized and in the process acquired some of the characteristics of Holy Writ. For the railways this was perhaps unfortunate, because electrification plans tended to be drawn up in conformity with the GOELRO proposals. This probably had two effects: it discouraged useful and practicable proposals which did not seem to fit in with GOELRO, and at the same time the increasingly obvious circumstance that neither home industry nor imports would be able to provide the equipment required for large electrification schemes created an atmosphere of unreality in the NKPS offices charged with studying electrification. It was probably this last circumstance which gave whatever justification there might have been for the accusations of inertia levelled against the electrification specialists of the NKPS.

The first electrification scheme to be completed was in fact not achieved by the NKPS. The line was a 20 km (12 mile) route from the centre of Baku to the oil installations of Sabunchi and Sükharany. This line, a branch of the Trans Caucasus Railway, had lost its freight traffic when local pipelines were laid, but had a heavy passenger traffic of oil workers travelling between home and workplace. By 1917, if not before, the traffic was well in excess of nominal capacity. By 1920, when the Bolsheviks finally took power in the city, the tortures suffered by regular passengers were horrific even by the standards of that time. With trains accommodating about 500 passengers offered to the thousands of peak-hour travellers, even the train roofs were not sufficient overflow areas. One and a half hours were required for the trip, even though there were only six stops.

Since urban transport was equally bad, the Baku city soviet in 1922 had decided to build an electric tramway. This, opened in 1924, was the first to be built under the Soviet regime. Having accumulated experience and electrical specialists in this enterprise, the Baku authorities set about the electrification of the Baku–Sukharany railway. A preliminary step taken in 1924 was the transfer of this line from the NKPS to the local authorities. Work began in 1925 and the first trains ran in July 1926. This was quite an achievement, as not only was electrification achieved, but also the complete reconstruction of the existing railway, including a rather grandiose terminus in Baku.

The transfer of the line from the NKPS does not appear in later years to have been regarded as a symptom of the NKPS's alleged hostility to electrification. Probably the NKPS and the Trans Caucasus Railway were very glad to rid themselves of this line, which needed complete reconstruction at a time when materials were short (that the Baku Soviet got what it wanted seems to have been a consequence of support from the local Party leader, Ordzhonikidze). In any case, at the opening cermonies the NKPS was well represented and at least one guest came from the Northern Railway, which at that time was in the process of electrifying its first suburban line out of Moscow. Undoubtedly this Baku line provided valuable experience. The Mytishchi Works, which provided the rolling stock (albeit with Austrian control gear and German brake pumps) must have learned useful lessons in the process; the rolling stock was built to NKPS standards, except that because of the climate lighter bodies were permitted, as well as the omission of train heating.

The Baku electrification seems to have been a great success initially. Because it was not an NKPS project some histories do not concede it the title of the first Soviet railway electrification, reserving that honour for the Northern Railway's Moscow scheme which was completed a couple of years later.[7] In the later 1930s, the line again fell on bad times. Speeds, punctuality and reliability sank close to the pre-electrification level, while utilization rates of rolling stock also declined drastically. The cause of all this seems to have been a rapid wearing out of rolling stock, combined with an absence, perhaps involuntary, of capable organizers. New rolling stock could not be obtained because all production was reserved by the NKPS for its own electrified suburban lines. In these circumstances the Baku Soviet chose what was probably the best option, returning the line to the NKPS in 1940.[8]

On the NKPS lines in the inter-war years, electrification remained well behind the plans. The alleged lack of enthusiasm in the electrification offices of the Commissariat was most likely simply a lack of faith in the electrical engineering industry. Reorganizations and purgings in the NKPS, which were frequent in the First Five-Year Plan, were ostensibly intended to stimulate a more active attitude, but probably had the opposite effect. They certainly led to unhelpful confusion. For example, the installation of equipment on the electrified lines was the responsibility of the NKPS Construction Directorate, which had its Electrification Bureau; the latter was 'reorganized' in October 1930, and it is characteristic of the NKPS of that period that when, a few months later, the head of this Bureau was asked to whom he was subordinated, he replied that he did not know.[9]

At the time of the June 1931 Party resolution Soviet Railways did not possess a single electric locomotive, and the only electrified section was the commuter line of the Northern Railway out of Moscow. The lengthy gestation period of this latter scheme became a salient characteristic of inter-war electrification. It was in October 1924 that the Northern Railway set up an electrification bureau to plan the conversion of the Moscow–Mytishchi and Mytishchi–Shchelkovo and Mytishchi–Pushkino commuter lines, which were heavily overloaded. Despite the NKPS's 1921 decision to standardize 3000 V dc supply, the 1500 V dc system was chosen for this and succeeding commuter electrifications on the grounds that it was easier to design reliable traction equipment for the lower voltage, given the technical facilities then available. This seems a reasonable decision; in the light of the troubles experienced with the lower voltage equipment it is quite likely that an attempt to use 3000 V would have represented a threat not only to reliability but also to human life. Apparently, though, some thought was given to the use of single-phase current but this would have entailed equipping the electrical trains with very heavy transformers and in any case presented problems with trains making frequent stops.[10]

Work did not begin on the Moscow–Mytishchi section until 1927, and was finished in July 1929. The next two months were spent on trial runs, with a new regular timetable being introduced in

October. The trains consisted of a power car flanked at each end by a trailer. The power cars were fitted with Dinamo traction motors but the electrical gear (notably the advanced control gear) was by Vickers. The motors were grouped in pairs that could be connected both in series and in parallel. This, plus the provision of field weakening when in parallel, provided three economical speeds. Following this first conversion, adjoining suburban lines were electrified and by 1933 the Northern Railway could claim that apart from providing a vastly better service the electrification had enabled 32 three-car trains to replace 38 S class locomotives, 400 four-wheel passenger cars, and five O type yard locomotives.[11]

However, not all went well with this first NKPS electrification. The great weakness was the traction motor design of the rolling stock. In the winter of 1929/30, according to one report, of the eight train-sets in service only one was working.[12] For this, said the article in the newspaper *Gudok*, the wreckers Chekhovskii and Mitkevich were responsible, for it was they who had selected the DP–150 motors, of foreign manufacture, for these trains. In fact, the DP–150 was of Dinamo design and construction. Its main fault was the insulation, which was of a quite unsuitable material (cotton). In October 1930 an allegedly mass meeting of the Northern Railway maintenance staff was held to discuss the continuing motor problem and the Dinamo Works was asked to send a delegation but, according to *Ekonomicheskaya zhizn'*, only a handful of Dinamo workers turned up, together with a German engineer from that establishment.[13] Two months later the same newspaper printed an article headlined 'Why do Soviet electric motors burn out?'. By that time another cause of poor performance had been revealed; like so many other Soviet lines, the track was sand-ballasted, and the sand was proving lethal for the motors. When taxed with this problem the Northern Railway's chief of operations (for some reason held responsible by the newspaper for this problem) was alleged to have replied, 'But our ballast is of the very best quality sand'.[14]

Meanwhile the NKPS planners in the 1920s studied at length, even *ad nauseam*, a handful of mainline electrification projects for which the demand was more forthcoming than the required resources. Among these projects was the Moscow–Kursk main line and the Suram Pass scheme. The Moscow–Kursk conversion would have been in accord with the GOELRO plan for a Moscow–Donbas electrified 'super mainline'. Moreover, its northern extremity out of Moscow carried a substantial suburban traffic as well as heavy long-distance freight and passenger services. But the NKPS never seemed very enthusiastic about this electrification, or, at least, could never quite make up its mind about it. In 1929 there was evidently a divergence between the NKPS and Gosplan, with the latter favouring electrification and the NKPS proposing that Moscow–Donbas line capacity could be more usefully increased by improving several of the north – south lines.[15] In 1932, as will be described, there was still an argument about this route, and in fact its electrification was not achieved until the 1950s.

No such doubts and indecision hindered the adoption of plans for the electrification of the Suram Pass line of the Trans Caucasus Railway, which was destined to be the first mainline electrification completed in the USSR. The section between Khashuri and Zestafoni, even after substantial realignment in the 1890s, presented sharp curves and gradients of up to 29 per cent (1 in 34). This was, moreover, an area where hydroelectric potential was promising, and in tsarist times the line had been regarded as a prime candidate for electrification. Until 1924 this difficult section, which was carrying ever-increasing traffic, was powered by 'Fairlie Patent' articulated locomotives. But their advanced age resulted in their withdrawal, or allocation to pusher service, and the line was taken over by E type locomotives. The long rigid wheelbase of these locomotives was unsuited to the sharp curves, and moreover two or three locomotives were needed for each train. All these factors combined to make electrification almost obligatory, so in 1928 the long-matured plans were put into real execution, with a start being made on erecting catenary, sub-stations and transmission lines. 3000 V dc was chosen, which meant that in 1932, when the electrification was completed, the USSR had three electric railways, each with a different system (the Baku line at 1200 V, the Moscow suburban scheme at 1500 V, and the Suram Pass at the mainline standard of 3000 V). Although this might appear to be a symptom of aimless planning, the use by the NKPS of 1500 V for suburban and 3000 V for mainline electrification was in conformity with the technical situation at that time, given the decision to use locomotives on the mainline sections and self-propelled electric trains for the suburban services.[16]

The first diesel locomotives

Thanks to Lenin's personal involvement, a bold start had been made with mainline diesel traction. The decisions of 1922 had initiated three lines of attack. Three trial locomotives of different types were to be the joint effort of German and Soviet engineers. An international competition was expected to produce additional ideas, and meanwhile the Institute of Power Engineering was to prepare its own outline designs which in due course could be accepted for production. The suggestion that this Institute's designs should take account of Professor Grinevetskii's work seems to have been largely ignored. Although K. A. Shishkin, a pupil of Shelest, was a member of the design team of the Institute's locomotive that was eventually built, the main work was done by Professor Ya. M. Gakkel' and A. Raevskii; it was therefore very much a Leningrad affair. The locomotive in question is regarded as the USSR's first diesel locomotive (and hence the world's first mainline diesel-electric locomotive) and, despite the farming out of certain components to other designers, and particularly to Raevskii, the general scheme and principle were Gakkel''s work.

Yakov Gakkel' (Haeckel) was one of the most interesting of the engineers associated with Soviet diesel traction. Apart from building the pioneer mainline unit, he designed many more and his ideas, in retrospect, seem very close to the concepts which would lead to the successful modern diesel locomotive. In many ways he was unfortunate; many of his projects were not built, he was often diverted from his main interests to work which the government considered more urgent, and those of his locomotive projects which were actually built ultimately failed not because of faults in their design but because of faults in their manufacture. Gakkel' was the son of the engineer who built the harbour works at Vladivostok and Kronstadt, but had chosen not to follow in his father's footsteps, specializing in electrical rather than civil engineering. While still in his twenties he took a leading part in a substantial hydroelectric scheme built for the Lena Goldfields Company. After this, he became one more of the promising Russian engineers who developed their careers with the Westinghouse Company. He worked in the Company's design office in the capital, engaged on projects for the new St Petersburg electric tramway. After the tramway had been accepted into service by the city authorities, Gakkel' was promoted to technical director, a position for which fluent English was required. Meanwhile, as a hobby and thanks to the posthumous royalties of his father in law (the writer Gleb Uspenskii), he was able to design, build, and fly his own flying machines. He became well-known in aviation circles and made the first, albeit short, Russian inter-city flight.

However, when his funds ran short, he retired from aviation. In the First World War he was technical director of a battery factory in the capital, taking a hand in the start of Russian production of submarine batteries and of searchlight lamps. When this factory was mothballed in 1918 he moved to Kiev as a tramway manager. It was here that he began to work on his designs for diesel-electric locomotives. Under his leadership, the diesel locomotive bureau that was established at the Institute of Power Engineering worked out the designs of about thirty diesel locomotives after the completion of the first mainline locomotive in 1924.[17] As will be seen, one of these, the promising E–el–4, was actually started at the Putilov Works but was left unfinished when that factory was withdrawn from locomotive work. From 1927 a particular preoccupation of Gakkel' would be the design of a six-wheel yard locomotive, for the kind of service to which diesel traction was even then well suited. In 1933 he was diverted to what at that time seemed the urgent task of designing an agricultural tractor that would use wood fuel. The resulting steam tractor made its trial run in September 1934, but the idea was not carried further although the steam propulsion design was adapted for use in steam cutters. After this, Gakkel''s work was mainly as a teacher and administrator, although from time to time he was consulted on diesel locomotive matters. From 1936 he was dean of engineering at the Leningrad Institute of Railway Transport Engineers. In diesel locomotive matters, he was perhaps further-seeing than many; he favoured electrical transmission at a time when most engineers regarded it as inelegant, he did not prematurely advocate the diesel as a replacement for the steam locomotive, only as a useful supplement; he appreciated the vital importance of developing automatic control systems and wheel-slip indicators, and he seems to have realized that it was the small unspectacular yard locomotive which had the most immediate prospect of a useful role for diesel propulsion. To regard him simply as the designer of the first mainline diesel locomotive is therefore misleading in several regards.[18]

Gakkel', like Lomonosov, was working on the diesel locomotive problem well before the decisions of January 1922. In 1921 he produced an interesting design in which the engine and generator were divided between two separate permanently coupled sections, each riding on two two-axle trucks, all eight axles being powered by tramway-style traction motors. Power was provided by a 600 hp diesel engine of Russkii Dizel' manufacture. This design was submitted to the Scientific-Technical Committee of the NKPS but was rejected. However, Gakkel' enlisted the support of other specialists and at a meeting in Gosplan chaired by Krzhizhanovskii and attended by several specialists it was decided to let detail design work proceed, with a view to building an experimental version. That meeting was on 4 June 1921, but by September Gakkel' had ferreted out among the disordered stores of the Baltic Shipbuilding Works a 1000 hp diesel engine much more suited to his needs. This was of Vickers manufacture and had been originally ordered for the submarine *Lebed'*; it was no longer required for that purpose, so Gakkel' designed a new 1000 hp diesel locomotive around it.

Gakkel''s design team in March 1922, by an order of the Council of Labour and Defence, became the Bureau for the Construction of Diesel Locomotives of the Professor Ya. M. Gakkel' System. This order was part of the decision taken at the same time to allot credits for building Gakkel''s locomotive. The work of the Bureau was to be supervised by a technical council. The members of this council were almost identical with an earlier committee set up within the Supreme Economic Council (VSNKh) to study diesel locomotive designs; this latter committee had been established, as a sort of precautionary measure, at the June 1921 meeting which had allowed Gakkel' to continue with his work. The Chairman was the veteran N. L. Shchukin, who in this way, at the close of a life spent with steam locomotives, was enabled to have a hand in the first diesel locomotive. Leading members included Gakkel' himself, Raevskii, the two electric traction experts, G.O. Graftio and A. V. Vul'f, B. M. Oshkurov the diesel engine specialist, Academician V. F. Mitkevich (who was interested in electrical systems), and D. B. Samoilenko-Gol'dman, who early in 1921 seems to have aroused Gakkel''s interest by proposing that he design a locomotive using an aero-engine with electric transmission. It was this group of experts, then forming the VSNKh Committee for the Study and Design of Diesel Locomotives, which examined and approved Gakkel''s 1000 hp project and sent it on to Gosplan in February 1922, together with a cost estimate. Krzhizhanovskii thereupon notified Lenin, who said that funds should be immediately made available. Three months later, in July, the STO did allot the desired credits and the way was open for the building of the locomotive.[19]

This locomotive was first known as Ge – 1 (Gakkel' – electric No. 1), then as Yu–e–002, finally receiving the number Shch–el–1 when it was decided that the class letter should indicate the type of steam locomotive to which it was equivalent (see Figure 5). The

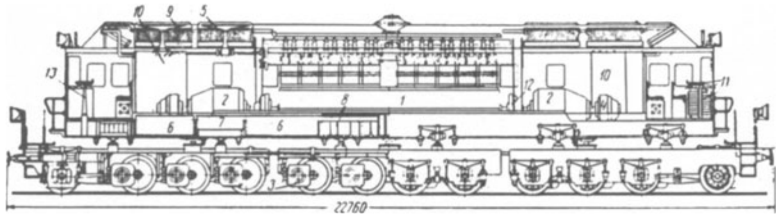


Figure 5 Gakkel''s Shch–el–1, his pioneer mainline diesel locomotive. Key: 1, diesel engine; 2, generators; 3, traction motors; 4, exciters; 5, fans; 6, fuel; 7, lubricants; 8, battery; 9, radiator; 10, water tank; 11, driver's control handle; 12, semi-rigid coupling; 13, hand-brake.

Vickers engine was used, and the generators were of 'Volta' submarine type. The traction motors were made at the Elektrik Works (formerly Deka), and the Putilov Works was entrusted with the chassis. The latter was designed by Raevskii, and was quite novel. Because of the weight and length of the locomotive it was decided to mount it on sprung trucks; apart from the usual axleweight problem it was also feared that the vibrations of the diesel engine would have a damaging effect on the track. Raevskii adopted a three-truck scheme with trucks of three powered axles fore and aft and a four-axle powered truck in the centre. This design of chassis proved very successful; although the locomotive weighed about 180 tons and was 22.76 m (75 ft) long it could safely move at speeds up to 75 kph (47 mph) and negotiate curves of 150 m (492 ft) radius.

Assembly took place at the Baltic Shipbuilding Works. The engine was bench-tested in August 1923 and by May 1924 was installed and connected to the generator. On 5 August 1924 the completed locomotive was rolled out on to the factory railway tracks. It was named 'Lenin Memorial Diesel Locomotive' in view of the recent death of Lenin, who had shown so much interest in diesel traction. Many adjustments had still to be made and the trial run was not expected until late September. However, the Leningrad floods of that month inundated the works and the locomotive's traction motors were damaged. As a result, delivery to the railway system was delayed, although it was possible to make the first mainline trip on Soviet Railways (from Leningrad to Obukhovo and back) on the revolutionary anniversary of 7 November.

Further adjustments were made and on 17 January 1925 the locomotive reached Moscow where, together with the diesel-electric locomotive ordered from Germany, it was formally received by the

NKPS. Line tests at this period revealed several defects, as a result of which the locomotive was not accepted by the NKPS until 30 December. Many of the defects were irremediable at the time. The main trouble seems to have been the diesel engine, which was not really suitable for railway use. Soviet commentators' statements that the design of the engine made it unreliable are ambiguous, but suggest that it suffered from the vibrations inseparable from railway service.[20] The electrical gear was rather complex and demanded frequent and expensive repairs. The battery which was used to start the diesel engine, apart from being heavy (seven tons) was unreliable. Finally, in the opinion of the NKPS officials, there was a disproportion between the heavy weight of the locomotive and its relatively small tractive power. In 1926, after acceptance by the NKPS, it worked some freight trains between Moscow and Kursk but spent at least six months out of service, running only 7500 km (4660 miles) in that year. It was returned to the Putilov Works for some improvements but in 1927 put up an equally unpromising performance. In December 1927 the Managing Committee of the NKPS Diesel Commission decided that it should be taken out of service.[21] In the meantime Gakkel' had worked out several schemes for improving it but these were never executed. For over two years it was stored and then, when the other diesel locomotives were transferred to Central Asia, it was sent to the Southern Railway for use as a mobile electric generator. It is now preserved, and normally is exhibited outside the locomotive depot of Khovrino on the outskirts of Moscow, where it can be glimpsed by passengers of the October Railway. Despite its lack of success it deserves its status as a museum-piece. In its main features it is closer to the modern diesel locomotive than was its contemporary, the more successful diesel locomotive brought from Germany under the auspices of Lomonosov.

The STO decree of January 1922 had envisaged the building of three different diesel locomotive prototypes in Germany. The first of these was a diesel-electric machine of 1200 hp, usually referred to by its final running number, E–el–2, but at first known as Yu–e–001. The technical office of the Russian Railway Mission was entrusted with the preliminary design requirements and on 15 December 1922 a contract was signed with the Hohenzollern Company for the detailed design and construction. Soviet specialists, notably Lomonosov, were to work with German specialists, notably Meineke, on this locomotive. But for various reasons, including the French occupation of the Ruhr, the contract was transferred in June

1923 to the Esslingen Works. This did not involve much change in the design group, but it had one advantage in that the director of the Esslingen Works, Dr Max Mayer, was keenly interested in diesel locomotives.

The locomotive, in accordance with the stipulations of the STO decree, was to be comparable with the E class freight locomotives then being built in Germany, so its technical characteristics were worked out with the E type as a basis. A ruling principle of the design was that it should make use of existing components rather than require the design and ordering of completely new parts. Thus, when it was decided that to match the E class steamer a 1200 hp diesel engine would be needed, a MAN submarine-type power unit was chosen; this had the additional advantage of being considerably cheaper than other possible engines (Lomonosov subsequently said the MAN installation was quoted at 48,000 gold roubles compared to Sulzer and Krupp quotations of over 90,000).[22] The electrical transmission was ordered from Brown-Boveri of Switzerland and here too Lomonosov was able to enlist the keen interest of one of the principals, for Dr Brown himself devised a novel 'cascade' system of regulating the excitation of the main generator. The mechanical parts were entrusted to the resources of Esslingen, which meant that the chassis and other parts would be designed and built on the basis of almost a hundred years' experience of steam locomotive construction. This might be taken as both an advantage and disadvantage, but in this case the end result was satisfactory; the steam locomotive-style wheels and suspension, arranged in a 2–10–2 wheel arrangement, distributed the weight so that the axleload was less than 18 tons, and the riding qualities were good. Nevertheless, the subsequent history of the diesel locomotive suggests that this rigid type of chassis was really a dead-end.

The most difficult part of the design, because there were few precedents, was the cooling system, and this was a problem which was troublesome throughout the inter-war years. Another weakness, repeated in subsequent designs, was the control system. Here, the technology was lacking for a really foolproof and simple method of controlling the relationships between diesel, generator and traction motors. The Ward-Leonardo system was used, which meant that the driver controlled the speed of the locomotive through a control handle which changed the resistance through which passed the excitation current. The five traction motors, one for each driving axle, were arranged in parallel; because of lack of experience in this kind of installation, and for the sake of simplicity, they were selfcooling, which meant that at slow speeds they were liable to overheat because the cooling air passed over them at a corresponding speed.

Lomonosov, being Lomonosov, was determined that the locomotive should be thoroughly tested and he designed a unique portable stationary testing plant, with the help of German engineers at Hohenzollern. Portability was achieved by dispensing with the solid foundations hitherto regarded as essential. Instead, a steel base frame mounted on timber was used. The wheels and brakes were immersed in water, this water being contained in interlocked tanks. It was said that the plant was built so that the preliminary tests could be held in secret; this might be true, but the second reason given, that line tests would have entailed an unacceptable interference with normal traffic, seems quite sufficient.[23] Transportability was required because the intention was to take the plant to Russia when the German order was completed. As things turned out, the plant's transportability was exploited more often than had been expected. First there was the move from the Hohenzollern Works to Esslingen. Then the plant was transferred to Krupp to assist with the second, diesel-mechanical, locomotive being built for Russia. Finally, the plant was returned to the USSR in the early 1930s, but not before the Esslingen managers had been so impressed by it that they built another for themselves.

On 5 June 1924 the locomotive was finished, its construction having begun in August of the previous year. Stationary tests began immediately. Because of the requirement that the diesel locomotive should be equivalent to the E class steam locomotive, one of the steam locomotives recently completed at Esslingen, E–5570, was tested at the same time. These first tests showed that the diesel locomotive consumed about three times less fuel than the steamer, and that its thermal efficiency was 24–6 per cent, depending on the conditions. On the other hand, the tests revealed that E–el–2 was still far from perfect. In particular, the cooling system was not working well. This was partly because in the course of design the original system had been reduced in size so as to compensate for the over-weight of other components. (At that stage of the design an axleweight of 18.5 tons had been accepted, but with the original cooling surface this would have risen to 20 tons. At least, that was the calculation, but when the locomotive was weighed in June the axleweight was still only just below 20 tons.) Also, it was found that the location in the driver's cab of the excitation equipment was very inconvenient.

Some considerable modifications were therefore made. The excitation equipment was relocated, a new semi-flexible coupling was installed between engine and generator, and the cooling radiators completely re-designed. Previously there had been radiators fore and aft, and these worked by passing air through pipes which themselves passed through the coolant water. Heat exchange in these circumstances was not very effective, so an entirely new radiator system was made, in which the process was reversed, coolant water itself passing through the pipes and the air being circulated around the pipes. At the same time, because of the weight problem entailed by fitting bigger radiators, one of the old radiators was mounted on the frame of the tender of E 5570, and permanently coupled to E–el–2. Fitting the diesel locomotive with a cooling tender was a crude solution, even though it solved the problem. It meant that, so long as a better solution was not found, the locomotive would be too long to be accommodated in the standard-length locomotive depot stall in the USSR, and at the end of each run the locomotive and tender would have to be detached in order to be turned on most turntables in the USSR. Total length of the combination of locomotive and tender was 23.5 m (77 ft), and total weight was 118 tons. However, the axleweight was only 17.5 tons and in terms of power/weight ratio this locomotive was somewhat superior to the Gakkel' locomotive.

In 1925 Lomonosov emphatically denied that there was any 'competition' between his and Gakkel''s diesel-electric locomotive.[24] He pointed out that they were very different, Gakkel' employing a compressorless diesel engine and himself a compressor type. At the time, this was perhaps a substantial difference, given the uncertainties about the best type of diesel engine for locomotive use. All the same, it is hard to avoid the impression that, at least, there was a certain rivalry, and this was centred especially around the question of which locomotive would be the 'world's first mainline diesel locomotive'. In this rivalry Gakkel' certainly had bad luck, for his locomotive was delayed a month by the Leningrad floods. It is hard to reject the suspicion that both Lomonosov and Gakkel' had 7 November in mind, the seventh anniversary of the Bolshevik Revolution. Gakkel' managed to make the first mainline diesel run on Soviet Railways metals on that day. But the previous day, at Esslingen, on a 5 ft gauge track laid at the Works, Lomonosov's locomotive (see Figure 6) had made its first trip and a 'protocol' had been compiled and signed by all the leading railway figures that Lomonosov could round up for the occasion. These included not only the Russian and German engineers working on the project, but also representatives of the British railway press and of the Netherlands Railways. The protocol itself took the form of the technical

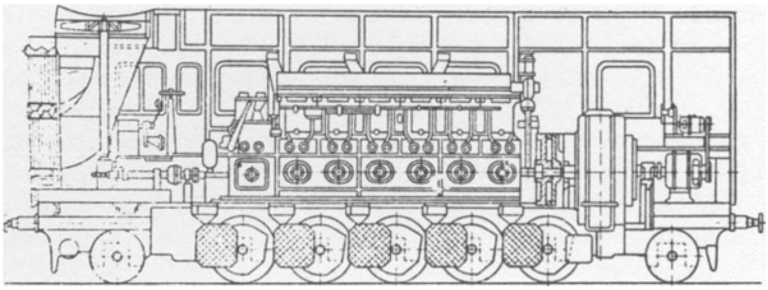


Figure 6 Lomonosov's E–el–2 diesel locomotive of 1924.

appreciation of the Russian and German engineers who formed the 'commission', with some flowery sentences about how 'the results of the trials of Diesel locomotive No. Yu–e–001 . . . have taken the idea of the diesel locomotive from the stage of academic discussion to its realisation in a form suitable for the regular haulage of freight trains'.[25] This protocol, therefore, was more than a formality; rather was it a reminder to future historians that the locomotive and its designers deserved a chapter, not a footnote.

However, as has been mentioned, within a few years, after Lomonosov had finally left the USSR, it was Gakkel's locomotive that was regarded in the USSR as the world's first mainline diesel locomotive. This was driven home by, among other things, the renumbering of the two locomotives. Gakkel''s machine changed from Yu–e–002 to Shch–el–1 and Lomonosov's from Yu–e–001 to E–el–2. Arguing about which engineer was 'first' is fundamentally frivolous, even though entertaining. But since a smokescreen has been laid, an opportunity should perhaps be taken to clear it. On 6 November 1924 Lomonosov's diesel-electric locomotive moved over a short length of track at the Esslingen Works. On that same day, Gakkel''s locomotive arrived at the locomotive depot at Leningrad No. 1 Station of the October Railway and this may be reckoned as the first day on which it moved on Soviet Railways. The following day it made its first trip over mainline tracks. Meanwhile Lomonosov's locomotive arrived, on a rail transporter, at Dvinsk on 4 December. Here it was replaced on its broad-gauge trucks and in the presence of Polish, German and Latvian railway specialists made a few short trips over the Latvian Railways. On 20 January it made its entry to the USSR, hauling a dynamometer car and a 980.ton freight train from Sebezha to Velikiye Luki. It arrived in Moscow on 23

January and soon afterwards, in company with Gakkel''s locomotive, was exhibited in action to NKPS officials and the press and Party. For the rest of that year it ran on an experimental basis over several main routes (October, Moscow – Kazan and Moscow – Kursk railways) and even reached as far as Tbilisi, Makhach Kala and Erevan. In later years it worked between Moscow and Kursk before being transferred to Ashkhabad. Although it spent much of its early life under repair or modification (a new cooling system was fitted in 1928, dispensing with the tender, and field-weakening was also applied) it lasted until 1954, running about one million km (621,000 miles) before withdrawal from service. Its acceptance by the NKPS was rapid, compared to the difficulties of the Gakkel' locomotive; on 2 February 1925 the acceptance run was made between Khovrino and Klin on the October Railway, hauling 1750 tons outward and 1920 tons back. On a 5.2 per cent gradient it developed a tractive effort of 13,450 kg at 15.2 kph (equivalent to a horsepower exerted at the wheel rim of 757 hp). Fuel consumption was 226 grams per horsepower hour (coefficient of thermal efficiency 28 per cent). After this capable display its acceptance was only a formality, although this formality was delayed until August.

Although neither Lomonosov nor Gakkel' had created a diesel locomotive that could compete with steam on economic terms, both locomotives had shown that mainline diesel traction was feasible. Gakkel', using the brainpower and equipment available in the USSR after seven years of destructive war, succeeded in building a locomotive that was the first to run on Soviet Railways but whose technical defects made it unsuitable for use in practice. Lomonosov, with all the technical resources of Europe and of an experienced and well-run German locomotive works to come to the aid of his talent, produced a locomotive which could be used in daily service. On the other hand, Gakkel''s locomotive had a greater resemblance in its arrangement to the diesel locomotive of the present day. So although in reality the Soviet claim to have built the first successful mainline diesel locomotive ought to rest on the achievement of Lomonosov's E–el–2, the insistence on Gakkel''s priority perhaps has a poetic justification. Really, both Lomonosov and Gakkel' are each entitled to a share of the honours. Both were highly talented and made the best use of the resources they were able to use. It seems a pity that quite recently Soviet writers attributed to the Gakkel' locomotive the celebrated trip to Central Asia and back by E–el–2 (see p. 111), as well as the latter's carefully worded 'protocol'.[26]

One of the three diesel locomotives which the Council of Labour and Defence had authorized for construction abroad was to have transmission 'of automobile type'. This locomotive was built in 1924–6 by Hohenzollern with some participation by Krupp, and with some mechanical parts supplied by the USSR. In the early 1920s, diesel railcars with hydraulic transmission had appeared in Germany, and the idea of installing hydraulic transmission in mainline units was so attractive that Meineke designed a very ingenious arrangement combining the most desirable features of existing transmissions.[27] Unfortunately, this required bearings of a strength which no manufacturer was prepared to supply and in any case the transmission was really too big to accommodate in a locomotive. Therefore, recourse was made to a mechanical transmission, again with the participation of Meineke. The locomotive, which for most of its life was numbered E–mkh–3, had a similar diesel engine to that of E–el–2, but used oil instead of water as a coolant. The chassis was again basically of steam locomotive type (4–10–2) and in fact its four-wheel truck was from the K class passenger locomotive of the old Moscow–Kazan Railway.

The transmission of E–mkh–3 was through a main friction clutch, and three-speed gear box, to a transversal driving shaft connected at each end by connecting rods to the ten coupled wheels. Since the main clutch was engaged and disengaged by a magnetic arrangement, the locomotive in its early days was sometimes described as a diesel-magnetic locomotive. The gear box had three speeds, with its three gear wheels representing maximum speeds of 14, 25 and 48 kph. At starting, the lowest gear would be engaged while the main clutch would be allowed to slip at a speed which decreased as the locomotive accelerated. Changing gear in motion was accomplished by first disengaging the main clutch and then bringing the required gear wheel into engagement with the teeth of the transversal driving shaft; care had to be taken to do this precisely, at the right moment. Rakov observed that handling this operation 'demands great attention on the part of the driver',[28] but test results published from time to time in the late 1920s indicate that this was a very polite way of expressing the problem. Briefly, this was a locomotive in which all hell could be let loose, and frequently was.

The main difficulty was that if the gear change was attempted at the wrong engine speed, the resulting jolts could not only split the train but also remove teeth from the gear wheels. These gear wheels were imported and were not quickly and easily replaceable. Moreover, the driver had so many other things on his mind that precisely judged gear changes were too much to ask. True, a special engine revolution indicator had been devised to help him, but this was only a palliative. At the best of times, changing gear needed about six to seven seconds, during which the locomotive would be exerting zero power; there were times when 15 or 20 seconds were needed, enough to bring the train to a halt on a stiff gradient. However, the Soviet engineers persevered (Lomonosov emigrated at about the time of this locomotive's arrival) and evidently there was a school of thought which refused to regard the failings of E–mkh–3 as a reason to abandon the diesel-mechanical system. After all, the fuel efficiency of this locomotive was somewhat superior to that of E–el–2, it produced less stress on the track than the latter (whose traction motors were only partly supported, tramway style, on springs), and because it dispensed with a generator it was cheaper and lighter for the same power output. In 1929 S.S. Terpugov, the diesel specialist who was then in charge of the diesel locomotive base near Moscow, suggested certain modifications to make this locomotive fit for daily use, and also made a case for building a second experimental version with a view to early series production.[29] As late as 1934 the Central Locomotive Design Bureau was designing a bigger diesel-mechanical locomotive on the basis of experience with E–mkh–3. This 2200 hp unit, with a four-speed gear box, was to be built at the new Orsk Locomotive Works; but as the Orsk Works were never completed, neither was this locomotive. As for E–mkh–3, this worked with the other diesel locomotives around Ashkhabad after 1931 but does not seem to have operated for long. When yet another catastrophe was inflicted on the gear box it was decided not to repair the damage, and the locomotive remained out of service henceforth. Frequent train breakages were probably a contributory reason for this decision although the official account refers, accurately enough, to the difficulty of obtaining replacement parts.

The third design of diesel locomotive authorized by the STO decree of January 1922 was intended to be a 'Diesel-Shelest'; that is, a unit with the gas transmission proposed by Shelest. Lomonosov had taken Shelest into his Russian Railway Mission at Berlin in 1920 and appointed him to take charge of the rolling stock section. However, although he appears to have had a good opinion of Shelest at this time, the two men soon fell out. The most likely cause of the friction was Shelest's gas transmission locomotive, since only Shelest seems to have had real faith in it. However, one account[30] asserts that in about

July 1921 Lomonosov became jealous of Shelest, who claimed to be on the verge of discovering a new important 'law of engineering'. According to this account, however, it was not until 25 September 1922 that Shelest actually wrote a letter of complaint about Lomonosov's conduct towards him, a letter addressed to Dzerzhinskii, Krasin, Krestinskii, and Avanessev; by that date differences of opinion about Shelest's locomotive might well have reached a critical point. The letter of complaint stated that Lomonosov had persecuted and maltreated Shelest, and that the latter had made a scientific discovery which had been published and applauded in Germany, but not by Lomonosov; 'He who knows Prof. Lomonosoff well, will understand that if it would be possible to drown me I would have been drowned long ago. He can accomplish this artistically.' The account adds that in response to this letter, Lomonosov was ordered to return Shelest to Moscow together with the latter's 'data'.

It would be tempting to treat this tale as just another of those fantastic histories which so frequently crop up in Russian and Soviet history. But this particular story is not so easily dismissed. There can be little doubt that Shelest's locomotive would not have won Lomonosov's approval; however promising the theory and the preliminary work, the building of a prototype at that time could only have been premature. Moreover, the Lomonosov versus Shelest dispute finds its echo elsewhere, including the published correspondence of Dzerzhinskii. In a letter to Krzhizanovskii,[31] Dzerzhinskii refers to the question of where the Shelest locomotive should be built. The Collegium of the NKPS and its Supreme Technical Committee had approved of building this locomotive abroad, but Dzerzhinskii writes that it would be better built in the USSR in order to gain experience both in traction engineering and in the modernization of industrial techniques. Besides it would provide a better check on the abilities of the 'brainy ones who eat Soviet bread for nothing'. Dzerzhinskii then refers directly to the Shelest versus Lomonosov dispute, 'I will not speak of political motives . . . Let Lomonosov build two locomotives abroad and Shelest one at home'. This was not a question of Shelest or any other engineer; it was a concern of the NKPS, VSNKh, and the Party. 'I fear that abroad this will be a question of struggle and intrigue of those two, Shelest and Lomonosov.'

In the end it was decided to build the Shelest locomotive in England. At the time it was ordered, according to Yakobson,[32] not only was there nobody abroad who believed in its practicability but no Soviet engineer had faith in it either, apart from Shelest. Part of this distrust came from the failure of a previous Russian attempt at a gas turbine, that of a naval engineer, Kuzminskii, whose 1910 model came to grief because there was no metal that could be used to make turbine blades of the required heat resistance.

The gas turbine experience had become relevant because, in his amended design, Shelest had inserted a gas turbine into his sequence of operations. This turbine was to be driven by the hot mixture of steam and gas en route to the high-pressure reservoir, and was intended to drive the air compressor of the first cylinder. The other features of the design remained as before. It was a very attractive proposition, especially to those of limited technical experience, for it seemed to solve the problem of transmitting internal combustion power to locomotive wheels, preserved the steam locomotive's advantage of having a reserve of power in its boiler, and promised to apply power very smoothly to the rails, without vibration. Shelest set himself up in Newcastle, where Armstrong Whitworth began to build the power plant under his guidance; the order had been placed on 11 October 1923. The initial project involved the construction and testing of just one of the intended six cylinders of the gas generator. This project was completed in late 1926 and tests showed that the idea was feasible. In 1927 it was decided to terminate the arrangement with Armstrong Whitworth and transfer the plant to the USSR. Among the reasons cited for this were the deteriorating political relationship between Britain and the USSR after the 'Arcos Raid' (Shelest's explanation) and (in Yakobson's version) the difficulties caused by the complexity of assembly together with the circumstance that it was Armstrong Whitworth who controlled the expenses while basing their charges on costs incurred. The plant was finally installed in the basement of the MVTU where, by an STO decree of 1 July 1927, a 'Laboratory of Diesel-Locomotive Engines of the Shelest System' had been set up. This soon was regarded as simply the Diesel Locomotive Laboratory, and although Shelest's project occupied much of the available space, and most of the avaialble time of its leading luminary, it did achieve significance as a place where serious research and testing for diesel locomotive traction could take place. Also, the new laboratory enabled students wishing to specialize in diesel locomotives to have at least some practical experience. But despite Shelest's efforts, prolonged right up to the end of his life in 1954, the 'Diesel-Shelest' locomotive never saw the light of day.

The third approach to diesel locomotive design prescribed by the STO decree of 1922 was the organization of a design contest with a million gold roubles' worth of prizes. Evidently this was the line which Lenin thought would produce the most useful results, hence his letter, already mentioned, in which he urged the relevant departments not to lose time in this matter. Conditions of the competition were announced by the STO on 10 March 1922. The trials were to begin on 1 March 1924 over the rails of the Petrograd railway network. Power output of the competitors was specified in detail (at least 12,000 kg [26,450 lb] of tractive effort at speeds up to 15 kph [9½ mph] etc.); 75 kph (47 mph) was to be the safe maximum speed; axleloading was to be no more than 16 tons on the driving axles and 12 tons on the carrying axles; enough fuel and supplies were to be accommodated to allow 1500 km (930 mile) trips without replenishment; and the locomotives were to be usable between temperatures of minus 30 degrees Celsius and plus 40.[33]

A year after the publication of the competition conditions, the situation did not appear bright, for no Soviet factory had seen fit to enter. In a new decree of 15 April 1925 the STO said that 'In view of the factories' non-submission by 1 March 1924 of a single diesel locomotive', the competition announced in March 1922 was no longer open, and a new competition, with new rules, was introduced.[34] This would have two parts. In the competition for designs (first prize 50,000 roubles) inventors, groups, institutions and factories could compete and the inventors could be foreign citizens. In the competition for the best diesel locomotive, only Soviet factories could compete. In this latter section there was a prize of 200,000 roubles (even adding in the second and third prizes, the total prize money allocated seems a long way short of the original one million roubles). Deadline for this competition was to be 1 November for the design competition, and 1 January 1927 for the locomotives. But this decree still did not seem to produce the expected results, and on 8 October 1926 the deadline for the design competition was extended to 1 May 1927.[35] As for the competition for the best locomotive, this seems to have fallen by the wayside.

The result of the design competition was declared in July 1928.[36] In view of the fact that no fewer than 51 designs were received, the postponement of the deadline by one year in 1926 seems open to question, if not suspicion; a likely explanation is that the extension was granted to enable one or more laggard Soviet entrants to compete. But it was evidently considered a legitimate cause for pride that not only were there 51 entrants, but 21 of them came from abroad (as might be expected, 15 German entrants dominated the foreign submissions, but there were two from the USA, and one each from such small territories as Austria, Bulgaria, Danzig and Uruguay). Few details of the entries are available, but the names chosen by Soviet entrants for their creations certainly betokened great enthusiasm. While the *Red Rocket*, *Triumph* and *Boldly Forward!* are unsurprising names, the background of the designers of the locomotive *Quidquid agis prudenter agas et respice finem* arouses some curiosity. Other names are more revealing; *The Steam Locomotive's Friend* was probably influenced by Gakkel', who at this period often attended students' debates on 'Steam Electric or Diesel?' and spoke in support of the diesel as an auxilliary to the steam locomotive. *Soviet Still* suggests that interest in the British Kitson-Still locomotive (which combined steam and diesel propulsion) was already alive in the USSR. However, none of these hopefuls received a prize. In fact no prize was awarded because, the jury said, no designs completely fulfilled the conditions of the competition or, if they did, included components of doubtful reliability, short life, or high cost. This must have seemed a very satisfactory outcome to the organizers of the competition, if not to the competitors. As Shelest later wrote,[37] 'The results of the competition showed that diesel locomotive construction in the USSR had made a great step forward. Individual inventors were already unable to suggest anything superior to the results already obtained.' This was a little overstated, because in fact, four projects were considered worthy of acquisition for further study by the NKPS. All of these were Soviet projects, and included Gakkel''s two projects *DEGAT* and *HJM*. These were studied by various commissions and sub-commissions until finally, in February 1930, certain features were accepted for use in future diesel locomotive construction. Gakkel' with his habitual geniality wrote that these long years had not been wasted because in the meantime great progress had been made with two-stroke diesel engines (of which he was a great protagonist for railway use).[38] In the end, nothing came of the two Gakkel' designs. *DEGAT* was a freight locomotive of 1800 hp and 2–12–0 wheel arrangement and *HJM* was a 2–8–2 passenger locomotive.[39] The former was a diesel-electric but the latter was to have been fitted with a new type of transmission with two hydraulic centrifugal clutches.

Thus by 1930 it was clear, except to some doubters, that of the several lines of attack initiated by the STO decree of 1922 just one seemed worth pursuing, the diesel-electric locomotive E–el–2, built under Lomonosov's care in Germany. It was improvements and modifications of this design that resulted in the final interwar standardization of a diesel-electric design for series production. By that time, however, Lomonosov was no longer in the USSR. He left for good in 1926, saying later that he felt he was no longer safe. In view of the large number of enemies he made in the course of his career, and the number of casualties among railway specialists after 1928, Lomonosov's fears in 1926 may be regarded as prescient, even though there lingers a suspicion that, with his talent for string-pulling, impressing the right people, and for 'intrigue', he might well have flourished in the 1930s. As it was, he went to live in London, associated with British and American railway engineers, published a textbook on railway mechanics, and finally went to live in Montreal, where he died in 1952. His books, published in German, had made available to a wide audience the USSR's experience with diesel traction.[40]

The dieselization debate

Pointed questions about the wisdom of the diesel locomotive programme were raised soon after the triumphal arrival of the first two locomotives at Moscow in early 1925. Later that year the journal of the State Planning Commission, *Planovoye khozyaistvo*, ran a series of four articles by critics and proponents of the diesel, with the main emphasis laid on the economic aspects.[41] The most critical was by Ya. Shatunovskii, who alluded to the fact that both the two new locomotives used diesel engines designed for submarine use:

> Both diesel locomotives are like submarines, one English and one German, put on rails. They are fishes, which have come ashore thanks to the energy of their designers and the generous funds of Soviet power, but they are fishes that are still unsteady when moving on dry land.

The writer then went on to acknowledge that the diesel locomotives were all very commendable, although over-praised. In particular, he questioned the utility of building both with electric transmission; if money was to be spent on two, then at least they should be fundamentally different. Also, oil was a scarce commodity, and it could not be for nothing that the USA still relied on steam locomotives. So far as fuel was concerned, the advent of the electric locomotive meant that the diesel's advantage was reduced; its field of activity would be limited to those areas that were close to oil resources but distant from the wood or coal which might fire power stations. (This last, rather weak, argument was probably provoked by the dieselizers' constant reiteration of the advantages of a locomotive that burned oil instead of coal.) Finally, Shatunovskii asked whether the proponents of dieselization had not perhaps mistaken the beginning for the end, and reminded his readers that through the GOELRO Plan Lenin had firmly backed electrification.

Professor Bernatskii in the same issue deplored the polemics that had already been deployed; as soon as something new appears, he complained, two camps invariably form of those who are for and those who are against. It would be better to allocate spheres for the rivals, rather like tramways had been reserved for electric traction. As an example of the dieselizers' polemical approach he cited Meineke's article in a German engineering journal,[42] in which Meineke likened electrified railways to cable railways on the ground that both used stationary power plants. The dieselizers were now claiming that diesels were better than steam or electric, even though there was not a single diesel locomotive in what could be called regular service. In any case, it would be some time before the repair costs of diesel locomotives became known, and until then no economic assessment could be made. Referring to the Ramsay and Ljungstrom developments, Bernatskii added that the steam locomotive was still being improved and the best assumption would be that there was a proper place for all three types of motive power.

Shelest, who was committed to his own form of diesel traction more than to the diesel-electric system, could take a dispassionate approach in his article in the same journal. He admitted that diesel costs were high; this was because no diesel engine existed that was made especially for railway use. Moreover, oil fuel was quite expensive (Shelest, of course, expected that his gas transmission system would utilize low grade fuel, even pulverized coal). He reproduced a comparison of the fuel costs of an E class steam locomotive and a diesel, showing how much the economics of a diesel locomotive were determined by the relationship of oil and coal prices.

It was left to Lomonosov to state the dieselizers' case with the required vigour. The editors gave him the opportunity to add his comments to Shatunovskii's article. He denied that there was any 'parallelism' between his and Gakkel''s projects and claimed that at his suggestion the Diesel Locomotive Commission had formed a sub-committee to sort out all the diesel-electric projects, and a sub-commission for compressorless locomotives. As regards fuel costs, the motor oil being used was only a trifle more expensive than *mazout* in Moscow, and in any case trials were about to begin with filtered *mazout* as fuel. The Germans had already found a way to produce synthetic oil from brown coal and this would enable inferior fossil fuels to be used by Soviet diesel locomotives. Finally, Shatunovskii was quite wrong to imply that dieselization was a deformation of Lenin's testament; in Lomonosov's book on the trials of Yu–e–001 enough documentation had been provided to show that it was Lenin who raised the diesel locomotive question and that it was only through him that diesel traction had been achieved. Lomonosov returned to this theme in his own article, again stressing that dieselization was not contrary to Lenin' s intentions. He also took issue with Shatunovskii on the riding qualities of diesel locomotives, denying that their dynamic qualities were as bad as Shatunovskii had claimed; in fact their dynamic coefficients were a little lower than those of steam locomotives. On the matter of capital cost, Lomonosov wrote that Yu–e–001 (E–el–2) was only 2.2 times the cost of an equivalent steamer, and the diesel-mechanical would be only 1.5 times more. The diesel-electric was running 8000 km (4970 miles) per month, which Lomonosov optimistically extrapolated to 96,000 km (59,650 miles) annually. Even if it only did 60,000 km (37,280 miles), wrote Lomonosov, that would already be two and a half times more than a steam locomotive.

Obviously, on Lomonosov's figures, the high capital cost of the diesel would be recouped by its extra mileage, but the basis of his calculations was attacked in a subsequent issue of the same journal by someone signing himself in Latin characters WZ'.[43] This critic pointed out that whereas Lomonosov had quoted 85,000 roubles for an E class steam locomotive, the German-built units of this type had cost only 65,000 roubles. At the same time Lomonosov had quoted a somewhat low price for the diesel-electric, and 'WZ' gently wondered whether the price was low because the German builders had hoped to recoup the prototype's costs from a subsequent production run. 'WZ' continued with the hope that for the USSR the choice would be steam and electric, as elsewhere in the world. Shatunovskii was right to say that the designers' energy and the

State's generosity had created the high-power diesel locomotive. Engineers in other countries had been less lucky and there seemed no grounds for replacing steam traction by diesel in the USSR.

This discussion in *Planovoye khozyaistvo* may be taken as marking the beginning of two decades of debate about the proper role, if any, of the diesel mainline locomotive. This debate had two main threads, the technical and the economic, but other matters like defence and industrial progress were brought in at times. On the diesel side, the main protagonists of the debate are fairly clearly identified, being a small group of leading engineers in the field. Innumerable articles written, or at least signed, by them appeared in the various technical journals and, less often, in newspapers. Their opponents were more numerous and varied. Quite often they were steam or electric locomotive specialists who had been stung into replies when one or other of the dieselizers' statements had hurt, appalled, or saddened them; in general the diesel protagonists were more aggressive in their approach, probably because they were aware that the diesel was an unwelcome newcomer, junior to electric and steam, and therefore really had to fight for recognition.

Since so many of the arguments were recurring, a chronological account of this discussion, as it took place in the late 1920s, would be repetitious. Instead, each debating point will be taken separately. It might be said at the outset that at any period the arguments put forward most forcibly by either side were not necessarily those arguments that they considered most weighty; rather they were the arguments which at that time were likely to be most effective, given the current preoccupations of the USSR. No diesel protagonist ever said that he enjoyed the challenge offered by diesel traction, but it can hardly be doubted that most engineers engaged in this field were enthused by the task, and this was perhaps the greatest force driving them forward.

The one great and unvarying argument in favour of the diesel locomotive was its higher thermal efficiency. That is, its greater output of horspower per unit of fuel. In the USSR this was a particularly powerful argument, because in the early years of the Soviet regime there had been fuel crises which, at the time, had seemed to threaten not only the economy but life itself. Also, there had been the occasional short transport crisis, when the railways had seemed unable to carry the most essential goods, including the coal needed by their own locomotives. Since oil fuel was so much less bulky than coal, dieselization would result in a far smaller burden of locomotive-fuel transport on the railways. The tests of the early diesel locomotives showed that the fuel requirements were indeed low. E–el–2, which from February 1926 was hauling trains of an average weight of 855 tonnes (except for two months when it was out of service), did so at an average fuel consumption of 47.6 kg per 10,000 ton-km. This at first sight compared unfavourably with the 40 kg registered during 1925, but 1925 was a year in which the locomotive lived a pampered life whereas the 1926 runs were in conditions more akin to normal conditions on the railways. (All the same, in 1926 this locomotive seems to have had the advantage of 'made-to-measure' trains, with weights suited to most efficient operation; a few years later, on the Ashkhabad Railway, fuel consumption deteriorated.) In terms of the coefficient of thermal efficiency, E–el–2 did more or less what was expected of it, converting 25–7 per cent of its calorific intake into tractive power. Steam locomotives were said to have a coefficient of nine per cent. This may have been so in theory, but a more accurate figure for Soviet steam locomotives would have been six per cent. The superiority of the diesel was overwhelming.

However, the dieselizers could not rest on this particular bundle of laurels. On the one hand the proponents of electric traction, with not excessive selectivity of assumptions, could claim that electrified railways had an even higher thermal efficiency, while the steam interests could claim that the diesels burned oil, which was likely to be scarce and was in any case more expensive than coal. In addition the electrifiers, harping on another fashionable theme, rarely failed to point out that power stations could burn inferior types of fuel, the brown coal and peats with which the USSR was well endowed. It was this particular claim that stimulated researchers to experiment with novel fuels. As early as 1929 Gakkel' was claiming that a Soviet researcher, R. Pavshkovskii, had found a means of burning pulverized coal in a diesel engine.[45] This was a theme which would be repeated periodically over the following decades, until in the 1940s diesel locomotives were actually built that could make and burn coal gas. A second point sometimes made by the dieselizers was that steam locomotives used much more lubricating oil that diesel-electric locomotives, and such oil cost ten times more than diesel fuel oil. But Shelest asserted in 1927 that the diesel used three or four times more lubricant than a steamer.[46]

As has already been noted, both Lomonosov and Shelest in their 1925 articles went out of their way to answer the charge that diesel fuel was expensive; Lomonosov asserted that the use of cheaper heavy oil (*mazout*) was imminent, while the study of synthetic fuels in Germany was already encouraging. Shelest contented himself with observing that there were regions where the relationship of coal with oil prices made dieselization worthwhile. In 1926 Martynov produced an array of equations showing that an E class steamer, even without modern features like a feedwater heater, would have lower fuel costs than a diesel, his assumptions being that each would haul a 50-car loaded train (1185 tonnes) at 40 kph (25 mph) over level track, and that coal cost 15 roubles per ton, and oil 75 roubles.[47] The result of this calculation was that the steamer would be 9 per cent cheaper if it burned coal but 11 per cent more expensive if it burned oil. If both locomotives were able to burn pulverized coal and the steamer had modern equipment then the latter would use 40 per cent less fuel per ton-km than the diesel. Adding to this other factors such as the more highly qualified (that is, higher-paid) diesel locomotive crews and the higher capital charges and assumed higher repair costs of the diesel, Martynov concluded that there was little future for the diesel, not even for yard work, except in city centres where there was a smoke nuisance but insufficient traffic to justify electrification.

Another string in the bow of the dieselizers was the water-supply question. So long as the high capital costs of diesel locomotives precluded their economic competition with steam there was always this technical factor to be emphasized, a factor which seemed to ensure that whatever the comparative costs might be, there would be a specialized use for diesels on lines where locomotive water supplies were a problem. One such line was the Trans Caspian Railway, which was obliged to operate special trains for locomotive water; diesel traction would eliminate this unproductive expenditure of train-hours. Outside the arid areas, there were lines where low winter temperatures caused their own water problems, or where worn-out pipes, pumps and reservoirs, or poor-quality water, caused problems. Even on main lines with good water supplies trains had to be halted for up to half an hour for locomotive watering, the supply pipes all too often being of small diameter and the water-pressure feeble; the commission of American railroad experts which visited Siberia in 1918 made several puzzled criticisms of this feature. Diesel locomotives used very little water but, as will be seen later, the steam designers eventually found their own ways to solve the water-supply problem.

Low fuel and water consumption, both undeniable except by a few steam enthusiasts like Martynov, were the dieselizers' trump cards.

But there were other arguments too, not always emanating from the diesel interests. The construction of diesel locomotives as a means to enlarge the experience of Soviet engineering and electrical industries was one such argument. This had been recognized, for example, in the already-quoted letter of Dzerzhinskii concerning the Shelest versus Lomonosov dispute, in which he recommended that the Shelest locomotive be built at home, partly to gain experience. Again, the same thought was implied when it was decided to build the later O–el series of diesel locomotives at home, it being '. . . proposed to give complete orders to home factories, the latter ordering abroad those components which they cannot make themselves, thereby acquainting themselves with the production methods of foreign factories'.[48]

Support from an unexpected quarter came from Siberia, where an engineer, perhaps dreaming of the good old days when Siberian export butter was rushed in special trains to the Baltic ports, wrote in 1926 that although there were still problems to be solved the diesel was winning itself a place and, by cheapening transport, would improve the prospects for exports.[49]

The relevance of the diesel locomotive to the requirements of national defence was already being discussed in the 1920s, and would continue to be an intriguing question right up to modern times. In this period, however, apart from a few sporadic and inconsequential doubts about fuel supplies, the discussion centred on whether the diesel could alleviate the strategic problem associated, rightly or wrongly, with railway electrification. Before the First World War Kaiser Wilhelm had prevented the Prussian Royal State Railways electrifying lines of military significance on the grounds that a single electrical fault during the mobilization period could result in a lost war. Similar arguments were put forward as late as the 1960s, when the Indian Railways' electrification plans were criticized as offering a hostage to Pakistani bombing. Much the same fears, it seems, were aroused by the railway electrification plans envisaged by the GOELRO scheme for Soviet Railways. The ever-optimistic Gakkel' put forward the comforting idea that on newly-electrified lines it would no longer be necessary to provide watering and maintenance facilities for the strategic reserve of steam locomotives; diesel locomotives could be used in emergency, and they required no extra facilities.[50]

In the same article Gakkel' pointed out that diesel locomotives had better adhesion than steamers (a proposition which really should have been qualified); this meant that gradients could be more severe or loads heavier, in the first case cheapening the construction of new lines and in the second increasing traffic capacity. The associated argument that with diesel traction new railways would be cheaper because of the possibility of dispensing with watering facilities was used by many commentators as well as Gakkel'. That Gakkel' was writing in an electrical journal reflects the situation between the dieselizers and the electrifiers in this period. Gakkel' himself was an electrical engineer, and regarded the diesel-electric locomotive as a form of railway electrification rather than a rival or alternative.

Gakkel' continued his article with an account of what was happening in the USA. As in other fields of Soviet technological advance, reference to what other nations were doing was frequently used as persuasive evidence that the USSR could itself pursue one or another line of development more vigorously. At the close of the 1920s low-power (not mainline) diesel locomotives were being built in significant numbers, especially in the USA and Germany. In the USA they were mainly diesel-electric, and Gakkel' used this information to press his point that electrical transmission was more promising than other methods. He was also a strong believer in the low-power diesel locomotive, a unit which though less spectacular than the mainline diesel could already achieve great economies. Here again foreign practice seemed to support him.

An engineer of the Diesel Locomotive Commission, S. N. Konshin, was quite forthright about the Americans:[51]

> The practical Americans have long been famed for their ability to rapidly take from Europe all the achievements that Europe has painstakingly and carefully thought out and created in embryonic form, and finally transform them into life . . . This is exactly what is happening with American diesel locomotive construction.

Konshin added that the Americans had not wasted time bothering themselves over complex problems, but had gone ahead along the line of least resistance. After the USSR had shown the possibilities of the diesel locomotive, the Americans had built several, but of lower power for yard and trip work. Konshin also reported, evidently on the basis of the American technical journals which he consulted for his article, that it was none other than the Russian Alphonse Lipets, who had worked on the diesel locomotive project of the Tashkent Railway in 1913–14, who was the consultant on diesel matters for the American Locomotive Company, the most successful of the US diesel locomotive builders. It might be added that Lipets at this period certainly was regarded as the spokesman of the diesel interest in the American Locomotive Company and was probably, too, the leading mind and enthusiast behind the scenes.[52]

Both the opponents and the champions of the mainline diesel agreed that the main defects of the new machines were their high capital cost and their somewhat low power/weight ratio. Both these disadvantages arose mainly from the transmission problem and from the non-availability of a diesel engine suited to railway use. Taking the latter problem first, a locomotive diesel engine had to be light, because the axleweight of any locomotive was a crucial parameter, determining the extent of the network over which it was allowed to operate. It also had to be powerful enough to compete with the 1000 to 2000 hp exerted by steam freight locomotives. Lastly, unlike marine diesels, it had to operate reliably in a situation where it was subject to considerable jolting and shaking. The submarine-type diesels used by early designers were far from ideal for railway use and it was not until lightweight diesel engines were developed in the USA in the 1930s that this problem would be solved, even though some tolerable compromises had been achieved before that time.

The problem of transmitting the fast revolution of the diesel engine to the slow-moving driving wheels of the locomotive has never been properly solved, except in the case of low-power locomotives where mechanical (geared) transmissions have proved reliable and long-lasting. The popular electric transmission is a compromise only; it works well but is complex, heavy, and expensive, providing useful ammunition for those diehards who question whether the diesel locomotive is really necessary. In the 1920s it was well understood that the diesel-electric, in which the engine was coupled to a generator which in turn fed electricity to traction motors driving the axles, was technically successful; its effectiveness was demonstrated by, among others, E–el–2. Yet it used three motors to perform one function (the generator being little more than an electric motor in structure). To well-brought-up engineers this was an inelegant solution. Hence the various efforts to perfect other forms of transmission. Shelest's gas transmission was one, and mechanical or hydraulic transmissions were also studied.

For the diesel proponents the transmission problem meant that their locomotives would cost considerably more to build than equivalent steam units, and it could be assumed (though simultaneously denied) that repair costs also would be higher. Exactly by how many times the diesel locomotive construction cost would exceed that of the steamer was disputed. This was a key issue. Except possibly in waterless zones, the diesel had no chance of replacing the steam locomotive unless it could show an economic advantage; a 300–400 per cent disadvantage in capital costs (reflected in correspondingly increased operating costs under the headings of interest and depreciation) meant that very high savings in fuel and other operating expenses or greater annual mileages would be required to compensate.

Lomonosov, in his 1925 article already mentioned, asserted that E–el–2 cost 187,000 roubles, but this claim was soon described, quite justifiably, as a distortion. Shelest, a diesel proponent but not enamoured of the diesel-electric or the diesel-mechanical, in December 1926 told a meeting of the Moscow section of the All-Union Association of Engineers (VAI) that it was impossible to determine exactly how much more the diesel locomotive would cost; realistically, he used a range varying from 150 to 350 per cent of the steamer's capital cost.[53] Gakkel', in the 1929 article already mentioned, reported that the diesel cost four times more than a corresponding steamer and that this was confirmed by American experience; he added that he had made enquiries among Leningrad engineering works which led to the conclusion that with a production run of at least 50 locomotives the price differential could be reduced to 2.7. Gakkel' of course was a strong proponent of electric transmission. He was well aware of its disadvantages, and his assertion that its complexity should really be regarded as constructional sophistication leading to *operational* simplicity was ingenious but hardly persuasive.

With a capital cost several times greater than a steam locomotive, carrying a higher-paid crew, with repair costs which might well turn out to be greater than those of a steamer, and with only fuel and water demand showing substantial superiority, the annual operating cost of a diesel locomotive was obviously uncompetitive. But in terms of costs per ton-km the picture would have been different if it could have been shown that the diesel locomotive performed considerably more work per year than the steamer. Moreover, the capital charges per year or per ton-km would have been more competitive if the diesel locomotive had a longer life than the steamer. At such an early stage of mainline diesel locomotive development there was not enough experience to determine how long a diesel locomotive could run before it became due for intermediate and capital repairs, and for scrapping. This uncertainty was fertile ground for subjective assumptions, while the ton-km achieved annually by steamers and diesels was also easy to misrepresent.

From the 1920s until the present day tables of comparative costs for different types of motive power have played a prominent part in the discussions leading to the successive decisions allocating work between electric, diesel, and, until recently, steam traction. Although by the 1970s such cost comparisons reached a high degree of sophistication (and, more important, integrity) the general level of the cost studies put forward by steam, diesel and electric interests in the 1920s was low.[54] Tables of comparative costs by Soviet engineers should therefore be taken simply as incidents in the process of persuasion and discussion, not necessarily as realistic appraisals of the economic performance of the various forms of locomotive.

Shelest's address to the Moscow branch of the VAI was largely in the form of a cost comparison which is characterized by an honesty of approach and a muddledness of conclusions. Having recently returned from England he used sterling as his measure of value, and worked out costs for both Russian and British conditions. As his steam locomotive, however, he took the Moscow–Kazan Railway's passenger 4–6–0 of class Ku, which he said was fast, economical, and did the same annual mileage as a West European freight locomotive (whether the implied criticism of Soviet locomotive utilization rates was intended is not clear). Rationally enough, he took the price of coal and oil as the really decisive factors, but his assumptions about other costs led him to the unusual conclusion that as the price of oil fell the economic advantage of steam over diesel would grow. In brief, though, the most striking of his conclusions was that where oil cost four times more than the equivalent steam coal, a diesel locomotive was competitive with steam if its capital cost was no greater than 150 per cent that of the steam locomotive. He omitted from this calculation the likelihood that a diesel would have a higher utilization rate (probably by 15–20 per cent, he estimated). He also claimed that the reduction of coal shipments on the railway should be added to the diesel's advantages. Moreover, he added, if a diesel locomotive could be devised to burn pulverized coal its advantages over the steamer would be overwhelming. Presumably it was no coincidence that the following article in the journal in which this economic appraisal was published was a further article by Shelest about his gas-generator locomotive, which was designed to burn pulverized coal.[55]

Among other assumptions used by Shelest were the following: the diesel locomotive would cost four to five times more for lubrication; the depreciation life of the steamer was 25 years; the life of the diesel locomotive was taken to be six to ten years for the engine (based on submarine high-speed engines of similar types) and for the remainder of the locomotive 25 years; interest on capital was taken to be nine per cent (the recoupment-period concept was not used); apparently despairing of attributing accurate repair costs to diesel locomotives, Shelest took repairs and maintenance to be equal in total for both types of locomotive.

Meanwhile, under the auspices of the Institute of Power Engineering, Gakkel' and a colleague were making a comparative cost study for the heavily-graded Zestafoni–Khashuri section in the Caucasus, a section which proponents of electrification regarded as ideal for their own projects. Gakkel''s conclusion was that at the existing traffic level dieselization was preferable to both steam and electric traction. At levels above 80 million pood/versts (1.3 million ton/km per km) electric traction was superior to steam, but only when traffic reached 135 million pood/versts (2.3 million ton/km per km) was it worthwhile to replace diesels by electric locomotives. Needless to say, a number of questionable assumptions needed to be made to draw up this study. One of them was that the diesel locomotive to be used would be Gakkel''s E–el–4, which had not then been built (and would never be finished).[56] Another was that the hypothetical electrification scheme was the one drawn up by the electrification department of the NKPS, while the steam locomotive chosen for the comparison was no longer the usual E 0–10–0, but the Lomonosov/Lipets US-built import of the First World War.

In 1927 and 1928 the researchers of the Diesel Locomotive Commission were making a thorough study of the economics of dieselizing the Turkestan–Siberia (Turksib) Railway. The Turksib was still under construction, and was to run southward from the Trans Siberian Railway deep into Central Asia to Tashkent. Some parts of this study were published in the journal of the Commission, and they are an interesting commentary on the thinking of this period.[57] On the one hand there is an apparent optimism concerning the ability of Soviet industry to produce the required number of reliable diesel units; on the other hand there is a certain modesty, demonstrated by the very unambitious utilization rates of the diesels and by the freely acknowledged handicap that with only one diesel-electric in regular service it was hardly possible to make more than informed guesses at the magnitude of the various costs imposed by diesel locomotives.

The initial study was made by the Diesel Locomotive Bureau, and it envisaged the use of 1800 hp diesel-electric units of 2–12–0 and 2–10–2 wheel arrangements, then under study by the same Bureau but far from ready for construction. With a starting 20-ton tractive effort, they were reckoned capable of hauling 900-ton trains at 30 kph (19 mph) up .0008 (1 in 25) grades. Improved suspension of the traction motors and axles of the 2–10–2 was expected to give a significant reduction of dynamic stress on the track. The assumed steam locomotive type was the E 0–10–0, with capabilities as expressed in its passport. The length of line under discussion was 1481 km (920 miles), divided into the 777 km (483 miles) from Bizha to Semipalatinsk and the 704 km (437 miles) from Bizha to Lugovaya. Traffic was expected to be five pairs of freight and one pair of passenger trains daily. Taking the annual mileage of a diesel locomotive to be 60,000 km (37,280 miles), and assuming that on average 20 per cent of the locomotives would be out of service for maintenance and repair, it was reckoned that 108 diesel locomotives would be required. That is, for each pair of trains, no fewer than 15 serviceable locomotives would be needed. This rather large number is explained by the average commercial (overall, including stops) speed of the trains which was taken to be 15 kph (9½ mph), a snail's pace which was not untypical of Soviet railways of that period. Moreover, because of the frequency of locomotive changes an active locomotive was expected to spend 40 per cent of its hours awaiting its next turn at a main or turnround locomotive depot. The researchers seemed to have little idea, or confidence, about one advantage of the diesel locomotive; that because it could run for hundreds of miles without refuelling there was no need to change locomotives as frequently as with steam locomotives. Possibly, though, the uncertain reliability of the diesel was considered a compelling reason to maintain short traction sections. The addition of just four diesels (making a grand total of 112) for yard work arouses suspicions that much marshalling and trip work at both terminals was to be entrusted to steam locomotives; this would have ensured that the diesel locomotives would, apart from those four yard diesels, be employed on the high-mileage, high-utilization runs. The 1481 km route (920 miles) was to be divided into ten traction sections. A locomotive crew would work ten hours in one direction, take five hours rest at the turnround depot, then work ten hours back to the home depot, after which it would take

37 hours rest at home. Thus on a give traction section, three locomotive crews would be required for each pair of trains. So for the complete service over the whole line 180 locomotive crews were specified.

This preliminary study was subjected to several re-examinations by various commissions, committees, and conferences. One of the first (29 May 1928) was a joint meeting of the Diesel locomotive Bureau and representatives from the machine-building and metal industries. The industrialists, faced with the proposition of supplying 112 diesel locomotives of an untried, even undesigned, type for the opening of the Turksib three years hence, limited their assurances to the production of 20 units of the 4–10–2 type (then under construction in Germany in prototype form) in 1931, with production rising to 45 in the following years. Although a month later (25 June 1928) the Scientific-Technical Committee of the NKPS recommended the Peoples' Commissar of Transport not to support the proposals, the organizing bureau of the Diesel Locomotive Commission decided that the question should continue to be examined, initially by reopening the question of what type of locomotive would be used, and how operations would be conducted. The conferences resulting from this produced several reports, the substance of which was as follows.

Because of reduced costs of permanent way, buildings, and water supply, a saving of 22 million roubles would be made in construction costs if the Turksib Railway was designed for diesel rather than steam traction. On the other hand, the cost of rolling stock would be 23 million roubles more, on the assumption that 112 diesel locomotives, averaging 80,000 km (49,710 miles) annually, would replace 181 steamers, running 40,000 km (24,855 miles); diesel locomotives were assumed to cost 350,000 roubles and steamers 94,000 roubles apiece. However, operating costs with diesels would result in an annual saving of 2.63 million roubles thanks to the virtual elimination of trains carrying locomotive coal and water, and to the reduced costs of certain inputs (notably fuel). But it was admitted that lack of experience prevented the confirmation of economies expected from diesels, especially in repair costs. It was also assumed that the depreciation life of steamers and diesels was identical.

Very realistically, the final conference (31 July 1928) decided that in view of all the uncertainties it could not really recommend the dieselization of the Turksib Railway. What was needed was a preliminary rehearsal on a smaller scale elsewhere, to provide data so far lacking. A line where steam locomotives were oil-fired, passing through an area where water was scarce or of poor quality, would be an ideal testing ground; the Stalingrad–Tikhoretskaya line (North Caucasus Railway) or the Urbakh–Astrakhan line (Ryazan–Uralsk Railway) were suggested as alternatives for this purpose. Only after such trials, over a considerable length of time, could the question of large-scale dieselization of new or existing lines be realistically studied.

Evidently not all the participants in this conference could agree with the final recommendations. Terpugov, Director of the Diesel Locomotive Base, reserved his comments, which he promised would be communicated in due course, and in writing. The comments of S. A. Bogdanov (Head of the Traction Department of the NKPS) are also intersting, since his department was subsequently accused of criminal conservatism in relation to modern forms of traction. Bogdanov complained that in some of the calculations relating to the Turksib line the older and weaker Shch type steam locomotive had been taken as an example, not the E type. Moreover, it was wrong to use as a standard of comparison a locomotive not equipped with a modern type of superheater or a feedwater heater. Furthermore, on a singletrack line like the Turksib it would have been fairer to assume that both diesel and steam locomotives would have the same annual mileage (45,000–50,000 km [28,000–31,000 miles]) especially in view of the fact that the steamers would benefit from the new techniques of hot-water washouts and also from longer traction sections. Nevertheless on 8 August 1928.the Organizing Bureau approved the conference recommendations.

The diesel establishment at work

In 1925 it was decided that the diesel locomotive question was sufficiently important to justify its own organizations. By a decree of 15 July 1925 the STO established the Diesel Locomotive Commission (*Teplovoznaya komissiya* or TK) of the NKPS.[58] It was to consist of a chairman nominated by the People's Commissar of Transport and members appointed by him in consultation with the chairman of VSNKh (in fact, it consisted of ten members from the NKPS and ten from VSNKh, the latter representing the locomotive works and their design offices). The first task of the TK was the selection of designs for construction. Then it was to organize the experimental programme.

For the more distant future it was to draw up standards and conditions for the design of diesel locomotives, organize the training of diesel locomotive crews and maintenance teams and, finally, evaluate the diesel locomotives on the basis of line tests. It was to have a five-man Organizing Committee of which the chairman of the Scientific-Technical Committee of the NKPS and the head of the traction directorate of the NKPS were to be permanent members. Later, in 1927, the Diesel Locomotive Bureau of the NKPS was added as a subordinate branch of the TK. This handled the testing and operational side, prepared material for discussion by the TK, and also occupied itself with drawing up new designs. Its leading lights were N. A. Dobrovol'skii, V. N. Tikhomirov, E. E. Lontkevich, and S. S. Terpugov. Dobrovol'skii was responsible for much of the design work of the E–el–2 and E–mkh–3 prototypes as well as the prototypes built after Lomonosov's departure. According to several non-Soviet accounts, Dobrovol'skii, Lomonosov's son-in-law, 'disappeared' when the TK was 'banished to Siberia in 1930'.[59] Be that as it may, Dobrovol'skii's name remained quite prominent in the 1930s and as late as the 1940s articles over his name were appearing in the Soviet railway press.

In 1927 the Organizing Committee issued the first number of its own journal the *Bulletins of the Diesel Locomotive Commission.*[60] The aim of this publication, explained the editorial of the first issue, was to foster the diesel locomotive by spreading information about Soviet and foreign progress and thereby 'drive out the unwillingness among most Soviet technicians to accept the internal combustion locomotive on a locomotive frame'; the diesel locomotive, preeminently a fuel-saver, would inevitably increase in importance as the years passed, but it still had to face the unfortunate problem of transmission, and the resulting complexity and high capital costs.

Much of the work of the TK and the Diesel Locomotive Bureau was concerned with the organizing and operation of the Diesel Locomotive Base at Lyublino. In early 1925, when the first Lomonosov and Gakkel' locomotives arrived at Moscow, the former was stabled in an assigned stall in a steam locomotive depot and the latter in a freightcar workshop. Without special facilities, it was hardly possible to conduct reasonable tests, so in January 1926 the first Experimental Diesel Locomotive Section (soon renamed Base) was approved. This was at Lyublino, 10 km (6 miles) from Moscow on the Moscow–Kursk main line, where the diesel locomotives were allocated five stalls in the locomotive roundhouse, with some repair equipment.

The following year, with the arrival in February of E–mkh–3, the base was moved to the territory of the nearby Moscow Railway Repair Works (Mozherez).[61] Here there were two large halls, relatively well lit and warm (important because the diesel engines would not start at temperatures below five degrees). Inspection pits, a ten-ton crane, and various items of heavy equipment were also provided. By this time, too, the Experimental Diesel Locomotive Base had been granted higher status, having become the equivalent of a railway (that is, it was a legal entity) and its subordination to the Central Directorate of the NKPS was direct.

Since everything was new, the experts attached to the Base had to proceed largely on a trial-and-error basis. The tasks were the testing and appraisal of the diesel units, their upkeep and repair, the compiling of instructions for driving and maintenance, the determination of repair cycles both for the units and for components, the training of operating and repair personnel, the discovery of defects and of measures to correct them. The nucleus of the Base was its Technical Bureau, staffed by diesel locomotive specialists. The latter spent much of their spare time writing articles about diesel locomotives with the aim of publicizing the diesel cause. Additionally, in the summers student-engineers from all over the USSR came to do their practical work at the Base. Many of the post-1945 generation of leading diesel locomotive engineers received their first practical experience here, and moreover the students often became avid propagandists of the diesel locomotive after returning to their institutes.

1926 was really the first year of daily diesel operation. At that time there were still no regulations or manuals, nor were there enough diesel specialists to make it possible to draw up a plan of action with any hope of realization. The traction section over which the locomotives were to work was Moscow–2 (Lyublino) to Kursk, about 500 km (310 miles). Freight trains up to 1000 tons were handled, either to Tula or for the whole distance to Kursk. An out-and-home working required two or three crews, so a rest car was attached to the train to house the spare crews; this car also carried a small diesel-compressor to replenish the locomotives' air reservoirs (needed for starting, and a frequent source of anxiety). Usually two or three trainees accompanied by an instructor were also carried. Since Shch–el–1 needed a four-man crew and the two German units each needed three men (driver, diesel and electric technicians), labour productivity could not be high, but that was only a minor handicap at a time when all efforts were concentrated on showing that diesel locomotives could actually work reliably and effectively.[62]

But although reports from the Base were usually optimistic (in the sense that defects were acknowledged, but not portrayed as difficult to overcome) the authorities of the Moscow–Kursk Railway were probably not at all enthusiastic, especially when the unreliable and destructive E–mkh–3 was at work. E–el–2 gave tolerably good results. It had defects in its early years, but these seemed to decline as time passed. Shch–el–1 had a tendency to break down, and this could hold up other trains for long periods in the worst cases. But the diesel-mechanical E–mkh–3 was the worst trial for the Moscow–Kursk operators; not only did it break down, but it all too frequently broke its train while changing gear. Train breakages were not unknown with the other two diesel locomotives either. However, because of the transfer of jurisdiction over the Base from the Moscow–Kursk Railway to the NKPS Central Directorate, there was little the Railway administrators could do except grumble, and perhaps pass on their disquiet for use by interests hostile to the diesel cause.

Since the Base was 9 km (5½ miles) from Moscow–2, the diesel locomotive would leave the Base 150 minutes before train departure time. In all, a return trip from Base to Kursk and back to Base took 72 hours. Even for locomotive men who had recently passed through very hard times, regular duties taking them from home for three days, stabled in a so-called 'rest vehicle' attached to the locomotive, would have been unwelcome. Added to this source of potential discontent would have been the difficulty of driving the new locomotives. Steam locomotives could survive countless errors of judgement, whereas diesels could give up the ghost in a cloud of sparks and smoke as a result of just one misjudgement. These suppositions about the crews' morale would seem to be confirmed by the measures ordered at a meeting of the Diesel Locomotive Commission (22 March 1929), when the results of three years' (1925/6 to 1927/8) operating experience were discussed.[63] The first point emphasized at this session was that the operating statistics for those years were only first approximations and could not be used to draw conclusions about the prospects of diesel traction. After constructing this sanctuary the Commission went on to its second point, which was to request the Central Directorate of the NKPS to do several useful things, and namely: (a) find a way of interesting locomotive crews in obtaining the maximum possible locomotive mileage with the least possible infliction of damage, the greatest economy of fuel, and the least time spent under repair; (b) hasten the publication of detailed manuals and instructions for the maintenance of all components, and require all those allowed to work on the locomotives to be well acquainted with such literature; (c) reduce the crews of E–el–2 and E–mkh–3 to two persons and of the Gakkel' unit to three, while taking due safety precautions; (d) strengthen the supervision of crews and their training so as to avoid damage caused by unskillful driving; (e) observe more carefully, frequently, and regularly, the technical condition of the locomotives and their fuel consumption; (f) take measures to reduce repair costs to the level that they should be; (g) broaden operating experience by organizing a railway section to be powered exclusively by diesel locomotives.

The data which this session of the Commission was examining was published at some length in the same source.[64] Table 2.1 gives an abbreviated version. Enough has already been said about the shortcomings of comparative cost tables. However, the adaptations given of the figures supplied to the Diesel Locomotive Commission by its researchers give the essence of the information on which both plans and claims had to be based. The data for the E class steamer was the *average* figure for all serviceable units of that type on the Moscow–Kursk line. The diesel locomotives did not undergo intermediate or capital repairs in the period. The E class intermediate repairs were included, but hidden away among the regular running repair heading. Finally, it might be added that with the diesels the figures could change sharply from year to year. Nevertheless these figures do help to explain why the proponents of the diesel locomotive were so confident. However, these costs did not include the all-important depreciation and interest-on-capital charges. Nor did they include the expenses incurred by the Moscow–Kursk Railway on account of train breakages and breakdowns.

Judging from the reports of its activities, published in great detail in its *Byulleteny* or *Sborniki*, the members of the Diesel Locomotive Commission and its bureaux led a very industrious life. Indeed, with the limited number of qualified workers available, the question arises of whether they did their work as thoroughly as they should have done, whether projects were examined by officials who were not really qualified or, if neither of these suspicions is justified, whether the members worked a 24-hour day. Diesel research was under the auspices of the Commission, but this did not mean that it was carried out directly under its supervision. There were enthusiasts, amateurs

TABLE 2.1 *Operating results: three Soviet prototype diesel mainline locomotives*

	First three years of regular (experimental) operation							
	1925/6		1926/7			1927/8		
	Shch–el–1	E–el–2	Shch–el–1	E–el–2	E–mkh–3	Shch–el–1	E–el–2	E–mkh–3
Annual mileage ('000 km)	13	32	20	64	25	4	33	43
Annual ton-kms (10,000)	478	2,960	1,015	5,436	1,799	294	2,552	3,275
Average train weight (t)	957	918	835	844	880	843	813	790
Days in service	65	190	105	250	110	22	(222)*	(243)*

* Calculated on a different, more favourable basis.

Operating expenses 1926/7 (roubles per 100 locomotive/km)

	Shch–el–1	E–el–2	E–mkh–3	E–0–10–0 steamer
Crew wages	62.30	42.50	53.98	33.00
Fuel	19.75	18.42	17.26	48.09
Lighting	1.00	0.26	0.13	0.10
Lubrication	9.90	4.16	4.15	1.17
Cleaning	1.34	0.78	1.21	0.32
Regular running repair	43.12	12.23	10.53	16.09
Unplanned repair	64.50	14.11	22.24	–
Design modifications	5.90	0.81	1.87	–
Intermediate repair	–	–	–	–
Capital repair	–	–	–	15.57
Water supply	0.05	0.04	0.04	1.70
Total	**208.36**	**100.31**	**111.41**	**100.47**
Operating expenses per 10,000 ton-km	25.90	11.85	12.72	16.19

almost, all over the USSR (typically teachers in railway engineering institutes who devoted part of their working time to their own diesel projects). From time to time these would-be inventors and innovators visited the Commission (to collect their research funds, said some cynics).[65] Sometimes they brought a completely worked-out design incorporating some novel feature which, potentially, might solve one of the great problems of diesel locomotive design. This then had to be thoroughly examined in the hope, all too forlorn, that it might prove viable. By the end of the 1920s such an examination, if all went well, might take six months. For example, the 'Trinkler' project was examined by the Diesel Locomotive Section of the NKPS Scientific Technical Committee in early 1928, which made its recommendations in April.[66] Then a Technical Conference with a widened membership was called, which made its own recommendations in early September. After this the Commission for the Study of Diesel Locomotive Construction of the Diesel Locomotive Commission took only a few days to issue its report and in the same month the Organizing bureau issued the final word on the subject. The Trinkler Project was a non-starter, but at least it had, formally, been thoroughly examined. In practice, the judgement of one or two respected diesel locomotive specialists was probably what counted most in these successive examinations.

It will be noted that the structure of the Diesel Locomotive Commission had undergone some changes. This was almost a continuous process, and is hardly worth recounting in detail; full accounts can be found in successive issues of the *Byulleteny* and *Sborniki*. Basically the problem was to evolve bodies and routines that could, with a relatively small number of specialists, examine projects, make plans, and above all coordinate the requirements of the NKPS with the capabilities of the locomotive, diesel engine, and electrical engineering industries of the VSNKh. The Diesel Locomotive Bureau of the NKPS had been established to handle practical testing, design and constructional problems for the Diesel Locomotive Commission. In the latter, which was attached to the NKPS, the small Organizing Bureau was evidently the centre of authority. By 1929 so many committees and sub-committees had been set up for particular problems, so much work remained to be done, so little of the work seemed to be translated, or translatable, into tangible benefits for railway transport, that a revised allocation of duties was adopted. This covered the duties hitherto performed by the Diesel Locomotive Construction Bureau at the Institute of Power Engineering in Leningrad, the Shelest System Diesel Locomotive Laboratory at Moscow, and the Diesel Locomotive Bureau of the NKPS. A main aim of the reorganization was to assert a clear division between the functions of the NKPS and of the VSNKh; that is, between the railways and industry. The VSNKh was henceforth limited to the organization of production, the detailed design of locomotives whose outlines were drawn up by the NKPS, and the construction of the diesel locomotives. Everything else was to come under the NKPS and its various organs, and this included the inspection of locomotives during construction and their testing. The Diesel Locomotive Commission of the NKPS would therefore be retained, with some slight change of functions; its main function was said to be the coordination of the NKPS and VSNKh activities.[67] However, this reorganization of spring 1929 was short-lived, the diesel offices soon being overtaken by the upheavals in the NKPS and the research institutes.

Although it was later asserted that the NKPS and its diesel organization, especially the Diesel Locomotive Commission, had achieved precious little in real terms in almost a decade of activity, the huge volume of paperwork actually published does at least demonstrate industriousness. For example, to take the 1927/8 programme,[68] eight designs forwarded by the Diesel Locomotive Bureau were approved by the NTK (these are listed in a note to this chapter).[69] The construction programme of 14 locomotives comprised another but improved diesel-mechanical E–mkh, a passenger version (S–mkh), a dieselized steam 4–6–0 (U–np), a steam-transmission freight loco (E–p), and two heavy yard or secondary line types (O–el), as well as three of the designs from the diesel competition (this plan having been drawn up before the announcement of the results of that competition). All the foregoing were to be built in Soviet works. At the same time another E–mkh, another S–mkh, and three other competition designs were to be built abroad. Work was going forward on many other projects. Gakkel''s allotted E–el–4 seems to have been held back because of a change from its designer's favoured two-stroke engine to a pair of four-stroke MAN vertical six-cylinder engines. In Odessa an old 4–4–0 had been allotted to Professor Prigorovskii for rebuilding with a diesel as a new variant of the compressed-air steam-type unit. Professor Prolygin had devised a generator with 'double rotation' and the Diesel Locomotive Base had been entrusted with the construction of a 6 kV model of this. And so on. The contrast between all this activity and the fact that there were still just two mainline diesel units capable of operating on Soviet Railways at this time was all too apparent.

Of the fourteen locomotives scheduled for construction, only two ever saw the light of day, and even these arrived years behind schedule. The ambitions of the Diesel Locomotive Bureau, however, were not quenched by such disappointments. For the following (1928/9) year the Bureau's proposals embraced ten experimental units, of which two were to be built abroad. Six of these were with mechanical transmission, two involved some kind of steam transmission (which if successful would enable existing steam locomotives to be converted to diesel power), and just two were diesel-electrics.[70] Evidently the engineers still sought to avoid electric transmission despite its proved efficacy. Terpugov was among those who were strongly in favour of mechanical transmission, but he received no support at this time for his proposed diesel-mechanical with an electromagnetic clutch. Quite apart from these experimental units, it was proposed to build in Soviet workshops a batch of twenty 4–10–2 diesel-electrics of the same type as had been ordered as prototypes from Krupp and Kolomna (see p. 109). The 1928/9 intentions may be regarded as the highwater mark of ambitious plans; after the tribulations of 1929/30 the surviving diesel proponents in their frequent polemical articles began to put their emphasis on the failure of industry to build, or even promise to build, the required numbers of diesel locomotives.

Foreign relationships

The locomotive problem for the USSR was twofold, so far as steam traction was concerned. Abroad, discussion and the building of prototypes suggested that better substitutes for the inefficient Stephenson locomotive might be just round the corner. Such substitutes included turbine locomotives, high-pressure locomotives, water-tube boiler locomotives, and others. On this worldwide question, whether there could be built a steam locomotive that would rescue the railways from their twentieth century problems, was superimposed the peculiarly Soviet problem created by breakneck industrialization in conditions of scarcity.

For orthodox steam and electric motive power, Soviet engineers were especially attracted by American practice. The Americans, too, were interested in building locomotives of higher sustained output, though for different reasons (not to make better use of freightcars and line capacity, but to beat highway competition without increasing labour costs). Of the various solutions proposed by the three big American locomotive companies, the 'super-power' concept of the Lima Works had most impressed the American railroads. The main features of this concept were a vastly enlarged firebox supported by a four-wheel truck, higher boiler pressure, and 'limited cut-off'. The latter feature ensured that steam entering the cylinder was automatically cut off after the piston had travelled not 75 per cent, but 60 per cent of its stroke, guaranteeing that the expansive potential of the steam would not be wasted by crews working their locomotives harder than was good for fuel economy. Although when Soviet orders were placed with American builders the Lima Works were not favoured, by that time the 'super-power' features had been appreciated by the two other builders, Baldwin and American Locomotive (Alco).

Students of the steam locomotive regard the Frenchman André Chapelon as the genius of inter-war steam locomotive development. The Chapelon rebuilds of older locomotives, from the 1920s onwards, produced impressive performances, often achieving 50 per cent improvements of power output for no increase of fuel and water consumption. In general, these advances do not appear to have been imitated by Soviet locomotive researchers, although it is possible that in some fields of locomotive thermodynamics there is an unacknowledged Soviet debt to Chapelon. It has to be remembered that French conditions did not match those of the USSR. The French locomotive crew was exceptionally well-trained and experienced, a circumstance far removed from the Soviet situation. Also, a great feature of Chapelon's work was his exhaust arrangement, whereas in the USSR the same object of even, predictable, and powerful draught was sought by other means: at first by installing fans in the smokeboxes and then, in the late 1950s, by doing what George Stephenson might have done at the start, taking advantage of ample Soviet headroom to fit taller chimneys.[71]

Among unorthodox foreign locomotive projects which attracted attention in the USSR was the Scottish Ramsay-Reid steam turbine electric (like a diesel-electric but with a steam turbine driving the generator), and two attempts to combine the virtues of steam and diesel locomotive, the British Kitson-Still and the Italian Ansaldo prototypes. Soviet engineers were at one stage so enthused by the Still and Ansaldo that they urged the ordering of Soviet versions, but wisdom prevailed, and it was decided to wait until the overseas ventures had actually shown what they could do (which, as things turned out, was not much).[72]

Frequent recourse to foreign success stories by Soviet engineers advocating one or another line of action was characterized by an almost routine distortion. Foreign journals were quoted not only selectively, but inaccurately. It is difficult to see whether this characteristic was regarded as part of legitimate polemical practice, came from wishful thinking leading to uncritical thinking, was a result of faulty translation or was merely a shameless twisting of evidence. Probably all these factors were involved. Possibly, it was wishful thinking that in 1930 prompted one diesel proponent to write, '. . . in America there is already a railway completely dieselized north of New York. On this line, about 120 km long, from Brockville to Belleville in Ontario the most powerful-ever diesel locomotive has been working . . .'.[73] This comment would have astounded the operating and engineering staff of Canadian National Railways, who for two years had been struggling with the teething troubles of this locomotive, which even in perfect condition could hardly have 'completely dieselized, this section of the CNR's busiest main line. Then there was Shelest who, in 1931, in the course of what seems to be his most aggressive critique of electrification, wrote that in Denmark electrification 'is bringing an obvious deficit'.[74] This statement was true but misleading. At that time the Danish State Railways were electrifying the first of their Copenhagen suburban lines but it would be many months before the trains would start running, to bring in some revenue. At first sight this seems a sly deception, but then the question arises of whether Shelest had confused Denmark with Sweden; after all, one of the electrification champions who wrote a stinging rebuttal of Shelest's article seemed to think that the electrification of the Brazilian Paulista Railway had taken place in Mexico.[75]

Around 1930 there was an increased flow of Soviet engineers abroad, especially to the USA. There was nothing especially new about this; the serf Cherepanov, who built Russia's first steam locomotive, had an all-expenses-paid trip to England in 1833 to see what the Stephensons were doing; one of Russia's greatest railway ministers, Prince Khilkov (who kept the Trans Siberian Railway operating during the Russo–Japanese War) spent some time working in a British locomotive factory; Raevskii visited most of the great locomotive works of Europe, knew many foreign engineers, and was a friend of the Austrian locomotive designer Golsdorf, with whom he had much in common. But in the late 1920s such travels became almost a mass phenomenon as the need to reconstruct railway transport made the American example an especially seductive subject for first-hand study. In April 1929 a preliminary agreement was signed between the NKPS and the Baldwin Locomotive Works.[76] This was mainly concerned with American help in organizing the equipping of repair workshops, but Baldwin also agreed to supply a design of a freight locomotive suitable for the USSR, and the visit of Soviet specialists to the Baldwin Works to assimilate the latest production techniques was also provided for. The presence of Baldwin experts in Soviet workshops was arranged at the same time; Japanese engineers were already in repair workshops, although according to at least one account their advice was not readily accepted by the natives.[77] In January 1930 a powerful Soviet delegation, which included more than 30 top specialists from the NKPS, VSNKh, and the Workers' and Peasants' Inspection, visited the USA in search of ideas.[78] Some of the delegates stayed four months and among the trophies they brought home were designs for a loco-

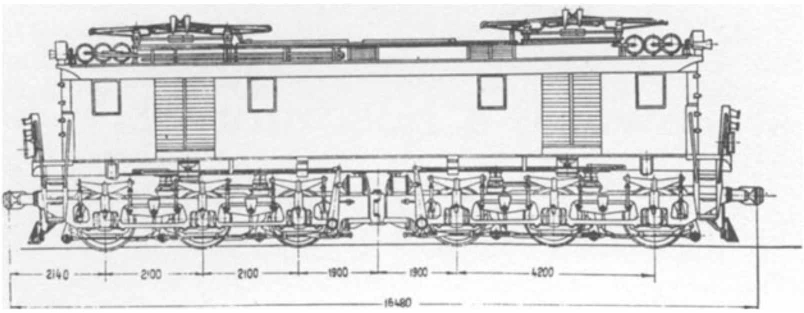


Figure 7 General Electric type S electric locomotive, the basis of subsequent Soviet designs. (Leading dimensions of electric locomotives are given on p. 214.)

motive capable of hauling 3000 ton trains.[79] In that same year there were Soviet engineers visiting Sweden and Germany, among others. Arrangements for such visits were not always faultless, as might be expected from the disarray of the NKPS at that time. Engineers detailed for foreign trips were released for language study without being told what precisely they were to concern themselves with in their host country, largely because the NKPS was itself slow to make up its mind where to send them. Moreover, 'those arranging trips do not take into account the real needs'.[80] In March 1930 an agreement between the NKPS and VSNKh on the one hand and the USA works on the other for the participation of Soviet designers in the design of electric locomotives being built for the USSR in American workshops (see Figure 7) was still unsigned; this was probably connected with the fact that the allocation of foreign exchange for these locomotives was diverted, by the steam interest inside the NKPS, to the construction of steam locomotives.[81]

3 Towards a Locomotive Policy, 1929–1931

The Background

The commotion that attended the adoption of the First Five-Year Plan in April 1929 proved to be only an overture; until the Second World War brought new priorities, Soviet life would be dominated by the theme of rapid industrialization. The Five-Year Plan was the most optimistic of two variants proposed, but, even so, during its course it was revised upwards as optimism was multiplied by enthusiasm to produce recklessness and then megalomania. Its first year went well, and at the end of 1929 it was decided that its targets should be achieved in four instead of five years. By 1931 Stalin was talking of 'the Five-Year Plan in three years'. In the end, when the First Five-Year Plan terminated (nine months short of five years), there had been great increases in industrial output, although these were usually less than the target figures.

The rapid growth of heavy industry, and of raw material output, put a great strain on the railways. For example, coal output rose during the Five-Year Plan from 35 to 64 million tons, and iron ore from 6.7 to 12.1 million tons. Although the Five-Year Plan had made some provision for increasing railway capacity, main reliance was placed on fuller utilization of existing lines and equipment. Moreover, when in the course of the Plan over-ambitious targets led to greater controls and the imposition of 'shock' priorities, railway investment fell far behind the already meagre intentions of the Five-Year Plan. Of the 16,000 km (9942 miles) of new railway scheduled, only about 5500 km (3417 miles) were completed, and much of the latter was built to gain access to new material and industrial sites and thereby exacerbated rather than eased the railways' problems. To a certain extent shortfalls in investment could be compensated by a larger deployment of labour; for example, an increase in locomotive men might raise the hours-in-traffic of the average locomotive. But the railways tended to lose their skilled men to industry, while receiving an influx of displaced peasants who were neither psychologically nor technically ideal.

The result of all this was that the railways as early as 1929 began to experience traffic blockages. While caring for the muscles of the Soviet economy the planners and the Party had wrongly assumed that the arteries would look after themselves. From 1929 successive winters brought transport bottlenecks, and by 1931 it was realized that something had to be done. But while the NKPS busied itself with the compilation of reconstruction plans (by which it really meant investment plans), the Party and government still held that the railway administration should make better use of the resources that it already had. This difference of opinion lay behind the frequent and not always bloodless staff changes inside the NKPS at this time.

In composing their plans for reconstruction, the NKPS officials had to demonstrate their faith in the ever more optimistic prognoses being handed down from above, while at the same time bearing in mind that pessimism was the only realistic attitude towards the possibility of receiving the resources they wanted. The railway reconstruction plan of 1931 was a short step towards resolving this dilemma. The plan, a final result of much debate in the NKPS, was approved by the Politburo and then by a Party Plenum in June 1931. Traction policy was one of its major themes, and June 1931 may therefore be regarded as the beginning of a new chapter in Soviet locomotive policy. Certain essential decisions, which had been debated endlessly in the past, were at last taken and given the authority of the Party. In traction policy, the basic guidelines imposed in June 1931 concerned the division of effort between steam, electric and diesel traction, and the adoption of a heavy freight locomotive somewhat smaller than the NKPS had hoped.

Locomotive research institutes

In compiling its reconstruction plans, the NKPS relied heavily on its research organizations. As in most countries, design and research was divided between the railway designers and researchers and those of the industries supplying the railways. In locomotive matters, there was a certain tension engendered by the question of where the line should be drawn between the spheres of the NKPS traction departments and their specialists on the one hand, and the sphere of the locomotive building industry's designers on the other. However, the present-day definition of the sphere of the railway traction researchers would probably have been acceptable by the later 1930s. In 1968 the role of the present-day Scientific Research Institute of Railway Transport (NIIZhT) in locomotive matters was defined as follows, and in the same order:[1] (1) the study of locomotive traction characteristics; (2) the study of the dynamic qualities of locomotives; (3) the establishment of the basic parameters of new locomotives; (4) the quest for optimum operating, maintenance and repair methods. This book is mainly concerned with the first and third items, but it is worth emphasizing that in the late 1930s the fourth heading occupied a great deal of the researchers' time, although never, it seems, as much time as the Peoples' Commissar, Kaganovich, demanded. Also, in the steam era much effort was devoted to the problem of utilizing inferior fuels.

The design offices of the locomotive industry were responsible for transforming outline drawings of new types of locomotive or major components into the working drawings used during construction. Possibly the greatest cause of friction was the division of responsibility between the 'outline' and 'working' stages. For the NKPS, composing an outline ('general arrangement') drawing was the work of many months, for all sorts of new ideas had to be explored, all kinds of permutations drawn and redrawn in order to test their feasibility.

Locomotive research organizations of the NKPS were only one part of the Commissariat's research establishment, and the structural changes which they repeatedly underwent during the Five-Year Plans reflected the changes in research policies of the NKPS (and USSR) as a whole. Two circumstances underlay these changes. Firstly, there were the reorganizations and purgings of the NKPS itself, beginning in 1930. The difficulties of the railways were regarded as the failures of their administrators and the latter were accordingly changed by the same methods as were used in other parts of the economy. Secondly, there was a very real organizational problem: should the different specialized research groups be organized into separate institutes, where they could concentrate on their own range of problems without disturbance and involvement in urgent tasks which were outside their specialization? Or should they be grouped in one organization, which would make them more easily controllable and permit an all-round study of those many problems which concerned several specializations? Because there is no answer to this question, no ideal form of organization, there were good opportunities for those who believe that reorganization solves everything. Thus from 1928 until 1945 there was a wavering between the concept of a central research institute, with specialized departments, and the concept of as many specialized 'branch institutes' as were needed.

These repeated structural changes were not, however, designed simply to meet the railways' problems. They were usually paralleled by changes in other industries, which suggests that they were more fashionable than serviceable. Dzerzhinskii (who died in 1926) had stressed the importance to industry of scientific research, but had been in favour of central all-embracing institutes for the different industries. But by the end of the 1920s decentralization was in favour, and the proliferation of railway research institutes was a result of this new general policy.[2] Later, in the mid-1930s, there was a re-centralization of railway research which was in line with the concurrent reduction of research institutes in the economy as a whole.[3] On the railways, at least, successive reorganizations probably had little positive impact on the quantity or quality of research. As happened with other departments of the NKPS during periods of purge, organizations might appear and disappear on paper without their workers being aware of any change, while other departments and their staff could disappear and their absence be unnoticed until someone knocked on their door and received no answer.

When the Five-Year Plans began, what had seemed a steady rate of useful research was condemned as stagnant and even hostile. Some of the old 'bourgeois specialists' were purged in 1929 and in March 1930 another group was erased, including many of those associated with the first batch; for example, Professor Streletskin, a civil engineer who made the mistake of insisting on speed and weight restrictions over some 200 weak bridges, was ousted from the NKPS and replaced by younger colleagues who, on 'scientifically-based principles', lifted the restrictions. Another troublesome engineer, Pravosudovich, had already been removed from the NKPS, so in 1930 his secretary was despatched, presumably *pour encourager les autres.*[4] Meanwhile, from 1928 the old Scientific-Technical Committee (NTK) of the NKPS was progressively divided into branch institutes. First came the Scientific Research Institute of Signalling and Communications, and by early 1931 there appear to have been nine major institutes (of

Traction Reconstruction, Permanent Way Reconstruction, Electrotechnics, Materials, Construction, Economics, Operating, and Road Transport, together with the research institutes embodied in the Leningrad and Moscow institutes of transport engineers).[5] The old NTK was criticized because it had harboured wreckers, and because those of its researchers who were not wreckers had insisted on obtaining for themselves topics that were too abstract, too close to pure science. The NTK's successor as general supervising agency was the Central Scientific-Research Directorate (TsNIU) of the NKPS. This, though, did not last long. By May 1930 the 'formerTsNIU' was being condemned as being far too academic, with its leading lights opposing the Party's wish for decentralized research institutions.[6] Evidently the hankering of pre-revolutionary railway researchers for scientific status lingered on.

One of the first tasks of the erstwhile TsNIU had been the selection of promising young research workers who could be elevated into top positions and thereby transform the whole approach, and in particular generate some enthusiasm for the solution of the practical problems that were multiplying at this time of rapidly increasing traffic. The replacement of new blood by old would occur again in the 1930s, but seems to have had little positive effect on the technical progress actually made. Throughout that period the criticism levelled against the researchers remained essentially the same, even though the form of words might vary. Purgings, demotions, and disgraces were always accompanied by the charge that researchers were unwilling to give immediate, concrete, answers to immediate, concrete, problems. In locomotive research, at least, these charges seem well-based; traction computations, passport compilation, the quest for improvements in heat-transfer efficiency were the topics which aroused the most enthusiasm even though these were all topics whose resolution was less urgent than, say, the cure of infirm frames and rapid-wearing tyres of the new locomotives. Again, what happened on the railways was paralleled in other industries, where complaints were voiced that researchers still had not shaken themselves free from the academic approach 'traditional' in Russia, and had turned a blind eye to the research problems suggested by production workers.[7]

As will be seen, the heavy-handed methods[8] employed to impel the researchers in the required direction probably made things worse, at least in the late 1930s. Successive purges may well have eliminated the wrong men, perhaps because of a failure to distinguish between the experienced and the 'conservative'. Possibly the younger, rapidly promoted men lacked the self-confidence to be truly revolutionary and masked this defect by a show of excess which typically resulted in a good idea being carried too far. All too often the bright young men were not so bright after all, or were too clever by half. When Party cadres were inserted into the institutions they had little effect, apart from perhaps intensifying the apprehensive atmosphere whose main fruits were the discouragement of honest speaking and the avoidance of research topics whose solutions seemed likely to run contrary to the prevailing policies. The decree in 1933 about Party cadres in the NKPS seems to describe accurately enought their effect in the NKPS research institutes:

> Moreover, it is intolerable that leading party cadres, occupying important positions in transport, neither know nor seriously study techniques and uselessly wave their Party Cards around while those who know the business and who know how to give a lead . . . are erased from leading positions because they do not hold a Party Card.[9]

In the early 1930s, although leading researchers tended to occupy themselves with old problems, the incoming projects were almost entirely short-term. Re-equipment, and the increasing disproportion between the work expected from the railways and the new resources put into them, were bound to raise technical problems requiring immediate solutions. In retrospect, much of the work done seems pathetically alarmist, but this is not how it appeared at the time. Metal shortages, for example, led to much scientific effort being devoted to the design of standard bridges built of wood, and to finding ways of using iron instead of copper for the conductor wires of electrified railways. At this period only the Institute of Materials had proper equipment. The institutes seem to have shared a common and inadequate building on Gorokhovskaya Street in Moscow. The six main institutes totalled only 199 research workers.[10]

In 1932 a leading Party worker, Razdobreev, who was in railway research, wrote that work was still plainly unsatisfactory.[11] He himself had shown unforgivable lack of vigilance in writing a foreword to a defective textbook on railway operation written by one of his researchers. Actually, he had not read it, but that was in itself a sad lack of proper Bolshevik vigilance. Egorchenko's book on the problem of automatic couplers had actually been published with the approval of the Institute of Traction, where Egorchenko did his research, even though the author minimized Soviet success in this field and overpraised American types of coupler. The institutes, continued Razdobreev, did have a few achievements to their credit, but in general they had failed to complete the important practical tasks entrusted to them. Directors of institutes had failed to understand the importance of the work their institutes were supposed to do, while the Party and trade union organizations that were supposed to be watchdogs inside the institutions had composed impressive critical reports without doing anything concrete to mend matters. There were still 'wreckers' lurking in the institutes. There was no control over the quality of research, and very slow dissemination of findings.

In February 1930 an order of the Supreme Economic Council (VSNKh), which was ultimately responsible for the locomotive industry, announced the creation of the Diesel Locomotive Institute.[12] This concentrated in one, potentially very effective, body, all the diesel groups that had previously been scattered and divided between the NKPS and VSNKh. These included, notably, the diesel locomotive departments of the Central Scientific Research Directorate (TsNIU) and of the locomotive directorate of the NKPS, the NKPS diesel base at Lyublino, the NKPS diesel laboratory installed on industry's territory at the Kolomna Works. From the VSNKh was transferred the diesel locomotive department of the Institute of Power Engineering. The Shelest diesel laboratory, which by then was established in the basement of the MVTU (Moscow Higher Technical School), was included and indeed could be regarded as the nucleus of the whole scheme. Also included was a surviving remnant of Soviet-German technical cooperation, Lomonosov's portable locomotive testing plant, which was still in Germany.

This order must have brought joy to the hearts of two interested groups: the locomotive industry, which henceforth would have its own locomotive research institute, and the diesel locomotive protagonists, who would have a research institute of their very own. It seems to have taken four months for the steam and electric locomotive interests to persuade the VSNKh to correct the imbalance, and the next new institute established for the industry was shared by the two remaining forms of traction. This institute was to be known as the Scientific Research Institute of Locomotive Construction (NIIL). That was in June, and in October 1930 the dieselizers were defeated, a new order deeming the establishment of the Diesel Locomotive Institute unnecessary since 'up to now insufficient progress has been made in creating it'.[13] Presumably the arrest of many NKPS diesel specialists, which seems to have occurred in May,[14] was one reason why the new institute had 'not been sufficiently created'. Following this order the Shelest and Kolomna laboratories remained with the VSNKh (that is, the locomotive industry) while the diesel locomotive base, the portable testing plant, and various personnel were returned to the NKPS. Later that year the Kolomna and Shelest laboratories were unified under the title 'A. N. Shelest System Diesel Locomotive Mechanical Laboratory'.

This reversal of October elicited some heated, if confused, polemics from the pens of three men already well-known for their strongly-expressed opinions.[15] None of them seems to have been quite clear about what was really happening. The Kolomna designer Vinogradov, for example, called a meeting of the Kolomna steam-diesel design bureau to condemn the transfer of 'the Institute' from the industry to the NKPS, but whether 'the Institute' actually existed seems as unlikely as its alleged transfer to the NKPS. Another designer, A. S. Martynov, was much more convincing in his arguments against the NKPS having a monopoly of locomotive research. The NKPS, he wrote, despite its huge research establishment had not done very much to solve current steam and diesel locomotive problems. This was because a basic mistake had been made. Whereas there were two separate fields of locomotive research, design and operation, in the USSR both had been entrusted to the NKPS; rationality demanded that industry should look after the former while the NKPS researched operating problems. As a result, he continued, the NKPS had a rather poor record. Its M type passenger locomotive was unsuccessful. Nothing had been done in the field of high-pressure or watertube boilers, there was no testing plant, premature orders had been placed for diesel-electrics while there had been a complete lack of attention regarding the 'so-far unique Shelest diesel locomotive patent'.

A pseudonymous representative of the NKPS diesel interests, '*Teplovoznik*', contributed a counterblast to the aspersions made by the industry's spokesmen. He did not lose the opportunity to point out that Martynov's advocacy of the Shelest system (which he noted existed 'only as an unfinished experimental Shelest motor, eternally working with one cylinder, on which Shelest has worked for more than 10 years without any results so far'), put Martynov firmly in the Shelest camp and was probably why he was so bitter about the

NKPS, and especially about the NKPS's decision to order more diesel-electric locomotives. As for Martynov's other complaints, well, Martynov was an experienced steam engineer working in the locomotive industry so perhaps he could explain precisely what he and his fellows had done to improve the M type locomotive or to design high-pressure or watertube boilers? On the question of a testing plant, a measure of gentle malice can be detected in '*Teplovoznik*'s' remark that the NKPS had indeed acquired its own locomotive testing plant (referring to the impending repatriation of the Lomonosov plant). Rather pointedly for the 1930 situation, he asked why the locomotive industry had not made proper use of old engineers experienced in constructing test plants, for, after all, the locomotive works needed such plants more than did the NKPS.

A little while later, writing probably in January 1931,[16] Martynov could express the hope that, following decisions made at the end of 1930, the NKPS would indeed be confined to locomotive operating research (through its Institute of Traction) while locomotive design research would stay in the industry's Institute of Locomotive Construction.

In the end, things did not turn out quite as Martynov had hoped. After an enquiry into the matter by the Workers' and Peasants' Inspection, two changes of title, and marginal adjustments of function, the industry's locomotive research institute emerged as TsNIIL (Central Scientific Research Institute of Locomotive Construction) of the People's Commissariat of Heavy Industry.[17] Its main tasks, as set out in an editorial in the first edition of its *Lokomotivostroeniye*,[18] were the establishment of the basic characteristics of new locomotives (a task that the NKPS considered to be its own special province, as user of new locomotives), the building of prototype components, the creation of a capable laboratory for locomotive construction, and participation in the factory trials of locomotives. Secondary tasks included the wide dissemination of information about foreign practice (largely through *Lokomotivostroeniye* itself), consultation with locomotive-using organizations (mainly the NKPS but including industries with their own industrial railways), and the study of coal dust and peat dust as locomotive fuels. The same editorial stressed that the TsNIIL was essentially industrial, which was why it was under VSNKh. The NKPS had proved useless in producing initiatives for new locomotive types because 'the factories were not prepared for the new types'; the new Institute would provide a better relationship with the factories. New designs and orders would be merely approved by the NKPS, and then immediately handed over to industry for execution. A powerful locomotive testing plant would be built, an important resource hitherto lacking.

In 1932 the diesel interest was still dominant in the Institute, 70 of the researchers working on diesel problems and only 16 on steam (the electric specialists were being dispensed with). No doubt the meagre accommodation (just three rooms totalling 75 m^2[807 ft^2] in the MVTU, utilized on a two-shift system) was a near-monopoly of the diesel specialists. Even so, an aggrieved diesel man wrote that 'The crowding of the premises could not contribute to a correct development of the TsNIIL's work'.[19] Worse was to come; perhaps in conformity with the general urge to cut down on the proliferation of research institutes, TsNIIL found itself starved of funds, and was liquidated in 1933. Research on high-pressure steam locomotives was transferred to the new Central Locomotive Design Bureau (essentially the old Kolomna Works design office), while the Shelest Diesel Laboratory remained at MVTU with an establishment of about 65 workers.

Thus ended the locomotive industry's attempt to wrest from the NKPS the projecting and preliminary design of new locomotive types. However, it could console itself with its dominance in the design of locomotives for the non-NKPS railways (these industrial lines had a mileage close to a half that of the NKPS). By 1935 the industry's All-Union Scientific Research Institute for Industrial Transport was doing traction computations on industrial locomotives, planning new industrial locomotive designs for all gauges, and seems to have had a monopoly of narrow-gauge locomotive design and research, possessing its own narrow-gauge dynamometer car for line testing.[20] Also, Shelest's diesel laboratory at MVTU continued to serve the locomotive industry, producing numerous outline drawings of locomotives (never built) and of components.

Another creation of 1930 was the Central Locomotive Design Bureau (TsLPB). Hitherto the locomotive works had had their own design offices, but the TsLPB was intended to end this situation by centralizing all detailed design work in one establishment. In this way, it was presumably thought, the urgent task of designing standard locomotives for the new conditions would be speeded up. What this meant, initially, was that the Kolomna design team was strengthened, and carried out all the work. The other works seem to have retained designers only for immediate production-type tasks, although those at Bryansk, at least, also engaged in the design of new or modified components. This situation did not continue long, for by the mid-1930s both Kharkov and Lugansk works had design offices capable of turning out the drawings of complete locomotives. According to a post-war commentator,[21] '. . . pre-war experience showed that the existence of a central locomotive design bureau leads to conservatism and inertia, and not to competition between collectives in the creation of the best and most economical locomotives'. As will be seen, in 1948/9 there would be a definite return to 'competition between collectives' when Kolomna, Ulan Ude and Voroshilovgrad each put forward a freight locomotive prototype for evaluation.

The NKPS, not the industry, determined the salient features of each locomotive project. The Leningrad and Moscow institutes of transport engineers, which were traditionally oriented towards the NKPS, not towards industry, shared with the NKPS Institute of Traction Reconstruction the preparation of these outlines. At the Leningrad Institute there had existed since the early 1920s the Bureau for Powerful Locomotives, in which at least one well-known old-school designer was employed (Delacroix, traction engineer of the former Ryazan–Uralsk Railway). This Bureau seems to have originated the second of the Soviet standard freight locomotive types, the SO. However, it disappears from view at about this period, possibly because the neighbouring Putilov Works ceased locomotive building in 1930. The SO outline drawing is now attributed to the Institute of Traction Reconstruction, which subsequently entrusted the Kharkov Works with the detailed drawings. At the Moscow Institute of Railway Transport Engineers a new research establishment (later known as MEMIIT) began to specialize in the thermodynamic side of locomotive design and around 1930 was engaged in a programme to fit superheaters to the old O type freight locomotive. The MEMIIT researchers appear to have established quite close links with Kolomna Works. The latter was easily accessible from Moscow and it was probably this, together with Kolomna's wide experience, that determined the location of the TsLPB.

The upheavals of the NKPS departments, the creation and re-creation and renaming and abolition of research institutes, the dissolution of works design offices, meant that many locomotive specialists of 1930 had no fixed address. Some of them, however, had an address that was very much fixed, in an OGPU establishment. This establishment was almost certainly created to concentrate minds which had been dallying too long over basic and urgent decisions. What was required of its involuntary guests was a final decision on the locomotive designs to be standardized for series production.

Yanush, writing for publication in 1950, refers to this design establishment as 'a special technical bureau acting as an auxiliary of the NKPS'.[22] Rakov, writing for publication in the mid-1950s, could be more precise, using what may be presumed to be its official title, the 'Technical Bureau of the OGPU Transport Department'.[23] It may be noted that the end product of this bureau was expected to be simply a series of outline drawings. The first of such drawings produced by the OGPU office were for the new FD steam locomotive, and they were achieved at the end of April in 1931. The other designs produced have not been named, apart from the *Iosif Stalin* passenger locomotive, which was a development of the FD.

That this office was concerned only with outline drawings, with the latter going to the Central Locomotive Design Bureau for elaboration into working drawings, suggests that the inmates of this OGPU office were mostly, or entirely, from one or other of the NKPS departments or organs. 1930, after all, was the year of the dissolution of many such departments: The Diesel Locomotive Bureau, for example, seems to have disappeared from the NKPS premises in May 1930, and its personnel might well have provided the diesel experts required by OGPU. What happened to the OGPU office when the required outline drawings had been completed is unclear, but it may be assumed that at least some of its personnel were released, judging from what is known of similar establishments for other industries.

Throughout this period the NKPS had firm control of the practice and science of locomotive testing and 'traction computations'. This was still the first love of its leading locomotive specialists, but the days had long passed when a test train had the same privileges as the Imperial Train; rising traffic demand meant that line testing was threatened by tightening restrictions. But the NKPS had already taken quite decisive steps to preserve the science of locomotive testing; indeed, this is a field where the NKPS locomotive researchers appear to have obtained what they needed without excessive argument among themselves. As an excellent substitute for main lines, a special testing track was built at Shcherbinka, near Moscow, and opened in 1932. This was a 6 km ($3\frac{3}{4}$ miles) circular track offering constant resistance, on which locomotives could haul their test trains in complete freedom. At the time it was the world's most advanced railway testing track, and probably still is; its equipment has been steadily augmented in the post-war years. This test track was NKPS property and was used for continuing 'passport' testing of existing locomotives and searching trials of new designs built by the locomotive industry.

The rapid ejection of electrical specialists from the short-lived Institute of Locomotive Construction was consistent with the tendency for electric traction research to take its own course. At first, railway electrification research came under the Experimental Institute for Transport (EIPS), which had an electro-technical section. The latter, after the formation of the NKPS Scientific Technical Committee (NTK), became the electrification department of the NTK. Specialists from the Polytechnical and Electrotechnical institutes in Petrograd were drawn into this department's work on electric traction, as were certain specialists from the Petrograd and Moscow institutes of railway transport engineers and from the Moscow Higher Technical School (MVTU). It was this department which in 1920/1 was responsible for the railway electrification component of the GOELRO scheme. However, most of its traction work, at least in the early 1920s, seems to have been devoted to tramway problems. At that period traction motors were the responsibility of two works, *Elektrosila* in Leningrad and Dinamo in Moscow; the designers at these works, with the help of the researchers of the NKPS, mastered the construction of electric traction motors in this period. Hitherto such items had been imported.

From 1928, however, the *Elektrosila* design work was taken over by Dinamo, which became the sole supplier of traction motors. This coincided with a reorganization of the research institutes which seems to have been intended to give a boost to railway electrification, said to have been wilfully allowed to lag behind the other railway programmes. In this initial 1928 reform a Bureau for Communications and Electrotechnique was established under the NTK, while in the Central Directorate of Communications and Electrotechnique of the NKPS a railway electrification group was established. At the same time special bureaux were set up for the electrification of the Moscow–Kursk, Northern, and other railways having electrification prospects. Meanwhile the State Electricity Trust (GET) had its own design and research staff and this was supposed to cooperate with the railway researchers in the elaboration of the several electrification projects. The NTK retained an overall supervising authority and at that time, for example, was entrusted with the ordering of British electrical equipment for the electric rolling stock and German equipment for the sub-stations.

Then, in line with the continued reorganization of research establishments on the railways and in the economy in general, in March 1929 a railway Scientific-Research Institute for Communications and Electrotechnique was established, with a special bureau for traction research and proper experimental facilities for the latter. In October 1930 this Institute became the Scientific-Research Institute of Transport Electrotechnique under the NKPS's Central Planning-Technical-Economic Directorate (TsPTEU). The Institute retained a special traction sector which in 1930 was occupying itself with deciding the parameters of electric locomotives and sub-stations for the Suram Pass electrification. Experimental facilities began at last to materialize both at Moscow 3 station (on the Northern Railway's electrification project) and at the new NKPS test track at Shcherbinka. A much-needed laboratory vehicle (for testing both locomotives and overhead current collection) seems to have been acquired at this time. A further, but far from final, reorganization occurred after the June 1931 Party resolution, when in October of that year the Scientific-Research Institute of Railway Electrification replaced the former and probably depleted Institute. The new Institute had four sectors (rolling stock, substations, catenary, and measurements) plus a special bureau for the design of a section of track intended to test the advantages of the latest techniques of high-voltage alternating current electrification.[24]

Steam traction

In June 1931 steam was recognized as the prime motive power in the short term, and would retain this primacy two decades longer than anticipated. The specific designs to be built were not settled at this time, although the ruling did narrow the choice. In 1929–31 all kinds of steam flowers sought a chance to bloom, and each had its proponents. It was generally accepted that the Su and E type locomotives were good designs but too small for future needs, and the problem was to find new wheel arrangements that would permit greater power outputs without demanding excessive resources for stronger track.

In general, there were two attitudes within the NKPS. A majority of those whose opinions can be divined from their printed comments favoured American-style railroading and believed that during the First Five-Year Plan sufficient of the trunk lines would be relaid with heavier rail, and sufficient of the freight cars fitted with stronger couplings, to make it feasible to introduce very powerful locomotives, 23-tonners in the first instance and 27-tonners subsequently. It should be remarked that 23 and 27 tons refers to the axleweight; discussion of locomotive policy at this time, confused in any case, sometimes became even more aimless when some discutants took 23 and 27 tons to refer to tractive effort rather than axleloadings.[25] A less vocal section had some doubts about rails and couplings, as well it might in view of industry's failure to deliver more than a fraction of the railways' minimum requirement of new rail, and the apparent failure of the research institutes to design a Soviet automatic coupler. From about 1930 to 1934, the concept of American-size trains hauled by American-size locomotives receded into an ever-more distant future; the June 1931 resolution was a considerable step towards recognizing this.[26]

The sheer variety of successive proposals is most conveniently expressed chronologically, especially as only a few of the projects warrant detailed discussion. In March 1929, as the scale of the railway problem was just becoming apparent, a spokesman at a planning conference said that the immediate aim was to build sufficient of the existing E type locomotives to haul all freight trains, although there was a willingness to build an experimental batch of 50 units weighing 100 instead of 85 tons.[27] But a month later came the agreement with the US firm of Baldwin which included the design of a much more powerful locomotive.[28] A few days later, reviewing the NKPS's latest reconstruction plan as approved by Gosplan, a long article in *Ekonomicheskaya zhizn'* mentioned in passing that a new, more powerful, steam locomotive was required that did not demand the laying of heavier rails. At this time, too, some engineers claimed that heavy locomotives could be used on existing rail types if more sleepers (cross-ties) were laid per kilometre of track. Meanwhile, inspired by the findings of the locomotive-testing specialists, the NKPS had decided to modernize the old tsarist types O, N, and Shch. To this end, superheaters, pistons and cylinders had been ordered from Latvia. Five years later these components were rusting away on NKPS dumps, it having been decided in the meantime that these modernizations were not such a good idea after all.[29] Towards the end of 1929 another article seemed to suggest that future policy would be the old and somewhat discredited NKPS traction plan, with some new American ingredients. That is, a new, heavier, freight locomotive was to be developed, as well as the maligned tank locomotive for commuter services, and the M 4–8–0 would be the mainstay of heavy passenger services. Yet the same article declared that the M was far from perfect. The article was illustrated by two photographs. One of these showed a US 4–8–2 locomotive over the caption 'Our future passenger locomotive' while the other was of another American type, the Union Pacific's 4–12–2, a multi-axle freight locomotive that had attracted attention among Soviet steam engineers because it combined high power with moderate axleload (see Table 3.1). This picture was captioned 'Our future freight locomotive'.[30]

TABLE 3.1 *US and Soviet top-link freight locomotives in 1929*

	Union Pacific Railroad 4–12–2	Great Northern Railway 2–8–8–2	Soviet Railways 0–10–0
Weight [full, without tender] (tonnes)	233	311	83
Axleweight (tonnes)	27	34	17
Firebox grate area (sq m/sq ft)	10/108	11.7/126	4.46/48
Superheater area (sq m/sq ft)	237/2,560	326/3,515	66/710
Tractive effort (tonnes/lb)	44/96,650	67/146,710	23/51,200
Adhesion factor	3.68	4.05	3.61

NOTE In simple terms, tractive effort represents pulling power at starting. The adhesion factor (weight on coupled wheels divided by tractive effort) expresses the ability to apply that tractive effort without wheelslip (the lower the factor, the greater the propensity to slip). Grate area reflects steam-raising capacity and is therefore an indication of horsepower output over sustained periods. Superheater area influences the efficiency of steam utilization and therefore affects both sustained horsepower and fuel economy.

Early 1930 witnessed a deterioration of locomotive work out on the line, as well as the despatch of the Soviet delegation to the American railroads and railway industries. On the line, the principle concern was the poor physical condition of the locomotives, which was leading to frequent failures and to accidents. Shortage of spare parts was crucial. The railway supply industry, principally heavy industry, agreed to supply only a proportion of the railways' needs and even then the promises were underfulfilled. Examples of this situation have been published elsewhere.[31] A piquant situation arose in March of 1930, when industry could not produce enough boiler tubes for the railways or for new locomotives. This impelled the directors of the Kharkov and Lugansk locomotive works to beg the NKPS to release to them, part of the VSNKh domain, tubes that the VSNKh should have provided. Unless the NKPS released these tubes (intended for locomotive maintenance), said the directors, they would have to stop building locomotives until fresh supplies came through.[32] To some extent imports made up for the domestic shortfalls but in 1930 the spending of foreign exchange was coming under severe scrutiny.

Passenger locomotives seemed to have a peculiarly poor record in 1930. One 'Vladikavkaz Pacific' on the October Railway was said to have been out of service for eight months, awaiting the supply of a new wheel. Driving axle failures on this type were also quite common and in April 1930 a writer suggested that it was time to ask the procuratorial departments to look for the guilty persons;[33] by this time the view that no accident was accidental, and no mistake mistaken, was becoming more prevalent in the official mind. Meanwhile the M type passenger locomotive was still in trouble. On the Moscow–Sevastopol run, which these locomotives handled, 'sprinklemen' (*polival'shchiki*) were carried on the locomotives, charged with watering any part that was in danger of overheating while the locomotive was running.[34]

To these material shortcomings was added a failure of morale on the part of those concerned with locomotives. Events in Soviet society, notably the assaults on the peasantry and the food shortage, together with deteriorating working conditions and coercive attitudes on the part of the authorities, may be assumed to have engendered a certain bloody-mindedness. Even without these events, the pressure on railwaymen to achieve high targets under the handicap of defective equipment and leadership would alone have been enough to have soured operating staff. Of all the cases reported in the press in 1930, Engineman Zinchenko of the Donetsk Railway seems to have broken all records, disabling five locomotives in one fell swoop. Manouevring two Su locomotives at his locomotive depot, he crashed full tilt into three similar units that were placidly simmering on a storage track. The result was three locomotives sent for capital repair, two for intermediate repair, and the 'wrathful indignation' of his fellow-workers.[35]

In April 1930 a short-lived NKPS Commission for the Choice of a

Steam Locomotive made its recommendations. From the USA were to be ordered a 23-ton and a 27-ton 2–10–4 design, the former being fitted with a booster. The question of a 30-ton locomotive was to be left open, but an attempt was to be made to acquire from the USA the detailed design of such a locomotive. Prices were to be obtained on the basis of an order for three, ten, or 'many' units of each of the two types. The proposed locomotive with four driving axles (presumably the 4–8–2) was not to be ordered, but new designs could be acquired. Enquiries were to be made in England and Germany in the hope of ordering three Beyer-Garratt type locomotives. The NKPS Traction Commission was to seek information about the operating results of Mallet-type articulated locomotives and of six-axle locomotives (the latter being the Union Pacific RR's 4–12–2).[36]

In the summer of 1930 the Deputy Commissar for Transport, D. E. Sulimov, after leading the Soviet railway delegation to the USA, wrote an article in which, presumably, current NKPS thinking as modified by the American trip was embodied.[37] Sulimov envisaged the use of 23-ton locomotives of the 2–10–2 or 2–10–4 wheel arrangement (these were the locomotives which Alco and Baldwin were to build for the USSR). Such locomotives would work on the so-called Group 2, or intermediate lines. On Group 1 lines, those carrying the very heaviest traffic and which were expected to be among the first to be electrified, Sulimov envisaged even larger steam locomotives. But more interesting was his forecast of the introduction of Beyer-Garratt Patent locomotives to the lines of Group 3, with their weak trackwork. This programme outlined by Sulimov was intended as a guide to the next four or five years. The question of the US locomotives (types Ta and Tb – see Figures 8 and 9) and of

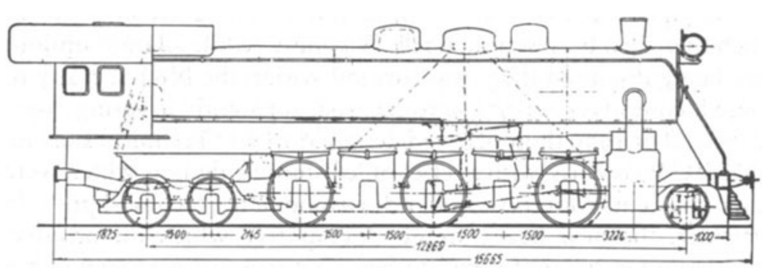


Figure 8 The American Locomotive Company's Ta design for Soviet Railways.

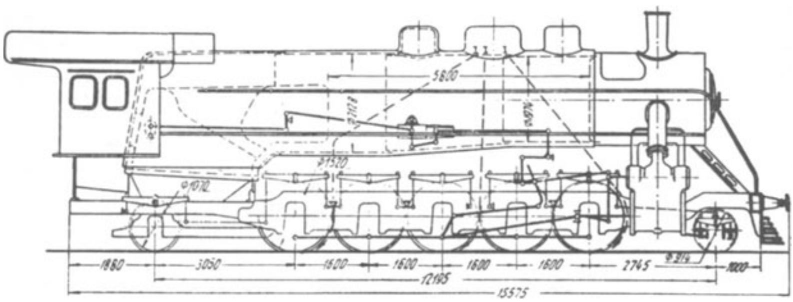


Figure 9 The Baldwin freight locomotive Tb design for Soviet Railways.

the Beyer-Garratt are sufficiently interesting to warrant a fuller description on a later page. In the meantime it might be mentioned that a lighter, Soviet–designed substitute for the American locomotives appears to have been designed for construction by the Putilov Works. This, the type T 2–10–2, presumably fell by the wayside in 1930 when Putilov ceased locomotive building. A further reference to the desirability of the Beyer-Garratt came at the end of the year, with an article in *Ekonomicheskaya zhizn'* entitled 'Let's put the Garratt on the agenda'.[38] This article suggested that the proposal for the Garratt type came from the Workers' and Peasants' Inspection (RKI), the NKPS 'being set on US standards'.[39] In this article, however, the fact that the Alco Works had taken out a licence to build Garratt locomotives in the USA was duly emphasized.

The foregoing seems an adequate summary of the intentions, or rather indecision, of 1930. Just two other circumstances should be noted. Firstly, 1930 did witness at last the signing of contracts with American locomotive builders (Alco and Baldwin) for the supply of five examples each of the 2–10–2 and 2–10–4 locomotives of which there had been so much talk. Secondly, while all these options were being discussed there was turmoil within the NKPS, many of whose locomotives experts were arrested, apparently in spring 1930. By the end of 1930 those arrested designers in the 'Technical Bureau' of OGPU were busy with a series of locomotive designs which were rather different from those under discussion in the technical press. In particular, the new heavy freight locomotive which the arrestees were designing was not going to be a 23-tonner or a 27-tonner but something much smaller. Somebody, somewhere, had acknowledged that 23-ton axleloads (and the high tractive effort they implied) were out of the question because in the next five years neither rails nor couplings would accept them.

Press articles in January 1931 seem to have been written in ignorance of the change of thought implied by what was being produced by the OGPU designers. On 7 January the press revealed yet another new locomotive project; Kolomna Works, it was reported, was to be reconstructed in order to build a 4–8–2 mixed traffic locomotive.[40] This, too, looks like an idea brought back from the USA.

In that same first week of 1931 a 'brigade' that had been organized by the newspaper *Ekonomicheskaya zhizn'*, to probe the railway administration's actions and prospects, made its report. It said, as might have been expected, that the NKPS blamed industry for non-delivery of locomotives and couplers. The report blamed the NKPS for 'rejecting' automatic couplings for three years and then expecting industry to supply enough for a complete changeover within five years. On the basis of enquiries made within the NKPS the brigade concluded that the NKPS had asked for 1500 23-ton locomotives but that VSNKh had felt able to offer only 405. The group supervising the reconstruction of Lugansk Works told the brigade that the only guide they had of the 23-ton locomotive to be built at the premises they were designing was an outline sketch, a picture, and 'some American index cards'.[41] In view of later events, this situation can hardly be said to indicate that certain decisions had been quietly taken, but rather that options were still open. The 20-ton locomotive being designed in the OGPU bureau (the future FD type) was still less an alternative than a supplement for the 23-ton machines.

Railway traction specialists were no doubt under great psychological pressure at this time. Since the Shakhty Trial 1928 there had been an appreciable tendency to persecute not only the old 'bourgeois' specialists but also their younger pupils. The insertion into leading positions of trusted but technically-ignorant Party men also hindered thoughtful decision-making. In the circumstances mistakes were perhaps creditably few, even allowing for the fact that in the apprehensive atmosphere of that time engineers tried to make as few decisions as possible, relegating unavoidable issues for decision not by themselves but by special commisions.[42] However, one technically illiterate decision has already been mentioned (the ordering of imported superheaters for the old O class locomotives). Another misjudgement was the acceptance of designs for the American Ta and Tb locomotives that were too wide for Soviet

Railways. So far as can be discovered, this mishap was passed off quietly, with no accusations of 'wrecking'. There was merely an announcement that the Donbas lines on which the American locomotives would run would have their lineside structures trimmed, in accordance with the long-term plan to enlarge Soviet railways' clearance limits.[43]

In early 1931 an article[44] in the NKPS journal emphasized the divergence between the NKPS and the locomotive industry ('*Parvagdiz*'). Basing himself on a *Parvagdiz* publication, 'Perspective Plan of the reconstruction of *Parvagdiz* factories in 1931–38', the author reproduced a table of NKPS requirements up to 1938 as they were listed by *Parvagdiz*. This list included the 4–8–2 passenger locomotive (2000 units beginning in 1932) and the 2–10–4 freight locomotive (said to have an axleweight of from 23 to 28.5 tons, and of which 550 units were to be built in 1932 alone). This table did not include any 2–10–2, and the old E type was shown as coming to the end of its production run in 1933. Then came *Parvagdiz*'s table of 'perspective' production (that is, showing what *Parvagdiz* in fact intended to do). Only three types were scheduled for production here: the old E (which was to continue into the Second Five-Year Plan and whose total production in the two Five-Year Plans would actually exceed the NKPS requirements); the old Su (whose production would lag far behind the NKPS requirement), and a 2–10–2 for which the NKPS had expressed no desire. Apparently there was some hope for the 4–8–2, because to fill the gap between the NKPS total requirement of 14,000 units and the capacity of existing locomotive works a new factory was to be built in the Urals, capable of building annually 1080 2–10–2 and 4–8–2 locomotives. *Parvagdiz* expected the 2–10–2 prototype to emerge from Kolomna in 1931, followed by two units from Lugansk, with the latter works then building it in series; this is very close to what actually happened with the FD 2–10–2, and there can be little doubt that the FD was already firmly embedded in the minds of the *Parvagdiz* planners even though the NKPS seemed, or pretended to be, unaware of it. The article was presumably written around the end of 1930, and another hint that the 23-ton 2–10–4 envisaged by the NKPS might not after all be the basis of the future locomotive stock came in February 1931.[45] At a meeting of the NKPS Collegium held to discuss the NKPS proposals for the reconstruction of transport, one member (Shuvalov) commented that maybe the suggested 23-tonner was not the best solution. Such locomotives, he said, would demand enormous supplies of steel at a time when the railways were already starved of that metal, the steel being required for the necessarily heavier rails. It would be better, said Shuvalov, to build new locomotives with a mere 20-ton axleload. At that time it may be assumed that the locomotive specialists working under OGPU were close to a solution of the problems involved in designing such a 20-ton locomotive. Their final outline drawing was approved at the latest by May, for it was in that month that it was handed over to the Central Locomotive Design Bureau for the intricate process of converting it into working drawings. The leading members of the design team entrusted with this task (K. N. Sushkin, I. S. Lebedyanskii, A. A. Chirkov) were Kolomna men.[46]

It took Kolomna only 100 days to make these working drawings, and in August they were sent to Lugansk (later Voroshilovgrad) Works which were scheduled to build the prototype (using cylinder and frame castings from Kolomna). In the meantime the Party in June had laid down its requirements in all fields of railway transport. So far as steam locomotive policy was concerned, it is not absolutely certain that the Party Plenum was properly informed of the options. The relevant paragraphs of its resolution used the NKPS division of Group 1, 2 and 3 lines, with 23-ton locomotives specified for the Group 1 routes. For the intermediate Group 2 lines, the locomotives proposed were '. . . locomotives of the Eu type with 20-ton axleload', according to the text published in newspapers at the time. In fact the Eu, a modernized version of the E, had a 17-ton axleload. The unmentioned (and in the NKPS perhaps unmentionable) 20-ton 2–10–2 did not figure in this text. However, in some subsequent reproductions of the text the one-letter-word (in Russian) 'and' has been inserted, so that the relevant passage reads '. . . locomotives of the Eu type and with 20-ton axleload'. Whether that word 'and' had been omitted or added by mistake or by calculation is unclear, especially as what might be the decisive reference, the 'CPSU in Resolutions and Decisions of Assemblies, Conferences and Plenums' includes the vital 'and' in its 1954 edition but omits it in the 1953 edition.[47] Perhaps the most likely hypothesis is that the 20-tonner did not figure in the NKPS plan but was put forward (probably by Ordzhonikidze, chairman of VSNKh and therefore responsible for the locomotive industry) during the Politburo discussion, with the result that the locomotive was slipped into some but not all copies of the text by means of that itinerant 'and'.

Interestingly, an article about diesel traction written about this time mentioned a KM (Karl Marx?) steam locomotive.[48] This may

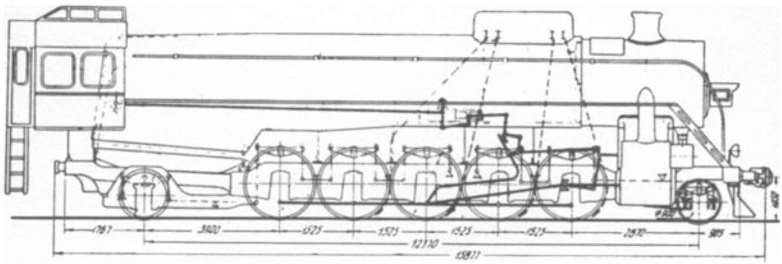


Figure 10 The FD freight locomotive.

well have been a reference to the forthcoming FD (the name *Feliks Dzerzhinskii* for this type was chosen later – see Figure 10). The author was V. Tolstov, who was a member of the NKPS Central Planning, Technical and Economic Directorate's Scientific-Research Sector. There seems little doubt then that the NKPS planners knew of the FD project at least in mid-1931. That the 20-ton FD was foisted on an unwilling NKPS would seem to be confirmed by the subsequent and rather unfair remark of a designer of the Central Locomotive Design Bureau, who said that the reason the NKPS found itself in 1931 faced with the fact that industry was building for it the FD and *Iosif Stalin* types was that the NKPS had not been able to tell industry clearly what it wanted.[49]

The June plenum resolution was duly elaborated by the government, with a decree on 28 July giving detailed instructions.[50] VSNKh was to reconstruct one of the existing locomotive works to make it suitable for building a 20-ton 2–10–2; the specific mention of the latter indicates that the first-fruit of the OGPU venture, the future class FD, had now been openly accepted for series production, even though Kolomna had not yet quite completed its working drawings. The Lugansk Works were to be reconstructed to build 23-ton locomotives; this reconstruction was to be completed by October 1932 with the first hundred locomotives built by April 1933. The NKPS was to furnish the locomotive industry (*Parvagdiz*) by 1 August 1931 with approved working drawings of the 23-ton locomotive (presumably, since this implied a deadline of only a few days, and the drawings were working drawings, the latter had been obtained by the NKPS from the USA). Meanwhile, to ensure that locomotive orders were actually fulfilled, the possibility was to be studied of relieving the locomotive works of the non-railway orders under which they had been submerged in recent years.

Thus by August, as this decree indicates, the stated intentions were considerably closer to what actually happened. In the end, the 23-tonner would be abandoned, and it would be Lugansk (Voroshilovgrad) that would build the 20-ton FD, but at least the decree recognized the existence of the latter.

In brief, then, before turning to the situation of the electric locomotive, the steam locomotive programme as it appeared to the NKPS in summer 1931 was that experimental heavy freight locomotives had been ordered from the USA, having 23-ton axleloads and intended to serve as advance prototypes for Soviet-built machines to be built at the reconstructed Lugansk works. Meanwhile, a late entrant, the 20-ton FD of Soviet design, was to be built in series at an unspecified works, this being a pre-off-the-drawing-board decision. Many projects favoured by the NKPS locomotive specialists had been ignored, or postponed. These included the tank locomotive for commuter services, and certain American designs. The idea of a 'Union Pacific' freight locomotive with 12 driving wheels had failed to find support although, as will be related, the concept was far from dead. A similar situation existed with regard to the Garratt type locomotive; neither the NKPS nor the Party seemed to favour this idea, yet in 1932 an order would be placed for a prototype. But, although it was not realized at the time, two decisions had been made which would determine the nature of Soviet steam traction up to its demise in the 1960s: the decision to rebuild the Lugansk works and the decision to build the 20-ton FD turned out to be not interim measures, but virtually final measures.

Electrification

In mid-1930 it was still possible for critics to assert that the NKPS had still not worked out a Five-Year Plan for railway electrification. This is hardly surprising; not only was there the enervating unreality of designing projects for which there seemed no hope of obtaining the required equipment, but the electrification specialists of the Commissariat were among those involved in the toils of the NKPS 'reorganization' of spring 1930. In an article whose title referred to 'leapfrog planning', a correspondent complained that the old NKPS department of electrotechnique and communications had vanished.[51] Another article in the same newspaper claimed that since the reorganization of the NKPS there was no department charged with electrification affairs.[52] At the end of the year both *Gudok* and *Ekonomicheskaya zhizn'* produced what were almost 'electrification' editions.[53] Both newspapers based their articles on the findings of the brigade organized by the latter newspaper to investigate the various departments concerned with electrification. The consensus was that electrification, which was supposed to be the foremost item in railway reconstruction, was in reality the most backward. In the NKPS, it was said, there were only a few hardy souls who still took electrification seriously and, of course, the wreckers had been especially busy in this sector. So far, the GOELRO Plan target for electrified mileage had been achieved only to the extent of two and a half per cent. According to *Ekonomicheskaya zhizn'*, the Central Planning-Technical-Economic Directorate of the NKPS had presented its Five-Year Plan for electrification only in the summer of 1930 (*Gudok* wrote that this event occurred in the autumn). That plan had been approved by the Collegium of the NKPS and would be approved by the government shortly. It involved the conversion of 3000 km (1864 miles), divided between ten projects. However, the 'criminal neglect' suffered by the electric locomotive industry threatened this plan. Podolsk Works were originally scheduled to take a major share in locomotive production, but after a bout of shifting and re-shifting the works from the NKPS to VSNKh and back again the intention of building electric locomotives there was abandoned. *Parvagdiz*, the article continued, planned to build no electric locomotives until 1934, and in that year only three (the NKPS plan had assumed 80 locomotives in 1932 and 169 in 1933). *Parvagdiz* appeared to have no person who was specializing in electric locomotives. Not only was there nobody designing locomotives, but there seemed to be no plans to design them. In January the STO had ordered from VSNKh 19 locomotives for the Suram Pass and Lun'evskaya branch (in the Urals) for delivery in 1932, but nothing had been done, and the investment already made in equipping the latter line had been mothballed. In effect, the part of the NKPS plan that could be taken seriously consisted of merely four projects (Moscow–Kursk, the Mineral'nyie Vody branch in the Caucasus, the Northern Railway Moscow suburban scheme, and the Suram Pass). In an interview, the chairman of the *Parvagdiz* management (Kuritsyn) described the NKPS electrification plan as 'not the Five Year Plan in four years, but the Five Year Plan in two weeks'. In *Gudok* the same wisecrack was ascribed to Filimanov, the deputy chairman of the Electrical Trust, parroting Kuritsyn. The chairman of the Electrical Trust (VEO), when asked whether his management knew of the Five-Year Plan for railway electrification, said 'No!'. He later added that 'our Dinamo works has one plan today and another tomorrow'. In Gosplan, the third apex of the electrification triangle, the spokesman said that information about the NKPS plan had to be dragged out bit by bit over the telephone, so reluctant was the NKPS Central Planning-Technical-Economic Directorate to divulge its thoughts. Gosplan had been obliged to ask the STO for a one-year delay for the Suram Pass scheme, because the orders for foreign electric locomotives had been held up so long by the steam interest in the NKPS. And even when the American locomotives were ordered it was only the NKPS and VEO which sent their specialists to work with the American designers; *Parvagdiz* sent nobody, which meant that it would in due course receive quite unfamiliar working drawings.

In late January 1931, A. Khudadov, the NKPS electrification specialist who had been closely involved with the first Moscow electrification, wrote that despite its fuel and metal-saving advantages electrification always seemed to come at the end of the queue when railway reconstruction plans were formulated.[54]

In early 1931 it was evident that the rising tide of complaints was having its proper sequel, as more and more attention was devoted to the practical problems of getting electrification really under way. At a meeting of the NKPS collegium in early February,[55] the Peoples' Commissar for Transport, Rukhimovich, summing up after listening to various proposals about the type of heavy steam locomotive to be ordered, was careful to emphasize that electrification should have priority over the most powerful steam locomotives, even though the visit of the Soviet delegation to the USA, plus the advice offered by the visiting American railway specialist Budd, had confirmed that a powerful steamer was indeed required. This session had been devoted to the NKPS reconstruction plan, and the collegium decided that it needed extra emphasis on electric and diesel traction. The following month the NKPS produced its next version of the reconstruction plan, in which 1800 km (1118 miles) were to be electrified by the end of the First Five-Year Plan (that is, in less than two years) and 3378 km (2098 miles) by the end of 1934. By this time, following metal shortages throughout the economy, emphasis was being placed by commentators (though not by the NKPS) on how electrification could save metal by eliminating the need to double singletrack routes.[56]

By May the NKPS had finally worked out its electrification plan for 1932–4, according to a report given by Rukhimovich to a plenum of Gosplan.[57] By the end of 1934 there were to be 3500 km (2174 miles) of electrified route in the USSR. Listed first were lines serving the new Urals–Kuzbas metallurgical combine, the Kizel–Chusovaya line through the Urals, the Suram Pass, the end sections of lines connecting Moscow and the Donetsk Basin, the dense traffic Krivoi Rog–Donbas line, some Leningrad and Moscow suburban lines, and the Mineral'nyie Vody branch. But the Commissar added that this could only be done if talk about electrification was succeeded by action. In particular, electric locomotives were a prerequisite. But in June, reported *Ekonomicheskaya zhizn'*, the situation had not really improved.[58] VEO failures had held back the 1931 plans. For example, the mercury rectifiers supplied for the Moscow suburban scheme had proved defective, so the Pushkino substation had been delayed nine months, and VEO had even urged the NKPS to import the replacement rectifiers. Electric train-sets were standing in NKPS storage tracks awaiting delivery of their traction motors; this threatened the suburban and Mineral'nyie Vody schemes and was caused by the Mytishchi Works, which were due to supply this equipment, being transferred to tramcar production. No decision had yet been reached about a new electric locomotive works; the only thing that had become clear was there was a 'great argument' between NKPS and *Parvagdiz* about which of the two should have this new works.

On 11 June began the Plenum of the Central Committee of the party which was scheduled to discuss three topics (agriculture, the railway problem, and the development of Moscow). On 11 June *Ekonomicheskaya zhizn'* published an article entitled 'Still only words; the depressing practice of electrification of transport; Has anything changed?'. This article enumerated the same sad facts, adding one or two details, especially about the lack of enthusiasm in the NKPS for electrification. The article, however, gave 3500 km (2174 miles) as the electrification target for the First Five-Year Plan while at the end of the Second Five-Year Plan no fewer than 40,000–50,000 km (25,000–32,000 miles) were to be electrified. This latter represented a third of the total mileage. It seemed that the more depressing became the general picture, the higher were pushed the targets. But the electrification proponents must have been very encouraged when the Party Plenum of 15 June accepted that 'In the future perspective, railway electrification is the leading link in railway reconstruction . . .'.[59]

Diesel traction

By the summer of 1932, when the NKPS was still awaiting the first electric locomotive from the USA, five mainline diesel locomotives were working on Soviet railways and one of them had already put in eight years' service. However, the diesel enthusiasts were not satisfied with the rate of progress.

Of the several locomotives planned under the 1927/8 diesel locomotive programme, only two units were ever built. These were intended to be the diesel equivalents of the old tsarist type O freight locomotive and, being diesel-electrics, were numbered O–el–6 and O–el–7. Among other things, they were intended to compare the merits of two forms of drive, that with the motors connected individually to each axle (O–el–7) and that with a jackshaft and connecting rods (O–el–6). O–el–7 was intended to have an 0–8–0 wheel arrangement, but the first attempts by the Kolomna diesel locomotive design bureau showed that it would be too heavy for this and it was accordingly changed to a 2–8–0. O–el–6 from the start was projected as a 2–8–2, and this did prove practical; the intention, never achieved, was to have axleloads no heavier than the steam locomotive these units were intended to replace (that is, 14 tons). Both locomotives were designed at Kolomna, with a heavy reliance on foreign components, it being recognized that not only was Soviet industry incapable of producing much of the equipment, but also that useful lessons for the future would be learned not only from the imported components, but also by the Soviet specialists who would travel to foreign workshops to help design and observe the manufacture of these parts. Indeed, it was subsequently claimed, very plausibly, that the long drawn-out travail with this pair of units enabled the Kolomna Works to gain the experience necessary for the series production of the more powerful E–el type.[60] The electrical equipment came from Brown Boveri (Switzerland), the diesel engine from MAN (Germany) and the spring coupling between engine and generator from Hohenzollern (Germany). The cooling system also came from Germany. The Kolomna Works occupied itself with the chassis and bodywork, with supervision by NKPS engineers. The latter, together with specialists from VEO, also supervised the assembly of the imported components at that works. The construction of these two 600 hp units dragged on for several years, and the Kolomna Works was repeatedly assailed in the press, and presumably elsewhere, for this tardiness. It was only in late 1930 that O–el–7 was ready, while O–el–6 did not appear until

November 1931. The main defect of these units, apart from their poorly-manufactured rheostatic braking, was the high adhesion-to-power ratio. This meant there was a temptation to overload them, for there was little danger of wheelslip. On one occasion O–el–7 had a train of a nominal 600 tons which in reality weighed 875 tons. In November 1931 O–el–6 was given a train said to be of 700–800 tons but which exceeded 1000 tons; on this occasion the result was a locomotive breakdown.[61]

In 1933 Kolomna produced a third unit, O–el–10, which was like O–el–6 but without rheostatic braking. All these locomotives went to the Ashkhabad Railway and were never fully tested, so that some of their original features were never properly appreciated. The type was not repeated, although at one time an O–el–11 was projected, modelled after O–el–7. The type represented a praiseworthy attempt to introduce diesel traction for that kind of service which steam traction could provide only at a high cost, short-distance and heavy yard work. In retrospect, this would have seemed to have been the best prospect for diesel traction at this time, as the O type steam locomotive was plainly unsatisfactory. These three units had a comparatively short life, being relegated to work as mobile power generators during the Second World War.

Possibly the insufficient care and attention bestowed on the trials of the O–el series was partly explicable by the circumstance that the diesel champions and the diesel designers found high-power diesel traction more exciting. Moreover, much inventive energy was being expended on the quest for non-electric transmission. This latter circumstance was a clear instance of the best being the enemy of the good. Lomonosov's E–el–2, despite its defects, had shown that the diesel-electric transmission system was sufficiently reliable in service to make the mainline diesel locomotive a practicable proposition. But the higher first cost of this solution (which had been wholeheartedly adopted in the USA, where heavy yard locomotives of this type were already economically competitive with steamers) meant that much diesel locomotive engineering talent was spent in pursuit of more perfect, but never really promising, transmissions. Apart from Shelest, who was beavering away at the 'Shelest Laboratory' on his never-to-be-completed gas transmission locomotive, there were several other projects still being funded. Of these, the diesel-mechanical or diesel-hydraulic transmission attracted the most intense support among Soviet engineers. Two such projects came very close to realization. One was a passenger diesel-mechanical unit designed by Dobrovol'skii and Tikhomirov between 1928 and 1930. Based on the erratic E–mkh–3 but with an improved transmission, this project presumably foundered because of the arrests of 1930. In 1932, when diesel locomotive construction design work was settling down after the upheavals, the Central Locomotive Design Bureau and the Kolomna diesel locomotive design bureau cooperated on a powerful 2300 hp 4–10–2 design, having a hydraulic main clutch. This design was approved by the NKPS Collegium, and a prototype ordered from Kolomna, but work stopped in about 1935.[62]

Of the various methods of using a gas transmission, only Shelest's was still showing signs of robust life, but there were other inventors who were still trying to find ways of perfecting their projects (see Figure 11). What was presumably a damaging blow to such systems was a series of investigations carried out by the diesel laboratory at Kolomna, beginning in 1928. In these, ten different systems, foreign and Soviet, of gas transmission were evaluated and the results showed that while most were theoretically viable, and some practicable too, their coefficient of thermal efficiency only averaged around 15–18 per cent, lower than diesel-electric or diesel-mechanical systems.[63]

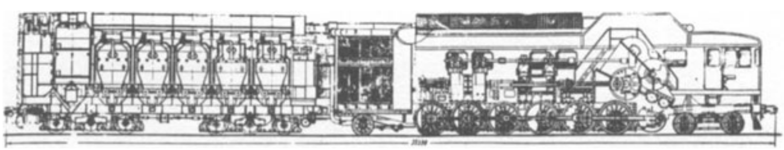


Figure 11 Gas-generator locomotive (Dyrenkov system), designed about 1930 by the Bureau for Powerful Locomotives. A few components of this anthracite-burning unit were made before construction was abandoned.

The idea of 'direct transmission' was still very seductive, and Soviet engineers would play, somewhat expensively, with this concept until the 1950s. M. I. Prigorovskii, although he never succeeded in producing a workable locomotive, rivals Shelest in the length of time he persuaded officials to fund his research. His idea was born in 1924 and he was still working on it at the time of his death in 1951. Briefly, his system involved the use of cylinders and valve gear of a steam locomotive. At slow speeds compressed air and fuel were to be ignited in the cylinders by sparkplug to operate the pistons. When the speed was high enough for a normal diesel engine to work directly on the pistons, the compressed air supply was cut off and the cylinders worked as in a diesel cycle. In 1928 an old South-Western Railway locomotive was allocated for a conversion on these lines at Odessa, but this was never done. Then in the mid-1930s an E type locomotive was obtained for conversion; again, this was never achieved. In 1949 an N class 2–6–0 was allocated. The Professor died before this conversion was completed. For about a year his assistants persisted with the work, but the fracture of a diesel-compressor shaft seems to have been the excuse for euthanasia in 1952.[64]

Another of the several projects funded in this period was Khlebnikov's novel diesel engine, designed to drive the locomotive wheels directly. The NKPS research institutes did much work on this between 1932 and 1945, but after Voroshilovgrap was entrusted with building an experimental version of the key component, the cylinders, nothing further was heard of it.[65]

The energy, talent, and resources spent in the 1930s on seeking ways to avoid the use of electric transmission, when such a transmission had virtually already proved itself on Soviet Railways, is surprising, and peculiar to the USSR. Other countries had made similar investigations in the 1920s, but in the 1930s were generally content with electric transmission. Germany, with its well-financed quest for a good hydraulic transmission, was perhaps an exception, but a modest exception.

However, this does not mean that the diesel-electric was abandoned at this time in the USSR. The experimental O–el type has already been mentioned. Much more important was the successful improvement of Lomonosov's E–el–2 design to create a locomotive that could be built in series. This new locomotive was E–el–5, the outline design of which was passed to the Hohenzollern works in Germany in 1927 by the NKPS. When that Works left the German locomotive industry, the order was transferred to Krupp, which finished and tested the unit at the end of 1931. This design, in which Lomonosov took a leading role in the months before his departure from the USSR, was virtually the E–el–2 with the latter's defects taken into consideration. Notably, the cooling system, that had given so much trouble with the earlier locomotive, was improved by the provision of a larger radiator (whose extra weight meant that the 4–10–2 wheel arrangement was adopted; one axle more than E–el–2). Although the same MAN diesel was used, it had mechanical fuel injection in place of the troublesome compressed air. The earlier locomotive's inability to deliver high power at the faster speeds was remedied by the provision of field weakening at the generator and traction motors. The tendency of the latter to overheat at low speeds was combated with forced air ventilation in place of natural ventilation. On the other hand, the complexity of the locomotive was increased by the provision of rheostatic braking. This locomotive was not, however, delivered to the USSR until after the Party had pronounced its views on dieselization at its June 1931 plenum, so its performance and significance will be described in the next chapter. Meanwhile, an identical locomotive was ordered from Kolomna (E–el–9); this was to have the same MAN engine but the electrical equipment was to be made in the USSR.

Unlike the electrification interests, the dieselizers did have the benefit of a detailed Five-Year Plan. The core of this were 20 4–10–2 diesel-electrics, like E–el–9, ordered from Kolomna under the 1928/9 programme and over-optimistically expected to be delivered during the course of the First Five-Year Plan. These 20 units were originally intended for the dieselization of that indeterminate 'short section' of railway which it had been decided in principle to turn over to diesels, instead of adopting the project for total dieselization of the Turkestan–Siberia Railway. The Five-Year Plan allocated 8.4 million roubles for mainline diesels, 24 million for O–el type and smaller yard locomotives, and 12.6 million for diesel railcars. The proportions show an awareness of where the greatest return on capital could be expected, although in practice it was the mainline diesels, allocated the least money in the Plan, which were pushed ahead in the First and Second Five-Year Plans. However, some progress was also made with the very smallest of yard locomotives (*motovozy*). Table 3.2 shows the First Five-Year Plan targets in physical units, as published in 1929:[66]

TABLE 3.2 *First Five-Year Plan targets*

	1928–9	1929–30	1930–1	1931–2	1932–3	Total
Mainline diesel locomotives	2	4	5	5	5	21
O–el type locomotives	0	7	11	11	12	41
Smaller yard locomotives	0	30	50	90	130	300
Diesel railcars	5	15	30	60	100	210

Compared with the figures for electrified railway mileage which were being talked about at that time, and with subsequent plans for diesel locomotive construction, these targets were quite modest.

Nevertheless, they were only fractionally achieved in the First Five-Year Plan. In fact, during the four years of the First Five-Year Plan home industry produced only two diesel locomotives. The failure to meet planned delivery targets occasioned much abuse, most of it directly or indirectly heaped upon the management of the Kolomna Works. Yet it was Kolomna which bore the brunt of the traction reconstruction effort at this period. Diesel locomotives were only a small part of its output. It built steam locomotives, and it was preparing to build electric locomotives in cooperation with the Dinamo Works. It was also the USSR's builder of high-powered diesel engines for non-railway use. Being fairly close to Moscow it may be surmised that its daily work was constantly disturbed by visits by men from the commissariats, only too eager to modify plans that had already passed into the design or production stage. In the mid-1920s Kolomna accounted for four-fifths of the Soviet output of diesel engines, producing MAN designs that were among the fruits of the Russo-German technical cooperation of that period. In 1930 a new diesel workshop was opened, and this too, was probably a disturbance to factory routines during its construction and assimilation. Yet, even at the most burdensome periods, genuinely innovative experience was sought. Welded locomotive boilers were one of Kolomna's specialities. In diesel engines, Kolomna was a pioneer in the application of Buchi supercharging, permitting increased power with negligible weight increase. It was at Kolomna that the Central Locomotive Design Bureau had been established. Somewhat earlier, at the time the O–el locomotives were ordered, Kolomna set up its own diesel locomotive design office, headed at first by V. I. Bespyatkin and then by B. S. Pozdnyakov, who would have many designs to his credit in two subsequent decades. For many years, while there was much talk of establishing specialized factories for diesel and electric locomotives, it was Kolomna which was actually producing them despite great difficulties of space, supplies and personnel. It is not perhaps surprising that V. Malyshev, who by 1938 had progressed from diesel locomotive driver to Kolomna designer to manager of Kolomna, eventually attained high ministerial office in the government. Anyone who could successfully manage Kolomna could manage a commissariat.

The slow delivery of diesel units meant that plans to dieselize a complete section of line, which was considered essential to obtain a fair representation of what diesel traction could do both physically and economically, were necessarily modest. As the two main points put forward in support of dieselization were fuel economy and the elimination of difficulties connected with steam locomotives' need for generous water supplies, a section on one of the more arid railways was favoured. There was some disagreement about which line to choose. The Traction Directorate of the NKPS preferred to dieselize the Stalingrad–Tikhoretskaya and the Sal'sk–Bataisk lines of the North Caucasus Railway, whereas the Operating Directorate preferred the Central Asian Railway, where water supplies were exceptionally difficult.[67] However, in June 1931 the diesels were still working from the experimental diesel locomotive base on the Moscow–Kursk Railway.

Sometimes, however, E–el–2 was used to make what can fairly be described as publicity-seeking trips far afield. At a time when the NKPS was having considerable and well-publicized difficulty in handling oil shipments out of Grozny in the North Caucasus, Lomonosov's E–el–2 was despatched south from Moscow to the rescue and returned with a trainload of oil. The round trip took 274 hours. This was an improvement on the steam-hauled trains, but nevertheless hardly breathtaking. In fact, of the 274 hours, 134 were spent waiting at stations or changing crews; for some reason, unspecified but presumably organizational, crew changes took up to six hours. In early October the locomotive made a similar trip, after which it was despatched to Kokand, deep in Central Asia, for a trainload of cotton.[68] On the latter trip, because 'some operating officials behaved with indifference',[69] its commercial speed was only about 4 kph (2½mph) on one long section. Nevertheless it returned with a 1100-ton train, averaged 410 km (255 miles) per day and, as was subsequently emphasized for two decades, it made that trip back without once needing to be uncoupled from its train for servicing. Such trips did provide useful technical experience and data (for example, on the return from Kokand the locomotive consumed a creditable 390 kg of fuel per 100 train-km) but they were mainly intended as demonstrations.

The dieselization debate continues

Public discussion of the merits and demerits of dieselization became increasingly acerbic in 1930 and 1931. From time to time a journal or newspaper would devote an issue to a presentation of for-and-against articles side by side. In January 1930 the newspaper *Ekonomicheskaya* *zhizn'* ran two such articles under the heading 'Steam or Diesel?'.[70] A frequent critic of dieselization, A. Zauer, wrote the first article and covered familiar ground, including the high depreciation cost of diesels. He also mentioned that the Germans were moving very cautiously with diesels and were still improving steam traction. He continued by pointing out that estimates of 15 per cent cost savings when diesels replaced steam were based on the work of the wreckers Mekk and Dmokhovskii. Mekk, the co-author of a comparative table of steam and diesel costs, had assumed an annual mileage for the diesel of 90,000 km (55,923 miles) per year and for a steam locomotive of 47,000 km (29,204 miles). That diesel mileage, said Zauer, was highly optimistic and, moreover, Mekk had disregarded the fact that in 1930 the average daily mileage of a type E steam locomotive had reached 170 km (106 miles) and 'Probably the author found it disadvantageous to take for his calculations the fact that in 1930 the average utilization of the power of our steam locomotives is already not 50–60 per cent, as in 1926 . . .'. Evidently Zauer, in the atmosphere of that period, did not feel it was excessively polemical to accuse a man, executed in 1929, of wilfully ignoring the facts of 1930.

This critique continued with a sceptical look at the long runs possible without change of locomotive claimed by the diesel enthusiasts, and mentioned that steam locomotives abroad could take water without stopping. Meanwhile, complained Zauer, before the claims of diesel traction had been properly tested the NKPS was proposing to squander tens of millions of roubles on really large-scale trials. This was a matter which needed public scrutiny, for there were many 'dark places' in the dieselization story. This article by Zauer was heady stuff, compared to the sober presentation of the dieselizers' case in the accompanying article. This latter said nothing really new although, unusually, it listed as the first advantage of the diesel the latter's compatibility with light trackwork and structures.

The railway newspaper *Gudok* also devoted a good deal of space to dieselization (although considerably less than it gave to electrification, a comment which applies also to *Ekonomicheskaya zhizn'*). In July 1930[71] *Gudok* published an article titled 'Re-examine the wreckers' five year plan for diesel locomotive construction'. This time the wreckers were not those who had pushed dieselization too fast, but those who had held it back in the NKPS, and created a situation where there was still no diesel locomotive in series production. The author, N. Zakharov, complained that the reorganization of the NKPS should have permitted a fresh start, but it was difficult to find anybody at the NKPS dealing with diesels. A month later in the same paper Zakharov was recommending greater application of low-powered diesel 'locotractors'.[72] On the same page another author recommended dieselization for overcoming particular difficulties with steam traction. His article had a conciliatory title, 'The diesel in aid of the steamer', and an editorial note mentioned that railwaymen were currently arguing the case for and against diesels and invited readers to send in their comments for publication in a forthcoming issue. Perhaps the readers did, but there was no sign of their comments in subsequent issues, probably because the editorial staff of *Gudok* was being purged at the time.

In mid-1931 *Rekonstruktsiya transporta* devoted most of one edition to dieselization.[73] It had earlier[74] published an article by a person signing himself 'M. Ya' which had been highly critical of the dieselizers' claims, and it was articles written in response to this that composed the 'diesel edition'. For the dieselizers, the pseudonym '*Teplovoznik*' reappeared to fight the good fight.[75] This author made the expected points, giving fuel economy as the diesel's first attraction, and emphasizing that the diesel locomotives' teething troubles were already largely overcome. He claimed (baselessly) that the foreign direct-transmission diesel locomotives (Ansaldo and Kitson-Still) had been quite successful and that in any case the diesel-electric was already competitive with steam. The recent trip from Kokand, when E–el–2 covered 3700 km (2300 miles) in nine and a half days, even though it had run 130, 000 km (80, 778 miles) since its last repair, demonstrated this. Moreover, it was no longer true that the steam locomotive offered higher power, for 'the diesel locomotives proposed by Ansaldo for the USSR' were of 2600–3400 hp. Soon diesel locomotives would burn powdered coal, which would dispose of the argument that they burned expensive and scarce oil fuel. The American periodical *Oil Engine Power*[76] had quoted diesel yard locomotive costs as $3.10 per hour, against $3.70 for a steamer. He then gave a detailed cost comparison of an E–el diesel and an E steamer in which, as usual, certain assumptions had to be made, and were made in such a way as to produce a result in favour of the diesel. On the Stalingard – Tikhoretskaya and the Sal'sk – Bataisk lines the lower operating costs of the diesels would recoup their higher capital cost within two years, claimed '*Teplovoznik*'.

Additional support came from engineer E. Gertsog,[77] who advanced the slogan 'The steam locomotive has fulfilled its historical role'. But, he continued, electrification, the other alternative to steam, was costly and therefore suited only to heavy-traffic lines. Also, it was vulnerable to air attack and it was not practicable in regions where there was no fossil or hydro energy (here the journal's editorial board interposed a statement that it did not agree with these views on electrification). On most lines, said Gertsog, the only good, and very perfect, locomotive was the diesel, but its significance for railway reconstruction was too often ignored. After enumerating the diesel's cost, operating, and other advantages, he forecast that in future electric locomotives would handle heavy-traffic lines, and diesels the remainder. Another engineer, N. Struve, added some data in support of the diesel locomotive. Diesel locomotives, he said, were doing 6000 km (3728 miles) monthly, as against 4000 km (2485 miles) of the average steam locomotive. He claimed (optimistically) that the mechanical transmission of the diesel-mechanical locomotive was now working completely satisfactorily, and that Ansaldo was solving the problem of designing a diesel engine specifically for railway traction. M. Ya's argument that the steamer could work traction sections of 600–700 km (370–435 miles) seemed to be based on the impersonal manning system; had he not heard a word about the Party's ruling that such manning was not permissible? As for taking water without stopping, this was no simple feat for a steam locomotive in winter. Struve then quoted another comparison between E–el and E type locomotives, undertaken by the Scientific Research Institute of Railway Construction to determine costs for a newly-built line; the conclusion of this was that for most prices of coal the diesel was cheaper.

An unusual defence of the diesel came from A. Alekseev, claiming to represent the locomotive crew's point of view.[78] In every five years, he wrote, a steam locomotive crew because of the physical conditions in which it worked would break operating regulations three times, whereas a diesel crew would not transgress once. Steam crews developed ulcers, catarrh, premature blindness and deafness, not to speak of rheumatism. '. . . the diesel locomotive will bring better working conditions, preserve a man's health, lengthen his life, and raise his cultural level.'

The journal printed an article by the redoutable Zauer to lead the anti-diesel case.[79] For at least the third time, Zauer referred to those 'dark places requiring careful illumination' in the diesel locomotive situation, although on this occasion he was pleased to report that the public was now responding to the call to look at the matter more critically; with both sides arguing, some truth might be revealed. He then pointed out that there was a difference between total replacement of steamers by diesels and dieselization of waterless zones. It should be remembered that not even in the USA was the diesel problem solved. The steamer was far from condemned, if only because world oil supplies were very limited. The defects of the diesel locomotive remained, and its theoretical advantages were unlikely to be realized in practice. It would hardly double the average mileage of the steam locomotive, which was needed to recoup its higher first cost. 'The defects of the diesel locomotive are so great and so serious in practice . . . that even a non-specialist can understand them. But somehow it is only the diesel-men and the dieselizers who do not understand . . .' He then repeated his habitual attack on Mekk and other wreckers who had tried to inflict a crushing blow against the Soviet State by recommending the building of diesel instead of steam locomotives. Later in the article he rejected the claim that steam locomotives would be vulnerable in wartime because their watering points could be damaged by bombs. Diesels should not even be used in dry zones, 'because Lenin was for electrification'.

A second article[80] criticizing the diesel programme was written by engineer Chirkov, a steam locomotive designer. He seemed pained by 'official and semi-official references' to plans for grandiose dieselization schemes and 'even' of special diesel locomotive factories. Many writers (and he mentioned Gakkel') were trying surreptitiously to introduce series production of diesel locomotives on the grounds that lack of diesels was hampering railway reconstruction. But the reality, said Chirkov, was that a *powerful* diesel locomotive had not even been designed. Abroad, only the Canadian diesel could be described as powerful, and a repeat order had not been given for that. American railroads were giving repeat orders only for diesel yard locomotives. Harping on the current metal shortage, Chirkov then pointed out that the diesel E–el–2 weighed 131 kg per hp, against the 113 kg of the E type steamer and 81 kg of the American 4–12–2 steamer in which Soviet engineers were still interested. Future steamers were even better in this respect; the Anglo-Swedish turbomotive would weigh only 60 kg per hp and the Swiss high-pressure locomotive 56 kg. Such sophisticated steam locomotives were expensive, but probably no more costly than a diesel of the same power. The money spent on series production of diesels should be divided between further research on bigger and better diesel locomotives and on experimental steamers but '. . . in the flush of inebriated diesel-electric patriotism we have wasted a lot of time'.

This particular edition of *Rekonstruktsiya transporta* was evidently prepared before the June 1931 Party pronouncement but went to press after the latter. Hence there were some obviously hasty amendments to conform to the new directives; even though it was a diesel edition and there were no articles on electrification, the leading headline proclaimed 'The leading link of railway transport is the electric locomotive', while Zauer's article on the superiority of steam over diesel ended with the unexpected statement 'I am for the electric locomotive'. V. Tolstov, a member of the NKPS Central Planning, Technical and Economic Directorate who was also on the editorial board of this publication managed to insert an article[81] in which, among other things, he pointed out that the dieselizers' contributions showed a subjective approach to the diesel locomotive; this love for one's own machine was praiseworthy, but could lead to a one-sided approach. In a rather conciliatory exposition Tolstov then rehearsed the arguments for and against the diesel, arriving at a recommendation which matched that of the Party; that is, that the diesel was promising, still had defects, and certainly deserved a role on selected lines.

In general, the published discussion of these issues was of a polemical nature, with one-sided presentations and misuse of evidence. Like was compared with unlike, the 20-year-old steam E was compared to diesel locomotives not yet built, foreign experience was distorted to suit each writer's arguments. Yet because both sides were presented, and from several angles, that benefit of a free press, the synthesis of a commonsense opinion from conflicting presentations, was achievable. On the more sophisticated level, in articles in the technical and economic journals, the level of debate was little higher. There was still the same shameless distortion, even if the vocabulary was sometimes a little more esoteric. There were exceptions; Gakkel', who had a foot in both the diesel and electric camps, was usually quite careful, but even Gakkel' was obliged to make assumptions that could be criticized. His 1930 paper to the 1930 All-Union Power Engineering Conference[82] may be taken as a model of moderation. In it he enumerated, quite soberly, progress in diesel locomotive construction up to that time, and concluded that both overseas and Soviet experience implied that despite the continuing lack of a diesel engine specially designed for railway use, and the need to use electric transmission, the diesel locomotive had won itself a place. The recent costly Brazilian and Algerian electrification schemes would have been unnecessary if diesel locomotives had been used instead of electric.

One of Gakkel''s main points was that although the capital cost of the diesel locomotive might be high, investment in electrification not only involved expensive power-supply facilities, but this investment remained unproductive for the several years required to complete a given scheme.

As might be expected, there were critical responses to Gakkel''s paper. One of the most interesting was by the engineer K. O. Rozen, who earlier had made cost studies of diesel and electric traction for the proposed Volga–Don Canal. He pointed out that Gakkel''s cost assumptions were misleading, and especially because as traffic rose the greater capital cost of diesel locomotives would give the advantage to the much cheaper electric locomotives. Rozen also revealed that the diesel-electric tramcars at Ekaterinodar had proved more expensive to operate than anticipated.[83]

By late 1930 what might be called the official view was clearly developing; that is, it seemed more and more likely that the Collegium of the NKPS (whose opinion would be submitted to the government and Party) was turning towards a division of work between the three forms of motive power which would not be especially favourable towards diesel traction. An interesting article on railway reconstruction appeared in mid-1930.[84] This, as usual, treated motive power as only a small part of the problem as a whole; matters like metal shortages, spare part shortages, slow turn-round of freight cars, weak track and weak couplers seemed more urgent than the types of locomotive to be chosen for future construction. However, the author admitted that the steam locomotive was outliving its time. Electrification was imminent, but there was the factor to be considered of the 'inertia' of investment in steam facilities. That is, the immense infrastructure that had been created over the years to enable the steam locomotive to function and which could not lightly be discarded. Given this enormous investment, he continued, steam traction would have to be renewed; the average age of a Soviet steamer was 16 years, 35-year old locomotives were allowed to survive, and these lives needed to be shortened. The renewal of the steam fleet would necessarily intensify the inertia of steam investment and thereby delay electrification, but this was 'a dialectical contradiction' that had to be faced. Electrification would proceed, however, and the first need was to ensure an electric locomotive industry that could produce 75 units annually. As for diesel traction, 'in principle' this offered great advantages as a transitional type preceding electrification.

This view might have been expected to gratify the dieselizers, since it at least took the diesel locomotive seriously. But the very limited extent of dieselization that was envisaged, and perhaps the reference to the unwelcome philosophy that the diesel was only a 'transitional' type, seems to have spurred the diesel interest into renewed article-writing. In August 1930 *Ekonomicheskaya zhizn'* published, on the same day, a pair of pro-diesel articles under the ambitious headline 'Diesel locomotives for the block trains!',[85] (block trains, *marshruty*, were being heavily publicized as a way of speeding traffic flows). The first article was by the diesel locomotive designer Yakobson, who cited the usual advantages, stressing that the diesel could run 750–1000 km (466–627 miles) between stops and that this gave it a great advantage over not only steam but also over electrics; the delightfully misleading latter claim presumably rested on the fact that there was not likely to be a 750 km (466 miles) length of electrified line for years. As a contribution to the high depreciation cost problem, Yakobson recommended that the average life of the 400–450 rpm diesel engine be taken as 20–25 years, not eight. In the second article N. Zakharov, another old warrior, criticized the diesel Five-Year Plan because it overloaded industry with too many prototypes. There was, moreover, still a great need for an organization unifying the NKPS and VSNKh diesel interests. This was a familiar complaint, and was presumably given force by the disappearance of NKPS diesel locomotive organizations. Zakharov added (another familiar plea) that since its reorganization the NKPS seemed to lack anybody in charge of diesel matters. This presumably was felt by the diesel interest to mean that the diesel case would not be properly presented in the NKPS.

By May 1931 the Collegium of the NKPS was formulating its final version of the reconstruction plan to be presented to the Party. A discussion in the Collegium at this time was commented upon under the headline 'NKPS is not giving leadership in diesel affairs'.[86] In this article the NKPS was castigated for still arguing the merits of electric and mechanical transmission, when the diesel-electric had already shown what it could do. The Collegium discussion had revealed that the NKPS was not even in a position to give clear guidance. The Scientific Research Institute of Traction, the article continued, had no facilities for testing engines or the components devised by innovators. There were 51 diesel research projects afoot, largely handled by individual inventors without any communication with the NKPS. The O–el–7 had been badly handled. It had been assembled and then stood for almost a year awaiting tests, and the tests revealed that it could not run on the oil which had been intended for it but only on the type of oil that the USSR was exporting. The NKPS was still unwilling to send its diesels to the Central Asian Railway, preferring the line from Stalingrad, and was at that moment contemplating Moscow–Vladivostok trips. Kolomna Works was dealing with diesel construction only 'among other things'. Looking forward to the Second Five-Year Plan, the article mentioned the 622 diesel locomotives that were to be built in that quinquennium, and the lines to be dieselized (Urbakh–Astrakhan, Aktyubinsk–Kazalinsk, and, on the Central Asian Railway, Aleksandrov Gai–Chardjou and Chardjou–Krasnovodsk); Rukhimovich (Peoples' Commissar) had correctly emphasized that the diesel programme should be got moving and at this session the Collegium had at last set up a special commission of inventors and interested organizations to sort out proposals for new diesel locomotive types.

Yet another commission to sort out an old problem at first sight does not seem a likely way of getting the diesel programme moving, but the new sense of urgency is conveyed by the ten-day limit that this commission was given to make its report. Just three days after this Collegium meeting, Rukhimovich went to Gosplan to make his reconstruction proposals to a special plenum.[87] In this report he emphasized that electrification was the 'pivot', but that diesel traction was significant because of its water and fuel advantages. After all, he reminded his listeners, Lenin had been for the diesel and it was only because of wreckers that the programme had lagged. The NKPS intention was to dieselize first from Chardjou to Krasnovodsk, then the Stalingrad–Tikhoretskaya line and its branch from Sal'sk to Bataisk (just outside Rostov).

Whereas, as has been described, the Party resolution of June 1931 recognized that electrification was the 'leading link' for the more distant future, while steam would necessarily bear the brunt of traffic in the immediate future, the role ascribed to diesels was small. In contrast to the 3690 km (2292 miles) of electrification to be achieved by the end of 1933, the Plenum merely acknowledged the need to introduce diesels on waterless railways, with the Krasnovodsk–Chardjou, Sal'sk–Bataisk, and Stalingrad–Tikhoretskaya lines to be dieselized in 1932–3. The significance of the term 'waterless lines' was probably not lost on the dieselizers; for them the diesel was superbly fitted not only for 'waterless' lines, but also for lines 'with water-supply difficulties', a very much wider sphere, given the deterioration of water-supply facilities all over the system and the particular difficulties of the most wintry lines.

The Party having settled the argument, it might have been expected that no controversialist would again set forth to do battle on behalf of his favourite form of motive power. This expectation was satisfied, but one protagonist, Shelest, had the misfortune to write a highly polemical article that was sent for printing well before, but published after, the Party's decision. In the period when the controversy was at its height, Shelest had often come out in support of the diesel (although with his habitual claim that the diesel-electric was a doubtful prospect compared with his own idea of a diesel gas-transmission locomotive).[88] Towards the end of 1930 he composed a long article titled 'The technical-economic basis of steam, electric, and diesel locomotives'.[89]

This article, littered with the graphs, tables and equations characteristic of Russian technical appraisals, was divided into three parts dealing with steam, electric and diesel traction. Shelest's appraisal of the steam locomotive, and in particular its low thermal efficiency and the improbability of turbine and high-pressure locomotives ever changing the picture, was fair enough, although he failed to mention the steam locomotives' advantages. With the electric locomotive he was superficially a little more generous, listing seven points in favour of this mode. However, these positive aspects were expressed with less than his usual vigour, and seemed intended to damn with faint praise, an impression reinforced by his remark, 'All these advantages gave reason to hope for a wide extension of electric traction'. The use of the past tense here was obviously intentional. Not only this, but Shelest's seven points omitted what had been a main argument of the electrifiers, the superior economic efficiency of the electric locomotive.

The reason for this glaring omission soon became clear. Basing himself on figures relating to European, especially German, electrification schemes, Shelest composed curves which showed that the energy losses in the total railway electrification system, from power station to wheel rim, were at a minimum when the power station was working at 75 per cent of capacity, at which point the overall coefficient of thermal efficiency reached just nine per cent. However, the experience of the Baden State Railways (which had actually disappeared 12 years previously; Shelest was not averse to using ancient data when it suited him), showed that the average generator loading of an electrified railway was only 30 per cent. From this, by a further succession of curves and equations, Shelest concluded that '. . . it must be concluded that in the matter of expenditure of thermal energy the electric locomotive is superior to the superheated steam locomotive only in rare cases'. Only where electricity was derived from waterfalls (not from the natural fall of a river) might electrification be economically worthwhile. As for recuperative braking, the experience of the Prussian State Railways electrification had shown that this could contribute only nine per cent of the required energy, not enough to justify its complexity.

Comparing steam with electricity (he never compared electrification with dieselization in this article, contenting himself with showing that steam was usually more economic than electricity, and that the diesel would be more economic than steam), Shelest concluded that on certain small railways, if coal was expensive, electrification might bring an operating 'profit' of up to 13 per cent, but the extra in capital charges would bring this down to a maximum of 1.35 per cent, a margin easily eroded by rising capital charges or cheaper coal. As a final blow to the electrifiers, he quoted a very recent German journal,[90] claiming that it demonstrated that only a few electrified railways (in America) had avoided a 'loss' on electrification. 'The majority of European electrified railways operate at a clearcut loss.' From all this he concluded that the place of electrification was limited to heavily-graded sections difficult for steam operation in close proximity to waterfalls. Moreover, he added in a provocative and somewhat ill-judged final shot, because electric locomotives relied on imported equipment while the steam locomotives' fuel costs were paid in Soviet currency, the steam locomotive might be said to 'work on coal, whereas the electric locomotive works on gold'.

Shelest then turned to a comparison of steam with diesel. Here again assumptions that had to be made for such headings as repair costs and annual mileage were weighted in favour of his own argument. For example, annual mileage of the E type steamer was taken to 'be' 35,000 km (21,747 miles), whereas mileage for the diesel 'can be taken to be' 60,000 km (37,282 miles). The summarized extract from Shelest's table of comparative costs[91] (Table 3.3) should therefore be regarded primarily as an example of the type of table presented in most serious studies of the economics of diesel traction (except that, perhaps, only Shelest would have used the word 'profit'). Shelest noted that if the diesel construction cost was, respectively, 100, 150, and 250 per cent of the steam locomotive, then

TABLE 3.3 *Comparative operating expenses of an E type steam locomotive, and a diesel locomotive costing twice as much as this steam locomotive (roubles)*

	per 100 train-km		per 10,000,000 ton-km	
	Steam	Diesel	Steam	Diesel
Fuel	55.20	15.30	614.00	170.00
Personnel	16.55	21.20	183.80	235.40
Lighting	0.07	1.40	0.78	15.55
Lubrication	1.77	4.67	19.66	51.80
Cleaning and wash-out	0.75	0.47	8.32	5.22
Water supply	2.80	0.26	31.10	2.89
Repairs	22.66	35.80	252.00	388.00
Interest and depreciation	25.40	30.30	282.00	337.00
Total	**125.20**	**109.40**	**1,391.66**	**1,215.86**
Saving with diesel locomotive	15.80		175.80	
Annual profit	9,480.00		9,480.00	
Per cent profit	14.5		14.5	

the profit would be 44.7, 29.6 and 0.55 per cent.

Despite its weaknesses, some of which must surely have been evident to its author, this table was used as a basis for a curve showing the various permutations of diesel construction costs and heavy fuel prices at which the diesel could become 'profitable'. From this curve Shelest concluded that in the central region the break-even capital cost of a diesel locomotive was two and a half times that of a steamer (except for yard work, where a relatively more expensive diesel would be worthwhile). If pulverized fuel was used for diesels, this picture would change in favour of the diesel.

Shelest then went on to consider German and American data, providing evidence for his additional contention that diesel railcars and small yard locomotives would recoup their costs in two or three years. In America, he wrote, there were many hundreds of yard diesels at work which was in contrast to the USSR where, because 'Lomonosov turned development in the wrong direction', there was only a handful of mainline units, plus two small yard engines and seven railcars.

Although what Shelest had written about steam traction was not contrary to the official decision to rely on steam in the near future, his caustically expressed attack on electrification, which the Party had declared to be 'the leading link' in the longer term, could hardly fail to bring him trouble. In early 1932 the monthly journal of the NKPS, *Sotsialisticheskii transport*, reviewed his article which, it wrote, 'apart from being an example of a "scientific" defence of capitalism, objectively disorientates scientific workers concerned with questions of locomotive design . . . and openly revises the general line of the Party in this matter'. It was absurd and harmful.[92] This review also accused Shelest of ignoring the Weir Report on electrification, which had made out the economic case for British mainline electrification and had dismissed the case for the internal combustion locomotive.[93] As the Weir Report of 1931 would have been unavailable when Shelest's article was written, this was an ungenerous line of attack.

A very reasoned criticism of Shelest was published by Khudadov in another journal.[94] Its title 'An attempt to revise the decision of the Party on railway electrification' was probably an editorial concoction because Khudadov avoided polemics and concentrated on Shelest's data, and in particular on his outdated statistics, his comparisons of like with unlike, and his distortion of the 1930 German articles (which in reality supported the electrification case). It was in the journal of the electrification interest[95] that the most ominous attacks were printed. This devoted two articles in the same issue to the Professor's misdemeanours. The headline, rather extensive even for this publication, was 'Against any revision of Party and government decisions on railway electrification; a reply to the article by Prof. A. N. Shelest, "The technical-economic basis of steam, electric, and diesel locomotives" (Journal *Lokomotivostroeniye* No. 1 – 1932): the "latest discoveries" in electric traction, or, a professorial revision of Party decisions'. The fraudulent attribution of the offending article to the 1932 No. 1 issue of the journal rather than to the delayed No. 1 of 1931 was also adopted by other journals,[96] and was evidently designed to drive out of the reader's mind any thought that maybe Shelest had written his article before June 1931. Further doubts of Shelest's guilt must have been dispelled towards the end of the attack, when 'Professor Shelest' began to change to 'Citizen Shelest'. The article was largely polemical, but the points of substance were valid, and concerned the points raised elsewhere by Khudadov. The judgement of the author was that ' . . . the declaration by Citizen Shelest that "most European electrified railways work at a clearcut loss" is a camouflaged libel on the decision of our Party . . . when our Party has said its word on this question'. Immediately following this article a prominent electrifier, A. Avatkov, had written another entitled 'On the subject of a certain baseless "basis"'. This described Shelest's article as 'politically illiterate', contrary to the Party line, distorted, and incorrectly portraying the three forms of traction as competitors. The diesel locomotive did have a place, as the Party had accepted, but it would be limited (especially, added Avatkov, who was a technical man, now that improved mercury rectifiers were on the way). As for Shelest's gibe that electric locomotives ran on gold, what could be more golden than the exportable oil fuel consumed by diesels?

Even the indomitable Shelest was unable to reply to these attacks, which serves to emphasize the effect of the Party's 'last word' of June 1931. He published nothing until 1933, and does not appear to have returned to the alleged economic superiority of diesel over electric traction for at least a decade. In a work published by the Academy of Sciences in 1959 he did, however, feel it safe to restate his case that electric traction could boast a thermal coefficient of only 8.12 per cent.[97]

4 Steam's Indian Summer, 1931–1952

The background

'It's understandable that we had to give these worthy men a punch in the teeth and politely escort them out of the NKPS adminstration' was Stalin's picturesque euphemism for a process which was rather more dire than a mere punch in the teeth.[1] As in Soviet society as a whole, on the railways shrift became progressively shorter as the 1930s approached the 1940s. Stalin was referring to the so-called 'limiteers' in the NKPS who, he said, were ejected because they insisted that there was a fixed technical limit to what the railways could carry at a given level of equipment.

The growing coercion of the 1930s was an accompaniment to the single-minded concentration on the formulation and achievement of economic targets which were formally embodied in successive Five-Year Plans. The spirit of wild optimism of the First Five-Year Plan continued into the period when the targets for the Second Five-Year Plan were formulated. The initial proposals for the Second Five-Year Plan targets, adopted in January 1932, envisaged incredibly high outputs by the final year of that plan (1937). However, 1933 was a bad year, especially for agriculture and transport, and in a new spirit of sobriety revised targets for the current Five-Year Plan were proposed and adopted in 1934.

For three years, 1934–6, things seemed to be going well. There was an emphasis on putting right the matters that had gone awry in the previous Five-Year Plan. There was a real effort to ease the transport situation by increased, if selective, investment. Several grand enterprises, like the Urals–Kuznetsk metallurgical combine, that had been started in the First Five-Year Plan, began production in these years. The standard of living began to recover from the abysmal level to which it had fallen in the First Plan. After 1937, most sectors of the economy grew at what in other countries would have been a very respectable rate, but much more slowly than in the early 1930s. The Third Five-Year Plan (1938–42) was affected by the massive purge of 1937, by rearmament and the war against Finland, and was finally cut short by the German invasion in 1941. But even without these factors, the growth rate would have been below target.

On the railways the changing situation can be described briefly enough. NKPS mileage rose from 80,000 km (49,710 miles) in 1928 to 82,000 in 1932, 85,000 in 1937, 106,000 in 1940, and 121,000 (75,185 miles) in 1955 (the last two figures reflecting territorial acquisitions as well as new construction). Freight traffic rose much faster than this, from 93 billion ton-km (56.8 billion ton-miles) in 1928 to 169 billion in 1932, 355 billion in 1937, 415 billion in 1940, and 971 billion (593 billion ton-miles) in 1955. In 1938, although ton-km were slightly higher than in 1937, this was due to increased length of haul, the absolute tonnage shipped being actually lower than in 1937.[2]

Despite the NKPS reconstruction plan, approved by the Party Plenum of June 1931, the railways continued to cause anxiety, with winter bottlenecks threatening the entire Five-Year Plan. Rukhimovich was succeeded as Transport Commissar by Andreev in October 1931. The latter had a seat in the Politburo, and was altogether of heavier political calibre. Possibly this helped to secure for the railways a marginally better share of resources. When, in response to even deeper railway crises in the winters of 1932/3 and 1933/4, Kaganovich was appointed Commissar from 1935, new equipment was already entering service, and this no doubt helped the new man to master the transport situation. Indeed, Kaganovich's violent methods probably did more harm than good, even though some might argue that the work of railway adminstrators, everywhere, is likely to respond positively to the threat of a bullet in the back of the neck. Kaganovich's part in the slaughter of railwaymen and railway administrators is hard to quantify; the allegations made at the Twenty-second Party Conference (1961) that 'Under Kaganovich arrests of railway workers went according to lists. His deputies, almost all heads of railways, the heads of railway political departments, and other leading transport workers were arrested without any foundation . . .' and that there still existed in the archives '32 personal letters of Kaganovich to the NKVD demanding arrests . . .' seem to be consistent with contemporary newspaper accounts.[3] It seems quite likely that the reappearance of winter difficulties in 1937 and 1938 was largely a consequence of the purge.

Among the victims in 1937 were many members of railway political departments who had themselves, in previous years, arranged the arrests of countless railwaymen. These departments were set up in 1933 in the belief that failures of railway transport were caused by various forms of sabotage committed by enemies of the regime hidden away in dark corners. These Party workers produced long lists of enemies and rushed in, where angels might have feared to tread, to impose their own 'rational' methods in place of time-honoured and usually sensible methods of work; their contribution to railway efficiency was probably small at best.

Because Kaganovich's task was to ensure that freight was not held up, his main concern was finding solutions to the most urgent problems. This meant that he soon lost interest in electrification and dieselization because these could not hope to solve the railways' problems in the immediate future. In his 1935 report to the plenum of the Party's Central Committee, devoted to railway reconstruction, he made no mention of dieselization or electrification, yet his words touched on everything else, including such minor matters as the desirability of fitting steam locomotives with electric lights.[4] To celebrate Railwayman's Day in 1938 the newspapers used a photograph showing a line-up of five different locomotive types, all steam.[5] Like Stalin, Kaganovich would intervene in details, and his approval of a project meant that anybody not showing enthusiasm might be at risk. In this way he 'adopted' the condenser steam locomotive, ordered locomotive works and depots to fit feedwater heaters to their locomotives, and was behind some of the more revolutionary experimental projects which flourished expensively and uselessly in this period.

The research institutes

The researchers of the Scientific Research Institute of Traction Reconstruction had remained faithful to the traditions of traction computations and locomotive testing. In 1931–3 their best work was the modernization of the E type locomotive (see Table 4.1). In 1931 they had created the Em, which on the same axleload produced more power; its permissible boiler pressure had been raised. However, its weight distribution was poor, resulting in a heavier axleload. In 1933 I. V. Pirin of the Institute of Traction Reconstruction made small but

Table 4.1 *Development of the E type freight locomotive*

	1912	1913	1915	1926	1931	1932
Purchaser	Vladikavkaz and Ryazan–Uralsk Railways	North Donets Railway	State Railways	NKPS	NKPS	NKPS
Type	E	E	E	Eu	Em	Er
Weight in working order (tonnes)	81	81	81	81	83	86
Axleweight (tonnes)	16	16	16	16	18	17
Cylinder diameter (mm/in)	600/23.8	630/25	650/25.8	650/25.8	650/25.8	650/25.8
Boiler pressure (kg-sq cm/psi)	12/171	12/171	12/171	12/171	14/199	14/199
Grate area (sq m/sq ft)	4.2/45	4.2/45	4.46/48	4.46/48	4.46/48	5.09/55
Superheater area (sq m/sq ft)	52/560	52/560	51/550	66/708	64.6/695	72/775
Tractive effort (tonnes/lb)	20/43,550	22/48,100	23/51,200	23/51,200	27/60,000	27/60,000
Adhesion factor	4.05	3.68	3.52	3.52	3.07	3.18

It will be noted that the paring of margins, as expressed in the adhesion factor, was a trend evident before 1917.

well thought-out changes to create the final E series design. This was the Er, with the same higher pressure and a larger firebox, giving more horsepower. The first unit was built by a locomotive repair works. It was very much an off-the -drawing-board affair, no time being spent in testing components, or, it seems, in discussion with outsiders. The locomotive building industry presumably had no part in this design, until after its adoption for series production.[6]

The relatively placid conduct of railway research ended in 1935. In line with a general move to reduce the number of institutes,[7] the railway research 'branch' institutes were merged into larger, central, organizations. Among the advantages claimed for this re-combination at a time when the branch institutes were just settling down after their previous upheaval, was the possibility of henceforth studying problems from all angles. The hitherto one-sided approach to the problem of the new FD locomotive's over-rapid tyre wear was often quoted as a telling example. This problem had been handed to the Institute of Materials, where it was treated as a purely metallurgical problem, whereas in reality it also concerned the traction and operating institutes, and even perhaps the Institute of Track. However, it is difficult to avoid the impression that this problem was regarded as a particularly hot potato which other researchers were only too glad to hand over to the metallurgists. It must have been obvious to all that the rapid tyre wear was connected with the Stakhanovite movement among locomotive crews, which abetted wheelslip and other undesirable phenomena.

So in 1935 Kaganovich recombined the branch institutes. But there was a reversion not to a single institution, but to two. These were the Scientific Research Institute for Railway Transport (NIIZhT) which embraced the former institutes of traction, operation, signalling, electrification, and materials, and the Scientific Research Institute of Track and Construction (NIIPS), which unified the previous institutes of permanent way and construction. As director of NIIZhT Kaganovich appointed V. N. Obratsov, who by professional interest should really have belonged to NIIPS. It was Obratsov who was entrusted with the weeding out of bad elements in the Institution, a task in which he was said to have had the unremitting support of Kaganovich.[8] Kaganovich does not seem to have found an equivalent man, obedient yet with scientific distinction, to head the NIIPS. This Institute attracted particular hostility from Kaganovich because it did not push ahead with the '*defektoskop*', a detector of faulty rails proposed by a young innovator but allegedly held up by reactionary elements in the Institute. Some blood appears to have been shed at this Institute. It was said that some long-entrenched enemies had been unmasked and from May 1937 to May 1938 the Institute lacked its scientific director, and for one and half years had no head.[9]

In addition to the two new institutes, scientific-research institutions were established or enlarged at the eleven training schools (VUZY) for railway engineers. This, too, paralleled tendencies elsewhere in the economy. Also, efforts were made to link the institutes more closely with the men on the line. The latter were supposed to send suggestions for problems to be studied, while the former were urged to popularize their findings among ordinary railwaymen. Branches of the scientific-technical societies (NIITO) were intended to be the vehicle for these exchanges. They were less successful than had been hoped, and it would appear that most of the suggestions sent 'from below' were pigeonholed 'from above'; some, however, were adopted by individual railway administrations.[10] Overall supervision of the two main institutes, the VUZY, and the NIITO projects, was the responsibility of the NKPS Scientific-Technical Council (NTS). Formally, the basic task of the NTS was to present to the Commissar or a deputy commissar scientific proposals to correct technical deficiencies in the work of transport, but it was not, apparently, doing this job very well in 1938. It had failed to persuade the institutes to join in the Stakhanovite movement; it had allowed them to have too many items in their annual 'theme plans' so that their efforts were diffused and little contribution was made to pressing problems; too many topics were passed from office to office; too many were of the 'On-the-question-of' or 'some remarks concerning' type; foreign literature was not properly studied and there was a dearth of translated material.[11] However, facilities were improving.[12]

Remedy was again sought in reorganization. In 1940 the two institutes were broken down, this time into six branch institutes. But in 1941, when they were all evacuated to Tashkent, they were perforce reunited as the All-Union Scientific-Research Institute of Railway Transport (VNIIZhT). This arrangement lasted, except that nowadays the title is Central Scientific Research Institute (TsNII) of the Ministry of Transport. Its work is largely done at Shcherbinka (although there is now an additional test-track for high-speed trains), and it still comes under the general supervision of the NTS.

Although in the spring of 1935 there had been a flurry of criticism of the research institutes, probably in connection with their impending reorganization, so far as locomotive research was concerned 1936 was the year in which Kaganovich's strong-arm methods were most felt. The point at issue was the technique of traction calculations and compilation of locomotive passports. This seems to have arisen not so much because the passport specialists were regarded as an élite who should be brought down a peg or two, but because of the demands made by the Stakhanovite movement.

The first railway Stakhanovite was Krivonos.[13] He was the driver of an E type locomotive of the Donetsk Railway and by dint of working his locomotive (and his fireman) very hard showed that it was possible to haul heavier trains at higher speeds with the same locomotives. The resultant increase in repair costs and the inefficient use of fuel which this entailed was not mentioned at the time, but this was perhaps understandable since the ability to increase traffic capacity without corresponding capital investment seemed a gain far greater than the concomitant losses. Another fact which escaped the publicity surrounding Krivonos, and the 'Krivonosites' who soon followed his example, was that the ability to force exceptional performances out of ordinary locomotives was not a new discovery. Engineer Martynov, for example, who in the early 1930s was a frequent controversialist in the technical press, had mentioned, almost by the way, that the locomotive works no longer paid any attention to passport data, because the latter had proved wildly inaccurate.[14]

What Krivonos had done was to show that the passport was a false passport, and those researchers who had made of traction calculations their professional career could have reacted in different ways to this. They could have pointed out that the passports represented an optimum performance insofar as forcing an engine to work beyond its passport limits only brought a host of expensive problems. Or they could have explained that the passports included a safety factor because it could not be expected that natural conditions, coal, and crews would always be the best possible. Or they could simply have been contrite and promised to do better next time.

The onslaught on the traction calculators came at the beginning of 1936. A. Kogan, who at this time was frequently writing malignant articles praising Kaganovich and castigating his alleged foes, wrote a newspaper article in which, among other things, he claimed that 'Traction calculations are one of those trenches which pseudo-scientific Lilliputians and saboteurs count on occupying'.[15] He explained that passports issued by the NKPS gave, in essence, two indices, power as determined by wheel-rail adhesion and power as determined by boiler capacity. Kogan depicted the safety margin incorporated in the adhesion factor as the result of 'practical experiments' carried out with defective crews, defective sanding, and defective locomotives. The method of making these calculations, he continued, had been published in 1933 by the former Institute of Traction Reconstruction, and a corresponding textbook, 'Traction Calculations and Testing', had been published at the same time. Its author was the well-known 'ideologist' of that Institute, Egorchenko, while the head of the Institute had been the 'limiteer' Markovich.

A few days later it was revealed that Markovich, by then quietly working as secretary of the Scientific-Technical Council of the NKPS, had been dismissed from that post on Kaganovich's orders. He was sent to a highly dubious future as a locomotive depot engineer in the Urals. Before he left, however, he had appeared before a meeting of the NIIZhT Party members.[16] Here, apparently, he did not repent 'his most damaging work'. The latter was his 'New Rules for Traction Calculations', in which he was accused of blindly following the standards laid down by the 'Whiteguardist Lomonosov'. In reality it was Egorchenko who had drawn up those 'New Rules', and he too was required to explain himself. Evidently Egorchenko's self-criticism and his promise to mend his ways was considered sufficient, and he was allowed to continue as a research worker under the supervision of a trustworthy colleague (this was Shishkin, then head of the traction department of NIIZhT). Markovich had no hope of such mercy. At this same meeting his former colleagues accused him of showing Trotskyist tendencies in the not-so-recent past. He was also said to have opposed the condensing steam locomotive idea; together with his assistant Kharitonov he had deliberately chosen a worn-out locomotive to send to Germany for fitting with the first condenser. Under his leadership the former Institute had long resisted the introduction of the FD locomotive, and had obliged Voroshilovgrad Works, just as it was struggling to produce the FD, to build a useless prototype of the 4–14–4 type. Since he had already been dismissed, the meeting could only add to his discomfiture by recommending his (and Kharitonov's) expulsion from the Party.

By February 1936 it was clear that work was under way on the recasting of the passports to incorporate the lessons taught by Krivonos. An article titled 'We shall create a new science of traction calculations' pointed out that the existing calculations and passports were based on the work of the 'accursed' Lomonosov.[17] The old traction calculations took no account of the quality of the crew, the article complained. For example, rail sanding had not been allowed for on the grounds that the crew would apply sand too late. The adhesion factors were constructed on the basis that the maximum tractive effort could not exceed 17–20 per cent of the weight on driving wheels. In the new passports greater adhesion would be assumed, maximum evaporation rates would be increased, and speed limits be raised. This article implied that the power output norm would henceforth be what could be achieved in ideal circumstances; incentive wage structures combined with a severe penalty system were expected to increase the number of 'ideal' locomotive crews.

This article was not written by members of the NIIZhT, but by the chief engineer of the NKPS Locomotive Directorate and Professor A. M. Babichkov. The latter, as was admitted in the article, was himself a co-author of the condemned rules for traction calculations. He was by then head of the Faculty of Traction at the Moscow Institute of Transport Engineers (since 1931 known as MEMIIT).[18] MEMIIT at this period was playing an ever-increasing role in the projection of new designs, both for complete locomotives and for modifications. As will be shown later, many MEMIIT ideas were accepted by the NKPS and imposed on the locomotive works for detailed study and prototype construction.

A prominent member of MEMIIT was S. P. Syromyatnikov, who would later be regarded as number two after Obratsov in the pantheon of distinguished Soviet railway researchers. Like Obratsov, he was evidently a man in whom Kaganovich had great faith; the latter gave him a decoration in 1936, and another in 1939, not to speak of Syromyatnikov's elevation in 1935 to a doctorate awarded 'with dispensation of dissertation requirement'. Syromyatnikov would later receive other orders and decorations, as well as membership of the Academy of Sciences. In 1943 he was appointed General-Director First Class of Traction. A laudatory biography was published in 1953 by the Academy of Sciences; its co-author was Professor Babichkov.[19]

Syromyatnikov was the son of a railway doctor, and is said to have spent his boyhood leisure on railway stations, cadging rides on locomotives. In 1909 he graduated from his Penza gymnasium, having won the latter's silver medal. He then entered the Moscow Higher Technical School (MVTU), graduating in 1917 with specialization in locomotives. He immediately became a teacher in locomotive matters at the Moscow Institute of Transport Engineers, becoming professor in 1925. From 1917 to 1921 he was occupied in laying the foundation of his career as a theorist. He did this, significantly, by laboriously sifting through the archives of all the locomotive line-testing since 1906, with the aim of constructing general theories from all that accumulated data. In the words of one of his more exhilarated biographies,[20] just as Zhuravskii had drawn strict scientifically-based theories from the practice of bridge construction, Syromyatnikov '. . . moved from blind experimentation in steam locomotive affairs to the development of the theory of locomotive thermodynamics'. As will be indicated, what his biographers extol as his main strength, his devotion to theory, might be regarded rather as his greatest weakness. Syromyatnikov's strong point could well have been his aptitude as a teacher. With the joviality of the obviously well-fed, Syromyatnikov seems to have had excellent relations with his students, who, quick to notice that when in motion he appeared to roll rather than walk, christened him 'bread-bun' (*kolobok*). A man so enthused with theory, and so fertile in the production of ideas based on theory, would have been a valuable asset in the lecture hall but a more doubtful proposition in a design office.

From 1927 Syromyatnikov combined his academic career with consultant-membership of the NKPS Scientific-Technical Committee and its successors. In 1938 he became chairman of the locomotive and rolling stock section of the NKPS Scientific-Technical Council and in 1940–8 held the office of 'Chief Locomotive Expert' of the NKPS Expert-Technical Department. In the 1920s his published work included articles stemming from locomotive line-testing and the first of several editions of his book 'The Thermal Process of the Steam Locomotive'. Each edition of this incorporated his latest research, which increasingly after 1935 tended to produce the findings most acceptable to the spirit of the time. In 1938, for example, a new edition of this work was quickly followed by a corrective brochure incorporating the author's latest findings about how the capacity of a boiler could be pushed beyond its previously accepted norm.[21] Among his many other publications was a work on the designing of powerful locomotives,[22] said to have been consulted by the designers of the FD locomotive. In 1936 he made a flying visit to the Donets Railway, where FD locomotives were working and where the Krivonos movement had just originated, and returned home to write a book called 'What the FD locomotive can do with Krivonosite methods'.[23]

From this brief biography, two points may be suggested. Syromyatnikov, by virtue of the offices he held and the apparent favour of Kaganovich, was in a very influential position; whether his influence was enhanced by, or enhanced, the preeminent role allotted to steam traction in the late 1930s is impossible to judge; certainly Syromyatnikov (unlike Lomonosov, Raevskii, Shelest, Lebedyanskii, Shishkin and other outstanding Soviet locomotive men) was interested in one form only of motive power. The other point is that he appears to have had no real experience of everyday working with locomotives out on the line; in this he was not alone among Soviet locomotive researchers.

While Syromyatnikov was a researcher of great knowledge and assiduity, it is hard to resist the impression that he was not as outstanding as he was, and is, portrayed. His work in steam traction will be described later, and in the main supports this impression. Meanwhile, two incidents may be mentioned which would seem to gnaw at his reputation. The first is a fairly insignificant article he wrote, a review of the recently translated-into-Russian American reference book 'Locomotive Cyclopedia'.[24] In it he criticized the 'limited cut-off' arrangement of American locomotives but does not appear to have grasped, or wanted to grasp, the purpose of this feature, which was to prevent locomotive crews wasting steam (this device, of course, had been adopted in the FD and IS locomotives and was hardly in the interests of Krivonosites, because it hindered the 'thrashing' of a locomotive). The other incident concerns falsely favourable results published by Syromyatnikov after testing one of his 'complex-modernised' locomotives (see p. 196).

Another MEMIIT innovator whose fertile imagination seems to have been excessively funded was L. Maizel'. When he originated his ill-fated steam-diesel locomotive (see p. 156) in 1935 Maizel' was described as a student of MEMIIT. Three years later he was described as a member of the influential NKPS Scientific-Technical Council, an advancement which was rapid even in the circumstances of that time. In 1937, while the steam-diesel idea was being developed, Maizel' came up with another astonishing idea. The application of cylinder steam jackets was being considered in Western Europe at that time, the idea being that since the degree of superheat was limited by the maximum steam temperatures sustainable by lubricants and metals, part of the benefit of superheating (the elimination of steam condensation in the cylinders, especially that caused by the relatively cool cylinder walls) could be obtained by keeping the cylinders hot with an external steam jacket. Maizel''s idea was that with a steam jacket the cylinders would actually be cooled because the steam jacket steam would be cooler than the superheated steam entering the cylinder. If the high-temperature parts of the cylinder were cooled in this way, then a higher degree of superheat could be used, obtainable from a special superheater slung beneath the boiler. In other words, the steam jackets which in the West were intended to enable steam with a lower superheat to be used, in Maizel''s project were intended to permit higher superheat. At first sight, and at second and succeeding sights, this idea is mystifying, but that is how it was described in *Gudok* under the headline 'A new contribution to locomotive technology' in January 1937. In April 1938 Maizel' himself wrote an article for this newspaper in which he mentioned that the suggestion about steam jackets had been made in 1936 and within a year 'the foreign press' had acknowledged it as one way to develop steam traction.[25]

In 1936 the idea had been submitted to NIIZhT, where a 'special commission', two of whose members were Babichkov and Pirin, recommended its incorporation in an experimental test-bed. This sequence is perhaps illustrative of how research or design organizations handled projects that were unwelcome but which were suspected, rightly or wrongly, of having political weight behind them. The first move was a 'special commission' to spread the blame in the worst case and in the better cases to give the greatest possible weight to conclusions that might be unwelcome to influential backers. Secondly, there was the device of an experimental set-up which would give the suggestion just enough rope to hang itself, and at the same time provide an interval in which enthusiasm for the suggestion might cool, or at least be succeeded by enthusiasm for a newer and better idea. In the case of the steam jackets, nothing further seems to have been done after 1937.

Syromyatnikov was not the only traction researcher providing theoretical support for the Krivonos Movement. N. I. Kartashov, a 'bourgeois specialist' who made a very successful transition to respected Soviet expert, was a very different man. He spent his working life in Siberia, mostly as a teacher, researcher, and administrator of the Tomsk Technological Institute. The author of a pre-revolutionary textbook,[26] by 1936 he was publishing articles about how better traction calculations could be made. His academic work was supported by an enormous fund of practical experience. In the nineteenth century he had worked at a locomotive depot, and then been in charge of locomotives on the just-opened Ussuri

Railway (the eastern part of the Trans Siberian Railway). In the 1930s he used to potter around Siberian locomotive depots in search of inspiration. His articles in the newspaper 'Kuzbass Railwayman' (*Zheleznodorozhnik Kuzbassa*) did a lot to ease the introduction of the unfamiliar FD locomotive, but apart perhaps from the indirect influence of his textbooks Kartashov had no effect on locomotive design.

Electric traction

Up to the outbreak of the Second World War electrification proceeded very slowly. In the Second Five-Year Plan alone 5000 km (3106 miles) were scheduled to be electrified, but by 1941 the total electrified mileage was only 1870 km (1162 miles). Much of this was accounted for by the Moscow and Leningrad suburban electrifications. The remainder was divided between a section of the Murmansk Railway where electrification had obviated the need for expensive reconstruction, a hilly heavy-traffic line in the Urals, heavy-traffic mineral lines in the Donets and Kuznetsk basins, and the Suram Pass line. In 1932 (and later) industry was accused of blowing 'a cold wind' over electrification plans.[27] But so long as industry was not provided with an electric locomotive works[28] (and this did not occur until 1947) the combined resources of Kolomna and Dinamo could provide only a fraction of what was needed. Lineside equipment was similarly difficult to obtain. Yet the first mainline electrification, inaugurated in 1932, over the Suram Pass, showed very good results.[29] By spring 1933 there were 10 electric locomotives there. Two of these were kept in reserve and the others handled 10–12 pairs of trains out of the total of 17 pairs. Of the steam locomotives 26 had already been released.

Towards the end of 1934 NKPS electrification officials, who had long blamed industry's failures for the slow pace, began to be attacked on the ground that they had not fought hard enough for their proposals. Averin, the chief of the NKPS Electrification Department, was the first to fall. (He then found a quiet job as editor of the new journal 'Electrification of Railway Transport' where, however, he was soon sniffed out and unmasked.) Khudadov, one of the most vocal and busy of the NKPS electrification enthusiasts, was also condemned at the same time for the same reasons.[30] At the second All-Union Conference on Transport Electrification the new head of the NKPS Electrification Department, V. M. Bezgreshnikov, did not receive an unopposed hearing for his report. He was also accused of sending out invitations to the conference only the day before it started, which suggests that he might have been expecting trouble. At the conference, G. Lomov, a heavyweight speaker (he was Chairman of the All-Union Energy Committee) regretted that only a fraction of the credits granted for railway electrification were being spent.[31]

The first section (Zaporozhe–Nikopol') of the Donets electrification was inaugurated in 1935. The plan had specified that the whole length (Zaporozhe–Dolgintsevo) should be completed in 1934, and even on the reduced length there was still uncompleted work. *Gudok* claimed that local railway officials were against the electrification because with the higher speeds greater care was needed with train formation (presumably this meant that an awkward number of fully braked vehicles, or of travelling brakemen, had to be provided). The several occasions when an electrically-hauled train was diverted into an unelectrified loop and left high and dry were, implied *Gudok*, a result of this hostility. Nikopol' was the temporary base for the locomotives, and the workshop there was distinguished by a total lack of electricity. Lathes could not be operated, and whenever a locomotive needed to be taken in or out of the workshop the entire labour force was called to shift it by hand.[32] But this electrification, too, produced good results. The mineral traffic was handled relatively expeditiously and the locomotives achieved daily mileages of 800–900 km (497–559 miles). In summer 1938, by which time the electrification had reached Dolgintsevo, six of the new VL19 series electric locomotives handled the bulk of the traffic, hauling 2200–500 ton trains at an average technical speed of 50–60 kph (31–37 mph). Previously the line had used 35–40 E type steam locomotives which hauled 1 400 ton trains and needed an extra locomotive on grades. The performance of the electrics would have been even better if they had not suffered from lengthy station delays and low tension in the catenary.[33]

In preparation for the Suram Pass electrification, orders had been placed for eight American General Electric and seven Italian Brown-Boveri locomotives (types S and Si respectively). Meanwhile in 1929 the Dinamo Works began to design its own version of the GE design, identical except for the use of Soviet components. This was type Ss, whose construction began in 1932, the American units being begun in 1931 and delivered in 1932. It was one of the latter which on 16

August 1932 hauled the ceremonial inaugural train up the Suram Pass. For the following weeks just two American locomotives were available; the remaining six units arrived later, having by agreement been supplied without motors, the latter being provided and fitted by the Dinamo Works. It was only in May of that year that this Works produced its first two motors for electric locomotives, modelled on General Electric designs. These Soviet and GE locomotives were able to exert 2750 hp on hourly rating. They were fitted with recuperative braking. The latter enabled trains on falling gradients to utilize their momentum in the production of electric energy that could be fed back into the catenary for consumption by climbing trains; this was very seductive for Soviet engineers, its technical drawbacks not being fully appreciated at the time. The Italian locomotives were of similar power and weight (22-ton axleload, which could be increased by ballasting to obtain extra adhesion), but had a few novelties which Soviet engineers thought might be usefully studied. For example, auxilliary equipment worked directly off the catenary supply, and the traction motors were somewhat more powerful, giving the locomotive 3050 hp. The first Italian units arrived in late 1933 and the first Dinamo locomotive in early 1933. The wheel arrangement of all three types was very different from the rigid chassis of the German-built diesel-electric locomotives, consisting of a pair of three-axle power bogies, rather better suited to operation on curved track.

With two exceptions, inter-war electric locomotive design would be based on the General Electric units. But just as in 1931 it had been decided to build a fairly light 'heavy' steam freight locomotive, so it was decided to build a series electric locomotive smaller than the American imports and more suited to the light track and weak couplings anticipated in the Second Five-Year Plan. Thus was built the VL19 series, which could be regarded as the electric equivalent of the FD. There was some lively discussion before this design was accepted. Many would have preferred a much bigger unit with a 23-ton axleload instead of the VL19's 19 tons. An outline drawing was in fact prepared of the larger unit, by the graduating class at MEMIIT, but it was not accepted.[34] VL19–01 was assembled at the Dinamo Works and completed in November 1932. It was therefore the first Soviet-built electric locomotive (it is now preserved at Khashuri). When VL19–02 appeared, the first of the series units, there were complaints that it differed widely from the prototype that had been approved by the NKPS as a standard type.[35] Most of the criticisms seem baseless, but the change from recuperative to rheostatic braking was a major difference and must have been disappointing to those who still had an optimistic concept of recuperative systems. Designing the VL19 is said to have given Soviet engineers confidence, which they showed by demanding changes in the designs of some industrial locomotives ordered from Italy for the Magnitogorsk metallurgical works.[36]

Probably about 145 VL19 units were built up to the changeover to the larger VL22 type in 1938. The VL22 and its successors, the VL22m and the post-war VL23, were the mainstay of Soviet electrification well into the 1950s, and were successive developments of the original American units. Prior to the VL22, and as a possible substitute for it, a handful of SK locomotives had also been built. These combined the features of the American units and the VL19; in particular, they reverted to recuperative braking. They were not unsuccessful, but they seem to have been built in response to uninformed clamour and were not multiplied.

The first of the more interesting, quite un-American, electric locomotives was PB21–01, a 4–6–4 passenger unit with a rigid wheelbase. This locomotive likewise belonged to the same school of thought as the FD, and may well have been designed in outline at the same OGPU establishment. It remained a prototype only, although it appears to have achieved all that its designers could have hoped. Painted sky-blue, it often appeared on celebratory occasions to haul a train of dignitaries. Completed in 1934 at Kolomna, it ran its trials on the Suram Pass line under the supervision of the ubiquitous Professor Shishkin. Running without a train on specially prepared track, it reached a speed of 128 kph (80 mph), which was apparently a Russian record.[37] At the opening of the Zaporozhe–Nikopol' section, it hauled the inaugural train and reached 110 kph (68 mph).[38] In 1941 it reappeared from the workshops of the Northern Railway as a dual-voltage locomotive, able to work on the 1500 V suburban system and the 3000 V main line.[39]

The second of the innovative electric locomotives produced in the 1930s was OR22–01, intended as an experimental prototype for the study of high-voltage industrial-frequency alternating current, which presented many advantages, notably a substantial economy in the thickness of copper wire used in the power distribution system and in the number of sub-stations. The USSR was very much in the forefront of progress in this field, at least in terms of decisions made. For it was at the first All-Union Conference on Railway Electrification in 1932 that a resolution was passed to electrify a length of line with that kind of power. But in 1935, when the next such conference was held, there was no sign of such a conversion. The much-abused Averin was blamed for this too, but what seems to have happened is that the Moscow–Savelovo section had been chosen for the experiment, and Dinamo had been requested to supply three locomotives to work on the new system. Dinamo, however, would only promise one, at which the Northern Railway administration withdrew its agreement. After all, no railway manager likes to have only one locomotive to work his train service, especially in a Kaganovich–Stalin ambience. So when the one locomotive was eventually turned out from Dinamo Works in 1938, there was nowhere to test it. In February 1939 its designer, B. Tikhmenev, complained that the location of the test section was still undecided. Moreover, the general question of what type of current should be used in future electrifications was still awaiting a solution, even though the Academy of Sciences had been studying the matter for nearly five years. Apparently the experts of the Academy could not agree whether an increase to 6000 V dc or to 11,000 or 22,000 V ac would be the best solution.[40] Eventually the locomotive turned up at Shcherbinka in December 1939 and was given brief tests which showed that it was quite practical for a summer operation (in winter the water cooling system of the mercury rectifier froze up). This locomotive, built on the SK chassis but with a new body and complex electrical system, was a creditable effort in the conditions of that time. During the war it was cannibalized, and it was not until 1954 that a new high-voltage attempt was made on the specially converted Ozherele–Pavelets line. These tests led eventually to the decision to adopt industrial frequency for most future electrifications.[41]

As can be seen in the Appendix, electric locomotive production after the 1931 Plenum considerably exceeded that of diesels, but nevertheless fell far behind the Plan. The Second Five-Year Plan (1934 'project') specified 400 units to be built in five years, while the final variant scaled this down to 350. In reality only 148 were built. Moreover, production fell to just nine units in 1940. The promised special works for mainline electric locomotives did not materialize until after the war, when the Novocherkassk industrial locomotive works were reconstructed to build electrics. However, the shortfall of locomotives was less than the shortfall of electrified mileage, so there was no real locomotive shortage and the previous intention that passenger trains should continue to be steam-hauled on electrified lines was only partly fulfilled.

Dieselization

Although the Party Plenum resolution of June 1931 had been a disappointment for the most ardent dieselizers, it had at least confirmed the diesel locomotive's right to exist. With this seal of approval, there was scope for wide-scale dieselization, and in late 1931 many diesel proponents realized this. As Engineer Struve wrote,[42] for the dieselizers the question of 'to be or not to be' had been decided positively, and within the formula Electric-plus-Steam-plus-Diesel there was room for manouevre to determine precisely what the diesel's role should be. For the time being, he continued, study and research was still needed, but at least it could already be said that diesel traction was competitive. The Kolomna designer, V. Malyshev, wrote that the decision of the Plenum followed a ten-year struggle by the dieselizers, who should now support it completely.[43] Malyshev, writing from where the real action was taking place, was anxious that the slow construction of diesel locomotives should be accelerated, so that the dieselization projected by the Party would not be seriously held back. In 1931 Kolomna was building only two diesel locomotives. It was very short of diesel designers and technicians. Foreign experts should be invited to help and relevant foreign literature supplied in translation, wrote Malyshev, who was one of the few commentators to stress that dieselizing the Asian lines would need much preparation. On the basis of experiments with the diesel-mechanical locomotive running from Chardzhou it could be foreseen that the track would need strengthening, and freightcar couplings also. Malyshev's point about strengthening the track seems to have been largely ignored by both detractors and champions of the diesel; the essential point was that diesel locomotive axleloads were much higher than those of corresponding steam locomotives. The intended diesel equivalent of the O type steam locomotive (O–el–7), had an axleload of no less than 22 tons, not only heavier than the O (14 tons) but even heavier than the future mainstay of heavy freight traction the FD (20½ tons).

1932 was the last year of the First Five-Year Plan, so increasing attention was paid to the targets of the Second Five-Year Plan. In the resolution of the Seventeenth Party Conference (1932) which specified highly optimistic intentions for the Second Five-Year Plan, diesel traction was the very last on the list of railway reconstruction objectives. Nevertheless the Plan envisaged a requirement of 1000 diesel locomotives for the dieselization of an increasing number of

Asian and Volga lines.[44] Earlier preliminary forecasts of the Second Five-Year Plan requirements had mentioned the figure of 622 diesel units. However, it is clear from the discussions of 1932 that the locomotive requirement was far from being fixed. In the middle of that year Terpugov wrote that for the 5900 km (3666 miles) of new and the 4800 km (2982 miles) of old line to be dieselized in the Second Five-Year Plan, 2660 mainline diesels would be needed, not to speak of the 4000 small yard units that would be built.[45] Terpugov suggested that Kolomna's annual output would have to be raised to 300 units, that Sormovo would have to start building the units (200 annually), and that a specialized new works would need to be built with a capacity of 500 units.[46]

In mid-1932 Gosplan envisaged a more extensive dieselized network than did the NKPS, yet its forecast requirement was 1000 diesel units against the NKPS's estimate of 2000. At precisely the same period the Commissariat of Heavy Industry was proposing to manufacture just 850, all for freight.[47] One estimate for dieselized mileage in 1937 (final year of the Second Five-Year Plan) was 6510 km (4045 miles).[48] The NKPS and Gosplan also varied in their choice of lines for conversion. The NKPS still hankered after the dieselization of the new Turkestan–Siberian Railway, whereas Gosplan preferred to work this line with 20-ton steamers. Gosplan had a scheme to dieselize what it termed the Urusha–Bogdanovich line; this apparently modest proposal in fact represented the dieselization of the greater part of the Trans Siberian Railway, Bogdanovich being a junction close to Sverdlovsk and Urusha a station close to the present Bam station of the Trans Baikal Railway.[49] However, the NKPS was ready to consider this latter proposal if its tests of a gas-generator diesel locomotive proved successful. This proviso (or, more likely, delaying tactic) was in accordance with the acceptance that dieselization should take place on lines with water-supply problems not far from oilfields. The Gosplan Trans Siberian proposal did not fulfil the latter condition, but a gas-generator locomotive would have burned coal, and low-grade local coal, thereby increasing the diesel's area of acceptability.

The question of water supply was still not thoroughly clarified. There were lines with water problems (that is, needing more or renewed piping, reservoirs and pumps), and there were lines where the rainfall was quite inadequate. A line such as Astrakhan–Krasny Kut or Orenburg–Kazalinsk traversed waterless territory but a significant traffic growth was not expected. On the other hand, there were lines where there was adequate rainfall but a shortage of pipes meant that it would be very difficult to increase water-supply in line with expected traffic increases. The Turkestan–Siberia line for the most part could be regarded as one of the latter category, which is why the NKPS wanted to dieselize it.

There were, of course, other solutions to the water problem. One was to increase the output of piping, and the NKPS was proposing to transfer one of its 31 locomotive repair shops (Saratov), to pipe-making. But in 1932 another idea began to attract attention, an idea which would eventually lead to the frustration of the dieselizers' hopes. This idea came to the surface at the 1932 Conference on Transport Reconstruction in the Second Five-Year Plan and was voiced by an engineer from the Lugansk Works; he wanted to know why, with 'seventeen organizations' involved in diesel locomotive research, not one was occupied with the problem of designing condenser-tenders for steam locomotives. A locomotive which could use its water over and over again might well be a substitute for the diesel locomotive.[50]

As for diesel locomotive production, a deputy commissar of the Commissariat of Heavy Industry was quoted as saying that quite apart from the difficulties presented by conflicting forecasts from Gosplan and NKPS, Kolomna was unable to cope alone with the requirements. There would therefore be diesel locomotive assembly at the new locomotive works to be built at Orsk. Orsk would produce annually 500 steamers and 500 diesels, the latter using diesel engines brought in from Kolomna.[51] A number of locomotive specialists, including D. A. Vinogradov[52] of the Scientific Research Institute of Locomotive Construction and V. I. Kuritsyn[53] of Kolomna stressed the need for a diesel-mechanical locomotive; the diesel-electric was too heavy, too expensive, demanded too many scarce technicians, and lacked the simplicity of the steam locomotive. In the meantime it would be useful if the various diesel design organizations (Kuritsyn numbered them at seven) stopped competing with each other and unified their efforts.

In the end, the Orsk factory never produced a single locomotive, although the 1938 edition of the 'Great Soviet Encyclopedia' listed it as being still under construction. The final version of the Second Five-Year Plan reduced mainline diesel locomotive construction to 248 units, with annual production rising to 110 units in 1937.[54] For actual production, see p. 211.

Meanwhile the diesel locomotive stock had been moved from the experimental Diesel Locomotive Base at Lyublino, no doubt to the great satisfaction of the local railway management, and been despatched to Central Asia (for a short period three locomotives had worked on the October Railway out of Moscow, where they were said to have replaced 15 steam locomotives). Ashkhabad on the Central Asian (Trans Caspian) Railway had been selected as the diesel centre, and the first unit arrived in August 1931; ten years later there would be 34 units there.[55] Shelest later wrote that they had been sent so that they could be tested in more difficult conditions,[56] but this seems implausible. The diesel locomotives were to work at first on the waterless Krasnovodsk–Chardzhou line. On this line conditions were extremely difficult for the diesels.[57] The threadbare track and their high axleloads meant severe speed restrictions.[58] They were now thousands of kilometres from Moscow. Specialized engineers could no longer be called in for consultation. It was difficult to amass in Ashkhabad the required technicians, and there was no special diesel locomotive workshop. To this was added the high temperatures, which meant that traction motors were more likely to overheat. However, the low indices were not immediately apparent and much play continued to be made with the fact, for example, that the veteran E–el–2 had already run 400,000 km (248,548 miles) by 1932. A 1933 report, despite growing evidence to the contrary, described the operating results as very promising.[59] Diesel proponents, perhaps sensing that they were losing impetus, began to complain of the slow rate of dieselization, which they ascribed largely to the NKPS and partly to the locomotive industry. In early 1934 one of the more vocal dieselizers, T. N. Khokhlov, called on the Party to intervene to end the inertia and confusion; he wrote that the Political Directorate of the NKPS should be asked to explain why it had tolerated so much wasted time.[60]

But 1934 was not a good year in which to press the diesel cause, in view of the poor, if not catastrophic, operating results of the Ashkhabad diesels. Design and constructional defects were exceptionally damaging in Central Asia, because of the shortage of technicians and of spare parts. When the Dinamo traction motors (designed for ambient temperatures up to 40°C) operated over the desert in 45–7° temperatures they soon went out of service, and Dinamo was very slow in sending spares. Despite agreements made with Dinamo and Kolomna about the supply of spare parts, neither of these works in 1934 was maintaining its promises.[61] Apart from traction motors, the diesel engines frequently failed, sometimes dangerously. In mid-1936 it was stated that the 18 standard diesel locomotives then at Ashkhabad had run a total of 987,150 km (613,385 miles), during which period 30 cylinder covers had fractured and 66 outlet valves cracked. The cylinder covers, it seems, began to crack from the first weeks of operation, becoming critical after about 10,000–15,000 km (6213–9302 miles). Other components failed prematurely.[62] In these circumstances, with cylinder and valve failures alone occurring on average every 10,000 km (6213 miles), it is hardly surprising that annual mileages were low, lower in fact than those of corresponding steam locomotives, being a mere 40,000 km (24,855) in 1935.[63] Probably this performance was why the NKPS began to lose whatever enthusiasm it had for diesels even before the arrival of Kaganovich. In April 1934 there was a complaint that the chief of the NKPS diesel locomotive sector, F. Zinoviev, as well as the Institute of Traction Reconstruction, had refused to take any interest in the trials of the new VM diesel locomotive; in fact the chief, when asked by a colleague about the results of the trial, replied that he knew nothing about it.[64]

Average annual diesel mileage increased very slightly in 1936, but then in 1937 dropped to below the 1935 level. The increasingly evident insignificance of dieselization as an answer to immediate operating problems, its absorption of much research and manufacturing attention, and the much-vaunted promise of the steam condensing locomotive, could only have cooled Kaganovich's already lukewarm attitude to diesel traction. Those still in favour of dieselization could, however, point to recent American success with this form of motive power;[65] it was no longer a question of Alco medium power locomotives, but of the General Motors' powerful freight diesel-electric locomotive which was already making such an impression on US railroad managements that they were buying it purely on its commercial merits. In October 1937 two engineers of the Dinamo Works published a long article[66] about the prospects for diesel traction in the Third Five-Year Plan, due to begin in 1938. They pointed to the defects of the Soviet series production locomotive, which had proved unsuited to the hard conditions of Central Asia. But the success of the multi-unit General Motors 3600 hp diesel-electric meant, they rightly said, that it was no longer possible to talk of the diesel as essentially a yard or secondary-duty locomotive. In America the problem had at last been solved of producing a lightweight diesel engine suitable for railway use. Moreover, they wrote, the Americans had devised highly automaticized controls to aid the driver and avoid damage to the electrical equipment through overloading. What the USSR needed was something similar, consisting of multiple units controlled from one cab and having equivalent power output to the FD steamer (3000–4000 hp).

Since the diesel had lost its claim on the operation of waterless lines, still burned oil fuel regarded as precious, and was producing unsatisfactory mileages, the diselizers had been obliged to search around assiduously for fresh arguments. The defence argument was sometimes brought up. That is, the diesel's independence of electric and water supply; one enthusiast had made the interesting suggestion of a combined electric and diesel locomotive which would secure the advantages of electrification while possessing the required strategic invulnerability.[67] Then in 1937 came the claim, very relevant to the difficult supply situation of that period, that dieselization could save copper, since electrification required so much wiring. The same year the ability of the diesel locomotive to serve as a mobile electricity generator (for civil engineering work or in emergency) was also stressed; this might also be regarded as a reference to the needs of defence.

Nevertheless in 1937 the NKPS decided to cease ordering diesel locomotives. Although presented as a temporary cessation, this did in fact prove to be the end of what might be called the Lenin/Lomonosov dieselization project. An article in the Gosplan journal[68] at the end of 1937 presented some of the thinking behind this decision. There was the condenser locomotive programme, and despite the recent US successes, the economics of mainline diesel traction in the USA were still doubtful, although the case for diesel yard locomotives was 'indisputable'. 'Diesel locomotive construction is a big and complex problem. The temporary cessation of production in 1937 does not ameliorate this problem. There is a need to study the diesels we have already built in operational conditions, and to build a series of new experimental units with electrical and mechanical transmission for fast passenger services, after which a decision can be made about renewed series production.' There was already a 2300 hp freight diesel-mechanical locomotive in progress.

As things turned out, no more experimental locomotives were built, and nothing more was heard of the proposal about fast passenger diesel units, an idea presumably originating from the publicity surrounding the American streamlined diesel trains. But at

Kolomna the diesel locomotive design bureau worked on, and although some sources show that diesel locomotives were not produced after 1937, in fact production did continue; the additional units were described, however, as 'mobile diesel electric generating plants' and it is uncertain how and where they were used.[69]

For a time the diesel seemed to become an 'un-locomotive'. The 1937 Annual Plan (which included figures for 1935 and 1936) no longer mentioned diesel locomotives, whose output was quietly included in the steam locomotive totals. When a railway monthly organized a union-wide competition for the best scientific and inventive ideas, it published a long list of likely themes which included no reference to the innovatory needs of diesel locomotives.[70] In 1940 a long Railwaymans' Day address by the Deputy Commissar of Transport, S. Bagaev, made no mention either of electrification or dieselization even though he managed to touch on every other possible railway topic.[71] Again, three months later, the chief of the technical-experimental section of NKPS wrote an article on 'Technical Progress in Railway Transport' in which electrics and diesels were unmentioned.[72]

Together with events in America, it was the encouraging results reported from Ashkhabad which kept the diesel cause alive in these last pre-war years. The line through Ashkhabad was destined to be the only section entrusted to diesel traction until after the war (and even this line was not completely dieselized). In 1938 the special diesel locomotive workshops at Ashkhabad, under construction since 1935, were at last completed. Although they were grievously short of materials, spare parts and skilled labour,[73] they were at least designed for the job and were probably the main factor in raising the average annual mileage to about 60,000 km (37,280 miles) in 1939.[74]

The Central Asian Railway's traction department had no diesel specialist, so its freightcar expert was charged with looking after the diesel workshop's needs. Evidently, too, the diesels suffered the same lack of crews and the same lack of discipline as affected other locomotive depots. One 1939 article[75] mentioned that only five of the locomotives had complete sets of crews. Another issue reported, 'When Driver Popko of the Ashkhabad depot was called for duty he wrote in reply: "I cannot turn up at the depot because I still have a hangover". The diesel locomotive had to wait six hours for its driver's hangover to pass.'[76]

With all these difficulties, the achievement of the depot in increasing average mileages seems outstanding, albeit it was an increase from a low level. There seems from scattered evidence to have been a good deal of initiative shown at this depot. It kept most of the diesels running through the war and gradually arrived at a point where it could itself manufacture the spare parts which it needed so badly, and these included welded steel cylinder covers and outlet valves to replace the defective iron components. It seems, too, that Driver Popko was balanced by drivers who despite the difficulties of driving the Soviet diesel locomotives managed to work wonders. In 1937, for example, one of the newest series diesels, E–el–35, whose crew was headed by a woman driver, was frequently achieving 1000 km (621 mile) daily mileages. In 1940 E–el–25 ran 125,000 km (77,670 miles) as against the (rather low) norm of 25,000 km (15,535 miles) between scheduled repairs.[77]

While the average fuel consumption of the diesel's great rival, the condensing steam locomotive (SOk type) fell to 190 kg/10, 000 ton-km in 1939, diesel consumption was at a steady 60 kg average. This, together with lengthening periods between repairs (between intermediate repairs, this index rose from 75, 000 to 225, 000 km, or 46, 602 miles to 139, 808 miles, 1936–9), meant that diesel operating costs were below those of the vaunted SOk, being 34 roubles per 10, 000 ton-km for the diesels and 52 roubles for the SOk.[78]

In these circumstances, the urge for a resumption of diesel construction was strong. *Gudok* in January 1941 published an article by an Ashkhabad foreman detailing the good results that were by then being achieved, and assailing the locomotive specialists of the NKPS for stopping diesel construction and thereby setting an example to other departments of how to ignore the needs of the existing diesel locomotives. The Ashkhabad depot, he complained, was not included in a single one of the centralized supply plans; diesel specialists were no longer being trained; there were no diesel locomotive manuals; great improvements might be obtained for just a little expenditure.[79] Two weeks later eight Kolomna designers, headed by Lebedyanskii, wrote an article in the same paper urging a resumption of construction. The new General Motors 5400 hp diesel locomotive, US high-speed diesel trains, the Baltimore & Ohio Railroad's conclusion that diesel traction was cheaper than steam for passenger trains, the 14 per cent of German railway passengers who were diesel-hauled, were all stressed, and the question asked and answered: 'What conclusions has the Locomotive Directorate of the NKPS drawn from the indisputable successes of diesel traction? In essence, none.' This Directorate, continued the designers, seemed to have forgotten Lenin's interest in diesels, and the intentions embodied in the 1931 Party Plenum resolution. Apart from stopping construction at Kolomna, it had stopped the production at Kaluga of the 800 and 400 hp diesel multiple-unit train prototypes. Since oil-burning steam locomotives were being built, it could hardly be said that the diesel was unacceptable because it consumed scarce oil. Adding a precautionary word in favour of modernized steam locomotives, the distinguished authors concluded by urging an early return to diesel construction.[80] The indifference of the NKPS had also been assailed in *Gudok* in 1940. The writer, an engineer, accused the Locomotive Directorate officials of holding the opinion that diesel traction had no future in the USSR, and putting forward the condenser locomotive instead; and all this in spite of the fact that the Ashkhabad diesels had an availability factor of 62 per cent, compared to the previous 17.5 per cent.[81]

Finally, on 20 April 1941 *Pravda* announced that diesel locomotive construction was to be restarted. Six units were to be built in 1941. But Germany, which had done so much for Soviet dieselization, put an end to this renewal when it invaded a few weeks later.

In retrospect, the NKPS cessation of diesel orders from 1937 could be justified by the inferior performance of the Soviet locomotives, compared to their American counterparts. In Central Asia, a diesel locomotive that ran 1000 km (621 miles) daily on several occasions was exceptional enough to be reported in the newspapers. In the USA, there were diesel locomotives that did 1500 km (933 miles) or more on regular daily schedules. Whereas 62 per cent availability was considered an achievement at Ashkhabad, 99 per cent was claimed by some US railroads. Evidently, then, the NKPS pause for thought was not unjustified.

On the other hand, the diesel locomotives, imperfect though they may have been, seemed capable of outperforming the steam condenser locomotives in several ways. Their high construction cost was still a disadvantage, but the condenser locomotive was itself expensive, and it is quite conceivable that, given a large production run, the diesel price could have been brought down to equal that of the condenser locomotive. But the latter benefited from Kaganovich's personal patronage, as will be described, and its unsatisfactory aspects (maintenance costs, reliability) were ascribed to human negligence and ill-will rather than to technical considerations. On technical and economic grounds, the decision to build thousands of condenser locomotives for water-problem lines, and to relegate the diesel locomotive, seems unjustified.

However, it is unlikely that it was technical and economic circumstances that were decisive. In technical decision-making it often happens that the really compelling arguments are concealed. For example, the majority of US railroads contemplating dieselization preferred to leave unmentioned the opportunity which the diesel offered for introducing one-man locomotive crews. Similarly, in the USSR in 1937 there was a connection between building locomotives powered by submarine-type diesel engines, the limited output of such engines, and the adoption of a naval programme in which submarine construction was the most important feature; this was an unadvertised connection, but real.

Diesel locomotive designs

In the decade following the 1931 Party Plenum decision, over 30 mainline diesel locomotives were turned out by Kolomna Works. Most of these units were of the type selected for series production in 1932 (see Figure 12). At the time of the Plenum, Kolomna was working on two O – el type units and on the larger E – el – 9. The latter was a Russian-built version of E–el–5 being built by Krupp and representing an improvement of Lomonosov's E–el–2. E–el–5 arrived at Kolomna from Germany in October 1931, while E–el–9 was completed by Kolomna in November 1932 (claimed) or August 1933 (actual).[82] The latter was taken as the prototype of the new series-built units, commencing with E–el–12; these were built at

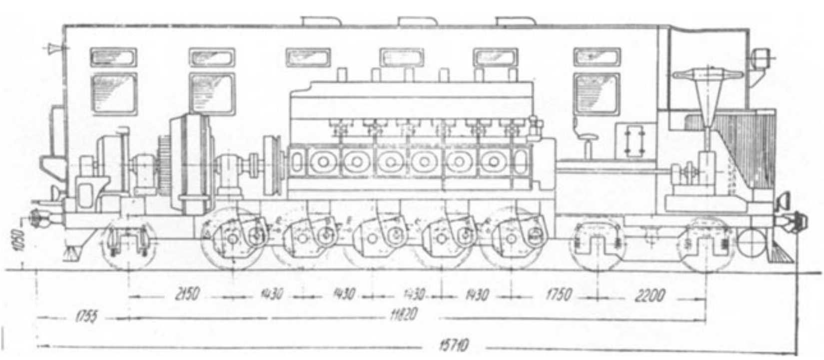


Figure 12 The standard inter-war diesel locomotive, type E–el. (Leading dimensions of diesel locomotives are given on p. 215.)

Kolomna, with generators supplied from the Kharkov electrical machinery works and traction motors and other electrical equipment supplied by Dinamo. With an axleweight of 20 tons, these units could develop 1050 hp on hourly rating and 21 tons of tractive effort at 11 kph (7 mph) (falling to 1.6 tons at the maximum speed of 55 kph [34 mph]). About 24 are believed to have been built, plus others intended for use as generators. Some of their early faults have already been mentioned. Improper materials (cast iron) were probably the cause of their frequent cylinder-cover and valve fractures. Their fuel pumps were another weakness, but it was long before these were replaced. The frames were rather weak and the engine foundation plate too flimsy; when the engine was removed, this plate rose by up to 4½ mm. Described by one critic[83] as an unsuccessful Soviet version of E–el–5, they were less powerful than the E steamer but had a heavier axleload. Another fault, making the driver's life even more nerve-wracking, was that the driver was placed close to the power plant so that he could keep an eye on it. This meant he was disturbed by noise, heat and fumes as he strove to regulate the quite complicated controls and watch for signals. After the war these units worked until the 1960s, and some substantial improvements were made to them in their last decade. One, E–el–27, was modernized with several components of the post-war TE1 type diesel locomotive.[84] One diesel designer (Shishkin) complained that this rebuilding of E–el–27, undertaken by the Railway Ministry and not by the builders, was a good example of the lack of interest in their own products shown by the locomotive industry.[85]

An advanced prototype, E–el–8, was ordered from Krupp in 1931, arriving in the USSR in 1933. This was a 4–10–2 in which there were two diesel generator sets. Sulzer engines were used, of 825 hp each. The traction motors were mounted on the frames and connected to the driving wheels by the new Swiss (Secheron) sprung transmission. The result was a powerful locomotive with a starting tractive effort of 26 tons and an axleweight of 21 tons. It was sent to Ashkhabad and appears to have worked well, but it was difficult to find trains heavy enough to take advantage of its tractive capacity. The design was not repeated, although the Secheron drive, in view of its success elsewhere, must have been a great improvement on the standard diesel locomotives. E–el–8 was designed by Dobrovol'skii, and was intended to match the new FD and *Iosif Stalin* steam locomotives. On its first trials on the October Railway it tended to derail on the sharp curves of locomotive depots, and the flangeless second and fourth pairs of driving wheels had to be hurriedly modified, with wider tyres. Its end came in the war when the springs in the drive broke and could not be replaced. It was stored until 1953 and then withdrawn.

The second mainline prototype of these years was Soviet-built. This was the VM twin-unit locomotive, designed largely by Dobrovol'skii, Pozdnyakov and Khokhlov. This was intended to be a diesel equivalent of the FD steamer although, by operating either one or two units and changing the gear ratio, five variants could be obtained. Each unit was of the 4–8–2 wheel arrangement, with a single cab. For the first time, the cooling system was not mounted prominently at the front, but was concealed, being ventilated by side grilles. Because of production difficulties, the intended 175 KWT traction motors could not be used, and the 140 KWT type used by the standard diesels was provided by Dinamo. (Since a single-unit VM had only four driving axles, this meant that it was less powerful than the standard E–el series with five). The axleweight was 20 tons and the hourly output of the twin-unit locomotive 1635 hp. The foundation frame for the engine was a one-piece casting; Kolomna had refused to undertake this on the grounds of excessive difficulty, but Voroshilovgrad (Lugansk), perhaps glad of an occasion to show that there was at least something it could do better than Kolomna, successfully tackled this job.[86]

The two units, VM20–01 and VM20–02, were completed by Kolomna in January 1934. They worked as a twin-unit locomotive on the Moscow–Kursk and Moscow–Leningrad routes before going to the test track at Shcherbinka. In August 1935 the locomotive was inspected by Kaganovich himself. This inspection was described in *Gudok* by the head of the NKPS Locomotive Directorate's diesel traction group, F. A. Zinoviev (the same Zinoviev whom *Gudok* had castigated on 23 April 1934 for ignoring the trials of this locomotive). Whatever Zinoviev's deficiencies as a diesel man, he was certainly a fine publicist for Kaganovich, as he related how the Commissar had spent no less than two hours with the locomotive, socializing with its crew and asking the most perceptive questions imaginable.[87]

The locomotive was then sent to Ashkhabad, where its chief defect was that suitable work could not be found for it. As a twin-unit it was too powerful, heavy trains being difficult to provide because of couplings, operating requirements and, presumably, the length of loop lines. On the other hand the single units were less powerful than the standard diesel locomotives. It was only as a passenger locomotive, working in single units, that this design could justify itself, and then not without some operating inconveniences. Yakobson claims that this locomotive would have been the prototype of a successful series if diesel construction had not ceased. This might be accepted, but the prototype itself was not without faults. The smaller-than-intended traction motors meant that its diesel-generator produced more power than the traction motors could absorb, and it was not easy to handle, like the other Soviet diesels.

This difficulty in handling was a result of the lack of progress, even perhaps the knowledge of a lack of progress, in devising automatic control processes. Whereas in the USA the Alco-General Electric diesel locomotives had long had the benefit of the Swiss engineer Lempe's self-adjusting control system, the need for such a system seemed hardly recognized in the USSR. After all, the skill required by a diesel crew seemed no greater than that needed by a steam crew. But the big difference was that a steam locomotive could happily survive bad handling, whereas a diesel could not. There were three main components of a diesel-electric's power; diesel engine, generator, and traction motors; failure to keep these in step with each other could result in, at best, excessive wear, and at worst, the burning out of motors or even ignition of the entire locomotive. American diesels made these constant regulations automatically and the driver needed to operate a single control handle. Soviet diesel drivers had to match up their system with the aid of several controllers and gauges. This was one reason why Soviet diesels carried three-man crews. On the VM, for example, the crew worked in conditions more characteristic of a submarine than a railway vehicle. The dieselman sat in the body, close to his engine, and could not see the driver, who sat in the cab. The driver signalled required changes in the diesel engine's regime by lightbulb and sound codes. On trials this system did work, but it is not hard to imagine it failing in daily service. The Dinamo Works had attempted to install a circuit by which the driver could regulate both diesel engines simultaneously, but it did not work.[88] However, when working as a double unit, the rear walls of the two sections could be removed, enabling one dieselman to supervise both engines. On the E–el series, the driver, electrician (who acted as assistant driver) and the dieselman normally sat together.

In the inter-war period, production of small yard locomotives, *motovozy*, was mastered, and several thousand were built by the Kaluga Works. These, however, were of very low power and for industrial use. Gakkel' made an attempt at a more substantial yard locomotive. This was his AA–1 of 1933, a diesel-mechanical 300 hp machine of the 0–6–0 wheel arrangement with connecting rod drive. Intended also for suburban passenger work, a novel feature of this locomotive was that many of its mechanical parts were identical with those used by the old O type steam locomotive. This would certainly have simplified the spare parts problem, but it was the engine which was the weak point of this design. So failure-prone was this latter that AA–1, although actually built, unlike most of Gakkel''s designs, made only a few trial runs before being abandoned.

Of the several mainline locomotive designs worked out after 1937, two are of particular interest. There was a 2000 hp design which was specifically intended to haul heavier trains than the SOk condensing steam locomotive then being used on lines that had previously been planned for dieselization. This supports the presumption that there was still a very conscious struggle between the dieselizers and the steam interest. The second design was drawn in two variants, a single unit and a permanently coupled twin-unit B–B +B–B, with each unit riding on two two-axle powered trucks. For the first time, therefore, the rigid wheelbase, favoured ever since the first Lomonosov German design, was abandoned for the flexible wheelbase provided by swivelling powered trucks. With this chassis, and the smoothly-contoured body, the new design looked very much like the present-day concept of a mainline diesel locomotive.[89]

Throughout this period research continued on diesel transmissions. Not so much on diesel-mechanical projects, but on the direct transmissions that had been so alluring to Soviet researchers in the preceding years. Yakobson complained in 1934[90] that the researchers were being starved of resources: Maksimov's project was at a standstill because of lack of facilities. Khlebnikov and Prigorovskii wanted to obtain Deutz-type engines from the Voronezh factory but neither the Heavy Industry nor Railway commissariats would help. Shelest's laboratory was still in the cellar of the MVTU. Yakobson urged that the NKPS organize an experimental workshop, the Commissariat for Heavy Industry 'being obviously uninterested'. On the other hand Yakobson could report that Dyrenkov's locomotive (which worked on the Otto cycle using gas from a gas-generator tender and incorporating a planetary clutch) was being built at the *Mozherez* Works of the NKPS (it was never completed). Experiments were being carried out with Khlebnikov's engine, but Shelest's project was running into trouble not only because of the design problems posed by the high temperatures inflicted on the combustion chamber and turbine but because the experiments so far had only been half-hearted.

In terms of resources actually expended, Yakobson was wrong to imply that the commissariats had been stingy. Much talent and production capacity would be expended on direct-action diesel locomotives. These resources were devoted to a species of locomotive, three of which were actually built, known as *teploparovozy*, or steam-diesel locomotives, which were said to combine the best features of steam and diesel.

The concept was neither Russian nor original. The German Max Mayer had proposed a 4–6–4 tank locomotive with steam and diesel propulsion in 1925. His proposal was published in Germany in 1925[91] and translated into Russian in 1927[92] with an explanation that although it was once impracticable, the recent introduction of the MAN slow-running engine now made it possible. However, nothing came of this. Next, the Ansaldo and the British Kitson-Still prototypes attracted attention, and were proclaimed as very significant even after Italian and British engineers had concluded the opposite. The idea of having compressed air or steam power at low speeds, and then internal combustion at higher speeds in the same cylinder, must have seemed very elegant, but in practice these prototypes were unpromising.

In 1935 L. M. Maizel', a student at the MEMIIT, suggested for Soviet Railways a variation of the Kitson-Still locomotive. The novelty of this was that the cylinders, while working with steam up to the cutting-in speed for diesel operation, at those higher speeds would work with steam and diesel cycles simultaneously. When working that way, it was claimed, it would be a very powerful machine, with the power of the boiler supplemented by the power of diesel combustion. Because the machine would resemble a steam locomotive, it would be more easily assimilated by locomotive staff brought up in the steam tradition. The Scientific-Technical Council of the NKPS decided that the idea was worth pursuing and requested the Scientific-Research Institute of Railway Transport to work out the technical design. In September 1938, at a conference at Voroshilovgrad on locomotive construction, a speaker mentioned the desirability of putting a diesel engine on a steam locomotive and, after mentioning Prigorovskii's ever-maturing project, mentioned that a design for a *teploparovoz* had been worked out.[93] The *Proletarskii* repair shops at Leningrad established a special bureau for converting an old K type 4–6–0 into a *teploparovoz*. However, it was decided to abandon this particular project because it was too complicated. Whereupon two entirely new and even more complicated prototypes were ordered from Voroshilovgrad and Kolomna.[94]

These orders were placed in 1939, and were welcomed neither at Kolomna nor Voroshilovgrad. The first to appear was the passenger unit from Voroshilovgrad, in September 1939. This was a 2–8–2 incorporating certain components of the IS steamer and the boiler of the Su type. Its cylinders, as in all the *teploparovozy*, were placed outside, between the second and third pairs of driving wheels, and had opposed pistons. Up to about 20 kph (12 mph) the cylinders were entirely steam-worked, and above that speed the central area of the cylinder, alternately contracting and expanding as the pistons approached and receded, became the combustion chamber for the diesel cycle. Thus the outward thrusts of the pistons would be powered by internal combustion while the inward strokes would continue to be worked by steam. After some trial runs on the North-Donets and Southern railways the machine went for tests at the Shcherbinka research establishment. After what Rakov subsequently termed 'far from complete tests', the commission entrusted with examining the results of the tests announced that the Voroshilovgrad Works had solved a complex technical problem, the 'creation of a new locomotive working on the principle of combining the steam engine with the internal combustion engine'.[95] Among other things, the commission found that fuel consumption was half that of the IS steamer, and that the dynamic qualities were good.

Despite the glowing report of the commission, immediately afterwards the machine was returned to Voroshilovgrad for a complete reconstruction. However, since this reconstruction would cost almost as much as a new edition, it was decided to make just a few small changes. After these modifications the locomotive returned north, hauling a light train (900 tons) on the way. It then hauled a 1100-ton train on the October Railway (again, a modest load for a unit of 3000 hp). It continued to run its trials throughout the war, mainly hauling passenger trains between Moscow and Ryazan, where its coefficient of thermal efficiency was said to be about 10–11 per cent. In 1943 Maizel' suggested a scheme whereby, after ignition of the diesel fuel, steam would be admitted to the central part of the cylinder after the pressure had dropped to around boiler pressure. This modification was carried out, at the height of the war in 1943, and was tested on the Tashkent Railway, where it was found that the locomotive's performance had slightly improved insofar as it could maintain somewhat higher speeds. In 1946 the locomotive was again tested on the October Railway where, it seems, its defects began to be openly recognized. Apart from constructional faults such as the tendency of the cylinders to develop cracks (making diesel operation hazardous), there were design faults too. The dynamic qualities, once described so positively, were inacceptable for track suffering from wartime wear. Quite apart from the axleload of 25 tons, the absence of axlebox slides contributed to poor riding qualities. But there were fundamental difficulties too. The basic idea seemed defective, for in practice the simultaneous working of internal combustion and steam expansion in the same cylinder resulted in sudden sharp fluctuations of the tractive effort. When the diesel was switched out the thermal efficiency dropped sharply and, moreover, there was insufficient steam to keep heavy trains on the move. In 1948 this machine was put into store, and it never worked again.[96]

Even more complex than the passenger *teploparovoz* was the freight version built by Kolomna; indeed, it is doubtful whether a more complex locomotive was ever built anywhere during the age of steam (see Figure 13). It was of the 2–10–2 wheel arrangement, and intended to be the equal of the FD locomotive. It had two outside cylinders on each side, again with opposed pistons, but its main difference from the Voroshilovgrad unit was its use of gas fuel. This was achieved by mounting a gas generator on its enormous tender. The gas produced here from anthracite was fed to the 'diesel' section of the cylinders where it was ignited by spark plugs. That part of the anthracite destined for stoking the boiler passed through a pulverizer and was fed to the firebox in powdered form. In addition to all these

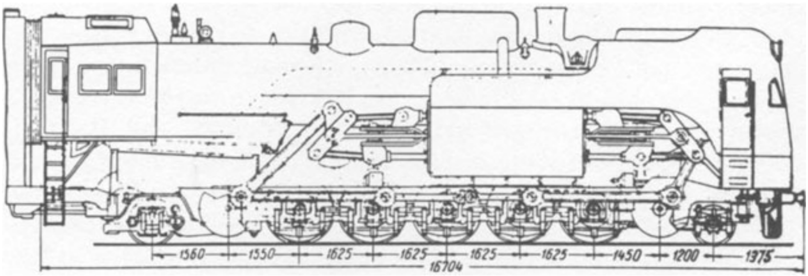


Figure 13 The opposed-piston, gas-producing, condensing, combined steam and diesel *Stalinets* locomotive.

complications, it was decided that this should be a condensing locomotive, so the exhaust steam was led to condenser elements in the tender. A smokebox turbofan replaced the steam draught through the chimney. As the footplate accommodated so much activity, the driver was secluded in his own cab at the front of the locomotive. The face of this cab carried the locomotive's name, *Stalinets*.

Completed in December 1939, *Stalinets* in the latter half of 1940 was under test at Shcherbinka, making 76 trips which totalled 1790km (1112 miles). It was found that the locomotive could only function satisfactorily at between 25–30 kph (15–19 mph), an impractically narrow range. Above that speed it worked normally for about 15 minutes, but then suffered from premature ignition of the fuel entering the cylinders. On the eve of the war, Kolomna reduced the length of the eight piston heads (in effect, reducing the cylinder pressure) in an attempt to remedy this fault. But the war brought the trials to a permanent but hardly premature end.

Lebedyanskii appears to have been the leading designer of this locomotive, working on the basis of outline drawings supplied by the NKPS. Judging from his later work, *Stalinets* represents a complete reversal of what might be called his design philosophy. Moreover, Kolomna at that time was engaged in the construction of diesel locomotives, electric locomotives, Su passenger and 9p industrial steam locomotives, as well as smokebox fans, condenser tenders, diesel engines, and tunnelling shields. It was experiencing considerable difficulty with several of these, so *Stalinets* must have been very close to the last straw, presented by the researchers of the NKPS and MEMIIT with scant regard to production problems. A similar situation prevailed at Voroshilovgrad; in 1947 an NKPS researcher and traction engineer, Shishkin, criticized the unwillingness with which Voroshilovgrad had undertaken the passenger *teploparovoz*.[97]

It might have been expected that this would have been the last of the *teploparovozy*, but in 1940, before they had finished their trials, Voroshilovgrad began the design of a third unit. This was to be a freight version of its passenger unit, but when it was partly complete the war intervened and work ceased until 1945. Then, in view of the experience with the earlier units, it was redesigned. The main change was that Maizel''s idea of having steam expansion and diesel ignition taking place almost simultaneously in the central part of the cylinders was incorporated. Completed in 1948, the unit's trials showed the virtual impossibility of making this steam-diesel cycle work, for reasons of pressure and temperature. By this time the diesel-electric locomotive, in its American manifestation, had really proved itself on Soviet railways and so, at last, the idea of the steam-diesel locomotive was laid to its long-deserved rest.

Although it had been the heavy General Motors diesel-electric locomotive that had aroused the greatest interest among Soviet engineers,[98] it was the rival American firm, Alco, which was destined to rejuvenate diesel locomotive design and construction in the USSR. In 1945 a batch of Alco road-switchers (general-duty diesel locomotives) arrived in the USSR, followed soon afterwards by some Baldwin streamlined passenger locomotives. The latter, type Db, worked for some years in the USSR but did not have any great influence. The Alco units (type Da) aroused much more enthusiasm. In fact, because these locomotives were a hasty revision of an existing design (to reduce the axleweight they had been fitted with six-wheel instead of four-wheel trucks, but the electrical system was unchanged, leading to a certain lack of correspondence between the traction motors and the generator) they were not the most perfect example of the US diesel. Nevertheless, they made a great impression on Soviet engineers and railway operators. In 1945 Yakobson compared them very favourably with the existing Soviet E–el series, whose engines weighed 26 kg per hp (compared to the Da's 10 kg), whose traction motors weighed 21 kg per hp (compared to 10 kg) and whose generators were three times the weight of the American generators. But what really seemed to excite Yakobson, both in this article[99] and in a subsequent article in *Gudok*,[100] was the sophistication of the control systems. There was a push-button starter (and starting was by battery), a simple handle controlled the engine revolutions. Büchi supercharging (in which the USSR had been a pioneer but had not pursued the idea) raised engine output by 50 per cent. There was a patent regulator (Woodward's) which held the revolutions constant irrespective of load, or changed revolutions in conformity with tractive effort and speed, and stopped the diesel automatically should the oil pressure drop; there was Lempe's electrical control, 'much superior to our Leonardo transmission'; there was a selection of connections between the traction motors, chosen automatically. In short, the control was a driver's dream because he was required to regulate only the engine revolutions; everything else happened automatically. Sent to the Ashkhabad and Orenburg railways, these locomotives ran 15,000 km (9320 miles) monthly without any need for depot maintenance. On a run from

Moscow to Berlin (a broad-gauge route in 1945) there was no need for any fuelling stop. They could also work 'multiple-unit'.

After the USSR had begun to build its new range of diesel locomotives, which initially were copies of the Alco Da, the enthusiasm for the American locomotives was muted, and they were treated warily by subsequent historians of Soviet dieselization. Yakobson in his 1960 history of Soviet diesel locomotives does not even mention them (except for an accidental reference contained in the title of a book listed in his bibliography). Shelest, however, freely acknowledges that they were the basis of the Soviet TE1 design[101] (see Figure 14). What is especially piquant about this situation is that a Russian was largely responsible for the existence of the Alco diesel locomotive. Alphonse Lipets, who with Lomonosov had designed a diesel locomotive for the Tashkent Railway before the First World War, had emigrated to the USA after the Revolution. Here he had become a leading, probably the leading, mind behind the move of Alco into the diesel-electric locomotive business.

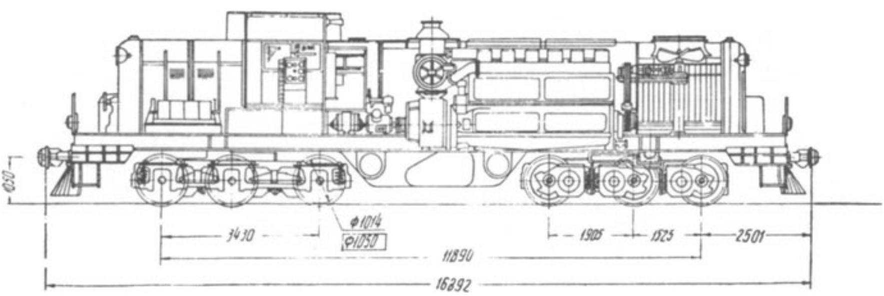


Figure 14 TE1, the post-war diesel design modelled on American imports.

Series production of the TE1 began in 1947 at a new locomotive works in Kharkov (nominally a rebuilding of the old Kharkov Locomotive Works). It was almost identical to the Alco design. About 300 units were built before construction ceased in mid-1950. The successor to the design eliminated two undesirable features of the TE1. One of those features was its low power (an engine of 1000 hp in a locomotive with an axleweight of 20 tons). The other was that the American road-switcher configuration was not altogether suitable for Soviet conditions, as in order to inspect or adjust the engine the crew had to stand on the exterior walkway and approach the engine through hatches. In wintry conditions this was detrimental both to engines and to humans, so an all-over body, which could create a warm house for the engine, was specified (in 1948 two of the TE1 type were fitted with a partial all-over body for this reason, being reclassified as TE5).

The successor to the TE1, whose series construction began at Kharkov in mid-1950, was the TE2. In this, a pair of what were essentially TE1 units were permanently coupled back to back and provided with a smoothed all-over body. In this way a more convenient locomotive was produced. It had the same axleweight, despite the substitution of four-wheel tracks, and double the power of the TE1. Yakobson was chief engineer of the diesel locomotive department of the Railway Ministry at that time, and played a major part in drawing up the outline drawing.

Just as series production began of the TE2, design work started on the TE3. This was a much bigger locomotive. It employed opposed-piston diesels (said to be derived from American Fairbanks-Morse engines used on small craft received by the Red Navy during the war). Externally, it resembled the TE2, but it had six-wheel trucks instead of four-wheel and each of its two sections contained a diesel engine of 2000 hp. The prototype appeared from Kharkov in 1953, and it went into series production in time to become the basis of the new dieselization drive initiated as part of the Khrushchevian plan for railway reconstruction. Several thousand units were built, although it was not a completely satisfactory design. In 1959, by which time Kolomna, Lugansk and Kharkov were building mainline diesel locomotives, production of such locomotives for the first time exceeded 1000 per annum.

Since then many prototypes and several series designs have been produced. Their history does not belong to this book, but as a final note to the early history of Soviet diesel traction it might be added that in the 1970s Soviet-built diesel locomotives were hauling trains in the homeland of Dr Rudolf Diesel, and that at the end of that decade the USSR was the world's biggest producer of diesel locomotives.

Steam traction

The Party resolution of June 1931 had recognized that in the immediate future steam traction would be hauling almost all Soviet trains. What it had not anticipated was that the steam locomotive would continue to be the basic motive power for the next three decades, and that the heavy freight locomotive, key to the entire operation, would not be an American-size locomotive, but the more modest FD. The latter could be regarded as a scaled-down and redesigned version of the American [Baldwin] 2–10–2 ordered by the USSR. By 1940 it would form over 14 per cent of the freight locomotive stock. Over 3000 units would be built and it would become the standard locomotive for the most heavily loaded lines. In the 1980s, examples were still at work in China, where they were sent after withdrawal from Soviet service. Chinese railwaymen, however, tended to be uncomplimentary about them.

Preliminary discussion of this new design must have started in the special 'technical bureau' of OGPU very soon after the return of the 1930 Soviet railway delegation to the USA. This sequence, and the incorporation of so many American features in the design, makes it tempting to speculate whether certain NKPS traction specialists were arrested immediately on their return to the USSR. This does seem quite likely, but not certain; enough experience of American practice had already been accumulated from other visits and exchanges. Among the American features of the FD design were: bar frames; the casting in one block of one set of cylinders, valve chests and half the smokebox saddle; the Elesco type small-tube superheater; the provision of a combustion chamber, thermic syphons, and mechanical stoker for the firebox; the multi-valve regulator; the arrangement for limited cut-off so that steam would automatically cease to enter the cylinder after the piston had travelled 60 per cent of its stroke (the same percentage employed by Lima 'Super Power' locomotives and with the same small slits in the valve chamber bushings to allow significant extra steam to seep into the cylinders at slow speeds);[102] the introduction of grease lubrication in place of oil, and in the case of the prototype, a feedwater heater very similar to the American Worthington device.

The prototype was built at Voroshilovgrad, with components sent in by Kolomna, Sormovo, and the Izhora Works. Completion was in time for FD 20–1 to make its first public appearance in Moscow for the November celebrations of 1931. At the Party Conference of February 1932 the design was decreed to be the basic freight locomotive of the forthcoming Second Five-Year Plan. However, this did not mean the end of the search for a 'powerful' locomotive; in April 1932 this question was put under study by a special sub-committee under Professor D. A. Shtange set up by the NKPS's Committee for Railway Reconstruction. In May this sub-committee recommended that 500 units of the FD be built in 1933 for use on heavy-traffic lines, as this design made the best possible use of existing track and existing couplings. However, the sub-committee also recommended the speeding-up of the trials of the big American imported locomotives and the immediate testing of the proposed alternatives for intermediate grade track (18-ton axleload); that is the Beyer-Garratt on order and the Soviet-designed 4–14–4 locomotive. Meanwhile, the future *Iosif Stalin* type (IS) 2–8–4 passenger locomotive, using most of the components of the FD, was to be developed so that trials could start in the beginning of 1933. An even bigger, 4–8–4, locomotive was to be designed for passenger services on the heaviest traffic routes. This sub-committee finally buried the old NKPS proposal for a suburban steam locomotive, saying that pending electrification made this proposal redundant.[103]

It was the reconstructed Works at Lugansk (known as Voroshilovgrad 1935–58) which produced the FD in series. Indeed, no other Works could handle it, and it formed the bulk of Voroshilovgrad's output; the latter's capacity to mass produce even larger (23-ton) locomotives was never required. Highest output was in 1936, when the Works turned out 664 units of this type. The series locomotives incorporated a few changes suggested by the trials of the prototype. One major omission was the feedwater heater, as a result of which the forward part of the locomotive weighed considerably less than anticipated. There was a resultant weight difference between the coupled axles of over two tons. The Scientific-Research Institute (NIIZhT) worked out a ballasting scheme as early as 1935, but this was not applied by the NKPS Traction Directorate, allegedly because the latter was directed by wreckers[104] but more probably because the locomotive authorities were experiencing sufficient trouble with this locomotive without adding a new complication.

The most serious FD defect was the tendency of the main frames to fracture. There appear to have been two causes of this. The autogenous cutting of the metal was a new technique, and the newly-cut edges of the transverse stiffener were neither cut out nor treated. This meant that these border areas were of different quality than the remaining areas, a sure recipe for trouble. Added to this, the Stakhanovite style of driving, with the engine working hard continuously, not just at starting, placed more stress on the frames than had been anticipated. This was made worse by the generous tolerances of the Voroshilovgrad Works, which meant that driving wheels could slip fractionally twice each revolution as they took up excessive play. Eventually, after rather prolonged study in the research institute, it was decided to incorporate strengthened frames on future locomotives. The other defect of the type was its rapid wear of driving wheel tyres. This too, was partly explicable by momentary wheelslip as excessive tolerances were taken up, but the real kind of wheelslip was far more damaging. With the fast 'heavyweight' trains handled by Stakhanovites, wheelslip, not dramatic but sometimes almost continuous, was a natural consequence of locomotives being pushed to, and a little beyond, their limit of adhesion. As has been mentioned, adhesion limits were deliberately raised at this time to give theoretical backing for the exploits of the new breed of Stakhanovite enginemen. Such enginemen, too, sometimes applied sand too late (as the Lomonosov school of traction computations had assumed). In some quarters it was thought that the constant sanding of the rails was itself a factor leading to excessive tyre wear. Possibly it was, but since large-scale sanding was inevitable in Stakhanovite conditions there was little that might be done about it. This did not deter the Bryansk Works, however, from inventing a device that was claimed to prevent sand wearing the locomotive's trailing and tender wheels. This, essentially, was a steam blower which swept the railhead just behind the last pair of sanded driving wheels.[105] More worrying to the locomotive researchers than to the operating departments was the growing reputation of the FD as a 'coal-eater'. One reason for this was the provision of American-style mechanical stokers. Although Soviet locomotives carried a three-man crew it had been realized that, in order to secure the high evaporation rates needed for continuous outputs of over 2500 hp, mechanical firing would be needed. But the coal provided for these locomotives could rarely be the riddled kind most suitable for mechanical firing, with the result that when working hard they threw about 25 per cent of their coal intake straight up the chimney, unburned. A new stoker, the Rachkov type, was later fitted, but this does not appear to have brought much improvement. Other new designs were tried, including one which threw the coal from the front, rather than the rear of the firebox, but this problem was never quite solved. Nor was the use of low-grade coal ever mastered completely. A few of the FD type were fitted with their own pulverizer, converting low-grade coal into powder for injection into the firebox, but large scale application of this device never occurred.

It was partly because of the deposits of unburned fuel, partly because of deposited ash, that the superheater elements of these locomotives tended to burn out. A new wide-tube superheater was developed and fitted and this did bring, apparently, a marginal improvement.

Material or manufacturing defects also accounted for some of the unpopularity earned by this type in its early years. Voroshilovgrad, at the time it was trying to bring production up to 1000 units annually, was also burdened by non-railway orders and orders for prototype locomotives; it was foisted with the no-hope 4–14–4 locomotive project against its will, and all kinds of non-railway orders came its way. In 1938, for example, it was castigated for paying insufficient attention to an order for caterpillar tracks, which it insisted on casting instead of stamping and thereby achieved a defect rate of 85 per cent.[106] In these conditions, defective output of locomotives was hard to avoid, and the NKPS inspectors attached to the Works do not appear to have been very conscientious; according to one report these men rarely turned up at the roll-out of new locomotives.[107] Thus defects were tolerated. FD20–63, one of the first batch, had 112 defects, and such defects were likely to be discovered only when the new locomotive had started work at its depot. Units with metal shavings in their cylinders and steam chests, or with parts of their valve gear fitted upside down, were reported. Voroshilovgrad was having to cope with shortfalls in the deliveries of components, and with poor quality materials. It could happen that in order to keep production moving, a part intended for one locomotive would be fitted to a locomotive waiting for just such a part in order to be rolled out. Firebox sheets for the FD units, which should have been one-piece welded, were two-piece rivetted. Steampipes were of carbon steel instead of molybednum steel. Metal quality was one reason advanced for the short tyre life. Voroshilovgrad was so conscious of the varying quality of the metal supplied for tyres that it tried to work a system whereby best quality tyres were reserved for the driving wheels and the poorer quality for the other coupled wheels, with some attempt being made to 'match' sets of wheels according to their metallurgical virtues. Voroshilovgrad was also trying to obtain agreement with the NKPS over a relaxation of acceptance standards.[108]

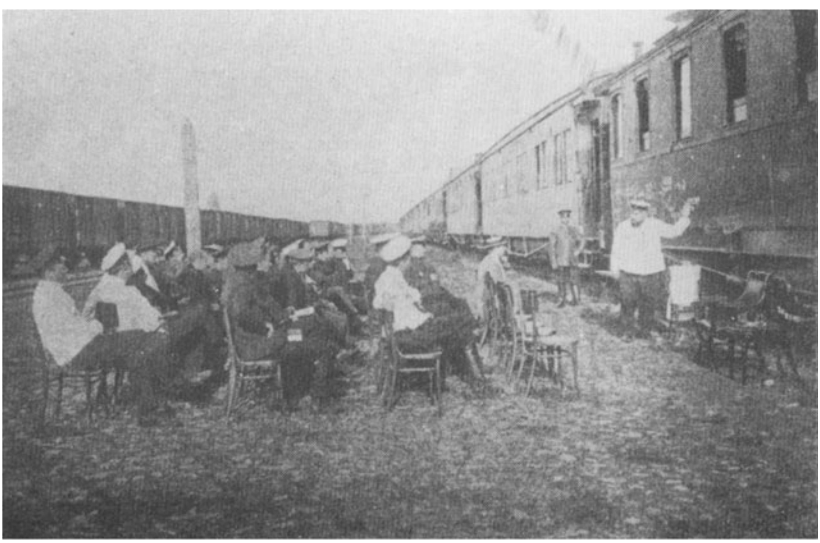
Rapid tyre wear must have been discovered very early, because the NKPS Institute of Materials had been handed the problem as early as 1932, which suggests that the trials of the prototype had revealed the

1. A veteran O type freight locomotive still at work in 1959 on an electrified section of the Moscow network.

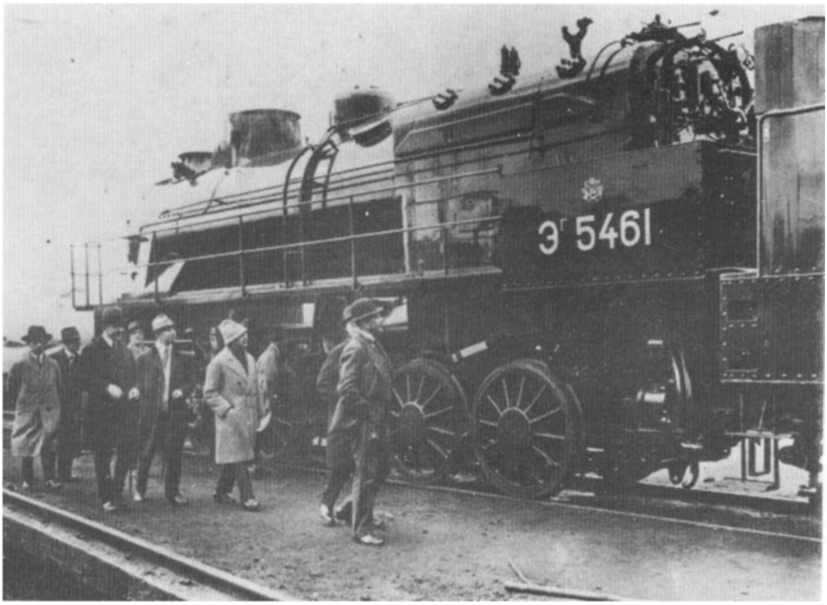
2. Professor N. L. Shchukin.

4. George Lomonosov at the end of his career.

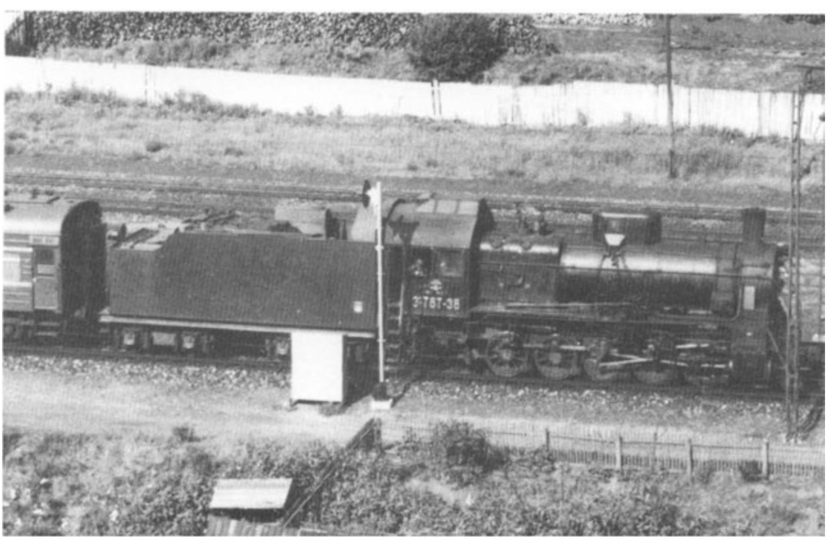
3. Professor A. S. Raevskii.



5. Lomonosov lectures trainee engineers, using his test train as a blackboard. The photo was taken at Velikiye Luki in about 1913.

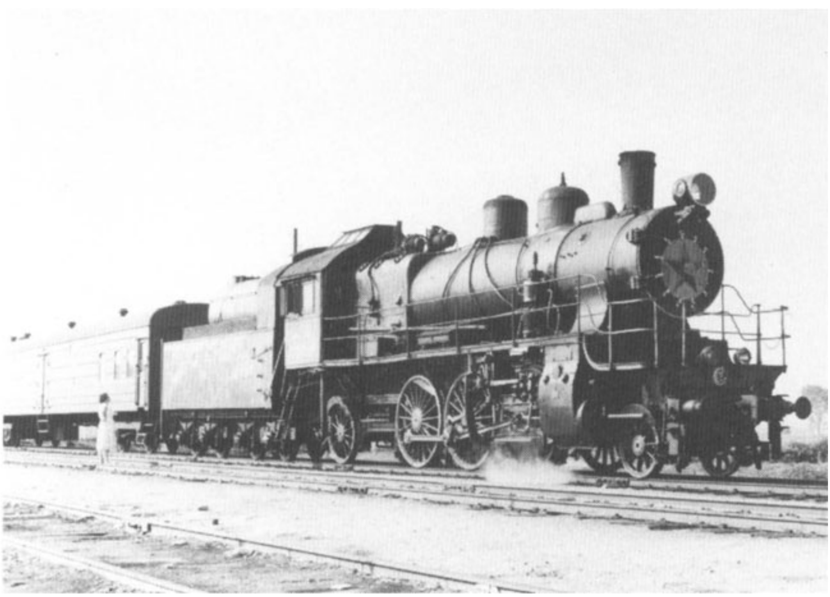


6. One of the E type locomotives ordered from Germany ready for movement from Essen to a port in 1922. The cab and boiler mountings have been removed, and standard-gauge trucks have replaced the driving wheels.

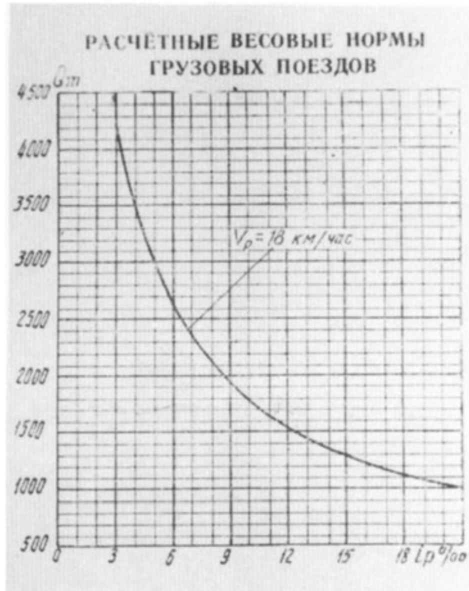


7. An Er type locomotive at Kiev in 1961.

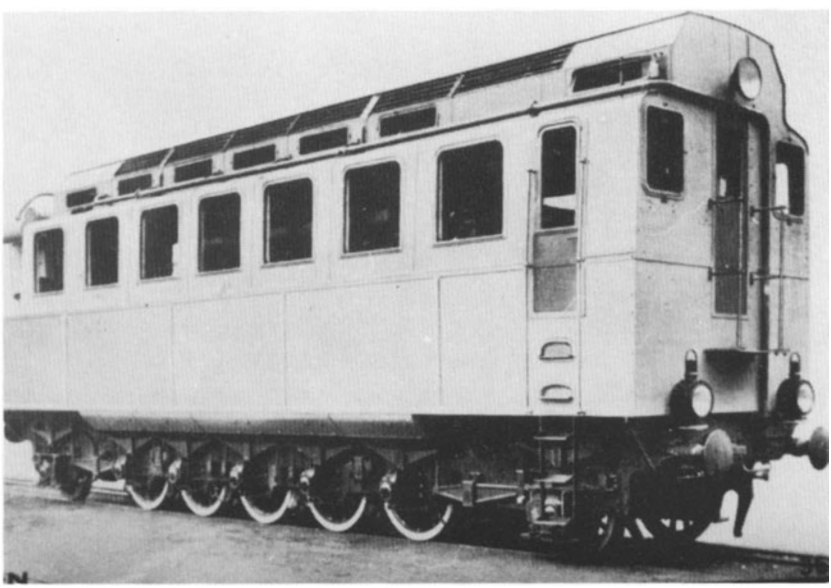
8. An Su passenger locomotive of the first series, one of the early post-revolutionary designs.



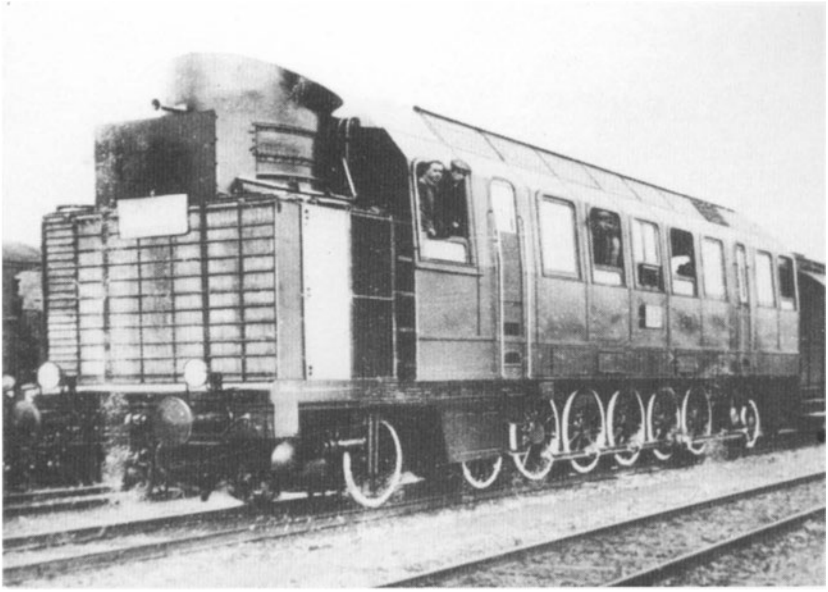
9. The Su design, as it had developed by the mid-1930s.



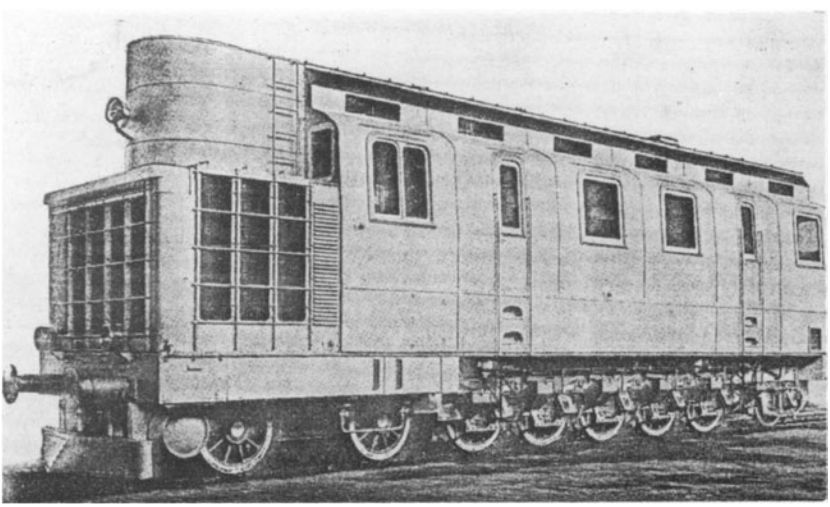
10. The locomotive passport: an important component was the curve, shown here, plotting speed against train weight (vertical axis) and gradient (horizontal axis). This is from the passport of the American freight design imported during the First World War, and the curve represents a speed of 18 kph.



11. Lomonosov's diesel mainline locomotive E–el–2 as delivered in 1924.



12. Diesel-mechanical locomotive E–mkh–3 on trial in Germany.



13. E–el–5, prototype of the inter-war E–el series of diesel locomotives.

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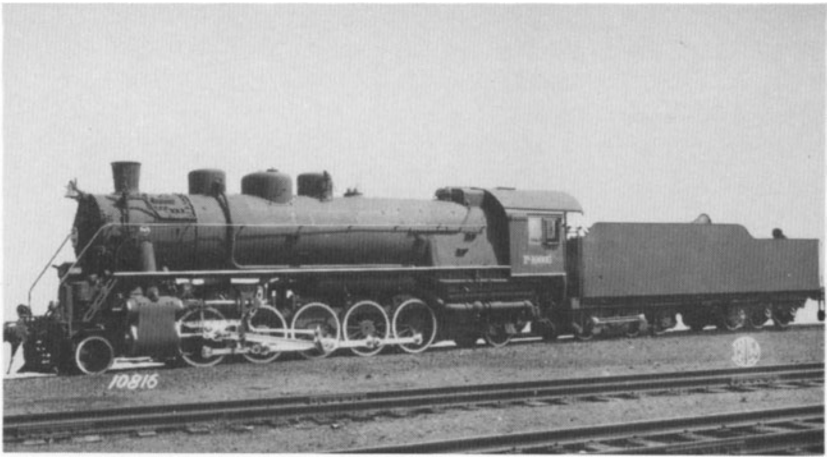
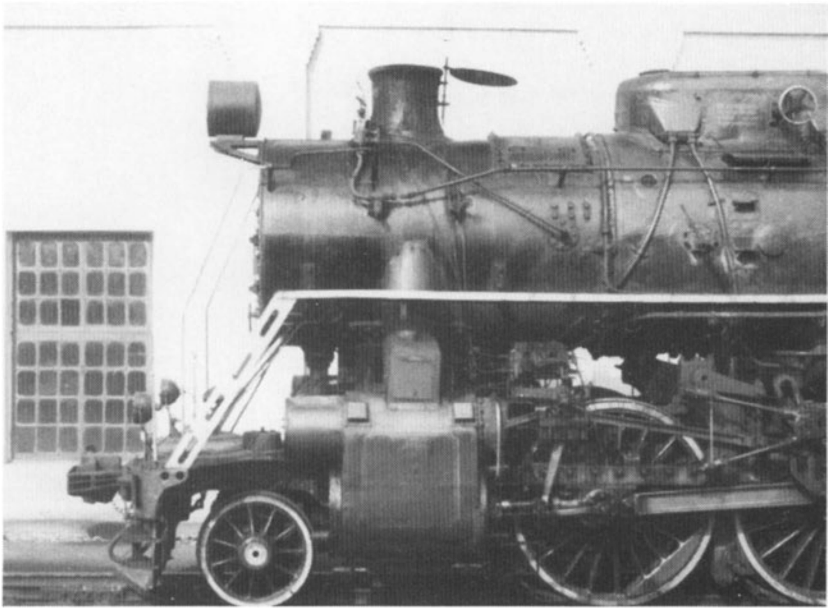
14. 'Our future freight locomotive', as presented to readers of the newspaper *Ekonomicheskaya zhizn'* in November 1929. The locomotive is a thinly disguised 4–12–2 of the Union Pacific Railroad.

15. Modernized watering facilities: the locomotive of a Moscow–Simferopol train takes water at Zaporozhe in 1961, by which year only eight minutes were scheduled for this purpose.

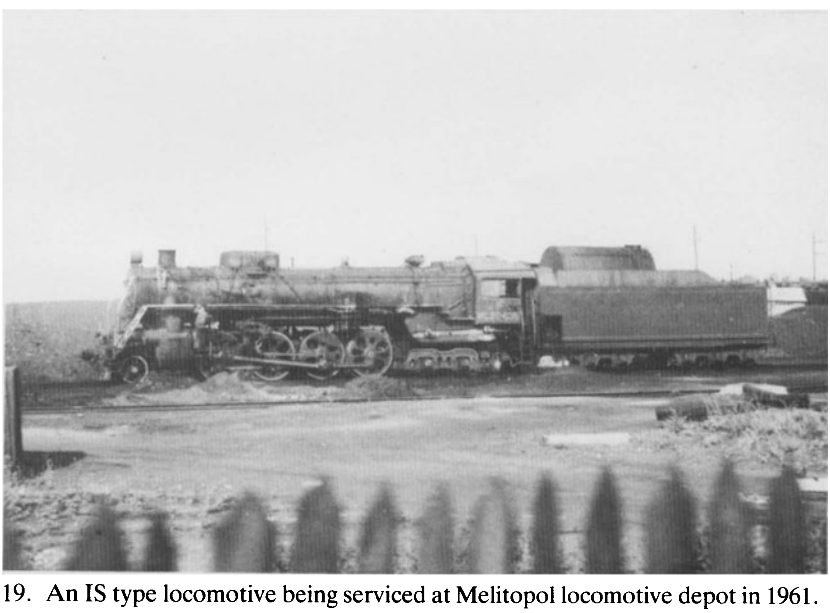


16a. The Tb type freight locomotive supplied by the Baldwin Locomotive Works.

16b. Two FD type locomotives head a freight train near Moscow in 1959. The chimney extension and smoke deflectors were later additions.



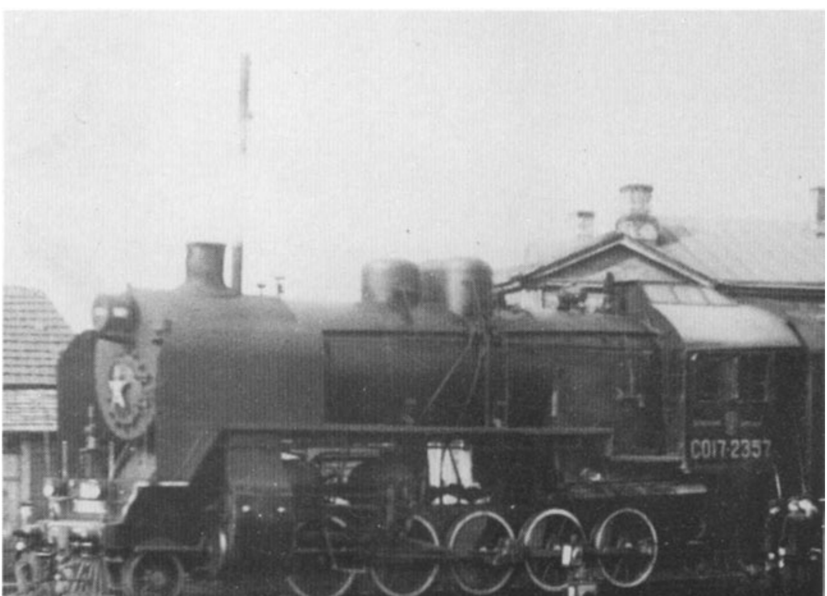
18. The IS type, showing the American-style front end.



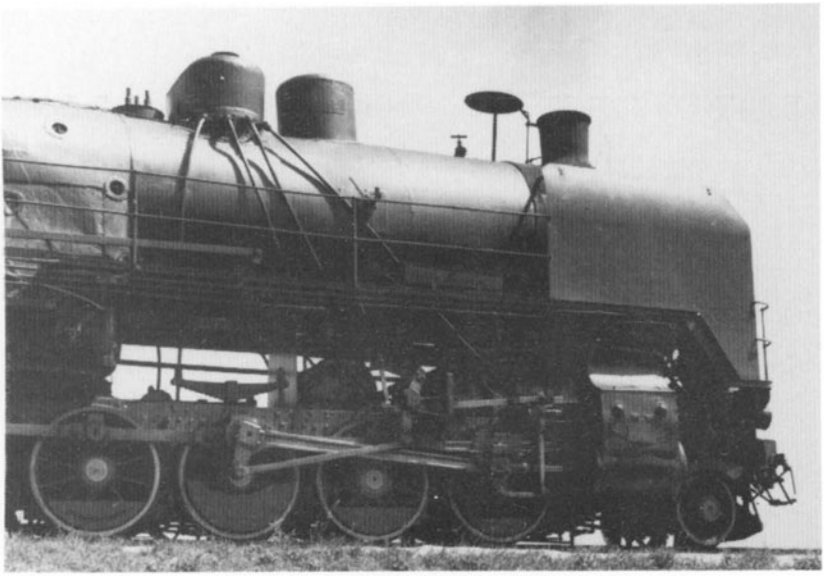
19. An IS type locomotive being serviced at Melitopol locomotive depot in 1961.

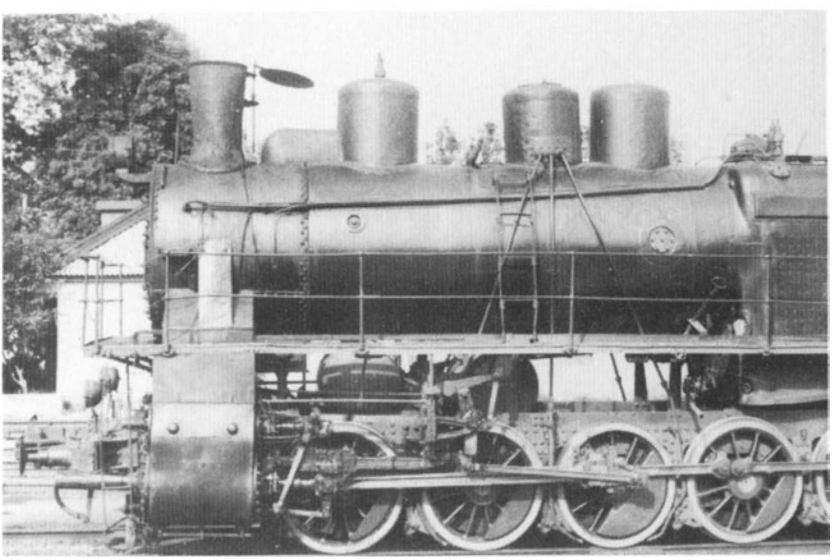
20. Lazar Kaganovich.

21. Professor A. N. Shelest.



22. An SO type locomotive and its three-man crew at Kalinin in 1954.

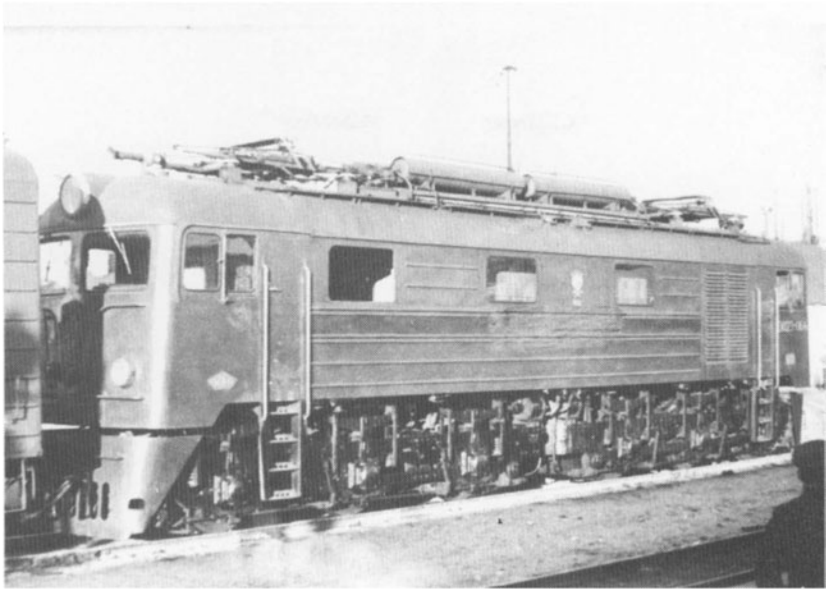




23 and 24. The SO and E types compared. A weakness of the SO design (upper photo) was its chassis, which was virtually identical with that of the E type (lower photo), despite the heavier loadings it had to bear.

25. The VL19 type, an early Soviet development of the General Electric design.

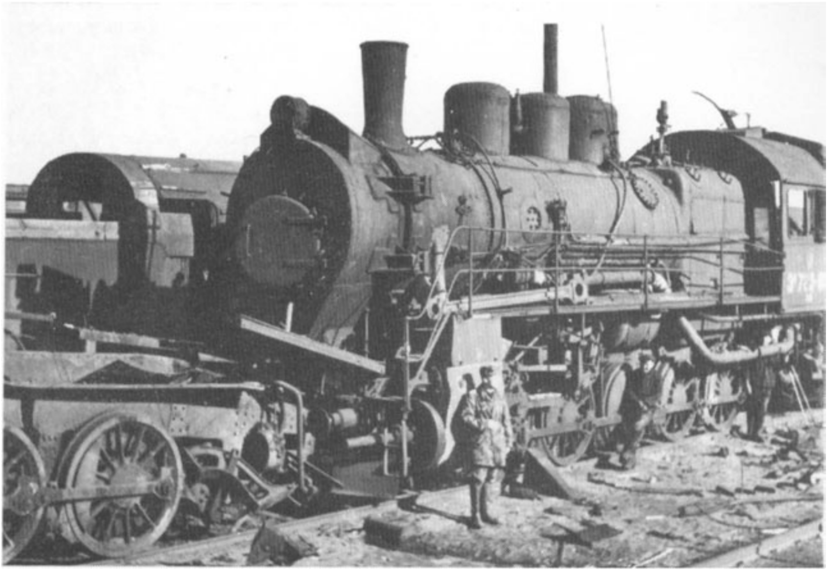
26. The VL22m type electric locomotive, a further development of the General Electric design.



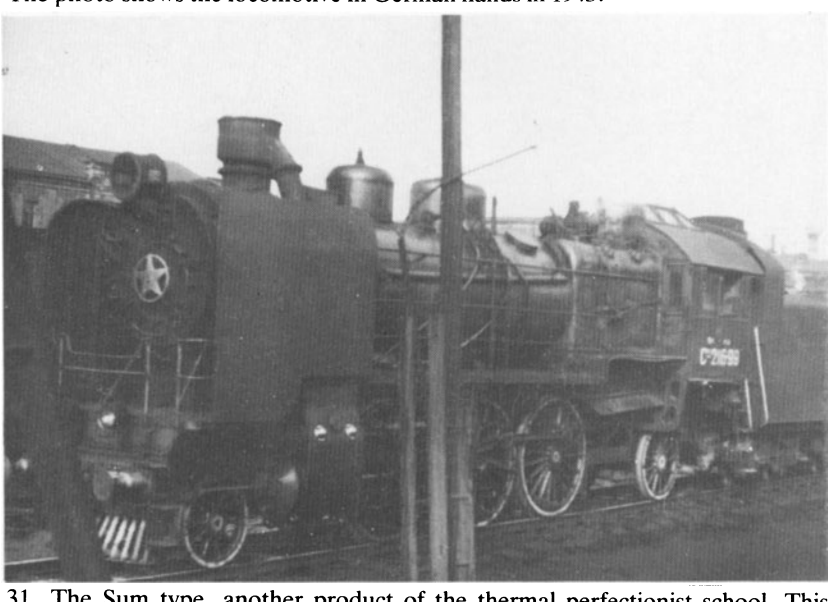
27. The VL23 type electric locomotive, a post-war Soviet development of the American locomotives imported in the early 1930s.

28. I. S. Lebedyanskii, an outstanding locomotive designer.

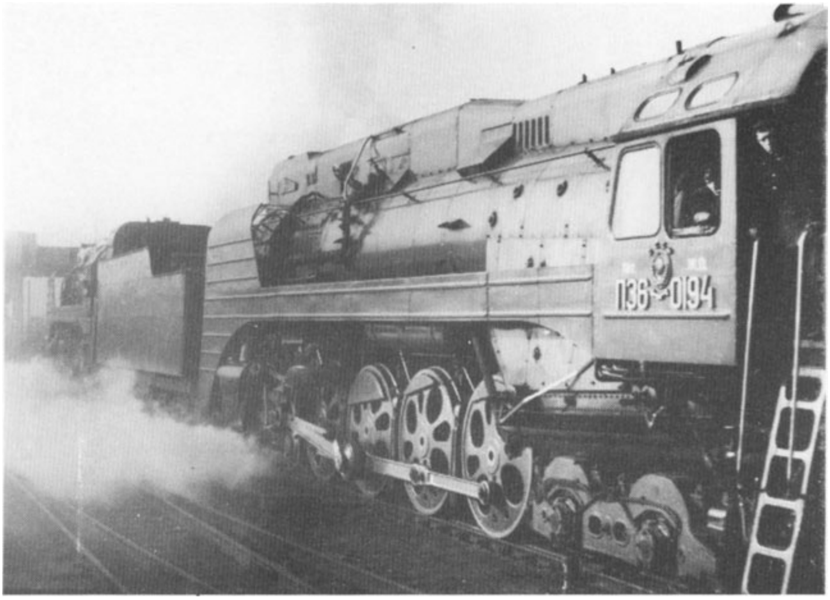
29. Professor S. P. Syromyatnikov, locomotive theoretician.



30. An E type locomotive fitted with an air pre-heater, a product of Syromyatnikov's theories. Air was collected through the scoop in front of the chimney and passed through the drum beneath, in which were arrayed heating tubes kept hot by exhaust gases. The warmed air was then piped to the firebox. The photo shows the locomotive in German hands in 1943.



31. The Sum type, another product of the thermal perfectionist school. This photo was taken at Kalinin in 1954, after this particular unit had been partially 'demodernized'. The smokebox fan and its chimney arrangement are still in place, but the battery of air heating elements flanking the firebox have been removed, leaving a noticeable void.



32. A pair of P36 type locomotives leaves Leningrad with a heavy train to Kislovodsk in 1959.

33. An L type freight locomotive helps with the summer passenger traffic on the North Caucasus Railway in 1954.

34. Voroshilovgrad Works in 1956, as the TE3 diesel locomotive replaces the LV steam locomotive on the production line.

problem. In 1938, however, *Gudok* was complaining that nothing had been achieved after six years, although a solution was in sight. The author of this article was a research engineer of NIIZhT, and he reported that wheelslip was the main cause. Some depots managed to obtain 40,000–50,000 km (25,000–31,000 miles) between wheel re-profilings, but there were cases of mileages as low as 13,000 km (8000 miles), with the average being 20,000–30,000 km (12,000–19,000 miles). The recommended solution was the use of specially hardened metal, and it seems that a beginning was made with this just before the war.[109]

The difficulties encountered by the FD in daily service have to be seen against a general background of strain and breakdown in the locomotive departments of all the railways, due to the headlong growth of traffic, the shortage of skilled and competent staff, and material deficiencies. The campaign, associated with Kaganovich, to 'eliminate hidden reserves', that is, to allow no margins, meant that there might be nothing in reserve when things went wrong. Shortages of locomotivemen, with the skill and the attitude necessary for their highly responsible job, was only to be expected when both the increased number of trains operated and the rejection of impersonal manning had contributed to a situation where there might be more available locomotives than there were available crews. An attempt to use two-man crews had on at least one occasion been ended by NKPS order.[110] There had been a brief campaign to attract former peasants displaced by collectivization to join up as locomotive firemen, but these did not make the best enginemen. Then there was a campaign to recruit women as locomotive drivers. As these were usually selected from those already working in repair workshops, they had a quite hopeful potential. At the end of 1938 just one railway, the Stalinsk, had 119 women attending night schools; after a three and a half month course they would be qualified to become assistant drivers, able to drive locomotives independently in case of need. After some years (five years seems to be typical), such assistant drivers could take the examinations to become a driver. Things did not, however, always go smoothly; one such recently-qualified driver, taking the driver's seat on an FD for the first time, was removed on the instructions of the chief of traction because' . . . in the depot there continues to be respected the false "theory" that women cannot drive locomotives . . .'.[111]

Thus the average quality of enginemen declined, lack of skill, lack of the right attitude and, perhaps, brooding resentments or short irritations all contributed to this. Accidents became more frequent, and when Kaganovich assumed office his first campaign was directed against the accident rate. In 1934, of the South Eastern Railway's 13,614 accidents and mishaps, about 3000 were cases of train breakage.[112] Cases of drivers running through signals were horrifyingly numerous and could result in considerable bloodshed. There were over 80 casualties in 1935 when the Leningrad–Tifflis train was run into by a following train that had passed signals at danger. The driver of the latter train had apparently instructed his assistant driver to look out for signals while he attended to various defects on his locomotive (which had left the depot with quite major faults). This driver was sentenced to ten years, as was the local station-master, who was said to have been drunk at the time. On that same railway, the October Railway (usually regarded as a standard-setter for the rest of the network), there were 173 cases of overrun signals in 1934 (reported cases, that is), and although such figures were published more rarely in later years the accident problem does not appear to have been mastered. Probably enginemen, as well as operating staff, were working at both their psychological limit and their technical limit.[113] Faced with operating crises or equipment breakdowns they lacked sometimes the will, sometimes the skill, to cope with the situation. A characteristic, though not everyday, incident was reported on the Orenburg Railway, when the gauge glass of an E type locomotive burst. This glass could have been replaced, after closing the gauge valve. Instead the crew, perhaps in their inexperience alarmed by the flow of steam, hit the gauge with a hammer, putting their locomotive completely out of action.[114] It was incidents like these that caused the holding up of trains because no locomotive was available.

In the Donets Basin, where mineral traffic had grown enormously, pressure on the locomotive depots was self-intensifying. Shortage of locomotives meant that defective units were pressed into service, broke down on the main lines, blocked traffic, caused locomotive foremen and heads of traction to be hauled before the courts, and meant an arrival of inexperienced men to replace those whom the courts had despatched elsewhere. For example, at the key Uzlovaya depot there was a shortage of crews, which meant that *de facto* impersonal manning had to be accepted. In July this depot averaged more than one locomotive failure on the main line each day, and in the same month there were 94 cases of enginemen not turning up for work. The Railway's chief of traction, and the depot chief and deputy chief were sent to court. Here they were accused of failing to master the new FD units, having arranged no instruction for their crews, of committing acts of sabotage, and of sending in false optimistic reports. In reply the accused blamed the shortage of spare parts, but when one was stated to have once been a Menshevik, and when all those who spoke in their favour were described in court as former Socialist Revolutionaries, it was clear that these three men were doomed.[115] And yet, the plea about spare parts deficiencies seems very plausible. Not far away, at Taganrog, it was reported that of that depot's fleet of E type locomotives only one had left-hand and right-hand cylinders of the same diameter. On other units the diameters varied from 639 mm to 661 mm.[116] It was not unknown for depot chiefs to be executed after being accused of using parts taken from reserve locomotives for their operating units, and in 1940 the NKPS issued an order forbidding depots to remove parts from locomotives about to be despatched to the repair workshops.[117]

When the FD units arrived at the select number of depots scheduled to receive them they produced varying reactions. It was not long before the press reported new record-breaking feats of haulage by these machines. On the main line between the two halves of the Urals–Kuznetsk Combine they were supposed to haul 1800-ton trains, but early in 1936 it was reported that one of them had handled a 6000-ton load, albeit with some assistance when starting.[118] But nine months previously there had been some misgivings at the Kartaly depot of this line. By July 1953 Kartaly had received five FD locomotives and was soon to receive ten more, but they were out of use because the track was not yet fit for them. Melting of the subsoil, said the track departments, would affect the line for many years. This assertion was, for some reason, described as 'opportunistic'; whatever it was, the trackmen were evidently soon induced to change their minds, because the FD went into service here very soon afterwards.[119]

Nevertheless, the infrastructure was not really ready to receive the new locomotives. Just before the First World War, the idea of a 2–10–2 locomotive had been rejected because there were no turntables long enough to handle such locomotives. The situation was the same in the mid-1930s. This was particularly serious for the roundhouse type of depot, where the turntable gave access to the covered locomotive stalls. The stalls themselves were sometimes too short for the FD, which meant that the doors could not be closed in winter. Depot tracks were typically laid with light rails that were liable to fracture under the weight of the new arrivals, or were sharply curved and caused derailments. Not all depots had these troubles, but there were few which did not experience at least one of them.

When the FDs were taken out of the depots there were fresh problems. Some of these were problems of success, however. Greater power meant faster trains, and freightcars which could be relied on to trail contentedly behind an E type locomotive at 25 kph (15 mph) were less amenable at 45 kph (28 mph) behind an FD. Their axleboxes caught fire, their couplings broke, or they derailed. Drivers were usually blamed for these mishaps, which is perhaps why so many drivers do not seem to have welcomed the new machines. On the busy Donets line between Krasnyi Liman and Osnova, for example, in 20 days during August 1934, 60 cars had to be detached from FD-hauled trains and in July there were 55 breakages of FD trains.[120] Breakages were often caused by a wrong choice of speed over graded routes (where one half of a train might be descending and the other half ascending). At watering stops, when the enginemen misjudged momentum, stopping short of the column, they frequently produced a train break by re-opening the regulator to enable them to reach the water (there was a regulation providing for the locomotive to be uncoupled in this situation, but because of the pressures to waste as little time as possible crews tended to ignore this; presumably an inevitable penalty for losing time was a worse evil than a possible penalty for a train breakage). As operations with the FD became more familiar, and especially when it became possible to marshal a block of cars with automatic brakes and couplings next to the locomotive, this situation improved. But instructions and guidance to FD crews continued to pay great attention to the correct and by no means easy handling of heavy trains over saw-tooth profiles.[121] In 1935 the example of Driver Reshet'ko of Belgorod was held up for public indignation. On 9 December Reshet'ko's FD had broken a freight car coupling, for which Reshet'ko paid a 17-rouble fine. Four days later, presumably because his train was too heavy for the wintry conditions, he divided it into two portions and thereby blocked the line for two hours. Three days later he again stopped on the main line for three and a half hours while he set out a defective car. Two days later, perhaps unnerved by all these experiences, he passed a signal at danger and stopped only just in time to avoid running over a broken rail; for this offence he received a reprimand. Three days later he left the yard at Kharkov without realizing that the last six cars (carrying his conductor) had not been coupled up; for this he was fined 10 roubles. On 8 January he broke another coupling, and on 14 January divided his train again. On 15 January he braked too vigorously, thereby derailing several cars.[122]

In studying accounts such as these the reader is very much at the mercy of the newspaper reporter and his sub-editor. No doubt, in the quest for horror stories, there was some exaggeration. Even more certainly, there was unfairness; Driver Reshet'ko never had an opportunity to give the public his side of the story. But there can be little doubt that although Reshet'ko was an exceptional case in the sense of how much damage he did in so short a time, his experiences were not untypical.

Rather uselessly, the Party and government introduced '*klassnost*', the categorization of labour by competence. This meant that, for example, a 'First Class' driver would be allowed to handle passenger locomotives and FD freight locomotives. But to attain First Class a driver had to attend courses (for which there were no training manuals) after working hours. So there were often insufficient First Class enginemen for the duties required. At Krasnyi Liman there were 152 drivers handling FD units, of whom only 11 were First Class. Second, Third and Fourth Class handled the others.[123] But presumably this situation improved later.

The FD's passenger version, the *Iosif Stalin* (IS or, after 1956, the FDp) was as successful as the former in hauling loads faster. By 1940 it accounted for 12 per cent of the passenger locomotive stock. Its series production came somewhat later than the FD. Kolomna was entrusted with a pre-production batch of these machines, the intention being to try them and then, after suitable modifications, transfer production to Voroshilovgrad, which was the only works capable of building such a large design in series. But at that time Kolomna was seriously overloaded, and seems to have given low priority to the IS order, managing to produce one unit per annum in 1932 and 1933. But the Works managed its public relations superbly, giving the impression that it was busy with IS production. It achieved this by doubling (!) its production in 1934 and producing each unit in time for some great political event. Thus IS20–3 appeared amid great publicity to mark the Seventeenth Party Conference, IS20–4 to celebrate the seventeenth anniversary of the Revolution, and IS20–5 to mark the Seventh Conference of Soviets.

The FD cost 265,000 roubles to build, compared to the 135,000 roubles of its predecessor the E type. Its consumption of coal, even on a work-done basis (kg/10,000 ton-km) was much greater. It was only by making the assumption that the FD produced twice as many ton-km as the E that it could be shown that its operating costs were just below those of the latter.[124] Its extravagant fuel consumption, its fast-wearing tyres, and its frame fractures were all defects that were exacerbated by the Stakhanovite style of driving. In 1935 some depots had a third of their FDs out of service with cracked frames, and many others must have been awaiting new tyres. In March 1940, of the 25 railways using FD units, seven had more than a third of those locomotives out of service. In December 1940 the network average of FD units under repair amounted to 22 per cent of the total.[125] Yet, for all its early difficulties, the FD can be regarded as a success, for it met the demands of the times, and more. The decision to concentrate on a locomotive of moderate axleload and moderate tractive effort was right; the difficulties which the FD encountered with weak couplings and weak track are sufficient demonstration of the unfeasibility of the heavier American-style locomotives. However, in 1932 the latter were still regarded as future motive power, and full testing was envisaged. In fact as late as the Seventeenth Party Congress of 1934 Andreev was talking of the need to progress from the FD to a more powerful locomotive.[126]

The American locomotives arrived at Leningrad in October 1931, and were assembled at the Proletarskii repair shops (the former Aleksandrovskii Works where, eighty years previously, Harrison and Eastwick had assembled their American locomotives for the St Petersburg–Moscow Railway). There were five 2–10–4 units by Alco (class Ta) and five 2–10–2 by Baldwin (Tb). These both had 23-ton axleloads, but the power characteristics were different. The Ta, apart from having a larger firebox, had a higher boiler pressure (17 against 14 kg/cm^2 [242 against 191 lb/in^2]), the cylinder dimensions being the same. The locomotives included a number of American refinements which the Soviet engineers had thought worth trying. Notable among these was the provision of a booster working on the tender wheels.

Service trials were arranged on the Stalinsk Railway in the Donets Basin, and the results were fully reported in the technical press.[127] Many officials of the Stalinsk Railway were apprehensive about the 23-ton axleloading, and at first insisted that the locomotives should not run over the type 11a rail, which still existed in long lengths of the main line. Eventually they were persuaded to accept the machines, subject to a speed limit of 25 kph (15 mph). The line was divided into a number of lengths that were provided with better ballast, or better rails, or more crossties per kilometre. These lengths were located near stations, and fully-manned repair gangs were placed at these stations, ready to hurry out and repair the track after the passage of the American 'mastodons'. In the first seven weeks of 1932, on the 220 km (137 mile) main line over which these locomotives ran, there were 1102 cases of broken fishplates and ten cases of IIa rails, worn less than 4 mm, breaking. Unfortunately the published material does not indicate the 'normal' rate of fractures, although it would appear that the six-bolt fishplate used on this line had an inherent tendency to break at the second or fifth hole. These trials took place when the ground was frozen, and it could be expected that the degree of settlement reported would have increased greatly in the spring, when sand-ballasted track virtually rested on mud. In general, the conclusion was that these locomotives could work at speeds up to 45 kph (28 mph), but really needed stone or gravel ballast. It was also concluded that the Baldwin locomotives were kinder to the track on curved sections, the Alco units having a lateral dynamic effect 40 per cent greater than the former.[128]

Tests of the locomotives as traction units, although thorough, could not be described as conclusive because the Stalinsk Railway authorities provided loads that were no greater than those hauled by the existing E type locomotives, and the American locomotives were also required to observe the same schedules as E-hauled trains. But, in general, the conclusion was that these locomotives were far from perfect, but could be improved. In particular, they had a tendency to pass hot water to the cylinders as well as steam (but this priming was probably due to the notoriously poor quality of the local water), and they tended to slip. The Soviet engineers pointed out that the manufacture of such locomotives would only be possible in the USSR if the same high-quality metal was made available, and if the same high level of workmanship could be provided, especially the same precision.

During the tests one of these locomotives exploded. This was partly because, apparently, the enginemen had such great faith in the American workmanship that, at least on the ill-fated Ta–10002, the safety valves had been tampered with to raise boiler pressure to no less than 20 kg/cm^2 (285 psi). However, this was not the whole story, for it was alleged that the Alco designers had been not only miserly but also incompetent in their firebox staying arrangements.[129] In later years, other units of these classes burned out their fireboxes, sometimes disastrously, and it was probably not always the fault of their crews. It might be noted that American locomotives used in Britain during the Second World War suffered similar mishaps. On the other hand, a locomotive driver working on the Stalinsk Railway mentioned in 1934 that on the Ta locomotive the water level was usually kept low in order to maintain steam pressure; too low, in fact, to be visible in the gauge glass, as a result of which 'the fireboxes of these locomotives are all burned out, and boiler explosions are possible'.[130] It is also interesting to note that in their appraisal of the thermic syphons fitted to these locomotives the Soviet test engineers concluded that whatever the thermal merits of these devices might be, they had a definite advantage when boilers exploded. In the case of Ta–10002, the thermic syphons had held the firebox together and diverted the blast forward. So although the superheater tubes were flattened and the smokebox door blown out, the locomotive men survived to tell the tale, although this was not entirely to their advantage.

Because of the several defects in components and design it was suggested that these locomotives should be modified in small ways to obtain vastly better performances. However, by that time only one locomotive was considered to be in good enough condition to make this worthwhile; the others were hopelessly 'russified' (an unusual euphemism to describe the cumulative effect of bad maintenance, home-made spare parts, and improper driving techniques).[131] The one good locomotive, Ta 10003, was in a fine state because instead of being worked into the ground by the Stalinsk Railway it had spent one and a half cosseted years being studied by the designers at the Lugansk Works. It may be assumed that part of what Lugansk learned from this locomotive was incorporated in the details of the production version of the FD. It may also be assumed that the unsatisfactory working of the boosters of the American locomotives provided decisive arguments for those who opposed the fitting of boosters to Soviet locomotives.

The testing of the American locomotives, and the reports of those tests (see Table 4.2), seems straightforward, as does the permanent postponement of orders for similar locomotives. Whatever their technical virtues, they were simply too big for Soviet railways at that period. The case of the Beyer-Garratt locomotive ordered from Beyer, Peacock of Manchester, is less simple. The Garratt locomotive consists of two engine units (chassis and cylinders), widely spaced and linked by the boiler and cab swung between them. The advantages of this patented design, very popular in the British Empire, were several. The two engine units provided the tractive effort of two locomotives, and although there was only a single boiler its firebox could be large and have an unobstructed air-flow. The engine units could swivel, making the locomotive suitable for operation over sharp curves. Axleloads were low and, moreover, the total weight of the locomotive was spread over its long length, so that it would never be concentrated, say, in the centre of a bridge span. This was a locomotive which could provide high power yet not demand the easing of curves or a very robust permanent way; it would seem to have been ideally suitable for the demands of the Soviet Railways of the 1930s.

Evidently its virtues were not unnoticed in the USSR. Even Shelest in 1930 felt impelled to point out that while the Garratt had definite advantages it could not compete with a Shelest-system diesel.[132] Evidently, too, many Soviet locomotive men were against the idea. There were several good reasons for this distrust. The Garratt was a long engine, and although it did not require turntables (another advantage, which its Soviet proponents seem to have ignored) its length would have presented problems at the locomotive depots. It also had long steam pipes to the cylinders, which in winter could lead to a premature cooling of the steam. Manufacture in the USSR would have been difficult because of its length.

If there were good for-and-against reasons from the point of view of the NKPS, there were much more positive prognoses from the non-NKPS railways. The USSR had a mileage of industrial and feeder railways which equalled about half the mileage of the NKPS. The coal, timber, and metallurgical industries in particular had extensive systems whose neglect since 1914 was even more noticeable than the neglect of the NKPS lines; one reason, perhaps the major but usually unspoken reason, for the freightcar shortage was that industrial railways were physically unable to return promptly the cars they received from the main lines. Industrial railways typically had light tortuous track and for these the Garratt seemed particularly appropriate. The same was true of those industrial systems which were of narrow gauge.

Pressure to purchase Garratt locomotives for trial seems to have come, naturally enough, from the industrial ministries. Heavy industry had its own narrow-gauge railway research sector,[133] with its own narrow-gauge dynamometer car for locomotive testing. Sometime, probably in 1930 or 1931, there was a special study made of the Garratt's potential, as a result of which a report was submitted to the Workers' and Peasants' Inspection and to the NKPS recom-

TABLE 4.2 *Freight locomotives on trial*

	FD 2–10–2	Ta 2–10–4	Tb 2–10–2	Ya 4–8–2+2–8–4	AA 4–14–4
Builder	Lugansk	Alco	Baldwin	Beyer, Peacock	Lugansk
Weight in working order (tonnes, without tender)	137	168	152	266*	208
Axleweight (tonnes)	21†	23	23	20	20
Firebox grate area (sq m/sq ft)	7.04/76	8/86	7.34/79	8/86	12/129
Superheater area (sq m/sq ft)	123.5/1329	60/1722	150/1614	114/1227	175/1883
Tractive effort (tonnes/lb)	29/64,500	36/78,500	29/64,700	41/90,500	39/87,200
Adhesion factor	3.58	3.19	3.96	3.85*	3.41

* The 'Garratt' weight includes coal bunker and water tanks and contents. Its adhesion factor is calculated on fully-loaded basis.

† Although the FD was spoken of as a '20-tonner', its axleweight was 21 tonnes.

mending the purchase of a narrow-gauge Garratt.[134] The timber industry was especially interested, having many miles of forestry lines. The oil industry was also keen. The NKPS seems to have decided to order a narrow-gauge and a 5 ft gauge unit; presumably, although many NKPS engineers were against the idea, there was sufficient pressure to secure a mainline version. At one stage an effort was made to order three units from Germany but this was either unsuccessful or abandoned, probably because Beyer, Peacock did not regard their patents lightly. But just as negotiations for Manchester-built Garratts were in a late stage, foreign currency was refused for the narrow-gauge unit, and only the mainline version was ordered.

Beyer, Peacock took special care of this locomotive, which was the largest they had built. They even published a glossy Russian-language booklet about it.[135] It was the Company's Order No. 1176, from Arcos (the Soviet agents in Britain) on behalf of *Mashtrans-import* for delivery 3 December 1932, with penalties agreed for late delivery. The management's copy of the Order Book still exists.[136] This, as usual, had a typewritten and very detailed specification which included the provision that special care was to be taken to keep the locomotive as light as possible, with the weights of all individual components to be taken and entered into a special book. Other details were handwritten, being later additions, and these included special provisions to maintain the heat of steam passing through the pipes. Presumably Soviet misgivings about this point were communicated only after the order was already under way; arrangements were noted for enclosing the main steampipes in a special casing, and all external pipes for steam, water and lubricants were to be wrapped in asbestos cord. An intriguing special entry in the Order Book reads 'The weight of the Boiler must *NOT* be painted on the boiler when it leaves the works'. Whether this instruction was issued at the request of a nervous Soviet inspector, or without his knowledge, is uncertain. What does seem certain is that weight was a very sensitive issue. It also seems certain that the inspector was not told the result of the factory weighing (or, if he was, that he kept quiet about it), for there was a considerable discrepancy between the right-hand and left-hand wheel loadings of the leading and trailing trucks of the leading engine, both the trucks being about one and a half tons heavier on each of their right-hand wheels.

In February and March 1933 this locomotive, Ya–01 (see Figure 15), was tried on the Perm Railway in the Urals, and it then went to the Stalinsk Railway. Trials conducted by the Scientific Research

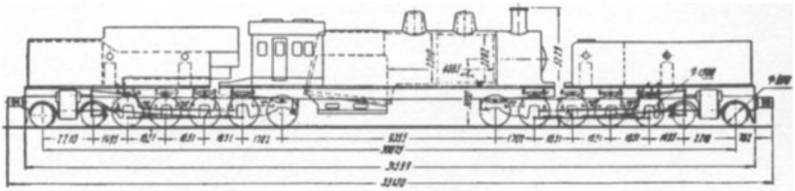


Figure 15 The Garratt locomotive supplied to Soviet Railways.

Institute of Track revealed that with ten year old rails (111a) on sand ballast, cracks appeared in the ballast at speeds above 50 kph (32 mph). Above 35 kph (22 mph) there was visible settlement of the ballast and the supporting trucks produced as much settlement as the heavier driving axles. It was also noted that the right-hand rails were depressed more than the left hand, and the Institute's researchers quite perceptively recommended that Ya–01 be properly weighed (whether this was ever done is doubtful). The E type locomotive which was being tested at the same time for comparison purposes also produced a greater settlement on the right-hand side and this puzzled the researchers. They suggested that as the E was tried after the Garratt, and the track was not restored between the tests, it was possible that the settlement produced by the Garratt had affected the results of the E trial.

As to the traction qualities, there was evidently a hot dispute about the Garratt's prowess. Its highly-qualified driver wrote an article in 1934 which praised its many virtues, and refuted earlier claims about its likely defects.[137] Among other things, this driver praised the cab, which he said was far more comfortable than a Soviet cab. As critics also admitted, the workmanship of the locomotive was far superior to Soviet standards.

After a spell on the Stalinsk Railway, Ya–01 was sent for testing by the Scientific Research Institute of Traction Reconstruction. The same driver, quite plausibly, described the attitude of the NKPS researchers:

> From 25 May the locomotive went for tests at the Institute of Traction Reconstruction, where their attitude was quite unfriendly. There was talk about it being 'a useless folly', that 'the Mallet type had demonstrated the problems of articulated locomotives' and so on.[138]

A few months later came some of the researchers' findings, and the opinions of this driver were specifically refuted. One paragraph, summarizing the results of the trials, declared that the Garratt was inferior to the FD in efficiency.[139] A fuller article[140] in the same journal about the same tests said that although it was difficult to repair, because of its size, there could well be a limited role for it when new locomotive depots had been built and freightcars had been fitted with couplings strong enough to make such a powerful locomotive worthwhile. It behaved well on curves and its boiler had great potential. As for the loss of temperature in the steampipes, it had been found that, with 25 degrees of frost, steam which had been taken from the collector at 390 degrees arrived in the rear steam chests at 365 degrees.

That the Garratt was controversial had become evident from articles which appeared even before Ya–01 was delivered. Both the proponents and the critics displayed at times a strange ignorance of what this type had done elsewhere in the world. One proponent[141] apparently believed that in the outside world railways which did not use Garratts were using two locomotives per train as a matter of course. He was soon put right by a Garratt critic,[142] who wrote that the British had invented the Garratt because it saved locomotive crews, whose wages were very high in the British Empire. I. German, at the time an influential member of the NKPS Traction Directorate, wrote[143] in 1932 that the Garratt worked well only in warm climates, and that its short boiler was inefficient (a decade later Syromyatnikov and his men would be writing that long boilers were inefficient). In 1933 Terpugov, at the time a member of the NKPS Committee on Reconstruction, claimed that the USSR was developing its own 'super-power' locomotive and this would make the Garratt unnecessary.

Of the four types of experimental steam locomotive tried in 1932–5 the Garratt, in retrospect, seems the one most suitable for use in the Soviet Union. Despite the maintenance difficulties it posed, it would have been a transforming acquisition, capable of hauling very heavy or accelerated trains over track of less than mainline standard. The reasons for its rejection can be divided into the real reasons, the reasons given at the time, and the reasons given later. The real reasons were that foreign exchange was not available for its import in numbers, and its construction in the USSR would have been extremely difficult. The reasons given at the time centred around such questions as steam temperatures in winter (remediable), the fact that as coal and water were used up the adhesion weight of the locomotive decreased (over-emphasized), and maintenance problems. The standard post-war histories of Soviet locomotive design, however, give different reasons for the rejection of the Garratt idea. Rakov wrote that the Garratt had been designed for African narrow-gauge railways where large fireboxes would have been impracticable on conventional designs because of the height limitations, so there was little point in the USSR, which had the world's most generous height restrictions, buying them. Yanush wrote similarly, with the additional comment that the Garratt was bought because of the agitation of a group of locomotive specialists in 1928–32.[144]

Among the opponents of the Garratt was Egorchenko, who was the leading light of the locomotive testing specialists. He was a proponent of the SO 2–10–0 locomotive project then being worked out; the SO was a conventional machine and an alternative solution for lines with intermediate track standards. In the end, the SO was adopted for series production and when the time came on secondary lines to haul the kinds of load a Garratt could handle, the SO engines were used in pairs, just as the FD machines were later used in pairs on trains more suitable for 23-ton locomotives. As a dyed-in-the-wool theoretician of locomotive testing, Egorchenko may be presumed to have had an aversion to a locomotive whose adhesion factor changed minute-by-minute. Theoreticians' prejudice is certainly suggested by the preamble to the traction specialists' report of their tests, which began with the statement that the results were 'as theoretically expected'.[145] The reported remarks by Egorchenko's men about 'useless folly', made before they had properly examined Ya–01, support this interpretation.

Finally, before leaving this locomotive, it might be emphasized that the Soviet flirtation with the Garratt was a misjudged and mishandled affair. The Garratt had been suggested as a solution to the problems of the industrial and narrow-gauge railways. Somehow, within the toils of the NKPS, the original purpose was forgotten and the locomotive which arrived was for the NKPS lines. Like the American locomotives, its tractive effort was excessive for that period, and was known to be excessive. Meantime, the industrial railways would soldier on, and in the 1950s would still be the weakest link in the Soviet railway transport system and still for the same reason, the lack of powerful locomotives suitable for defective track.

The fourth of the heavy freight locomotive prototypes was designed specifically as an alternative to the articulated concept embodied in the Garratt. This was AA20–1, which was an attempt to incorporate a large number of driving axles (only one less than the Garratt) in a rigid (non-articulated) wheelbase. The outline drawing of a 2–14–4 was made by the graduating class of the MEMIIT in 1931, perhaps at the instigation of those NKPS locomotive specialists who advocated such a multi-axle locomotive. However, the completed locomotive took to the rails only at the end of 1934. In the interval there had evidently been considerable argument (at one stage a 2–12–4 design was suggested instead).[146] Soviet engineers had travelled to Germany and the USA to seek information about existing 10–and 12– coupled-wheel designs. Delay may also have been caused by Lugansk's reluctance to undertake the project and, perhaps, the need to persuade the NKPS Collegium that this was just what Soviet railways needed (the project seems to have gone forward only after an upheaval in the NKPS that occurred in July 1933).

At first two prototypes were ordered from Lugansk. The designers of that works, engaged on the working drawings, reported pessimistically and obtained permission to add a pair of carrying wheels at the front end to help the weight distribution. Presumably it was at about the same time that the order was limited to a single (4–14–4) unit (see Figure 16). The outstanding feature of the new locomotive was, of course, its 14 driving wheels in a rigid frame, a world record which has never been beaten, for very good reasons. Less noticeable, but a striking feature, was the provision of two mechanical stokers to feed the great firebox. In order to make the long wheelbase a feasible proposition, only the three leading axles were coupled to the fourth (driving) axle in the normal manner; the rear pair were coupled to the fifth axle, with the latter coupled by an extra rod to the fourth (this was a feature of America's 'super-power' locomotives). The first two and the rear driving axles had some sideplay while the wheels of the

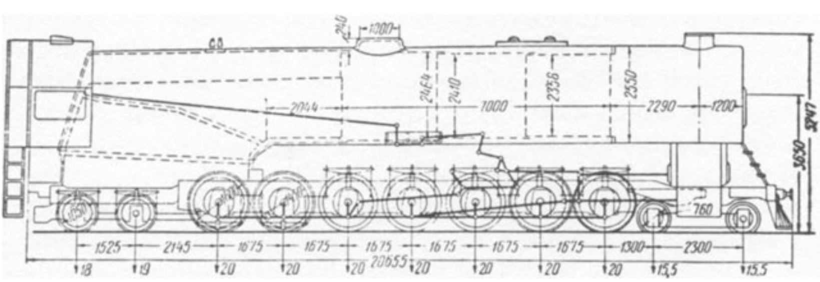


Figure 16 The unique 4–14–4 freight locomotive built at Voroshilovgrad.

other, central, coupled axles were flangeless. Despite the 12 m^2 (130 ft^2) of firebox and the two stokers AA20–1 steamed badly; on trial it appears to have developed a maximum of 3500 hp, whereas its designers had hoped for 5000 hp. As for tractive effort, it could exert enough pull to break the couplings of most Soviet trains.

In early January 1935 the new locomotive left the south for Moscow, where it was scheduled to arrive on 9 January, in time to serve as fringe entertainment for the Seventh Conference of Soviets. Its departure was reported in *Gudok* on 8 January, with the additional information that it was hauling a 2800-ton auto-coupled train, had left Belgorod (697 km, or 433 miles, south of Moscow) at noon, and had been timed at 40 kph (25 mph) up a 10 per cent grade. Delegates from Lugansk Works were aboard. However, readers of *Gudok* who looked forward to the report of its arrival in Moscow must have been disappointed, for there was no mention of it on 9 and 10 January. But on 12 January it was reported to have arrived, with its enginemen helped by the presence on the footplate of 'its designers'. These latter were named as Korolev and Markovich; Markovich, it will be recalled, would later come to a bad end, with AA20–1 being accounted one of his misdeeds. On 14 January an interview with the designers was printed. It was said that the locomotive had worked superbly, and could certainly cope with 160 m (524 ft) radius curves (the standard for the Soviet network). After Belgorod there had been some difficulties with wind and low temperatures, and it was said that the train's automatic brakes had tended to apply themselves voluntarily. AA20–1 would be thoroughly tested and, in the meantime, would haul a 4500-ton train to Leningrad.[147] Little more was heard of this locomotive, which later historians of the Soviet locomotive treat almost as a folly of its time. It was certainly untimely to build a locomotive with so high a tractive effort in 1934; the automatic coupling problem would be with Soviet railways for many more years (by 1940 less than a third of the freightcar stock was so fitted). It was also boldness bordering on idiocy to hope that such a long wheelbase would function faultlessly; in theory it might have met the demands of 160 m (524 ft) curves, but with Soviet tracks in such a poor state it could hardly have been expected to stay on the rails at any speed higher than walking pace. Rakov later wrote that AA20–1 deranged the track, derailed at switches, and was too long for turntables. Yanush wrote additionally that the idea of three adjacent unflanged wheels was bound to lead to derailments, that the coupling of the wheels was defective, and that steamraising was poor.

The design finally chosen for series production to serve the lines of intermediate track standards was the SO 2–10–0, with a 17-ton axleload. According to Yanush, the outline drawing was made by the Bureau for Powerful Locomotives in Leningrad. According to Rakov, it was made by the Scientific Research Institute for the Reconstruction of Traction; the discrepancy is presumably explicable by the disappearance of the former bureau about the time of the formation of the latter. The working drawings were made at Kharkov, probably in 1933/4; thus the design did not pass through Kolomna and the Central Locomotive Design Bureau. According to Chirkov,

> The fear of being accused of putting forward a 'new' type which might be regarded as a counterweight to the FD locomotive persuaded the designers and initiators of the SO project to seek conciliatory formulations and in all possible ways play down transport's need for the building of this very type.[148]

This fear of designing a locomotive that might outshine the Party-approved FD is a partial, perhaps complete, explanation of the built-in mediocrities of the SO. The limitations imposed by the need to build the new type in unreconstructed factories may have been paramount, but this did not make the use of obsolete 1912 components obligatory. The SO was essentially the engine and chassis of the old E type, carrying the boiler of the Lomonosov/Lipets US-built 2–10–0. That boiler was improved, with a larger superheater, and to carry the extra weight the leading two-wheel truck of the FD was added. Thus the SO was a serviceable machine but had serious defects. The chassis was too weak, subject to troubles with axleboxes and cracked frames. The steam valves and steampipes were constricted, resulting in losses of pressure between boiler and cylinders of as much as 2 kg/cm^2 (28 lb/in^2).[149] Proposals to redesign this machine were, according to Chirkov in the same article, rejected by the locomotive specialists because redesign implied the creation of an entirely new locomotive. Over 2000 units were built, the type's future having been assured when its condensing version was sponsored by Kaganovich. Unlike the FD, whose construction ceased at the start of the war, the SO production re-started in the mid-1940s; even the locomotive repair works at Ulan Ude had begun to build it in 1939.

The problem of locomotive water supply was attracting some attention by 1930, but little action was taken; perhaps the promise of diesel traction was sufficient excuse to let the neglect continue. In the mid-1930s the NKPS water supply network (about 12,000 km or 7450 miles of pipeline) exceeded the total length of water pipe in those Soviet cities having a piped water system. Its rehabilitation would therefore have been a daunting task at a time when there were so many other problems. The problem could be crudely divided into the problem of waterlessness and the water-supply problem. There were few lines where local water was really unavailable; the Trans Caspian line was quite exceptional in the scale of its problem. But there were lines passing through areas of low rainfall where an adequate supply for increasing needs could only be obtained by expensive construction of pipelines and reservoirs. One water-supply problem was excessively hard or chemically unsatisfactory water; eventually chemical methods could be evolved for dealing with this. More important was the time spent by locomotives taking water. Neglect of supply pipes, which were often age-expired or furred up, together with the small diameter of most water columns, meant that the rate of flow into locomotive tenders was slow. Whereas in the USA most water columns used a 300–400 mm (11–16 in) diameter pipe, in the USSR three-quarters of the supply columns had pipes less than 150 mm (6 in) in diameter. The state of the pipes supplying these columns, which limited the flow-rate, compounded this problem. The typical Soviet column therefore delivered its water at 1–2 m^3 per minute; some only delivered 0.15 m^3. The tender of the FD held 51 m^3 (13,500 US gal). In other words, in extreme cases, half of a locomotive's working day could be spent waiting at the water columns.[150]

It was not surprising therefore that the idea of a steam locomotive that could re-use its water over and over again had a great attraction, especially for those brought up in the steam tradition, to whom the other solution, dieselization, seemed unappealing. In 1933 the NKPS arranged for an E type locomotive, one of those built by Henschel, to be returned to that German works for the fitting of a condenser-tender. The reconstruction entailed the provision of a steampipe down the side of the locomotive to take the exhaust steam from the smokebox back to the tender, the enlargement of the tender to accommodate cooling elements, a pump for the cooling air, and a turbo-fan in the smokebox, driven by exhaust steam, to replace the draught normally provided by the exit of the steam up the chimney.

The two turbines, in the smokebox and on the tender, consumed about 200 hp of energy, and the locomotive was somewhat heavier after these alterations. On its return to the USSR it was thoroughly tested, and in 1937 sent to work on the Stalingrad Railway.

Some of the researchers of the Scientific Research Institute of Traction had great doubts about condensing; 'mistakenly' adds Rakov.[151] They held that any economy in water would be more than balanced by extra repair costs, and they thought that certain faults in this first prototype were irremediable, namely the tendency of lubricating oil to attach itself to the exhaust steam and thence to the feed water, the freezing up in winter of the condenser elements, and the difficulty of regulating the smokebox draught. In fact, all these problems did arise when condenser locomotives multiplied; remedies were found, but only at a certain cost. In 1935, under the patronage of Kaganovich, the Kolomna Works were instructed to convert two SO locomotives to condenser units. This was done, following the German model; a leading part in the design team was played by B. S. Pozdynakov, better known as an enthusiastic designer of diesel locomotives. The first of the pair, SO17–85, was taken for exhibition at the Kiev Station in Moscow, where it was inspected by Kaganovich and the Commissar for Heavy Industry, Ordzhonikidze; Nikita Khrushchev went along too, and all three listened to the explanations of the Kolomna designer, Lebedyanskii.[152]

The first ten units, classified SOk (see Figure 17), were allocated to Kotelnikovo, a locomotive depot of the Stalingrad Railway where the water was of especially bad quality. Early reports spoke of local opposition by 'limiteers', who claimed that the SOk was too complex for the normal crew to handle.[153] In this the so-called limiteers might well have been right. However, the SOk was very closely associated with the reputation of Kaganovich, who was stated on numerous occasions to have supported the concept of condenser locomotives right from the start.[154] From the benediction of Kaganovich it was a short step to recognition as an outstanding constituent of Stalin's Five-Year Plan, and these associations made it difficult to question the design and, even more, the policy. All defects were described as teething troubles. One of these teething troubles was malfunctioning pumps, which were not easily repaired; by 1938 it was reported that Kotelnikovo was making its own spare parts for these pumps.[155] That depot was under the particular surveillance of the NIIZhT, which found that even after five years of operation the condenser locomotives at that depot were being used just like any other

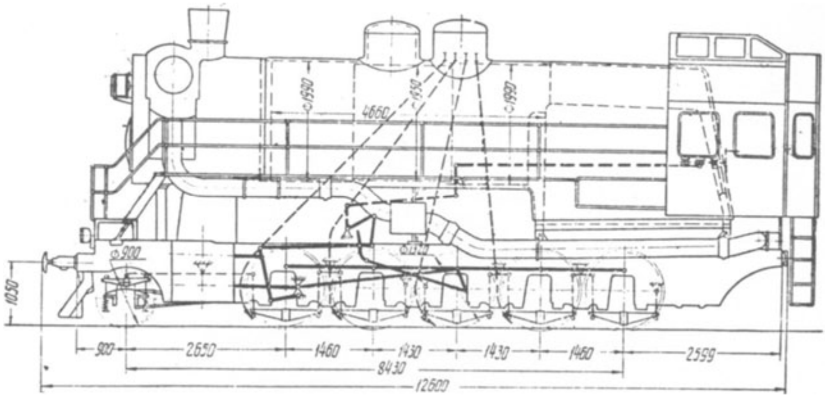


Figure 17 The condenser SOk locomotive (condenser tender not shown).

locomotive, taking water every 100–150 km (62–91 miles) instead of the 1000 km (621 miles) envisaged for this class.[156] By that time (1939) there were complaints that the designers had lost interest in improving their system, and that the Traction Directorate of the NKPS was too timid in demanding improvements from the locomotive industry (Kolomna built the condenser tenders, and other works built the locomotive).

Kotelnikovo was not the only depot to experience difficulties with condenser locomotives. In 1940 the Orenburg Railway, which had been using these machines for three years, was still finding that only a few of its crews could get good results from them, although at the same time the arrival of the SOk was said to have eased the Railway's winter problems. The latter observation seems strange in view of the report that the main trouble experienced on this Railway was the freezing of condensers.[157] At Aktyubinsk it was reported that steamchest valves were wearing out very fast because the SOk crews habitually kept their boilers full (because they feared a breakdown of the boiler feed pump) and hence much water was carried over into the cylinders. The shutter arrangement which the Kolomna designers had installed to protect the condensers from overheating or freezing, and which were supposed to be adjusted by crews in accordance with the outside temperature, were too easily forgotten; in winter, if they were not closed when the engine was halted the condenser could freeze and suffer severe damage. Similarly, the variable-speed cooling fan was sometimes operated in winter, by error, at speeds intended for summer, with the result that the exhaust steam entering the condenser was transformed into solid ice.[158]

Meanwhile the SOk was declared to be the 'basic' locomotive of the Third Five-Year Plan, and its efficiency and economy as well as its necessity repeatedly emphasized;[159] this laudation continued after the war. Attempts (unsuccessful) were made to fit the FD and E types for mass conversion to condensing. It was only in the mid-1950s that the SOk drifted into obscurity. Whether this was because the diesel locomotive was resurgent, or because Kaganovich was in retreat, is uncertain. In wartime Russia, however, these locomotives had a great value to both the Germans and Russians, because water installations in fought-over areas were so often lacking. The German railway troops requested that German war-service locomotives destined for the Eastern Front should be fitted with Russian-style condensers, and this was done.[160]

Nevertheless, at the end of the war very few condenser locomotives were operating. In the Urals and Siberia it was reported that frozen feed pumps had put most of the SOk units out of action in 1945.[161] On the Omsk Railway that year the SOk locomotives were typically taking water every 40–50 km (25–31 miles), and many had been put out of action because their cooling elements had frozen. Drivers tended to keep their boilers too full, the reason given in this case being that since the exhaust no longer went through the chimney, the presence of water droplets could no longer be noticed. Such priming on a condenser locomotive quickly led to oil and grease carry-over into the boiler.[162]

What really went on at the depots, as opposed to what was merely reported, is an intriguing question with only speculative answers. But it is hard to reject the suspicion that many locomotive men were only too glad when condensers failed, because these locomotive must at times have seemed to be much more trouble than they were worth. In 1947 the type was reported as handling only 15 per cent of total ton-km, a small proportion for a large and so numerous mainline type. The same report itself explains this poor showing. with a statement that only 45 per cent of the SOk units were in working order, and about half of those had apparently been relegated to yard work (where, of course, a failure would have less unfortunate consequences). Those which were used on the main lines still took water at the old non-condenser intervals, half an hour being allowed every 60–80 km (37–50 miles) for this purpose. All this was in spite of the programme of the Ministry, undertaken in 1946, to rehabilitate these locomotives with an adequate supply of spare parts. This same report referred darkly to locomotive depot chiefs who were opposed to the SOk, and to certain engineers who asserted that repair costs made the type uneconomic.[163]

The 1000-km-without-watering claim was in any case no guide to the handling of these locomotives. Possibly it was thought up as a slogan to consternate the dieselizers. The forgotten fact was that the SOk condenser tender could only accommodate 11 tons of coal, so the locomotive had in any case to detach itself from its train after 200–400 km (124–248 miles), the distance depending on the type of work and the quality of the coal. Kolomna did design a condenser tender holding 18 tons, but it was found that this presented an unacceptable axleweight. However, post-war condenser tenders managed to accommodate 14 tons, which was an alleviation but not a remedy.

It seems likely, therefore, that the misgivings of those who, like the ill-fated Markovich, opposed the condenser locomotives idea in 1933 and 1934, were quite justified. A precise economic evaluation of the SOk is not possible, but what information there is does not refute the suggestion that there were better and cheaper ways in the 1930s of overcoming the water problem. The constructional cost of the SOk in the late 1930s was 390,000 roubles, more than double the non-condenser SO at 170,000 and considerably more than the powerful FD at 265,000.[164] On the Ashkhabad Railway, SOk locomotives were said to have operating costs of 52 roubles per 10,000 ton-km compared to the diesel's 34 roubles (the capital cost of diesel locomotives was 700,000 roubles). So far as other steam locomotives are concerned, the SOk, although it burned far more fuel than a diesel, was in an advantageous situation because its water was fed to the boiler at a high temperature; for this reason it was 12 per cent more fuel-efficient than the non-condensing SO, and 40 per cent more efficient than the extravagant FD. So long as oil did not enter the boiler, it could run three or four times longer between boiler washouts than a conventional locomotive. Its repair costs are not really known, because it is hard to produce a trustworthy figure in a situation where spare parts are unobtainable. But on the Ashkhabad Railway the diesel locomotives repair costs were only 33 per cent more than the SOk, which in effect means that in the SOk the basic virtue of the steam locomotive, simplicity, had been sacrificed.[165] According to Yanush the SOk was 60–70 per cent more expensive than the SO for maintenance and repairs. It may be surmised that the tender turbofan (7000 rpm) and the smokebox fan (4000 rpm in high temperature conditions) would have created especially difficult maintenance problems.

Four years of war meant that the track standards of Soviet Railways declined to the level of the early 1930s. The question of what type of locomotive to build in these circumstances was broached well before the war ended, and a special commission was set up to decide this question. It was under the chairmanship, inevitably, of Syromyatnikov, but as it seems that the locomotive which was eventually built was not up to his expectations,[166] it would appear that this chairmanship did not give him the deciding voice. It was the designers of Kolomna, headed by Lebedyanskii, who were responsible for the new locomotive, a responsibility symbolized by the choice of L for the type designation; this was to honour the chief designer, and was no light step for it entailed the reclassification of the existing L type Vladikavkaz Pacifics. Possibly the commission, however, was instrumental in ensuring that a new design would actually be introduced, for there were voices urging the continued construction of the SO (some units were indeed built post-war) or even of the American Lomonosov/Lipets 2–10–0 of which additional, improved, units had been received during the war from the USA.

The new L, of which several thousand units were built in the post-war decade, was a fairly successful attempt to embody the virtues of the FD and the American 2–10–0 in a new design which would avoid their disadvantages. Thus improved steam passages were incorporated, as well as a larger superheater. Because the small wheels of the pre-war locomotives put stress on both track and engine, the L had somewhat larger driving wheels. The need to build the locomotive in existing workshops, with expected shortages of tools and materials, was taken into account in the design, as was the desirability of a low axleweight in view of the weak tracks of, especially, the western USSR. The methods adopted to keep weight down, and the compromises made to ease production, were the source of most of the defects of this locomotive; these defects included the development of cracks in various components, which was remedied by building units after 1952 to a slightly revised design.

From the L was developed the LV, a 2–10–2 of lower axleweight than the FD and much more economical. A feature of this design was a device by which the crew could temporarily shift part of the load borne by the two carrying axles to the driving axles, thereby increasing adhesive weight at starting and at slow speeds when the extra axleweight would have negligible effect on the track. This device was presumably developed from that fitted to Latvian locomotives absorbed by the Soviet Railways in 1940. The LV was the last steam freight locomotive to be built in numbers. Its passenger counterpart, the P36, was a 4–8–4 with a lesser axleweight than the IS. Both the LV and P36 were built only up to 1956, when steam construction ceased at the behest of Khrushchev. The LV was a Voroshilovgrad product, while the L and P36 were from Kolomna.

The LV owed its existence to its feedwater heater, a device that could not be accomodated on the smaller L. The LV could therefore be regarded as at least a step towards the 'thermal perfection' advocated by the Syromyatnikov school. But the Kolomna P36 and L were characterized by a simplicity of construction that was not, it seems, to the liking of Syromyatnikov and his associates. A discussion in the monthly *Zheleznodorozhnyi transport* in 1947/8 was initiated by a complaining article by Syromyatnikov which brought forth comments by Lebedyanskii and others.[167] Syromyatnikov's article damned the L with faint praise, describing it as a 'not-bad' locomotive (a derogatory term for a machine whose designers received Stalin Prizes). Pirin, the locomotive researcher, supported Syromyatnikov and added that the L would have had fewer defects if Kolomna had heeded the advice of the NKPS researchers. One of Pirin's criticisms expresses the essence of the dispute; he wrote that the L's superheater was too small, leading to unnecessary thermal inefficiency, but Terentev of the locomotive industry retorted that even at the existing degree of superheat the high steam temperatures were causing excessive wear in the L cylinders. Thus it was again a question of the NKPS researchers putting fuel economy first and the industry's designers giving priority to reliability in service. Lebedyanskii, chief designer at Kolomna, wrote that it was useless to load locomotives with untried devices; reliability was all-important. He criticized a design of 2–10–0 which Syromyatnikov and his colleagues had proposed; a main feature of this was a new feedwater heater that had been devised by MEMIIT but which was not only untested but still unbuilt. Lebedyanskii also wrote that when the Kochetovka locomotive depot discovered distortions of the L frames, Kolomna immediately made tests and took remedial action. Although he did not make the point, his readers would doubtless have remembered how long it had taken the NKPS researchers to propose remedies for the FD defects in the 1930s.

All in all, by the mid-1940s the Kolomna designers' attitude towards the NKPS and MEMIIT researchers was far from deferential. Possibly wartime conditions, or the withdrawal of

Kaganovich from the NKPS, had changed the atmosphere or the 'balance of power'. The industry seemed to play a bigger role in locomotive design than it did in the late 1930s; some prototypes appear to have been created by the locomotive industry with little participation by the NKPS. In 1948, for example, the Scientific-Technical Council of the NKPS's successor, the Ministry of Transport (MPS), in rejecting Kolomna's project for an articulated 2–6–6–2 locomotive criticized the industry's practice of designing and building locomotives without any preliminary examination of the design by the MPS. Interestingly enough, despite the MPS rejection, the 2–6–6–2 was built.[168]

Several interesting prototypes were built during the last two decades of steam traction. One, illustrated in Rakov's book (p. 223) but about which there is tantalizingly little information, was V5–01, built in 1937 and carrying the Ramzin continuous-flow boiler. It had a boiler pressure of 80 kg/cm^2 (1138 lb/in^2), a geared transmission, and a designed 500 hp output. Pozdnyakov of Kolomna took a leading part in its design. A larger continuous-flow locomotive was planned for Voroshilovgrad, but never appeared.

In the late 1930s, no doubt conscious of the well-publicized streamline era in the USA, four streamlined passenger locomotives appeared from Soviet workshops. First came a standard IS unit from Voroshilovgrad, encased in a kind of upturned sheet-metal bathtub, and with American-style disc driving wheels (the latter were soon adopted for the IS class). In 1937 and 1938 Kolomna built a pair of streamlined 4–6–4 locomotives. These had 2000 mm (6 ft 7 in) driving wheels, could develop 3000 hp, and reach a speed of 130 kph (81 mph). They were designed by Lebedyanskii and Shchukin, and the outline design may have come from Kolomna and been accepted by the NKPS, rather than vice versa. These units incorporated several innovations. They were hardly tested completely, because in daily service on the October Railway 232 No. 1 and 232 No. 2 pulled trains identical with those rostered for Su haulage. But they were regarded as very successful locomotives and, but for the war, ten units would have been built to permit the introduction of accelerated trains between Moscow and Leningrad. A competing design was built in 1938 by Voroshilovgrad, another streamlined 4–6–4 but, unlike the Kolomna units, having components standard with the IS. Its driving wheels were of 2200 mm (7 ft 2 in), and it could develop 3400 hp.

In 1944–6 the special commission under Syromyatnikov which was entrusted with establishing the parameters of post-war locomotives gave its approval to the construction of two 23-ton prototypes. A conventional 2–10–4, the 23–001 was designed in outline by the VNIIZhT and the Main Directorate of Traction of the NKPS, and the working drawings were completed at Ulan Ude, where the repair shops had become a locomotive works. Its competitor was built at Voroshilovgrad and was unusual in that it had opposed pistons, with the cylinders set midway above the coupled wheels. This was said to reduce track stress, but evidently brought complications with it; it was copied from the system used in the ill-fated *teploparovozy*. Also, in 1948 Lebedyanskii and his Kolomna team built a Mallet-type 2–6–6–2. This was to have an axleweight comparable to the SO but when weighed was found to have a 20-ton loading. The size and wheel arrangement were determined by the capacity of the trollies in the Kolomna assembly shops; its designers would have preferred more wheels. On trial, the Ulan Ude locomotive was marginally the most efficient, but in their effect on the track all three were very similar, and not noticeably better than the FD. In the next decade two other experimental types appeared. The first, OR21–01, was a proposed successor of the LV, having ten per cent more boiler capacity but with a 21-ton axleload. The other, actually two prototypes, was Lebedyanskii's swansong, a 2–8–8–4 Mallet. This had a 20-ton axleload and, in contrast to other countries' Mallet-type locomotives, had flexible instead of jointed steampipes. Like the 1948/9 prototypes, neither of these designs was proceeded with; appearing in 1954 they were overtaken by Khrushchev's decision to end steam locomotive construction.

The invention or improvement of locomotive components accelerated after 1935. Among the practical problems which received great attention were superheater and mechanical stoker design. Both these became recognized as pressing problems with the entry into service of the FD. The original superheaters were American type (Elesco) with narrow tubes. These tubes tended to become blocked by the unburned coal that the FD type was notorious in passing through its firebox: A Soviet 'L–40' wide-tube superheater was developed , and fitted to most new units. This seemed to solve the blocking problem, and was quite efficient, but it appears to have given rise to other problems associated with rapid wear. Throughout the Soviet period superheaters received a great deal of attention; the inept attempt to fit them to O type yard locomotives has already been detailed. It is interesting to note, however, that when in 1945 the British government despatched a mission to Germany to report how the railways had stood up to war conditions, among the items noted by the locomotive engineer H. Holcroft was that the Germans had been so impressed by the Russian method of attaching their superheaters that they had copied that method in their own locomotives.[169] As for mechanical stokers, the real problem, which was not openly recognized, was that the coal was unsuitable for mechanical devices; riddled coal was apparently not supplied to the railways, but that was what was needed for stoker-fired locomotives. Despite this, Soviet researchers, in a head-against-the-wall endeavour, continued for years to devise new stoker variants, including one which threw the coal upwards from the front, not the rear, of the firebox. No significant successes appear to have been attained in this field.

There was endless experimentation with pulverized coal as fuel. The fear, partly justified by events, that the railways would need to use low-grade coal was the motivation for these efforts. The experiments began during the Civil War and did not end with the cessation of steam locomotive construction. In 1920, an apparatus using compressed air to direct the powdered coal to the grate was tried. In 1933 Eu701–83 was fitted with a different apparatus which, however, failed because the fuel simply blocked the grate and tubes. Despite this, a very similar gear was fitted in 1935 to FD20–400, with the same results (this locomotive was thereupon converted to burn shale). To alleviate blockages, when FD20–894 was fitted with similar apparatus in 1936 it was provided with a wide-tube superheater. This seemed a little more acceptable, but whatever success it had was attended by a problem of success: shortage of suitable fuel. It had been intended to obtain the coal dust from the Kashira power station, which burned low-grade fuel, but this source appears to have failed. For the very same reason that mechanical stokers were unsatisfactory, the failure of the coal industry to riddle its product, there was a shortage of separated small coal and coal dust. FD20–894 was therefore provided with its own 'mill' on the tender to pulverize its coal. This system was followed in 1940 with several other FD units. However, all these were converted to shale fuel in the mid-1940s. In 1939 similar systems were fitted to 30 E type units, but these too were soon changed to shale. At least one SOk was treated in the same way. In 1951 Em729–13 was converted, but was said to have lost power as a result. The following year SO18–1731 was fitted with a system using a pneumatic delivery, while at the same period FD20–802 received a system devised by A. P. Chirkin of

MEMIIT in which a mixture of fractionated coal, shale, and coal dust was prepared in the locomotive's tender. This too, was unsuccessful and soon removed.[170] In the 1950s an E type unit was equipped to burn waste oilfield gases.[171] Among the post-war diesel prototypes were TE1 and TE2 type locomotives fitted with gas generators. No doubt all the accumulated experience enabled the researchers to solve quite promptly the problem which arose unexpectedly in 1955, when trains on the Trans Siberian line began to falter to a standstill after the decision to supply to locomotive depots coal from the newly-exploited Kuzbas opencast deposits.[172]

After the late 1930s the drive to increase thermal efficiency took extreme forms, typically involving air preheaters and feedwater heaters. American locomotives had long used feedwater heaters of the Worthington type which, being fairly simple, did not cancel out thermal gains by extra capital and maintenance expenses. Variations of such devices were fitted to several Soviet locomotives. But even better thermal gains were sought through the introduction of tender feedwater heaters, in which exhaust steam was led to the tender and used to warm the feedwater. Practice did not quite bear out theory, and this apparatus was disliked by engine crews because, apparently, it was a continual source of trouble. Kaganovich, easily enchanted by innovations that seemed both revolutionary and relevant to current problems, put his weight behind this idea and in June 1939 ordered workshops and locomotive depots to fit tender feedwater heaters to 5000 locomotives. This was never achieved. One or two depots did what they were told, but others found reasons to lag behind the programme. Moreover, half the locomotives that did have this equipment were operated with it switched out.[173] One reason for its unpopularity was that a valve failure could result in water being sucked directly from the tender through the steampipe directly into the cylinders; there was a technique to avoid this, but that added yet another burden to the locomotive crews' lives. Once water entered the cylinder, the locomotive was liable to fracture its piston rod. In winter there was the extra hazard that water would accumulate in the steam pipe and freeze solid. It appears that all the tender feedwater heaters were removed during the war.

Another thermal improvement, beloved of the researchers of the MEMIIT and of the NIIZhT, was the air pre-heater. In its various forms this entailed passing air, destined for the grate, over or between heating elements through which passed either exhaust steam or hot firebox gases. The front of the locomotive was the usual situation for the 'battery' of elements, and some strange-looking locomotives resulted. The Su passenger locomotive was the usual subject for these experiments. From 1933 to 1940 various units were fitted with vertical or drum-shaped arrays of pipes in front of their smokeboxes, through which incoming air was heated as it passed towards the grate. Accumulation of soot and ash inside the pipes prevented these arrangements meeting even the MEMIIT's criteria for success. In 1940 NIIZhT fitted Em724–50 with another variety of air heater, with poor results, whereupon an 'improved' (but no better) one was fitted to Em707–40.

While all this was happening the researchers found the time to seek even more exciting ways of enhancing thermal efficiency. The smokebox fans that had been fitted to condenser locomotives to replace the steam draught of orthodox locomotives began to be fitted to non-condenser locomotives. It was claimed that this provided a more even draught, making better use of the coal and allowing inferior coal to be used. SO engines were fitted in large numbers, becoming SOv or SO18 (the 18 signifying that their axleload was 18 tons compared to the 17 tons of the non-condenser SO and the 19 tons of the SOk). Bryansk Works appears to have effected the first transformation in March 1939, but around the same time Kolomna fitted the same fan to two Su locomotives; the latter were destined for the North Caucasus Railway, and it was thought that, being oil-burners, they would benefit from artificial draughting. In the event they were re-allocated to the October Railway and built as coal-burners, but nevertheless left Kolomna with their turbofans. Some FD locomotives were also fitted with smokebox fans.

The smokebox fan appears to have been another of those devices whose defects were obvious but unmentioned. Experience with the condenser locomotives had shown that these fans, revolving very fast in high but fluctuating temperatures, were a constant source of trouble. Nevertheless, being an idea emanating from researchers enjoying the favour of Kaganovich, they were fitted on a large scale. They did bring one advantage; during the war they enabled locomotives to function on very low-grade fuel. On the other hand, apart from increased maintenance problems they suffered from a fundamental drawback: when locomotives worked hard the fans choked, the draught ceased, and the train had to stop through lack of steam. They also produced considerable back-pressure, sometimes amounting to 1 kg/cm^2 (14 psi), in the cylinders; they were not therefore conducive to mechanical efficiency however much they might enhance thermal efficiency.

In 1941 Em707–32, under the supervision of Syromyatnikov and his MEMIIT colleagues, was 'complex-modernized' at the Rostov workshops. This modernization included the provision of air preheater, tender feedwater heater, and an enlarged superheater to compensate for the thermal changes entailed by these two devices. The feedwater heater was soon out of service, and Syromyatnikov admitted that it needed much more research (which was being conducted by the MEMIIT and NIIZhT). Even without the feedwater heater, claimed Syromyatnikov, a fuel economy of 20–30 per cent had been obtained.[174] On trials, conducted by Syromyatnikov and his associates, a somewhat different economy figure was reported a year later, of 7–21 per cent.[175] Evidently Kaganovich was enthused by this latest achievement of the MEMIIT researchers, for he made a generous distribution of decorations at that institution and ordered that 20 more units should be 'complex-modernized' for further trials. Fortified, no doubt, by this support, Syromyatnikov wrote that those in charge of the Traction Directorate of the NKPS should 'take into account the favourable prospects' of complex-modernization. However, when in 1949 tests were made by NIIZhT, absolutely no gain in efficiency was revealed; back pressure, among other things, balanced any thermal gains.[176]

In 1939 two Su locomotives, 215–48 and 215–49, were turned out from Kolomna fitted with a complete set of the thermal devices that were so popular among the locomotive researchers. They had fan draught, and air heaters in which the elements were arranged alongside the grate and were heated not by hot gas but by exhaust steam. 215–49 had a tender type feedwater heater while 215–48 had a Worthington type apparatus. The NKPS, after trials, decided to standardize the 215–49 variant, resulting in the appearance of a new class, type Sum. About 200 of these were built but by 1954 the air and water pre-heating apparatus had been abandoned. Not only did they have the defects that could be forecast from previous experience with air heaters, tender water heaters, and turbofans, but their changed thermal characteristics meant that their superheaters had become too small. Air-heater SO locomotives were presumably de-modernized at about the same time.

The post-war blossoming of the Syromyatnikov school of locomotive research produced, in 1951, Lk–4276. This was a standard L type unit fitted with a smokebox superheater designed by Pirin of NIIZhT under the inspiration of Syromyatnikov. Bryansk made the final drawings and Voroshilovgrad built the locomotive.

The smokebox was divided internally, and the locomotive had two chimneys. Syromyatnikov had long claimed, with theoretical justification, that the conventional position, inside the boiler barrel, did not give enough space for a really large superheater. Many years previously a US-built 2–10–0 had been fitted with a smokebox superheater but this had not been successful. Pirin's design might perhaps have been better, but its trials were cut short, and never resurrected, when the device ruptured and burned out.

The crowning glory of the Syromyatnikov school emerged shortly after the Professor's death, in 1952. This was FD21–3128 (see Figure 18), which had a revolutionary boiler designed under the supervision of Syromyatnikov. In 1940 Chapelon in France had built an innovative freight locomotive, one of whose novelties was the use of the leading section of the boiler not for steam-raising, but to accommodate a feedwater heater. Syromyatnikov's boiler took this idea much further. Arguing that only that part of the boiler nearest to the firebox produced steam in really rewarding quantities, Syromyatnikov reserved the leading two-thirds of the boiler barrel for the accommodation of an air pre-heater (in the forward part) and a large superheater (in the central part of the boiler barrel). For this fitter's nightmare a 7–18 per cent fuel economy was claimed. But it was not further developed, although nothing impolite appears to have been written about it.

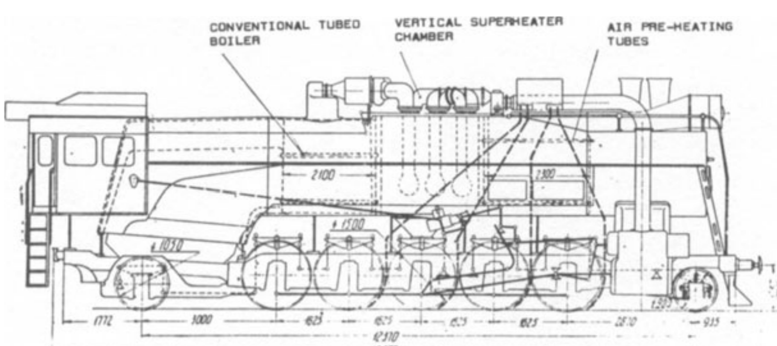


Figure 18 The last fling of the thermal perfectionists, the FD 21–3128.

There were very few research projects after 1935 which aimed to enhance the mechanical efficiency of locomotive designs. There was an unsuccessful attempt in 1935 to fit Lentz poppet valves to Su205–58 and Su205–59, and there was an abortive device fitted to SO17–

2877 in 1951. The latter aimed to effect a temporary increase of adhesive weight by switching on an array of electromagnets mounted on the locomotive. One inexpensive mechanical improvement was devised in 1936 by an engineer of the October Railway, N. I. Patlykh, a former pupil of Raevskii. This was a new valve gear arrangement which enhanced minimum cut-off to 20–30 per cent while maintaining a maximum cut-off of 80 per cent. This implied both better performance when starting and better economy at high speed.[177] Su204–71 was thus fitted in 1936, probably on the initiative of the October Railway. The device was not tested at that time by the research institute, nor did the NKPS show any interest in it. It was not until 1947 that the Patlykh valve arrangement was tested outside the October Railway. The NIIZhT finally compared it with three other variants of Su valve gear, including the two types used in pre-war and post-war batches. The Patlykh gear was clearly the most successful, but the tests had come too late for it to be widely used, for the long construction life of the Su type was just coming to an end.

5 Summary

When the Civil War ended in 1921 there seemed to be only one urgent locomotive problem in the Soviet Union, the need to restore the locomotive stock to its 1913 level. Designers and researchers could therefore afford an unhurried approach; new passenger locomotives were developed, and the methodical testing of locomotives continued on pre-war lines. During these years a number of younger men, typically engineers who had graduated in the previous decade, took over responsible jobs from those who had died, emigrated, retired, or been dismissed. It was to this new generation that men like Egorchenko and Syromyatnikov belonged; men who, while they seemed to thrive in the new revolutionary society, never abandoned that fundamental characteristic of the pre-war traction specialists, the preference for the theoretical approach and the quest for something better than excellence.

It is tempting though not particularly useful to regard this quest for absolute, theoretical, perfection as merely one more manifestation of that alleged Russian trait, the pursuit of excess. Be that as it may, the path trodden by Soviet locomotive policy is littered with the remains of projects which failed because they tried to take a good idea too far, or even, in the Kaganovich years, because they tried to take a bad idea too far. The striving for improved thermal efficiency through the design of devices like feedwater heaters and air pre-heaters may be regarded as an example of both the pursuit of perfection and the primacy of theory over practice. Theory proved conclusively that great gains in efficiency were attainable with such devices, while practice manifested itself in the impossibility of maintaining complex equipment in daily service and the fact that gains in one sector could be offset by losses in another. The so-called science of traction computations, together with the institution of locomotive 'passports', was perhaps the prime manifestation of a theoretical approach. The wondrous array of curves and tables which the researchers produced to show the official capability of the designs they tested may have been impressive, but their hasty revision in the

1930s to give theoretical backing to what Stakhanovites were achieving was a ludicrous episode which might have been expected to discredit the specialists for ever.

A good example of the quest for perfection is the Soviet pursuit of non-electric transmissions for mainline diesel locomotives. As early as 1925 it seemed fairly clear that in Lomonosov's E–el–2 a diesel locomotive had been produced which showed that diesel traction was feasible and advantageous. This locomotive's electric transmission was certainly not ideal either from the point of view of cost or of engineering elegance, but it did solve the biggest problem of mainline diesel traction; the continued devotion of much and varied talent to the search for a better alternative seems excessive (see Figure 19). American manufacturers, as Soviet engineers pointed out at the time, were less prone to such hesitation; once the diesel-electric was shown to be workable and saleable they began to build it, and overtook the Soviet lead in the 1930s.

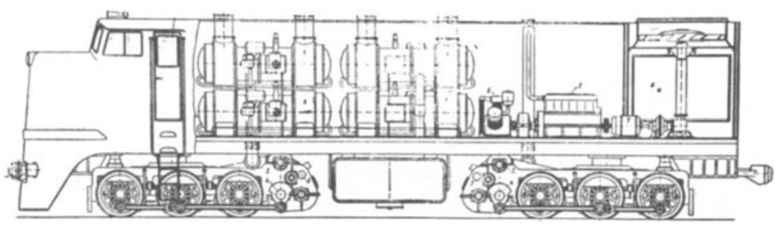


Figure 19 One of the final (1952) designs for a Shelest gas-transmission locomotive. This project, never built, had turbo-mechanical drive 'in order to liberate the locomotive from electrical transmissions'.

Because the dieselization programme initiated in 1922 came to a virtual end in 1937 it carries a retrospective aura of failure. But there was much that was positive about this attempt to revolutionize the motive power situation by a bold leap into promising darkness. The line of attack adopted in 1922 guaranteed that all likely options would have a fair trial and the result was the building of one successful (though far from perfect) diesel-electric, and of two other prototypes that were disappointing but nevertheless instructive. Towards the end of the 1920s the ambitions of the dieselizers outran the manufacturing capacities of that time, with more projects being initiated than could be completed.

When the diesels were transferred to Central Asia they produced disappointing operating indices. It may be surmised that the arrival of Kaganovich, coinciding with the presentation of depressing diesel operating statistics, was the point at which the prospects for the dieselizers turned decidedly downwards. For diesel proponents, it must have been especially frustrating to learn that the NKPS had decided to cease ordering diesel locomotives just when vastly improved operating results were being achieved, and just when General Motors in the USA was making a great success of the mainline diesel locomotive.

It seems fair to acknowledge that foreign interests benefited from Russian initiative in diesel traction, although it is hard to trace the exact path followed by such a transfer. It can hardly be denied that a beneficiary of Soviet gold and Soviet talent was the German locomotive industry. The design and manufacture of individual components must have taught many lessons. Unsuccessful features revealed in tests at least indicated which lines of development were best avoided. The construction by a German works of a stationary testing plant modelled after that designed by Lomonosov is another example of the benefit derived by Germany from the Soviet orders. So, although it is hard to point to any one feature of German diesel practice which was derived from the Soviet locomotives, it can hardly be doubted that subsequent diesel ventures like the *Flying Hamburger* owed something to the initiative of Lenin and Lomonosov. Another kind of indebtedness can be traced in the USA, where the Russian emigrant Lipets appears to have inspired the early ventures into diesel traction of the American Locomotive Company.

What the USSR gained from its early dalliance with mainline diesel traction, apart from a pioneer's glory, is also hard to prove but difficult to doubt. That it was American-style locomotives which set the pattern for the second, permanent, dieselization process would seem to imply that the inter-war Soviet diesel locomotives represented a dead-end technology with no contribution to make to the future. However, it would be wrong to ignore that the inter-war diesel programme created a pool of experience and specialized talent that must have eased the building and assimilation of the post-war diesels. On a higher level, among designers and traction specialists, the pre-war diesel experience must surely have demonstrated what qualities to value and look for in future generations of diesel locomotives.

The transfer of locomotive technology between the USSR and Germany was unusual in that it was two-way. No such reciprocity attended the Soviet acquisition of American technology. US practice profoundly influenced, both in detail and in fundamentals, Soviet locomotive design, and this is true of steam, electric and (after 1945) diesel traction. In the late 1920s there was a conscious effort made to acquire American experience. With the mirage of Soviet orders dangling before their eyes, American locomotive companies willingly allowed Soviet engineers to acquaint themselves both with design techniques and with production methods. In the end American companies received only meagre orders. These units were tested on the Soviet Railways network, and at least one was dissected in a Soviet locomotive works. The basic heavy freight locomotive of the 1930s, the FD, was essentially an American-style design. However, in some instances the Soviet designers could improve or modify the American designs. This happened when American practice had been imitated without reference to the special conditions of the USSR, and a prime example is the introduction of mechanical stokers in a country where riddled coal was virtually unobtainable. With electric locomotives, the result of American influence is still apparent, for six-axle locomotives built in the 1950s and 1960s are plainly of General Electric ancestry. British influence was small; the imported Beyer-Garratt locomotive was disliked even before it arrived, and seems to have had no effect on Soviet thinking. French research may have been influential. André Chapelon's novel boiler of 1940 could have been the inspiration of Syromyatnikov's FD 21–3128, in which Chapelon's idea seems to have been taken too far.

While technology transfer was all-important at certain times, the role of technology non-transfer should not be ignored. Despite the flood of Soviet experimentation, certain concepts were not touched. These included, notably, the theoretically attractive proposals for turbine and high-pressure steam locomotives, where the USSR was content to observe the progress made in other countries (especially Germany). Some design work was done, but lack of progress abroad may be presumed to have dissuaded those who would have liked to build Soviet prototypes. Some western engineers might regret that the USSR did not pursue turbine locomotives with the same persistence as it demonstrated with the hopeless *teploparovozy*, for it does seem quite likely that the turbomotive would have proved a viable proposition if it had been backed by larger resources than the various western companies could allocate.

The NKPS locomotive policy was most actively discussed in 1929, 1930 and 1931. The debate centred around two subjects, the relative importance of steam, electric and diesel traction, and the choice of locomotive designs for all three modes. The researchers of the repeatedly-reorganized traction research institutes of the NKPS produced successive proposals that were published, discussed, and quietly dropped; it was one thing to draw up plans for reconstruction, and quite another to obtain the resources to execute those plans. The NKPS for long assumed that American-size locomotives would be acquired, either imported or Soviet-built. The necessary assumption, or prerequisite, was that the economy would make available the resources needed to strengthen freightcar couplings and to raise the maximum axleloading permitted on the main lines. But in the course of 1931 it became apparent that a new design of locomotive, hitherto unrepresented in the successive NKPS schemes, would be introduced. This 'heavy' locomotive (the future FD) would in fact be relatively light.

The design of the FD, in retrospect, seems to represent the best possible compromise, in the circumstances of that time, between haulage capacity and the realities of Soviet track and couplings. Indeed, the serious difficulties encountered with the introduction of this locomotive suggest that anything larger would have been disastrous. Who originated the concept of this locomotive is unclear. There is some evidence that influential NKPS traction specialists were against it when they first heard of it (this was one of the accusations flung at Markovich). It is known that the outline or 'arrangement' drawing was accomplished by NKPS specialists arrested and re-established for that purpose. During the long drawn-out process of producing this drawing, a few of the members of the NKPS traction and research directorates who were still at large began to express, hesitatingly at first, the view that the American-size locomotive would be too large and something a little smaller was required. Then, in June 1931, came the Party Plenum resolution.

One interesting feature of this resolution is that although it opened the way for the FD it made no mention of that locomotive, and there are discrepancies in the several texts (see p. 99). It was not until 1934 that the Party voted for the FD as the 'basic' locomotive of the Second Five-Year Plan, thereby postponing (for ever) the introduction of American-size locomotives. In the last decade of steam traction the need for American-size tractive effort was satisfied by the widespread use of two locomotives per train, a solution that seems to have been unmentioned in the lively pre-war discussions.

Decision-making at its worst was exemplified by the case of the Garratt-type locomotive imported from Britain in 1933. The case for such a locomotive was urged by industries having their own railway networks, and opposed by many in the NKPS. To solve their own special problems the industries wanted to import a small Garratt, but what turned up at the Leningrad docks was the largest Garratt locomotive ever built, ordered by the NKPS for testing by specialists who, before examining it, decided that theory showed the Garratt idea to be unacceptable. This prejudice was unfortunate, for the Garratt locomotive would seem to have been quite promising; if not for the NKPS, at least for industrial lines, which continued for three decades to be handicapped by unsuitable motive power.

Foremost among the opponents of the Garratt concept was Egorchenko, described as the 'ideologist' of the locomotive-testing fraternity. Evidently a talented man, and probably one to whom younger researchers looked up with respect, Egorchenko is also an example of one of the problems which Kaganovich encountered in the railway research institutes. Brought up in the pre-1917 tradition, when locomotive-testing was regarded by its practitioners as a science, even an elect science, Egorchenko was reluctant to abandon his scientific heights to fish around for solutions to current everyday problems. He was induced to change his spoken views by a self-criticism session and the examples made of colleagues who had been despatched to an uncertain future, but his subsequent contributions to locomotive research were continuations of his old theoretical work. The purging of railway research institutes really began in 1929, and at first hit mainly the cautious. Streletskin, for example, came to grief because he insisted that weak bridges should be passed at reduced speed. But it was not until the arrival of Kaganovich that the research institutes felt the full force of coercion from without. Unfriendly exhortation, accusations, arrests, self-criticism sessions, periodic reorganizations, dismissals and demotions of the disfavoured and the elevation of the favoured did not, however, produce the required results. Researchers remained reluctant to abandon their theoretical preoccupations in favour of seeking simple solutions to current everyday problems. One reason for this failure may be discerned in the circumstance that the researchers who were favoured by Kaganovich were all too often those who were most obsessed by the theoretical approach. The case of Syromyatnikov is too prominent to be ignored. This was a man who seemed to lack the slightest perception of what effect a theoretically-derived improvement might have in daily use on the line. He and his colleagues originated a succession of improvements-that-worsen which Kaganovich's NKPS obliged the locomotive works to elaborate and build, and the long-suffering locomotive operators to endure. It would be wrong, however, to regard Syromyatnikov as the Lysenko of locomotive research. He may have made falsely optimistic reports of his inventions, but he was evidently a man of great erudition with a significant contribution to make. What was unfortunate is that he was given the opportunity to transform half-developed ideas into prototypes and even whole classes of locomotives. This meant that scarce resources were expended on inauspicious ventures. In biological terms, an engineer closer to Lysenko was Maizel', whose three *teploparovozy* were intended to be hybrids combining the best qualities of diesel and steam locomotives, but turned out to be only mongrels.

Although Syromyatnikov was a total steam man, and probably had little part in the *teploparovozy* venture, it was in his institution, MEMIIT, that this idea originated. Under Kaganovich, the MEMIIT increasingly dominated locomotive research and it was within its walls that the work of inventing unsuccessful economizing devices was carried on. Why this particular institution should be favoured is difficult to explain, but circumstances as much as personalities are most likely to be involved. It was close to the NKPS headquarters and to the Shcherbinka testing track. Kolomna Works was not too far away. A convenient triangular relationship therefore existed which helped to cut out some of the delays and muddles that might have intervened between organizations physically further apart. MEMIIT's rise coincided with the decline of Leningrad as a centre for locomotive research and development; the removal of the NKPS to Moscow, and the closure of the Putilov Works' locomotive business, must have been the factors here. Useful research did continue at the Leningrad Institute of Transport Engineers, but it was not on the scale of that at MEMIIT. In any case, to judge from the kind of results achieved, the ability of MEMIIT, presumably through its contacts with Kaganovich, to get its ideas built by Kolomna, was unfortunate. While demanding that research should be concentrated on everyday problems, Kaganovich put his faith in researchers whose main interest was the creation of devices which, far from solving everyday problems, created new ones.

The first moves towards the condensing steam locomotive had been made before the arrival of Kaganovich but, like many political characters of his type, he could not resist the bold technological leap. He ordered that condenser locomotives be built by the thousand, even though in practical use they were deficient. Whether condenser locomotives, even in small numbers, were a better investment than diesels or water-supply renewal, seems very doubtful from the evidence given in Chapter 4.

In many countries, promising locomotive innovations came to a depressing end because early disappointments resulted in a cutting-off of funds for further development. To criticize the NKPS for abandoning one project too soon and another too late can be unjust. On the whole, continuing too long was the usual pattern. In a society suffering acute shortages of resources, it is surprising that at least two projects for direct-drive diesel locomotives were funded for more than a quarter-century without ever producing a prototype.

Evidence for the neglect of promising ideas is less easily found than that for the excessive development of unpromising ideas. The history of steam locomotive development outside the USSR suggests, however, that it is most unlikely that any really propitious ideas were neglected; the steam locomotive was very close to the end of its life, and technological miracle-cures were not awaiting discovery. Indeed, it is tempting to add that if there had been such a miracle-cure, Soviet engineers would probably have found it; they tried hard enough. The case of the Patlykh valve arrangement (see p. 198) could well be exceptional, and was in any case a marginal improvement; still, the fact does remain that this innovation, devised by an engineer of one of the railways rather than a favoured research institution, was ignored until it was too late to properly exploit it.

The received impression that Kaganovich in some way was the salvation of the Soviet railway system in the late 1930s is hardly supported by his record in the field, admittedly narrow, of locomotive technology. The locomotive types which were built in thousands of units and performed the tractive work of Soviet railways for two decades were already designed before Kaganovich became Peoples' Commissar. No prototype locomotive devised by the research institutes between 1935 and 1941 ever became a successful series-production item of railway equipment; admittedly, the Sum and SO18 types were built in large numbers, but they were abandoned after the disappearance from the railway scene of Kaganovich and Syromyatnikov.

Failures are more interesting and often more instructive than successes and this is perhaps a partial excuse for the detail which this book provides of less-than-successful ventures in locomotive policy. Nevertheless, it is perhaps worthwhile to point out that in certain fundamentals, in the really decisive areas, the solutions adopted were probably the right solutions. For example, in inter-war locomotive policy the decisive choice that determined the shape and indeed the ultimate success of freight operations was the adoption of the FD locomotive. The technical deficiencies revealed in the first years of this locomotive's life were the consequence not so much of the design as the onset of new circumstances; the introduction of Stakhanovism meant that this locomotive was worked far harder than its designers had anticipated. As an interesting digression it might be added that, taking into account the rapidity with which Stakhanovite driving methods put these locomotives out of service, and the tardiness with which they were returned to traffic, a good case could be argued to assert the proposition that on the lines using FD locomotives (at least), the Stakhanovite movement for a year or two (at least) decreased rather than increased the capacity of the locomotive stock.

The verdict that in the really decisive choices the right decision was eventually, perhaps painfully, made conforms to the general impression left by a study of Soviet railway history as a whole. In the not unimportant matter of obtaining the most benefits from the least expenditure of resources the record of Soviet railway policy compares favourably with the experience of other countries. In locomotive policy an examination of other countries' experience would probably reveal similar errors and disappointments to those detailed in this book. Recent British experience, for example, both in detail and in fundamentals can be compared to earlier Soviet experience. In the matter of new locomotive types built not because of need but to gratify their designers or patrons, the history of British locomotive production has 'many dark places which await illumination' (to borrow a Soviet phrase from the 1930s). The early steps in Soviet dieselization, as initiated by Lenin, compare favourably with the policies of the British dieselizers three decades later. The Soviet plan sought prototypes both at home and abroad, and was quick to see the advantage of exploiting German technology. The British ordered whole batches, nor mere prototypes, of excessively numerous designs, while carefully refraining from doing business with the two most successful and experienced diesel locomotive builders, which were American.

That the fundamental shortcomings of the British dieselization scheme owed more to political than to engineering opinion serves to emphasize that the role of the Party in Soviet locomotive policy was neither especially influential nor extraordinary in comparison with the experience of other countries. What the Party wanted (and in the

First Five-Year Plan had great difficulty in getting) was clear expert advice embodied in an agreed and rational policy which might then be given the stamp of political approval.Unfortunately, the NKPS specialists were for long unable to formulate proposals that conformed with the Party's intention to restrict the allocation of resources to the railways. Also, there was continuing friction between the NKPS and the locomotive industry. The latter for a time seemed likely to possess its own locomotive research institute and thereby limit the NKPS role to the operation, not the design, of locomotives. Although the NKPS won this particular battle in 1933 it was the industry, not the NKPS, whose preferences for locomotive construction were finally, in the main, accepted. The Party's resolution of June 1931 may have confirmed an NKPS proposal, but the latter had been modified by pressure from industry exerted through the mediation of Gosplan.

In the late 1930s, under Kaganovich, the NKPS may have reasserted itself against the locomotive industry, but the war seems to have reversed this trend. In 1928–52 as a whole, the industry seemed to have a more accurate appreciation of what the railways needed than did the NKPS itself, and usually its preferences for locomotive construction overrode the NKPS proposals. Why the NKPS should have been so weak in this field is debatable, although one factor was probably the divided function of its Traction Directorate, the NKPS having insisted that the latter should embrace not only locomotive operations, but also locomotive design.

The Party resolution of June 1931 could perhaps be considered as intervention in a technical matter, but on the whole the Party's influence was of a scene-setting nature. Judging from results, the Party's enthusiasm for the GOELRO Plan did not do much to help railway electrification. Lenin's support for the diesel locomotive was a governmental rather than a Party initiative, and so was Khrushchev's decision three decades later to replace steam traction.

So far as scene-setting is concerned, the Party did of course approve the creation of circumstances in which the railways would face an enormous increase of traffic without a corresponding increase of resources. At least initially, the apprehensive atmosphere of the 1930s was cultivated by the Party; the effect of this has to be left largely to the imagination, aided by occasional news items and revelations. One especially noteworthy observation is that by a locomotive designer (see p. 183), who hinted that the SO freight locomotive (of which several thousand were eventually built) incorporated obsolete features partly because its designers did not wish to be accused of creating a locomotive that might compete with the FD type, which the Party had formally approved as the basic freight locomotive.

The ability of the NKPS in later years to foist a succession of complex prototypes on overloaded locomotive works was presumably a result of Kaganovich's influence. The Kaganovich years may, perhaps, be regarded as a case of Party intervention in technical matters, for he was clearly the representative of the Party, which had entrusted him with the salvation of railway transport. In the field of traction, he was confronted with clear-cut choices that had been too long-delayed, and made them; they may not always have been wise choices, but at least they were made. The abandonment of the dieselization drive, the mass production of condenser locomotives, the weight put behind one group of researchers, and the boot put behind another, all seem to have been Kaganovich's personal handiwork.

Apart, then, from the Kaganovich years, the Party's role in technical matters was not great. It might be remarked, too, that in other countries traction power policy has often been determined more by political than engineering interests. Where there is no political pressure, there can still be that capitalist manifestation of the party line, known as the 'corporate plan'. The writer of this book, while employed by a large North American railway company that had recently opted for diesel traction, was once asked to make a cost study of a branch line. His research showed that diesel operation would be more expensive than steam, but he was promptly informed that this finding was 'against company policy'. Being a well-brought-up economist, he made a fresh assumption, that a new steam locomotive would have to be designed and built for the branch line, and thereby he achieved the result required by his masters.

This glimpse into the real world of railway economics, and into the integrity of those who draw their livelihood from that world, seems a fitting *caveat emptor* with which to conclude this study.

Appendix

Table A *Total locomotive output, 1900–1930*

	Steam	Diesel	Electric	Hybrid
1900	1005	–	–	–
1913	654	–	–	–
1917	420	–	–	–
1918	221	–	–	–
1919	96	–	–	–
1920	84	–	–	–
1921	74	–	–	–
1922	71	–	–	–
1923	163	–	–	–
1924	174	–	–	–
1925	216	–	–	–
1926	380	–	–	–
1927	473	–	–	–
1928/9	813	–	–	–
1929/30	826	–	–	–

Source V. A. Rakov, *Lokomotivy zheleznykh dorog Sovietskogo Soyuza* (Moscow, 1955) pp. 70, 175. Includes deliveries from domestic workshops to mainline and industrial railways.

TABLE B *Mainline locomotive output, 1931–1957*

	Steam	Diesel	Electric	Hybrid
1931	810	2		
1932	827	1	3	
1933	930	1	17	
1934	1165	8	19	
1935	1518	4	34	
1936	1153	13	46	
1937	1172	4	32	
1938	1216	4	32	
1939	1011	5	17	1
1940	914	4	9	1
1941	708[a]	0[b]	3[b]	
1945	8			
1946	243		1	
1947	674	25	16	
1948	1032	69	38	1
1949	1187	128	82	
1950	985	125	102	
1951	665	76	113	
1952	254	75	110	
1953	668	101	147	
1954	758	120	158	
1955	654	134	194	
1956	490	161	216	
1957		400	270	

SOURCE *Promyshlennost' SSSR* (MOSCOW, 1957) p. 220

[a] From Table C

[b] Estimates

In 1944 and after, additional locomotives were acquired as reparations. There were also at that time imports of diesel locomotives from the USA and of E type steam locomotives from Hungary and Czechoslovakia. Hungarian-design passenger 4–8–0 units were also supplied. During the war American builders supplied about 2000 2–10–0 freight locomotives.

TABLE C *Steam locomotive production, 1928–1941*

	Output[a]	Placed in traffic[b]	Locomotive types[c]							Total weight of metal[d] (tons)
			FD	E	SO	IS	Su/Sum	M		
1928/29	575			437			84	54		57,060
1929/30	625			564			50	11		61,105
1930 est.[e]	500[e]			450[e]			41[e]	9[e]		48,850[e]
1931	810		1	809						80,367
1932	827	829	1	680		1	147			90,145
1933	930	907	21	704		1	181			99,800
1934	1185	1066	181	659	3	2	220			127,651
1934 FYP[f]			*900*			*360*				
1934 Plan[g]	*1253*		*300*	*668*		*5*	*280*			
1935	1518	1495	521	537	65	2	370			189,733
1936	1153	1137	664	50	309	3	111			169,258
1937	1172	1178	541		353	105	179			173,050
1937 Plan[h]	*1425*		*600*		*500*[j]	*100*	*225*			
1937 FYP[k]			*925*			*200*				
1938	1216	1216	485		406	132	191		(plus 2 streamliners)	179,915
1939	1011	1012	329		417	137	128		(includes 403 condenser SO)	153,665
1940	914	891	261		328	174	128		includes 92 condenser SO	128,769
1940 Plan	*1300*	350	*350*		*570*	*230*	*150*		*includes 295 condenser SO*	
1941		708	202		325	91	90			

[a] Except where indicated, this column is from *Promyshlennost' SSSR* (Moscow, 1957) p. 220. The 1928–30 figures are from *Sotsialisticheskoye stroitel' stvo SSSR 1936–1938 gg* (Moscow, 1939) p. 163.

[b] Except where indicated, this column is derived from A. Naporko (comp.), *Zheleznodorozhnyi transport v gody industrializatsii SSSR* (Moscow, 1970) p. 10 (for 1941), p. 402 (for 1939, 1940), p. 134 (for 1934), p. 414 (for 1932–38). Discrepancies between output and 'placed in traffic' columns are explicable by (1) in the mid-thirties it appears that some E type units were supplied to non-NKPS railway (2) output would include a few units not officially accepted by the NKPS (e.g., the 4–14–4); (3) locomotives rebuilt would presumably be claimed as new output by the industry but not as new locomotives by the NKPS.

[c] As note b. Locomotive totals in 1928/9 and 1929/30 are from *The Soviet Railroad Equipment Industry* (Chapel Hill, 1954) pp. V–37, quoting *Sotsialisticheskoye Stroitel'stvo*, op. cit., p. 163.

[d] With the change from copper to steel fireboxes (1931 onwards), these figures may be taken to represent ferrous metal, almost entirely steel. They do not represent metal consumed, only the weight of finished locomotives (and tenders) derived from the designed empty weight of each type multiplied by the number produced. A small margin of error is to be expected, given the tendency for different units to depart from their designed weight and because with some types an estimate has been necessary to allow for sub-types.

[e] This estimate is a pro-rata adjustment of the 15-month 1929/30 year, modified in the light of known circumstances. 1929/30 covered October 1929 to December 1930 inclusive. 1928/9 covered October 1928 to September 1929 inclusive.

[f] This is the target of the initial version of the Five-Year Plan, in *Proekt vtorogo pyatiletnego plana razvitiya narodnogo khozyaistva SSSR (1933–1937 gg)* (Moscow, 1934) vol. 1, p. 77, referring to'powerfullocomotives' (i.e. FD and IS types). For the five years, the same source gives the target as 2350 FD and 500 IS units, with total putput 1933–7 at 5700 freight and 2025 passenger locomotives.

[g] 1934 annual plan, in *Narodno-khozyaistvennyi plan na 1935 g* (Moscow, 1935) vol. 2, p. 512.

[h] 1937 annual plan, in *Narodno-khozyaistvennyi plan SSSR na 1937 g* (Moscow, 1937) pp. 80–1.

[j] These are all condenser locomotives. Condenser SO units are not indicated separately in 1936 and 1937.

[k] Final version of the Third Five-Year Plan, in *Vtoroi pyatiletnii plan razvitiya narodnogo khozyaistva SSSR (1933–1937 gg)* (Moscow, 1934) vol. 1, p. 81. In the five years, 2375 FD and 255 IS units were to be built within a total of 5861 freight and 1885 passenger steam locomotives.

TABLE D *Soviet direct-current electric locomotive types*

	Year	Weight in working order (tonnes)	Axleweight (tonnes)	Power (hourly rating, kwt)	Traction motors (kwt)	Electrical braking	Wheel arrangement
S, Ss	1931	132	22	2040	6 × 340	Recuperative	0–3 +3–0
VL 19	1932	120	20	2040	6 × 340	Rheostatic	0–3 +3–0
Si	1933	132	22	2280	6 × 380	Recuperative	0–3 +3–0
PB	1934	131	22½	2040	3 × 680	None	4–6–4
SK	1936	132	22	2040	6 × 340	Recuperative	0–3 +3–0
SKu	1938	138	23	2670	6 × 445	Recuperative	0–3 +3–0
VL22	1938	132	22	2040	6 × 340	Recuperative	0–3 +3–0
VL22m	1941	132	22	2400	6 × 400	Recuperative	0–3 +3–0
N8	1953	180	22½	4200	8 × 525	Recuperative	0–4–4–0 +0–4–4–0
VL23	1956	138	23	3150	6 × 525	None	0–3–3–0

NOTE Type N8 was later reclassified as VL8. Some, if not all, units of types VL22, VL19, Ss and SK later received the more powerful traction motors of the VL22m design. Locomotive weights can be varied marginally by ballasting.

TABLE E *Soviet diesel locomotive types*

	Year	Weight in working order tonnes	Axleweight (tonnes)	Engine horsepower (hourly)	Engine speed (revs/min)	Traction motors (kwt)	Wheel arrangement
Shch–el–1	1924	180	16	1000	395	10 × 100	1–3 +4 +3–1
E–el–2	1924	125	18½	1200	450	5 × 142	2–10–2
E–mkh–3	1926	131	18	1200	450	none	4–10–2
E–el–5	1931	134	19	1200	450	5 × 140	4–10–2
E–el–8	1932	149	21½	2 × 850	640	5 × 203	4–10–2
E–el–9	1933	140	20	1200	450	5 × 140	4–10–2
E–el–12 etc.	1933	138	20	1050	450	5 × 140	4–10–2
O–el–6, O–el–10	1931/33	100	18	600	700	1 × 350	2–8–2
O–el–7	1930	100	21½	600	700	4 × 140	2–8–0
VM	1934	246	20	2 × 1050	450	8 × 154	4–8–2 +2–8–4
Da	1945	121	20	1000	740	6 × 99	0–3–3–0
Db	1946	123	20½	1000	625	6 × 181	0–3–3–0
TE 1	1947	124	20½	1000	740	6 × 98	0–3–3–0
TE 2	1948	170	21¼	2 × 1000	740	8 × 152	0–2–2–0 +0–2–2–0
TE 3	1953	252	21½	2 × 2000	850	6 × 206	0–3–3–0 +0–3–3–0

NOTE The weight of E–el–2 applies to its post-1928 condition.

TABLE F *Basic dimensions of leading steam locomotive types*

	Weight in working order (tonnes)	Axleweight (tonnes)	Grate area (sq m/sq ft)	Superheater area (sq m/sq ft)	Boiler pressure (kg-cm/psi)	Cylinders (mm/in)	Coupled wheels diameter (mm/in)	Tractive effort tonnes/lb	Adhesion factor
Freight									
O 0–8–0	(1897) 52	13	1.9/20	nil	12/171	500 × 650/19½ × 25½ 730 × 650/29 × 25½	1,220/48	12/26,000	4.33
Shch 2–8–0	(1902) 78	16.5	2.8/31	nil	14/199	510 × 700/20 × 27½ 765 × 700/30 × 27½	1,320/52	14/31,400	4.71
Ye 2–10–0*	(1916) 91	16	6/64	62/660	13/180	635 × 711/25 × 28	1,320/52	24/53,800	3.33
E 0–10–0†	(1932) 86	17	5.1/55	72/775	14/199	650 × 700/25½ × 27½	1,320/52	27/60,000	3.18
FD 2–10–2	(1932) 137	21	7/76	123/1,329	15/213	670 × 770/26½ × 30	1,500/59	29/64,500	3.58
SO 2–10–0	(1934) 98	17	6/64	93/1,005	14/199	650 × 700/25½ × 27½	1,320/52	27/60,000	3.25
L 2–10–0	(1945) 102	18	6/64	113/1,220	14/199	650 × 800/25½ × 31½	1,500/59	27/60,000	3.33
LV 2–10–2	(1952) 122	18/19	6.5/70	149/1,605	14/199	650 × 800/25½ × 31½	1,500/59	27/60,000	3.33/3.65
Passenger									
N 2–6–0	(1904) 60	15	2.6/28	nil	13/180	500 × 650/19½ × 25 750 × 650/29½ × 25½	1,920/76	8/17,700	5.98
S 2–6–2	(1911) 76	16	3.8/41	52/555	13/180	550 × 700/21½ × 27½	1,850/73	13/27,800	3.63
Su 2–6–2	(1925) 87	18	4.7/50	89/960	13/185	575 × 700/22½ × 27½	1,850/73	14/31,400	3.86
M 4–8–0	(1933) 95	17	6/64	89/960	14.5/205	540 × 700/21 × 27½	1,720/68	14/31,300	5.00
IS 2–8–4	(1932) 135	20	7/76	148/1,595	15/213	670 × 770/26½ × 30	1,850/73	23/52,000	3.56
Sum 2–6–2	(1939) 89	20	4.7/50	72/770	13/180	575 × 700/22½ × 27½	1,850/73	13/27,800	4.51
P36 4–8–4	(1949) 133	18	6.8/73	132/1,420	15/213	575 × 800/22½ × 31½	1,850/73	18/39,500	4.02

* First World War import from USA and Canada

† For earlier varieties, see Table 4.1 (p. 128).

The dates are the official dates for the start of construction (of rebuilding in the case of the M type). In some cases the dimensions are those of a later sub-type.

Notes and References

Abbreviations

EZ *Ekonomicheskaya zhizn'*
PK *Planovoye khozyaistvo*
ST *Sotsialisticheskii transport*
ZT *Zheleznodorozhnyi transport*
L *Leningrad*
M *Moscow*

Chapter 1

1. *Gosudarstvennaya duma: Doklady byudzhetnoi komissii, SPB* 1907, p. 158.
2. *Proceedings of the Institute of Mechanical Engineers*, vol. 37 (London, 1886) pp. 297–302.
3. For more on testing plants, see: S. A. Sokolova, 'Razvitiye laboratornogo metoda ispytanii lokomotivov', in *Trudy instituta istorii estestvoznaniya i tekhniki*, vol. 29 (M, 1960) pp. 165–201 and D. R. Carling, 'Locomotive Testing Stations', in *Transactions of the Newcomen Society*, vol. XLV (Cambridge, 1975) pp. 105–82.
4. Yu. Lomonosov, *Opyty nad tipami parovozov* (Berlin, 1925) gives not only technical and background information, but also conveys the pride of its author in his science.
5. For a world wide summary of locomotive testing history, see D. R. Carling, 'The Development of Locomotive Testing', in *Railway World* (Shepperton, September 1976) pp. 372–5.
6. The academicism of Central European and Russian engineers is clearly discernible in the potted biographies given in J. N. Westwood, *Locomotive Designers in the Age of Steam* (London, 1977).
7. *Railway Gazette* (London, November 1952) p. 1928 (obituary).
8. A. S. Martynov in *Lokomotivostroeniye*, no. 1 (M, 1931) pp. 52–3.
9. V. A. Rakov, *Lokomotivy zheleznykh dorog Sovietskogo Soyuza* (M, 1955) pp. 111–12.
10. These include A. V. Yanush in his *Russkiye Parovozy za 50 let* (M, 1950) p.46.
11. *Trudy nauchno-tekhnicheskogo komiteta NKPS*, no. 12 (M, 1925).
12. *Trudy NIIZhT*, no. 360 (M, 1968) p. 35.

13. Raevskii, for example, at the end of his life was a teacher and researcher in an academic institution, a member of several NKPS committees, including the influential NTK, but was employed by the locomotive industry at Putilov Works.
14. *Railroad History*, vol. 128 (Cambridge, Mass., 1974) pp. 35–49.
15. Letter to Brian Reed, 6 April 1933.
16. M. Larsons, *An Expert in the Service of the Soviet* (London, 1929) pp. 40–8; M. Larsons, *V sovietskom labirint* (Paris, 1932) pp. 115–32.
17. A. N. Krylov, *Moi vospominaniya* (M, 1945) p. 298.
18. This paragraph is based on *V. I. Lenin: Biograficheskaya khronika*, vol. 8 (M, 1977) pp. 584, 585, 605, 610, 632.
19. V. V. Fomin, *Lenin i transport* (M, 1973) pp. 49–50.
20. S. Zarkhii, *Narkomput F. Dzerzhinskii* (M, 1977). This book is based on archival sources.
21. Zarkhii (p. 52) hints that an anti-Soviet but Soviet-appointed inspecting agent was making trouble. More plausible reasons for the difficulties are the Soviet misgivings about Nydkvist & Holm's ability to deliver promptly so large an order, and the disputed ownership of the 'Russian gold' with which the transaction was to be financed.
22. Technical details of diesel locomotives mentioned in this book may be found in the books by Shishkin, Shelest, Yakobson and Rakov (see Bibliography).
23. V. I. Grinevetskii, *Problema teplovoza i ego znacheniye dlya Rossii* (M, 1923).
24. N. S. Ryshchik (ed.), *Ucheniye i izobretateli zheleznodorozhnogo transporta* (M, 1956) gives a biography of Shelest (pp. 184–94).
25. Shelest describes these events in his 'Razvitiye teplovozostroeniya v SSSR', in *Trudy instituta isotorii estestvozaniya i tekhniki*, vol. 21 (M, 1959) pp. 177–81.
26. Letter of Lomonosov to Brian Reed, 6 April 1933.
27. Westwood, *Locomotive Designers*, p. 233.
28. *Leninskii sbornik*, vol. XXIII (M, 1933) pp. 178–9.
29. *V. I. Lenin: Biograficheskaya khronika*, vol. 8 (M, 1977) p. 160.
30. Shelest, op. cit., p. 182.
31. A. Naporko (comp.), *Zheleznodorozhnyi transport SSSR v dokumentakh kommunisticheskoi partii i sovietskogo pravitel' stva* (M, 1957) pp. 158–9.
32. Ibid., p. 164.
33. Ibid. See also Fomin, op. cit., pp. 62–3.
34. W. Messerschmidt, *Von Lok zu Lok* (Stuttgart, 1971) p. 133.
35. D. K. Minov, '*Nekotoryie materialy . . . v oblasti elektricheskoi tyagi*', in *Izvestiya Akademii Nauk SSSR: otdeleniye tekhnicheskoi nauk*, no. 8 (M, 1950) pp. 1212–41 gives a useful account of early Russian achievements in railway electrification.
36. The salvation of the Murmansk Railway is described in G. F. Chirkin, *Transportno-promyshlenno-kolonoziatsionnyi kombinat Murmanskoi zheleznoi dorogi* (M-L, 1928).
37. V. I. Lenin, *Sochineniya*, vol. 35 (M, 1950) p. 371.
38. See G. I. Lomov (ed), *General'nyi plan elektrifikatsii SSSR: materialy . . .* (M–L, 1932) vol. 9, pp. 187–243 and vol. 3, pp. 1–220.

Chapter 2

1. The structure of the locomotive-building industry is described in: Institute for Research in Social Science, *The Soviet Railroad Equipment Industry* (Chapel Hill, 1954).
2. A. Naporko (comp.), *Zheleznodorozhnyi transport v gody industrializtsii SSSR* (M, 1970) p. 44.
3. Naporko (1957), op. cit., p. 211.
4. Ibid., pp. 236–7.
5. This paragraph is largely based on a very full account in S. S. Khromov, *F. E. Dzerzhinskii vo glave metallopromyshlennosti* (M, 1966) pp. 28–43, 188–93.
6. Naporko (1970) op. cit., p. 40–2. This NKPS plan was submitted in October 1927. An article by Prof. Bernstein Kogan (*PK*, no. 1, 1929, pp. 127–53) illuminates NKPS thinking in 1928 and the pros and cons of an American-style reconstruction. He writes that in April 1928 the NKPS submitted to Gosplan a plan which revolved around three basic locomotives, the existing E, a '5-axle 20-ton' type T, and the '5-axle 30-ton' type A. Evidently rebuffed, the NKPS submitted a new, scaled-down, plan in August.
7. In 1934 was celebrated the *fifth* anniversary of the 'first' electrification.
8. The Baku scheme is described in: G. A. Akhmedov, M. A. Kuz'min, *Pervaya v SSSR* (Baku, 1966); *Elektrifikatsiya zheleznykh dorog*, no. 10, 1932, pp. 20–5; *Ucheniye zapiski Azerbaidzhanskogo universiteta, seriya obshchestvennykh nauk*, no. 4 (Baku, 1960) pp. 95–109.
9. *EZ*, 5 Feb. 1931, p. 4.
10. Rakov, op. cit., p. 342.
11. Ibid., p. 344. The NKPS engineer closely associated with this scheme gave some detailed figures (especially for crew and fuel requirements) in A. N. Khudadov, *Tekhnicheski-ekonomicheskiye predposylki elektrifikatsii zheleznykh dorog SSSR* (M, 1932).
12. *Gudok*, 26 Dec. 1930, p. 3.
13. *EZ*, 24 Sep. 1930, p. 3.
14. *EZ*, 14 Dec. 1930, p. 3.
15. *EZ*, 24 Feb. 1929, p. 2. By the mid-1930s the NKPS opinion seems to have prevailed, with the creation of the steam-operated Moscow–Valuiki–Donbas main line.
16. The decision to use electric trains rather than electric locomotives was uncontroversial, given the technical level of that period.
17. An account of its work, including names of its personnel, is in *Byulleteny teplovoznoi komissii*, no. 1 (M, 1927) pp. 22–6.
18. Biographies of Gakkel appear in Ryshchik, op. cit., pp. 174–83, and N. A. Zenzinov, S. A. Ryzhak, *Vydayushchiesya inzhenery i ucheniye zheleznodorozhnogo transporta* (M, 1978) pp. 250–62.
19. Rakov, op. cit., pp. 272–3; *Vestnik NIIZhT*, no. 6 (M, 1957) pp. 59–63.
20. See, for example, *Tekhnika i ekonomika zheleznykh dorog*, no. 8 (M, 1948) p. 21.
21. *Byulleteny . . .* , op. cit., no.2 (M, 1929) pp. 11–17.
22. *Railroad History*, vol. 128, pp. 35–49.
23. 'High Powered Diesel Locomotives in Russia', in *Diesel Railway Traction* (London, 2 Dec. 1932) pp. 672–4.
24. *PK*, no. 5, 1925, p. 163.

25. P. V. Yakobson, *Istoriya teplovoza v SSSR* (M, 1960) p. 39, quoting Yu. Lomonosov, *Teplovoz Yue–001 i ego ispytaniya v Germanii* (Berlin, 1925).
26. Zenzinov and Ryzhak, op. cit., pp. 257–8.
27. For full description and diagrams of this locomotive and of E–el–2 see Yakobson, op. cit., pp. 43–58 and 35–43.
28. Rakov, op. cit., p. 280.
29. Ibid., p. 281.
30. Letter by J. L. Koffman in *Diesel Railway Traction* (London, July 1960) pp. 282–3. As the writer's comments on other matters in this letter seem well-informed, it is hard to lightly dismiss his observations about Shelest and Lomonosov.
31. F. E. Dzerzhinskii, *Izbrannye proizvedenii*, vol. 1 (M, 1957) pp. 373–4.
32. Yakobson, op. cit., p. 59.
33. Rakov, op. cit., p. 272.
34. Naporko (1957) op. cit., p. 193.
35. Ibid., p. 200. In February 1926 the prize money was 'increased' to 500,000 roubles.
36. *Byulleteny . . .*, op. cit., no. 2, p. 83. The results were also published in *Izvestiya TsIK SSSR*, 163 (3897) 15 July 1928.
37. Shelest, op. cit., p. 191.
38. *Elektrichestvo*, no. 19 (M, 1930) pp. 732–7.
39. *Izvestiya Leningradskogo tekhnicheskogo instituta*, no. 17 (L, 1931) pp. 59–76.
40. These include: G. Lomonosoff, *Die Thermolokomotive* (Berlin, 1925) and G. Lomonosoff, *Die Diesel-Elektrische Lokomotive* (Berlin, 1924).
41. *PK*, no. 5, 1925. The articles were: Ya. Shatunovskii, 'Teplovoznoye preuvelicheniye' (pp. 157–61); Yu. Lomonosov, 'Kto preuvelichivaet?' (pp. 162–3); A. Shelest, 'K diskusii o teplovozakh,' (pp. 164–70); Prof. Bernatskii, 'Isklyuchitel' nost' v vybore roda tyagi' (pp. 171–6).
42. *Zeitschrift des Vereins Deutsches Ingenieure*, no. 37 (Berlin, 1924) pp. 937–42.
43. *PK*, no. 6, 1925, p. 144.
44. *Byulleteny . . .* , no. 1, 1927, p. 27.
45. Ya. M. Gakkel' 'Teplovoz s elektricheskoi peredachei v sravneniye s parovozom i elektrovozom', in *Izvestiya elektrotekhnicheskogo instituta*, vol. XVI (M, 1929) pp. 7–18.
46. *Vestnik inzhenerov*, no. 7 (M, 1927) p. 285.
47. Ibid., no. 9, 1926, pp. 366–7.
48. *Byulleteny . . .* , no. 3, 1929, p. 8.
49. S. I. Kuks, 'K problemu teplovoza', in *Vestnik Sibirskikh inzhenerov*, no. 1/2 (Tomsk, 1926) pp. 10–20.
50. *Izvestiya elektricheskogo instituta*, vol. XVI, 1929, pp. 7–18. Electrification and strategy is also discussed in *ST*, no. 9, 1937, pp. 20–28, and *ZT*, no. 4, 1944, pp. 58–62.
51. *Byulleteny . . .* , no. 2, 1929, pp. 58–60.
52. The American technical press carried several articles by Lipets about diesel traction. For example: *Railway Age*, no. 8, 1927, p. 1869, and no. 6, 1926, pp. 241–5; *Mechanical Engineering*, no.8, 1926, pp. 797–806, and no. 9, 1926, pp. 929–40.
53. Shelest's address is summarized in *Vestnik inzhenerov*, no. 7, 1927, pp. 285–8.

54. V. A. Dmitriev, *Narodnokhozyaistvennaya effektivnost' elektrifikatsii zheleznykh dorog i primeneniya teplovoznoi tyagi* (M, 1976) is an exemplary modern cost study.
55. A. N. Shelest, 'Teplovozy s mekhanicheskimi generatorami gazov sistemy A. N. Shelest', in *Vestnik inzhenerov*, no. 7, 1927, pp. 288–92.
56. *Byulleteny* . . . , no. 1, 1927, p. 50.
57. Ibid., no. 3, 1929, pp. 41–3, 19–21.
58. Naporko (1957) op. cit., p. 194. This commission replaced a similar commission (of the STO) which had been established 5 Dec. 1924.
59. *Diesel Railway Traction*, May 1960, p. 184. Although evidence is lacking, it seems possible that Dobrovol' skii and his colleagues were incarcerated, as were steam designers at this time, in a special establishment where they could sort out their problems in an atmosphere designed to concentrate their minds.
60. *Byulleteny* . . . , see Bibliography.
61. In addition to the mainline units, two 300 hp diesel-mechanical yard locomotives would arrive from Krupp in 1931, two four-axle diesel railcars from Esslingen in 1929, and two two-axle diesel railcars from Linke-Hoffman-Busch in 1929. Also present were several pre-1914 attempts by the Mytishchi Works at kerosene railcars.
62. *Byulleteny* . . . , no. 1, 1927, pp. 17–21.
63. Ibid., pp. 55–9.
64. Ibid., Three pages of tables are on pp. 57–9.
65. S. M. Postnikov, 'Litsom k sovietskomu teplovozu', in *ST*, no. 6, 1931, pp. 142–6.
66. *Sborniki teplovoznoi komissii*, no. 3 (M, 1930) pp. 10–18.
67. STO decree, 19 June 1929 (*SZ*, 1929, art. 417 of no. 47).
68. *Byulleteny* . . . , no. 2, 1929, pp. 6–10.
69. The approved designs were the 4–10–2 E–el; the 2–8–2 o–el; the 2–8–0 o–el; Prof. Trinkler's 2–12–0 and 2–10–2; a steam-transmission 2–10–0 (E–p); a steam-diesel conversion of a 4–6–0 (U–np); and a mechanical transmission 4–8–4 (M–mkh) for heavy passenger work.
70. *Sbornik teplovoznoi komissii*, no. 3, pp. 9–10. The proposals were later thinned out by an 'enlarged Technical Conference' which included the designers of the various projects as well as men with practical experience from the Diesel Locomotive Base. It was probably the latter who were behind the recommendation that new experimental units should not be merely new versions of locomotives already ordered.
71. FD and IS coalburning locomotives seem to have received taller chimneys after 1955, perhaps to aid the combustion of inferior coals.
72. *Sbornik teplovoznoi komissii*, no. 3, 1929, pp. 9, 18.
73. Gakkel in *Elektrichestvo*, no. 19, 1930, p. 734.
74. *Lokomotivostroeniye*, no. 1 (M, 1931) p. 20.
75. A. Avatkov in *Elektrifikatsiya zheleznykh dorog*, no. 2/3 (M, 1932) p. 22.
76. *EZ*, 16 Apr. 1929, p. 2.
77. *Gudok*, 28 Dec. 1930, p. 4.
78. *Gudok*, 16 Mar. 1930, p. 3.
79. *Gudok*, 31 Aug. 1930, p. 3.
80. *EZ*, 23 Mar. 1930, p. 4.
81. *EZ*, 14 Dec. 1930, p. 3.

Chapter 3

1. *Trudy NIIZhT*, no. 360, p. 31.
2. R. A. Lewis, *Science and Industrialisation in the USSR* (London, 1979) pp. 143–4.
3. Ibid. p. 23.
4. *EZ*, 15 Mar. 1930, p. 2.
5. *ST*, no. 4/5, 1931, pp. 50–2. Other institutes made fleeting appearances. Possibly some of these were self-styled, and others existed for only a day or two. Among them was the NKPS Central Scientific Research Institute for Diesel Locomotives, whose existence is revealed (or perhaps merely proclaimed), by a handful of its publications in 1931.
6. *EZ*, 8 May 1930, p. 3. By the mid-1930s the Scientific Technical Council (NTS) of the NKPS was supervising research.
7. Lewis, op. cit., pp. 131–2, 95–6.
8. The Egorchenko affair, to be related, is one demonstration of the heavy-handed approach. Indirect evidence includes the well-documented assault on the Institute of Track (which among other things was without a director or research chief for many months in 1937–8), and the equally-well-documented slaughter of railwaymen in general under the Kaganovich regime, briefly mentioned in Chapter 4.
9. Naporko (1957), op. cit., p. 268.
10. *ST*, no. 4/5, 1931, pp. 50–2.
11. *ST*, no. 1/2, 1932, pp. 23–5.
12. 'Vsesoyuznyi nauchno-issledovatel'skii institut lokomotivostroeniya, ego zakrytiye i organizatsiya teplovoznoi laboratorii MMMI', in *Lokomotivostroeniye*, no. 6, 1934, pp. 104–29, gives a very detailed account of what happened in 1930–3.
13. This was a joint order of NKPS and VSNKh, no. 2178 of 20 Oct. 1930.
14. Letter of Lomonosov to Brian Reed, 2 April 1933.
15. *Gudok*, 16 Oct. 1930, p. 2; 18 Oct. 1930, p. 4; 19 Nov. 1930, p. 3.
16. A. S. Martynov, 'Zadachi instituta lokomotivstroeniya v oblasti proektirovaniya moshchnykh parovozov i ikh kharakteristika po dannym Amerikanskoi mezhdushtatnoi torgovoi komissii', in *Lokomotivostroeniye*, no. 1, 1931, pp. 48–63. The author describes the establishment of the new Institute as a complement to the 1930 concentration of detailed design work into the single Central Locomotive Design Bureau.
17. *Lokomotivostroeniye*, no. 6, 1934, p. 105.
18. Ibid., no. 1, 1931, pp. 5–7.
19. Ibid., no. 6, 1934, p. 109.
20. A. A. Armand (ed.), *Nauchno-issledovatel'skiye instituty tyazheloi industrii*, vol. 2 (M-L, 1935) pp. 608–10.
21. Terent'ev in *ZT*, no. 3, 1948, p. 46.
22. Yanush, op. cit., p. 66.
23. Rakov, op. cit., p. 192.
24. A fuller description of the electrification research institutes, with the names of their leading participants, is given in *Trudy NIIZhT*, no. 360, pp. 13–16.
25. For an example of two locomotive engineers at cross-purposes in this way at the

1932 conference on railway reconstruction, see K. N. Tverskoi, (ed.), *Transport vo vtorom pyatiletii*, pt. 1 (M-L, 1932) pp. 86–7.

26. The Politburo issued its decree on railway reconstruction 25 May, and the Party Plenum resolution of June 15 approved this decree. The text, which may be regarded as the final version of the NKPS reconstruction plan, is given in Naporko (1970) op. cit., pp, 109–16 and Naporko (1957) op. cit., pp. 244–52.
27. *EZ*, 14 Mar. 1929, p. 3. The spokesman was presumably referring to the proposed T type, whose *adhesion* weight was 100 tons.
28. *EZ*, 16 Apr. 1929, p. 2.
29. *Gudok*, 4 Oct. 1934, p. 3. Fitting superheaters to locomotives unlikely to work hard for sustained periods is useless. Fitting them to the O type, used mainly and increasingly for yard work, was a particularly bad decision. Spending foreign exchange on the scheme made it absurd.
30. *EZ* Supplement, 27 Nov. 1929, pp. 1, 3. But the same newspaper (28 Dec. 1929, p. 2) soon reported Rudzutak's complaint that the NKPS planners were still thinking in terms of 'super-mainlines' and 'super-locomotives', despite the metal shortage.
31. See, for example, H. Hunter, *Soviet Transportation Policy* (Cambridge, Mass., 1957) pp. 61–6.
32. *EZ*, 6 Mar. 1930, p. 4.
33. *EZ*, 20 Apr. 1930, p. 3; 18 Mar. 1930, p. 6.
34. *Gudok*, 19 Apr. 1930, p. 1.
35. *Gudok*, 14 Aug. 1930, p. 1.
36. Naporko (1970) op. cit., p. 81.
37. *EZ*, 24 June 1930, p. 3.
38. *EZ*, 5 Dec. 1930, p. 3.
39. The RKI at this period was frequently concerning itself with railway questions and was of value, presumably, in assessing differences of opinion between the NKPS and other commissariats. Its members accompanied the railway delegations to Japan and the USA, and were also involved in the dispute between the NKPS and the locomotive industry over research institutes.
40. *EZ*, 7 Jan. 1931, pp. 2–3.
41. *EZ*, 4 Jan. 1931, p. 2.
42. The proliferation of committees and commissions means that in this book important-sounding bodies appear and disappear often without comment; their story belongs to a different book.
43. *EZ*, 2 Jan. 1931, p. 1. This incident seems to have fired some longlasting red faces, for as late as its 1956 edition the official locomotive diagram book (*Spravochnik po lokomotivam zheleznykh dorog Sovietskogo Soyuza*), published by the Ministry of Transport, omitted the width of these two American designs.
44. The two tables are in *ST*, no. 1/2, 1931, pp. 51 and 54.
45. *EZ*, 5 Feb. 1931, p. 4.
46. Rakov, op. cit., p. 192.
47. See *Trud*, 17 June 1931, p. 3; *ST* no. 6, 1931, p. 10; *KPSS v rezolyutsiyakh s'ezdov, konferentsii i plenumov* (M, 1953) pt. 2, pp. 643–56 and ibid. (M, 1954) pt. 3, pp. 100–13. The two collections of documents edited by Naporko in 1957 and 1970 (op. cit.) differ in their rendering of this sentence.

48. 'Nauchnaya rabota v teplovoznom dele', in *Rekonstruktsiya transporta*, no. 11 (M, 1931) pp. 3–4.
49. Tverskoi, op. cit., pt. 1, pp. 3–4.
50. Naporko (1957) op. cit., p. 254. The decree was by the SNK (*SZ*, 1931, no. 43, art. 292).
51. *Gudok*, 12 Nov. 1930, p. 2.
52. Ibid., p. 3.
53. There was a whole page devoted to electrification in *EZ*, 14 Dec. 1930, p. 3, and *Gudok*, 24 Dec. 1930, p. 3.
54. *EZ*, 28 Jan. 1931, p. 3.
55. *EZ*, 5 Feb. 1931, p. 4.
56. *EZ*, 13 Mar. 1931, p. 4.
57. *EZ*, 17 May 1931, p. 2.
58. *EZ*, 4 June 1931, p. 1.
59. Naporko (1970) op. cit., p. 111.
60. G. P. Efremtsev, *Istoriya Kolomenskogo zavoda* (M, 1973) pp. 176–7.
61. Engineer Tertychko, 'Teplovozofikatsiya; uroki sovietskogo teplovozostroeniya', in *Podvizhnyi sostav*, no. 2 (M, 1932) pp. 4–7.
62. Yakobson, op. cit., pp. 93–4 and 97–9.
63. Yakobson, op. cit., pp. 91–2.
64. Yakobson, op. cit., pp. 66–9.
65. Yakobson, op. cit., pp. 77–81. Yakobson also describes and illustrates other diesel projects, including the Trinkler, Sidorov, Maksimov and Lontkevich schemes. See also P. V. Yakobson, 'Novyie idei v teplovozostroenii', in *Parovoznoye khozyaistvo* (M, Oct. 1934) pp. 10–15.
66. *Rekonstruktsiya transporta*, no. 3/4, 1931, p. 4.
67. 'Litsom k sovietskomu teplovozu', in *ST*, no. 6, 1931, pp. 142–4.
68. *Gudok*, 16 Oct. 1930, p. 1.
69. *Gudok*, 4 Dec. 1930, p. 3. Four articles in support of dieselization were printed on this page.
70. *EZ*, 5 Jan. 1930, p. 4.
71. *Gudok*, 29 July 1930, p. 3.
72. *Gudok*, 31 Aug. 1930, p. 3.
73. *Rekonstruktsiya transporta*, no. 11, 1931.
74. M. Ya., 'Parovoz ili teplovoz?' in *Rekonstruktsiya transporta*, no. 3/4, pp. 4–5.
75. *Rekonstruktsiya transporta*, no. 11, 1931, pp. 8–10.
76. The writer was referring to the 1927 volume of *Oil Engine Power*, pp. 7–8.
77. *Rekonstruktsiya transporta*, no. 11, 1931, pp. 5–7.
78. Ibid., p. 16.
79. Ibid., pp. 19–20.
80. Ibid., pp. 17–18.
81. Ibid., pp. 3–4.
82. Ya. M. Gakkel', Ekonomicheskaya tselesoobraznost i tekhnicheskiye vozmozhnosti shirokogo primeneniya teplovoznoi tyagi, v svyazi s voprosom elektrifikatsii zh-d. linii v SSSR', in *Elektrichestvo*, no. 19, 1930, pp. 732–7. The same paper under the same title was also published in *Izvestiya teplotekhnicheskogo instituta*, no. 6/7, 1930, pp. 69–75.
83. K. O. Rozen, 'O teplovoznoi tyage na zheleznykh dorogakh SSSR', in *Elektrichestvo*, no. 7, 1931, p. 375.

84. S. Bessonov in *EZ*, 4 June 1930, p. 2.
85. *EZ*, 14 Aug. 1930, p. 4.
86. *EZ*, 14 May 1931, p. 2.
87. *PK*, no. 5/6, 1931, pp. 10–21.
88. See, for example, his article in *Izvestiya teplotekhnicheskogo instituta*, no. 5, 1930, pp. 87–100. In this he recommends the 'diesel locomotive of continuous power' (that is, one equipped with a rotary compressor to produce high-pressure gas) as the best prospect.
89. *Lokomotivostroeniye*, no. 1, 1931, pp. 8–32.
90. The articles were by W. Wechmann, in *Elektrischenbahnen*, nos. 1, 2, and 3 of 1930.
91. *Lokomotivostroeniye*, no. 1, 1931, p. 25.
92. *ST*, no. 1/2, 1932, pp. 139–41.
93. The Weir Report, recommending the electrification of British railways, attracted great interest among the Soviet enthusiasts for electrification. That the British companies soon declared their indifference to the Report was ascribed to the links between the railway- and coal-owning capitalists rather than to the awkward problem of where the railway companies, which were not prospering, could find the £341 million of capital envisaged in the Report.
94. *Rekonstruktsiya transporta*, no. 9, 1932, pp. 25–8.
95. *Elektrifikatsiya zheleznodorozhnogo transporta*, no. 2/3, 1932, pp. 20–4, 24–6.
96. The article in *Rekon. trans.* also gave 1932 as the date of Shelest's article.
97. *Trudy instituta istorii estestvoznaniya i tekhniki*, vol. 21, op. cit., pp. 172–3.

Chapter 4

1. I. V. Stalin, *Voprosy Leninizma* (M, 1947) pp. 504–5.
2. *Transport i svyaz' SSSR* (M, 1957) pp. 30, 32.
3. *XXII s'ezd KPSS. Stenograficheskii otchet*, vol. 2 (M, 1962) p. 215.
4. *Gudok*, 28 Dec. 1935, pp. 1–4.
5. For example, *Mashinostroeniye*, 30 July 1938, p. 2.
6. Shishkin in *ZT*, no. 12, 1947, p. 58.
7. Lewis, op. cit., p. 23.
8. *ST*, no. 11, 1938, pp. 73–8.
9. A. Saprykin and A. Voinov, 'Likvidirovat' otstavaniye issledovatel'skoi raboty', in *ST*, no. 12, 1938, pp. 43–7.
10. S. Kogan, 'Vydayushchiisiya deyatel' transportnoi nauki', in *ST*, no. 11, 1938, pp. 73–8.
11. I. Rubinchik, 'Po-novomu organizovat' nauchno-issledovatel' skuyu rabotu', in in *ST*, no. 11, 1938, pp. 36–45.
12. I. Rubinchik, 'Protiv tekhnicheskoi perestrakhovkoi', in *ST*, no. 9, 1938, pp. 15–31.
13. Krivonos, who rose rapidly to chief of a railway, wrote his post-retirement memoirs in 1977: P. F. Krivonos, *Magistral' zhizni* (Kiev, 1978).
14. *Lokomotivostroeniye*, no. 1, 1931, p. 53.
15. *Gudok*, 3 Jan. 1936, p..2.

16. *Gudok*, 11 Jan. 1936, p. 4.
17. *Gudok*, 20 Feb. 1936, pp. 2–3.
18. MEMIIT (Moscow Electrical-Mechanical Institute of Transport Engineers) was created in 1931 on the basis of the Traction Faculty of MIIT.
19. A. M. Babichkov, N. I. Panov, *Sergei Petrovich Syromyatnikov* (M-L, 1953). The first 104 pages of Syromyatnikov's *Teplovoi protsess parovoza* (1955 edition) are devoted to its late author.
20. Zenzinov and Ryzhak, op. cit., pp. 308–9.
21. S. P. Syromyatnikov, *Teplovoi protsess parovoza* (M, 1930, 1933, 1938, 1940, 1947, 1955); S. P. Syromyatnikov, *Novyi metod issledovaniya teplovoi raboty parovoznogo kotla* (M, 1938).
22. *Trudy MIIT*, no. 14 (M, 1929) pp. 165–218.
23. S. P. Syromyatnikov, *Chto mozhet dat parovoz 'Feliks Dzerzhinskii' pri krivonosovskikh metodakh raboty* (M, 1936).
24. *ST*, no. 9, 1938, pp. 94–5.
25. *Gudok*, 8 Jan. 1937, p. 3; 3 Apr. 1938, p. 3.
26. N. I. Kartashov, *Konstruktsiya parovoza* (Tomsk, 1904). For more on Kartashov, see N. S. Ryshchik (ed.) *Ucheniye i izobretateli zheleznodorozhnogo transporta* (M, 1956) pp. 148–52.
27. Tverskoi, op. cit., pt. 1, pp. 171–2.
28. A new electric locomotive works at Kashira was expected to start production in 1933 and produce annually 600 units by 1935. Kashira did eventually produce electric locomotives, but they were for industrial railways, not the NKPS.
29. *ST*, no. 5/6, 1933, p. 128.
30. *Gudok*, 24 Nov. 1934, p. 1 and 12 June 1935, p. 2; see also 21 Feb. 1935, p. 3 and 22 April 1935, p. 3.
31. *Gudok*, 17 Mar. 1935, p. 3; 21 Mar. 1935, p. 2; 22 Mar. 1935, p. 2.
32. *Gudok*, 28 Feb. 1935, p. 3.
33. *Gudok*, 16 Aug. 1938, p. 2.
34. Rakov, op. cit., p. 321. Such a locomotive was specified in a decision by the Electrical-Technical Council in April 1932 (see Naporko, 1970, op. cit., pp. 150–1).
35. For this controversy, see *Gudok*, 20 June 1935, p. 3; 23 June 1935, p. 3; 5 July 1935, p. 3; 27 July 1935, p. 2.
36. *Gudok*, 5 July 1935, p. 3.
37. *Gudok*, 3 Jan. 1935, p. 4. The record was claimed for a 'continuous speed' of 120 kph (75 mph).
38. *Gudok*, 11 Mar. 1935, p. 4.
39. Rakov, op. cit., p. 334. A further attempt to find a locomotive for the 1500V lines was made after the war, when the USSR acquired German electric locomotives as reparations. These were of 12,000V, and Soviet engineers modified one of them to work on 1500V. The result was workable but not advisable. In the period before the conversion of these lines to 3000V, a number of VL 19 units, equipped for dual-voltage operation in the 1930s, were used.
40. *Gudok*, 10 Mar. 1935, p. 2; 21 Mar. 1935, p. 2; 14 Feb. 1939, p. 3.
41. A. S. Avatkov, *Elektrifikatsiya na odnofaznom toke promyshlennoi chastoty* (M, 1958) pp. 78–91, 231–45, 278–85.
42. *Rekonstruktsiya transporta*, no. 18, 1931, pp. 4–9.

43. Ibid.
44. N. Unshlikht in *PK*, no. 3, 1932, pp. 27–42. This article lists the lines to be dieselized, following the Party resolution. It also specifies that the Second Five-Year Plan would require the construction of 4000 powerful steam locomotives and 3000 E type, as well as 2000 freight electrics and the 1000 diesels.
45. *ST*, no. 7, 1932, pp. 89–94. By 1934 the story had changed; *PK* no. 5/6 1934, p. 6 reported that in 1933 the planned output of electric and diesel locomotives had been 24 and 15, of which 16 and 12 were delivered.
46. The rumour, or threat, that Sormovo might begin diesel locomotive construction seems to have aroused much opposition from water transport interests, which relied on Sormovo for river craft (see Tverskoi, op. cit., pt. 2, p. 57). The essential problem at this time was lack of locomotive building capacity. There had previously been seven locomotive works supplying the Russian railways, but Putilov had been lost, the Nevskii Works were devoted to industrial locomotives, while Sormovo, Kharkov, Bryansk, and Kolomna had substantial non-NKPS work. This left only Lugansk (the future Voroshilovgrad), which was in the throes of reconstruction.
47. Tverskoi, op. cit., pt. 3, p. 15. However, in January 1932 the NKPS Collegium was talking in terms of just ten series units for that year (*ST*, no. 1/2, 1932, p. 145). The special committee on railway reconstruction of the NKPS approved the recommendation of Terpugov (then head of the Diesel Locomotive Commission) in May 1932 that the series design should be the E–el type (Naporko, 1970, op. cit., pp. 158–9).
48. Tverskoi, op. cit., pt. 3, p. 14.
49. Ibid.
50. Ibid., pt. 2, p. 69.
51. Ibid., pp. 27–8.
52. Ibid., pt. 1, p. 177.
53. Ibid., pt. 2, p. 26.
54. *Vtoroi pyatiletnii plan razvitiya narodnogo khozyaistva SSSR 1933–1937 gg* (M, 1934) vol. 1, p. 81.
55. F. I. Zavarykin, *Zheleznodorozhniki Ashkhabadskoi magistrali v gody Velikoi Otechestvennoi voiny (1941–1945 gg)* (Chardzhou 1961) p. 22. The totals include the handful of yard diesel locomotives acquired in the 1930s.
56. *Teplovozostroeniye*, no. 9 (M, 1950) p. 33.
57. *Rekonstruktsiya transporta*, no. 18, 1931, p. 9. The rails were up to 30 years old, with their heads worn by up to 6mm.
58. Until 1936 the diesels were allowed to work only over the short Ashkhabad–Dushlak section. In 1944 their sphere was limited to Bami–Ashkhabad–Dushak; see V. A. Dmitriev, op. cit., p. 41 and Zavarykin, op. cit., p. 33.
59. *ST*, no. 5/6, 1933, pp. 126–36.
60. T. N. Khokhlov, 'Za teplovoz', in *Parovoznoye khozyaistvo*, no. 1 (M, 1934) p. 16.
61. *Gudok*, 15 Sep. 1934, p. 2.
62. I. N. Ivashko, 'Ustranit' defekty v konstruktsii teplovozov tipa 2–5–1', in *Parovoznik*, no. 15, 1936, pp. 19–21.
63. A. Poido, 'Razvitiye teplovoznoi i motovoznoi tyagi v SSSR', in *ST*, no. 10, 1940, pp. 10–15.
64. *Gudok*, 23 Apr. 1934, p. 4.

65. *Gudok*, 4 June 1937, p. 3. The author pointed out that even the British railway companies were listening to diesel protagonists who were emphasizing the success of American diesel locomotives.
66. A. D. Stepanov, E. V. Platonov, 'Dizel' elektricheskii transport v tret'ei pyatiletke', in *Elektrichestvo*, no. 20, 1937, pp. 1–5.
67. Tverskoi, op. cit., pt. 3, p. 14.
68. G. Vitik in *PK*, no. 11/12 1937. The quotation is from p. 69.
69. V. Dmitriev, in his 'Vazhnye voprosy dal'neishego razvitiya teplovoznoi tyagi na dorogakh SSSR', (*ZT*, no. 9, 1954, pp. 19–27) wrote that construction ceased 1937–47. Yakobson (op. cit., pp. 122–3), who was a diesel locomotive designer at Kolomna at the time, wrote that 'The NKPS stopped ordering diesel locomotives in 1937, but Kolomna continued to build the 4–10–2 units as mobile generating stations'.
70. *ST*, no. 4, 1939, p. 126.
71. *Gudok*, 4 Aug. 1940, p. 2.
72. V. Levin (Head of NKPS Expert-Technical Section) in *Gudok*, 7 Nov. 1940, p. 3.
73. *Gudok*, 16 Aug. 1939, p. 3.
74. *ST*, no. 10, 1940, pp. 10–15.
75. *Gudok*, 16 Aug. 1939, p. 3.
76. *Gudok*, 4 July 1938, p. 2.
77. Zavarykin, op. cit., pp. 45–6.
78. *ST*, no. 10, 1940, pp. 10–15. Fuel was measured in 'conventional units'.
79. *Gudok*, 31 Jan. 1941, p. 2.
80. *Gudok*, 14 Feb. 1941, p. 2.
81. *Gudok*, 8 June 1940, p. 3.
82. Khokhlov, op. cit.
83. Stepanov and Platonov, op. cit.
84. For details of the defects and modifications of these locomotives, see *ZT*, no. 3, 1948, pp. 75–8; *Tekhnika zheleznykh dorog*, no. 8, 1944, p. 18; Shishkin, op. cit., p. 5.
85. K. Shishkin, 'Kakimi putyami povysit' ekonomichnost' lokomotivov', in *ZT*, no. 12, 1947, pp. 57–9.
86. *Gudok*, 23 Apr. 1934, p. 4.
87. *Gudok*, 10 Aug. 1935, p. 1.
88. T. N. Khokhlov, 'Rezul taty ispytanii teplovozov serii VM i E–el no. 14', in *Parovoznoye khozyaistvo*, no. 9, 1935, pp. 22–7.
89. Yakobson, op. cit., pp. 122–3, 124–5.
90. *Parovoznoye khozyaiztvo*, no. 10, 1934, pp. 10–15.
91. *Zeitschrift des Vereins Deutsches Ingenieurs*, no. 19, 1925, pp. 635–42.
92. The translation (in *Byulleteny* . . . , no. 1) was complete, and with the original drawings.
93. *Mashinostroeniye*, 21 Oct. 1938, p. 3.
94. Rakov, op. cit., p. 306.
95. Ibid., p. 307.
96. Technical descriptions of these *teploparovozy*, and summaries of their trials, are in Rakov, pp. 305–12. Detailed technical discussion of the first two, with diagrams, are in *Transportnoye mashinostroeniye*, no. 4, 1940, pp. 3–13. The Kolomna unit, and especially the organization of its design work, is described in

Skorostnoye proektirovaniye i osvoeniye mashin (Moscow-Kharkov, 1940) pp. 163–75.

97. *ZT*, no. 12, 1947, p. 59.
98. Shishkin and Yakobson did outline a General Motors type locomotive suitable for Soviet railways, and it was suggested that such a design should be ordered from the USA, with the intention of later transferring production to the USSR (see *Tekhnika zheleznykh dorog*, no. 8 (M, 1944) pp. 17–21). It might be added that at the same period the USSR ordered electric locomotives from General Electric; several of these were completed, but owing to the post-war deterioration of US–USSR relations they were not delivered, being diverted to US railroads.
99. P. Yakobson, 'Perspektivy primeneniya teplovoznogo tyagi' in *ZT*, no. 10/11, 1945, pp. 21–30.
100. *Gudok*, 19 May 1946, p. 2. Other references to these Alco units are in: A. A. Poido *et al.*, *Teplovozy Da i Db* (M, 1947); *ZT*, no. 1, 1947, pp. 48–56; *ZT*, no. 12, 1947, pp. 51–2. Their alleged misuse is reported in *Gudok*, 12 June 1946, p. 3, and 10 July 1946, p. 3.
101. *Trudy instituta istorii ekonomiki i tekhniki*, vol. 21 (M, 1959) p. 197. The development of diesel traction in 1950–60 is described in J. N. Westwood, *Soviet Railways Today* (Shepperton, 1963) pp. 66–85.
102. In S. N. Surzhin, *Parovoz LV* (M, 1958) the maximum cut-off of the FD is given as 60 per cent. This would have limited the 'thrashing' which a Stakhanovite crew might impose on their locomotive although, even at 60 per cent, continuous running at maximum cut-off would have produced stress and high fuel consumption. The post-war L and LV designs marked a step away from limited cut-off, at 70 per cent each.
103. Naporko (1970), op. cit., pp. 151–2, 155–7. According to Rakov (p. 216) the 'authors of the project' (probably the OGPU design team) had decided on a 2–8–4 although the NKPS Traction Directorate had wanted a 4–8–2.
104. *Gudok*, 6 Feb. 1937, p. 3.
105. *Mashinostroeniye*, 14 June 1939, p. 3.
106. Ibid., 16 Sep. 1938, p. 2.
107. *Gudok*, 4 June 1934, p. 3.
108. *Gudok*, 8 Aug. 1937, p. 2 and 4 June 1934, p. 3. See also *Mashinostroeniye*, 23 Apr. 1939, p. 2, 15 July 1939, p. 1, 5 June 1939, p. 2.
109. *Gudok*, 15 Aug. 1938, p. 3. Part of the delay, according to this article, was because the former specialist, Prof. Grachev, had insisted on studying the problem with the aid of index cards for every locomotive.
110. *Gudok*, 22 May 1930, p. 1 and 4 June 1930, p. 3.
111. *Gudok*, a letter, 29 Mar. 1938, p. 1. See also *Gudok*, 11 Oct. 1938, p.1 and 10 Dec. 1938, p. 2.
112. *Gudok*, 21 Mar. 1935, p. 1.
113. *Gudok*, 8 Jan. 1935, p. 1, 9 Jan. 1935, p. 2, 16 Feb. 1935, p. 2.
114. *Gudok*, 4 Jan. 1935, p. 1.
115. *Gudok*, 11 Nov. 1936, p. 3, 15 Nov. 1936, p. 2, 16 Nov. 1936, p. 2, 17 Nov. 1936, p. 2.
116. *Gudok*, 29 May 1936, p. 3.
117. *Gudok*, 20 Mar. 1940, p. 3.
118. *Gudok*, 3 Jan. 1936, p. 1.

119. *Gudok*, 16 July 1935, p. 3.
120. *Gudok*, 23 Nov. 1934, p. 2.
121. See, for example, I. L. Blinov, *Moi opyt raboty na parovoze 'FD'* (M, 1944) pp. 10–18.
122. *Gudok*, 21 Mar. 1935, p. 3.
123. Ibid.
124. Yanush, op. cit., p. 23.
125. Naporko (1970), op. cit., pp. 352, 393.
126. *KPSS: XVII s'ezd. Stenograficheskii otchet* (M, 1934) p. 206.
127. D. V. Novov, 'Chto dal opyt s amerikanskimi parovozami Ta i Tb', in *Parovoznoye khozyaistvo*, no. 3, 1934, pp. 4–8 is a particularly full article, and also an interesting commentary on US practice as viewed by Soviet engineers.
128. B. K. Sergeev, 'Ustanovleniye vozmozhnosti i uslovii obrashcheniya tyazhelykh parovozov . . . ', in *Zheleznodorozhnyi put'*, no. 7 (M, 1933) pp. 153–65.
129. Novov, op. cit., p. 6.
130. *Parovoznoye khozyaistvo*, no. 3, 1934, p. 28.
131. Novov, op. cit., p. 6.
132. *Izvestiya teplotekhnicheskogo instituta*, no. 5, 1930, p. 98.
133. Tverskoi, op. cit., pt. 3, p. 247.
134. Ibid., pp. 242, 249–50.
135. *Beier-Garratt patentovyi lokomotiv-dupleks dlya zheleznykh dorog v SSSR* (Manchester, 1933 (?)). Copy in Beyer, Peacock Archive, Manchester.
136. The Order Book is in the Beyer, Peacock Archive. Handwritten amendments and additions were unusual.
137. Mashinist Chilikin, 'Parovoz Garratt pokazal khoroshiye rezul' taty', in *Parovoznoye khozyaistvo*, no. 3, 1934, pp. 27–8.
138. Ibid., p. 28.
139. 'Stranichka IRT', in *Parovoznoye khozyaistvo*, no. 6, 1934, p. 29.
140. Ibid., p. 27.
141. Zhitkov in *Ekspluatatsiya zheleznykh dorog*, no. 1 (M, 1933) p. 22.
142. Terpugov in *Ekspluatatsiya zheleznykh dorog*, no. 7, 1933, p. 15.
143. I. German, 'Parovoz sistemy Garratt', in *Tyagovoye khozyaistvo*, no. 11/12 (M, 1932) pp. 23–6.
144. Rakov, op. cit., p. 191; Yanush, op. cit., p. 28.
145. *Parovoznoye khozyaistvo*, no. 6, 1934, p. 29.
146. *Tyagovoye khozyaisto*, no. 5/6, 1933, pp. 12–16.
147. *Gudok*, 8 Jan. 1935, p. 4; 12 Jan. 1935, p. 4; 14 Jan. 1935, p. 4.
148. A. Chirkov in *ST*, no. 8, 1939, pp. 24–33. The quotation is from p. 30. Chirkov was a prominent designer associated with the FD and other types.
149. *Mashinostroeniye*, 14 June 1939, p. 3.
150. N. I. Fal' kovskii, 'Puti tekhnicheskoi rekonstruktsii vodosnabzhenii na zh-d transporte', in *Vodosnabzheniye i sanitarnaya tekhnika*, no. 2 (M, 1936) pp. 17–27. See also *ST*, no. 10, 1933, p. 86 and no. 9, 1938, p. 91; *ZT* no. 9, 1958, pp. 19–23; *Parovoznoye khozyaistvo*, no. 8, 1935, pp. 31–2.
151. Rakov, op. cit., p. 198.
152. *Gudok*, 9 Mar. 1936, p. 1.
153. *Gudok*, 11 Dec. 1936, p. 3.
154. See, for example, *ST*, no. 1/2, 1939, p. 30.

155. *Gudok*, 13 Mar. 1938, p. 1.
156. A. Chirkov, 'Parovozy s kondensatsiei para v tret'ei pyatiletke', in *ST*, no. 8, 1939, pp. 24–33.
157. *Gudok*, 2 Feb. 1940, p. 3 and 10 May 1940, p. 2.
158. *Gudok*, 21 May 1939, p. 3.
159. Test results were published in D. F. Terenin, V. A. Sokolov, *Rezul'taty ispytaniya parovoza tipa 1–5–0 serii SO s kondensatsiei para* (M, 1938).
160. R. Roosen, *Ein Leben für die Lokomotive* (Stuttgart, 1976) pp. 58–66. Earlier in this book the author recalls that Henschel built condenser locomotives for the Argentine before receiving the Soviet contract.
161. *Gudok*, 17 Jan. 1945, p. 2.
162. *Gudok*, 28 Nov. 1945, p. 3.
163. A. Tret'yakov, 'Ispol' zovaniye parovozov s kondensatsiei para', in *ZT*, no. 5, 1947, pp. 51–7.
164. Yanush, op. cit., p. 23.
165. A. Poido, 'Razvitiye teplovoznoi i motovoznoi tyagi v SSSR', in *ZT*, no. 10, 1940, pp. 10–15. See also Yakobson, *Istoriya . . .* , op. cit., p. 65. The Ashkhabad Railway costs relate to 1939–43.
166. S. Syromyatnikov, 'Sozdadim vysokoekonomichnyi sovietskii parovoz', in *ZT*, no. 2, 1947, pp. 7–9. Kolomna made not only the working drawings but also had a strong hand in the outline drawing, normally the work of the design section of the Ministry of Transport's Central Locomotive Directorate.
167. Ibid. Subsequent comments on Syromyatnikov's article were by Lebedyanskii (*ZT*, no. 9, 1947, pp. 28–32); I. Pirin (*ZT*, no. 12, 1947, pp. 53–7); K. Shishkin (*ZT*, no. 12, 1947, pp. 57–9); L. Terent'ev (*ZT*, no. 3, 1948, pp. 45–7). The discussion was unpolemical and polite, but not good-humoured.
168. *ZT*, no. 11, 1948, p. 92.
169. H. Holcroft, *The Railways of Germany during the Period 1939–1945* (British Intelligence Objectives Sub-committee) (London 1949) p. 55.
170. Details of these devices, as of other innovations described in this section, are from Rakov, op. cit., pp. 184–240.
171. J. N. Westwood, 'Soviet Gas-burning Locomotives', in *Locomotive Carriage and Wagon Review*, London, Dec. 1958, pp. 229–30.
172. *Trudy NIIZhT*, no. 360, p. 52.
173. *Gudok*, 20 Dec. 1940, p. 3.
174. *ZT*, no. 2, 1947, p. 8.
175. *Trudy MEMIIT*, no. 51, M., 1945, pp. 5–87.
176. Rakov, op. cit., p. 182. The possibility that it was NIIZhT, not Syromyatnikov, whose figures were distorted seems unlikely, since the results claimed by the Syromyatnikov group border on the incredible.
177. N. I. Patlykh, *Uluchshennyi paroraspredelitel'nyi mekhanizm parovozov* (M, 1958).

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