CHAPTER VI - BROWN COAL DUST FIRING FOR LOCOMOTIVES

From “Brown Coal” by H. Herman published by State Electricity Commission of Victoria, 1952

It has long been recognised that brown coal, even when briquetted, is an unsuitable fuel for locomotives if only because of the fire hazard associated with funnel sparks. In Germany, where successful use of brown coal briquettes on main line operation would be a major economic achievement, there has never been more than small local utilization -principally in or about open cuts. If brown coal is to partly or wholly displace black coal in Victoria's State railway system, no other solution is in sight than its use in the form of dried dust.

In 1920 the State Electricity Commission started investigations into the adaptability of brown coal for use in the pulverised form, concerning which at that time little information was available. In 1921 it was arranged that the Commission would erect and operate at Newport a plant to dry and pulverise Morwell (North Yallourn) brown coal, and that the Railways Department would conduct tests on the product in a stationary boiler at Newport A power house and in locomotives. In May 1923 the stationary boiler and one locomotive started to receive pulverised coal supply which was continued, with little interruption, until October 1925. The whole of this campaign has been fully described elsewhere136, and only the salient features of the locomotive experiments will be mentioned here. The flow sheet of the crushing, drying, pulverising and conveying plant appears in fig. 298.

Three classes of locomotives were used, A2, C and DD. In each case the feed from the tender bunker was with double-feed screws driven by a steam engine and a blower operated by a steam turbine. Comparative tests were carried out with each type in competition with a similar standard type locomotive burning lump black coal. With dust firing, operation was much less laborious than with hand firing, and it was always possible to maintain ample steam supply. There was very little smoke. Some minor troubles were overcome as the tests progressed. A source of real trouble was the noise in the cab made by the auxiliary equipment driving the blower fan and the screw feeders. This prevented the train crew from hearing audible signals and was a definite obstacle to the safety of train operation. In the later trials with the DD class locomotive the blower was placed at the rear of the tender and the noise was greatly reduced. Choking of the boiler tubes by sintered ash also gave some trouble, and although the firing equipment proved fairly reliable several breakdowns occurred. Pulverised carbonised brown coal residues from an experimental plant at Yallourn also were fired on two trial rums with the C class locomotive, which steamed well with this fuel, easily maintaining schedule running time. The residues however did not ignite as readily as the brown coal because of the low volatile content - 7%. The approximate boiler and furnace efficiencies obtained during the tests were as in table 60.

TABLE 60.-BOILER AND FURNACE EFFICIENCIES IN VICTORIAN LOCOMOTIVE DUST FIRING TESTS 1923-1924

Locomotive class	Pulverised brown Coal %	Wonthaggi black coal hand-fired %	Maitland black coal hand-fired %
A2, Saturated steam, goods	69.5	70.0	-
A2, Saturated steam, passenger	66.7	-	65.6
C, superheated steam, goods	70.8	63.7	-
DD, superheated steam, goods	66.2	68.3	-
DD, superheated steam, passenger	72.0	-	67.5

The tests on the whole showed a somewhat higher combustion efficiency for pulverised brown coal than for lump black coal but some practical problems of locomotive operation remained to be solved. At the time the relative costs of brown and black coals did not offer the Railways engineers sufficient inducement to attack these problems, although it was realised that in due course the relative cost trend might be to the advantage of brown coal.

When preparations were being made for the Victorian experiments in 1921, substantial pioneering of the pulverised fuel locomotive, using black coal, had been in progress for a year or more in England. The Great Central Railway Company had fitted two locomotives for burning, respectively, pulverised black coal and colloidal fuel, the latter a mixture of about 60 parts of pulverised coal and 40 parts of oil. The pulverised fuel locomotive was in regular service on one of the heaviest runs in England, between Gorton near Manchester and Dunford, a distance of nearly 18 miles; it had to take, its place with a 500-ton load among similar trains; half a dozen of these were following trains, all of which were likely to be held up if the pulverised fuel locomotive failed. All this indicated the confidence of the Railways officials in the reliability of the pulverised fuel locomotive under everyday working conditions. During August 1921 the author had a run on the footplate of the pulverised fuel locomotive on a day when the general traffic conditions were as described above. Running, tests had bees made previously with the two converted locomotives and with another using lump coal; for maintenance of steam pressure and rate of travel on the heaviest portions of the run, colloidal fuel showed best and pulverised coal next best. Two separate engines on the tender, which was specially built for this service, drove the feed screw for the coal and the blower fan. Technically these experiments appear to have been quite successful, but the official view of the company was that there would be no commercial gain in pulverising its high-grade black coal.[1]

In September 1921 the author visited Italy to ascertain, if possible, the experience obtained there with two locomotives of the Italian State Railways which had been equipped for firing pulverised Italian lignite. Like Victoria, Italy had to import black coal and was desirous of putting its limited supplies of brown coal to as many uses as possible. At the time of the visit the tests had been suspended owing to damage by fire to the pulverising plant. The locomotives were equipped with Fuller-Lehigh apparatus similar to that supplied later for the 1923-24 tests on Victorian locomotives. Up to the date of interruption the Italian tests had shown that lighting up and starting had been fairly successful with clean boiler tubes; when starting with cold water the pressure had risen to 170 lb/sq. inch in less than an hour, though forcing the boiler in this way was not favoured in ordinary operation. In the first trials only a short distance had been travelled when the firebrick walls and boiler tubes were blocked, partly by compact, not very friable, clinkered ash and partly by incompletely burned fuel. As the lignite used contained 26% ash, such a result is easy to understand. In later trials specially selected lignite with an ash content not exceeding 8% was used, and the difficulties were slightly reduced; but with a full train the trials were completely negative. The unfavourable outcome of the tests was attributed to too small a combustion chamber, but if lignite had to be specially selected to get the ash content down to 8%, it seemed clear that there was a rough road to travel to a successful commercial issue. The raw lignite, which came from the Arno valley in central Italy, contained 40 to 55%; moisture; as used in the tests it contained 43.06% volatile matter, 30.18% fixed carbon, 8.61% moisture and 26.76% ash. The calorific value was 4.346 kcal/kg. All the dust passed through a screen with a mesh of 4,900/cm^2.[2]

Following the publication[136] in 1926 of the details of the Victorian experiments, about 10 years elapsed during which the pulverised fuel locomotive was the subject of only occasional discussions between the State Electricity Commission and the Victorian Railways Department. In 1936, while on sundry investigations in Germany relating to various phases of the utilisation of brown coal, the author included in his enquiries the use of locomotives fired with brown coal dust. It soon became clear that developments in Germany since the Newport experiments justified renewed study of the prospects of the pulverised fuel locomotive for Victoria. Since about 1930 the German State Railways had been operating regularly in central Germany 10 freight locomotives fired with brown coal dust, mostly or wholly derived from the electrical precipitation stacks of briquette factories. There had been no abnormal operating troubles, and in the area of operation fuel and other costs were more favourable for brown coal dust than for black coal. Further, a new high speed passenger locomotive was under construction to run on pulverised coal, black or brown, between Berlin and Cologne, but eventually certain defects in design of the equipment for dust firing resulted in its conversion to grate firing. However, more freight locomotives were to be added to the ten in service.

In February 1936, after an inspection of fuelling methods, a trip was arranged for the

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[1] This information about the Great Central Railway experiments, and other facilities afforded to the author came from Mr. J. G. Robinson, then Chief Mechanical Engineer of the company. Details of the locomotives, of the line gradients and tests, appear in the Railway Gazette, London of 9/7/20, pp. 60-63.

[2] This information on the Italian tests was supplied to the author during discussion in Rome and in subsequent correspondence by Signor G. U. Quinto Orso, Engineer in Charge of Material and Traction Departments, Italian State Railways.

author on the foot-plate of one of the freight locomotives from Halle to Nordhausen; the load hauled was 55 trucks, about a quarter of a mile in length, and weighed 1,120 tons (metric). The journey was trouble-free. From officers of the Borsig-Tegel organisation, which had specialised in the pulverised coal locomotive, was ascertained the nature of the information required to prepare a scheme for conversion to dust firing of such locomotives and their tenders as might be deemed necessary in Victoria. This information was communicated to the Victorian Railways Department, and that Department then started with the German firm negotiations which, unfortunately, had not been completed when war broke out in September 1939.[3]

In August 1936 in flew York the author discussed with the Superheater Company, which had previously displayed interest in the pulverised fuel locomotive, the submission of one or more schemes for Victorian development. Contact was arranged between the company and the Victorian Railways Department. Discussions ensued oft the conversion of an N type locomotive to operate between Yallourn and Melbourne, but agreement was not reached on various technical aspects of the problem necessary for definite action.

Other countries that have shown interest in the dust fuel locomotive are: Sweden, where the Swedish State Railways made tests with pulverised peat as far back as 1913; Brazil, where the Brazil Central Railway converted 14 test locomotives and proposed to follow the tests with the establishment of a dust fired fleet of 250, though the larger project was not effected; and Hungary, where, about 1930, two AEG locomotives were supplied to the Hungarian State Railways. In England, some 10 years after the trials of the Great Central Railway Company, the Southern line experimented with pulverised black coal, using AEG equipment, on the non-stop passenger run between London and Brighton; the unsatisfactory result has been attributed to the dust being insufficiently fine and to failure to provide adequately for the peculiarities of the coal used and the service required of it. K. Pierson[236] says that this experiment was made to decide whether conversion to coal dust firing was preferable to electrification, and that if the basis had been brown coal dust the decision would have been in favour of the dust fired locomotive. He mentions also that in Germany the running of fast express trains up to a speed of 140 km/hr, at the same time fully maintaining the usual slower services, is a traffic problem not yet completely solved, and that meanwhile all other railway traffic, presumably including passenger trains, can easily be provided for by the brown coal dust locomotive.

In December 1940, under instructions from the Hon. the Premier of Victoria, a committee was constituted to investigate the extent to which Yallourn brown coal could be used, both on a short and a long term basis, as a fuel for essential services in the State. Two reports were issued.[4] In its second report (1/7/1941) the committee, inter alia, recommended the adoption of a definite programme of development for the use of pulverised brown coal for railway services, up to the conversion of 24 engines operating on the main Gippsland line. The adoption of this programme by the Government about a year later, with instructions to carry it into effect, for the first time translated departmental deliberations into State policy. In furtherance of this policy, W.O. Galletly and W.H. Chapman of the Victorian Railways, made detailed investigations in Germany in 1946[102]. These were followed by the conversion of a Victorian X class heavy goods locomotive to firing with brown coal dust, and by the initiation in 1949 of a new series of tests which are referred to later.

A brief history of the development of the dust fired locomotive in Germany may be given here. The initiative came in 1923 from the German State Railways administration, which brought into consultation representatives of the brown coal industry and the following manufacturers of locomotives - Berliner Maschinenbau A.G., Berlin; A. Borsig, Berlin-Tegel; Hanomag, Hannover-Linden; Henschel and Sohn A.G., Cassel; and Friedrich Krupp A.G., Essen. This consultation resulted in the formation of a commercial association, known as 'Slug' (Studiengesellschaft) for research on pulverised fuel firing of locomotives, which

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[3] The author, who was accompanied by his late colleague, W. G. Smellie, obtained the facilities for these enquiries, inspections and consultations through the personal assistance of Dr. Paul Wagner, then Chief Mechanical Engineer of the German State Railways.

[4] First report, date 17/12/40. Second report, date 4/7/41. Members of committee, C. F. Broadhead, representing gas interests; W. O. Galletly, for Railways Department; and H. Herman (chairman) for the State Electricity Commission. Reports not published.

developed the Stug system of firing. The early experiments and the subsequent conversion of locomotives to this system were carried out by Henschel and Sohn. Concurrently and independently the Allgemeine Elektricitäts Gesellschaft (AEG), Henningsdorf, was experimenting with a similar objective; it took over the locomotive section of Tegel-Rheinmetal Borsig, renamed it the Borsig Lokomotiv-Werke, Henningsdorf and converted some locomotives to the AEG system of firing.

Both Stug and AEG made their first experiments on stationary' boilers only. By 1928 sufficient was known to proceed with the conversion of two classes of goods engines, one class (G82) with a tractive effort of 42,000 lb, the other (G12) with a tractive effort of 53,000 lb. During three years (from the end of 1928 to the end of 1931) ten conversions were put into service, four of the G82 class and six of the G12 class. All of the former were AEG, with separate engines to drive the blower and the feed screws; of the latter two were AEG, two were Stug with separate drive, and two were Stug with combined drive (the fan and screws driven by the same turbine). Dynamometer trials were made on an AEG G82, and on three G12 locomotives having respectively AEG equipment, Stug separate drive and Stug combined drive. Similar trials were made on grate fired engines of the G82 and G12 classes using black coal for purposes of comparison. The boiler efficiencies were 72 to 80% for the AEG equipment, 75 to 78% for the Stug (equal results for separate and combined drive) and 68 to 79% for grate firing. The reliability of the locomotives was not appreciably affected by the dust firing auxiliaries, nor was the haulage capacity reduced by the conversion. The requirements of the auxiliaries were 3.7% of the total steam for the Stug combined drive, 4.7% for the AEG, and 6.25% for the Stug separate drive. The service records of the dust and grate fired locomotives may be compared in table 61.

TABLE 61.-SERVICE STATISTICS OF GERMAN DUST AND GRATE FIRED LOCOMOTIVES (1/1/1933 to 31/12/1936)

Class of Locomotive and firing system	Average km per year (based on 100% service factor)	Average ton/km per year (x 10,000)	Average train load (including locomotive) tons (metric)
G82 AEG dust	50,235	3,941	785
G82 AEG grate	57,379	4,557	794
G12 AEG dust	54,280	5,353	980
G12 Stug dust	53.063	5,217	983
G 12 grate.	53,496	6,200	972

The German State Railways specified that the brown coal dust should have the following characteristics:

- Maximum residue on 4,900/cm^2 mesh 20%
- Maximum residue on 900/cm^2 mesh 1%
- Maximum ash content 10%
- Maximum moisture content 14.5%
- Net calorific value not less than 5,000 kcal/kg.

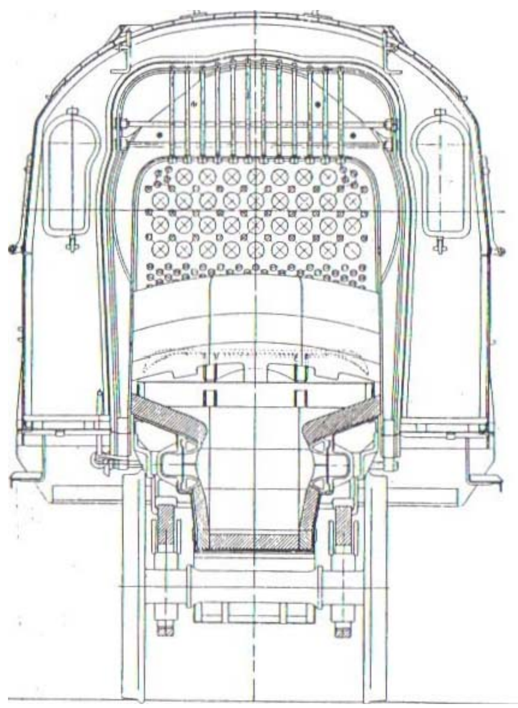
All the converted locomotives were operated in the Halle district until 1938, when six of the G12 class were transferred to Senftenberg district. Typical analyses of the electrically precipitated dust from these two areas are given in table 62.

TABLE 62.
TYPICAL ANALYSES OF THE BROWN COAL DUST USED IN GERMAN LOCOMOTIVES

	Halle district (1931)				Senflenberg district (1938)			
Residue on 4900/cm Mesh	14.73	14.5	15.5	13.6	15.4	26.3	16.6	27.9
Fixed carbon	34.9	31.4	32.0	32.1	36.6	36.5	37.7	38.0
Volatile matter .	42.1	45.3	43.3	44.7	46.2	45.4	46.1	45.6
Moisture	13.3	13.5	15.1	13.5	9.7	11.2	9.5	9.9
Ash	9.8	9.8	9.6	9.7	7.5	6.9	6.7	6.5
Cal. value (net) kcal/kg	5,187	5,198	5,111	5,105	4,920	4,886	4,917	4,897
Ash fusion temperature °C	-	-	-	-	1,315	1,225	1,265	1,265

During the German preliminary tests on stationary locomotive boilers there was apparently little or no ash or slag deposit, but trouble soon appeared with slag on the firebox tube plate in service operation with high boiler loads. The extent of the trouble was dependent primarily on the speed of combustion and the fusion temperature and composition of the ash. Definite improvement followed a re-design of burners to give a finer division of the airdust mixture, which resulted in more rapid combustion and a better opportunity for the ash particles to cool to below fusion temperature (1,250° to 1,295°C) before impinging on the tube plate. A further and very important improvement came from the introduction of about 50% of the combustion air as "secondary air instead of supplying it all from a primary source. It was estimated that the full use of secondary air could effect a reduction of up to 300°C of the flame and slag temperature at the tube plate. However some building up of swallows' nests still took place; steam tube blowers for operation during running were then provided; a device for spraying sand on to the tube plate in cases of bad accumulations was also fitted.

Fir. 498. Section through the firebox of an AEG



When the six G12 dust fired locomotives were shifted to the Senftenberg district the dust used gave rise to some new difficulties. It often fell short of the specified requirements both in heating value and fineness, and there was much fibrous material in it. The coarseness aggravated the formation of swallows' nests, the fibres clogged the burner openings and other troubles arose. After special investigations and consequent modifications in the firing technique, satisfactory operation was reported.

The definite intention in 1936 of the German State Railways to provide additional dust fired locomotives was not fulfilled; the reason appears to have been objections from the Army High Command who considered that such a step would complicate military requirements.

The principal features of the AEG equipment are shown in figs. 498 to 501. A recent account of it is given by Pierson[236].

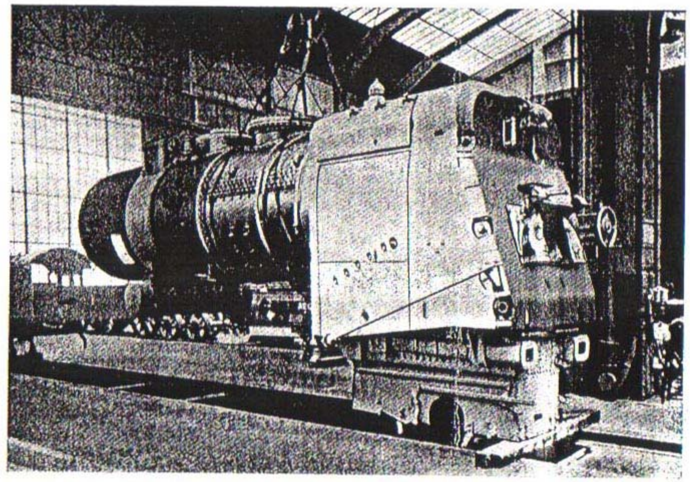


FIG. 499. The AEG coal dust fired locomotive on standing tests, showing burners and ash boxes.

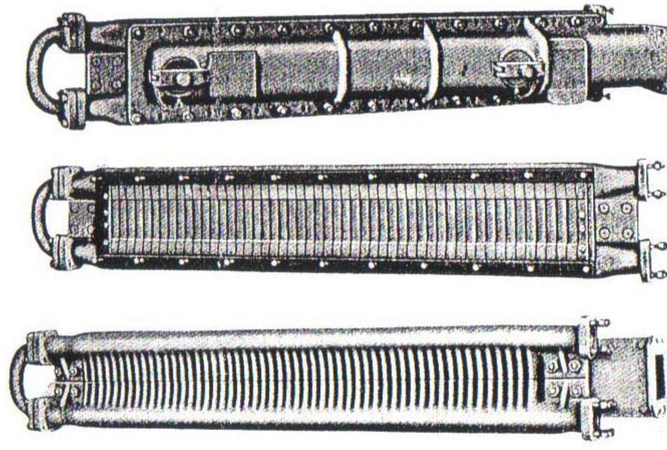


FIG. 500. Views of burners of the AEG dust fired locomotive.

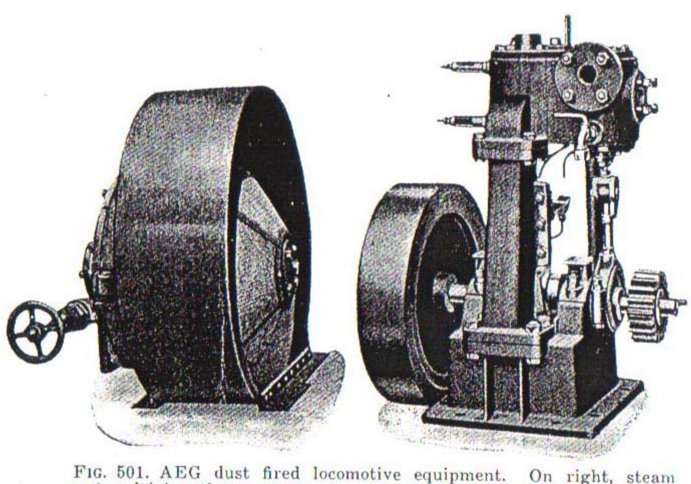


FIG. 501. AEG dust fired locomotive equipment. On right, steam engine driving the screw conveyors; on left, steam turbine and fan.

Features of the Stug equipment as used in the recent Victorian trials are described hereunder. The weight of German opinion is in favour of the Stug design because of its simplicity and lower maintenance costs. Both systems after years of running on brown coal dust showed economic savings compared with grate locomotives firing black coal; the savings ranged from 35 to 57 RM per 1,000 km, brown coal dust costing about 10 RM and lump black coal 23 RM per ton.

The 1946 investigations of Galletly and Chapman[102] became the starting point of the Victorian developments of the last four years. For the first of a series of tests an X class heavy goods locomotive X32 was chosen by the Railways Department because of its large firebox and combustion chamber; these give the necessary furnace volume and flame length. It is fitted with Stug equipment designed and manufactured by the German firm of Henschel and Sohn and was delivered in Melbourne late in 1948; similar equipment on two G12 class German locomotives was successfully in service from 1931 to at least 1944.

The German locomotives were fired with dust electrically precipitated from the drier stacks of briquette factories. The Victorian fuel is being similarly obtained from the drier stacks of the Yallourn briquetting works; it contains about 6% moisture, 2% , ash and has a calorific value (gross) of about 10,400 btu/lb. The Yallourn dust, nearly 50% of which remains on a No. 170 British standard screen, is much coarser than that specified for the German State Railways, but satisfactory results are being achieved with it in the Victorian trials.

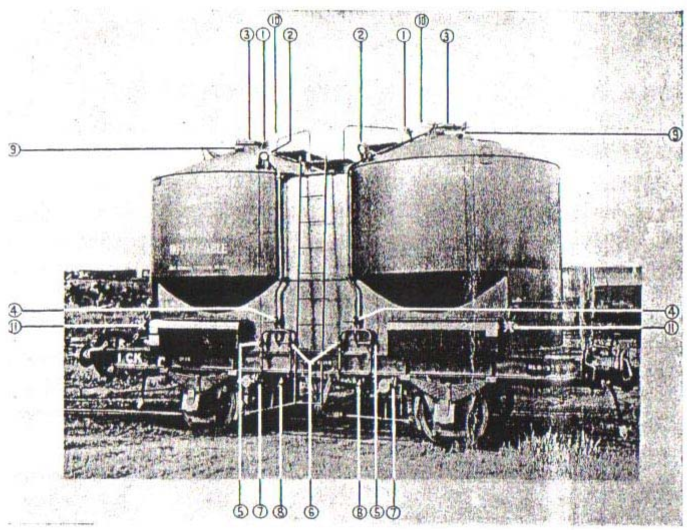


FIG. 502. Sealed tank wagons used by the Victorian Railways Department for transport of brown coal dust; 1 air exhaust cock, 2 pressure gauge, 3 manhole cover, 4 pressure regulating cock, 5 agitator air control cock, 6 discharge control cock, 7 coal dust discharge valve, 8 Westinghouse type air coupling, 9 screwed connector for filter bag, 10 safety valve, 11 CO_2 fire fighting equipment.

In order to provide the small quantity of dust required for the trials, it is being transferred from the briquette factory to the rail loading point about 300 ft distant with a Fuller-Kinyon pump. The supply line is attached to the transport wagon container at connection 9 (fig. 502) and filter bags are attached to connection 3 to permit dust free air to be exhausted from the container during filling operations. Each wagon container is fitted with CO2 fire fighting equipment, which has not needed use during 18 months' operation. Those special purpose sealed CK closed wagons held 14 tons of coal, have a tare of 12.5 tons and are used to transport coal dust from Yallourn to fuelling points. Their design is based on that of wagons used for similar purposes in Germany. They have bottom outlets, are discharged with the aid of compressed air, and have been used also as temporary storage containers from which the locomotive has been directly fuelled (fig. 503). Overhead hoppers of 56 tons capacity from which a locomotive should be refuelled in about ten minutes are to be erected at fuelling points. German coal dust hoppers and wagons being fed from them are shown in fig. 504.

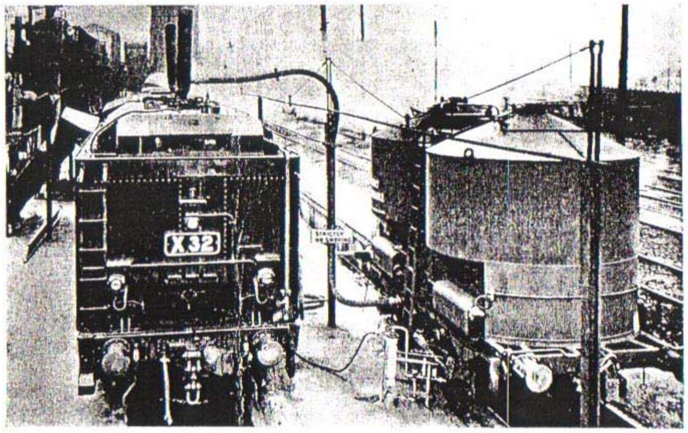


FIG. 503. Victorian locomotive (X32) being fuelled with brown coal dust from sealed special purpose wagon (CK class).

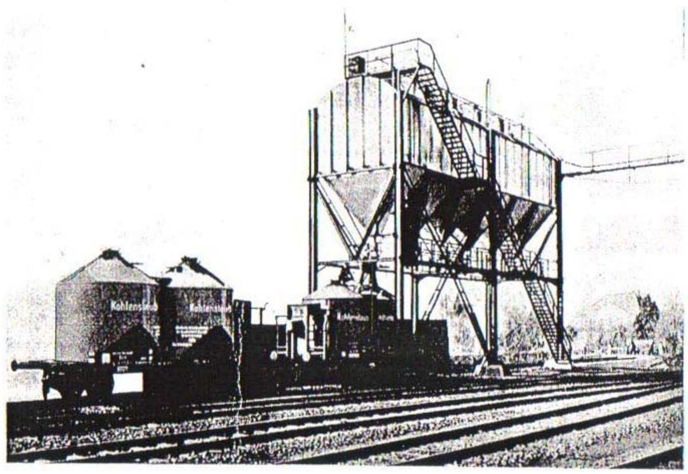


FIG. 504. German brown coal dust storage hoppers filling dust transport wagons.

The firing equipment of X32 is the Stug combined drive. Except for minor details the layout of the tender and firebox and the method of feeding coal dust and air are similar to those of the German installation shown in figs. 505, 506 and 507. In X32 the general arrangement is as shown in fig. 508; firebox details are as in figs. 509, 510 and 511; front and rear views of locomotive and tender as in fig. 512; location of controls as in fig. 513. The tender, which was completely reconstructed on the original underframe and bogies, has a sealed container with a capacity of 766 c.ft or approximately 10 tons 4 cwt of brown coal dust. The container tapers downward to two troughs which house the feed screws. These feed the fuel to two burners which may be operated together or independently with a combined maximum capacity of 4,850 lb/hr. With single burner operation, supply can be regulated satisfactorily down to 750 lb/hr. A 24 hp steam turbine at the rear of the tender (the combined drive) jointly drives the two feed screws and two fans which supply primary air to the burners. The fans have a combined output of 330,000 c.ft/hr at about 12 inch wg pressure. Of the total air about 45% is primary, 40% is supplied under the brick arch, 5% around the fire door and 10% through the fire pan floor (fig. 509). Steam pressure of at least 50 psig is required to drive the turbine; this is obtained initially by a lighting up wood fire or by tapping an auxiliary steam supply; the fuel is then ignited from the wood fire or from a piece of oily waste. An important safety feature is an interlock between the turbine steam supply valve and the clutch levers of the feed screws; this ensures a good flow of air through the ducts before and after the burners are in use and prevents accumulation of dust in the ducts or fire pan. Until the overhead hoppers are provided, fuelling at depots will continue to be done directly from the CK wagons with the aid of compressed air either from the locomotive or from a shop supply line.

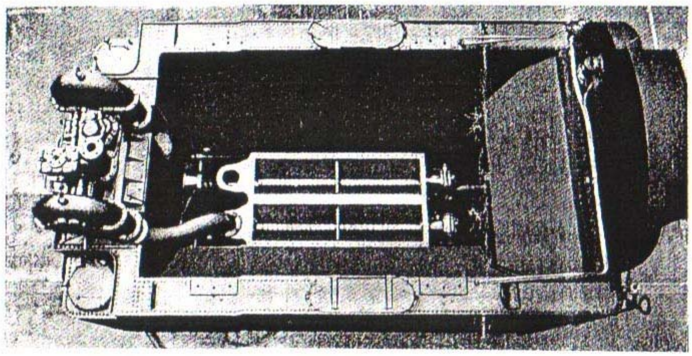


FIG. 505. Stug tender for dust fired locomotive. View shows water tank with the fuel bunker above it removed, conveyor screws at bottom, combined drive on left.

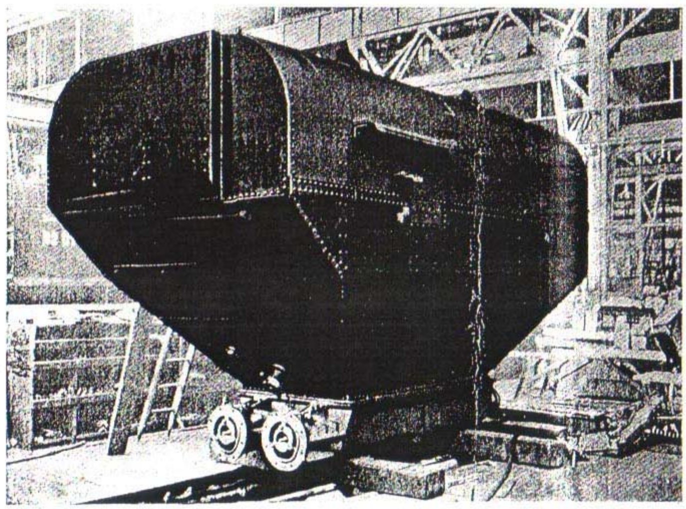


FIG. 506. Stug tender for dust fired locomotive. View shows fuel bunker with conveyor screws at bottom.

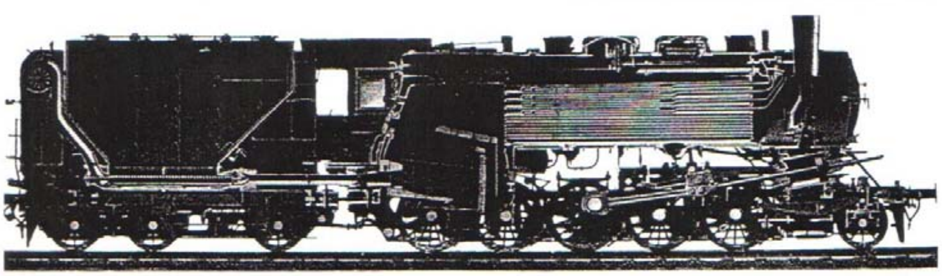


FIG. 507. Longitudinal section view of a German locomotive with Stug equipment for coal dust firing.

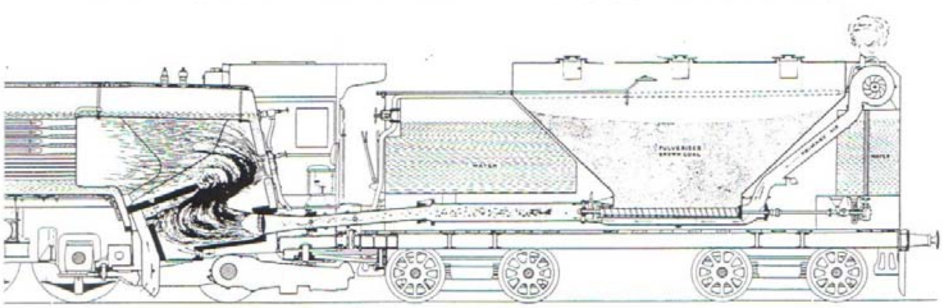


FIG. 508. General arrangement of brown coal dust fired locomotive and tender of the Victorian State Railways, 1950.

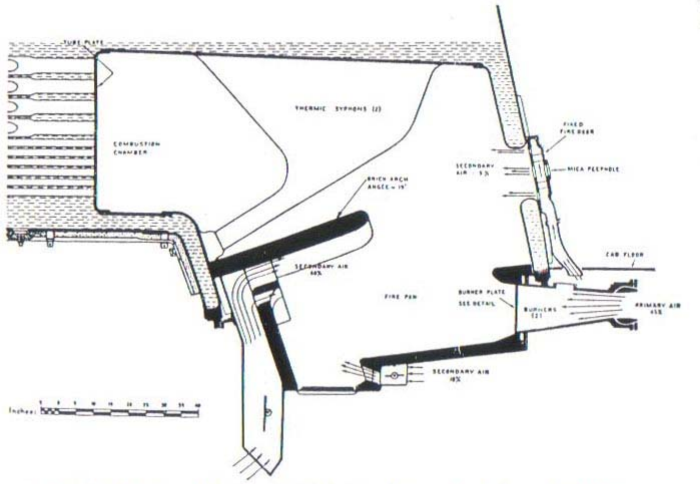


FIG. 509. Firebox details of Victorian brown coal dust fired locomotive, 1950.

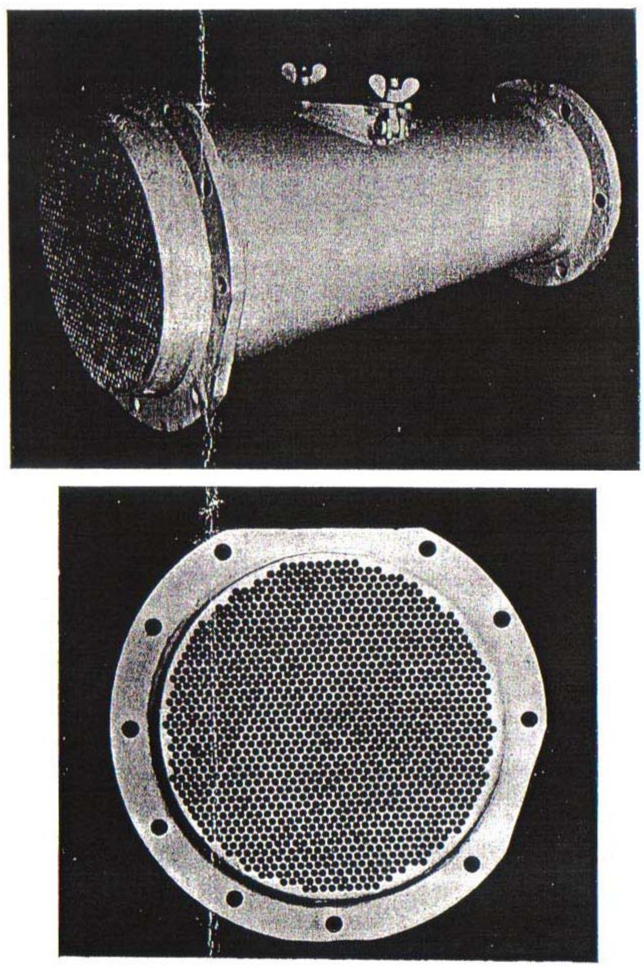


FIG. 510. The Stug burner as used on Victorian locomotive X32.

Tests made on the handling and storage of Yallourn brown coal dust have led the Railways engineers to the following conclusions: it can be transported safely in sealed CK wagons when the loading temperature does not exceed 130°F; the discharge from these wagons into a sealed storage hopper with the aid of compressed air does not induce any tendency to spontaneous combustion; storage of the dust in sealed hoppers at a temperature not exceeding

130°F is quite safe for a period of at least four weeks and probably indefinitely; should spontaneous combustion occur in a storage hopper the sealing of it from air is as effective as the combined effect of sealing and applying CO_2 under pressure; the German practice of using multiple overhead hoppers with gravity discharge can be satisfactorily applied to the fuelling of locomotives; the capacity of individual hoppers should not exceed 28 tons, which is the load of two CK wagons; after filling, each hopper should be sealed until all the coal in it is used and no fresh fuel should be added until the hopper is completely emptied; the maximum storage period in any individual hopper should be limited to two weeks and each hopper should be washed out every two months.

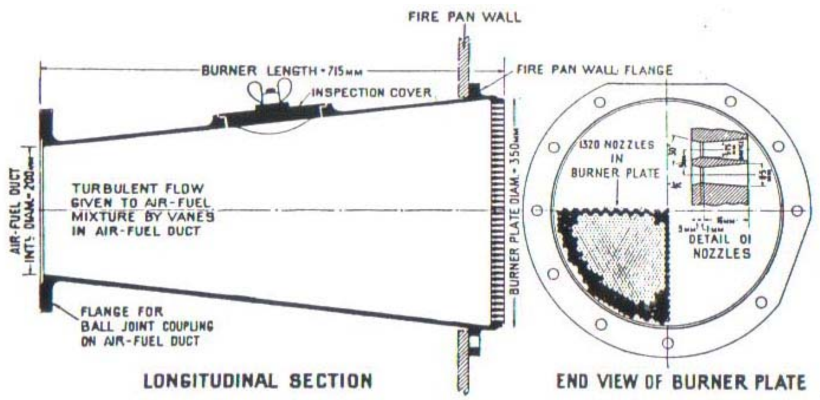


FIG. 511. The Stug burner as used on Victorian locomotive X32.

FIG. 512. Front and rear view of Victorian locomotive and tender X32, converted to firing of brown coal dust.

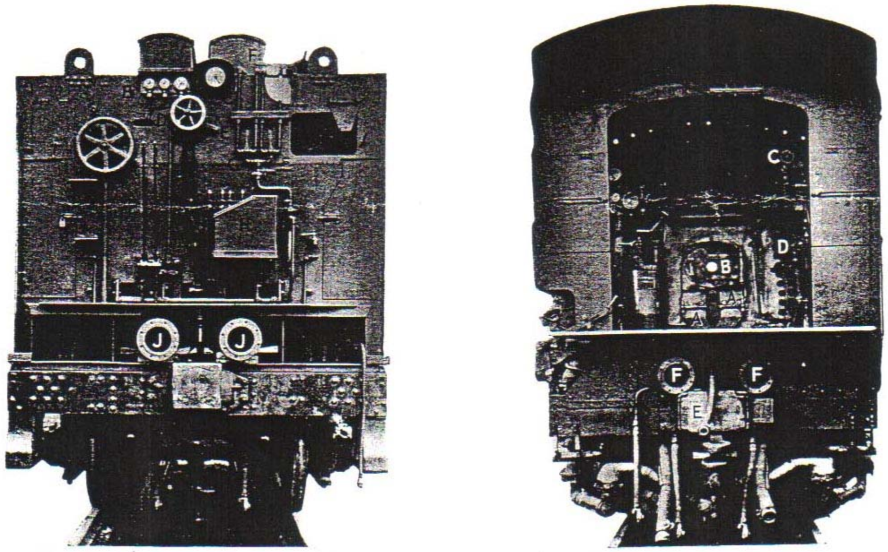


FIG. 513. Victorian pulverised fuel locomotive X32. On left, front view of tender; A levers for operating the two screw conveyors, B fuel bunker pressure gauge, turbine oil pressure gauge, and turbine steam pressure gauge, C turbine revolution counter, D turbine interlocker control valve, E interlocking lever, F fuel bunker level indicator, G fuel bunker turbulence pipes, H sand box, I turbine steam supply, J fuel and air ducts. On right, view of driver's cabin; A secondary air ducts, B firebox door, C turbine steam stop valve, D turbine steam regulating valve, E turbine steam supply, F burners.

Standing tests were initially conducted on the converted X class locomotive (X32) and on an equivalent grate fired unit (X30) burning various classes of black coal. They were followed by comparative dynamometer car road trials. The fuels used had the typical proximate analyses shown in table 63.

TABLE 63 – ANALYSIS OF FUELS USED IN VICTORIAN COMPARATIVE LOCOMOTIVE TESTS

		Yallourn precipitator dust	Black Coals	
			Maitland	Lithgow
Calorific value (gross)	btu/Ib	10,540	13,510	11,200
Moisture ..	%	5.48	2410	3·74
Volatile matter ..	%	46·86	36·05	27·44
Fixed carbon	%	45.90	53.74	48.86
.. Ash	%	1.70	7·81	19.96

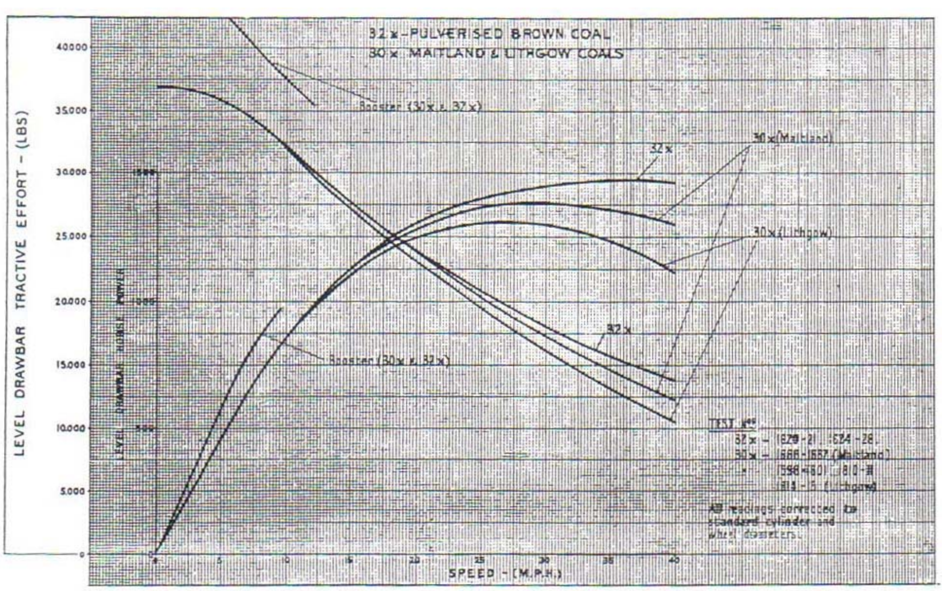


FIG. 514. Dynamometer car tests on Victorian brown coal dust locomotive X32 compared with tests on an X class locomotive burning lump black coal from Maitland and Lithgow, New South Wales.

The trials demonstrated that the brown coal dust is a satisfactory fuel for suitably equipped locomotives with fireboxes approximating those of the X class. Other Victorian locomotives fulfilling this requirement arc classes N, R, S and H, totalling 191 locomotives on hand or on order, which, if fired with brown coal dust will have an annual fuel demand of about 250,000 tons. The maximum power developed by these engines on brown coal dust should at least equal that which could be produced with Lithgow and Maitland coals (fig. 514). Average round trip efficiency figures obtained for the series of tests on through goods trains on the Melbourne-Bendigo line (about 100 miles) with long and heavy gradients in both directions are given in table 64.

TABLE 64 – AVERAGE ROUND TRIP FIGURES FOR THE SERIES OF TESTS ON THE MELBOURNE-BENDIGO

	X32 Yallourn brown coal dust	X30-Grate		
		Maitland	Lithgow	Wonthaggi
Load in tons and No. of vehicles	652 = 40	651 = 38	652=39	649 = 33
Running time .. minutes	472	462	501	503
Average boiler pressure psig	204	207	202	202
Average superheated steam temperature °F	635	611	612	605
Equivalent evaporation lb/lb coal	8·12	9·18	7.74	7.53
Work units per lb coal $2x10^6$ftlb	0·186	0·220	0·180	0.172
Calorific value of fuel (gross)btu/Ib	10.425	13.553	11.489	11.032
Boiler efficiency .. %	75.5	135·8	65·4	66.2
Evaluation-tons of pulverized brown coal equivalent to I ton of black coal on basis of -				
(a) Equivalent evaporation		1·13	0.95	0.93
(b) Work units per lb coal		1·18	0.97	0.93
(c) Calorific value ..	``	1.30	1 10	I .06

For the same service, the consumption of the dust fuel was about 4 to 7%. lower than with grate fired Lithgow or Wonthaggi coals, and about 15'% higher than with grate fired Maitland coal Throughout the trials no trouble was experienced with the operation of dust firing equipment. The train crews quickly became expert in its operation and much appreciated the following advantages over black coal grate firing without any associated disabilities: improved cab cleanliness; reduced noise; no hand firing and fire cleaning; uniformity of fuel; better control; improved steaming; elimination of smoke, spark hazard and spark arrester enabling him to concentrate on his firing technique and other operational details.

The formation of swallows' nests on the tube plates was less with the Yallourn dust than is usual in Germany. In this respect. it was found that there should not be trouble provided that a good coarse sand is applied at every 25 to 30 miles and that the tubes are manually cleaned every 3,000 miles.

Throughout the trials and subsequent service operation of X32, extending over two years, no case of an explosion has been experienced. The burners can be re-lit without difficulty from the hot furnace after a shutdown of up to three-quarters of an hour. No case of spontaneous combustion has occurred, either in the transport of fuel in the CK wagons, during its storage in them, or in the locomotive bunker except under …… taken against this hazard was to completely empty the wagons before returning them to Yallourn for refilling and to keep them sealed during the transport and storage period. At one stage during a prolonged transport strike the fuel was stored for a period of 8 weeks in a transport wagon and in the locomotive bunker without trouble.

A feature of the tests was the complete control over the dust firing to meet the most severe demands. This was particularly noticeable on booster gradients, when the requirements of both the booster and the engine could be met without trouble for unlimited periods and top steam pressure could be maintained easily against the action of the injectors. Almost perfect combustion conditions were maintained even on heavy and long gradients (fig. 515). There was at all times absence of smoke; the main concern was to limit excess air. Typical gas analyses are given in Table 65.

TABLE 65.-TYPICAL GAS ANALYSES IN DYNAMOMETER CAR TRIALS IN LOCOMOTIVE X32 FIRED WITH YALLOURN BROWN COAL DUST			
Speed mph	**Gas analysis**		
	CO_2 %	**O_2 %**	**CO %**
10	9.2	10.4	0.4
11	14.2	4.5	0.2
12	14.4	4.8	Nil
15	16.0	3.0	0.2
15	9'4	10.1	Nil
20	11.2	8.1	Nil
20	11.2	8-2	Nil
25	14.2	5.0	Nil
25	15.2	3.8	Nil
25	12.2	6.2	0.8
30	15.7	2.8	Nil
30	9.4	10.2	0-6
35	15.7	3.5	0.2

Since the completion of the dynamometer car tests X32 has operated for more than 12 months in general service, hauling both goods and passenger trains with 20 rostered crews. Throughout it has given every satisfaction and no delay has yet been debited to the firing equipment.

In view of the satisfactory results achieved with this locomotive it has been decided to convert the other 28 locomotives of this class by 1953-4 when their fuel demand of 60,000 tons per annum of precipitated dust should be available. These locomotives will operate throughout the State; for this, provision of 130 CK class transport wagons and 10 refuelling points will be necessary. With the current prices of fuels available to Victoria, the conversion of this group will show a substantial saving after allowing for the cost of conversion and the provision of the wagons and hoppers.

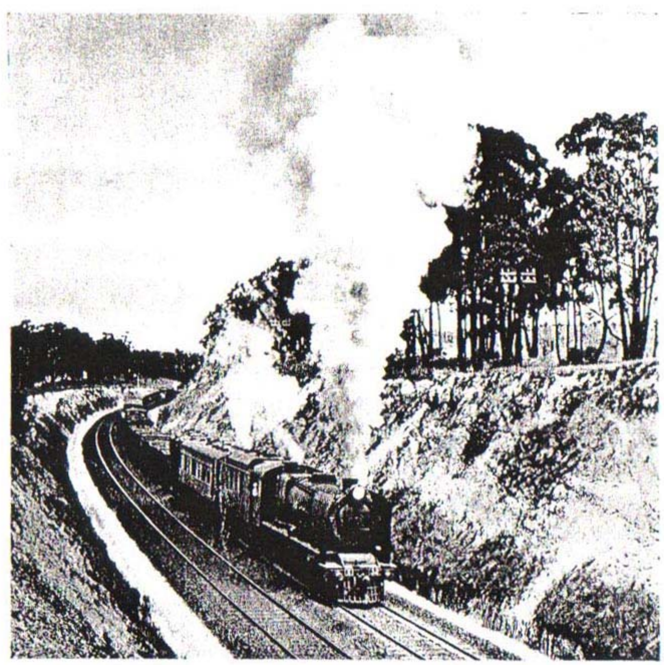


FIG. 515. Victorian brown coal dust fired locomotive hauling a load of 656 tons on a long 1 in 52 gradient at Macedon. Note the clear funnel exhaust and steam valves blowing.

An N class light line goods locomotive is now being converted for tests in that particular class. Two 56-ton overhead fuel storage hoppers, one at Yallourn and the other at North

Melbourne, will shortly be installed. The conversion of further groups will be considered as soon as assurance can be given that fuel supplies will be made available for them.

Much thought has been given by Germans and others to the practicability of pulverising coal on the locomotive tender, thereby making it unnecessary to provide large-scale operations either for numerous special purpose dust wagons or, alternatively, for pulverising plants at refuelling stations. In Germany particularly this matter has received a great deal of attention but so far a satisfactory solution has not been achieved. The main objections to schemes considered to date are associated with the tender. They are: additional weight and space; increased power demand; additional capital, servicing and maintenance costs; and reduced reliability of the locomotive. It may be presumed that there will be further effort to counter these disadvantages. In areas where dust is electrically precipitated the considerable expense of pulverising is avoided. In areas where pulverising plant must be used, either in stationary plants or on the tender, the local conditions in some cases may justify further consideration of the latter alternative.

Under the auspices of the Locomotive Development Committee of Bituminous Coal Research Inc. large-scale research into the development of a coal fired gas turbine locomotive has been in progress in the United States of America for several years. It is expected that the first locomotive of this type will be ready for service trials in a year or so. The same objective is receiving much attention also in Germany where special emphasis is laid on the use of brown coal rather than black coal[236b]. The coal consumption of such a locomotive is estimated to be about one-third of that of a steam locomotive. The low ash content of much Victorian brown coal should make it ideal for the coal fired gas turbine. It may be expected that some years must elapse before such a major engineering project, promising though it appears to be, can be matured to the stage of large-scale commercial use. It is of special interest that a pulverising tender is one of the main features in the experimental designs of the coal fired gas turbine locomotive[236b].