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BULLETIN No.3.

BRITISH RAILWAYS.

Mechanical & Electrical Engineer's Department.

Performance and Efficiency Tests with Live Steam Injector.

LONDON MIDLAND REGION - CLASS 4.
2 CYL., 2-6-0 MIXED TRAFFIC LOCOMOTIVE.

October, 1951.

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OCTOBER 1951.

List of Graphs.

BLIDWORTH COAL.

Performance Data.

Design Data.

Continued ....

BEDWAS COAL.

Performance Data.

Design Data.

Continued .....

LILLESHALL COAL.

Performance Data.

Design Data.

EXAMPLES OF INDICATOR CARDS.

Representative Indicator Cards. Full Regulator Working.

INTRODUCTION.

This class of engine was originally designed by the former L.M.S. Railway in 1947 with a double chimney and blast pipe. Road tests carried out by that railway had indicated no advantage of this arrangement for the duties normally undertaken, in comparison with a single chimney, and this single chimney was fitted to later built engines including a series completed after nationalisation for the Eastern and North Eastern Regions. It is one of these latter engines which was the subject of the tests herein described.

It was intended that this class of engine should form the basis of one of the 12 Standard types of steam locomotives for British Railways, and the tests were, therefore, undertaken in successive stages. First of all it was desired to ascertain what changes if any were necessary in fundamental design, and as will be seen, certain simple modifications to blast pipe, chimney and ashpan improved the maximum continuous steam production rate by 89%. Then data was obtained on the level of efficiency of the engine thus improved, and on the price in terms of coal and water of working at all the different rates of which the engine is capable.

The presentation of the data in this report is divided into two main parts.

The first defines the relationship between coal as fired, water as drawn from the tender, tractive effort and horse-power both as available at the drawbar, data directly applicable to the immediate commercial purpose of examining train loadings and schedules to obtain reduction in fuel consumption by working the locomotive where possible nearest their point of maximum operating efficiency.

The second part concerns itself mainly with thermal efficiency, giving data on a basis of indicated power covering boiler and cylinder efficiencies, factors of more importance in locomotive design.

The tests were carried out under the direction of Mr. R.A. Riddles, Member (Mechanical & Electrical Engineering) Railway Executive, the work being controlled by the Locomotive Testing Committee consisting of :-

Mr. E.S. Cox (Chair)	- Executive Officer (Design) R.E.
Dr. H.I. Andrews	- Research Dept., Derby.
Mr. D.R. Carling	- Superintending Engineer, Locomotive Testing Station, Rugby.
Mr. C.S. Cocks	- L.M.R. Derby.
Mr. S.O. Ell	- W.R. Swindon.
+ Mr. R.F. Harvey	- Chief Officer (Motive Power) R.E.
Mr. T.M. Herbert	- Director of Research, R.E.
Mr. R.G. Jarvis	- S.R. Brighton.
Mr. B. Spencer	- E.& N.E.R. Doncaster.

+ Replacing Mr. F.W. Abraham, Superintendent of Motive Power, L.M. Region as from 14th September, 1951.

II. NATURE OF THE TESTS.

The boiler and cylinder performances and efficiencies were established in the first instance by tests on the stationary testing plant where also the draughting arrangements were examined, modified and proved.

The stationary plant tests were followed by tests on the road on the Controlled Road Testing System. On these, the boiler and cylinder performances which had been established on the stationary plant were reproduced and their efficiences confirmed, and the coal and steam rates were related to horsepower at the drawbar.

The initial tests on the stationary plant indicated that the capacity of the boiler was severely limited by the designed single chimney draught arrangement for it was found impossible to produce continuously more than 9,000 lb. of steam per hour. The chimney dimensions were, therefore, modified by fitting a liner within the existing chimney although no alteration was made to the existing blast pipe orifice which is 4⅜" in diameter. The special liner reduced the choke diameter of the chimney from 1'-2¼" to 1'-0¾" and made the taper of the sides 1 in 14, with a minimum height above the choke of 2' - 4". The trials proper were all carried out on this modification and observations made showed that the draught at the choke invariably exceeded twice the final smokebox vacuum.

The maximum continuous rate of evaporation that could be maintained for the stipulated test period was raised to 17,000 lb/hr on each of the three coals tested, this being about 1500 - 2000 lb/hr less than the limit imposed by the size of the grate. The maximum rate of 17,000 lb/hr given above was in each instance obtained with the self cleaning smokebox plates in position.

The lowest rate of evaporation on which tests were made was just over 6,000 lb/hr.

The speed range covered was 15 to 50 m.p.h. the upper limit being imposed by the effect of mechanical disturbing forces on the fire. A major factor in this effect is considered to be the slope of the grate, which, being 1 in 4 continuous, is somewhat greater than usual.

Retaining the modified draught arrangements the controlled road tests were conducted at rates of evaporation ranging between 8,000 and 16,800 lb/hr, with loads up to 534 tons behind the tender. The cylinders were indicated on all tests.

On the controlled road tests the effect of the mechanical disturbing forces were experienced also and to an extent that caused break-down in the coal-steam relationship when the speed was allowed to exceed 50 m.p.h. for more than a short time.

This effect was successfully overcome for testing purposes by increasing the load relative to the steam rate, and by allowing the brakes to drag on some down gradients whilst the steam rate to the cylinders was maintained.

The superheater arrangement as designed is one in which elements of 1¼ ins. outside diameter are contained in flue tubes of 4.733 ins internal diameter, giving a free gas area; gas swept surface ratio (A/S) of 1/274. This is incorporated in a tube system for which the corresponding ratio of the small tubes (a/s) is 1/374. Because of this difference it was decided to repeat the stationary plant tests on Blidworth coal with the $1\frac{1}{4}$ ins. diameter elements replaced by others of $1\frac{3}{8}$ ins. outside diameter for which the A/S ratio is 1/290.

The effect of the change was reflected in the temperatures of the gases discharged from the superheater flues, but the ultimate effect on mean gas temperature and boiler efficiency could not be distinguished in the normal scatter of the points which define this characteristic.

No significant effect of the larger element was observable on admission steam temperatures.

II. METHOD OF TESTS.

As mentioned previously, the tests were carried out in two parts - as Stationary Plant Tests and as Controlled Road Tests, the first taking place on the Swindon Locomotive Testing Plant and the second on the Wantage Road - Filton section of the Western Region, with the Western Region Dynamometer Car as the testing unit.

Stationary Plant Tests.

These were conducted at constant rates of evaporation and combustion, some at constant speed but the majority at variable speed. Coal and water rates were established by direct measurement by the Summation of Increments Method, in conjunction with which the Swindon Steam Flow Indicator was used to control the rates of evaporation and combustion on the variable speed tests. This instrument was also used in both constant and variable speed tests for relating i.h.p. to the mean steam rate.

Controlled Road Tests.

The controlled road tests employed the same methods of measurement of and control over the rates of evaporation and combustion as the variable speed, stationary plant tests. Reference to Bulletin No.1 should be made for a detailed description of these methods and their application.

On the road tests the boiler and cylinder performances established on the stationary plant tests were successfully reproduced and their efficiencies confirmed. The coal and steam rates were related to work at the drawbar without difficulty at all rates of evaporation chosen for these tests and for all speeds from 15 to 50 m.p.h. in each rate.

Graph 5 shows the running of one of these tests in diagrammatic form.

IV. TEST ARRANGEMENTS.

The steam rates and speeds at which the engine was tested fairly covered the range between the limits in evaporation and speed given in the previous subsection. On the stationary plant the test period proper was approximately 90 minutes on the average; it was not less than 60 minutes at the highest rates, whilst it exceeded 120 minutes on the lowest. On the controlled road tests the periods were all of approximately 60 minutes of unrestricted steaming on stabilised conditions.

LOCOMOTIVE.

The locomotive selected for the tests was No.43094, which since it was built in December 1950, had run about 6,000 miles. In the interval it had received neither piston and valve examination nor had it been into shops for repairs. By the end of the tests the mileage had increased by 3240.

A diagram giving leading particulars of the locomotive is given on another page. Additional particulars of interest are:-

<table>
<tr><th rowspan="2"></th><th colspan="2">Superheater Elements</th></tr>
<tr><th>$1\frac{1}{4}$ ins.dia.</th><th>$1\frac{3}{8}$ ins.dia.</th></tr>
<tr><td>Free area through grate as a percentage or nominal grate area</td><td colspan="2">33</td></tr>
<tr><td>Free gas area : gas swept surface ratios
Superheater (A/S)</td><td>1/274</td><td>1/290</td></tr>
<tr><td>Small tubes (a/s)</td><td colspan="2">1/374</td></tr>
<tr><td>Free area through tube system as a percentage of nominal grate area.</td><td>17.0</td><td>16.3</td></tr>
<tr><td>Free area through superheater as a percentage of free flue area.</td><td>55.3</td><td>53.3</td></tr>
<tr><td>Clearance volume of cylinders as a percentage of swept volume.</td><td colspan="2">11.2</td></tr>
</table>

The valves are actuated by Walschaert Motion; the designed valve setting is shown in a table on another page.

The locomotive is provided with live steam injectors only.

As designed, the locomotive is equipped with a front damper only. A back damper was fitted at the Testing Plant for experimental purposes.

The locomotive was fitted with a rocking firegate having L.M.S. pattern integral firebars with longitudinal slots.

COALS.

The engine was tested on three coals:

Bedwas, a Grade 2A Welsh coal
Blidworth, a Grade 2B hard coal
Lilleshall, a Grade 2B hard coal.

Of these Blidworth is a coal common to all locomotive testing. Lilleshall is a coal which had proved troublesome in service.

The Bedwas coal in appearance was fairly bright soft and friable and its size varied from 3'0" in greatest dimension to dust, whilst the maximum size of the main bulk was about 1'6".

Blidworth was rather dull in appearance, very hard with patches of bright laminar structure. Its size varied from 8"

	BEDWAS		BLIDWORTH		LILLESHALL	
	As received	Dry	As received	Dry	As received	Dry
Calorific Value:						
Calories per 1 g.	7,805	7,893	6,977	7,568	7,031	7,577
British Thermal Units per 1 lb.	14,050	14,210	12,560	13,620	12,660	13,640
Pounds of water at 212°F converted into steam at the same temperature by 1 lb. of coal.	14.53	14.70	12.99	14.09	13.09	14.11
Proximate Analysis:						
Moisture %	1.1	-	7.8	-	7.2	-
Volatile matter, less moisture %	26.6	26.9	35.0	38.0	39.9	43.1
Fixed carbon %	64.3	65.0	52.0	56.4	48.2	51.9
Ash %	8.0	8.1	5.2	5.6	4.7	5.0
Total sulphur %	0.65	0.65	0.78	0.85	0.90	0.97
Coke :- Character	Fairly hard, porous		Hard, porous		Hard, porous	
Ratio of volume to that of coal	1.0 : 1.5		1.0 : 1.0		1.0 : 1.0	
Ash	Buff, grey-tinted.		Buff, pink-tinted.		Grey, pink-tinted	

in greatest dimension to 2" minimum dimension with an average size of 6"

Lilleshall was generally fairly bright in appearance, hard with a laminar structure, its size varying from 4'0" maximum to 1" minimum with an average dimension of 10".

In each coal the various samples showed little variation in calorific value and proximate analysis; representative values and analyses are given on a separate page.

Owing to the friable nature of Bedwas, in common with other Welsh coals, and the effect of fine coal on boiler efficiency, it was arranged that each increment of coal as bagged and weighed contained 8% of fines. This was generally less than the proportion of fines in the coal as fired, as the coal was subject to further breakdown by the fireman after the increment had been placed at his disposal.

OBSERVATIONS.

The method of testing and frequent sampling and analysis of the products of combustion imposed a rigid control over the frequency of firing and quality of combustion.

The firebed for Bedwas was thicker than for the hard coals at the same rate of firing, the depths being roughly in the ratios of the proportions of fixed carbon in the coal fractions. This was reflected in the respective resistances of the firebeds.

Whilst Bedwas and Blidworth could be burnt with equal efficiency the same efficiency could not be reached at the same firing rate with Lilleshall, especially in the most usual working range of the locomotive. Lilleshall proved troublesome with smoke and the production of carbon monoxide from which the other two coals were practically free at all rates of evaporation.

Owing to the tendency of the fire to move forward, firing had to be confined mostly to the rear of the grate.

A more even air distribution over the grate was obtainable when the experimentally fitted back damper was used in preference to the front. Its adjustment was much less critical in its effect on the loss of fuel from the grate, especially in the middle and low ranges of the firing rate. The values given for boiler efficiency in these ranges apply to the use of the back damper.

The resistances through the self cleaning plates of the smokebox accounts for 13% of the total draught loss at the maximum rates of evaporation obtained. Nevertheless reference to graphs 4, 25 and 45 shows that it has been possible to position the practical limit of the boiler (17,000 lb. of steam per hour) where the curves of coal per drawbar horsepower hour turn sharply upward, separating by so doing the economic and uneconomic ranges of the engine. This rate of evaporation was the highest at which a balance could be continuously maintained between steam production and demand; since it depended on the efficiency of the draught arrangement, it has been marked "Front End" limit on the graphs. Another limit - the "Grate" limit - is marked on the graphs; at this limit no increase in steam production with respect to firing rate is obtainable even if the air necessary for combustion can be supplied. With the self-cleaning plates in position, the "Grate" limit was not, of course, reached in the tests, and the values given (18,500 to 19,000 lb. of steam per hour according to the type of coal) have been obtained by extrapolation of the boiler efficiency characteristics.

Although the draught needs of Bedwas are higher for the same firing rate than the hard coals, it was possible to reach the same maximum rate of evaporation because the firing rate of Welsh coal was less at this rate due to its higher calorific value.

Superheat was measured in the exhaust from 60°F at the lower rates of working to 130°F at the higher. Relative to the admission steam temperature and cut-off, these are higher than those obtained in tests of other locomotives. This feature is considered indicative of leakage of steam past the pistons to an unusual extent in relation to the recorded mileage and has affected the cylinder thermal efficiency to some extent.

Leakages in the firebox - mainly around stays in the fire area - needed continual attention during the stationary plant stage of testing. After this a thorough repair was effected and there was no recurrence of the trouble during the road tests.

On the road tests the engine was mechanically very noisy and violent oscillations were recorded when the speed reached and exceeded 60 m.p.h. This, however, does not accord with the general reputation of this class of engine in respect to riding qualities.

The various defects which made themselves felt during the course of the tests are primarily connected with standards of construction and maintenance and are not, other than the slope of the firegrate, inherent in the design so far as can be judged from the performance of these engines elsewhere.

The effect has been that the test results herein described are representative of a locomotive of this class in somewhat less than first class conditions.

APPLICATION OF TEST RESULTS TO OPERATING CONDITIONS.

As indicated in the introduction, the main purpose of these tests was to provide data on which most economical working of the locomotive could be based, consistent with meeting traffic requirements.

There is no reason to think that in general present-day schedules and train loads based upon long standing practice and experience do not allow economical locomotive operation. But since in the testing equipment now available to the Railway Executive there is means of finding accurately the rate of coal range, it will clearly be of some value to examine present schedules and loads to check that they are in fact within the most economical range in their entirety and if not, whether by adjustments over particular sections acceptable to the Operating Department, they could not be so modified as to bring about a reduction in coal consumption. Similarly proposals for new or accelerated timings can be examined in relation to their cost in coal.

The manner in which the data contained in this Bulletin can be applied for the above purpose has been set out in full in Bulletins Nos. 1 and 2.

COMPARISON WITH PREVIOUS BULLETIN.

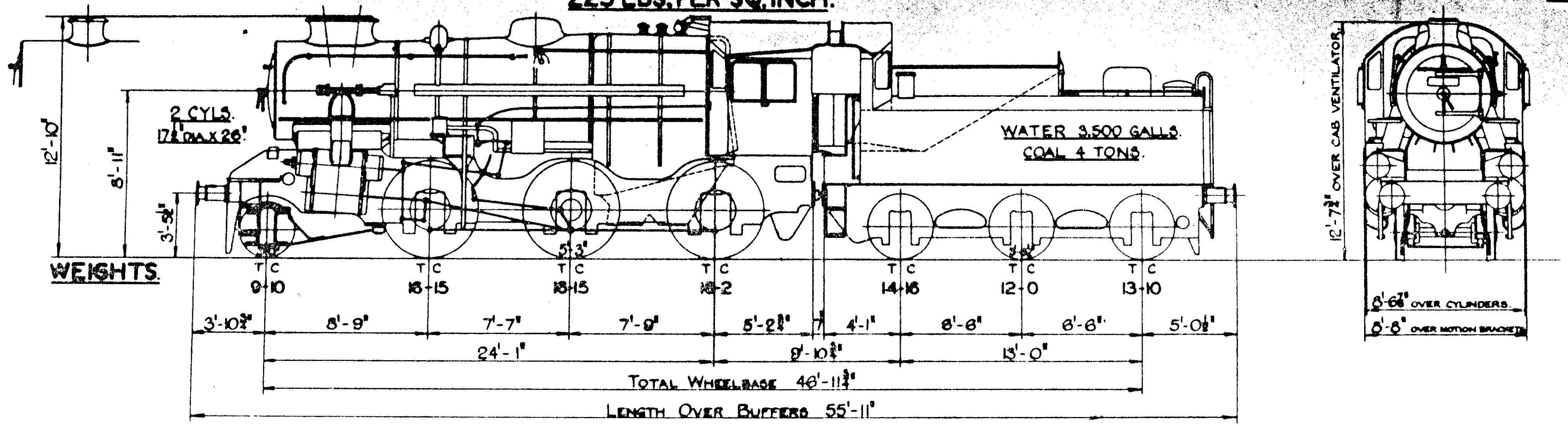
In comparing the results of this engine with those of the W.R. 'Hall' and E. & N.E. B 1 classes described in Bulletins Nos. 1 and 2, it is necessary to make allowance for the absence of the exhaust steam injector with its well marked economy in water and coal. Also for the presence in the smokebox of self-cleaning plates and spark arrester wire netting, features in which operating advantages are paid for by some reduction in steam production with the available draught.

NOTCH	ANGLE	INCHES	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D
75	29 1/2	6 7/16+1/64	1/4+1/64	1/4-1/64	1/32	1 21/32+1/64	1 23/32	3/32+1/64	77·3	71·6	5·7	15·4	18·2	2·8	92·7	89·8	2·9	146	144	2	90·9	93·6	2·7	3 11/32	3 7/32+1/64	[illegible]
70	25	5 25/32+1/64	1/4+1/64	1/4-1/64	1/32	1 11/32	1 7/16+1/64	3/32+1/64	71·2	66·1	5·1	19·3	21·2	1·9	90·5	87·3	3·2	141	140	1	88·8	91·7	2·9	3+1/64	2 29/32	[illegible]
60	19 3/4	5 1/32+1/64	1/4+1/64	1/4-1/64	1/32	31/32	1 1/16+1/64	3/32+1/64	60·7	57·4	3·3	26·0	25·8	·2	86·7	83·2	3·5	134	134	0	85·0	88·2	3·2	2 5/8+1/64	2 17/32	[illegible]
50	16	4 17/32+1/64	1/4+1/64	1/4-1/64	1/32	23/32+1/64	13/16	1/16+1/64	50·4	48·8	1·6	32·2	30·3	1·9	82·6	79·1	3·5	127	128	1	81·2	84·5	3·3	2 3/8	2 9/32+1/64	[illegible]
40	12 3/4	4 3/16+1/64	1/4+1/64	1/4-1/64	1/32	9/16+1/64	5/8	1/32+1/64	40·7	40·7	-	37·6	34·2	3·4	78·3	74·9	3·4	121	122 1/2	1 1/2	77·3	80·4	3·1	2 3/16	2 1/8+1/64	[illegible]
30	9 3/4	3 29/32+1/64	1/4+1/64	1/4-1/64	1/32	7/16+1/64	15/32	1/64	30·8	31·4	·6	42·0	38·6	3·4	72·8	70·0	2·8	113 1/2	116 1/2	3	72·4	75·5	3·1	2 3/32	2+1/64	[illegible]
25	8	3 25/32	1/4+1/64	1/4-1/64	1/32	3/8+1/64	3/8+1/64	-	25·4	25·9	·5	43·8	40·6	3·2	69·2	66·5	2·7	108 1/2	112 1/2	4	69·3	72·1	2·8	1 15/16+1/64	1 15/16+1/64	[illegible]
20	6 1/4	3 21/32+1/64	1/4+1/64	1/4-1/64	1/32	11/32	5/16+1/64	1/64	20·6	20·7	·1	44·7	42·3	2·4	65·3	63·0	2·3	104	108	4	66·0	68·5	2·5	1 7/8+1/64	1 29/32	[illegible]
15	4 1/4	3 19/32	1/4+1/64	1/4-1/64	1/32	5/16	9/32	1/32	15·3	14·7	·6	44·7	43·3	1·4	60·0	58·0	2·0	97 1/2	102 1/2	5	61·1	63·3	2·2	1 27/32	1 7/8	[illegible]
10	1 3/4	3 17/32	1/4+1/64	1/4-1/64	1/32	9/32	1/4	1/32	10·5	9·4	1·1	43·1	42·1	1·0	53·6	51·5	2·1	90	95	5	54·8	56·9	2·1	1 13/16	1 27/32	[illegible]
0	0	3 1/2	1/4+1/64	1/4-1/64	1/32	1/4+1/64	7/32+1/64	1/32	8·0	6·8	1·2	41·3	40·2	1·1	49·3	47·0	2·3	85	90	5	50·3	52·7	2·4	1 25/32+1/64	1 13/16+1/64	[illegible]

BACKWARD GEAR

NOMINAL CUT-OFF		TRAVEL IN	LEAD IN INCHES			PORT OPENING IN INCHES			CUT-OFF %			EXPANSION %			RELEASE %			ANGLE OF RELEASE DEGREES			COMPRESSION %			EXHAUST TRAV[EL] IN INCHES		
NOTCH	ANGLE	INCHES	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D	F	B	D
0	0	3 1/2	1/4+1/64	1/4-1/64	1/32	1/4+1/64	7/32+1/64	1/32	8·2	6·8	1·4	42·1	41·2	·9	50·3	48·0	2·3	87	91 1/2	4 1/2	51·4	53·8	2·4	1 25/32+1/64	1 13/16+1/64	[illegible]
10	1 1/2	3 17/32	1/4+1/64	1/4-1/64	1/32	9/32	1/4	1/32	10·4	9·2	1·2	43·9	42·6	1·3	54·3	51·8	2·5	91 1/2	96	4 1/2	55·0	57·6	2·6	1 13/16	1 27/32	[illegible]
15	4	3 9/16+1/64	1/4+1/64	1/4-1/64	1/32	9/32+1/64	9/32	1/64	15·3	14·2	1·1	45·6	43·7	1·9	60·9	57·9	3·0	99	103	4	61·2	64·1	2·9	1 27/32	1 27/32+1/64	[illegible]
20	6 1/4	3 21/32	1/4+1/64	1/4-1/64	1/32	5/16+1/64	5/16+1/64	-	20·7	19·8	·9	45·6	43·1	2·5	66·3	62·9	3·4	106	109	3	65·8	69·2	3·4	1 7/8+1/64	1 7/8+1/64	[illegible]
25	8	3 3/4	1/4+1/64	1/4-1/64	1/32	3/8	3/8	-	25·5	24·5	1·0	44·3	41·7	2·6	69·8	66·2	3·6	110	112 1/2	2 1/2	68·9	72·6	3·7	1 15/16	1 15/16	[illegible]
30	9 1/2	3 27/32	1/4+1/64	1/4-1/64	1/32	13/32+1/64	13/32+1/64	-	30·0	28·8	1·2	42·8	40·1	2·7	72·8	68·9	3·9	114	116	2	71·5	75·5	4·0	1 31/32+1/64	1 31/32+1/64	[illegible]
40	12 3/4	4 3/32	1/4+1/64	1/4-1/64	1/32	17/32	9/16	1/32	40·4	38·5	1·9	37·9	35·9	2·0	78·3	74·4	3·9	121 1/2	122 1/2	1	76·6	80·4	3·8	2 1/8	2 3/32	[illegible]
50	16	4 3/8+1/64	1/4+1/64	1/4-1/64	1/32	21/32+1/64	23/32	1/32+1/64	50·0	47·0	3·0	32·2	31·3	·9	82·2	78·3	3·9	127 1/2	127 1/2	-	80·4	84·0	3·6	2 9/32	2 7/32+1/64	[illegible]
60	20 1/4	4 27/32+1/64	1/4+1/64	1/4-1/64	1/32	7/8+1/64	31/32	1/16+1/64	60·1	56·2	3·9	26·0	26·5	·5	86·1	82·7	3·4	134	134	-	84·5	87·6	3·1	2 17/32	2 7/16+1/64	[illegible]
70	26 1/4	5 9/16	1/4+1/64	1/4-1/64	1/32	1 7/32	1 11/32	1/8	70·1	66·0	4·1	19·5	20·9	1·4	89·6	86·9	2·7	140	140	-	88·3	90·8	2·5	2 29/32	2 25/32	[illegible]
75	30 1/2	6 1/8+1/64	1/4+1/64	1/4-1/64	1/32	1 1/2	1 5/8+1/64	1/8+1/64	75·1	71·3	3·8	16·3	18·0	1·7	91·4	89·3	2·1	144	143 1/2	1/2	90·4	92·4	2·0	3 3/16+1/64	3 1/16	[illegible]

POWER CLASSⁿ 4 — 225 LBS. PER SQ. INCH. — E.D.Nº 274.A



DESCRIPTION.

BOILER. BARREL 10'-10⅜". DIA. OUTS. 4'-9⅝" INCREASING TO 5'-3".

FIREBOX. OUTSIDE FIREBOX 7'-8" × 4'-0½".

TUBES.
- SUPERHEATER ELEMENTS 24-1¼" DIA. OUTS. × 11 S.W.G.
- LARGE TUBES 24-5⅛" DIA. OUTS. × 7 S.W.G. } 10'-10½" BETWEEN TUBEPLATES.
- SMALL TUBES 160-1⅝" DIA. OUTS. × 12 S.W.G. }

HEATING SURFACE.
- TUBES 1090 SQ.FT. } TOTAL 1221 SQ.FT.
- FIREBOX 131 SQ.FT. }
- SUPERHEATER 231 SQ.FT.

GRATE AREA. 23 SQ.FT.

TRACTIVE EFFORT AT 85% B.P. 24172 LBS.

ADHESION FACTOR 4·6

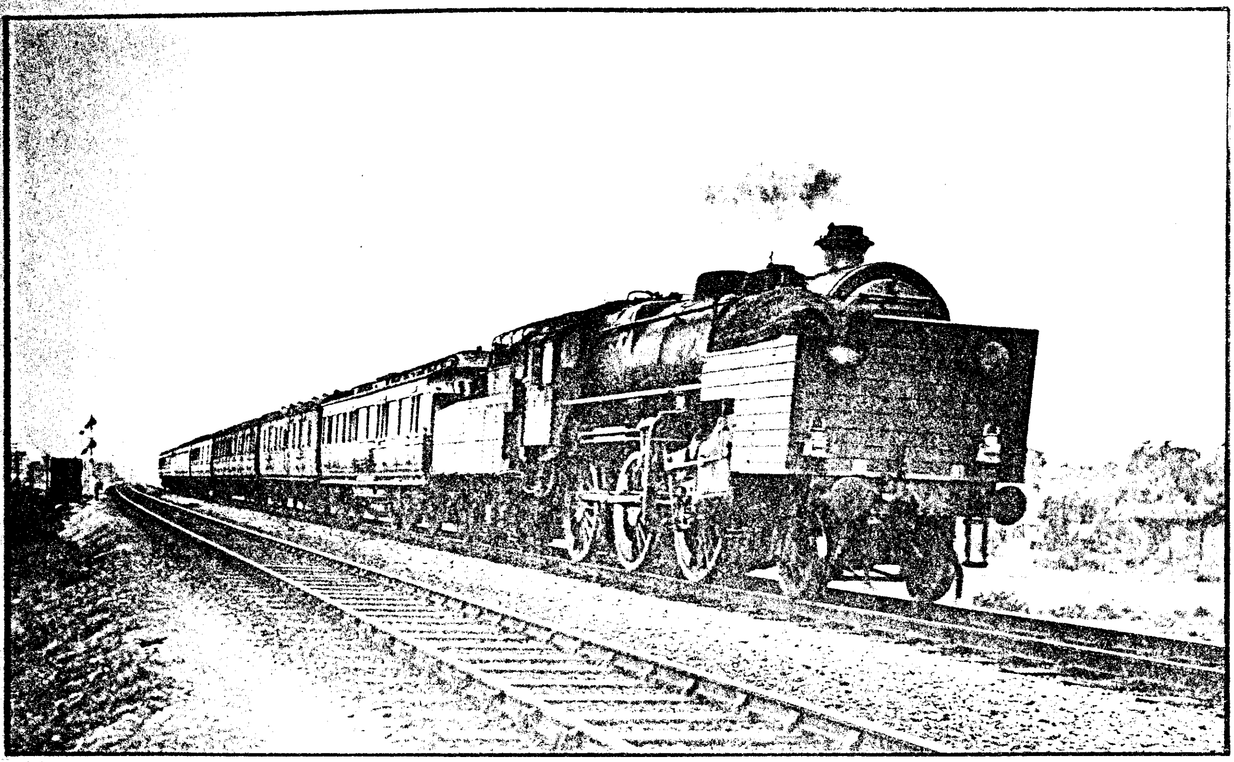
WEIGHTS.

	ENGINE T. C. Q.	TENDER T. C. Q.	TOTA[L] T. C. [Q.]
LIGHT.	55-5-2	20-13-2	75-19-[0]
LOADED.	59-2-0	40-6-0	99-8-[0]

RADIUS OF MINIMUM CURVE } 5 CHAINS.

BRAKE % ENGINE & TENDER 60·2.

2-6-0 SUPERHEATED FREIGHT ENGINE.



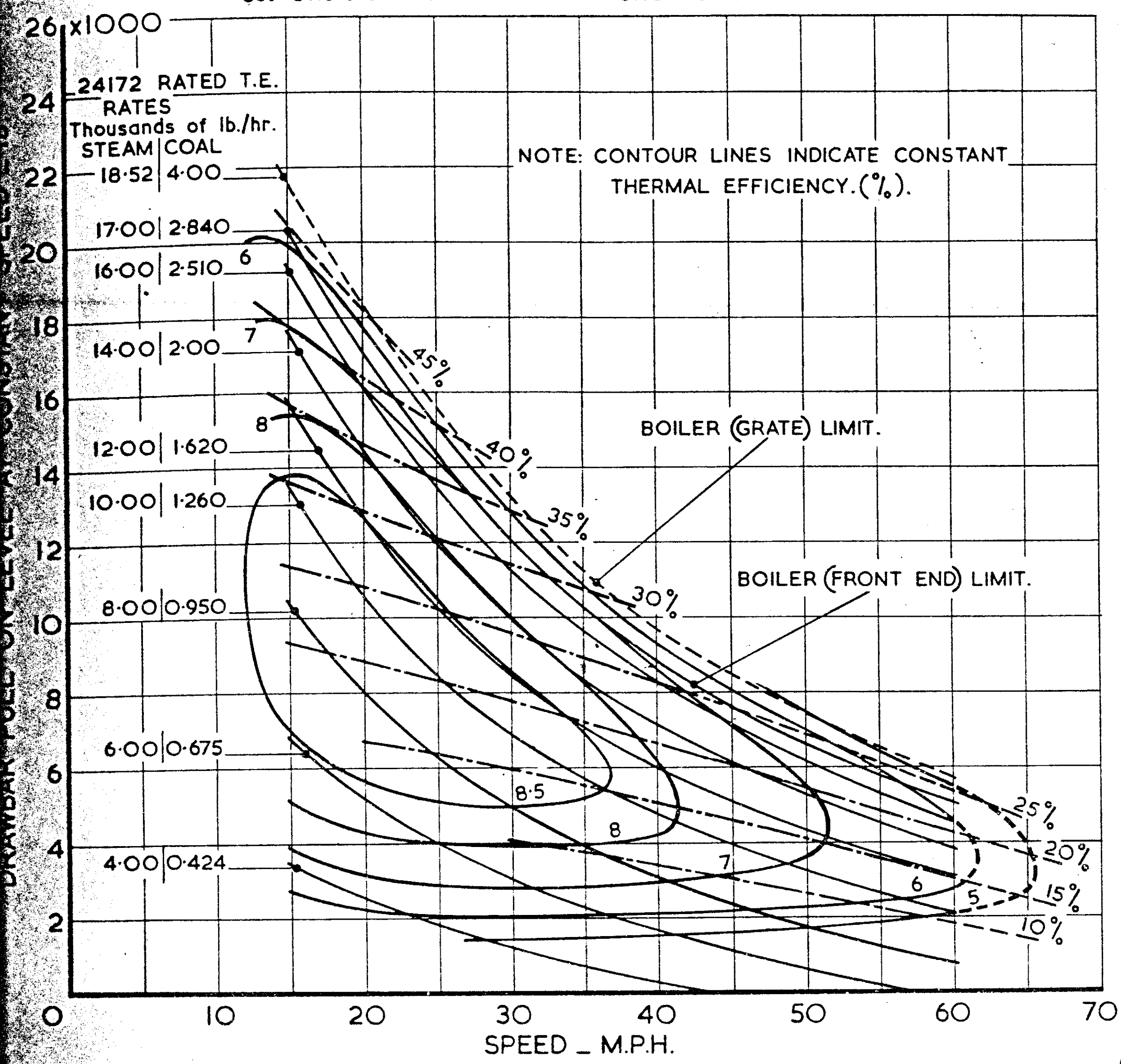
A Controlled Road Test in progress
No. 43094 approaching Swindon.
Testing Unit, the W.R. Dynamometer Car.

<u>BLIDWORTH COAL.</u>

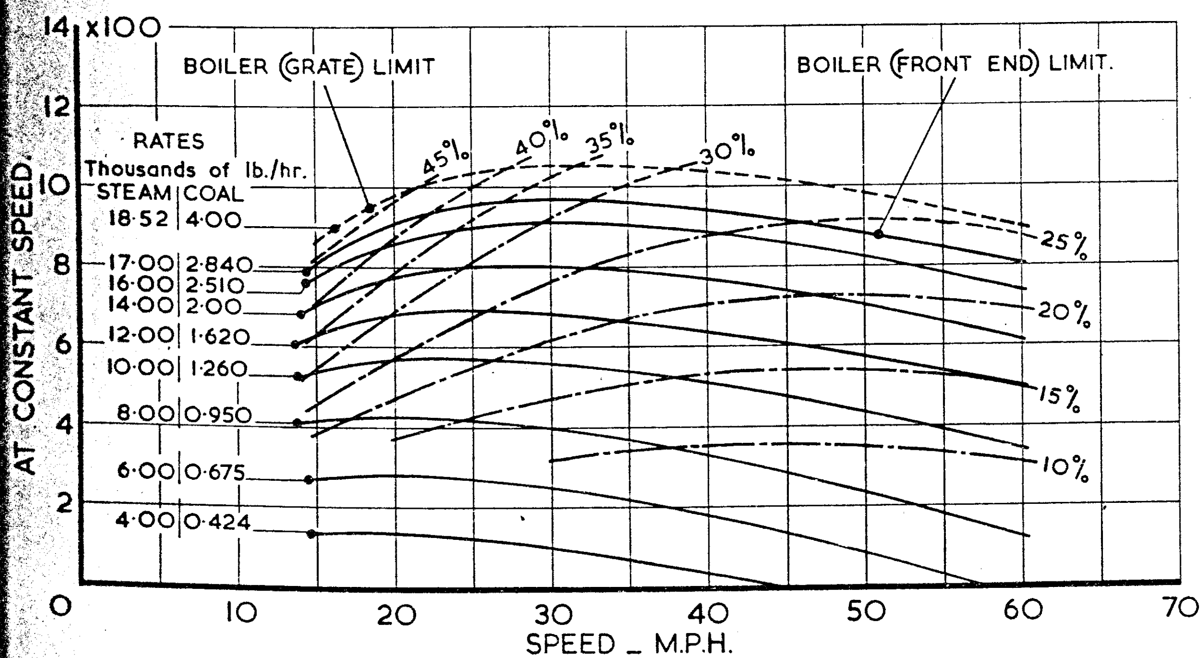
Performance data : Graphs 1 to 9.

Design data : Graphs 10 to 21.

Cut Offs shown refer to Maximum Steam Chest Pressure.



1

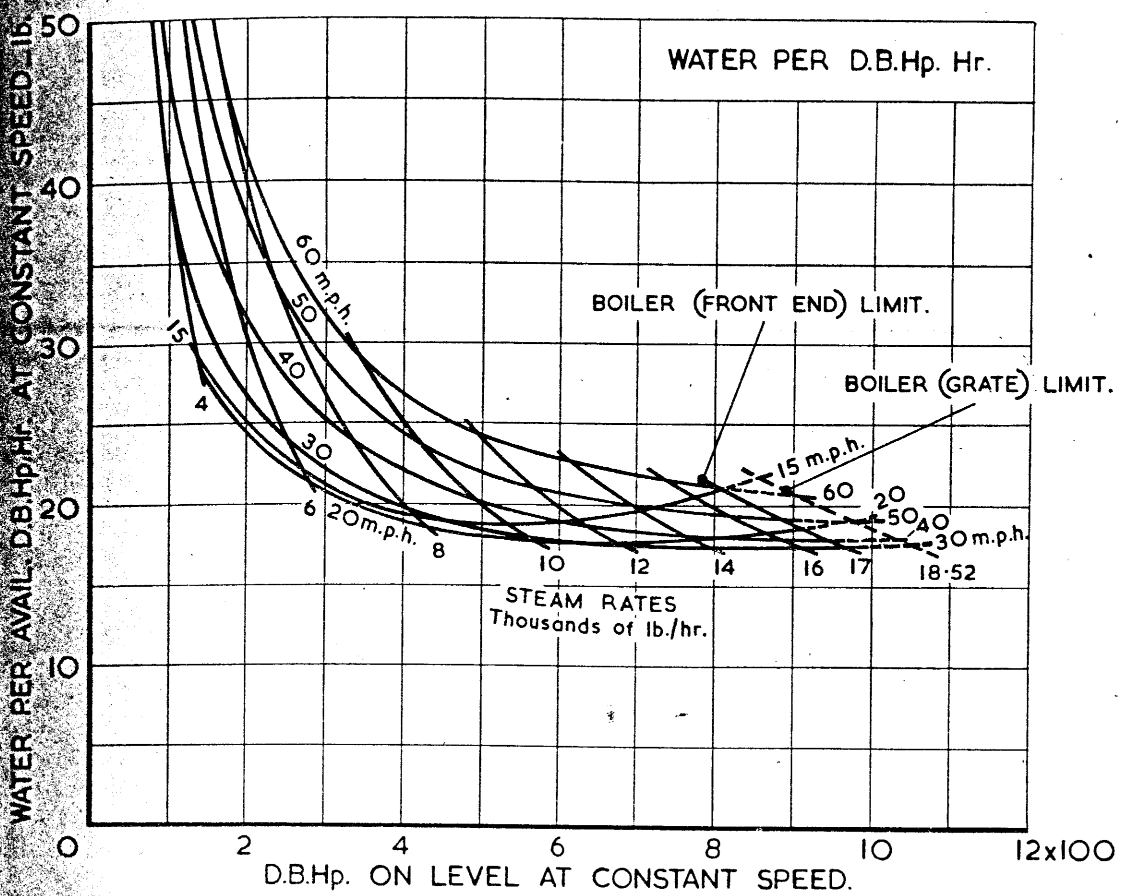


BLIDWORTH COAL _ 12560 B.Th.U./lb.

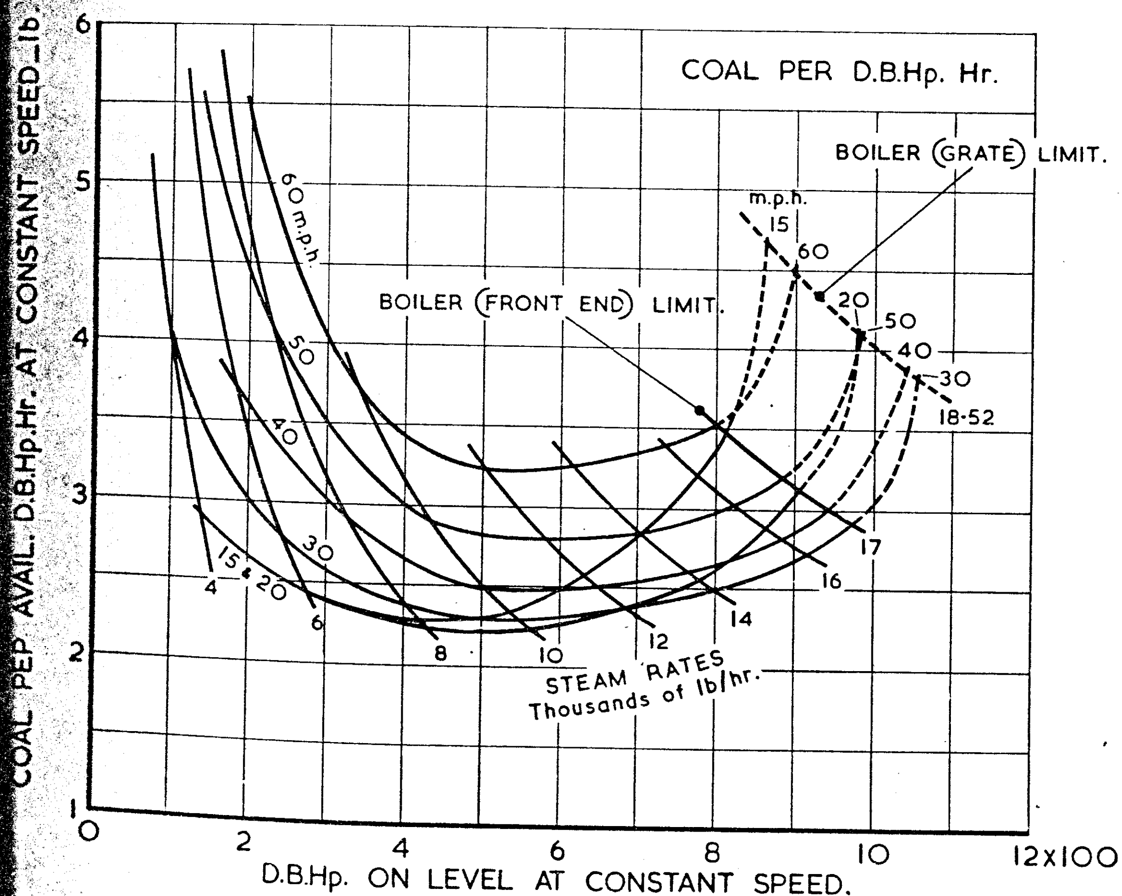
2

DRAWBAR CHARACTERISTICS.

4/43094/51.



3

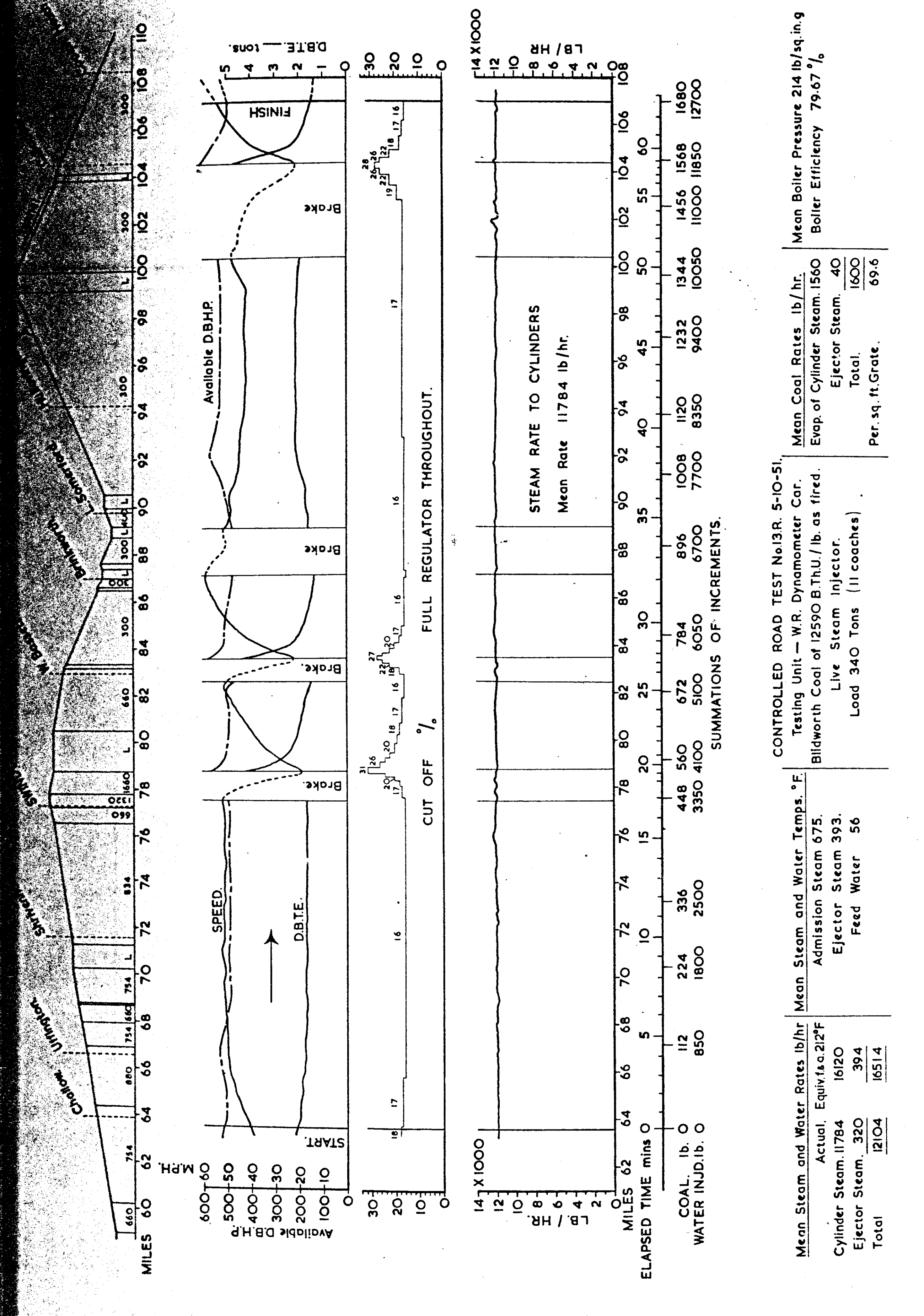


BLIDWORTH COAL _ 12560 B.Th.U./lb.

4

WATER & COAL PER D.B.Hp. Hr.

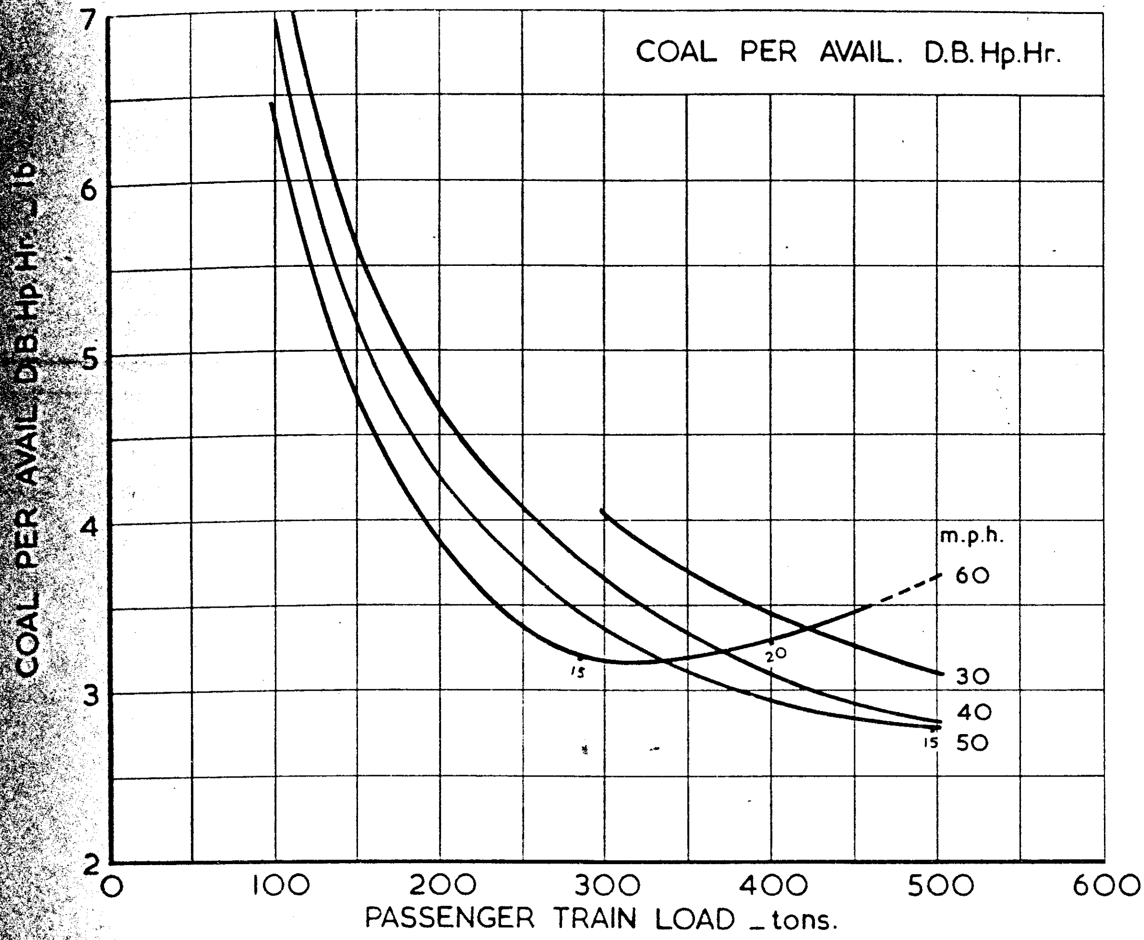
M4/43094/51.

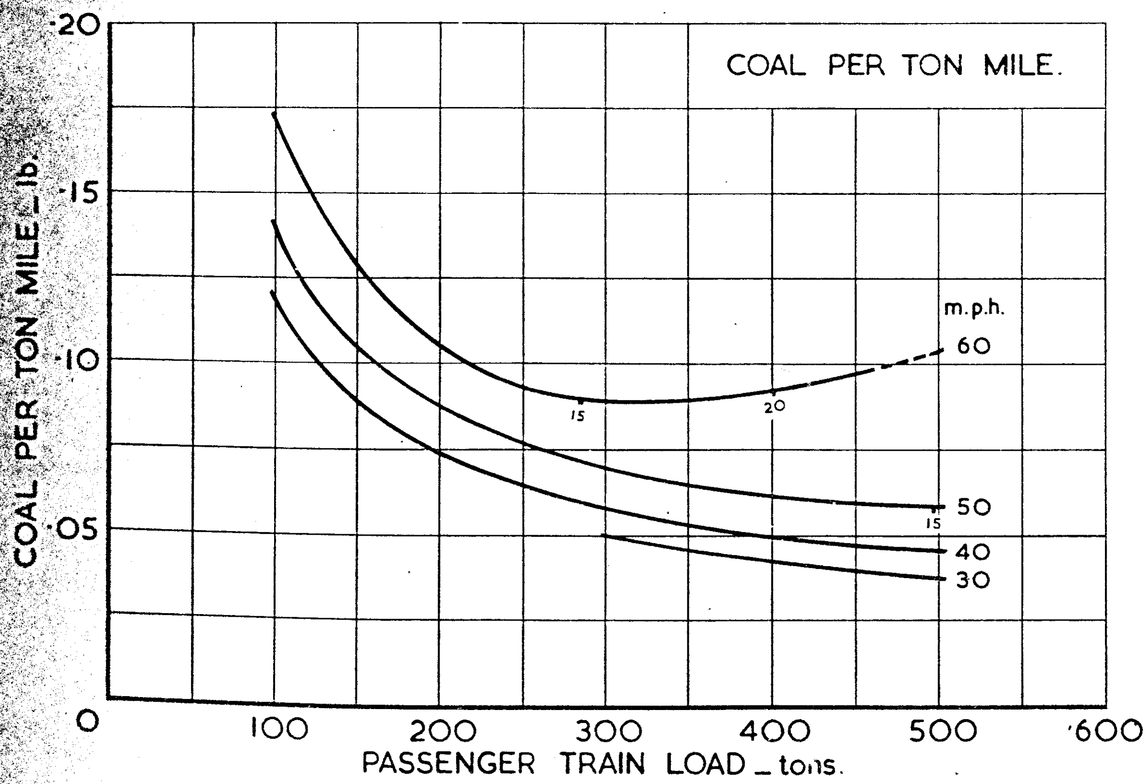


EXAMPLE OF TEST AT CONSTANT EVAPORATION UNDER CONDITIONS GIVING APPROXIMATELY MOST ECONOMICAL COAL CONSUMPTION.

M. 4./43094/51.

5





Small Figures on Curves Indicate Cut Off, Maximum Steam Chest Pressure.

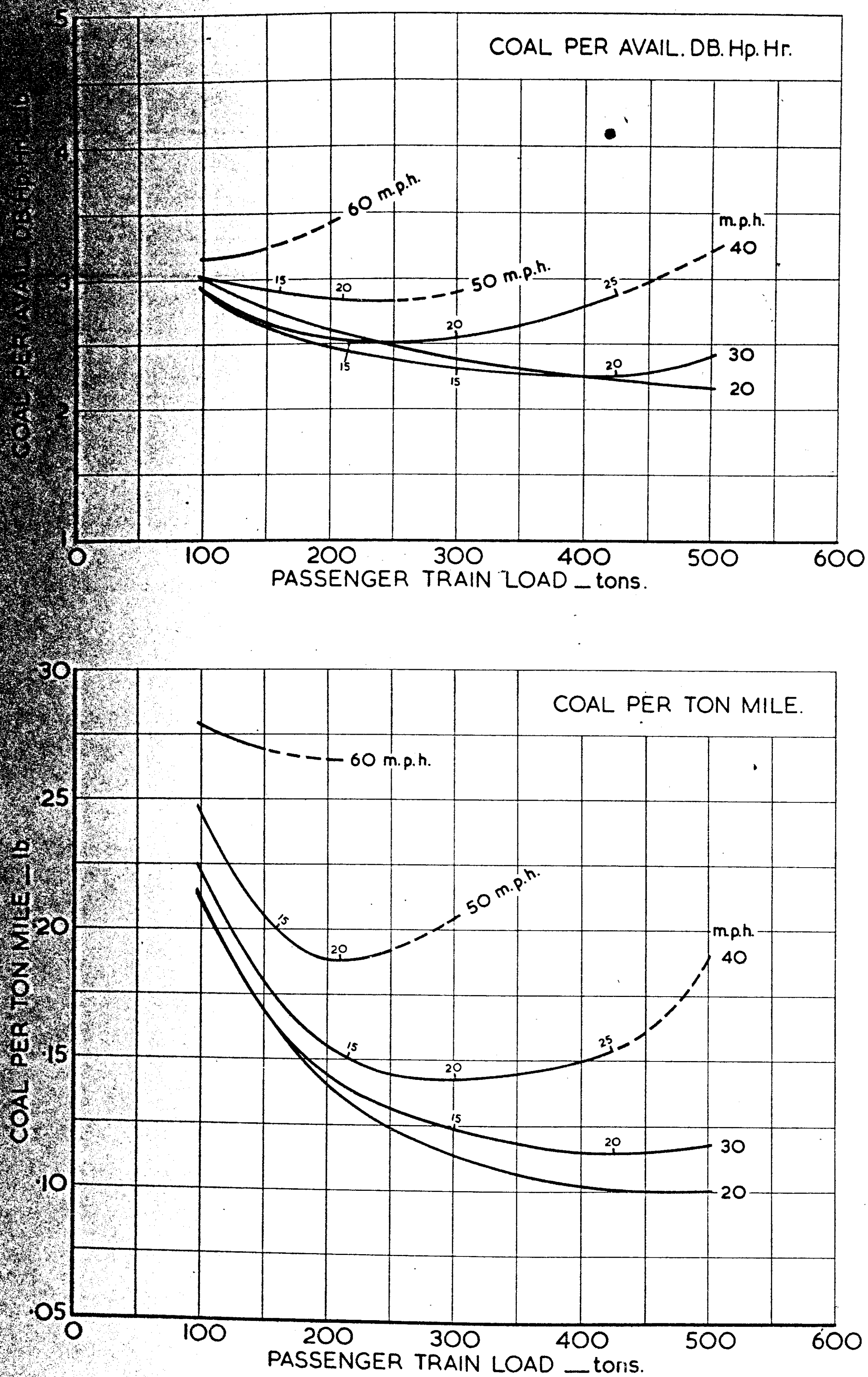
BLIDWORTH COAL _ 12560 B.Th.U./lb.

PASSENGER SERVICE _ LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT
TRAIN LOADS & SPEEDS.

6

M4/43094/51.



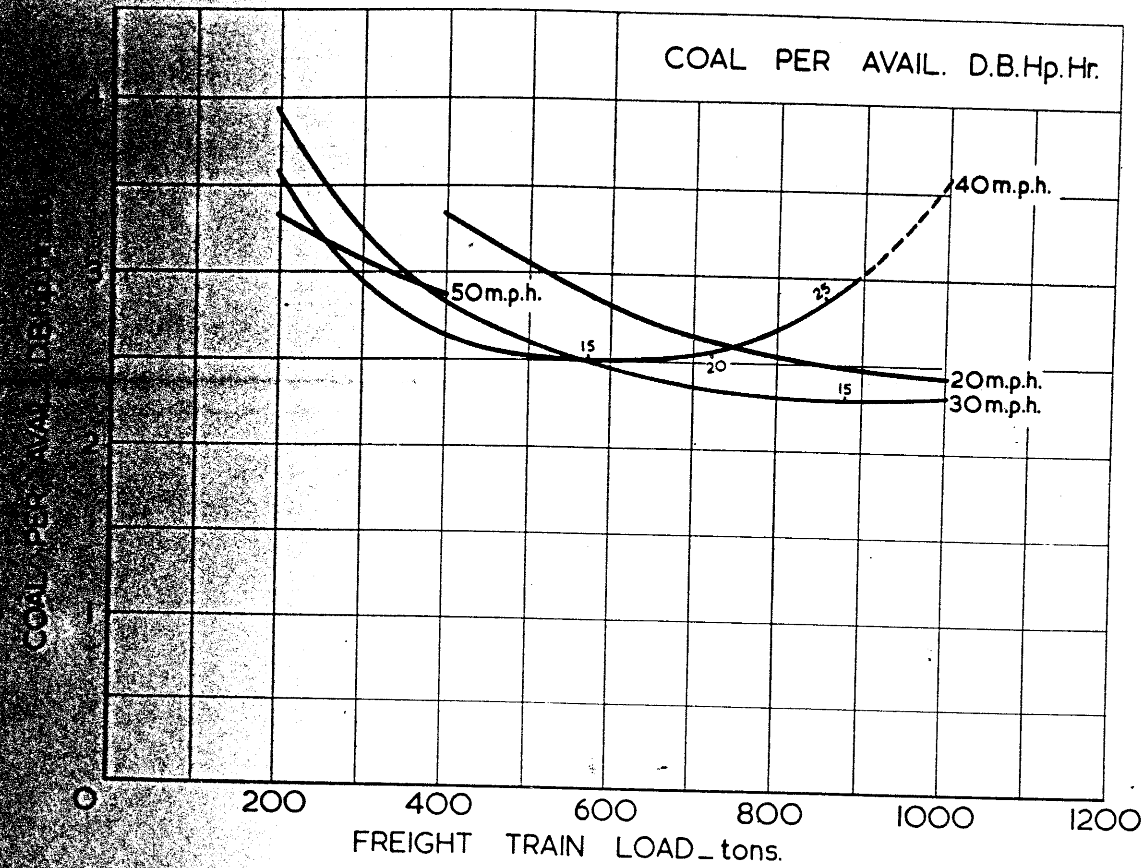
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

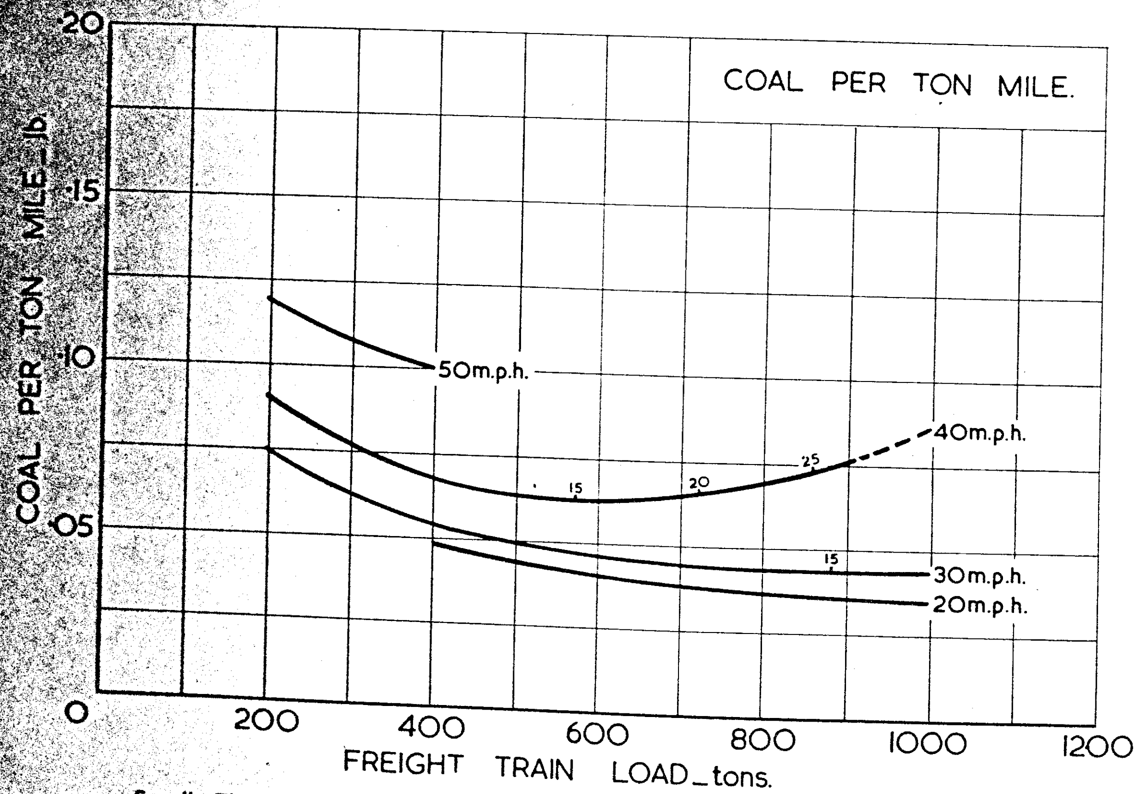
BLIDWORTH COAL — 12560 B. Th. U./lb.

PASSENGER SERVICE — 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





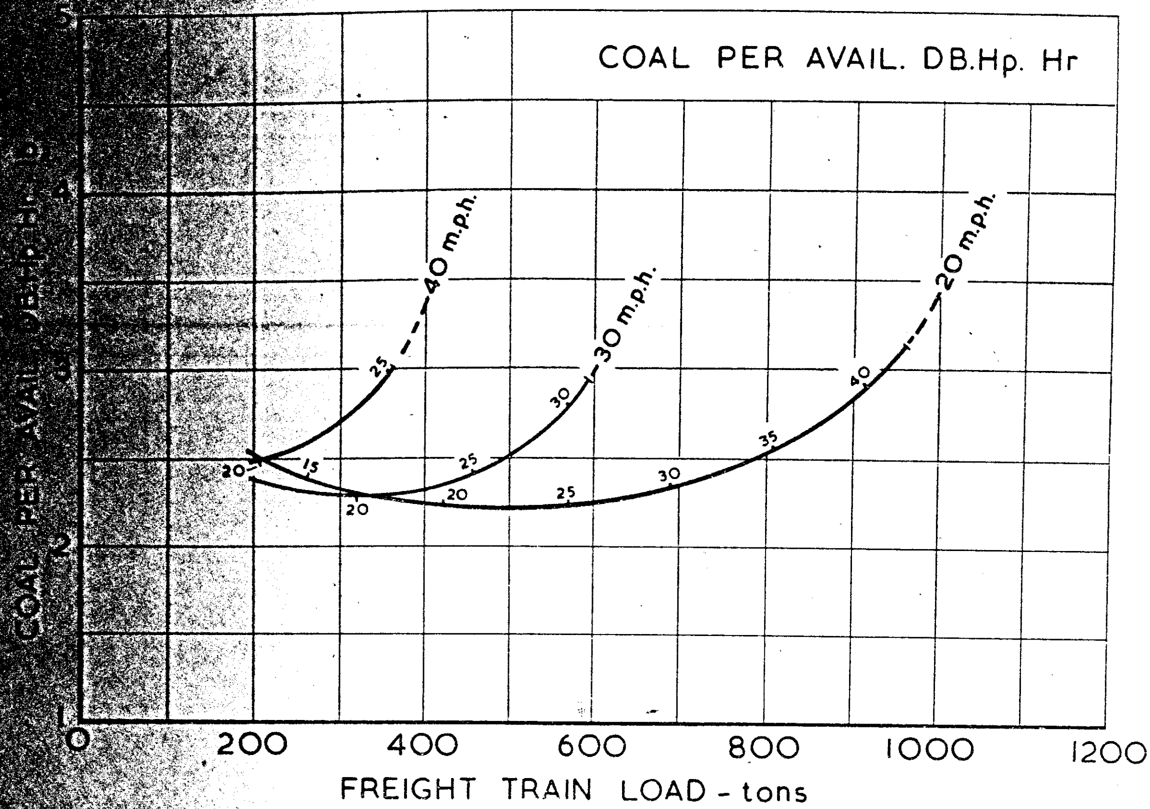
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

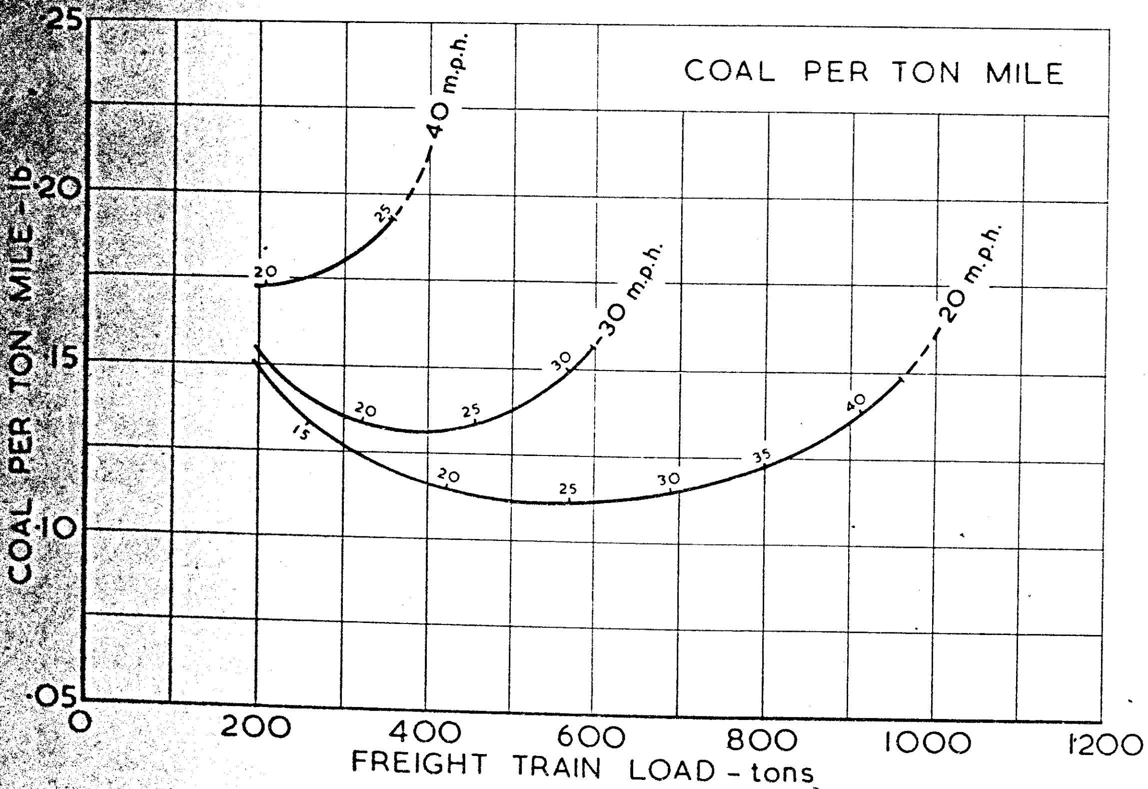
BLIDWORTH COAL _ 12560 B.Th.U./lb.

FREIGHT SERVICE _ LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





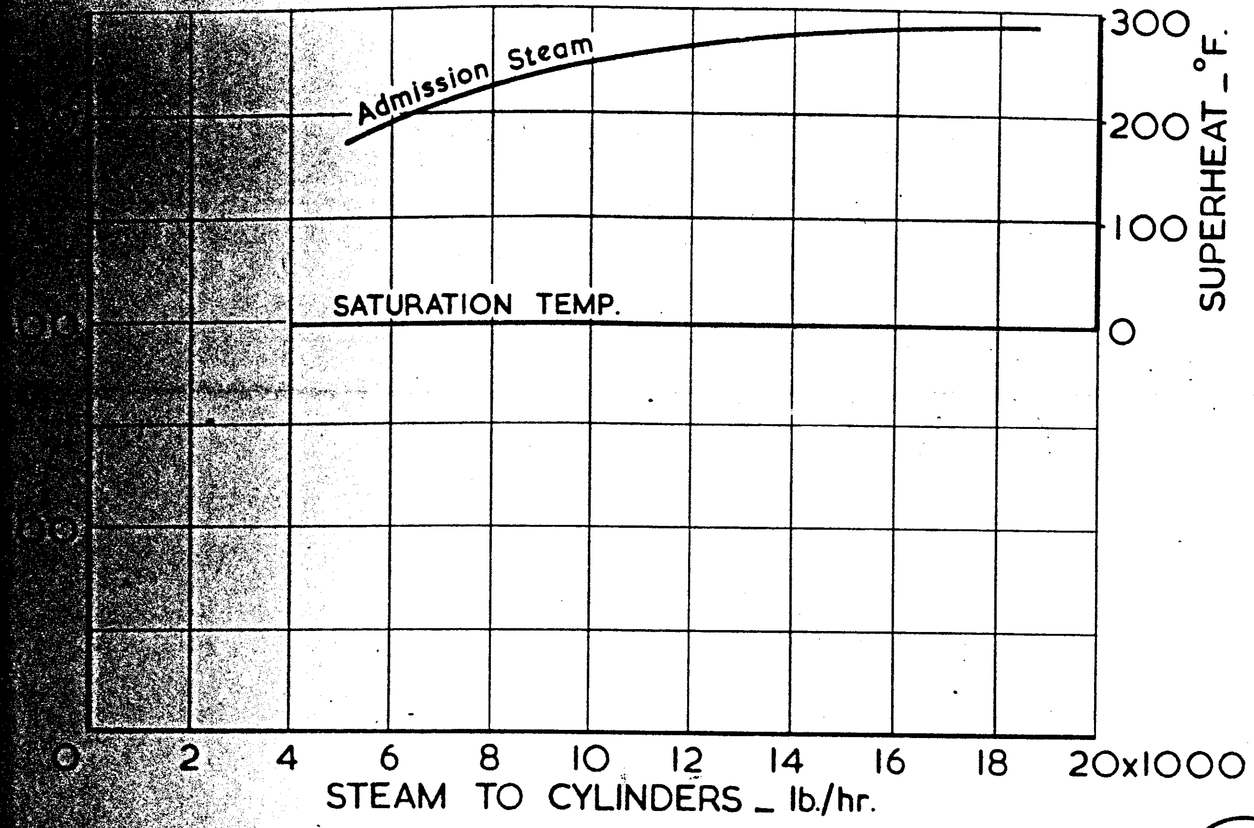
Small Figures on Curves Indicate Cut Off, Maximum Steam Chest Pressure.

BLIDWORTH COAL - 12560 B.Th.U./lb.

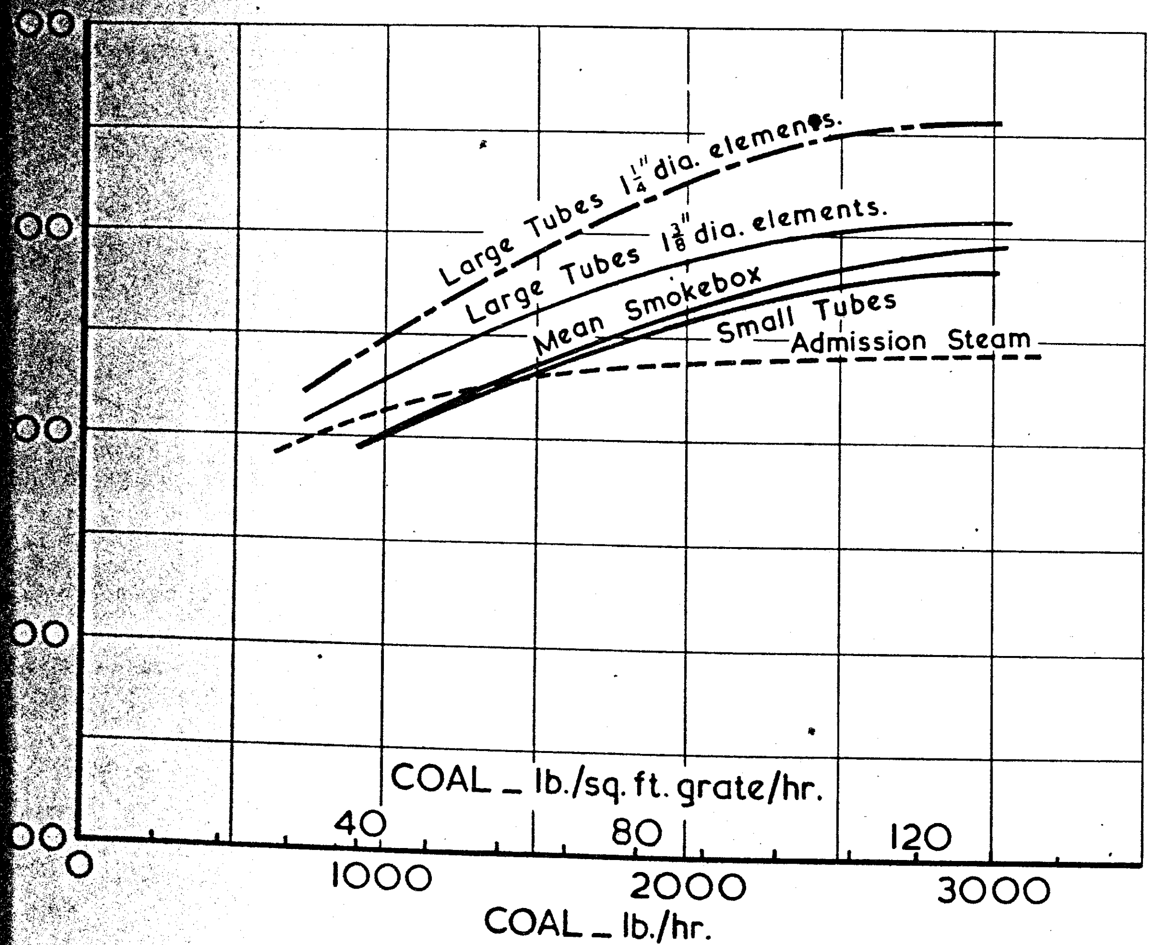
FREIGHT SERVICE - 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

M4/43094/51.



10

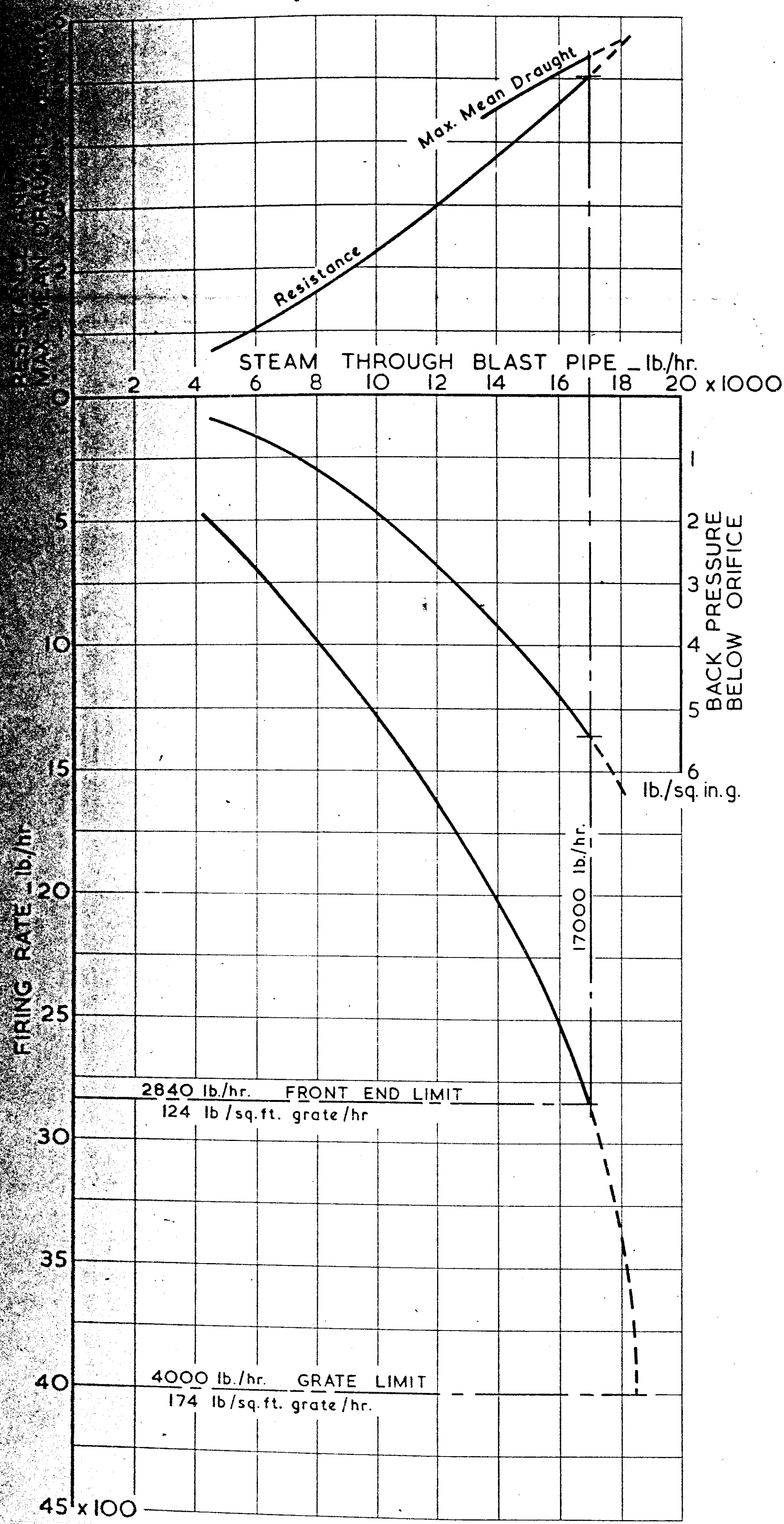


BLIDWORTH COAL
12560 B.Th.U./lb.

11

TEMPERATURES.

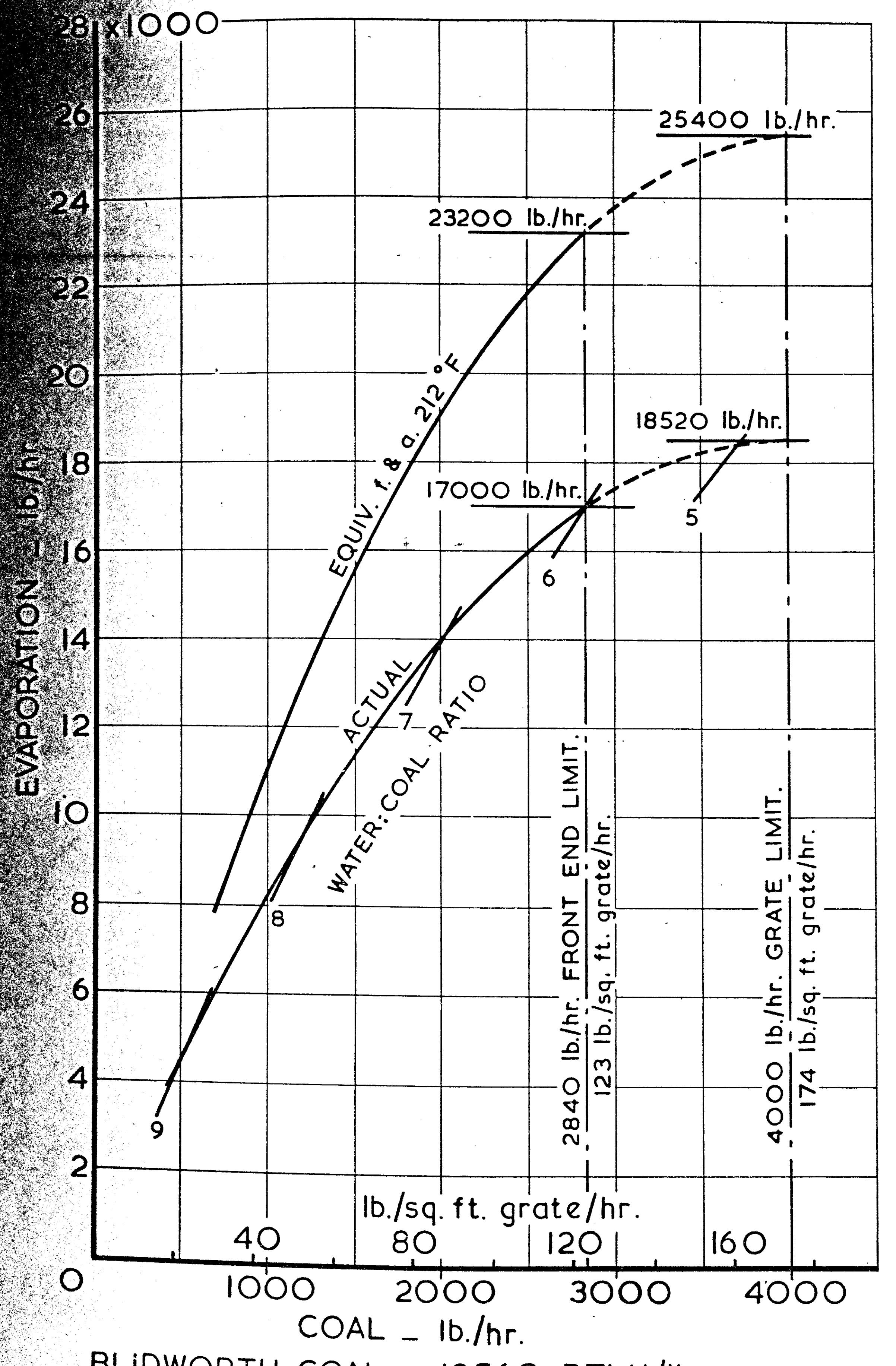
43094/51.



BLIDWORTH COAL _ 12560 B.Th.U./lb.

DRAUGHT

M4/43094/51.

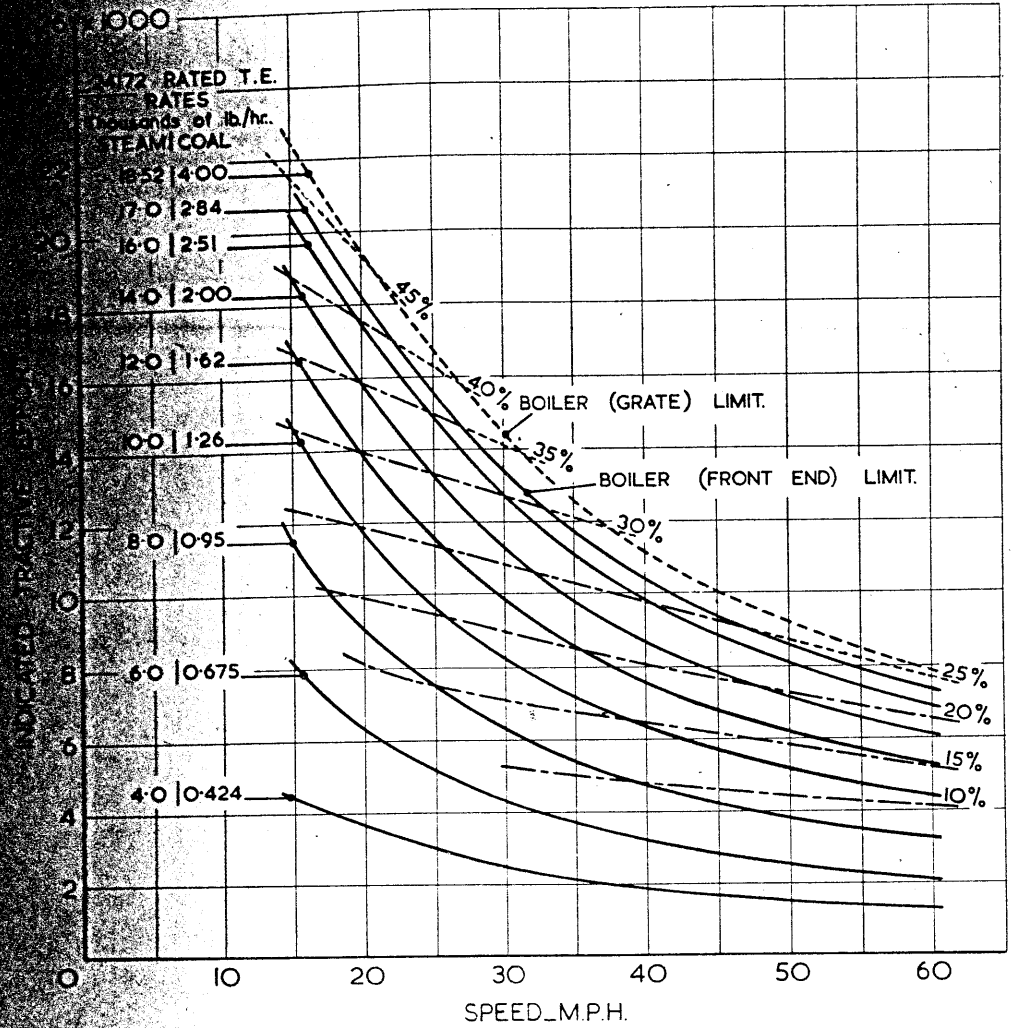


BLIDWORTH COAL _ 12560 B.Th.U./lb.

EVAPORATION.

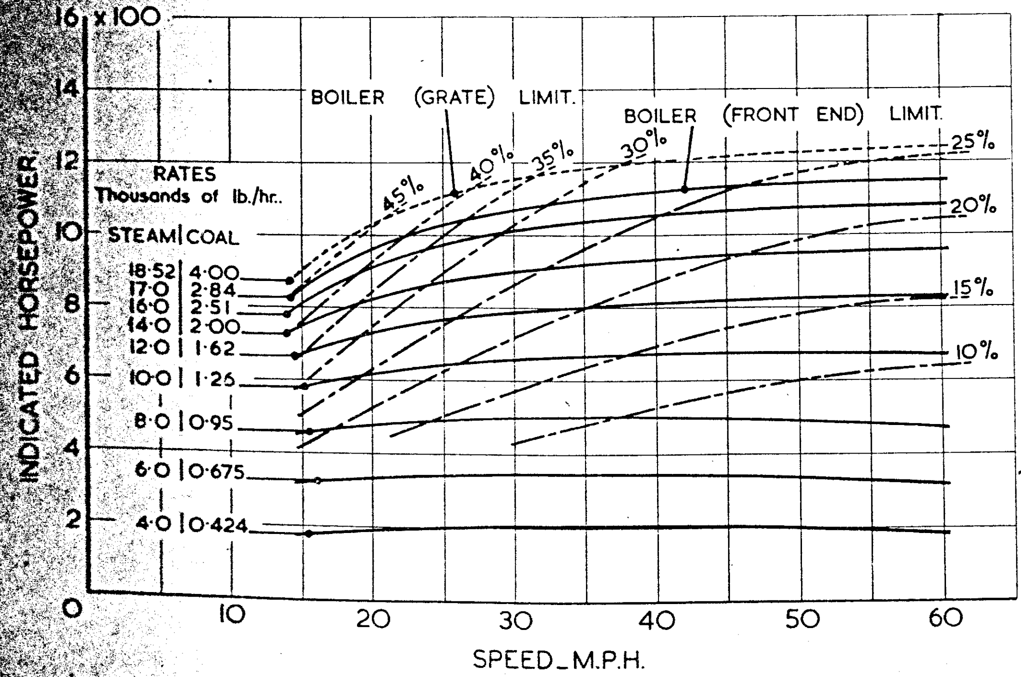
13

M4/43094/51.



14

Cut Offs shown refer to Maximum Steam Chest Pressure.

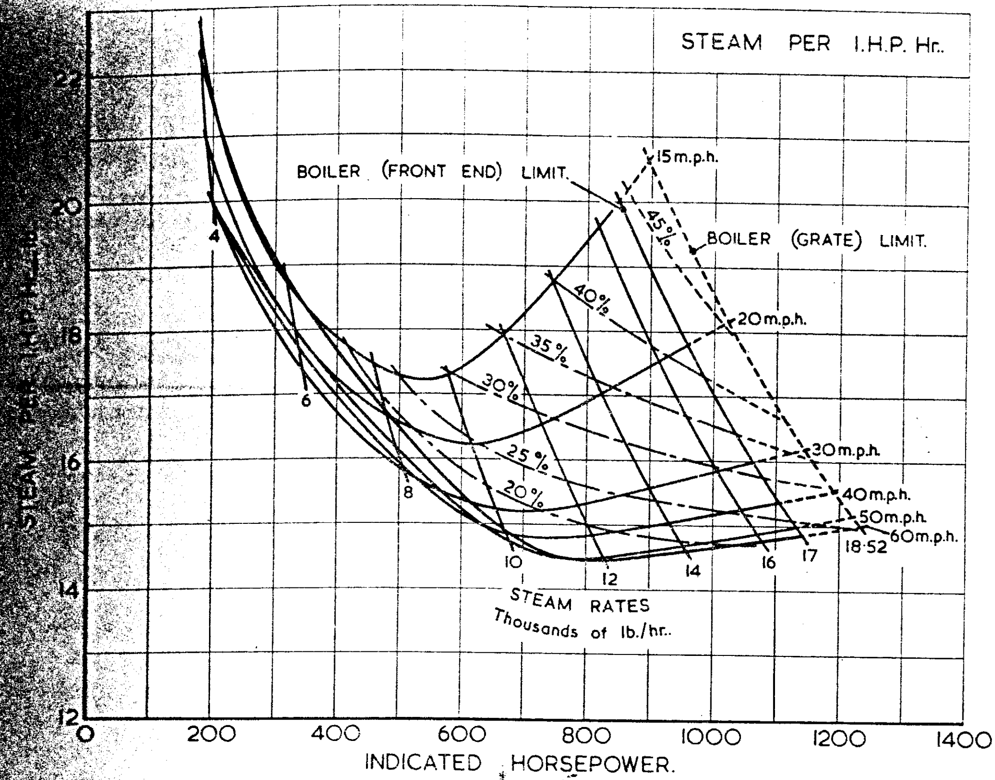


BLIDWORTH COAL _ 12560 B.Th.U./lb.

INDICATED CHARACTERISTICS.

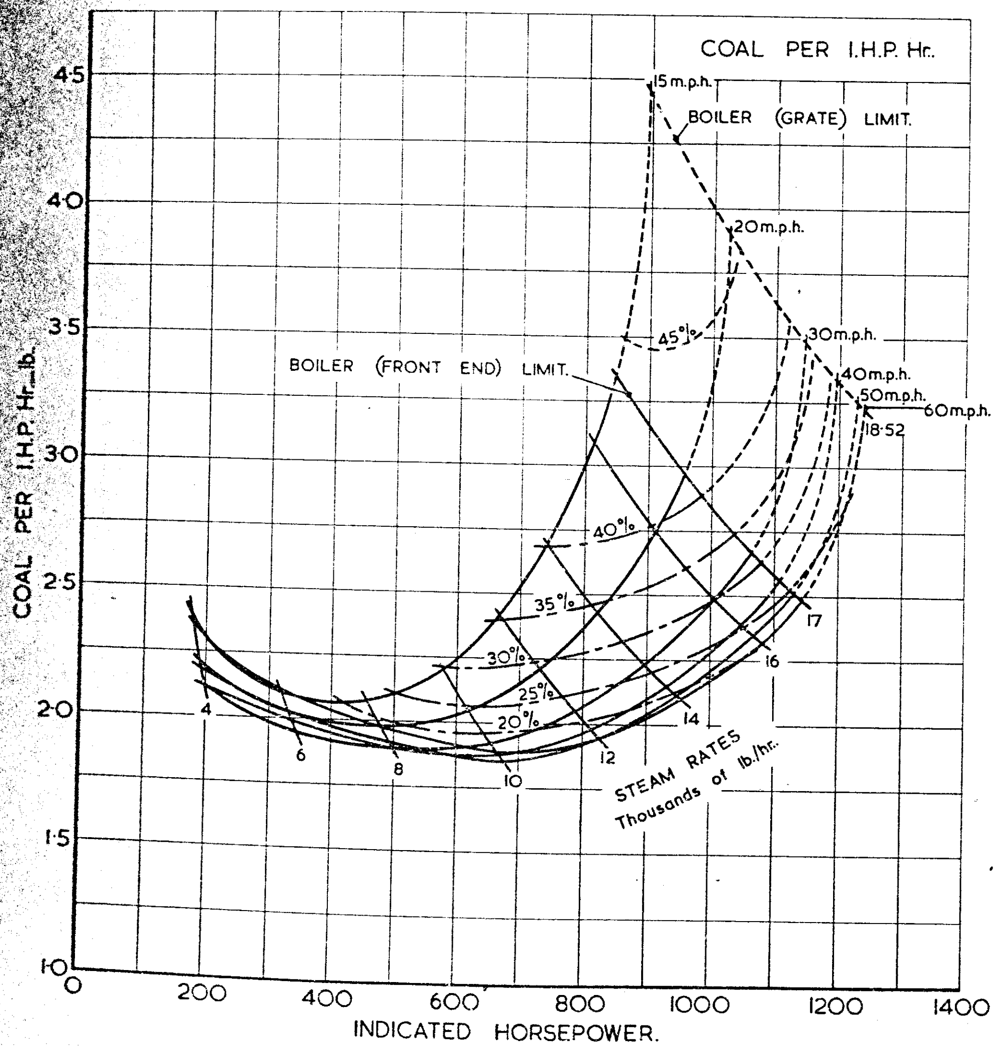
15

M4/43094/51.



Cut Offs shown refer to Maximum Steam Chest Pressure.

16

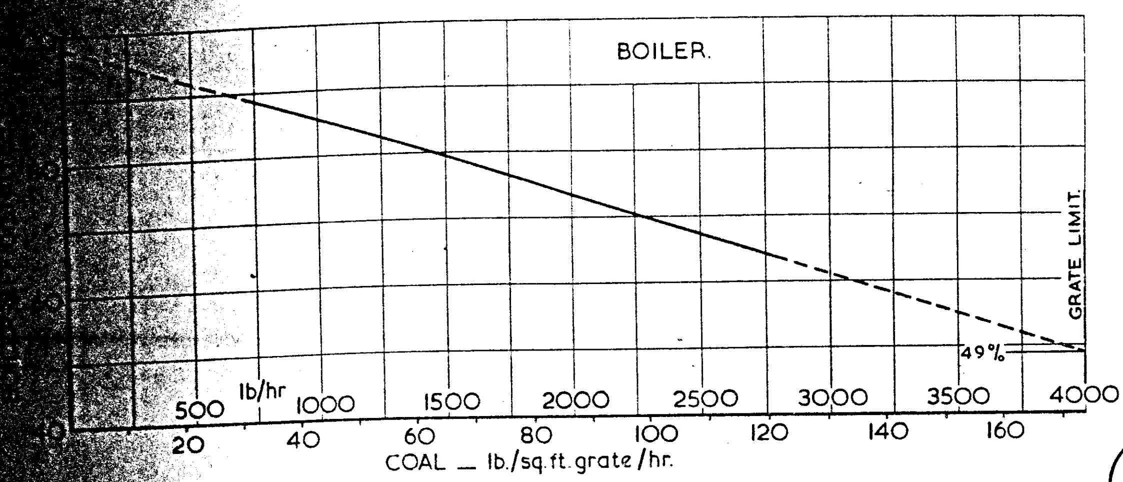


BLIDWORTH COAL – 12560 B.Th.U./lb.

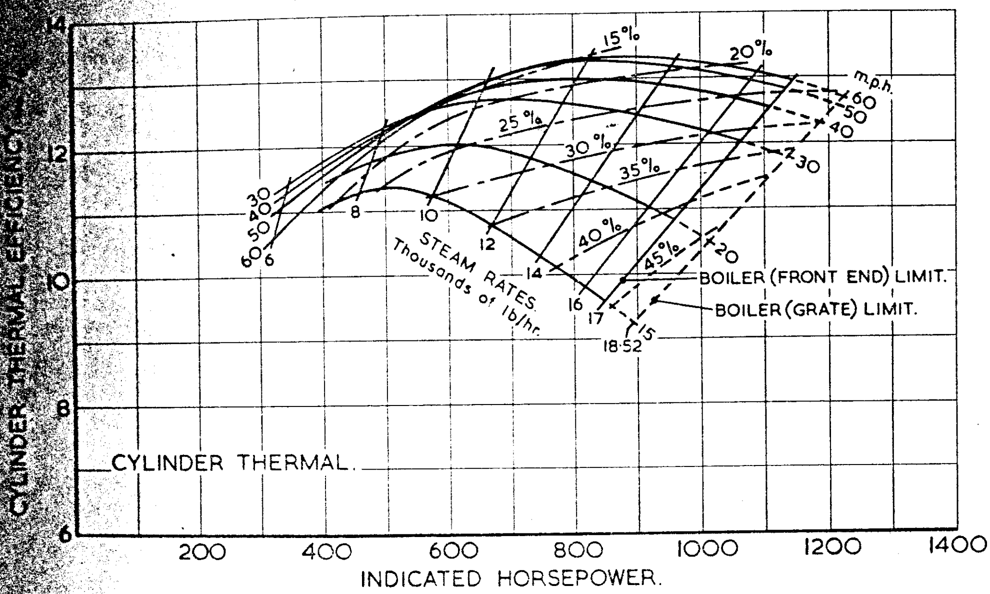
17

STEAM & COAL PER I.H.P. Hr..

M4/43094/51.

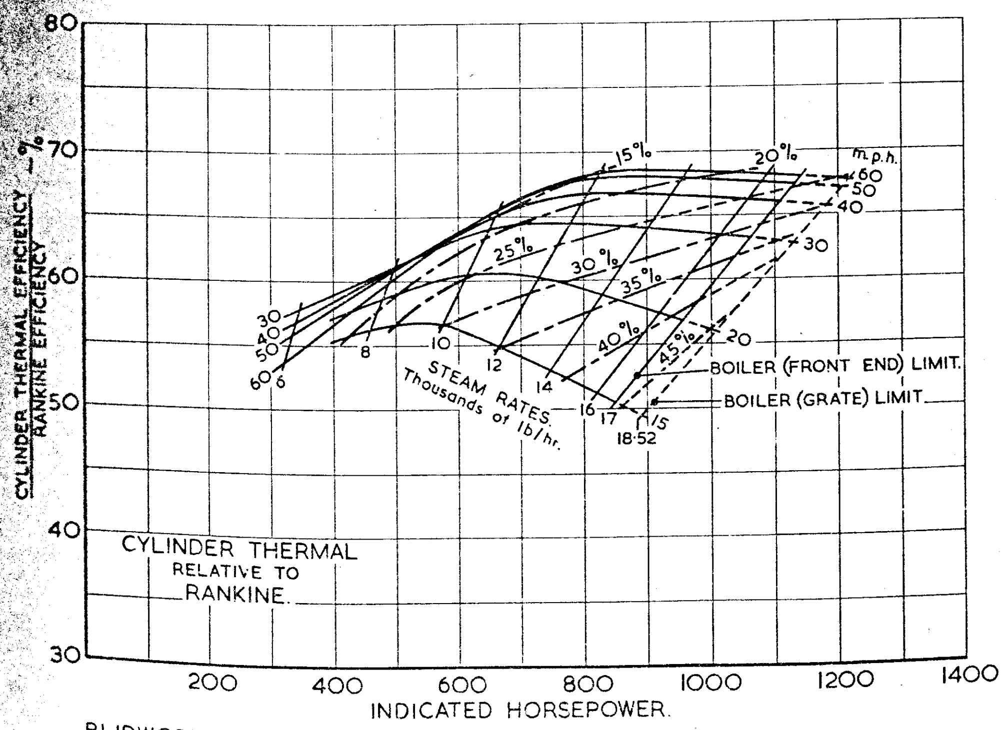


18



Cut Offs shown refer to Max. Steam Chest Pressure.

19



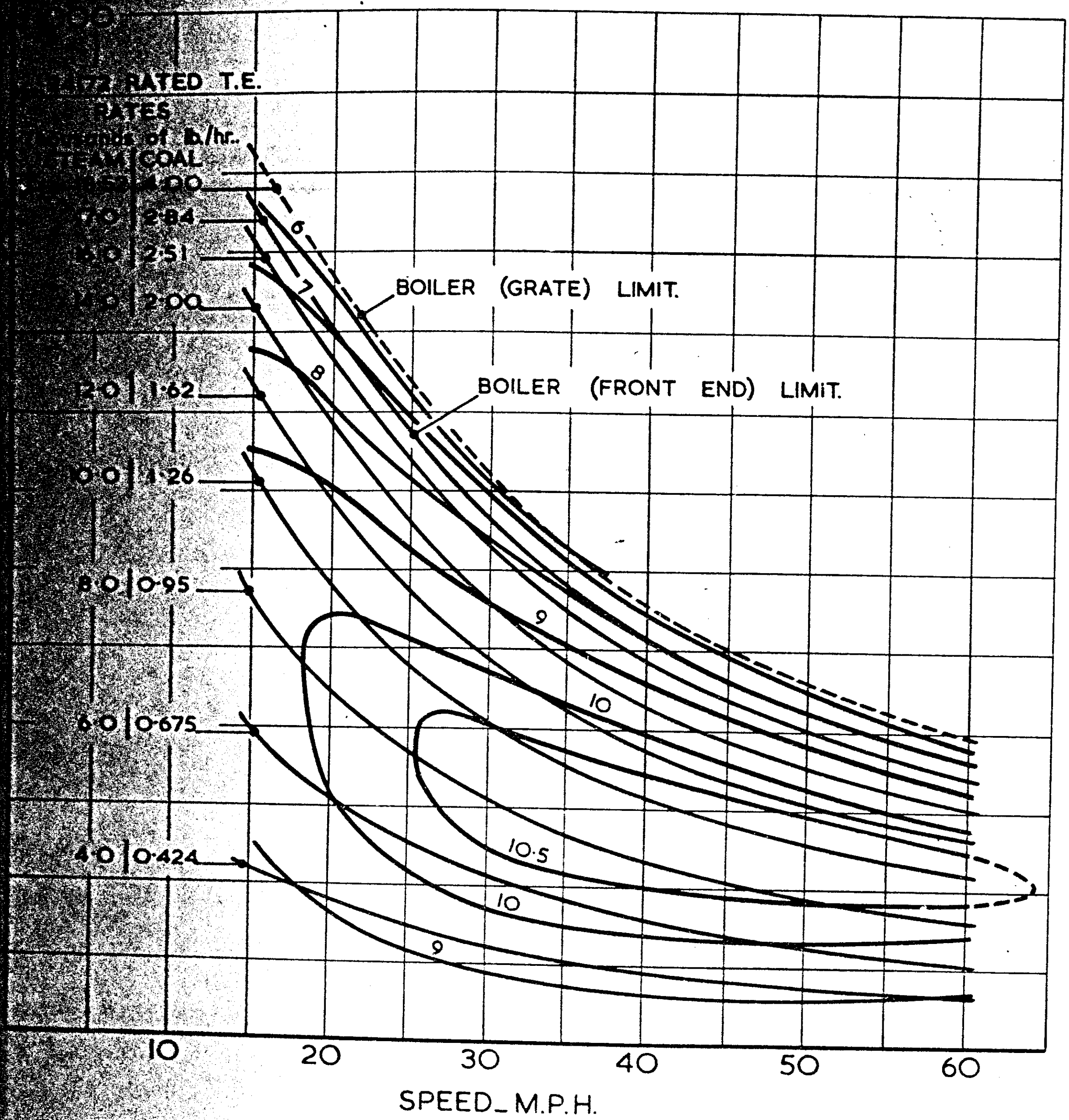
BLIDWORTH COAL — 12560 B.Th.U./lb.

20

EFFICIENCIES.

M4/43094/51

NOTE: CONTOUR LINES INDICATE CONSTANT THERMAL EFFICIENCY. (%).



BLIDWORTH COAL _ 12560 B.Th.U./lb..

ERALL EFFICIENCY REFERRED TO CYLINDERS.

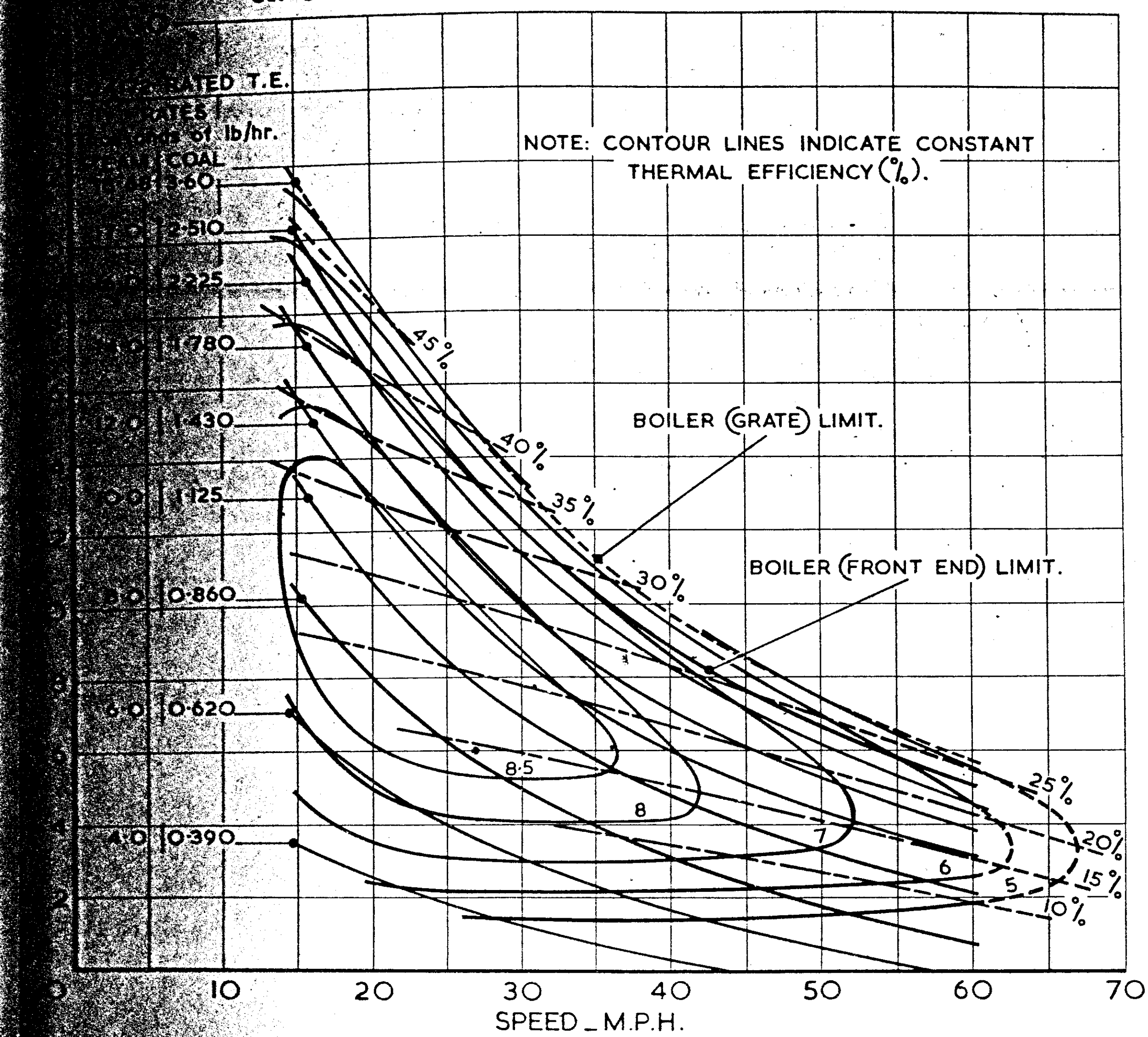
14/43094/51.

BEDWAS COAL.

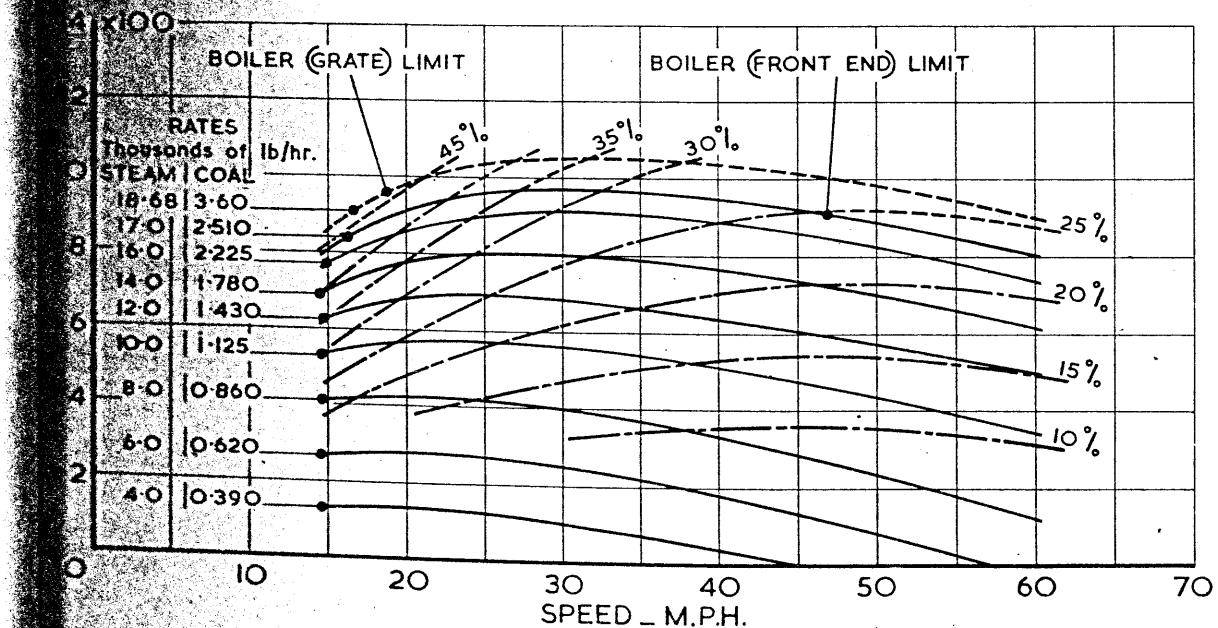
Performance data : Graphs 22 to 29.

Design data : Graphs 30 to 41.

Cut Offs shown refer to Maximum Steam Chest Pressure.



22

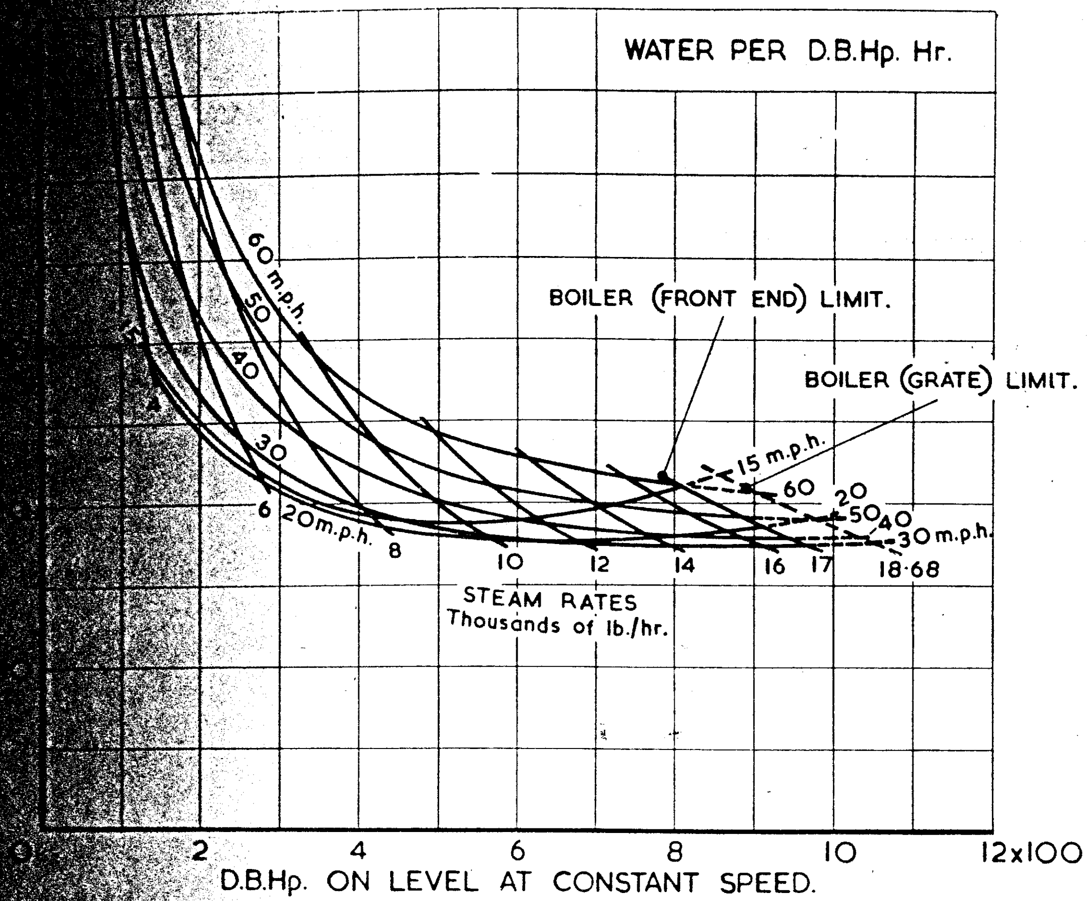


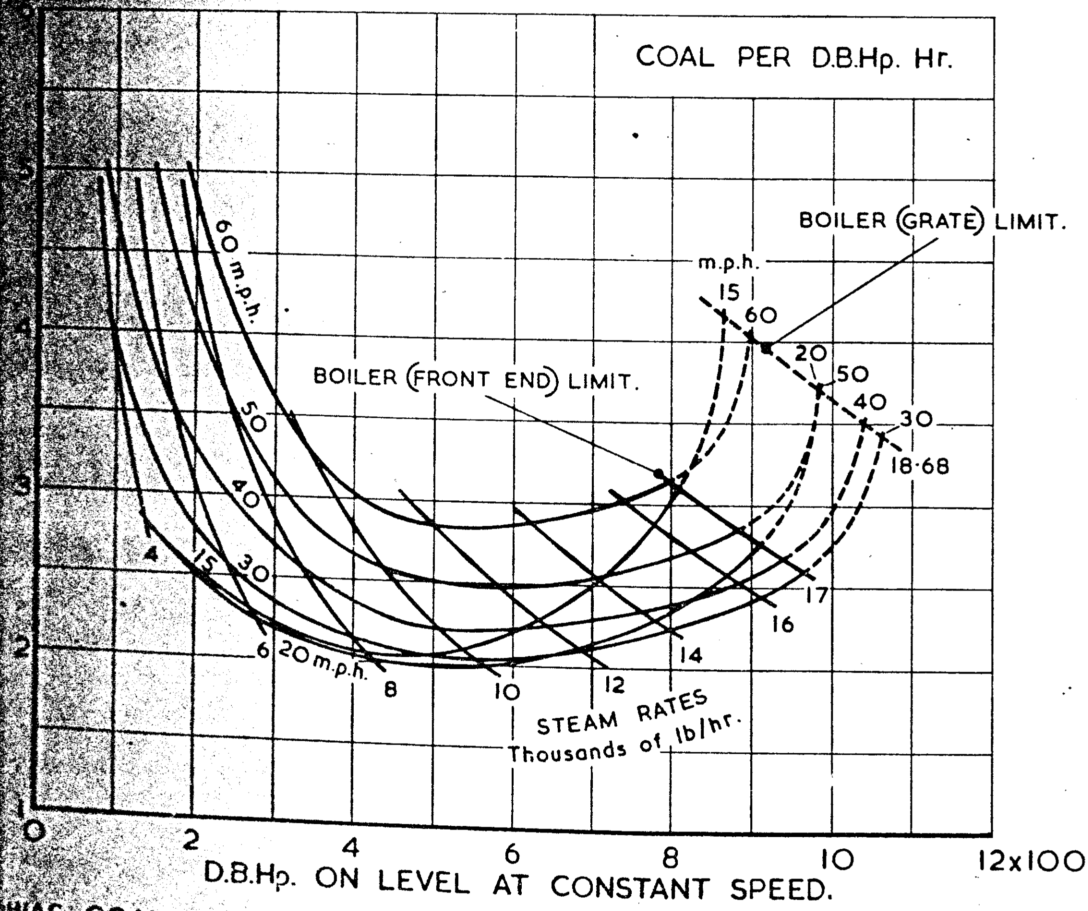
BEDWAS COAL _ 14050 B.Th.U./lb.

DRAWBAR CHARACTERISTICS.

23

3094/51.

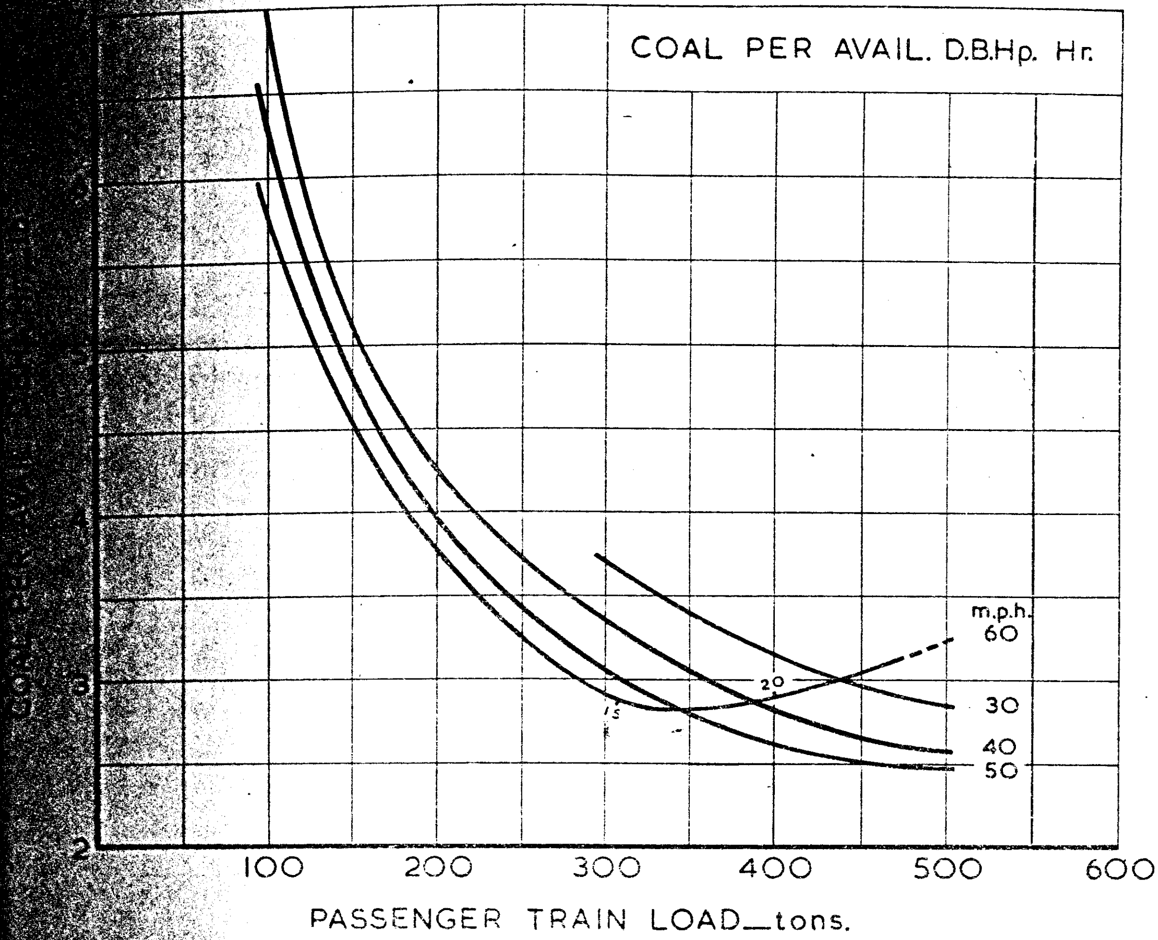


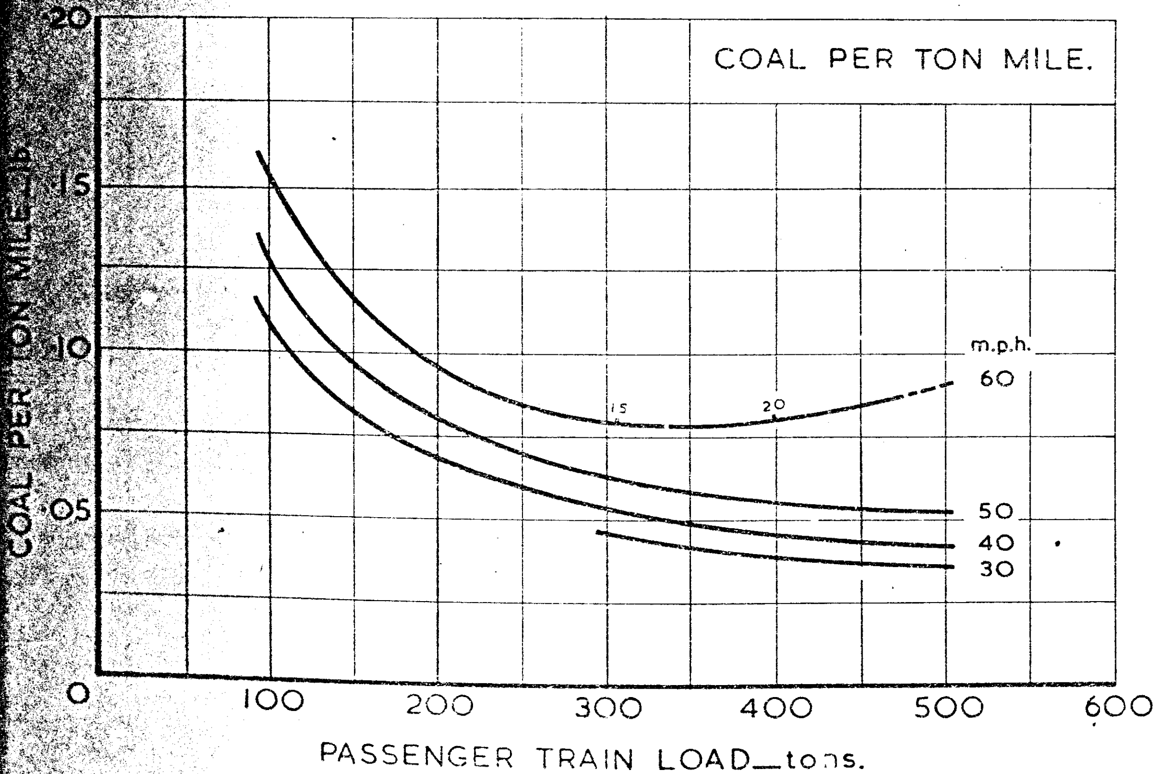


WAS COAL – 14050 B.Th.U./lb.

WATER & COAL PER D.B.Hp. Hr.

3094/51.





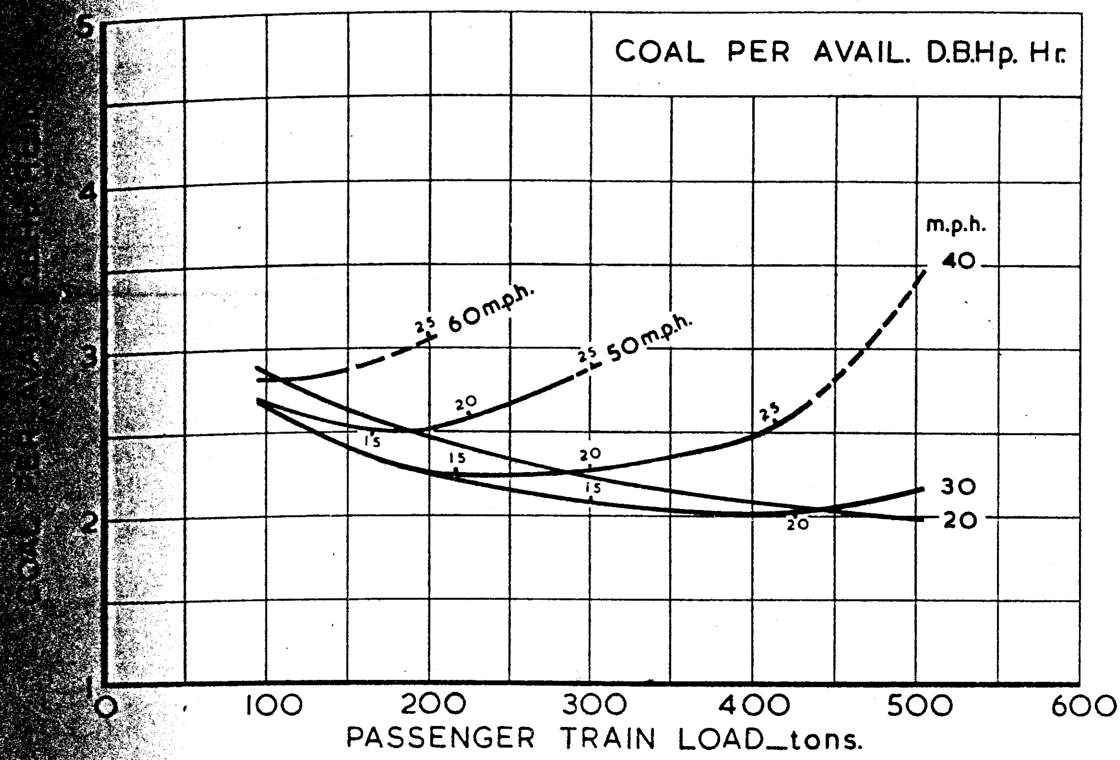
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

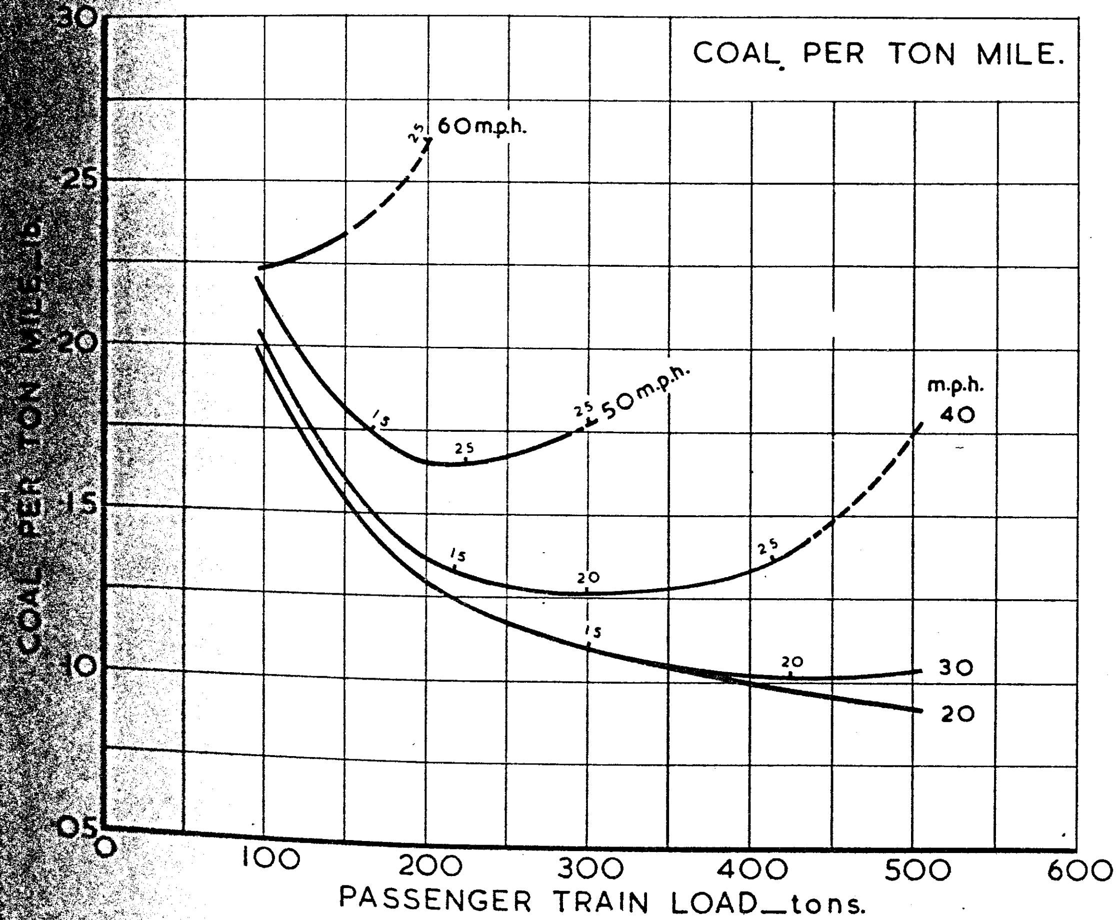
BEDWAS COAL—14050 B.Th.U./lb.

PASSENGER SERVICE—LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





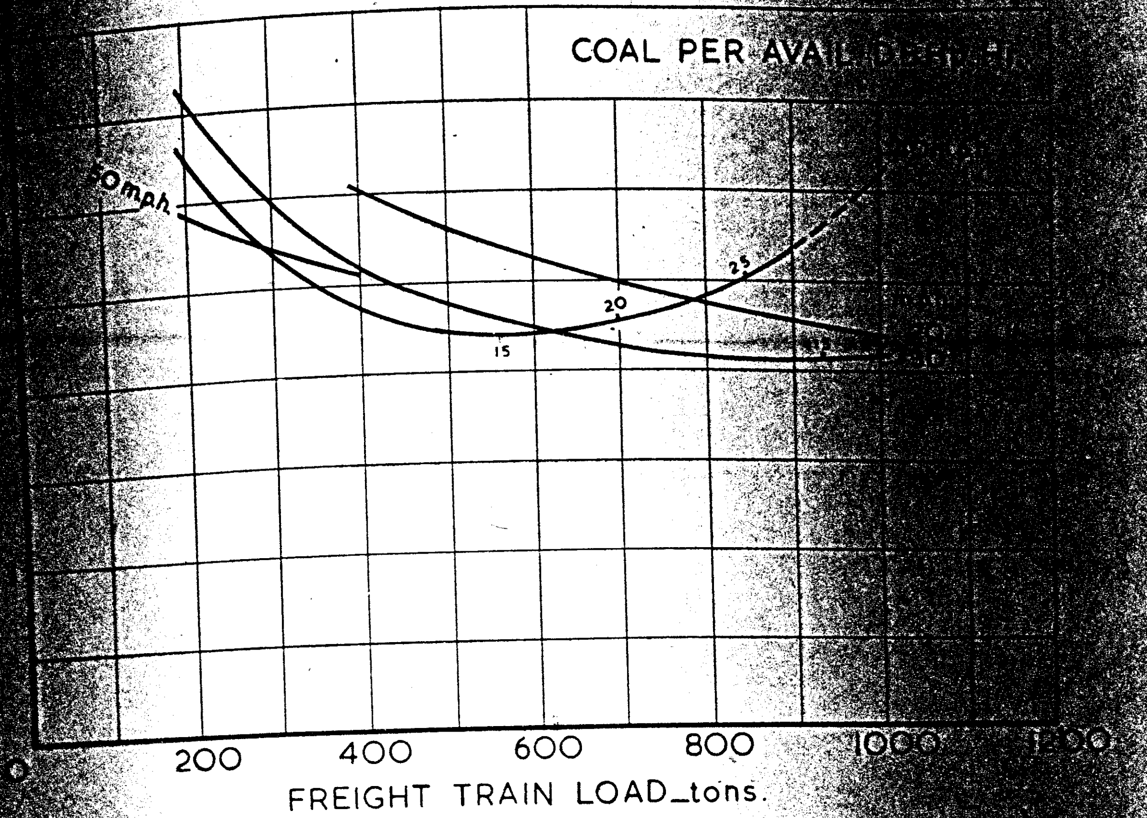
Small Figures on Curves Indicate Cut Off, Maximum Steam Chest Pressure.

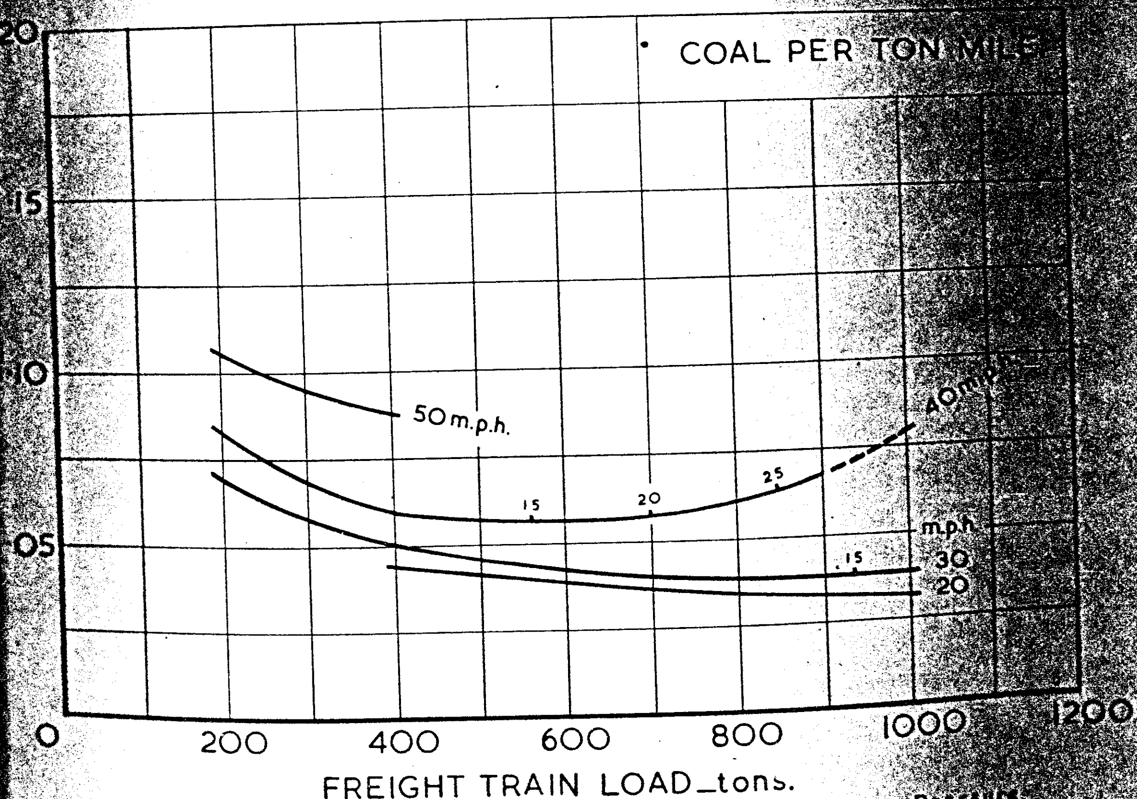
BEDWAS COAL__14050 B.Th.U/lb.

PASSENGER SERVICE — 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





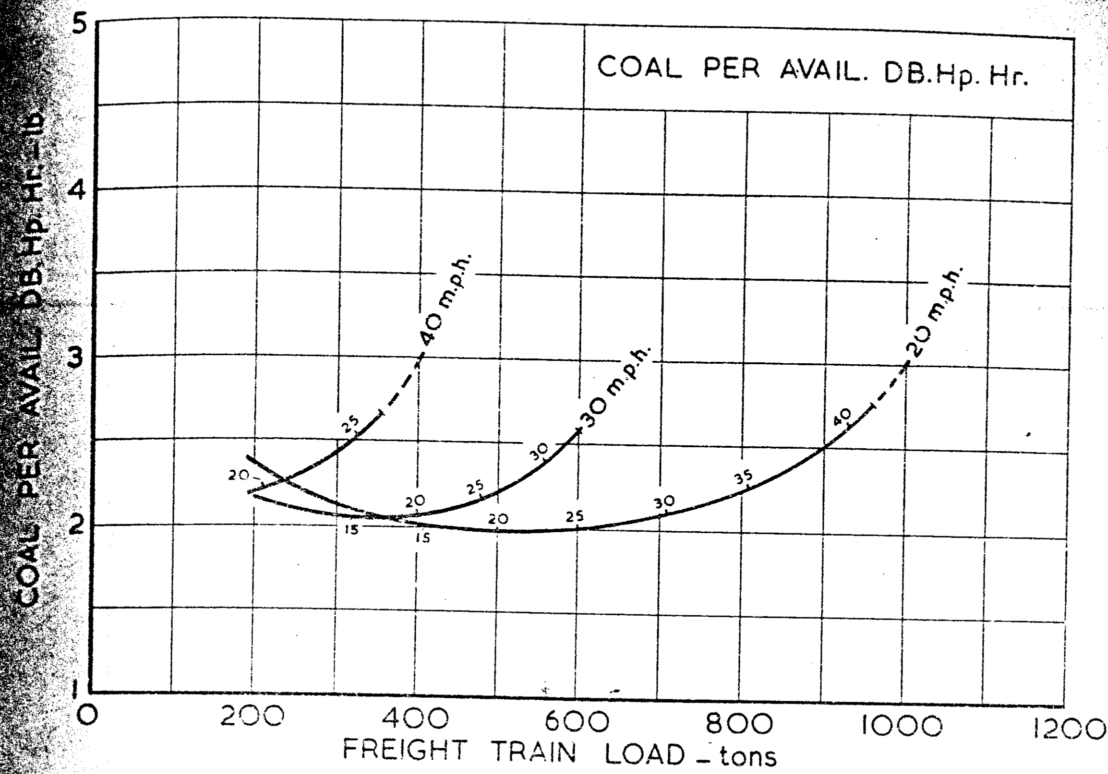
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

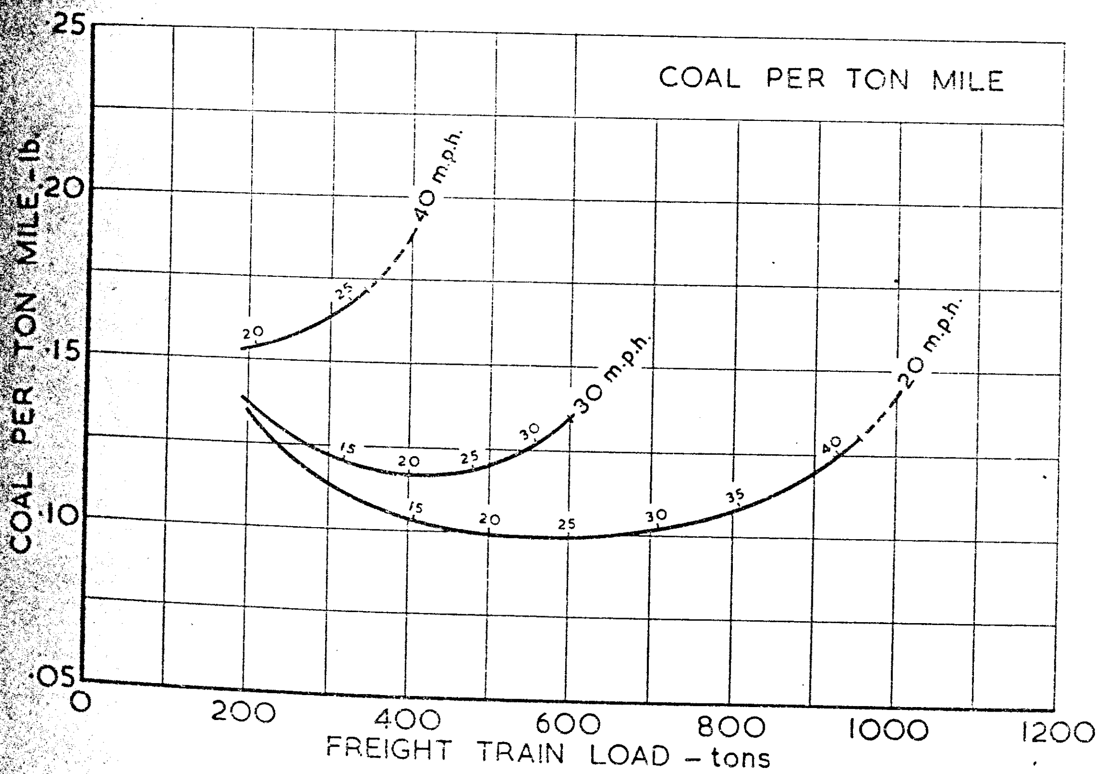
BEDWAS COAL_14050 B.Th.U/lb.

FREIGHT SERVICE_LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





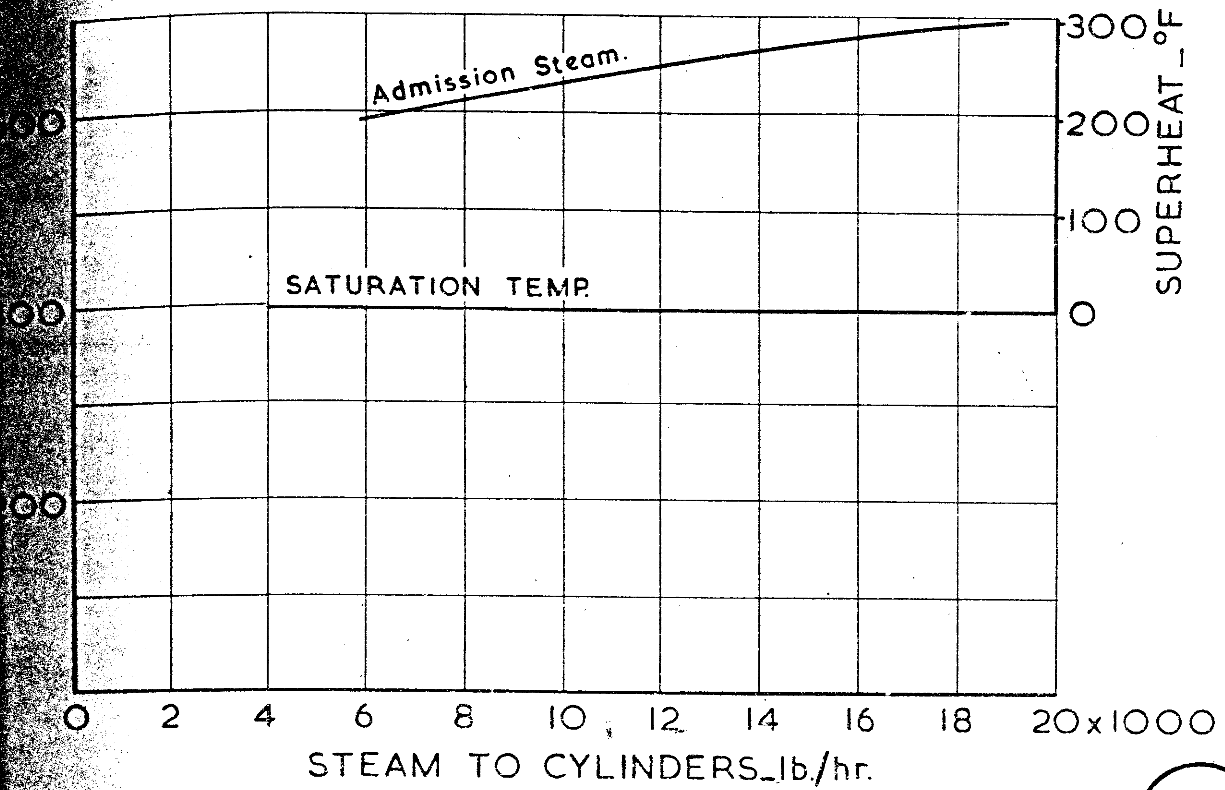
Small Figures on Curves Indicate Cut Off, Maximum Steam Chest Pressure.

BEDWAS COAL – 14050 B.Th.U./lb.

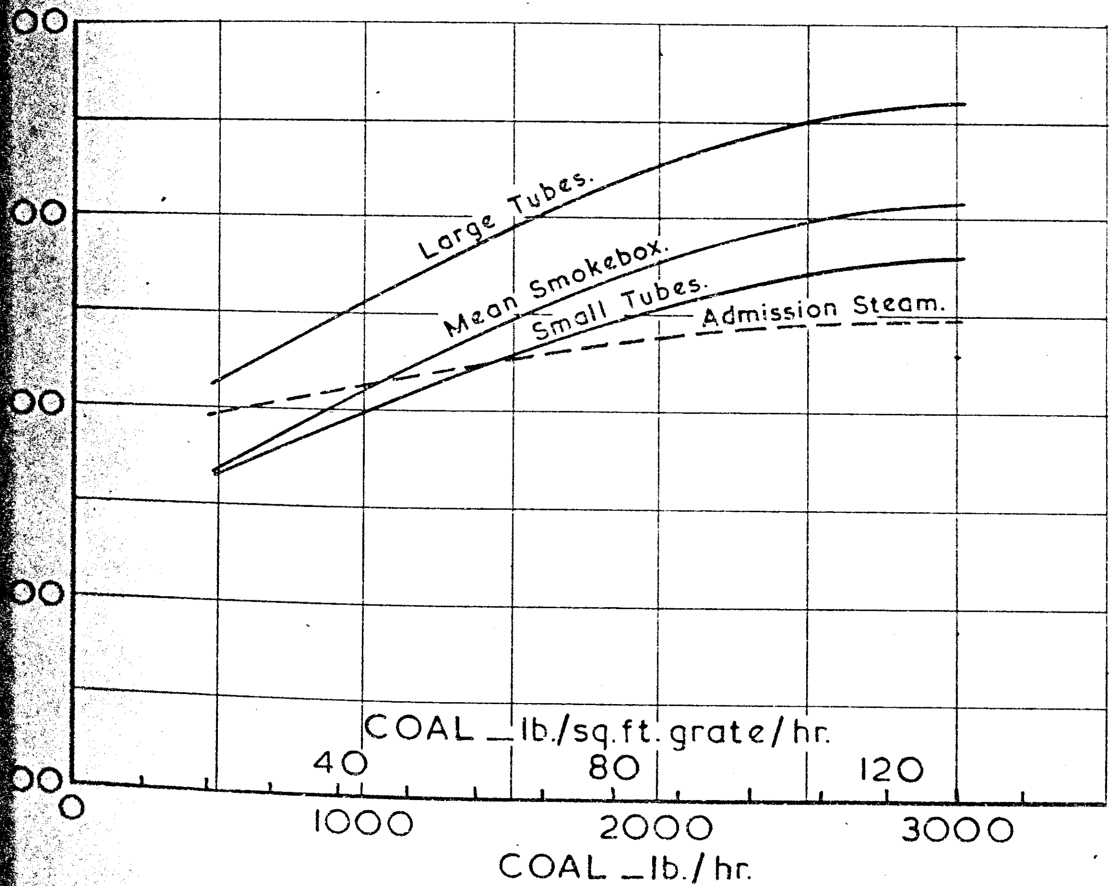
FREIGHT SERVICE – 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

M4/43094/51.



30

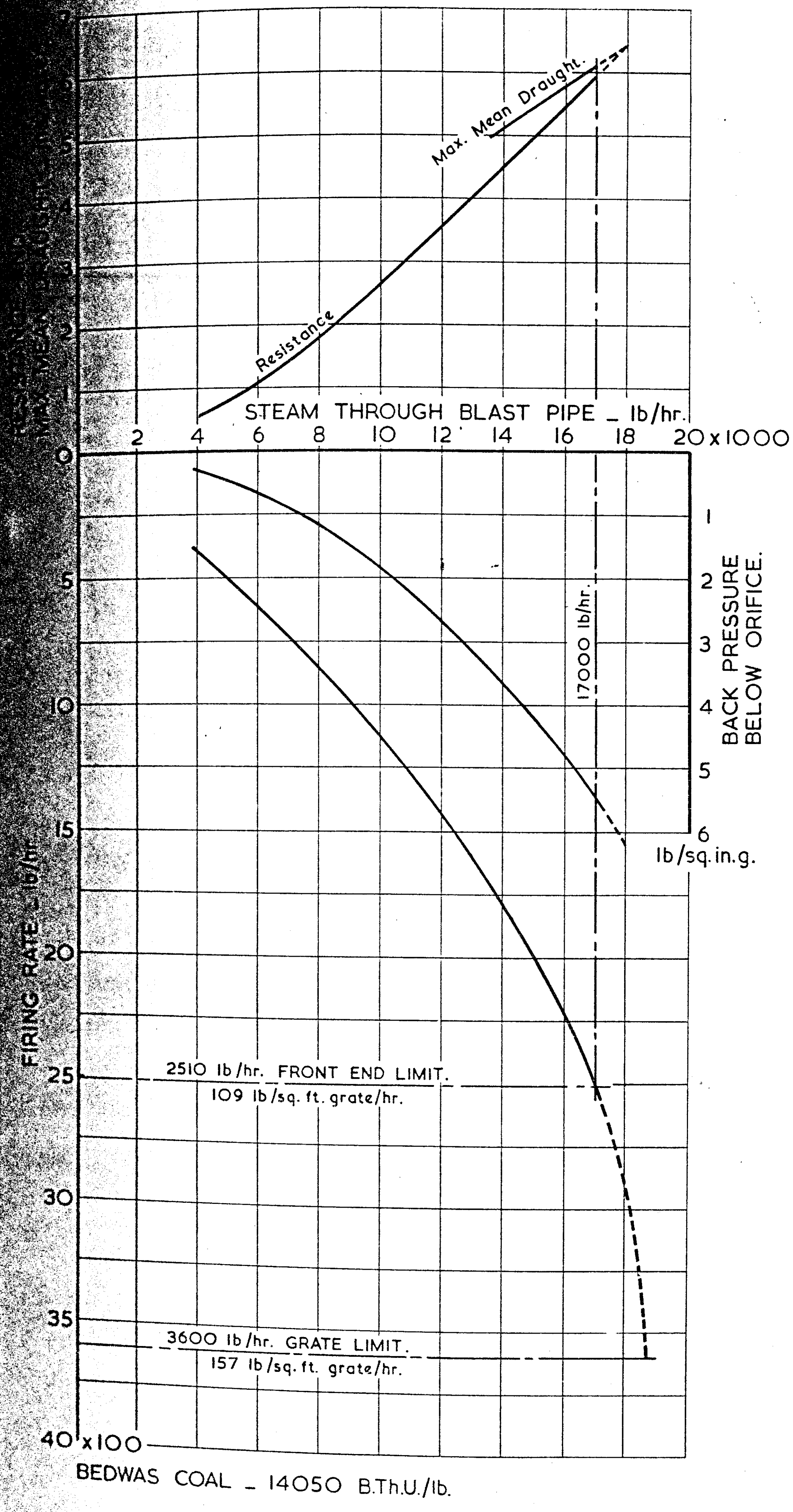


BEDWAS COAL
14050 B.Th.U./lb.

TEMPERATURES

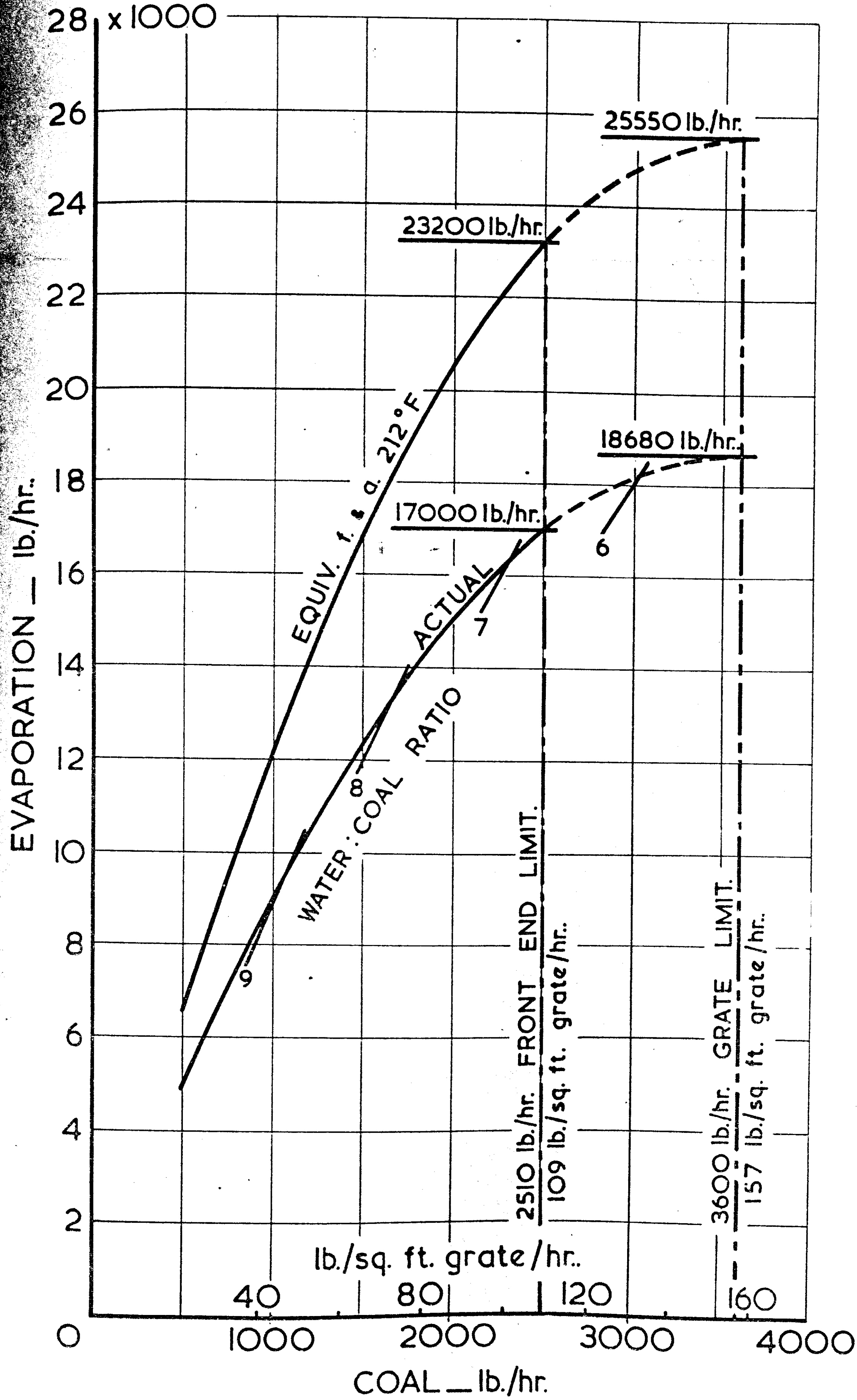
31

M4/43094/51



DRAUGHT.

M4/43094/51.

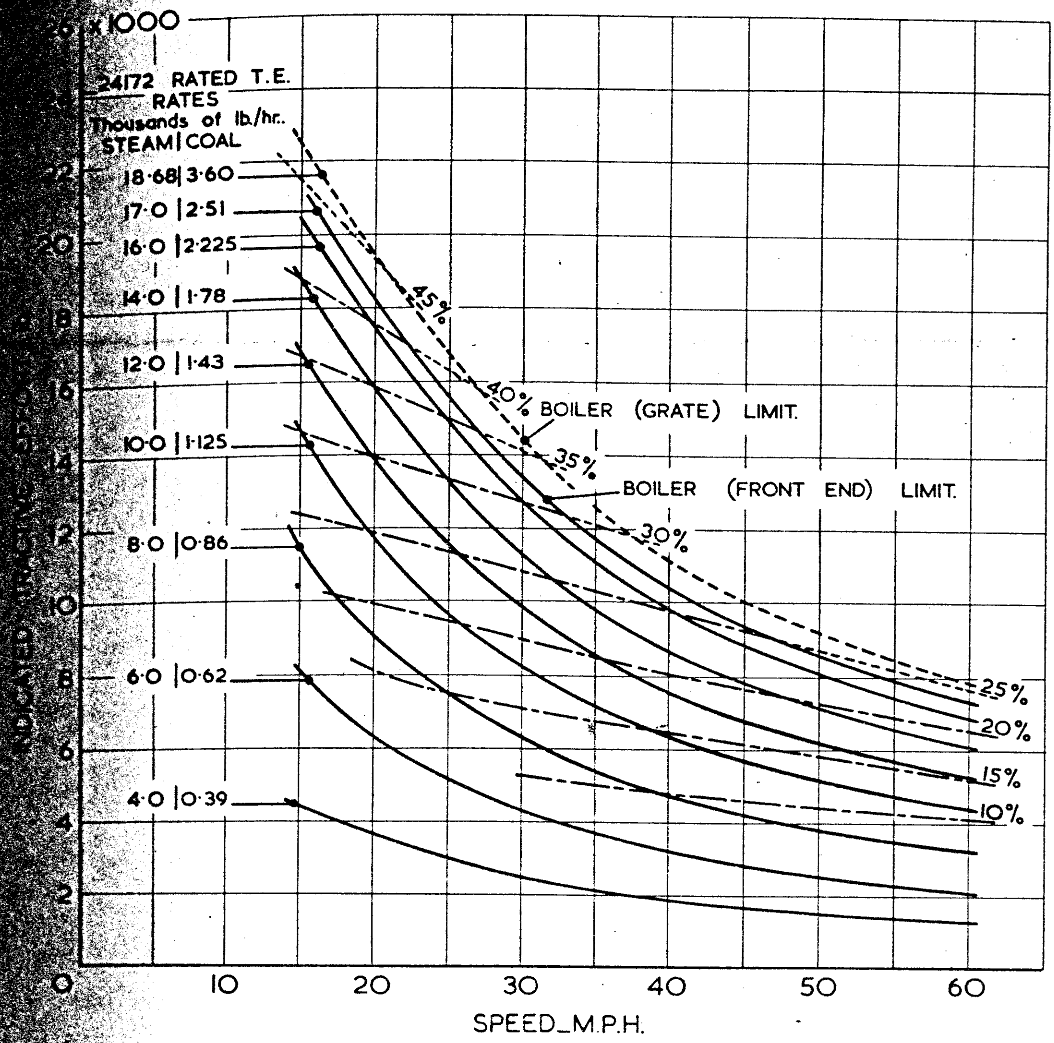


BEDWAS COAL — 14050 B.Th.U./lb.

EVAPORATION.

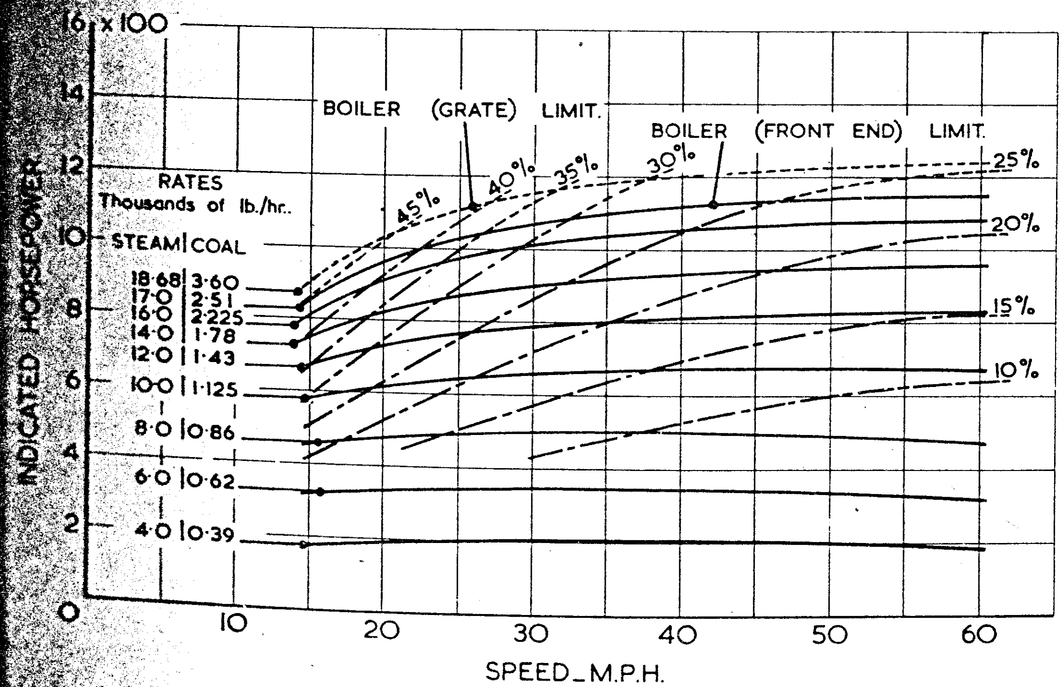
33

M4/43094/51.



34

Cut Offs shown refer to Maximum Steam Chest Pressure.

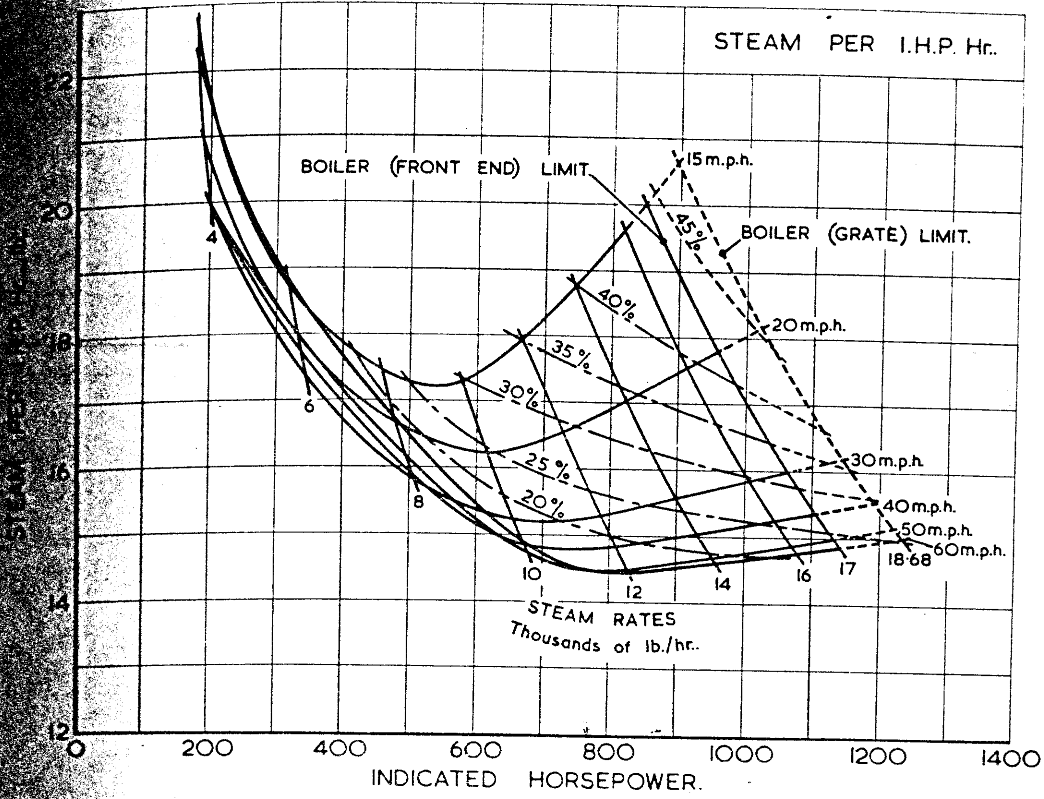


BEDWAS COAL _ 14050 B.Th.U./lb.

35

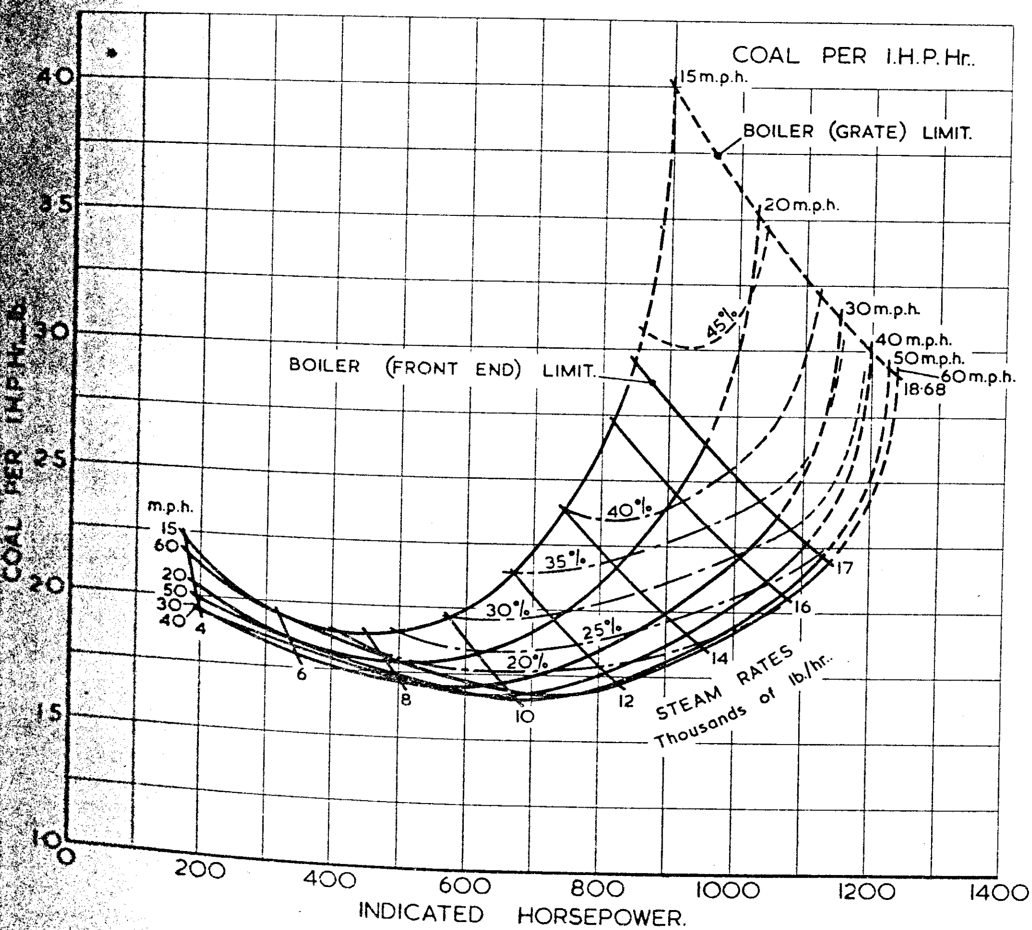
INDICATED CHARACTERISTICS.

M4/43094/51.



36

Cut Offs shown refer to Maximum Steam Chest Pressure.

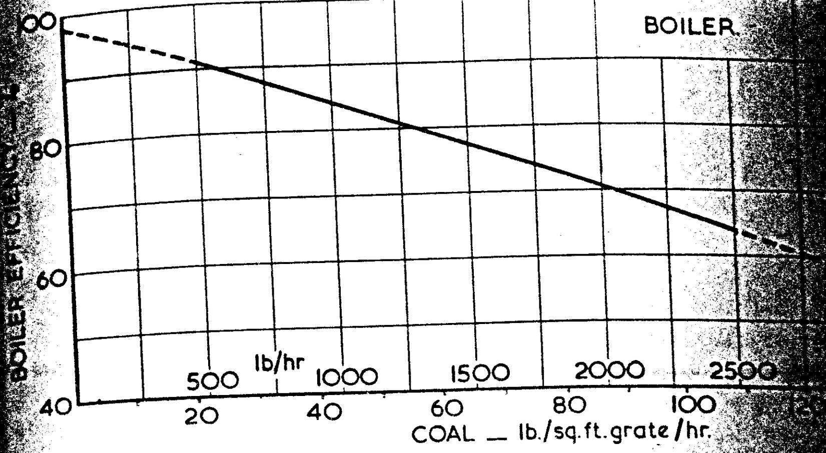


BEDWAS COAL — 14050 B.Th.U./lb.

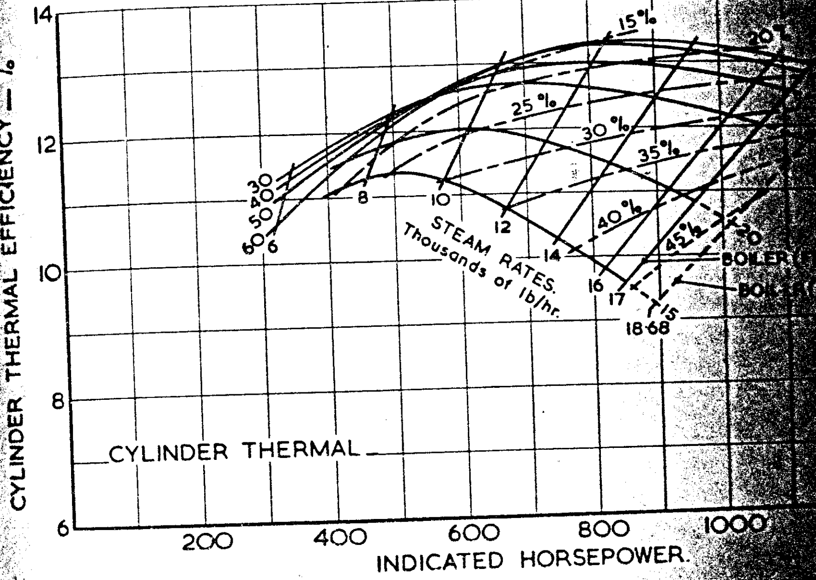
STEAM & COAL PER I.H.P. Hr.

37

M4/43094/51

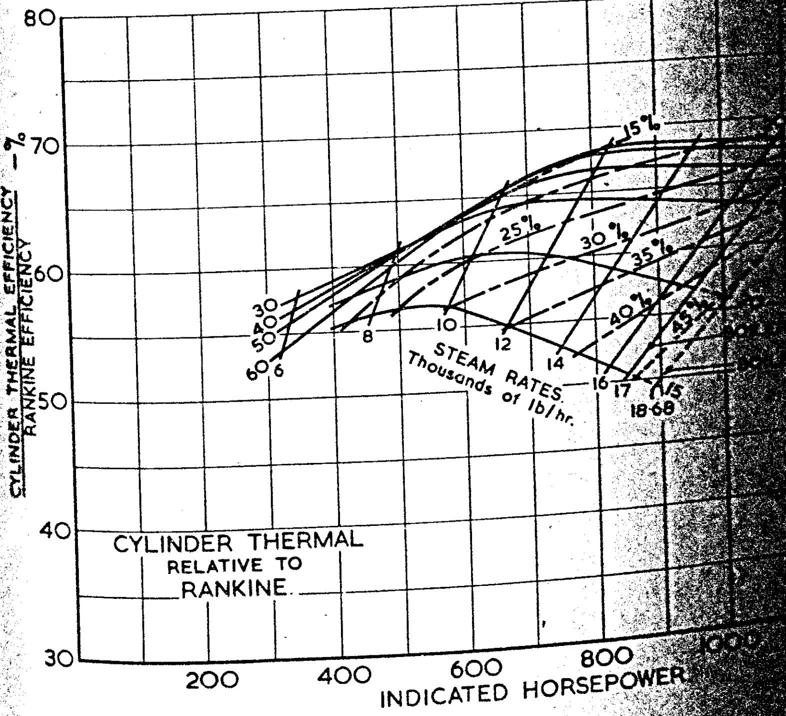


38



Cut Offs shown refer to Max. Steam Chest Pr

39

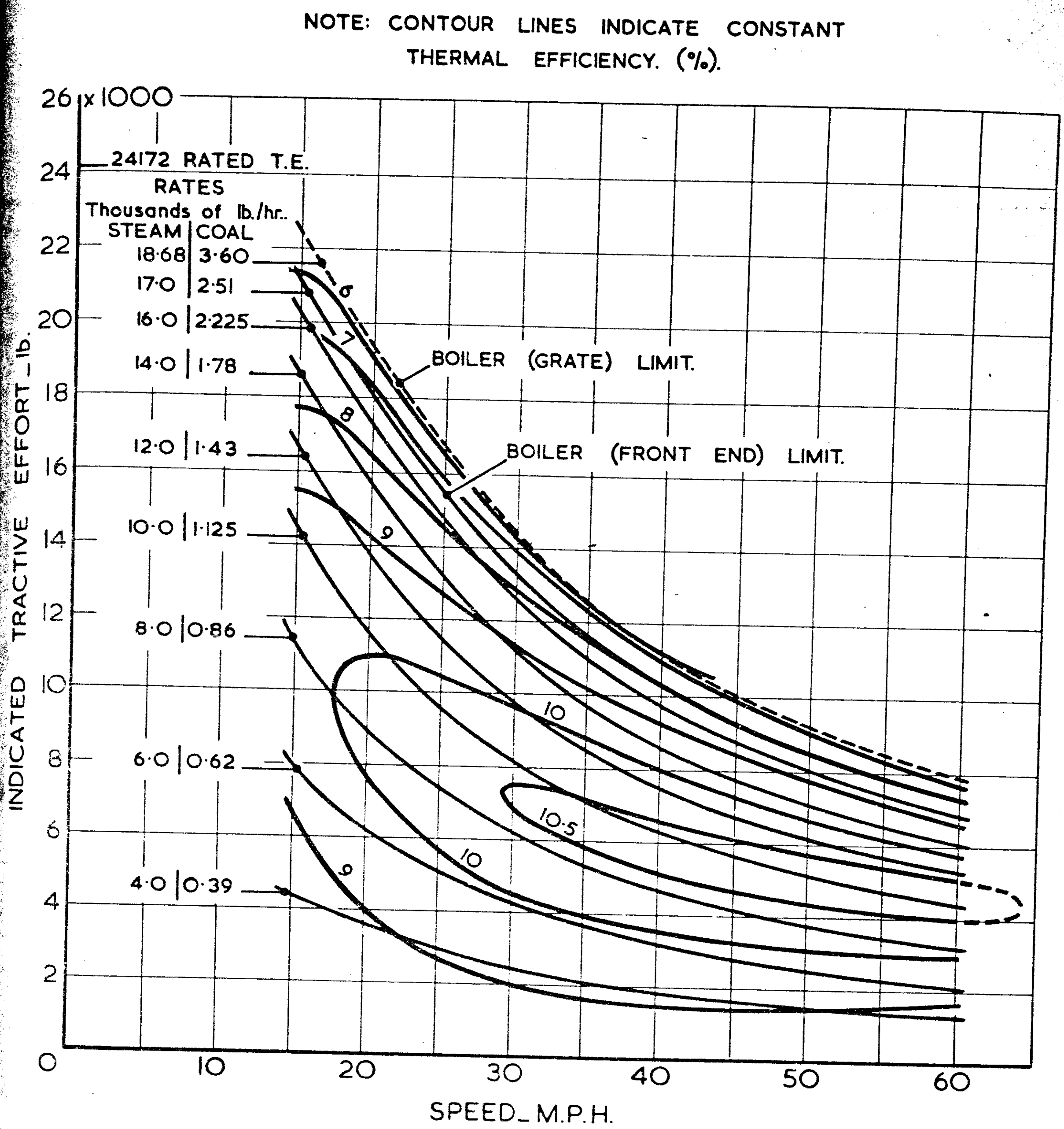


BEDWAS COAL _ 14050 B.Th.U./lb.

EFFICIENCIES.

40

M4/43094/51



BEDWAS COAL _ 14050 B.Th.U./lb..

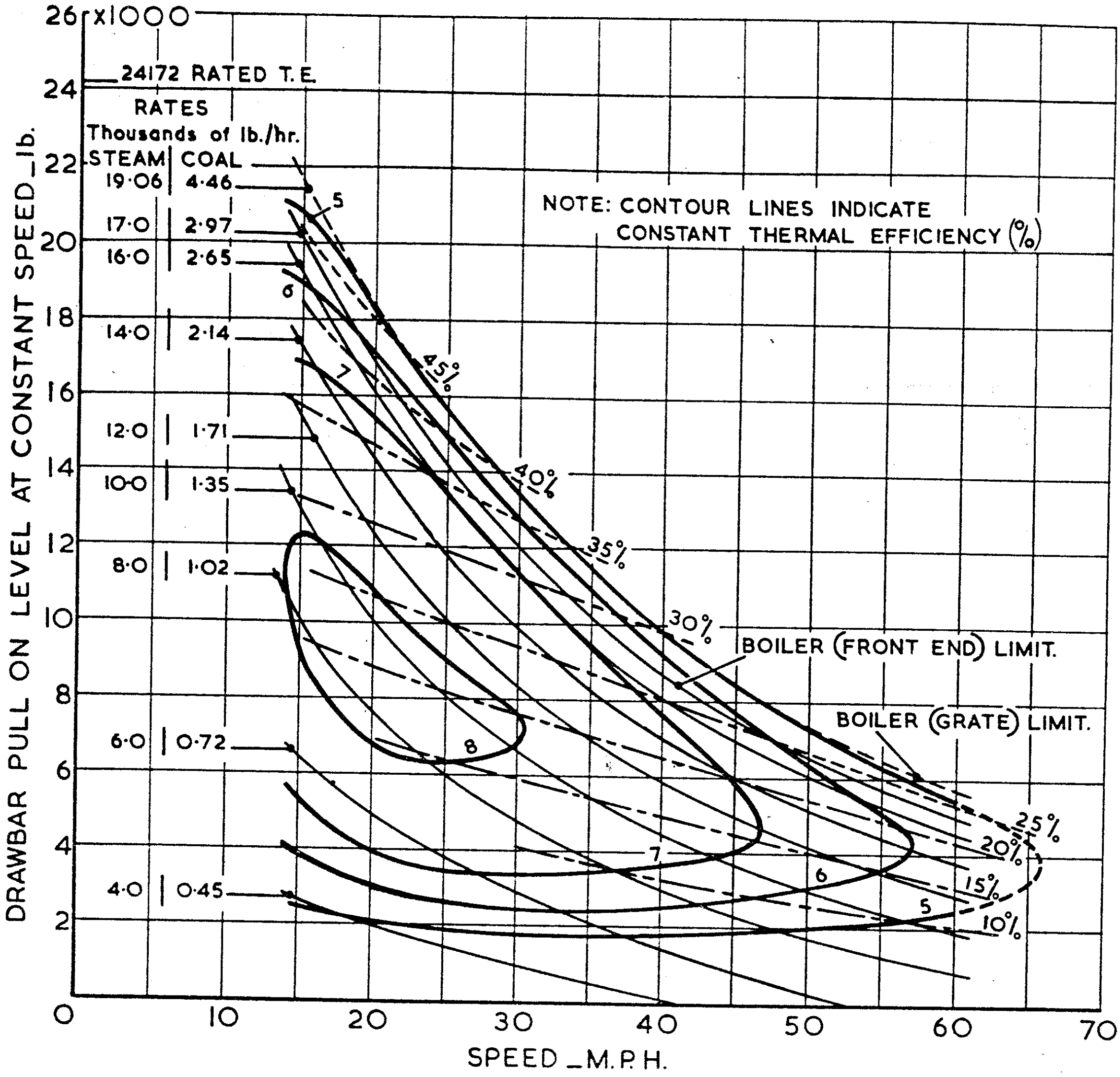
OVERALL EFFICIENCY REFERRED TO CYLINDERS.

M4/43094/51.

LILLESHALL COAL.

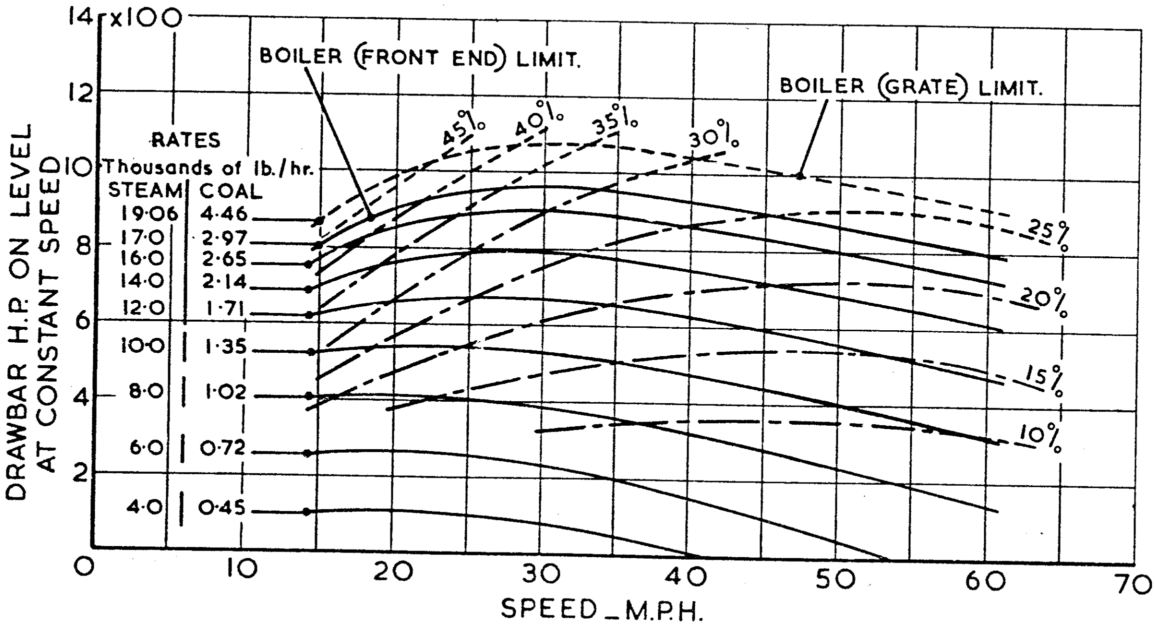
Performance data : Graphs 42 to 49.

Design data : Graphs 50 to 61.



Cut Offs shown refer to Maximum Steam Chest Pressure.

42

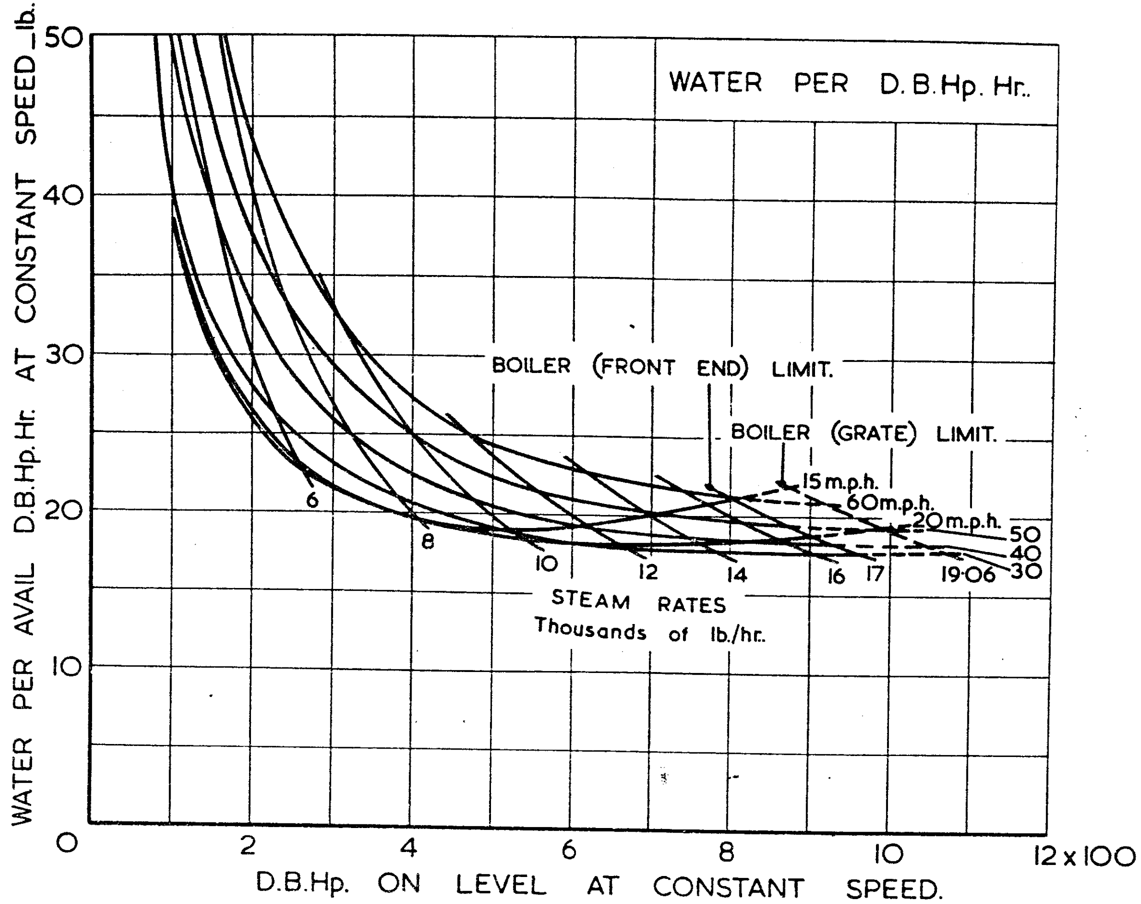


LILLESHALL COAL _ 12660 B.Th.U./lb.

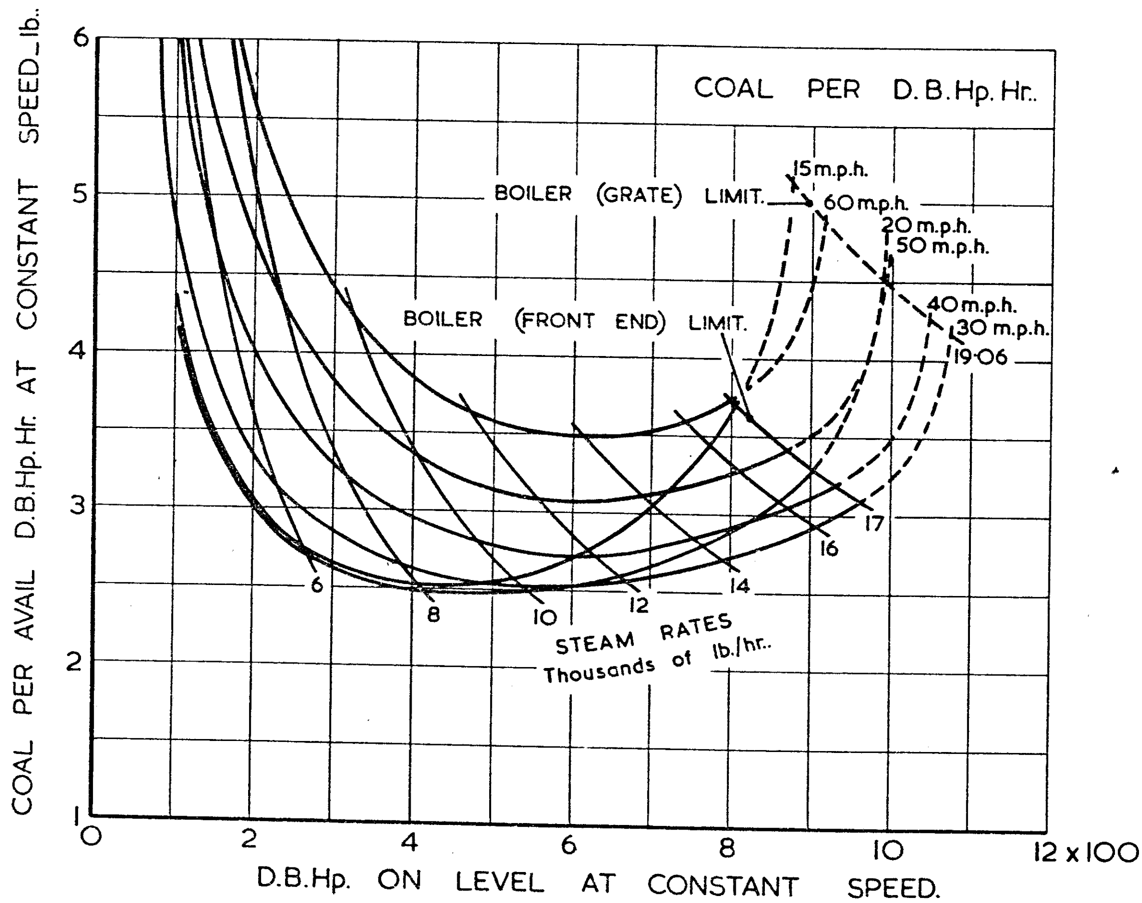
DRAWBAR CHARACTERISTICS.

M4/43094/51.

43



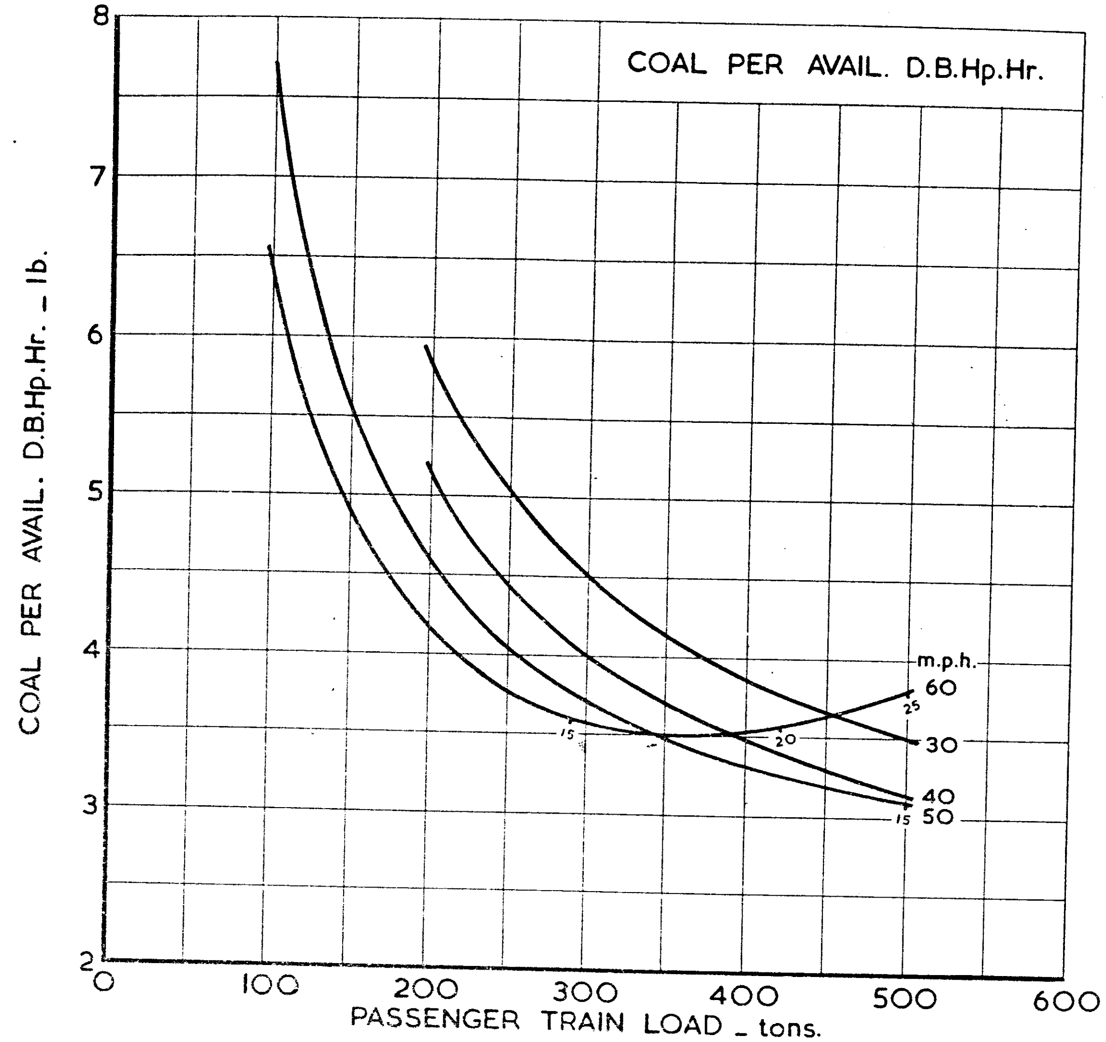
44

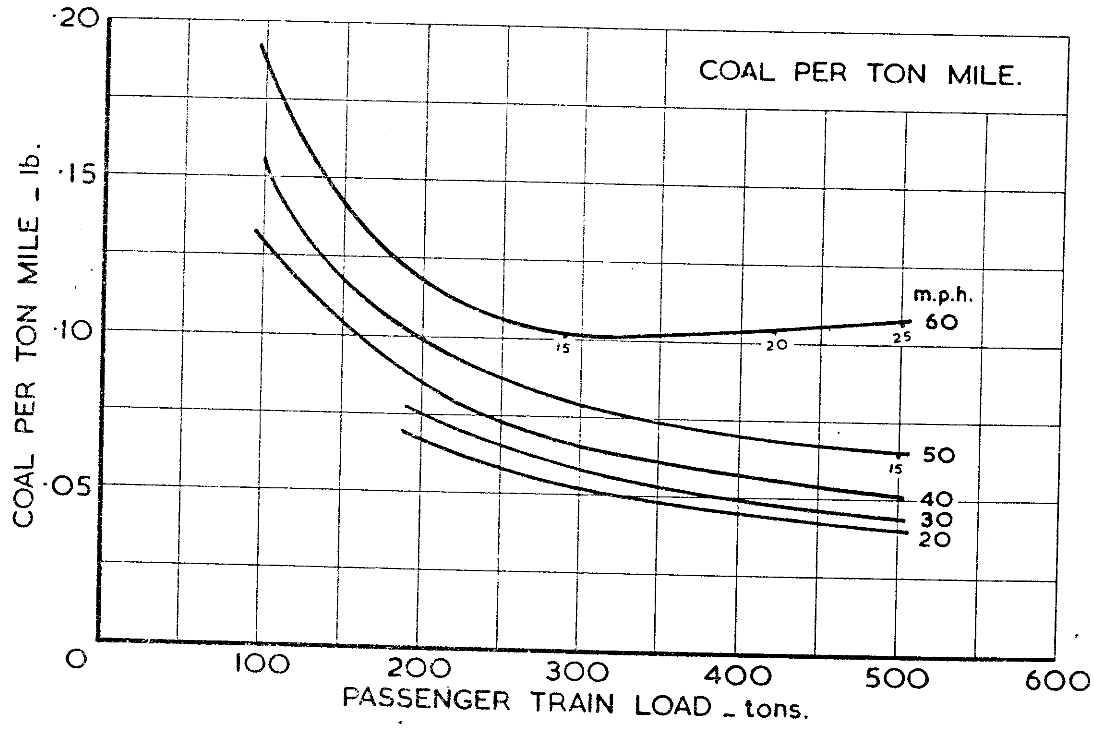


LILLESHALL COAL _ 12660 B.Th.U./lb..

WATER & COAL PER D.B.Hp.Hr..

M4/43094/51





Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

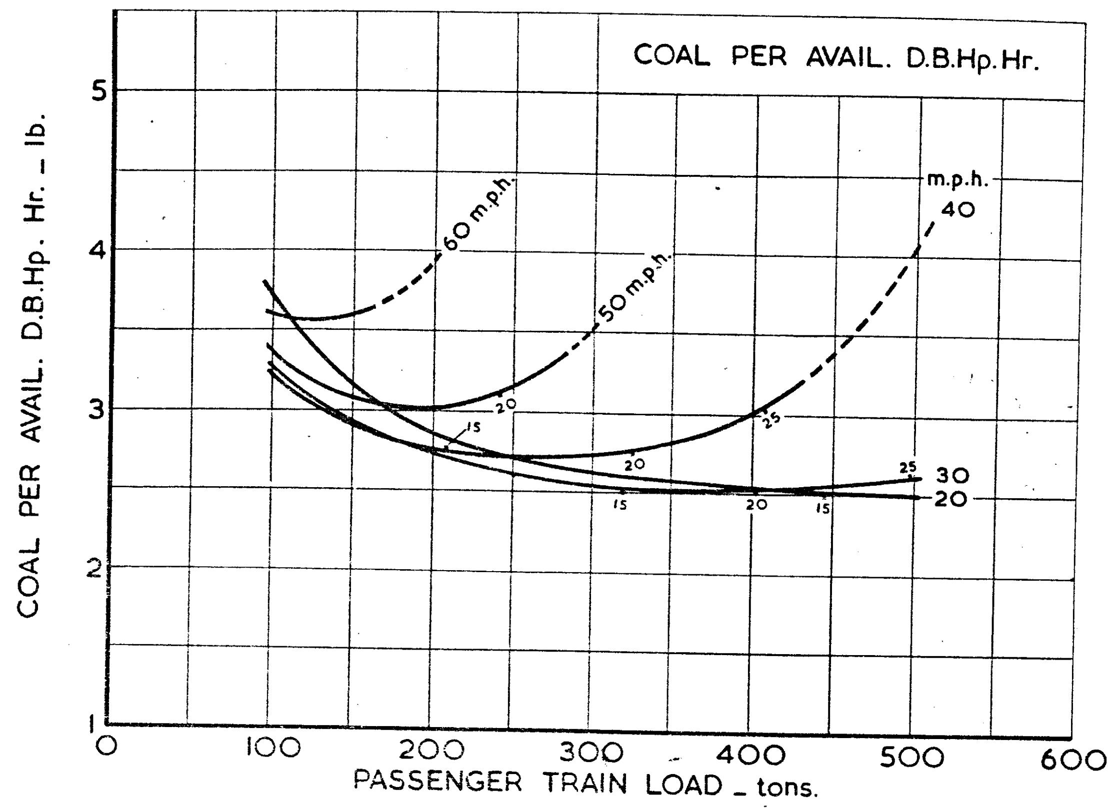
LILLESHALL COAL _ 12660 B.Th.U./lb.

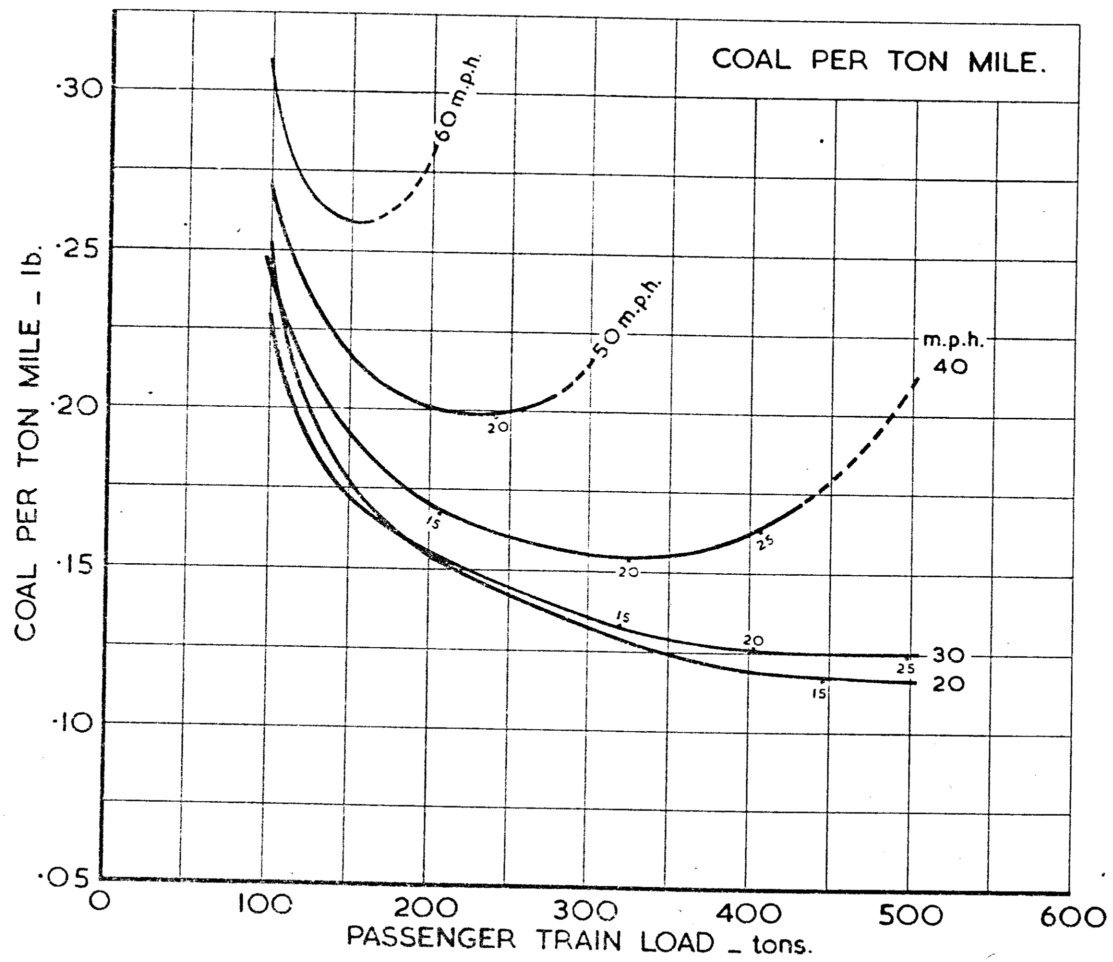
PASSENGER SERVICE _ LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

46

M4/43094/51.





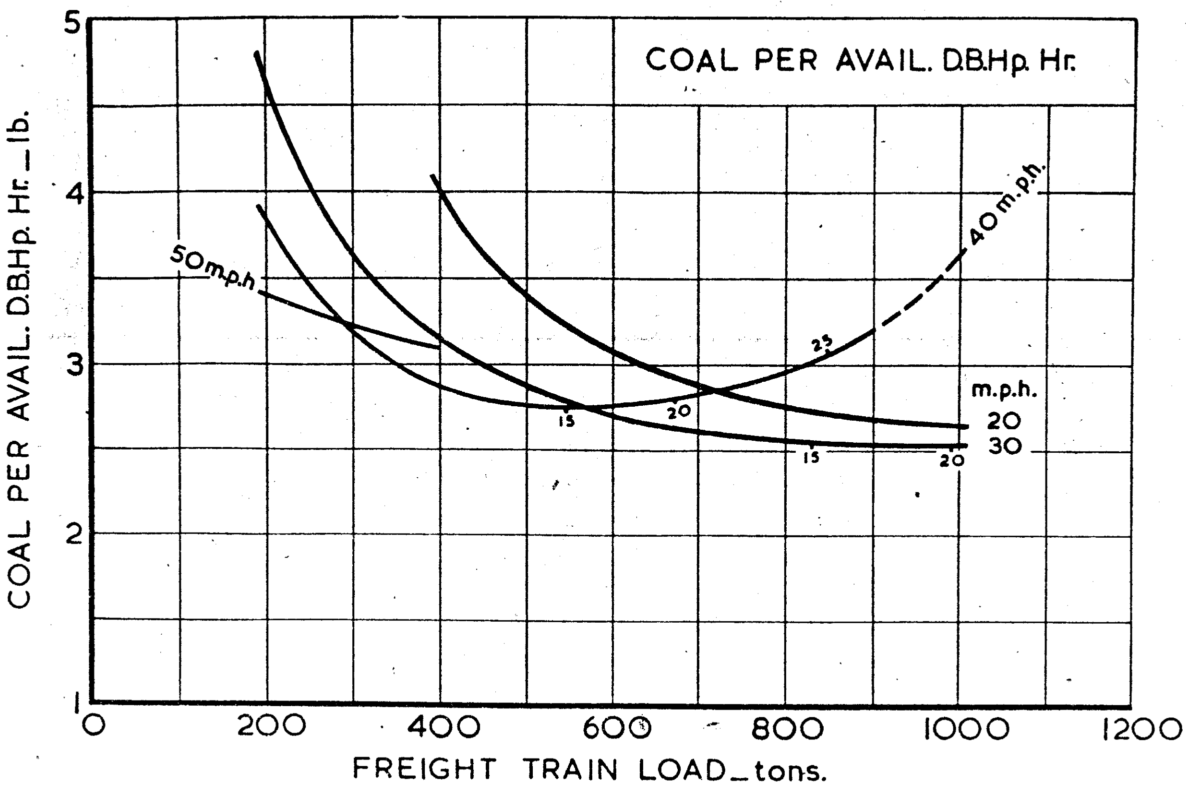
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

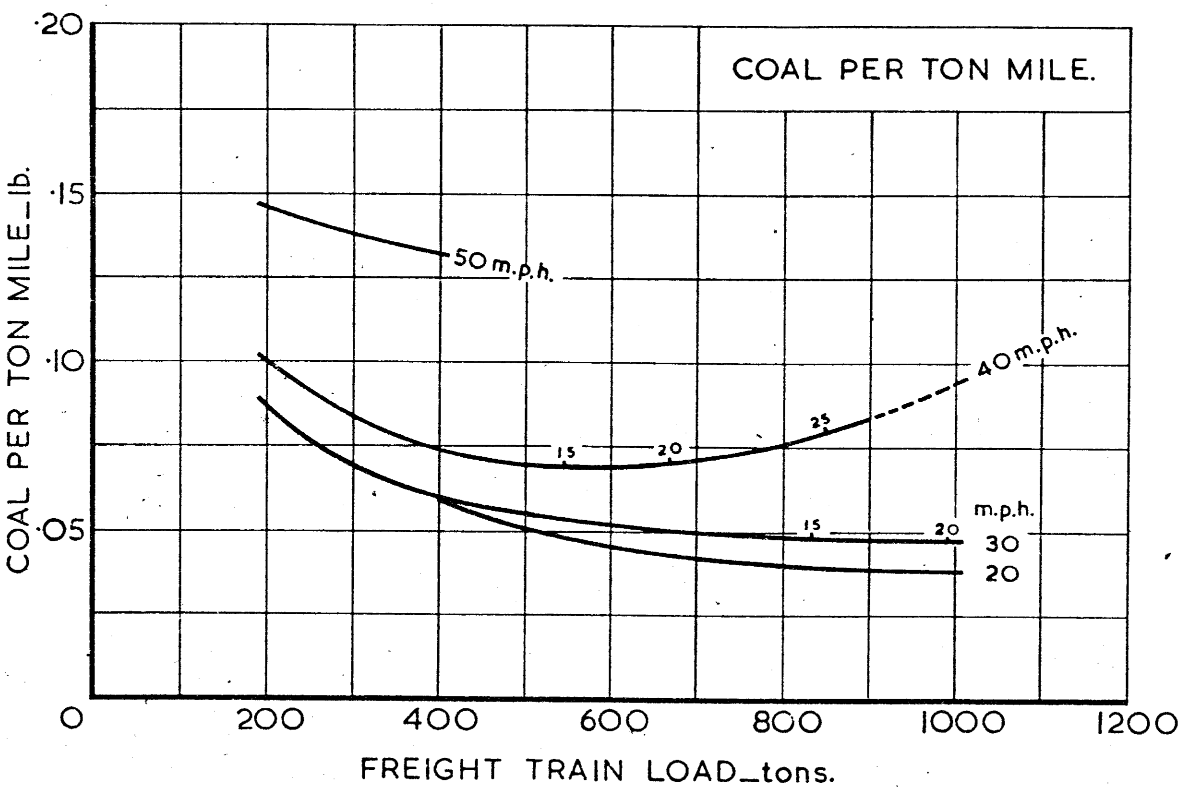
LILLESHALL COAL – 12660 B.Th.U./lb.

PASSENGER SERVICE – 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





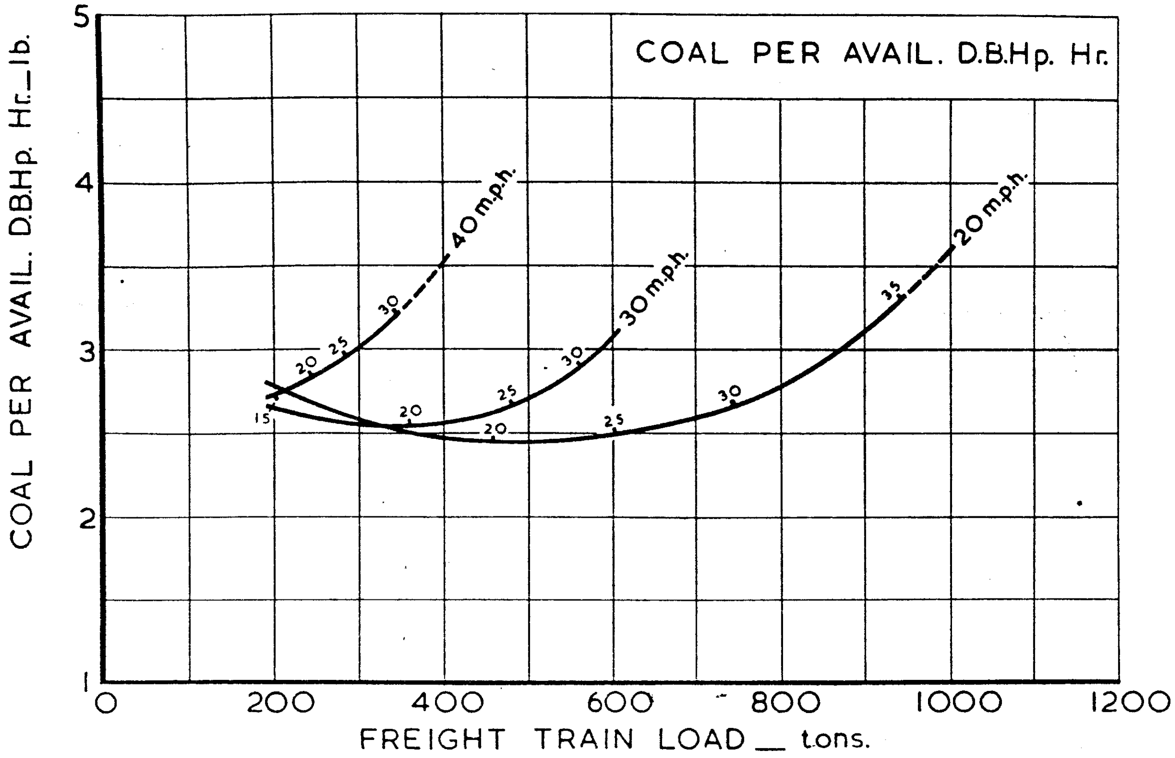
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

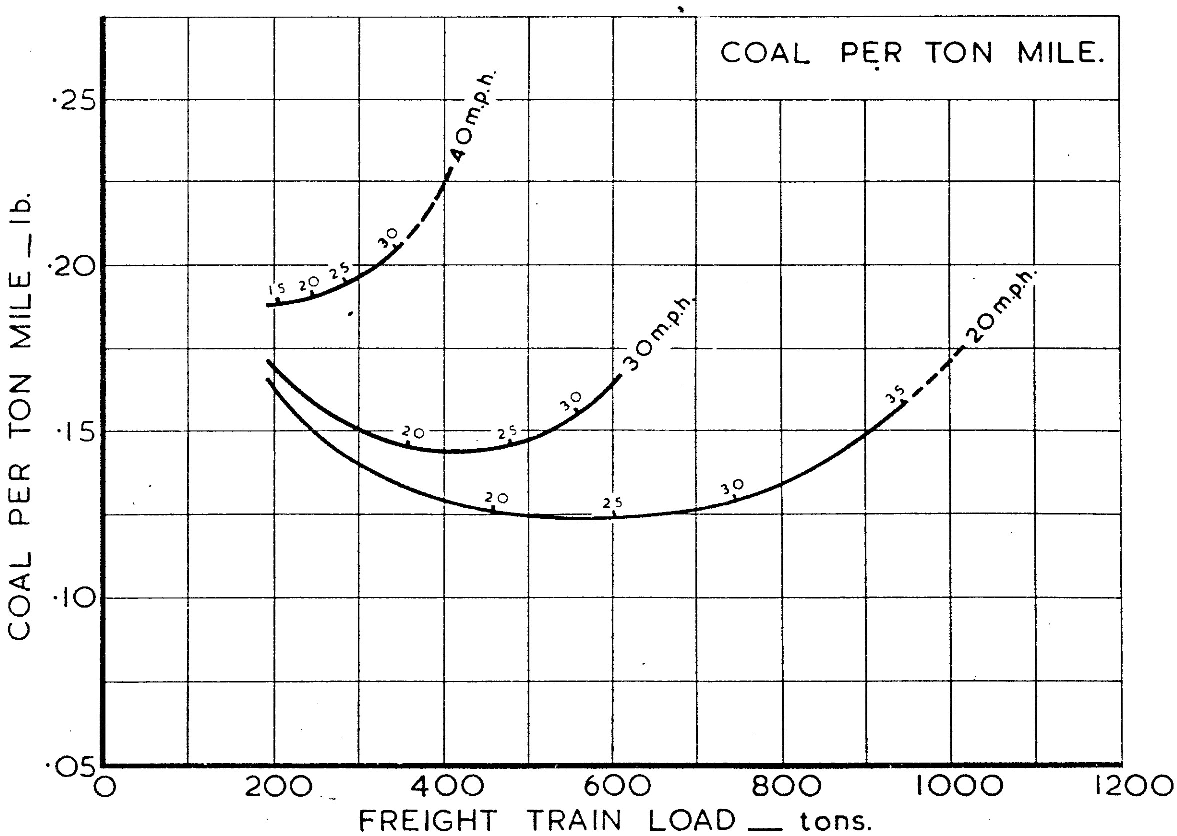
LILLESHALL COAL_12660 B.Th.U/lb.

FREIGHT SERVICE_LEVEL.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.





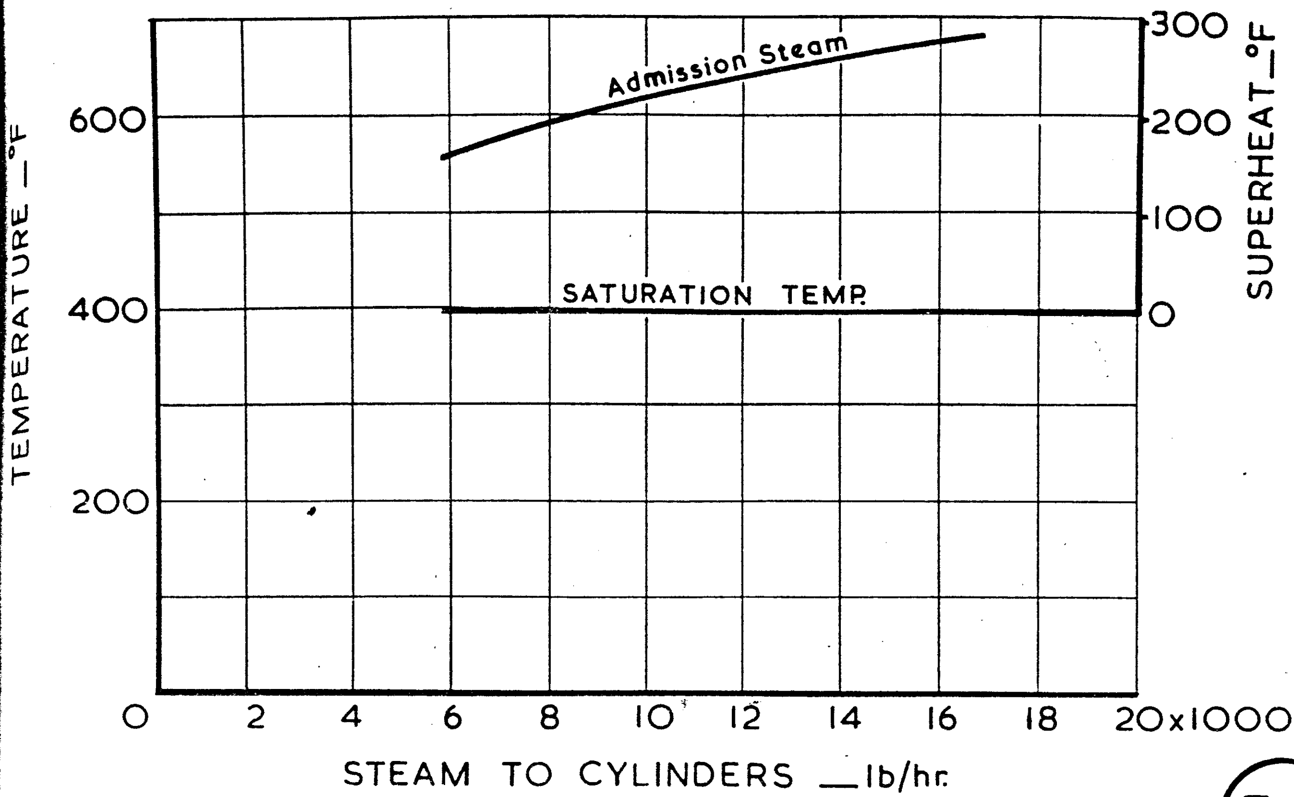
Small Figures on Curves Indicate Cut Off, Maximum Steam Chest Pressure.

LILLESHALL COAL 12660 B.Th.U/lb.

FREIGHT SERVICE — 1 IN 200 RISING.

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.

M4/43094/51.



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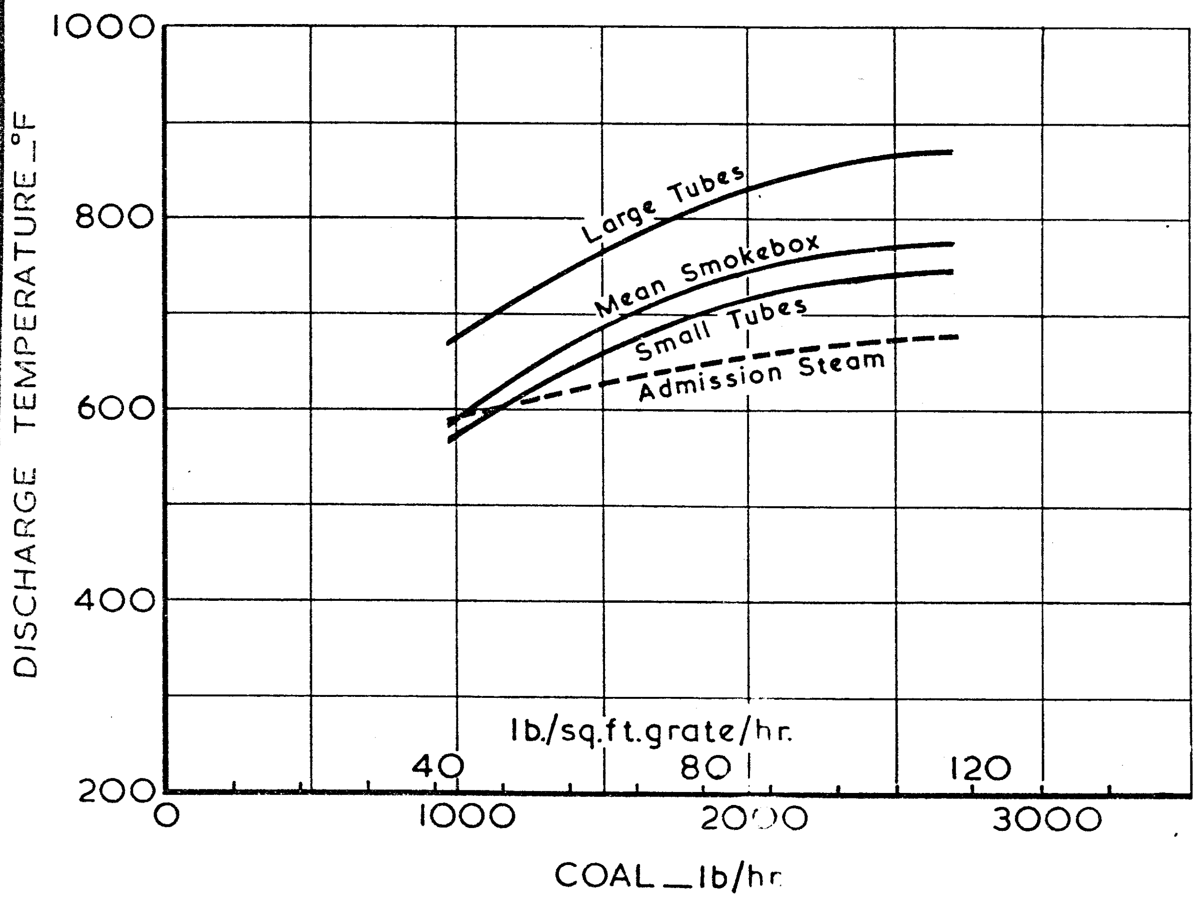
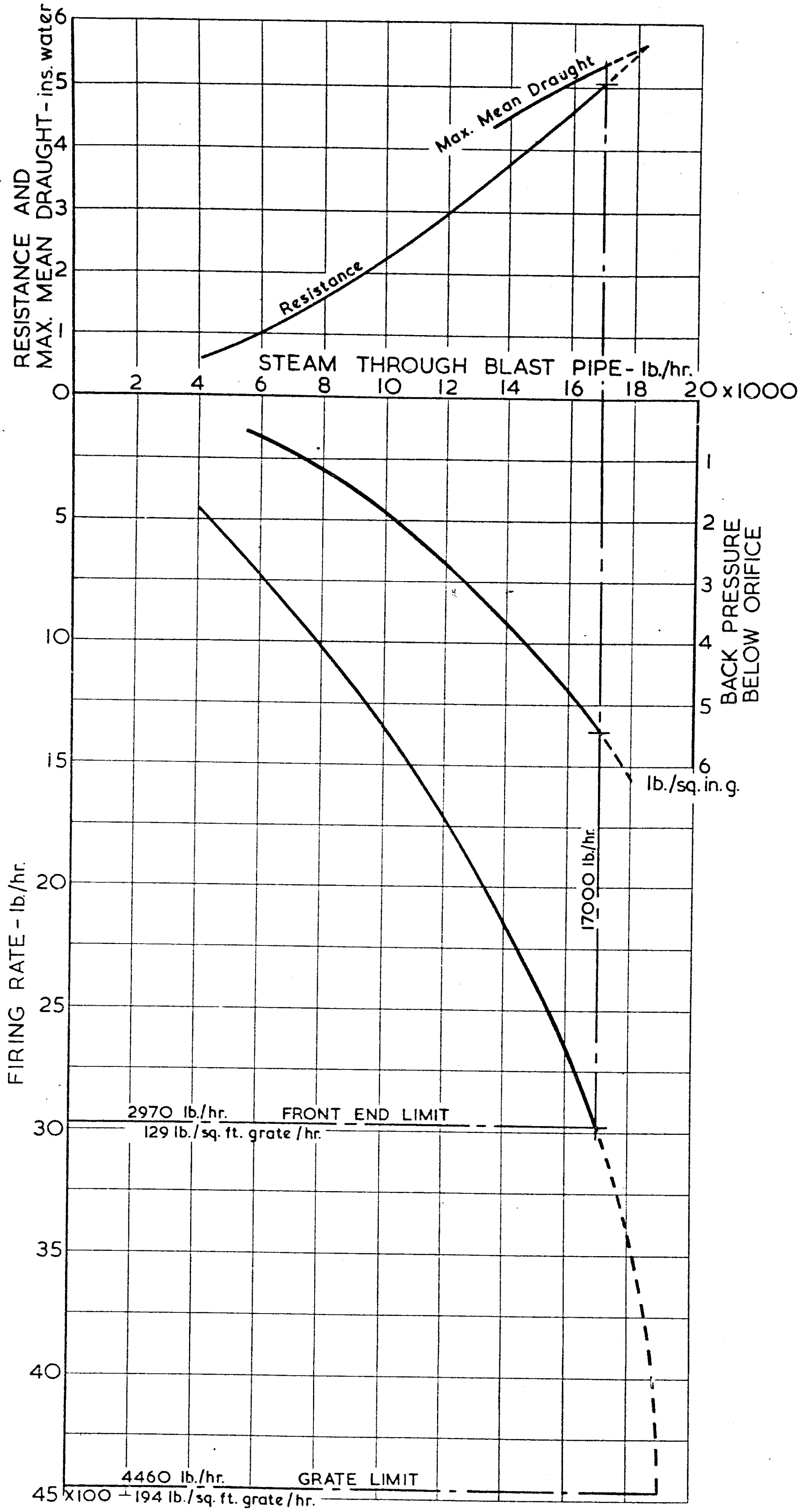


LILLESHALL COAL
12660 B.Th.U/lb.

TEMPERATURES

51

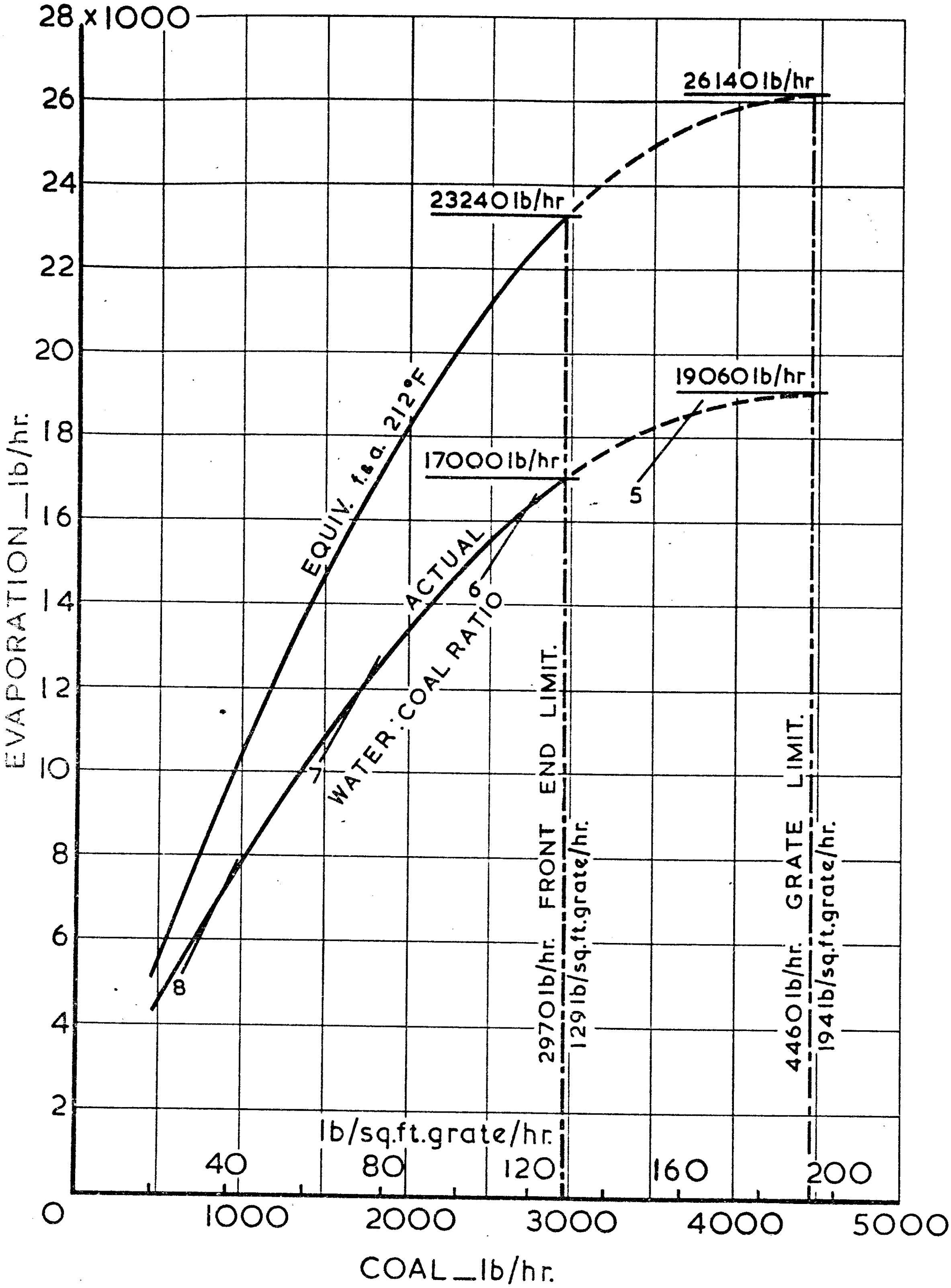
M4/43094/51.



LILLESHALL COAL - 12660 B.Th.U./lb.

DRAUGHT

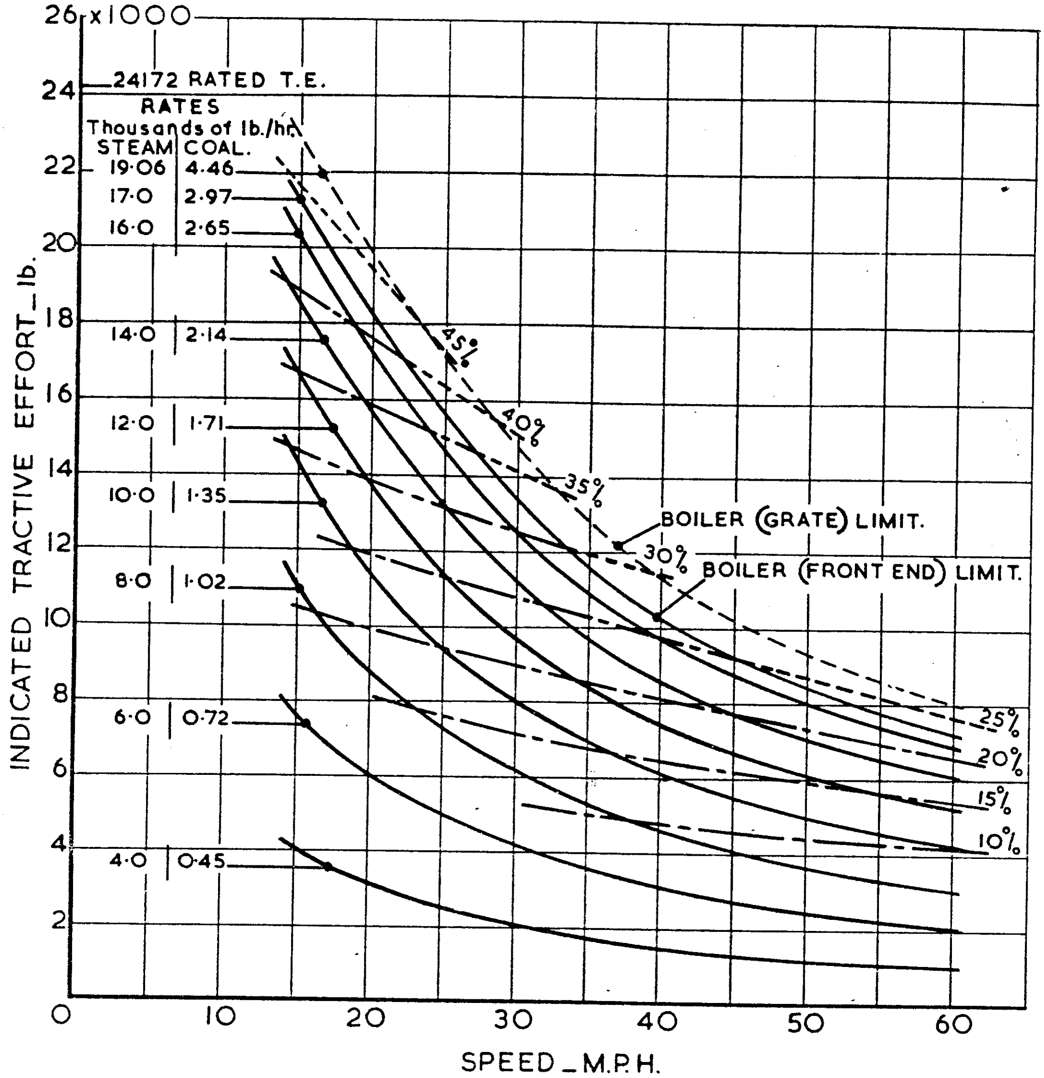
M4/43094/51.



LILLESHALL COAL — 12660 B.Th.U/lb.

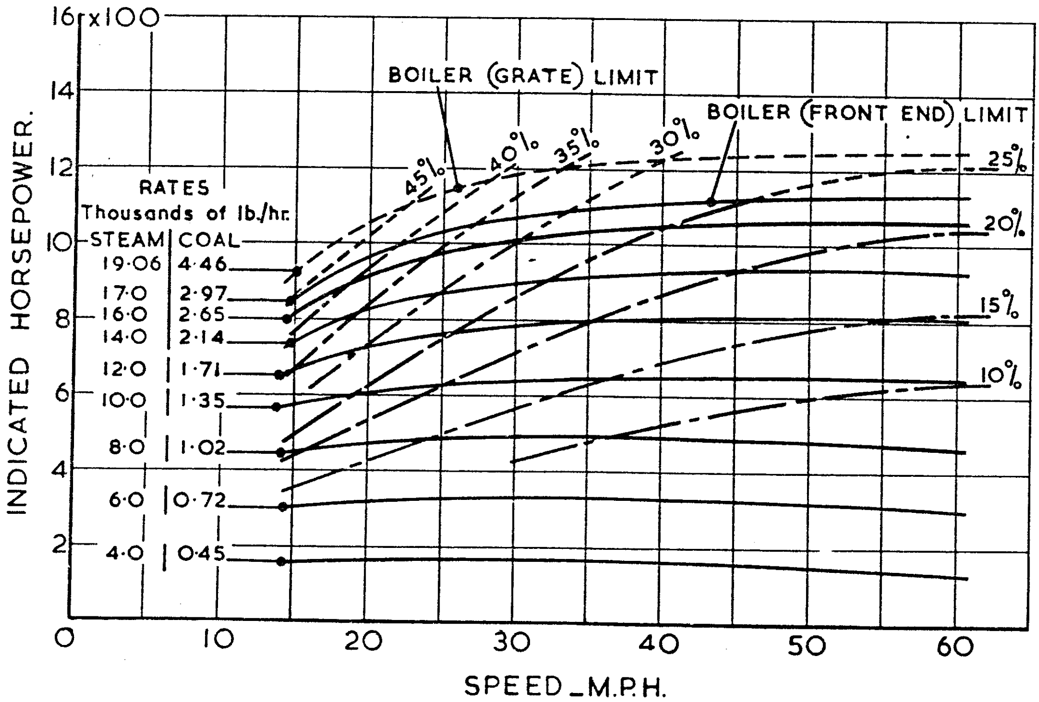
EVAPORATION.

M4/43094/51.



54

Cut Offs shown refer to Maximum Steam Chest Pressures.

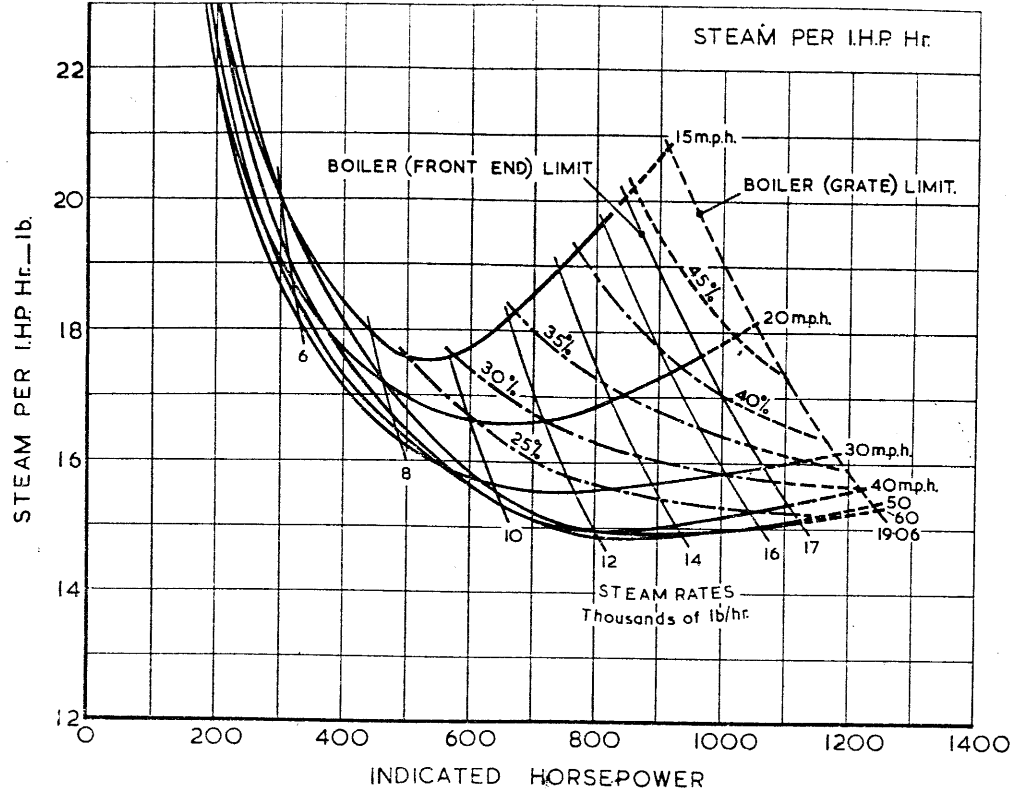


LILLESHALL COAL _ 12660 B.Th.U./lb.

INDICATED CHARACTERISTICS

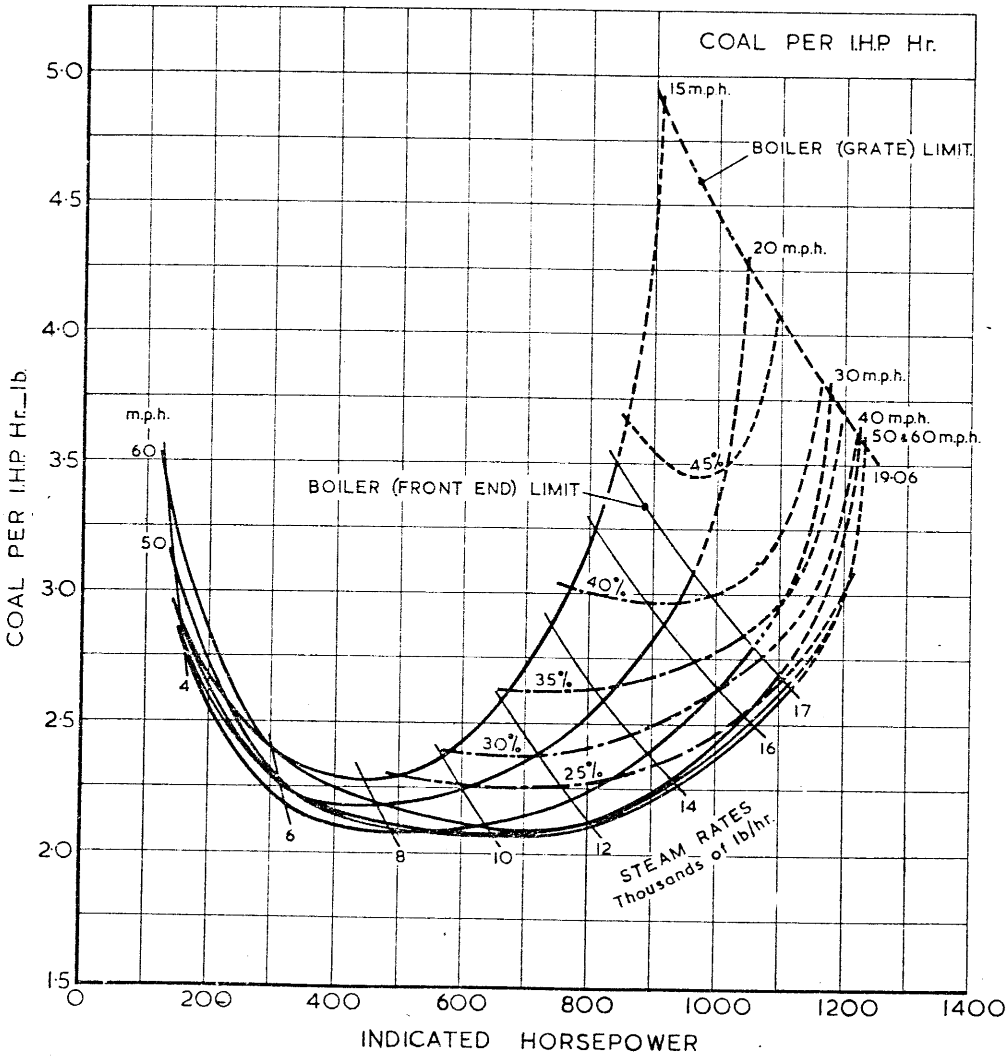
55

M4/43094/51.



56

Cut Offs shown refer to Maximum Steam Chest Pressure.

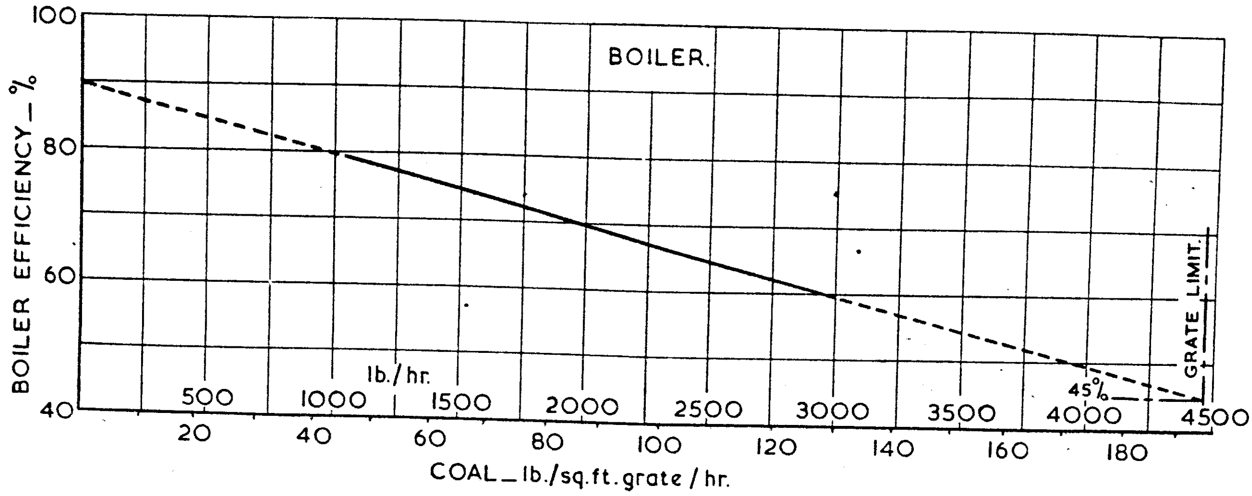


LILLESHALL COAL — 12660 B.Th.U/lb.

STEAM & COAL PER I.H.P. Hr.

57

M 4/43094/51



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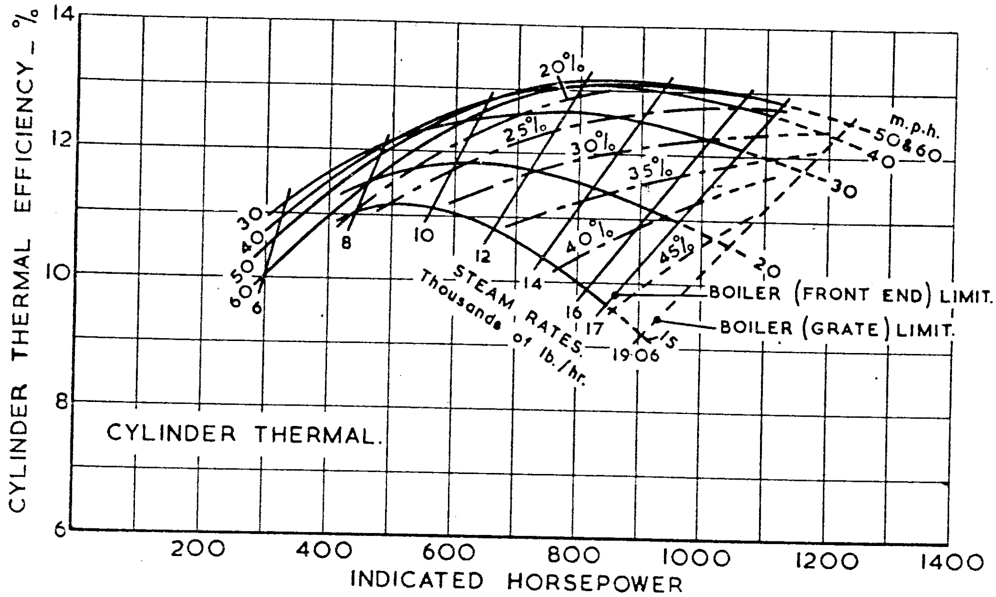
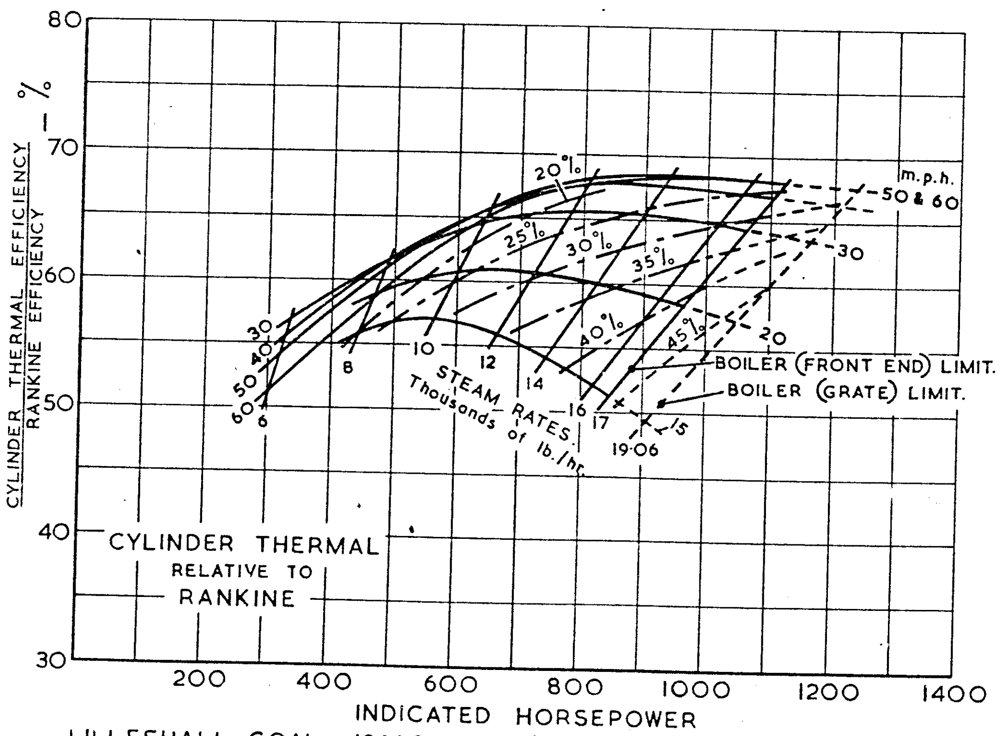


59

Cut Offs shown refer to Max Steam Chest Pressure.

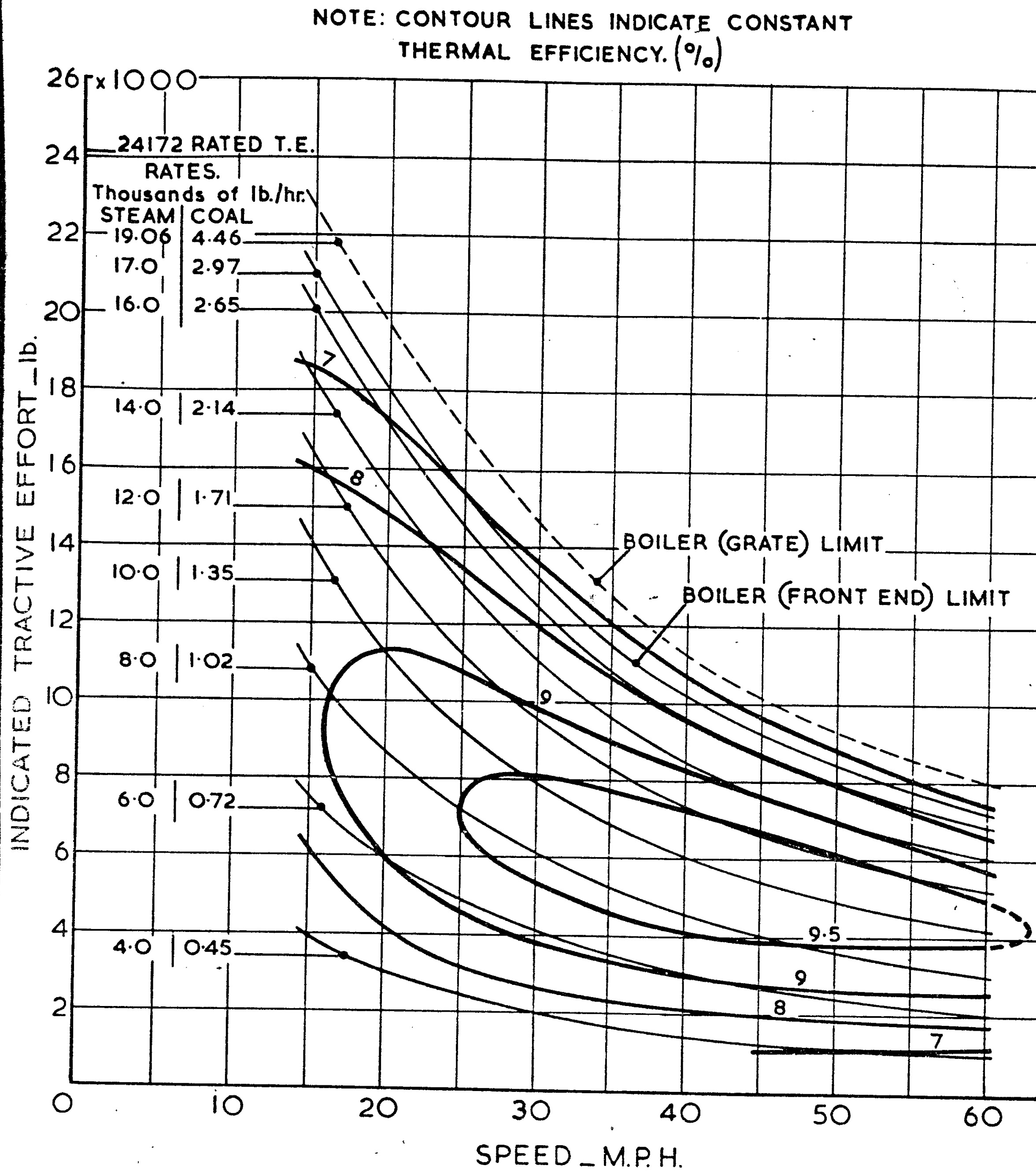


LILLESHALL COAL _ 12660 B.Th.U./lb.

EFFICIENCIES.

M4/43094/51.

60



LILLESHALL COAL _ 12660 B.Th.U./lb.

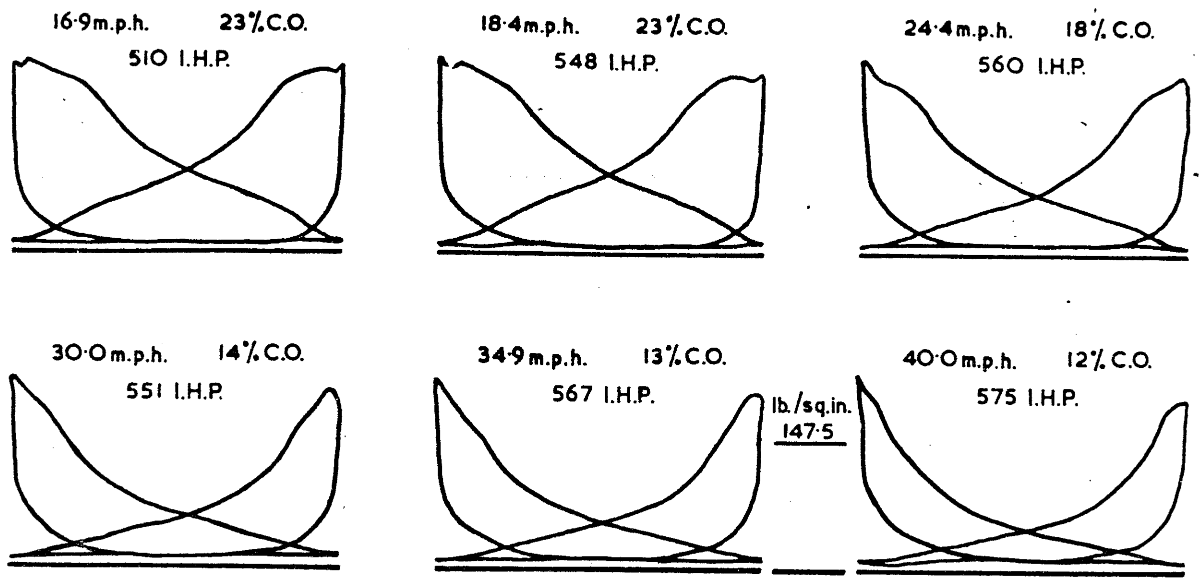
OVERALL EFFICIENCY REFERRED TO CYLINDERS.

M4/43094/51.

EXAMPLES OF INDICATOR CARDS.

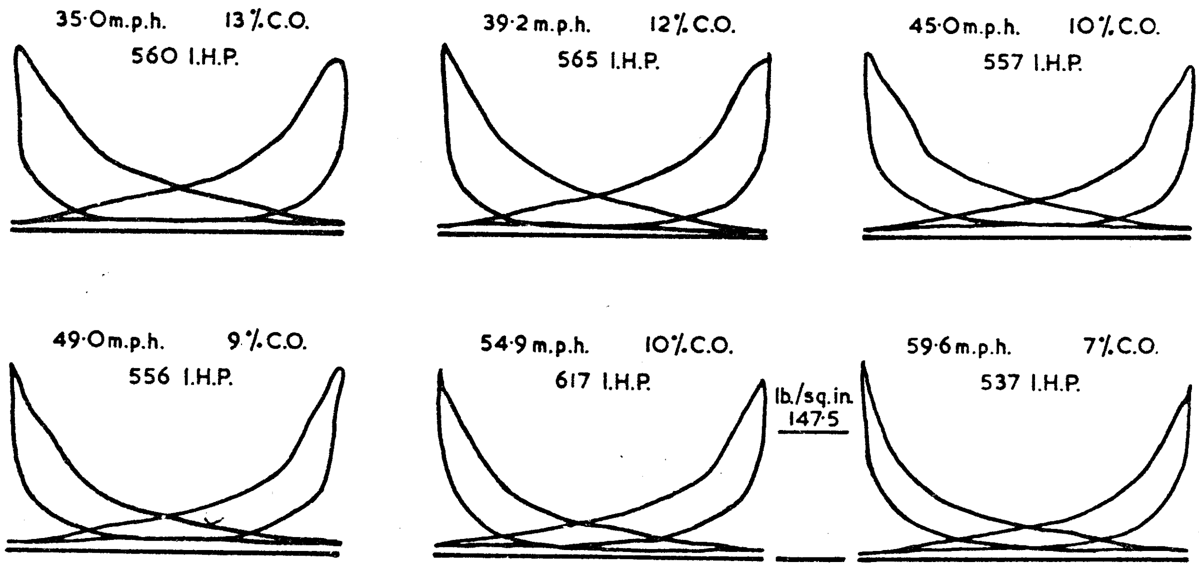
MEAN STEAM RATE 8850 lb./hr.. FULL REGULATOR.

Stationary Plant Test.



MEAN STEAM RATE 8800 lb./hr.. FULL REGULATOR.

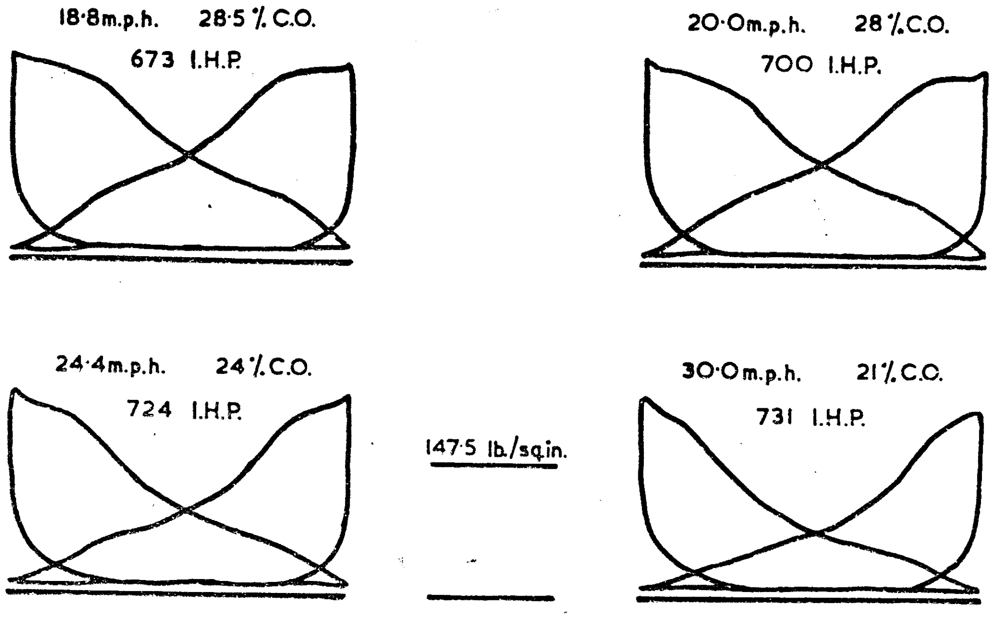
Controlled Road Test.



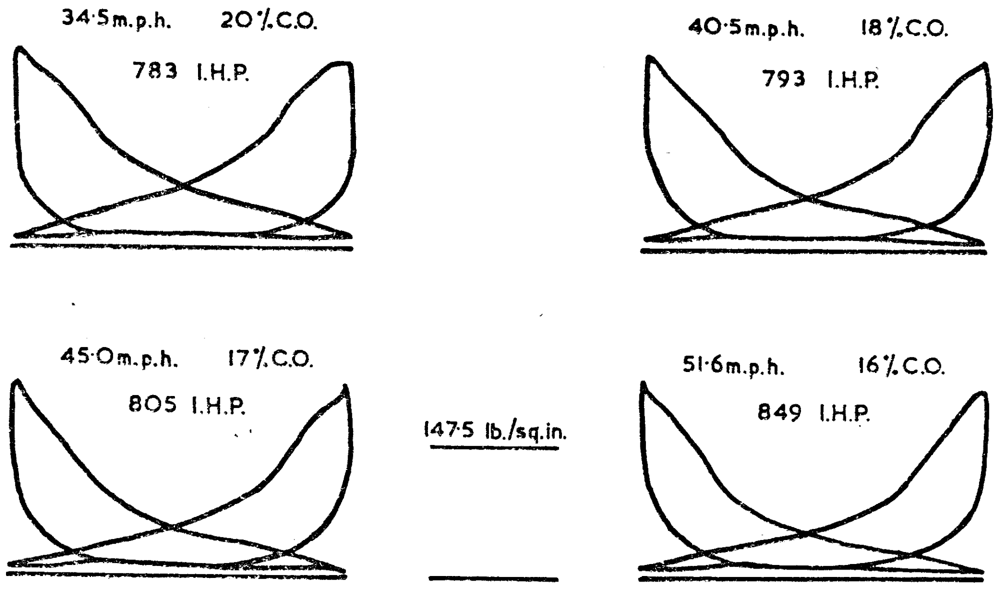
EXAMPLES OF INDICATOR CARDS.

M4/43094/51.

MEAN STEAM RATE 11300 lb./hr.. FULL REGULATOR.
Stationary Plant Test.

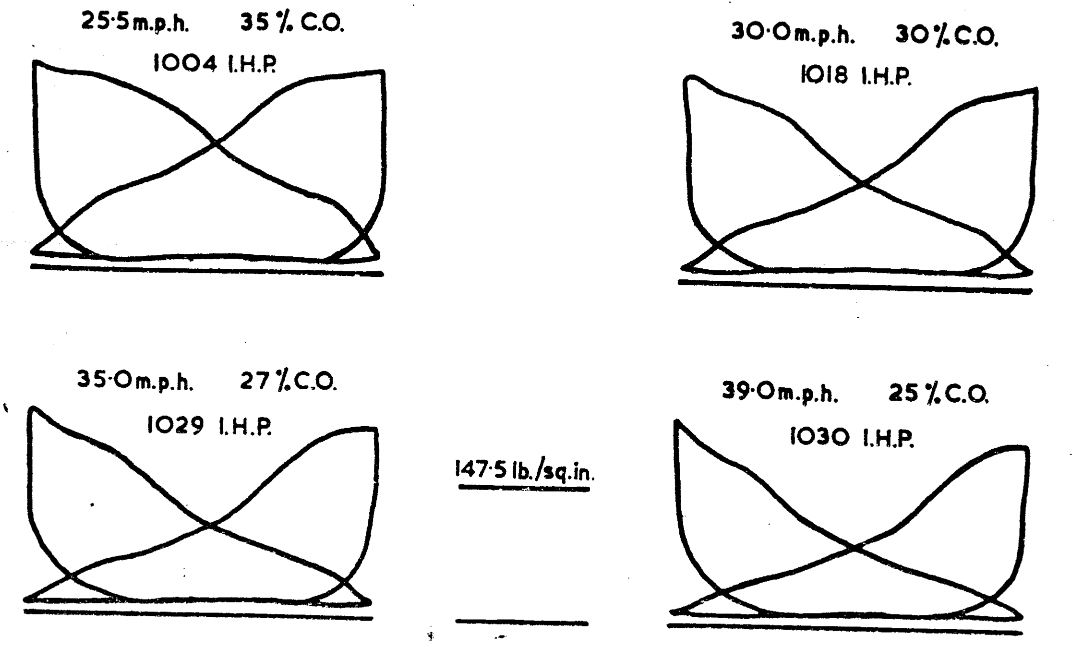


MEAN STEAM RATE 11950 lb./hr.. FULL REGULATOR.
Controlled Road Test.

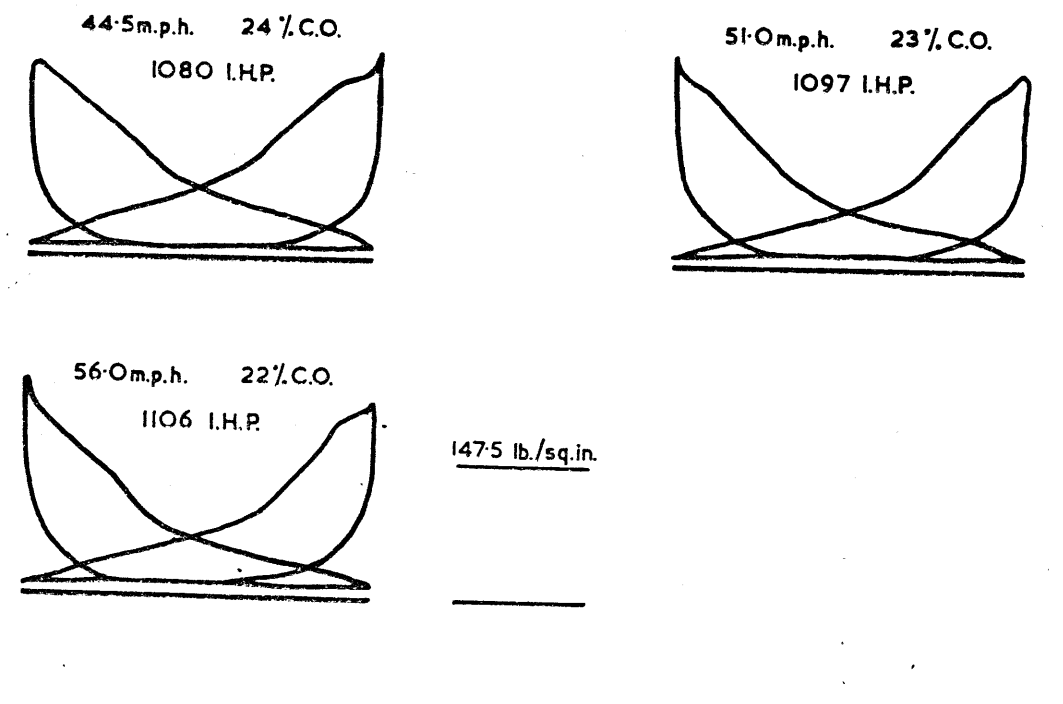


EXAMPLES OF INDICATOR CARDS.

MEAN STEAM RATE 16250 lb./hr.. FULL REGULATOR.
Stationary Plant Test.



MEAN STEAM RATE 16800 lb./hr.. FULL REGULATOR.
Controlled Road Test.



EXAMPLES OF INDICATOR CARDS.

M4/43094/51