

BRITISH RAILWAYS

Mechanical & Electrical Engineer's Department

Performance and Efficiency Tests
with Live Steam Injector.

BRITISH RAILWAYS STANDARD - CLASS 4,
2 CYL., 4-6-0 MIXED TRAFFIC LOCOMOTIVE.

January, 1952.

The Railway Executive
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Contd...

INTRODUCTION.

This class of engine, first built in 1951 is one of the 12 Standard types for British Railways. It differs from the Class 4, 2-6-0 engine, dealt with in Bulletin No.3, and also to become a B.R. Standard, in having a larger boiler and coupled wheels, which make it more suitable for undertaking work at the higher end of the Class 4 range of power output, whereas the 2-6-0 engine is more especially designed to deal with the lower end.

The Class 4, 4-6-0 by reason of its profile and axle weights, has an exceptional range of route availability, which coupled with the power range indicated in this Bulletin make it particularly suitable for mixed traffic working.

The engine tested was exactly as built. The design of front end was already based on experimental work recently carried out at Swindon, and no modifications to the draughting arrangements were required.

Self-cleaning plates are fitted in the smokebox, which were retained throughout the tests, and no exhaust steam injector is fitted.

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 locomotives 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,
Loco. 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 Sept., 1951.

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.

V. LOCOMOTIVE.

The locomotive selected for the tests was No. 75006 which had run 4,600 miles in traffic since it was built in September 1951. No piston and valve examination or repairs had been carried out in the period between building and the commencement of the tests. By the end of the tests the mileage had increased by 2,910.

Elsewhere in this Bulletin will be found a diagram giving the leading particulars of the locomotive followed by dimensional details and ratios and a table setting out the designed valve events.

The locomotive is provided with live steam injectors only, and fitted with a rocking firegrate with Hulson type firebars.

VI. COALS.

The engine was tested on two coals :

Blidworth Cobbles, a Grade 2B hard coal.
Bedwas, a Grade 2A soft coal.

The price of Blidworth Cobbles as delivered on the tender at Swindon Motive Power Depot at the time of the tests was 57s. 9d. per ton, exclusive of haulage.

The corresponding price of Bedwas was 67s. 1d. per ton.

Blidworth, a coal common to all locomotive testing, was dull in appearance, very hard with patches of bright laminar structure. Its size varied from 6" in greatest dimension to 2" minimum dimension with an average size of 4".

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".

CALORIFIC VALUES & PROXIMATE ANALYSES
OF REPRESENTATIVE SAMPLES OF COALS

	BLIDWORTH		BEDWAS	
	As received	Dry	As received	Dry
<u>Calorific Value (Gross)</u>				
British Thermal Units per 1 lb.	12930	13890	13970	14220
<u>Proximate Analysis</u>				
Moisture %	6.9	-	1.8	-
Volatile matter, less moisture %	32.7	35.2	24.6	24.9
Fixed Carbon %	56.0	60.1	65.6	66.9
Ash %	4.4	4.7	8.0	8.2
Total Sulphur %	0.65	0.70	0.95	0.96

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.

VII. 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 coal at the same rate of firing, the depths being roughly in the ratios of the proportions of fixed carbon in the coal fractions.

Blidworth and Bedwas could be burnt with equal efficiency at the same firing rates.

The fire had a tendency to move forward at speeds over 55 m.p.h.

The resistances through the self-cleaning plates of the smokebox were found to account for 10% of the total boiler resistance at all rates of evaporation. At the maximum rate of evaporation the loss of draught across the self-cleaning plates is about 22% of the total draught.

Nevertheless, reference to Graphs 4 and 25 show that it has been possible to position the practical limit of the boiler (19,600 lb. of steam per hour) where the curves of coal per d.b.h.p. hour turn sharply upwards separating, by so doing, the economic and uneconomic ranges of the locomotive. 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 obtained 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 (22,490 to 24,190 lb. of steam per hour according to the type of coal) have been obtained by extrapolation of the boiler efficiency characteristics.

Superheat in the exhaust as measured in the blast pipe attained nearly 50°F. at the higher rates of working.

Test results herein given are representative of a locomotive of this class in first class condition.

VIII. 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.

IX. COMPARISON WITH PREVIOUS BULLETINS.

This engine is of the same family of design as the engine described in Bulletin No.3, and the results are directly comparable, except that the latter was not in quite such good condition mechanically.

Presence or absence of self-cleaning smokebox and exhaust steam injector only enables an indirect comparison to be made with the contents of Bulletins Nos.1 and 2.

DIMENSIONAL DETAILS AND RATIOS.

Cylinders and Steam Chests.

Piston swept volume	cu.ft.	4.12
Cylinder clearance volume as % of piston swept volume		10.8
Steam chest volume (1) as % of piston swept volume		54.6

Piston Valve

Nominal diameter	ins.	10
Steam lap	ins.	1.11/16
Lead	ins.	1/4
Exhaust lap		Nil
Maximum cut-off. Fore gear	%	77.0
Maximum cut-off. Back gear	%	76.3
For designed valve setting see separate sheet.		

(1) Steam chest volume between valve heads and up to steam chest flange face.

DIMENSIONAL DETAILS AND RATIOS (Contd.)Boiler

Barrel diameter, outside min.		4' 9"
max.		5' 3"
Small tubes, number		157
outside dia.	ins.	1 $\frac{3}{4}$
thickness	S.W.G.	12
Large tubes, number		21
outside dia.	ins.	5 $\frac{1}{8}$
thickness	S.W.G.	7
Superheater elements (double return loop)		
outside dia.	ins.	1 $\frac{3}{5}$
thickness	S.W.G.	10
Length between tubeplates		13' 0"
Heating surfaces	} see Engine Diagram	
Grate area		
Water surface at half glass	sq.ft.	86.6
Volume of steam above water at half glass	cu.ft.	81.8
Total piston swept volume as % of steam volume		10.09
Firebox volume/Grate area		4.91
Firebox volume/Firebox heating surface		.92
$\frac{A}{S}$ Large tubes		$\frac{1}{368}$
$\frac{A}{S}$ Small tubes		$\frac{1}{405}$

Steam Circuit

Regulator area through pilot valve	sq.ins.	2.21
" " " main valve	sq.ins.	24.27
Main steam pipe through boiler, diameter	ins.	5 $\frac{1}{2}$
cross-sectional area	sq.ins.	23.76
Superheater elements, area through spherical ends	sq.ins.	18.35
through tubes	sq.ins.	20.64
Steam pipes to cylinders, bore	ins.	4 $\frac{1}{2}$
cross-sectional area	sq.ins.	15.90
Steam chest, cross-sectional area through liner	sq.ins.	74.8
Ports, width	ins.	2 $\frac{1}{4}$
cross-sectional area	sq.ins.	49.4
Passage, steam chest to cylinder, min. cross-sectional area	sq.ins.	37.1
Exhaust passage adjacent to steam chest. max. cross-sectional area at point of convergence of four passages below blast pipe	sq.ins.	65.2
Elast pipe cap, see Draughting Arrangements.	sq.ins.	145.0

DIMENSIONAL DETAILS AND RATIOS (Contd.)Gas Circuit

Area through ashpan dampers, front	sq.ft.	1.59
back	sq.ft.	1.06
Air space through grate as % of grate area		34.4
Free area through tubes, large	sq.ft.	1.74
small	sq.ft.	2.04
total	sq.ft.	3.78
Area through large tubes as % of total free area		46.0
Total free tube area as % of grate area		14.2
Chimney choke, see Draughting Arrangements.		

Draughting Arrangements

Blast pipe orifice, dia.	ins.	$4\frac{3}{4}$
area	sq.ins.	17.72
Chimney, dia. at choke	ins.	13.5
area at choke	sq.ins.	144.0
dia. at top	ins.	15.5
Chimney bell, dia. at bottom	ins.	23.6
Blast pipe orifice, below smokebox centre line	ins.	9.0
Chimney choke above blast pipe orifice	ins.	31.0
Height of chimney, choke to top	ins.	29.0
Chimney sides, taper		1 in 14
Chimney bell, depth below choke	ins.	9.25
<u>Chimney choke dia.</u>		2.84
<u>Blast pipe orifice dia.</u>		
<u>Height of choke above orifice</u>		2.30
<u>Dia. of choke</u>		
<u>Height of bottom of bell above orifice</u>		1.61
<u>Diameter of choke.</u>		

TABLE OF DESIGNED VALVE EVENTS

WALSCHAERTS VALVE GEAR

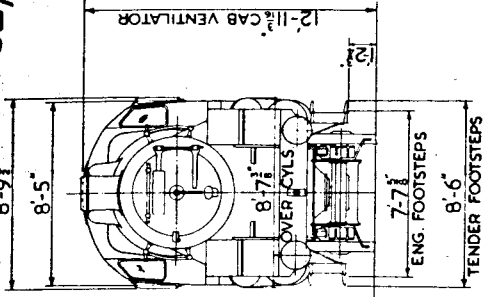
Forward Gear

Nominal Cut- off %	Travel of valve	Lead		Opening to steam		Steam Cut-off %		Exhaust Opens %		Exhaust Closes %	
		F.P	B.P	F.P	B.P	F.P	B.P	F.P	B.P	F.P	B.P
	ins.	ins.	ins.	ins.	ins.						
75	7.34	.25	.25	1.88	2.13	77.0	73.4	93.0	91.2	91.2	93.0
70	6.64	"	"	1.55	1.72	72.1	68.0	91.4	89.0	89.0	91.4
60	5.67	"	"	1.09	1.20	62.2	58.1	87.9	84.8	84.8	87.9
50	5.06	"	"	.80	.89	51.4	48.8	84.0	80.7	80.7	84.0
40	4.63	"	"	.61	.67	41.6	40.5	79.9	76.7	76.7	79.9
30	4.30	"	"	.44	.48	29.8	30.3	74.0	71.2	71.2	74.0
25	4.16	"	"	.38	.41	24.7	25.6	71.1	68.8	68.8	71.1
20	4.05	"	"	.33	.34	19.8	20.5	67.1	65.8	65.8	67.1
15	3.95	"	"	.28	.30	14.8	15.4	62.8	62.0	62.0	62.8
Mid- gear	3.88	"	"	.25	.25	6.9	6.8	50.4	51.8	51.8	50.4
<u>Backward Gear</u>											
75	7.0	.25	.25	1.64	1.98	76.3	73.8	92.1	90.5	90.5	92.1
70	6.34	"	"	1.31	1.66	70.7	69.7	90.4	88.9	88.9	90.4
60	5.48	"	"	.92	1.19	58.7	61.2	86.7	85.3	85.3	86.7
50	4.95	"	"	.69	.89	47.2	53.0	82.8	82.0	82.0	82.8
40	4.59	"	"	.55	.67	36.2	43.8	78.4	78.1	78.1	78.4
30	4.28	"	"	.41	.50	26.4	33.6	72.8	73.8	73.8	72.8
20	4.17	"	"	.38	.42	22.0	28.1	69.5	71.0	71.0	69.5
15	4.06	"	"	.33	.36	18.0	22.5	65.9	68.0	68.0	65.9
10	3.95	"	"	.28	.30	13.6	16.1	60.8	63.0	63.0	60.8
Mid- gear	3.88	"	"	.25	.25	6.6	6.4	48.8	50.2	50.2	48.8

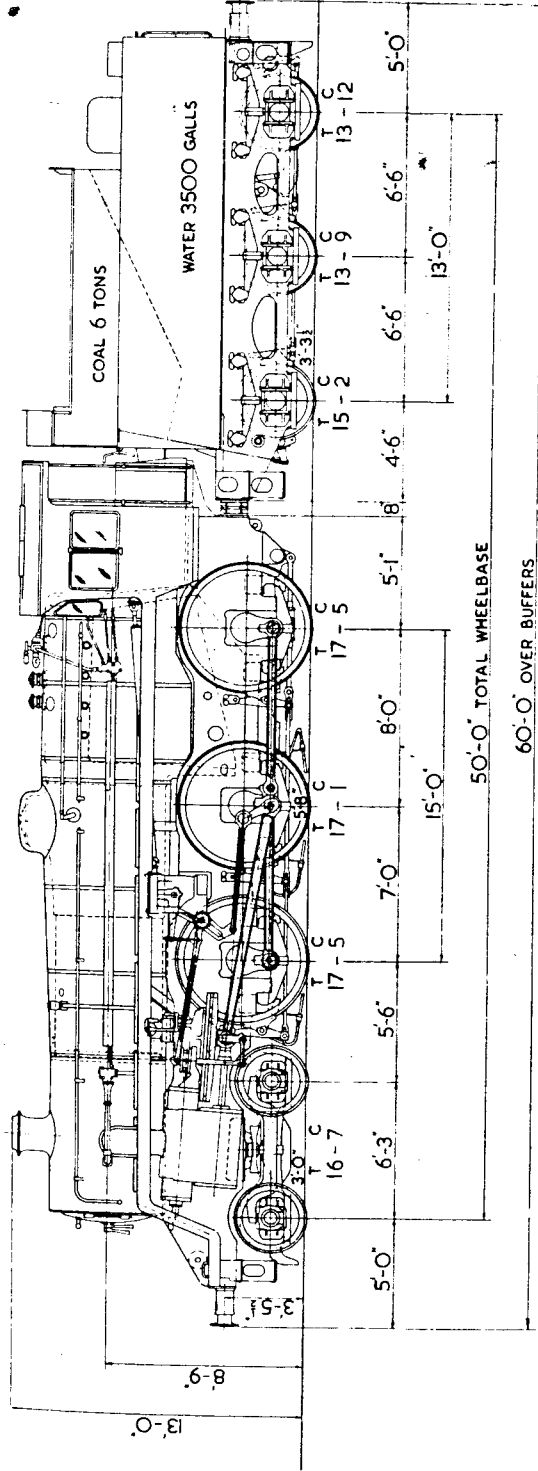
F.P. = Front Port;

E.P. = Back Port.

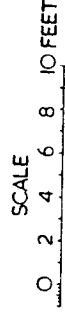
SL/4B/1



225 LBS. PER SQ. IN



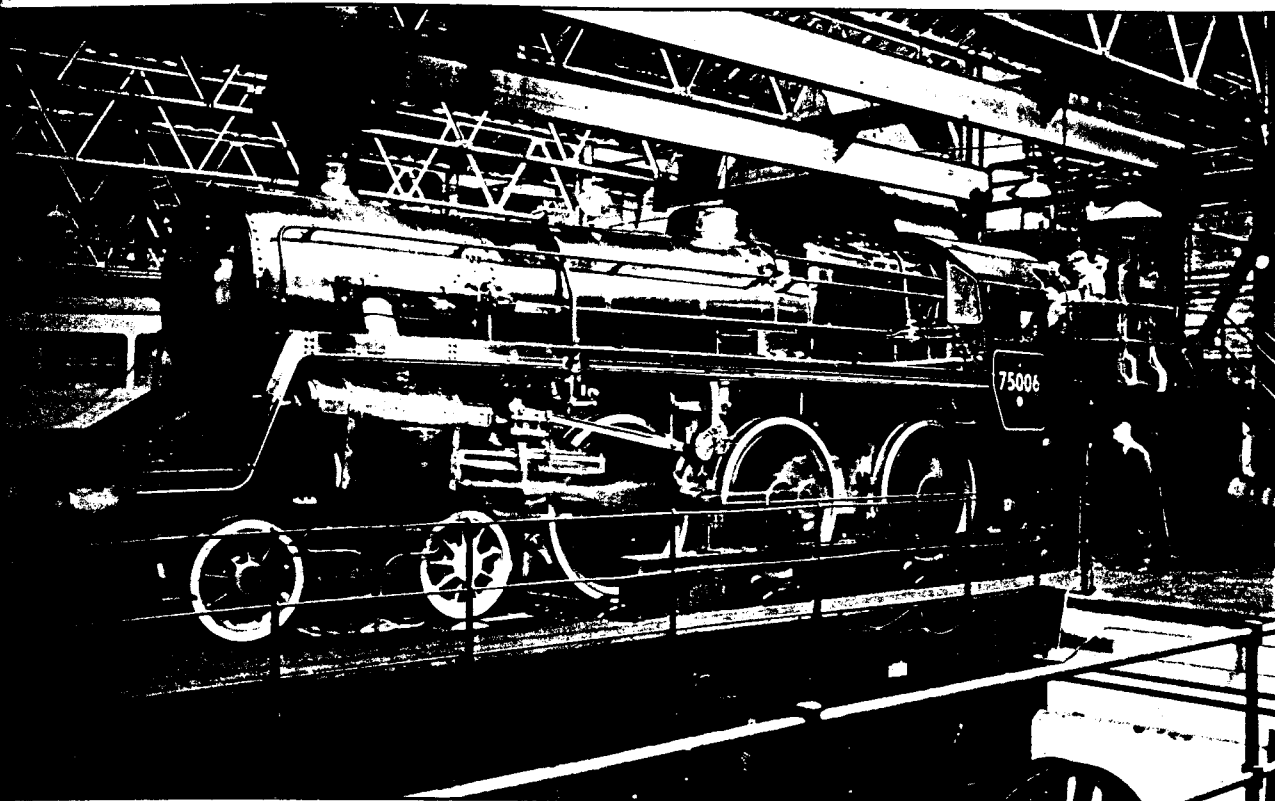
WEIGHTS		FULL		EMPTY	
		T	C	T	C
ENGINE		67-18		63-6	
TENDER		42-3		20-10	
TOTAL		110-1		83-16	



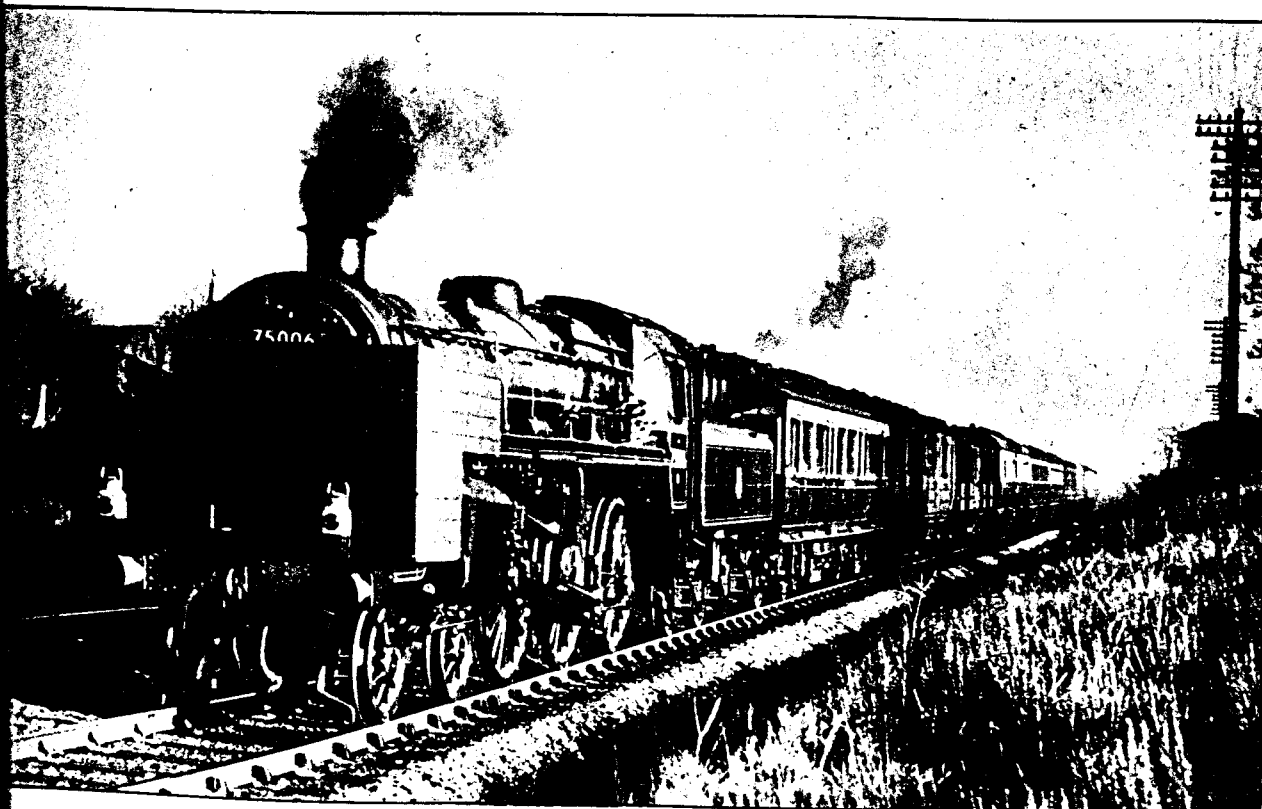
CYLINDERS (TWO)	18" x 28"
TRACTIVE EFFORT	25,515 LBS.
ADHESION FACTOR	4.52
BRAKE % ENGINE & TENDER	55.1
MINIMUM RADIUS CURVE (WITH SPECIFIED GAUGE WIDENING)	4 1/2 CHAINS
BOILER TYPE	BR 4
TENDER TYPE	BR 2

BOILER BARREL DIAMETER (OUTSIDE)	4'-9" INCREASING TO 5'-3"
FIREBOX (OUTSIDE) TUBES	8'-6" LONG x 4'-0 1/2" WIDE
SUPERHEATER ELEMENTS	21 LARGE 5 1/2" O.D. x 7 SWG
LENGTH BETWEEN TUBEPLATES	157 SMALL 1 1/2" O.D. 12 SWG
HEATING SURFACES: TUBES	11" O.D. x 10 SWG
FIREBOX	13'-0"
TOTAL EVAPORATIVE SUPERHEATER	1301 SQ. FT.
	143 SQ. FT.
	1444 SQ. FT.
	265 SQ. FT.
FREE FLUE AREA	3,785 SQ. FT.
GRATE AREA	267 SQ. FT.

B. R. STANDARD CLASS 4. 4-6-O ENGINE.



No.75006 ON TEST ON THE SWINDON PLANT.



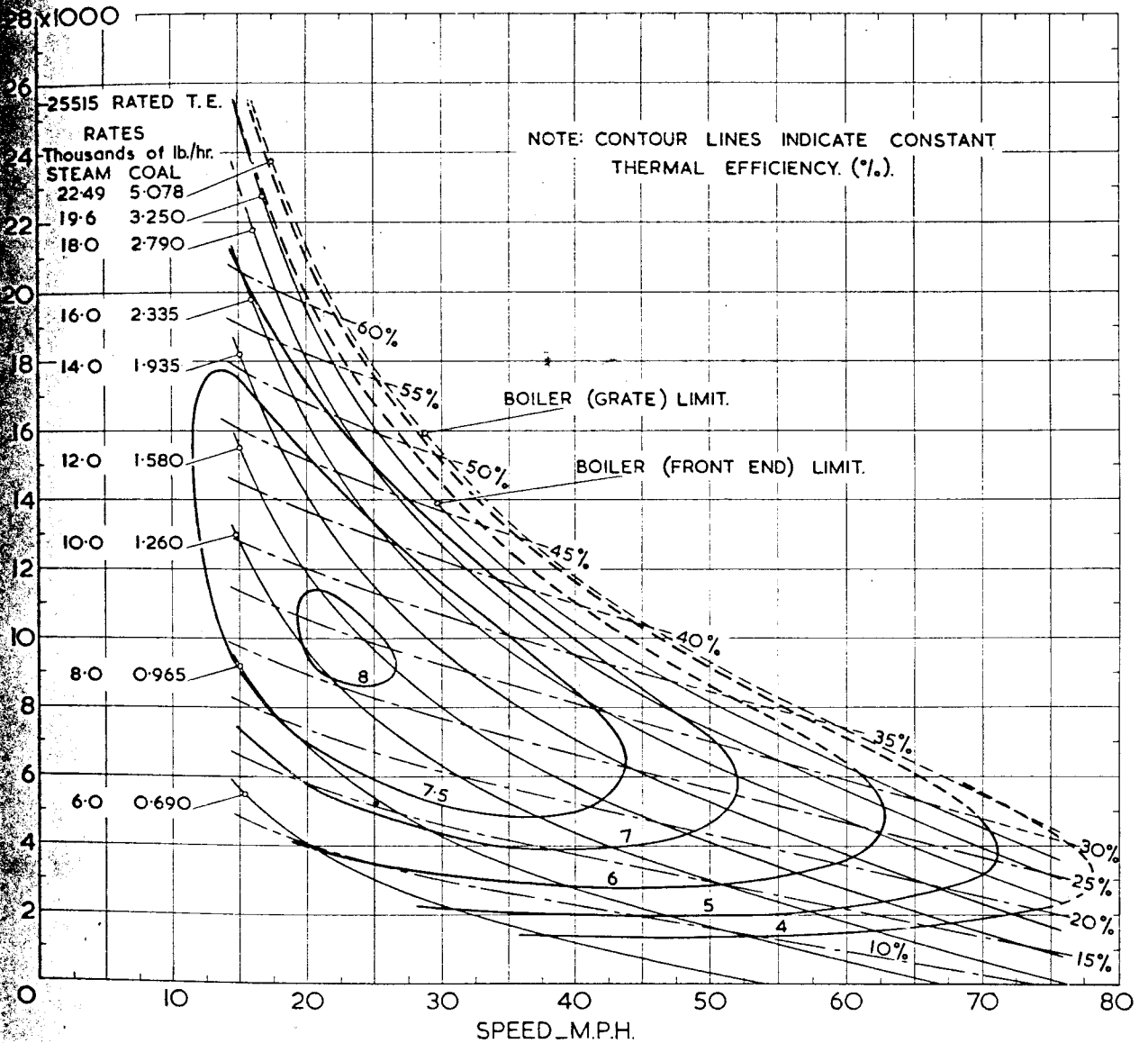
A CONTROLLED ROAD TEST IN PROGRESS.
TESTING UNIT: W R DYNAMOMETER CAR.

BLIDWORTH COAL.

Performance data : Graphs 1 to 9.

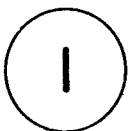
Design data : Graphs 10 to 21.

Cut Offs shown refer to Maximum Steam Chest Pressure.



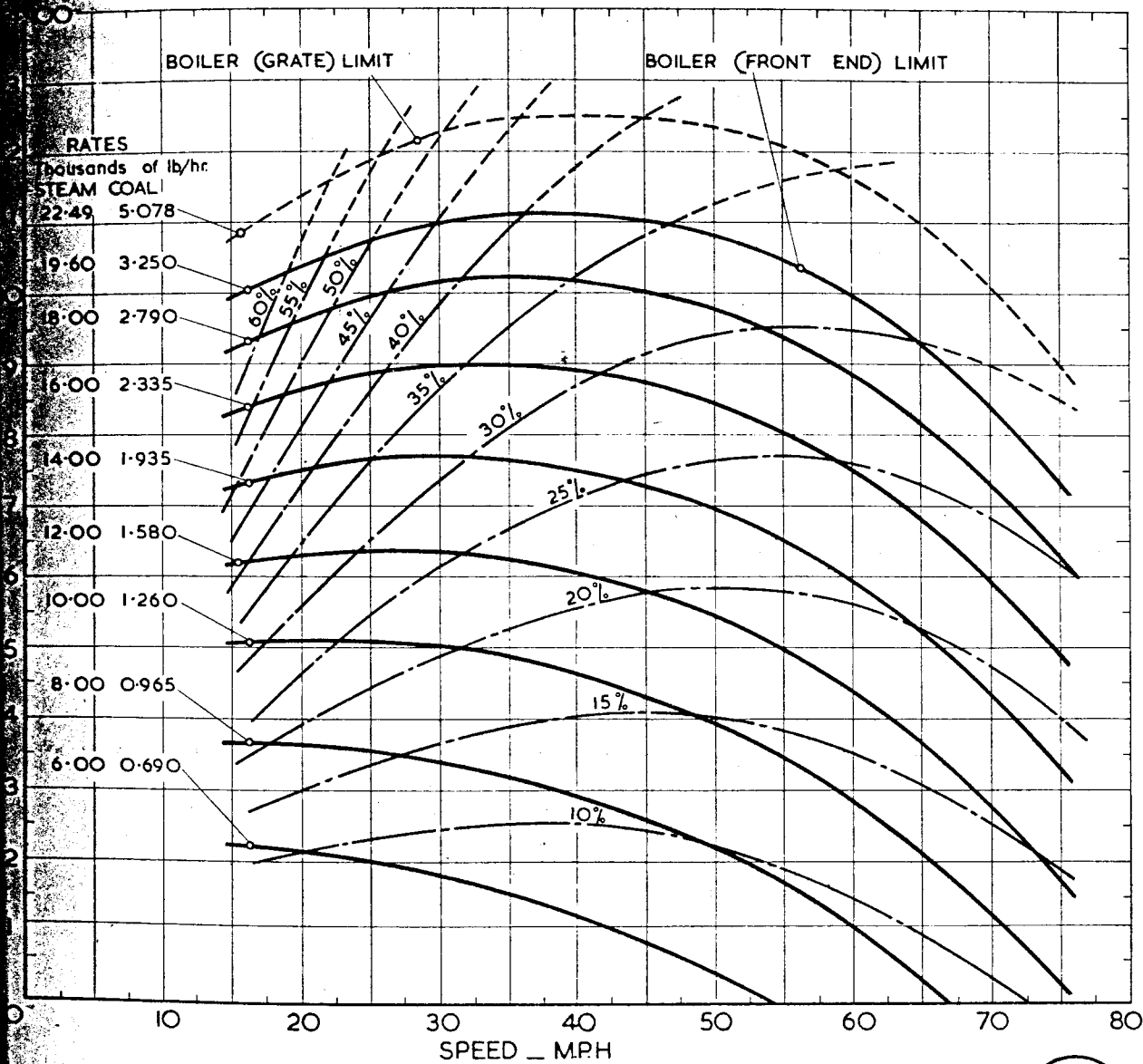
BLIDWORTH COAL - 12930 B.Th.U./lb.

DRAWBAR TRACTIVE EFFORT CHARACTERISTICS:



B.R.4/75006/51.

Cut Offs Shown refer to Maximum Steam Chest Pressure

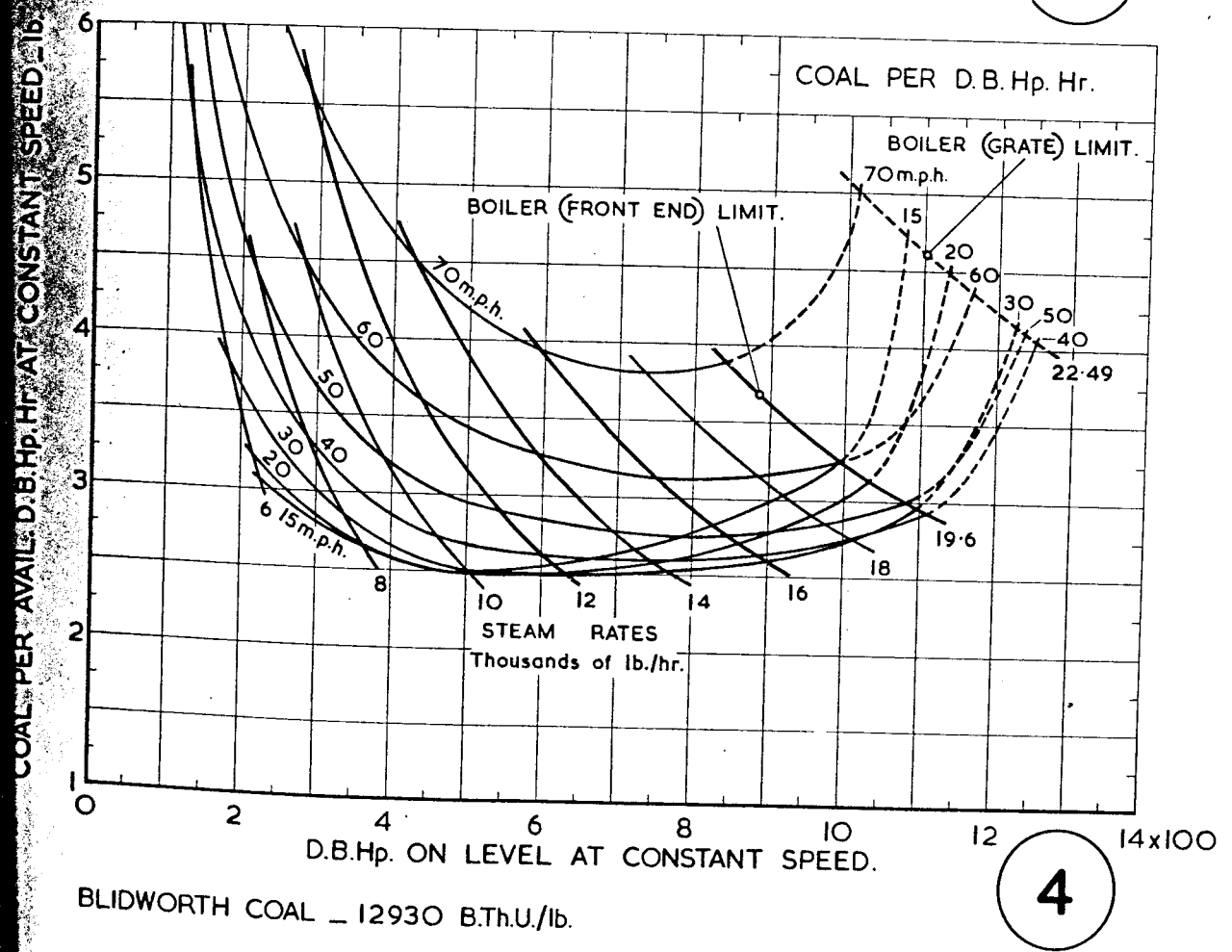
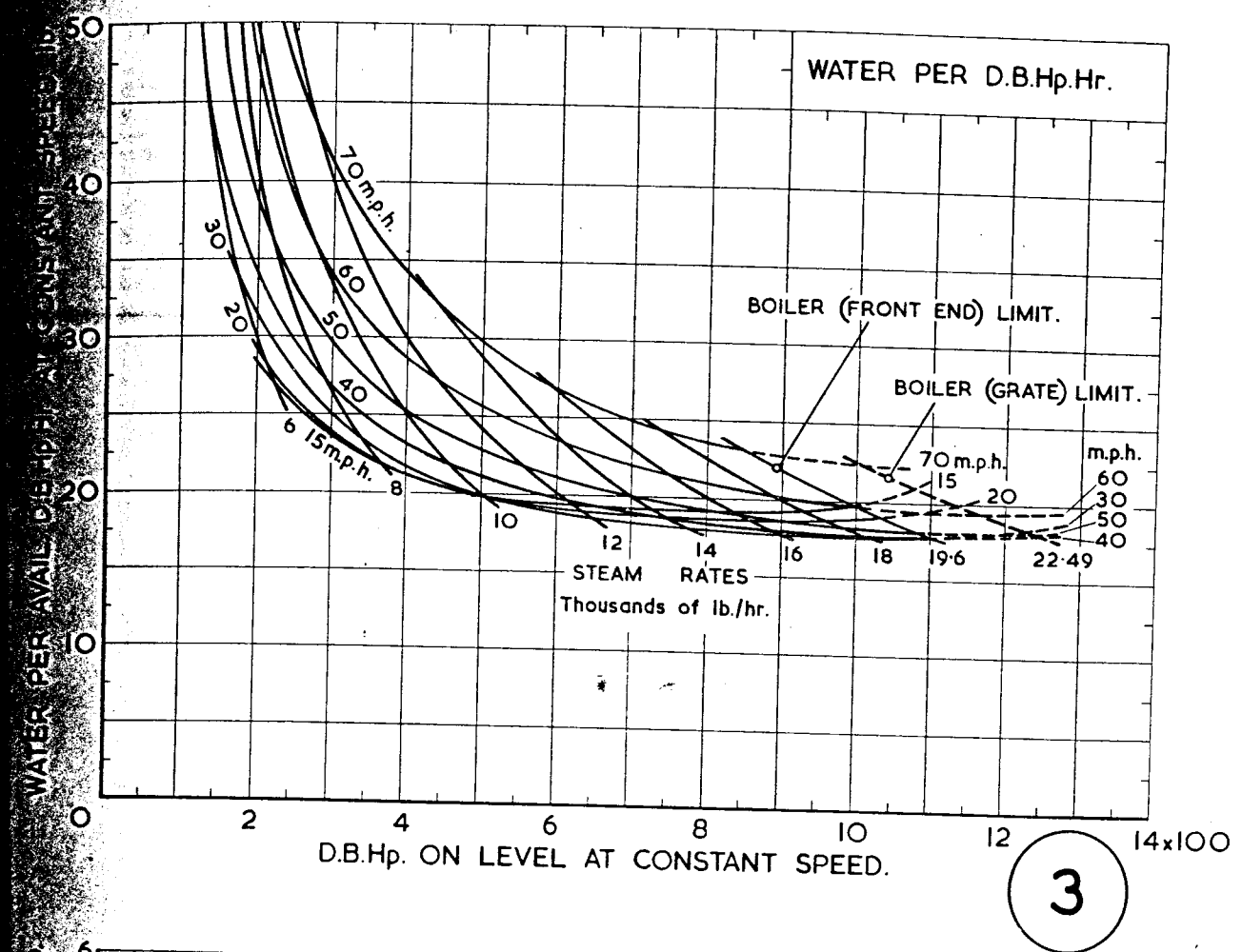


BLIDWORTH COAL - 12930 B. Th.U. /lb.

2

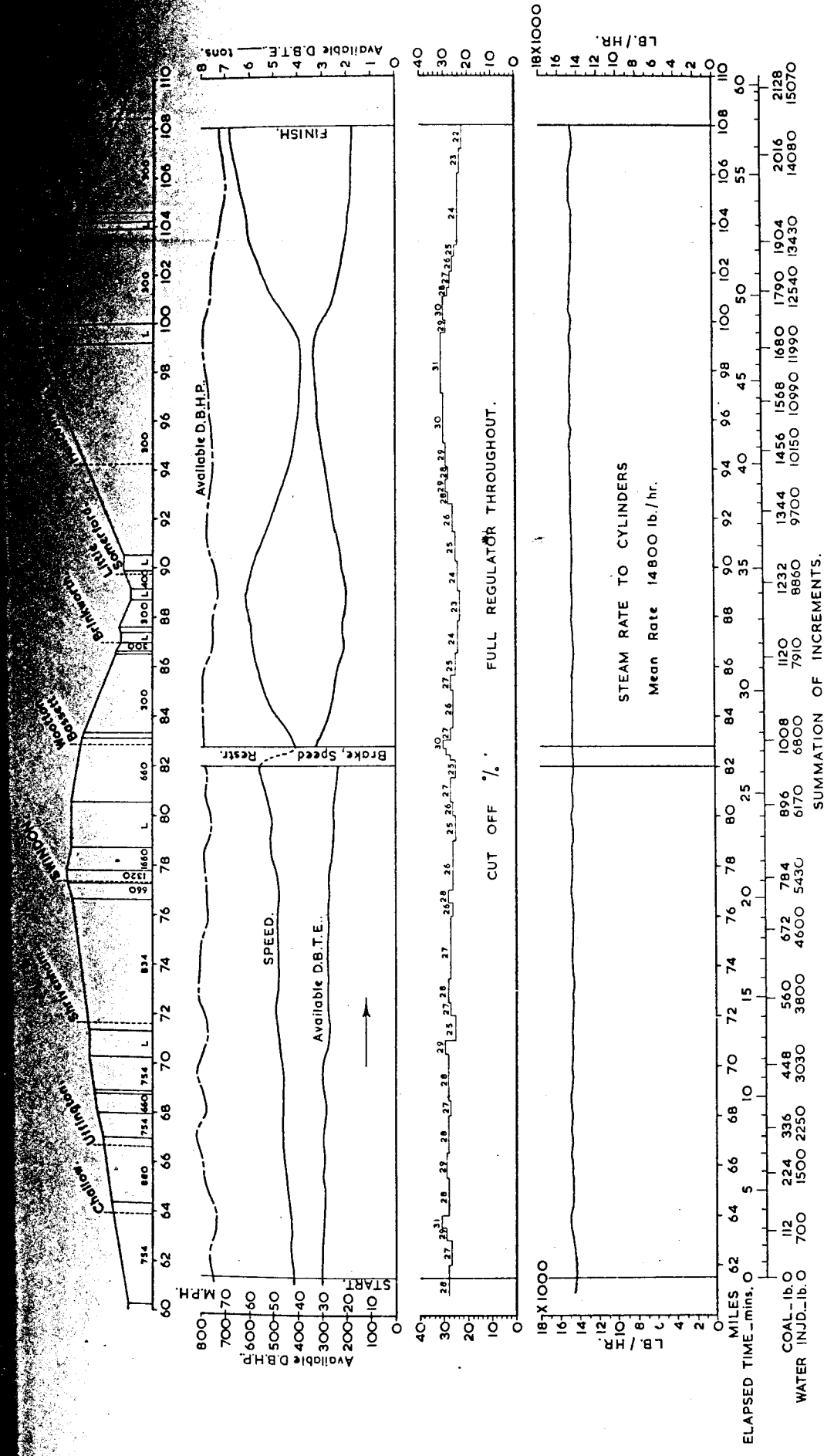
DRAW BAR HORSEPOWER CHARACTERISTICS.

BR.4/75006/SI.



BLIDWORTH COAL - 12930 B.Th.U./lb.

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

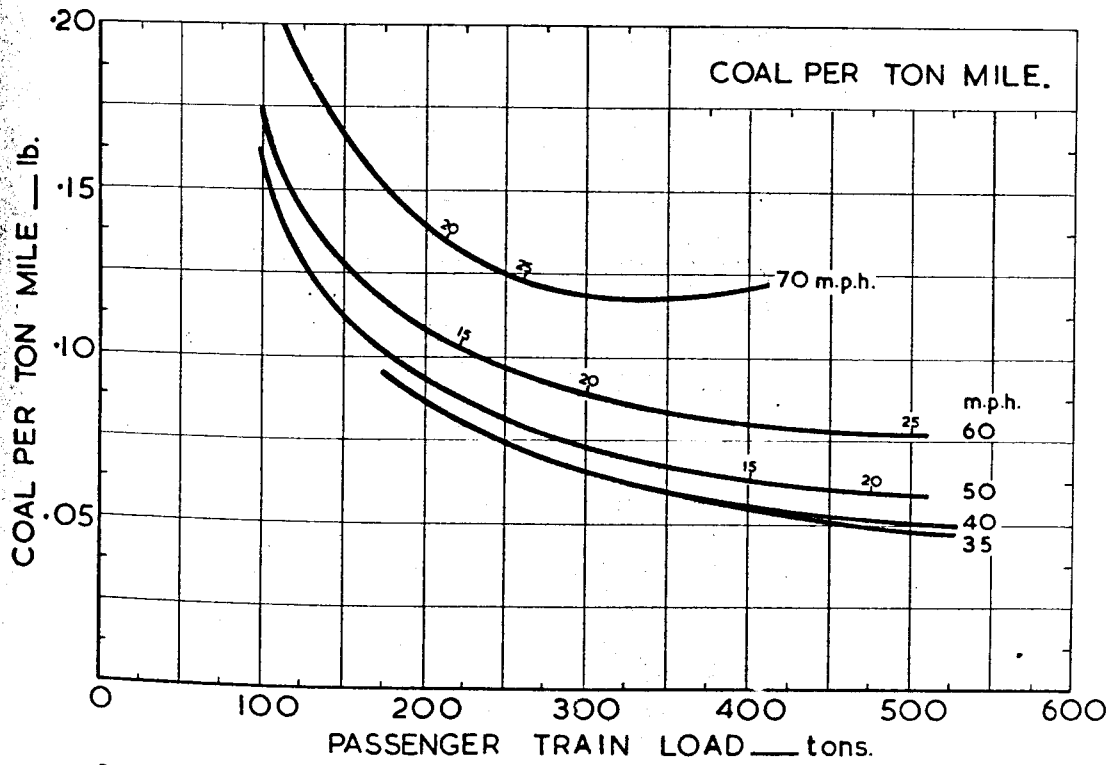
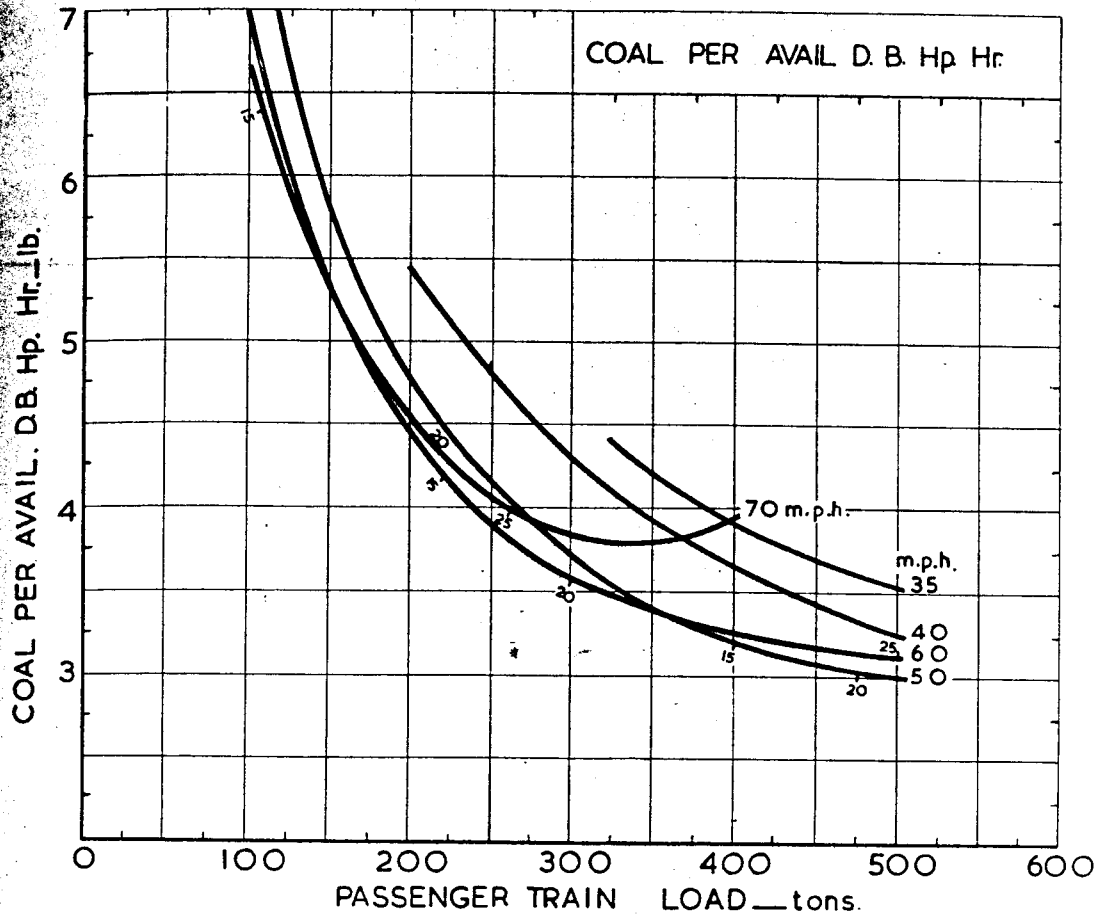


CONTROLLED ROAD TEST No. I.R. 15-1-52.

Testing Unit - W.R. Dynamometer Car
 Blidworth Coal of 12810 B.Th.U./lb. as fired.
 Live Steam Injector.
 Load 546.6 Tons. (18 coaches)

Mean Steam and Water Rates lb./hr.	Mean Coal Rates lb./hr.	Mean Boiler Pressure. 205.3 lb./sq. in. g.
Actual, Equiv. to 212°F	Evap. of Cylinder Steam. 2080	(Safety Valve Light.)
Cylinder Steam. 14800	Ejector Steam. 60	Boiler Efficiency 73 %.
Ejector Steam. 400	Total. 2140	
Feed Water. 46	Per. sq. ft. Grate. 80.1	
Total 15200	20644	

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

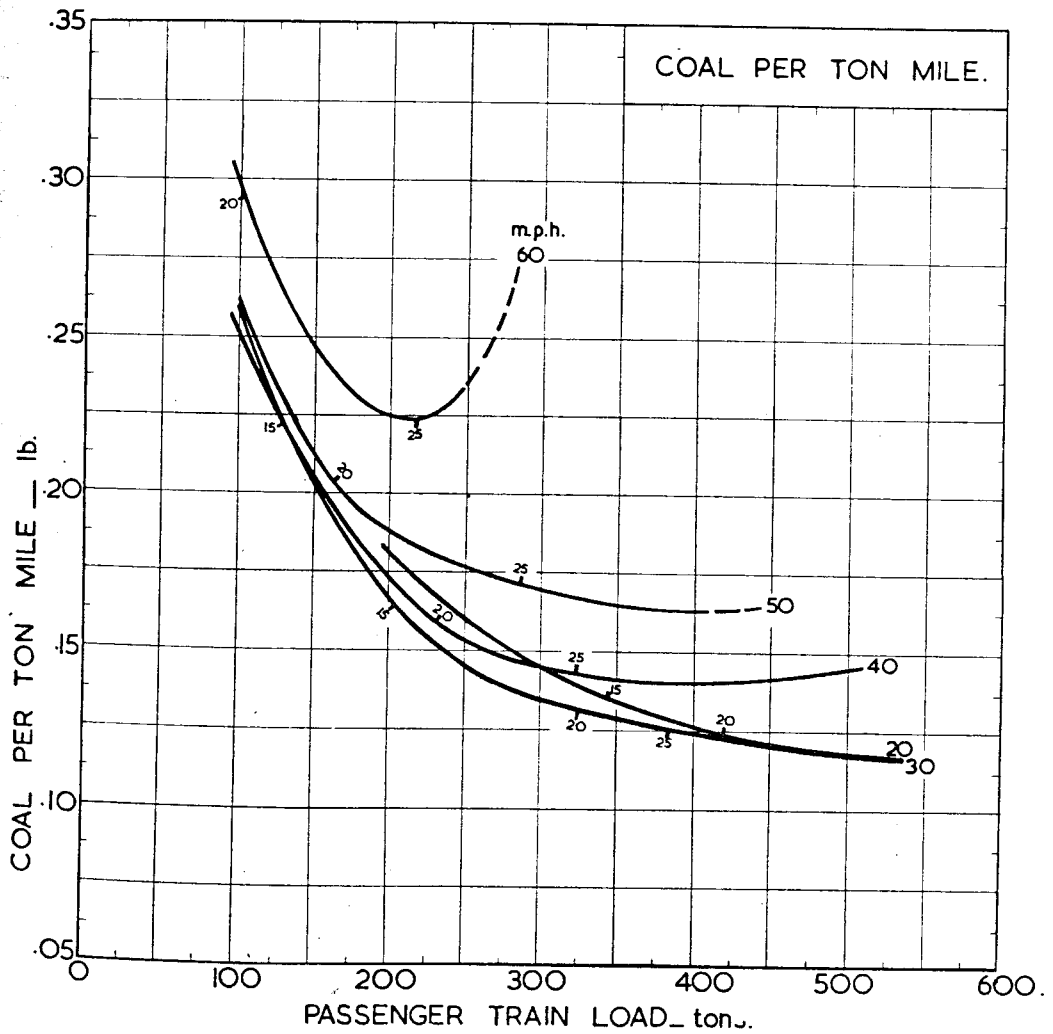
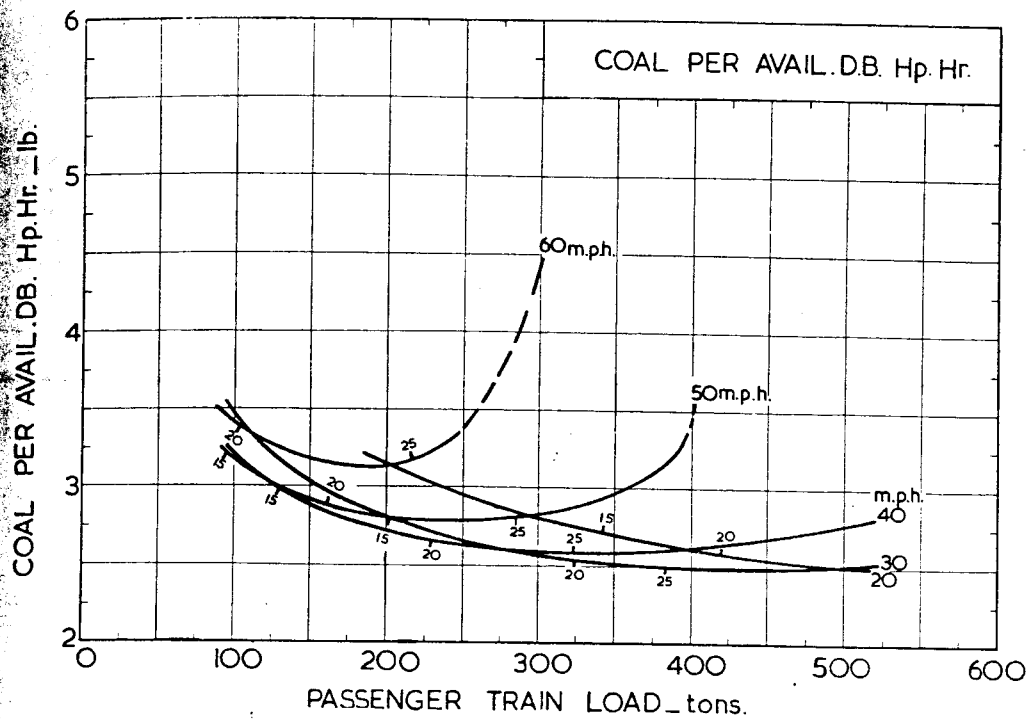


Small Figures on Curves indicate Cut Off. Maximum Steam Chest Pressure.

BLIDWORTH COAL — 12930 B.Th.U./lb.

PASSENGER SERVICE — LEVEL.

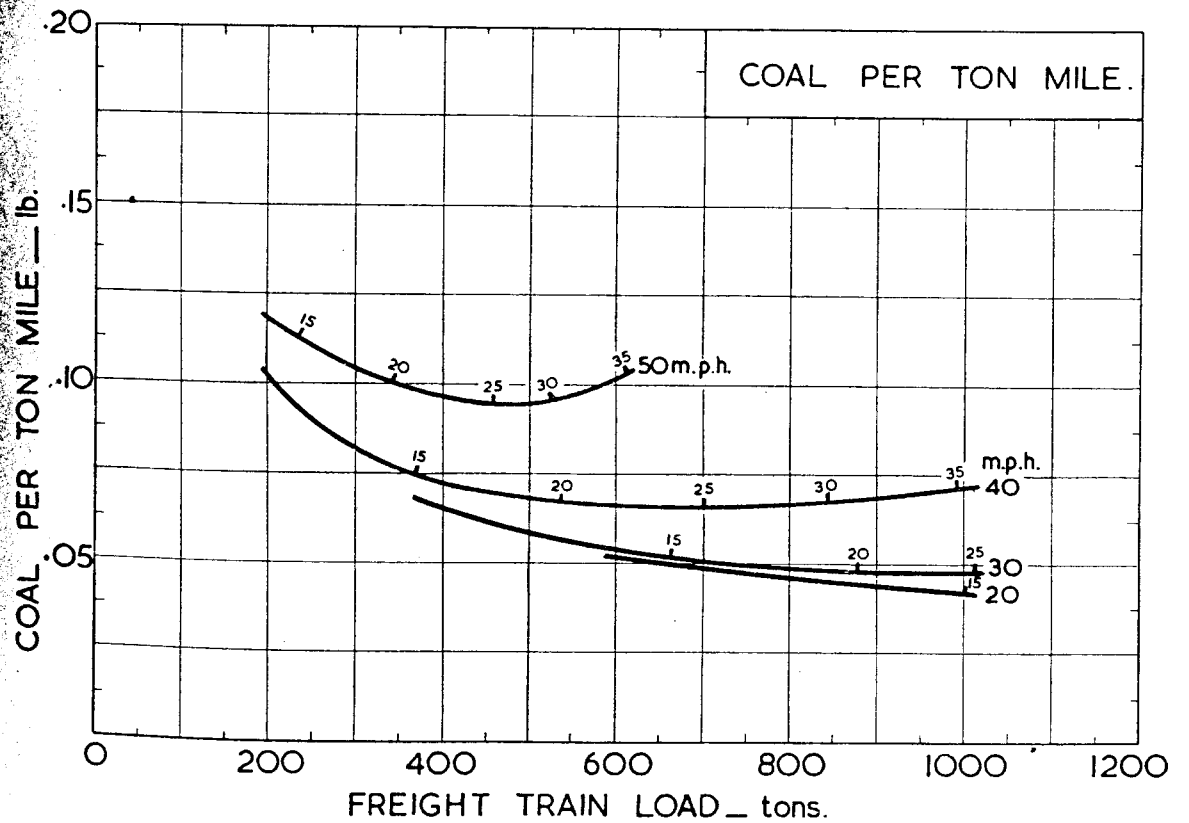
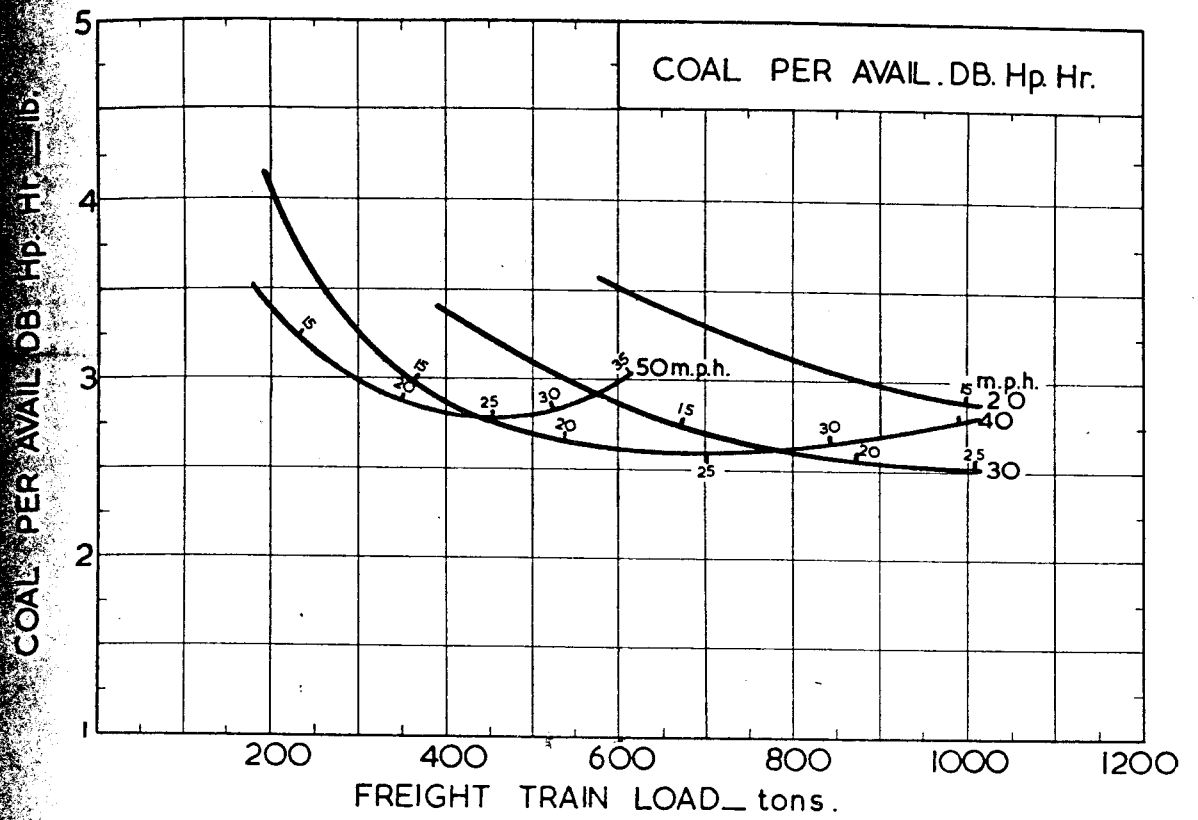
EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS.



Small figures on Curves indicate Cut Off. Maximum Steam Chest Pressure.

BLIDWORTH COAL - 12930 B.Th.U./lb.

PASSENGER SERVICE - 1 IN 200 RISING.
 EXAMPLES OF COST IN COAL OF DIFFERENT
 TRAIN LOADS & SPEEDS.



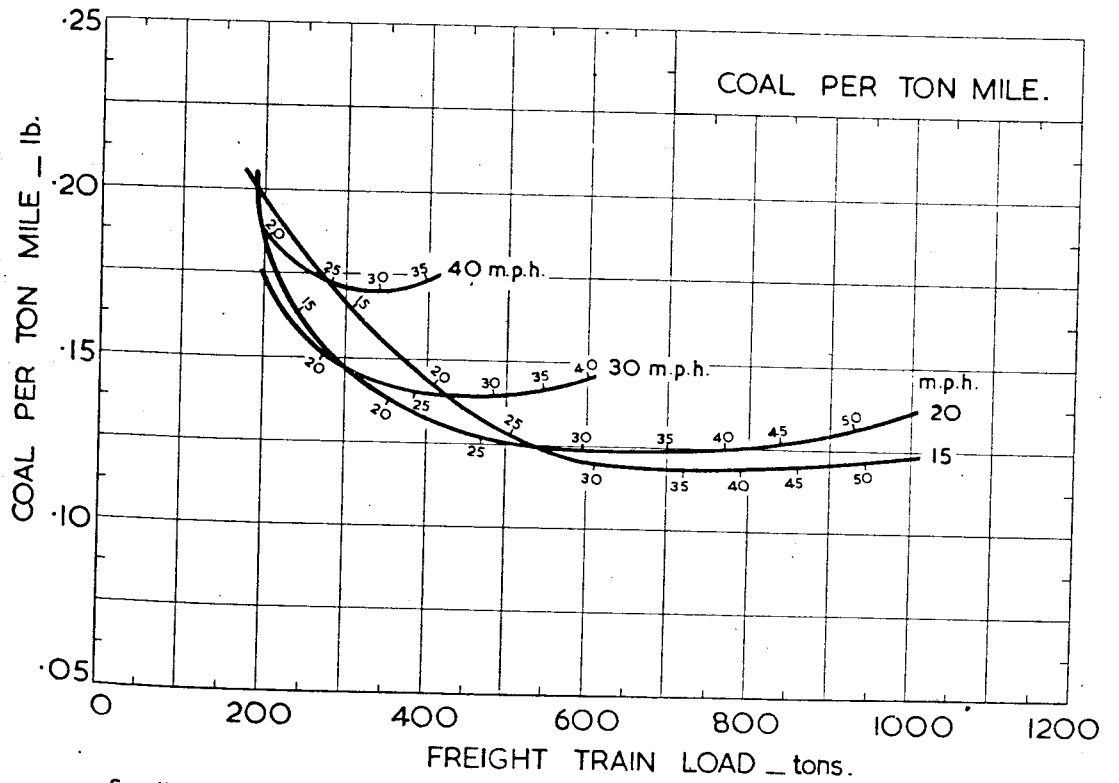
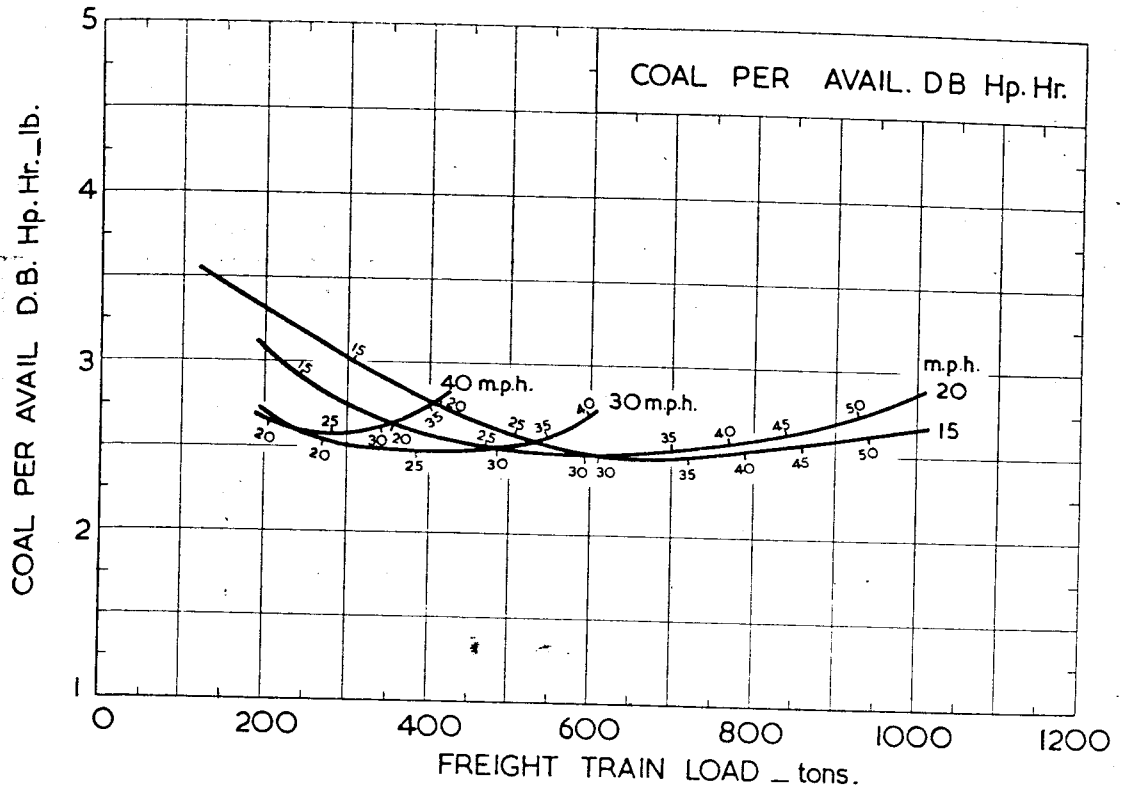
Small Figures on Curves indicate Cut Off. Maximum Steam Chest Pressure.

BLIDWORTH COAL — 12930 B. Th. U. / lb.

8

FREIGHT SERVICE — LEVEL.

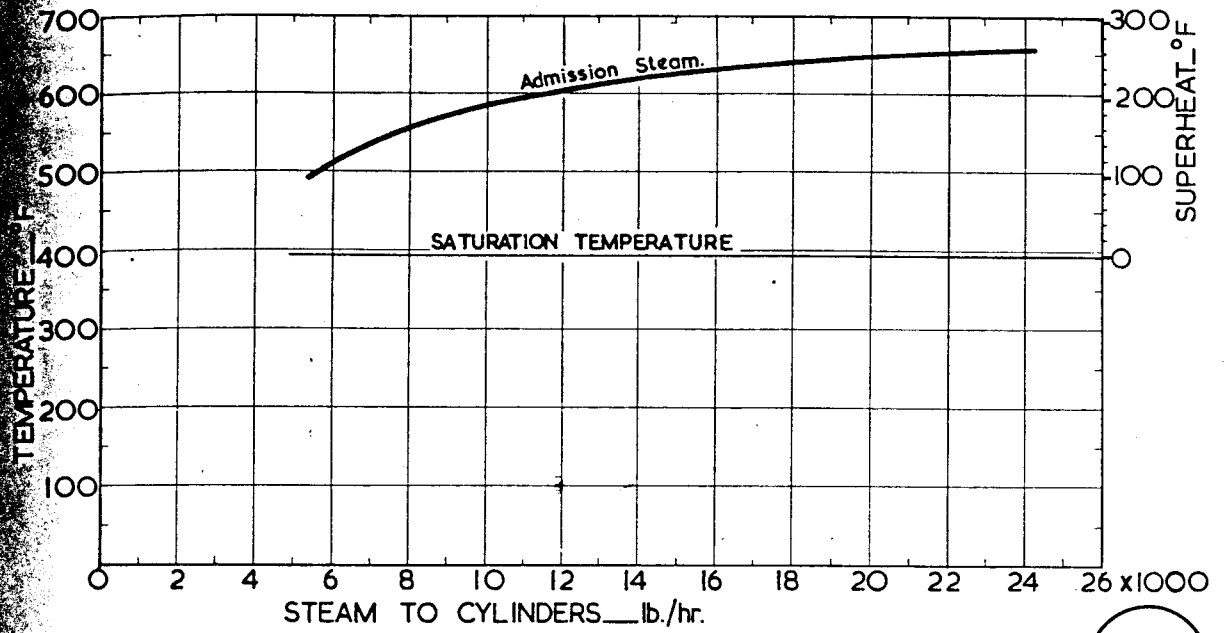
EXAMPLES OF COST IN COAL OF DIFFERENT
TRAIN LOADS & SPEEDS.



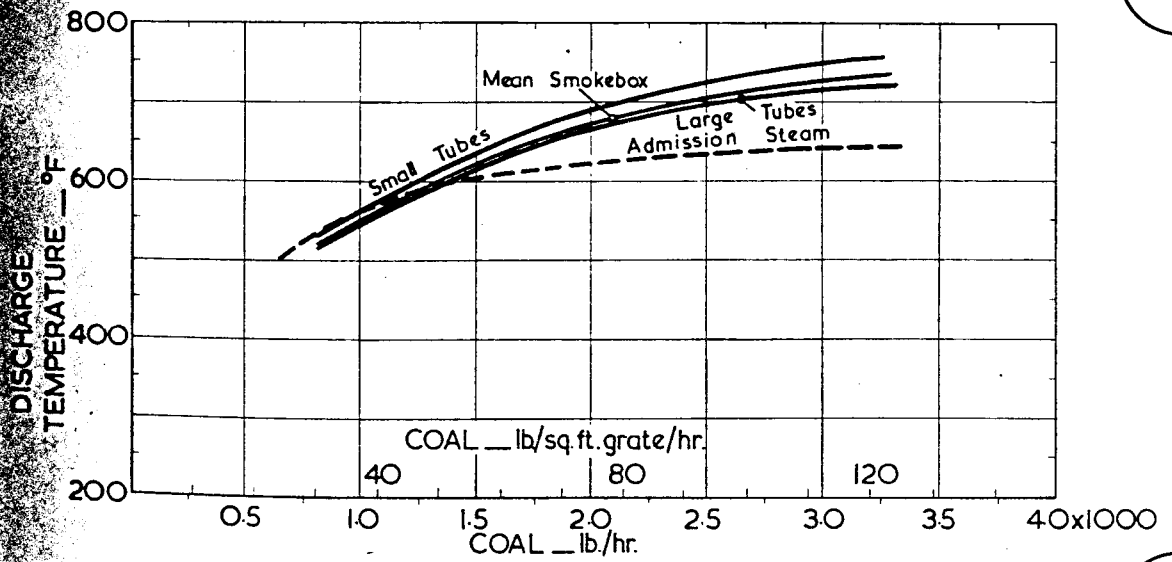
Small Figures on Curves Indicate Cut Off. Maximum Steam Chest Pressure.

BLIDWORTH COAL - 12930 B.Th.U./lb.

FREIGHT SERVICE - I IN 200 RISING.
 EXAMPLES OF COST IN COAL OF DIFFERENT
 TRAIN LOADS & SPEEDS.



10

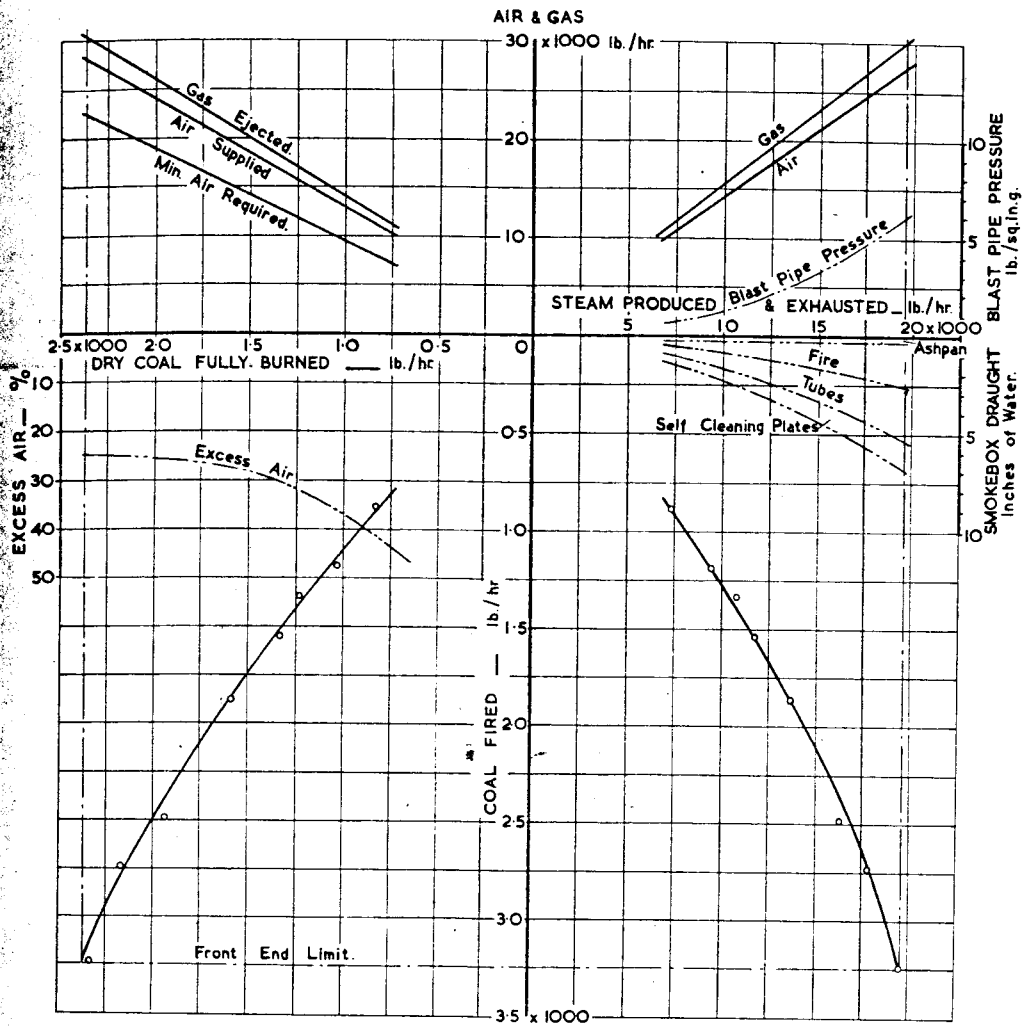


BLIDWORTH COAL — 12930 B.Th.U./lb.

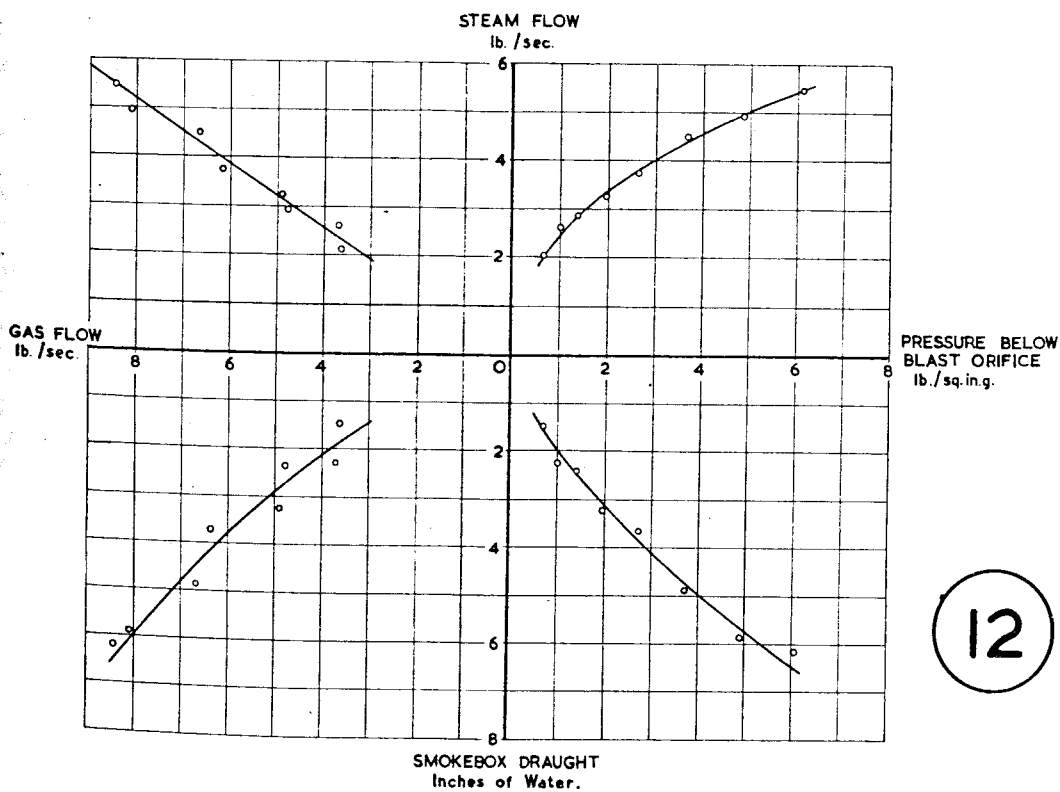
11

TEMPERATURES.

BR.4/75006/51.



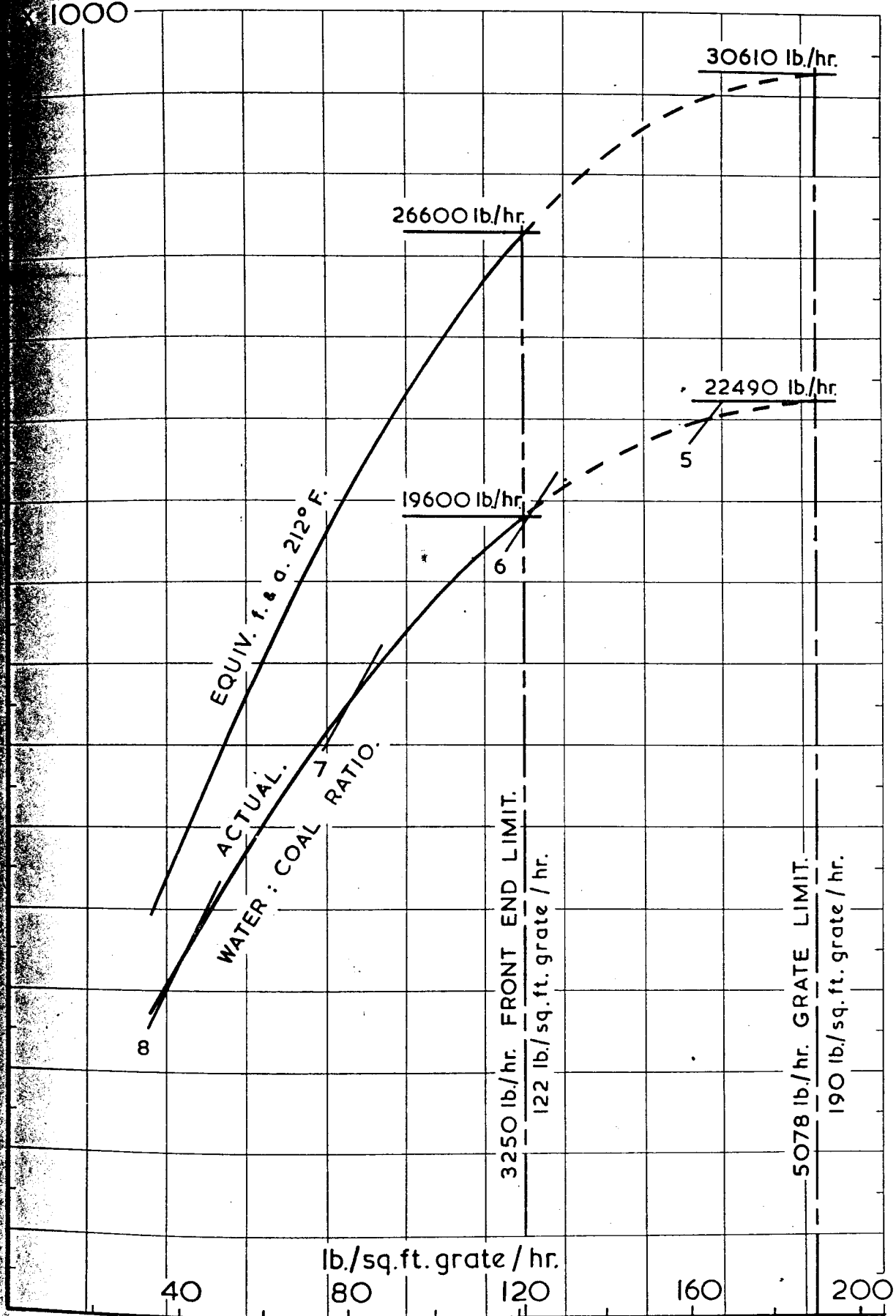
STEAM - AIR - COMBUSTION.



STEAM - GAS - DRAUGHT & BLAST PIPE PRESSURE.

BLIDWORTH COAL - 12930 B.Th.U./lb.

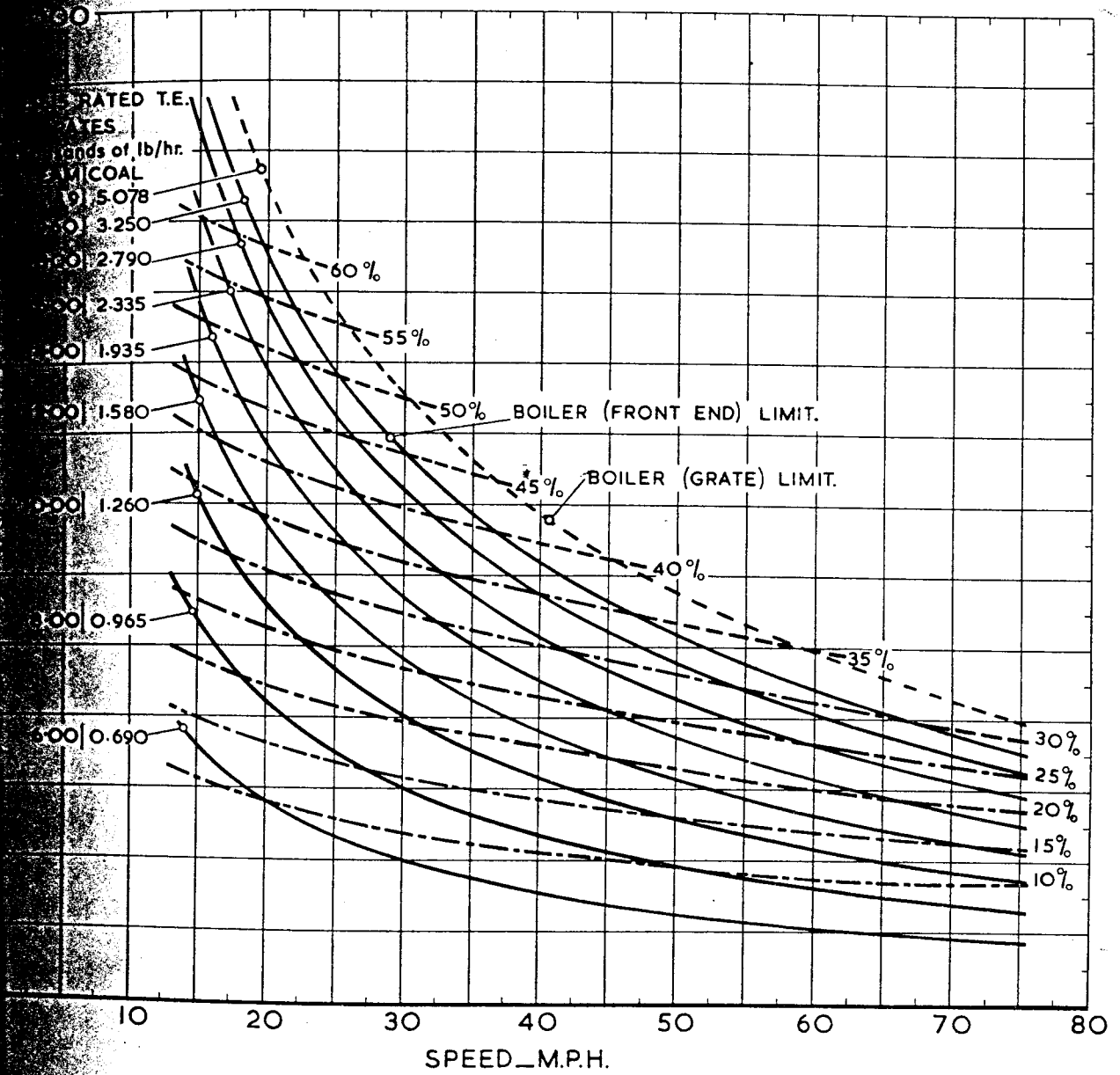
BR4/75006/51.



BLIDWORTH COAL — 12930 B.Th.U./lb.

EVAPORATION.

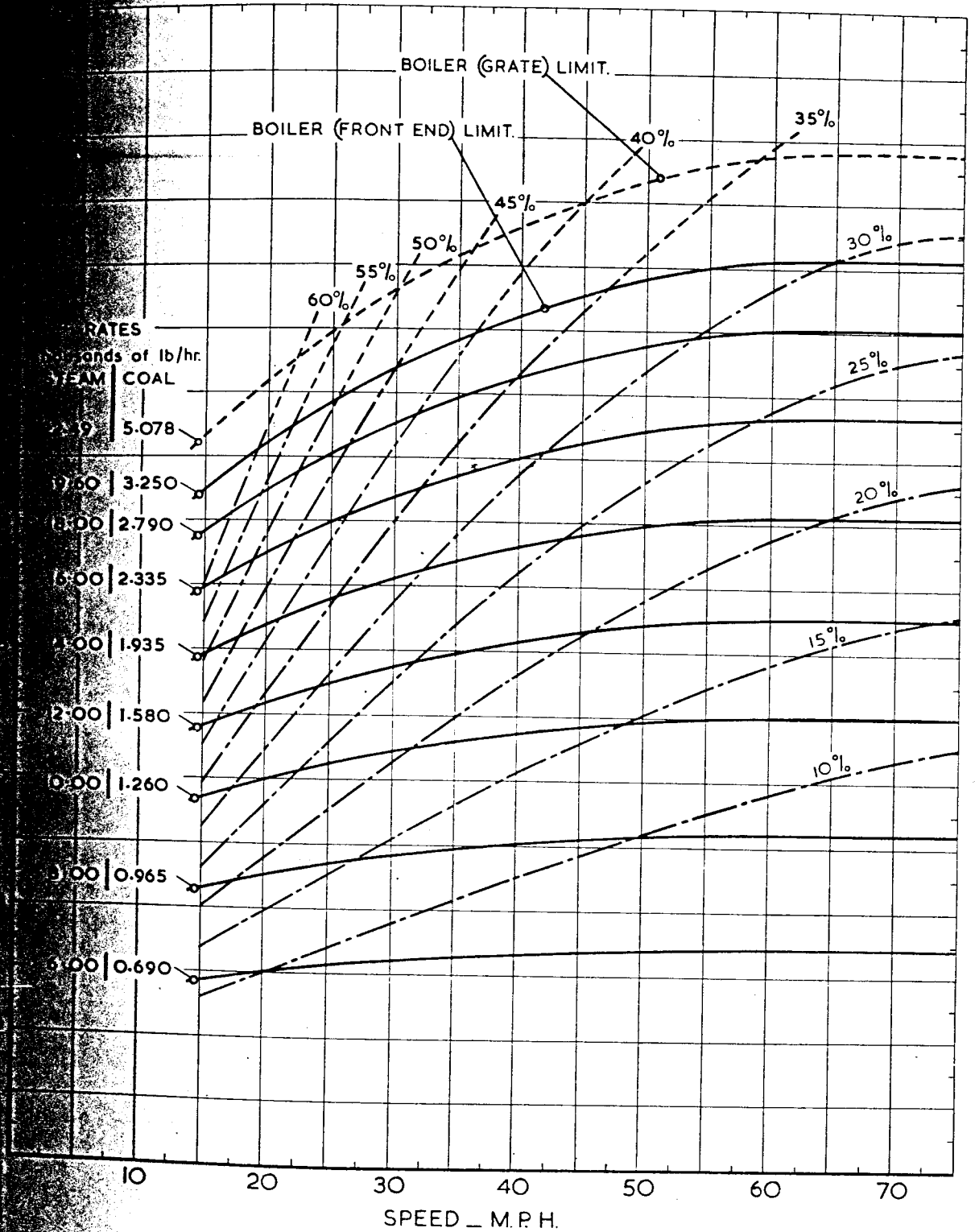
Cut Offs shown refer to Maximum Steam Chest Pressure.



LIDWORTH COAL — 12930 B.Th.U./lb.

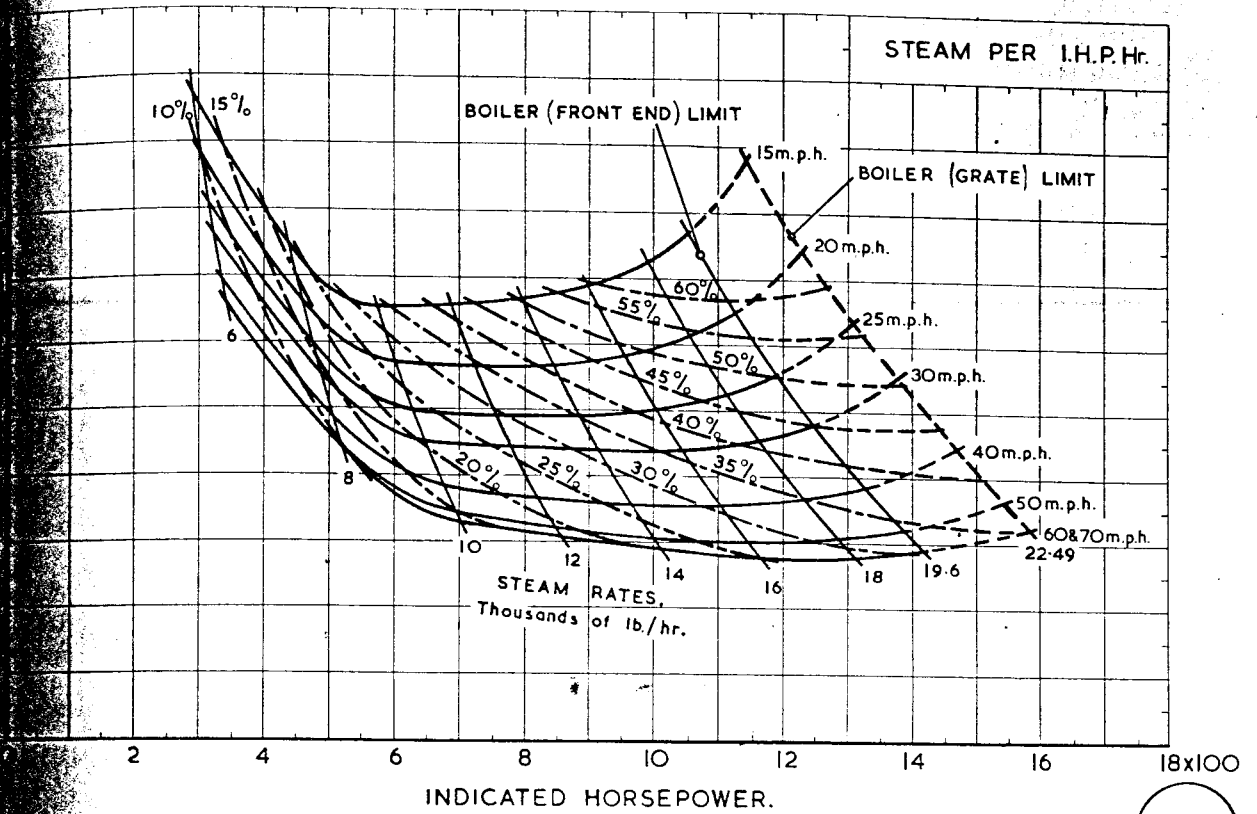
INDICATED TRACTIVE EFFORT CHARACTERISTICS.

Cut Offs shown refer to Maximum Steam Chest Pressure.



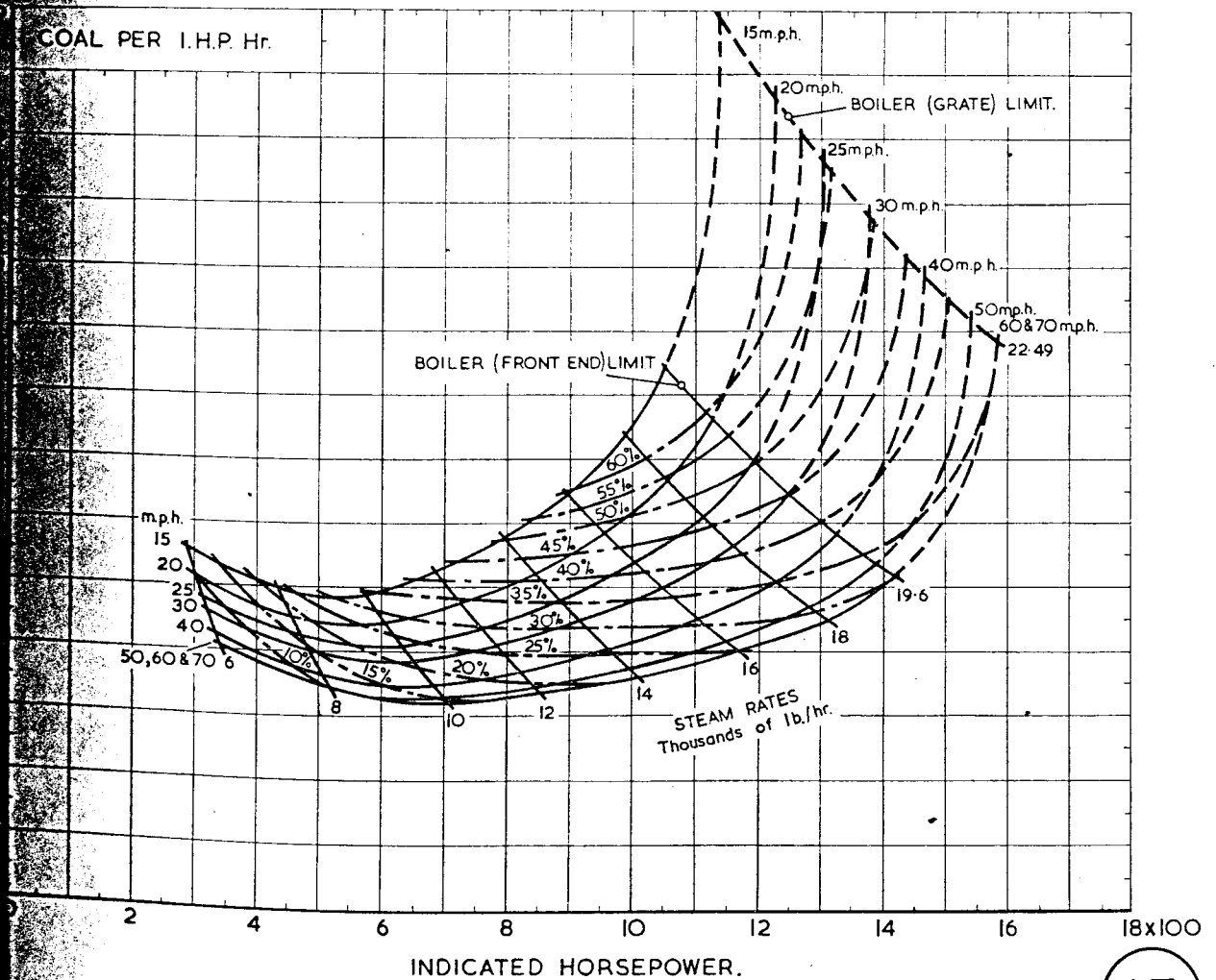
BLIDWORTH COAL — 12930 B.Th.U./lb.

INDICATED HORSEPOWER CHARACTERISTICS.



Cut Offs shown refer to Maximum Steam Chest Pressure.

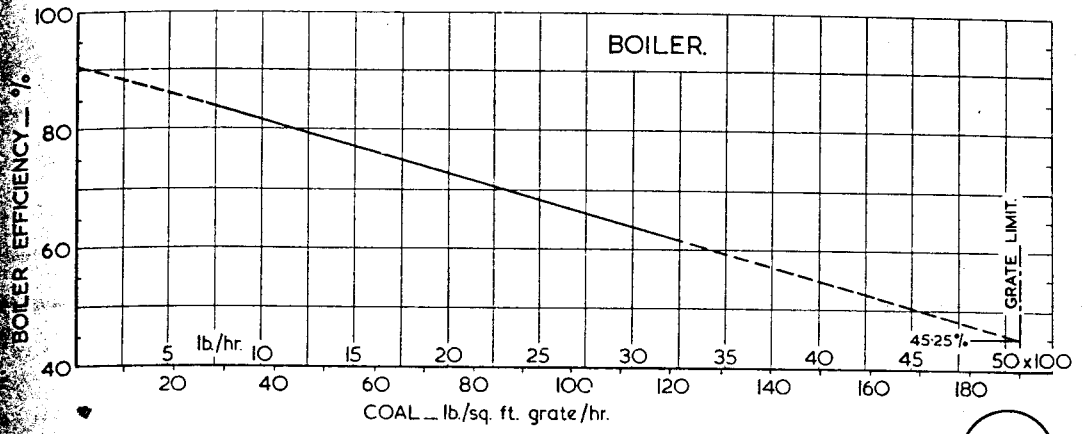
16



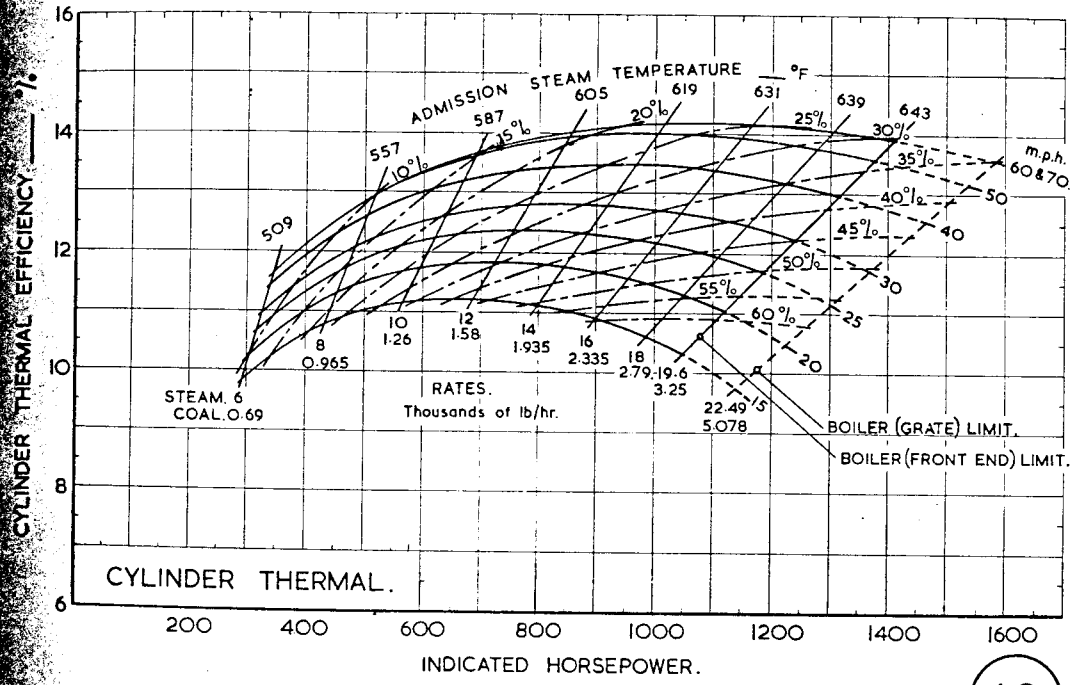
BLIDWORTH COAL — 12930 B.Th.U./lb.

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

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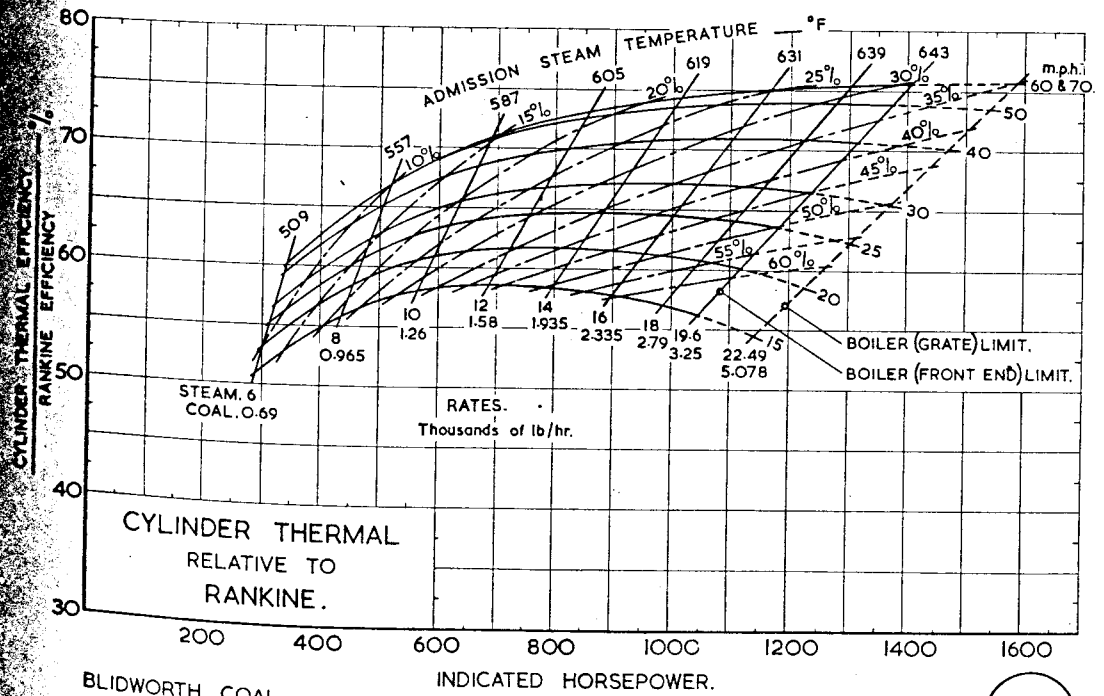


18



19

Cut Offs shown refer to Max. Steam Chest Pressure.

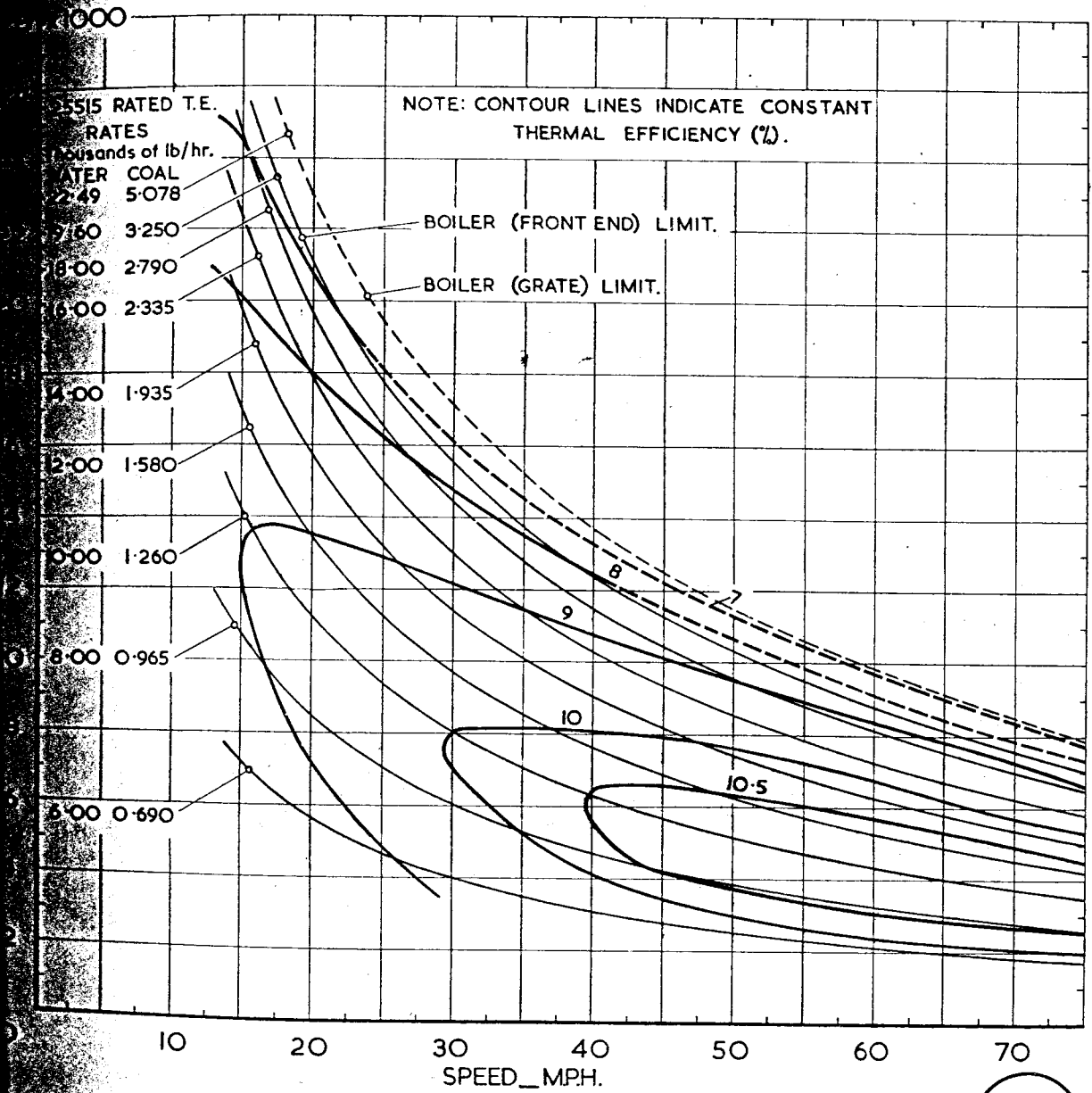


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BLIDWORTH COAL
12930 B.Th.U. / lb.

B.R.4/75006/51.

EFFICIENCIES.



BLIDWORTH COAL - 12930 B.Th.U./lb

OVERALL EFFICIENCY REFERRED TO CYLINDERS.

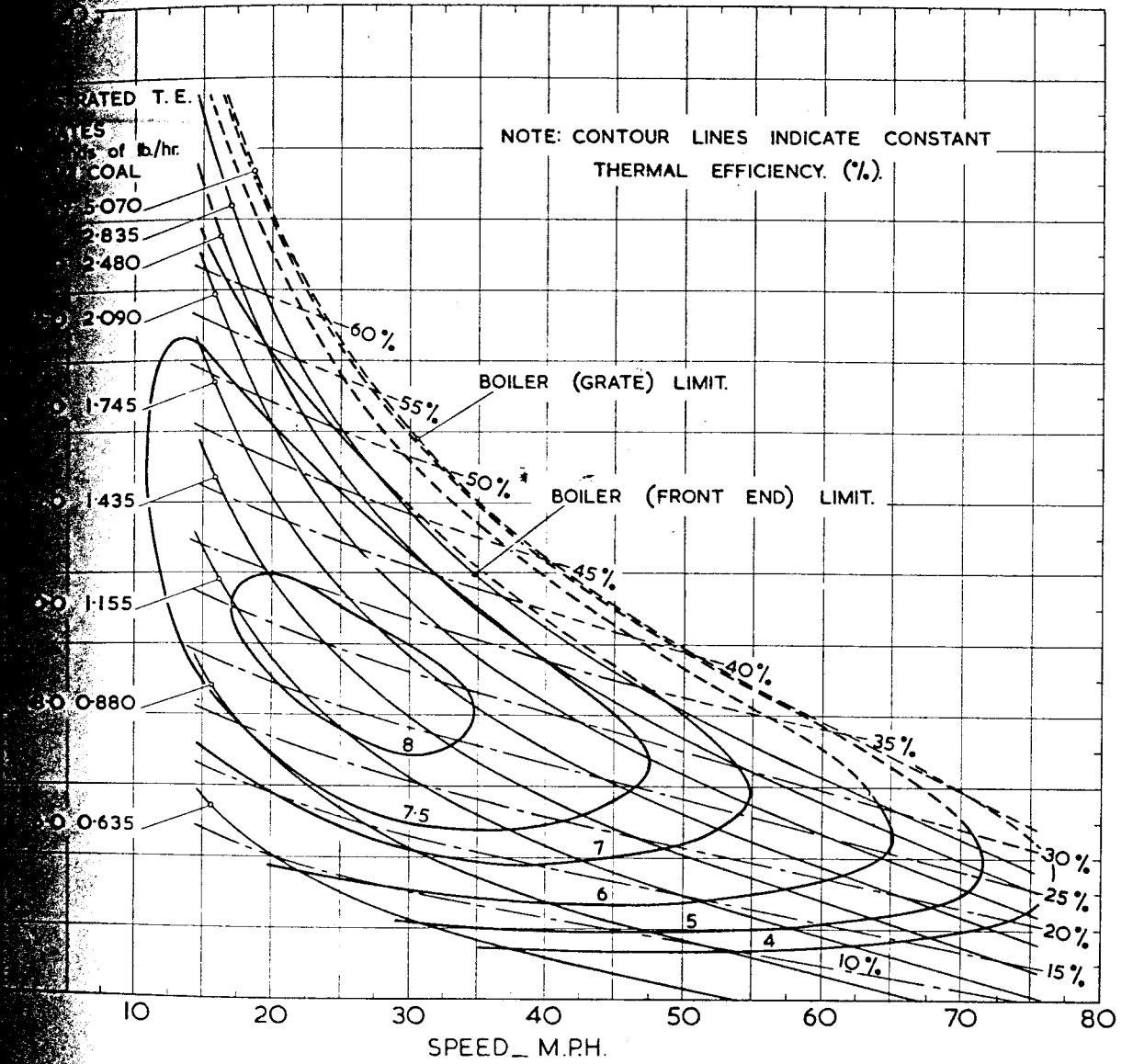
BRA/75006/51.

BEDWAS COAL.

Performance data : Graphs 22 to 29.

Design data : Graphs 30 to 41.

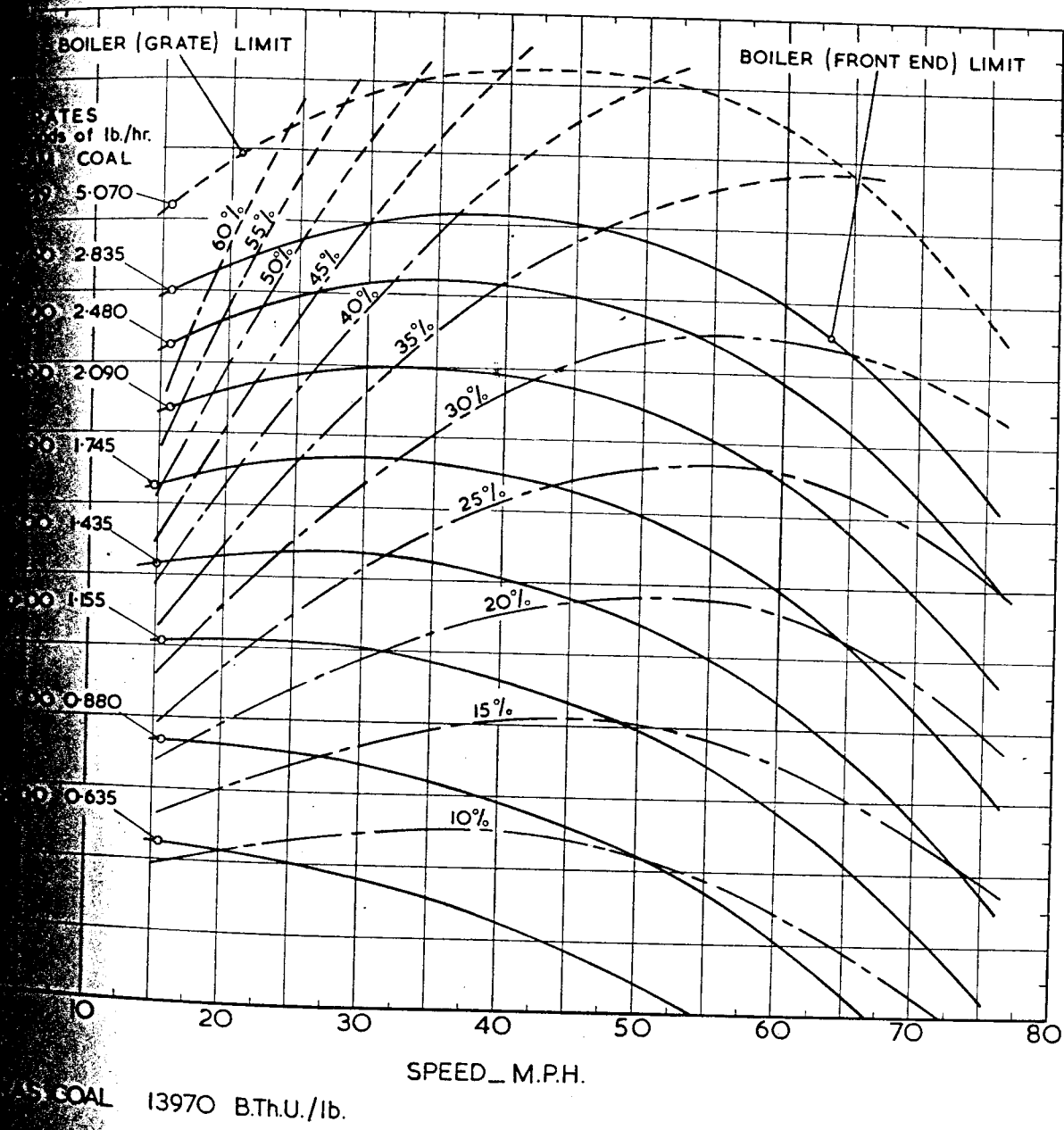
Cut Offs shown refer to Maximum Steam Chest Pressure.



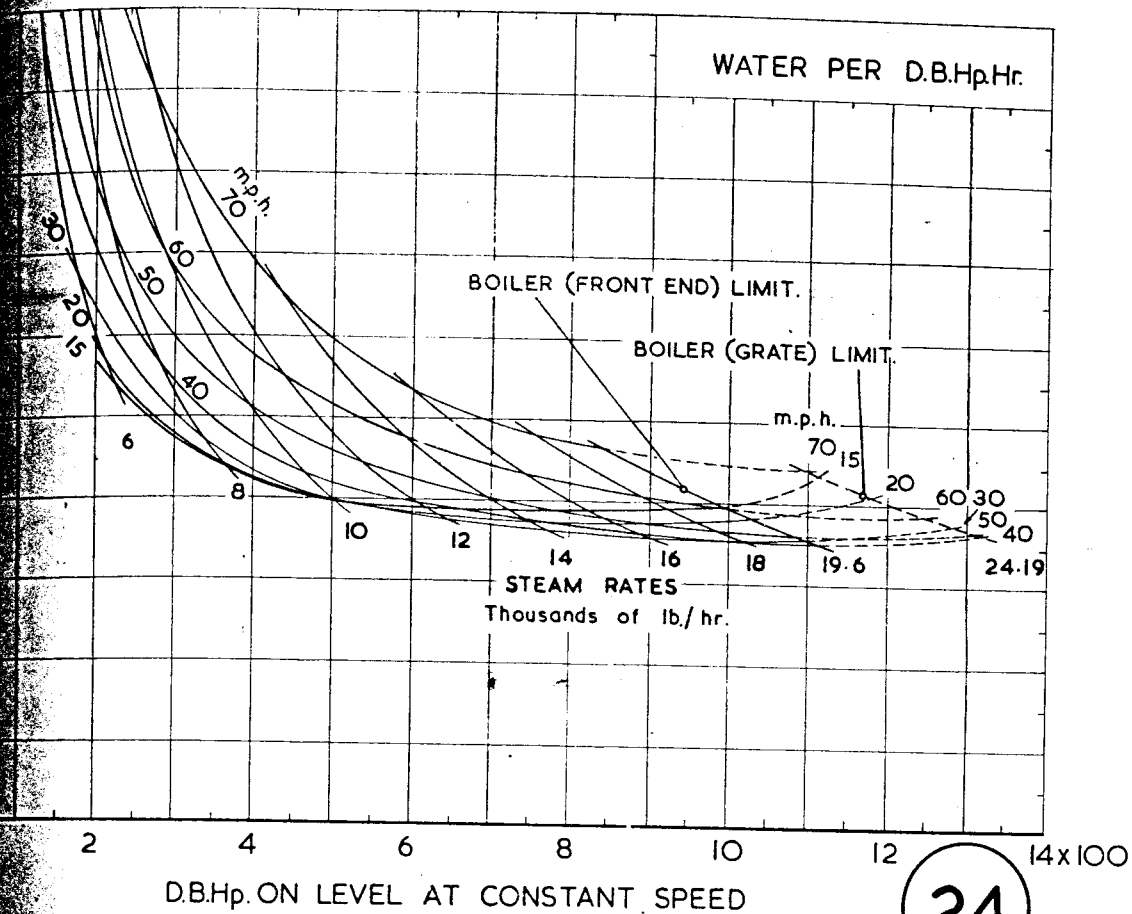
REDWAS COAL - 13970 B.Th.U./lb.

DRAWBAR TRACTIVE EFFORT CHARACTERISTICS.

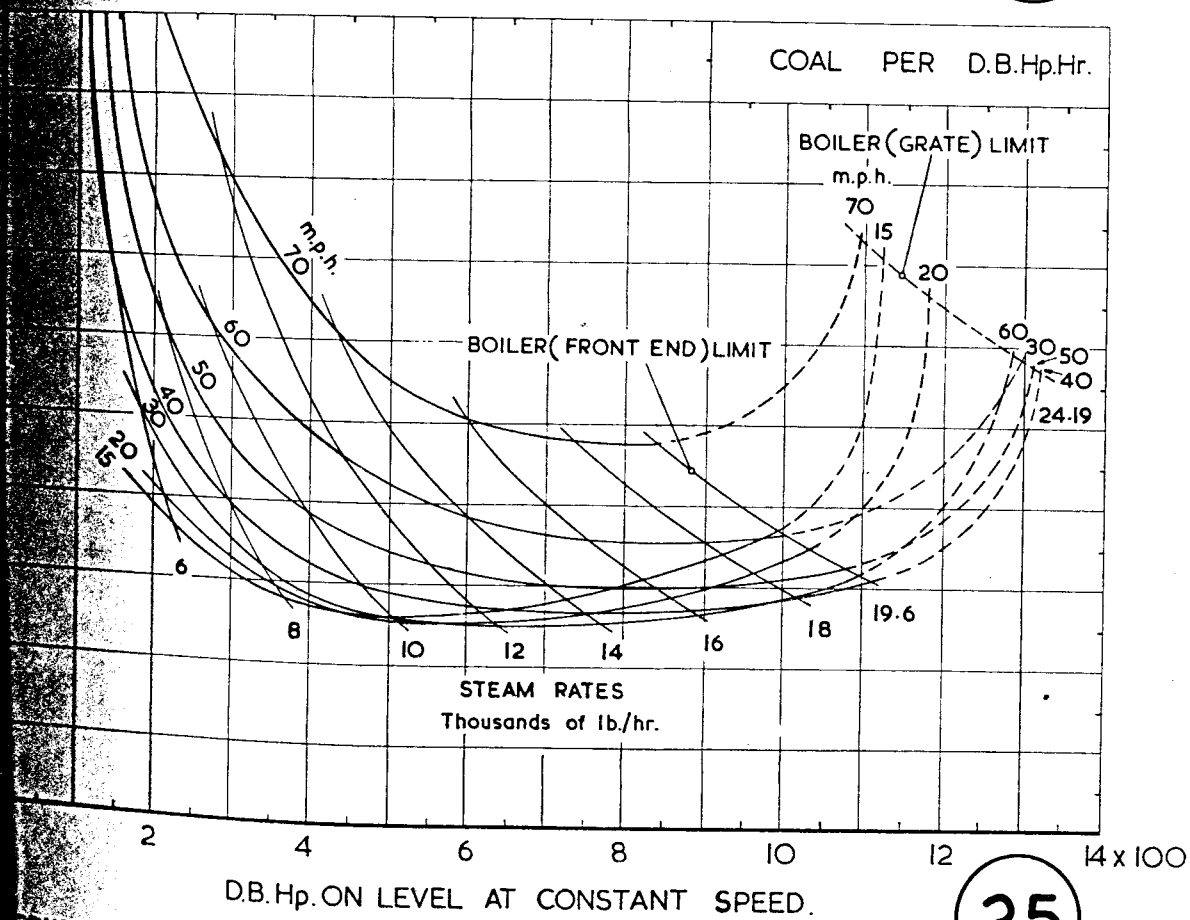
Cut Offs shown refer to Maximum Steam Chest Pressure.



DRAW BAR HORSEPOWER CHARACTERISTICS.



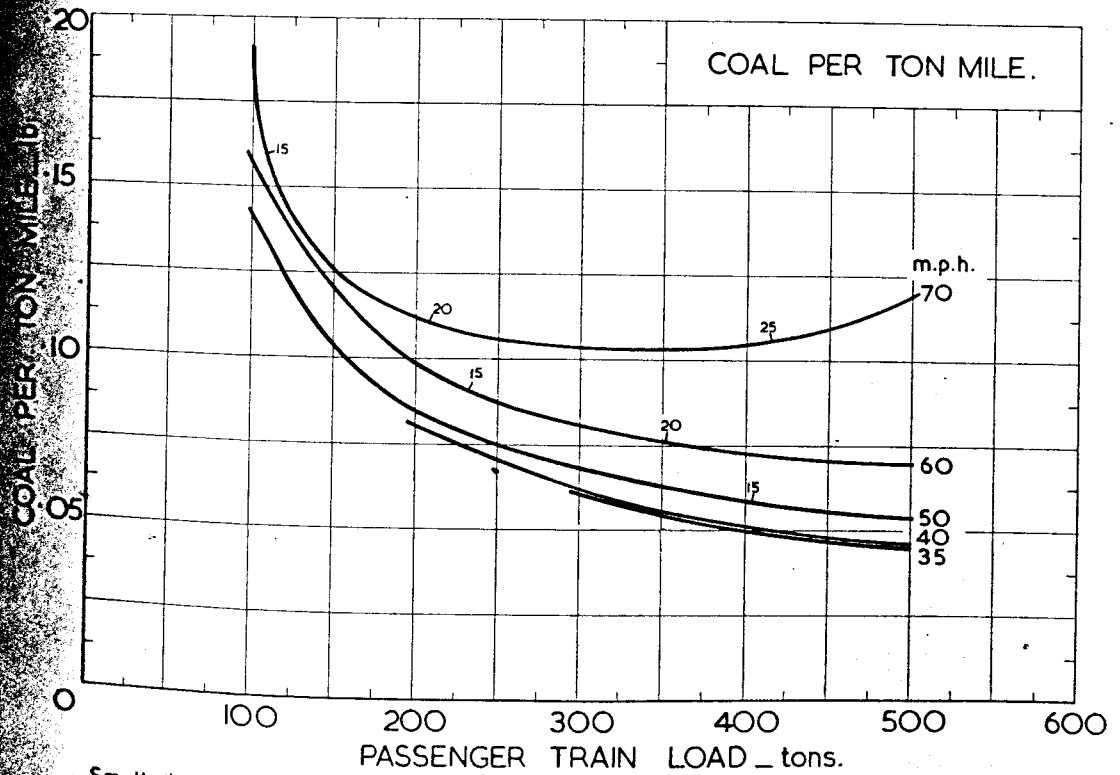
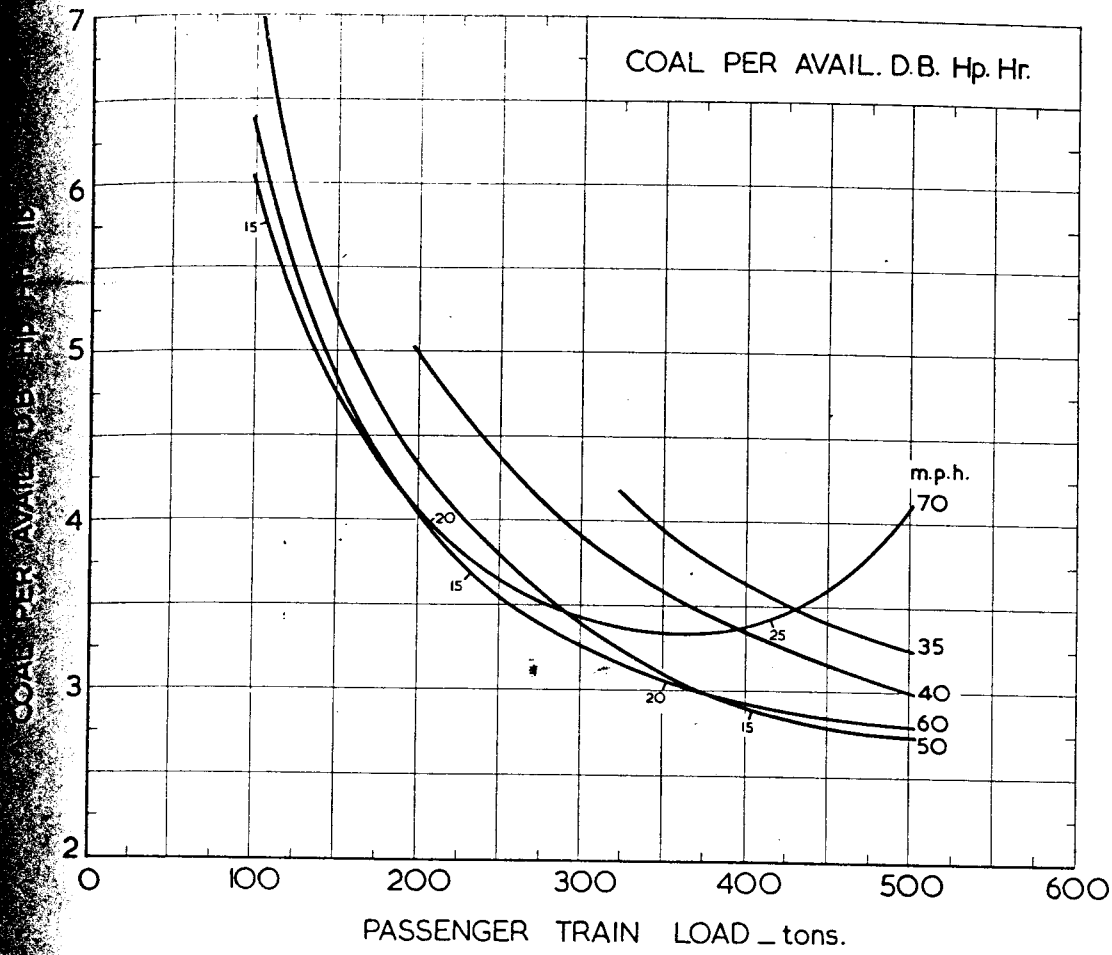
24



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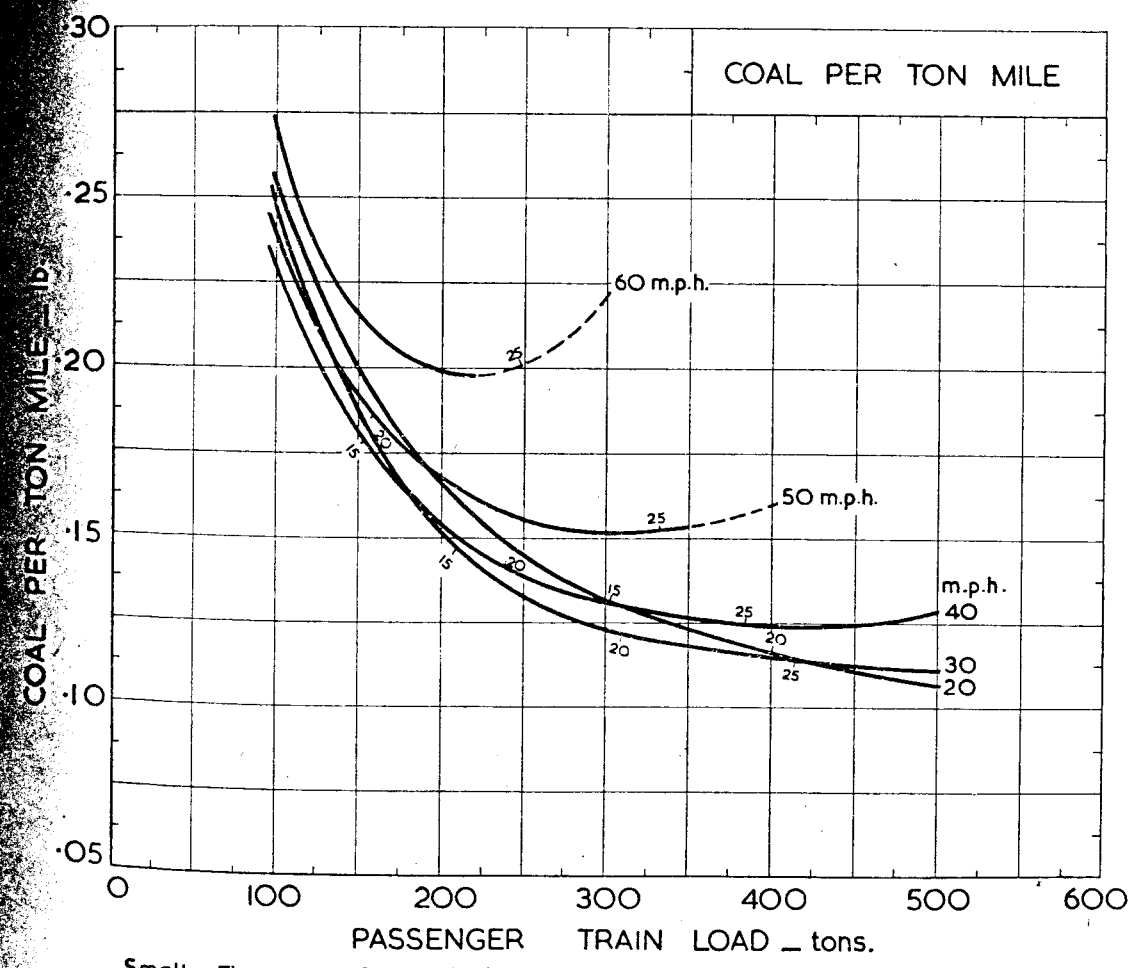
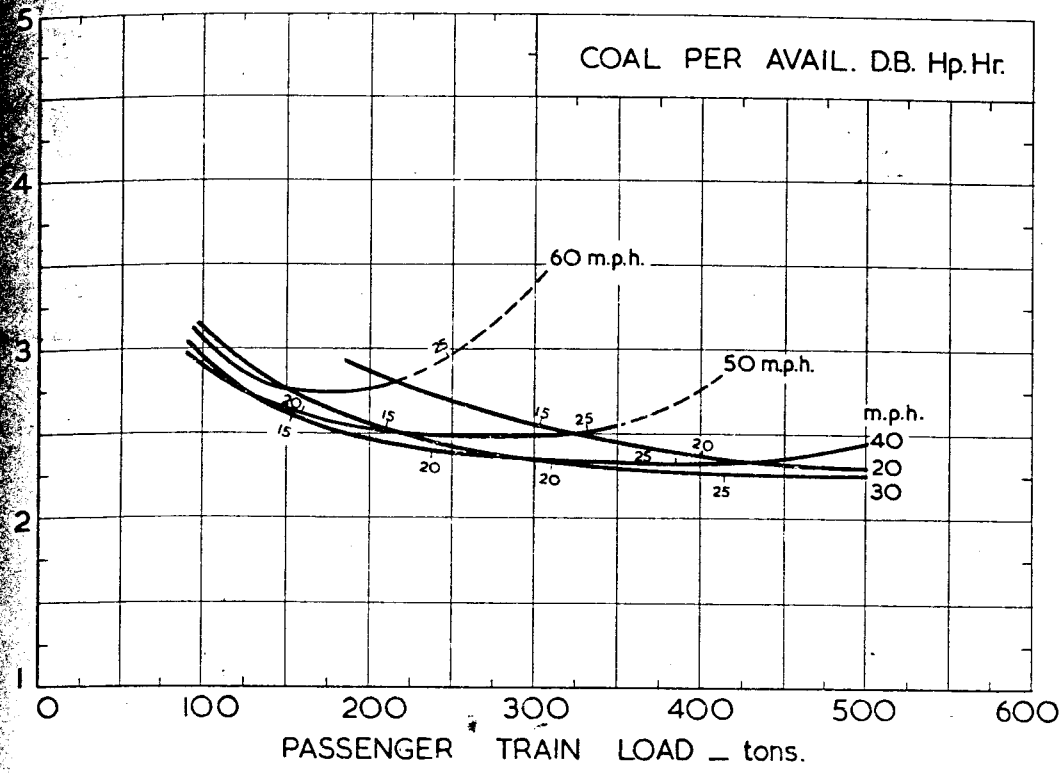
EDWAS COAL - 13970 B.ThU./lb.

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



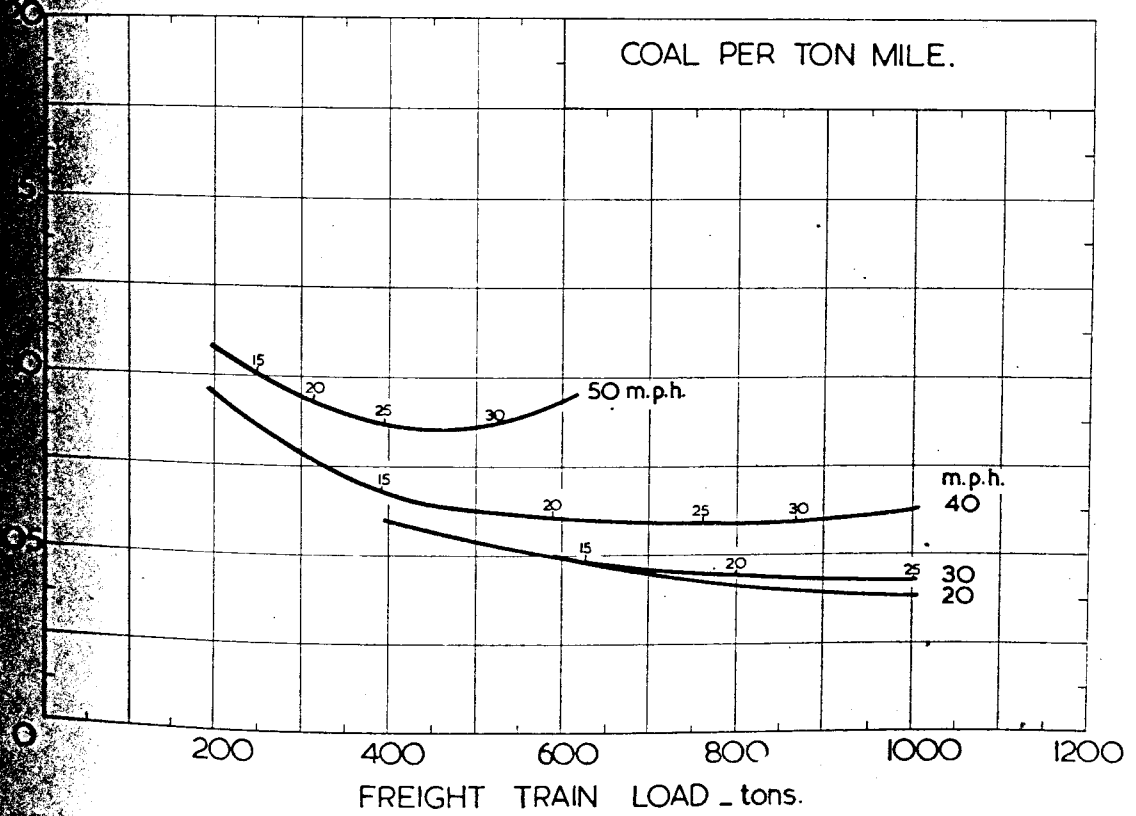
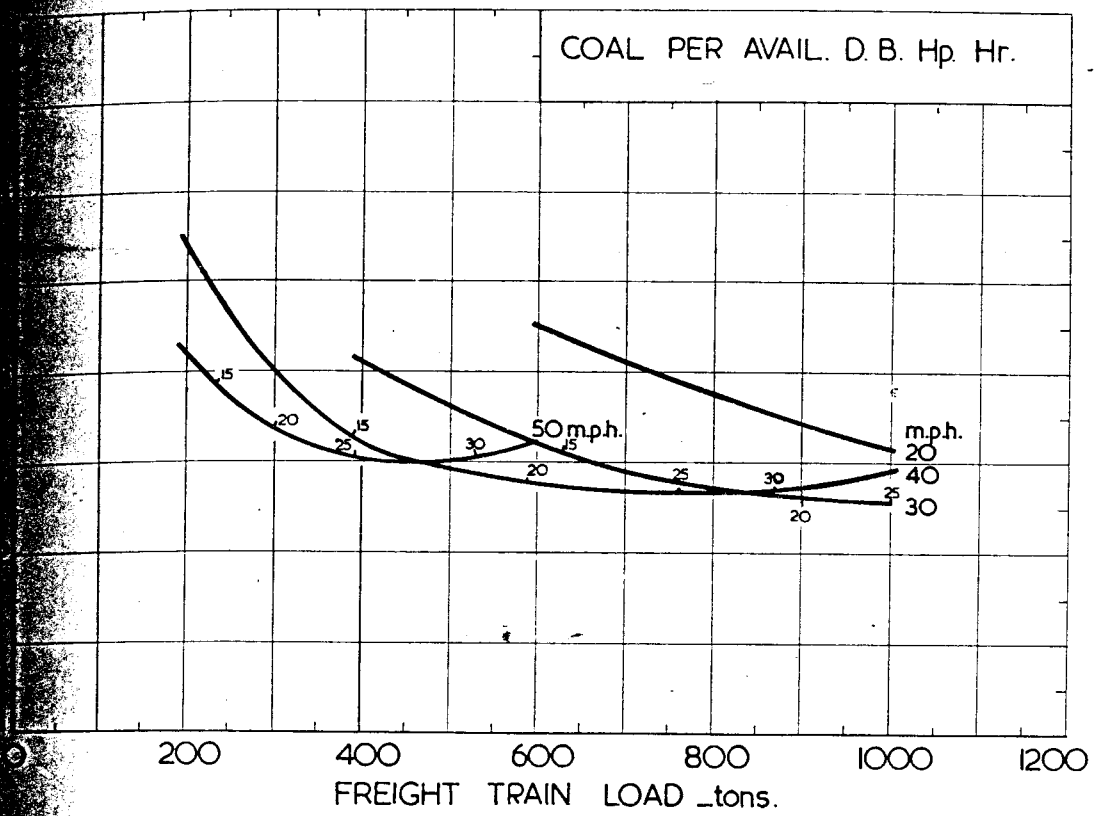
Small figures on Curves indicate Cut Off Maximum Steam Chest Pressure.
 BEDWAS COAL 13970 B.Th.U./lb.

PASSENGER SERVICE — LEVEL.
 EXAMPLES OF COST IN COAL OF DIFFERENT
 TRAIN LOADS & SPEEDS.



Small Figures on Curves indicate Cut Off. Maximum Steam Chest Pressure.
 BEDWAS COAL - 13970 B.Th.U./lb.

PASSENGER SERVICE - 1 IN 200 RISING.
 EXAMPLES OF COST IN COAL OF DIFFERENT
 TRAIN LOADS & SPEEDS.



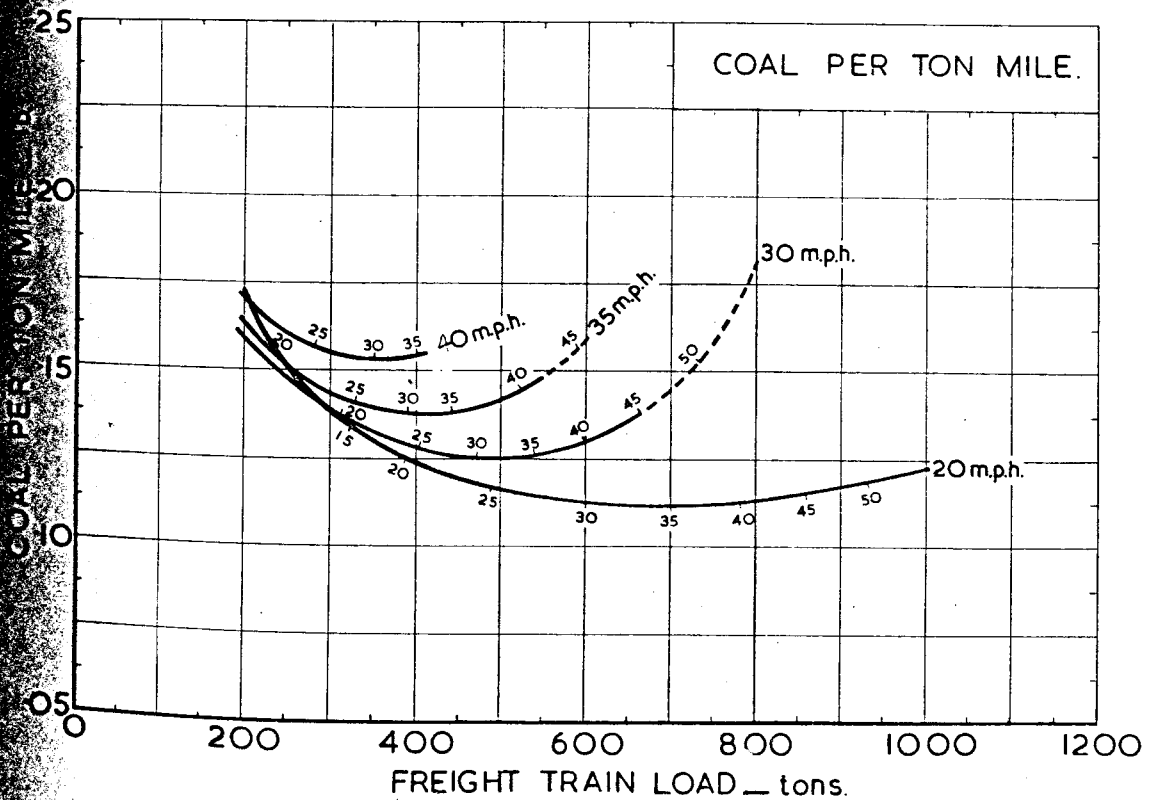
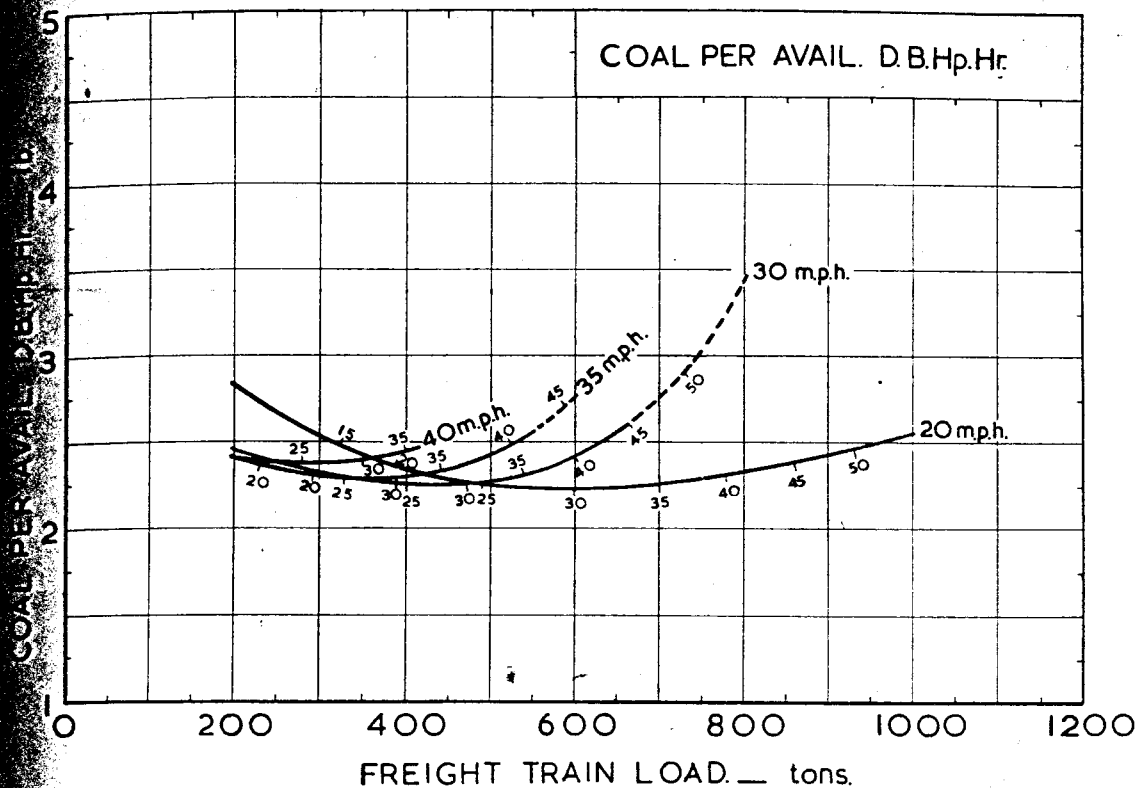
Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

BEDWAS COAL 13970 B.T.hU/lb.

FREIGHT SERVICE - LEVEL.

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

BR4/75006/51.

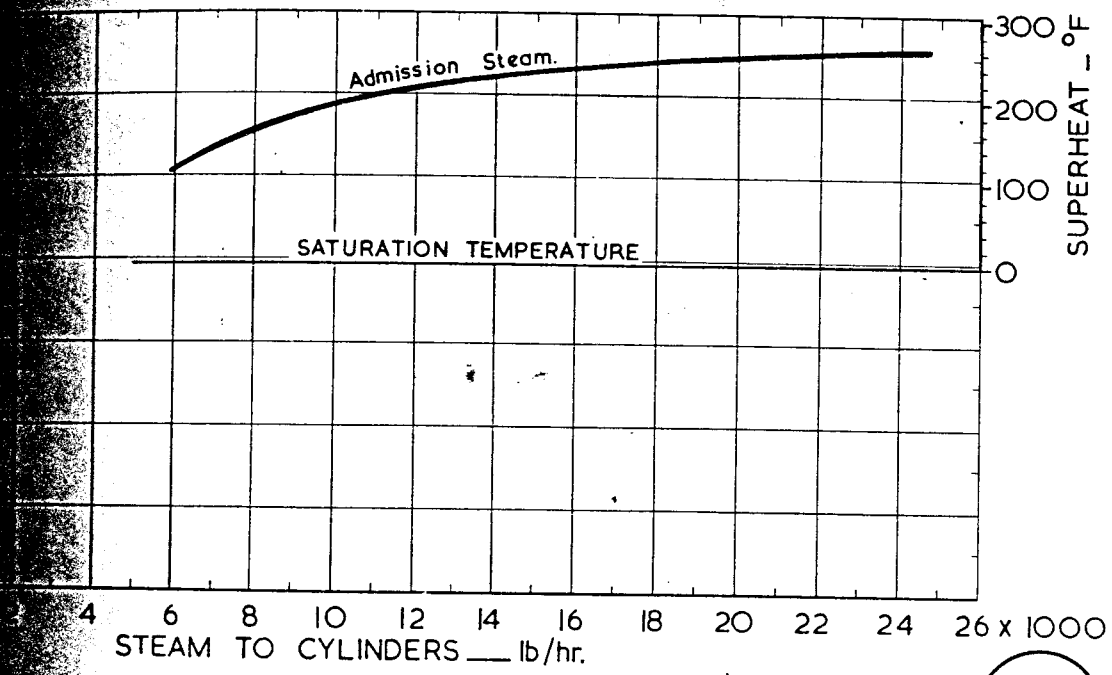


Small Figures on Curves indicate Cut Off, Maximum Steam Chest Pressure.

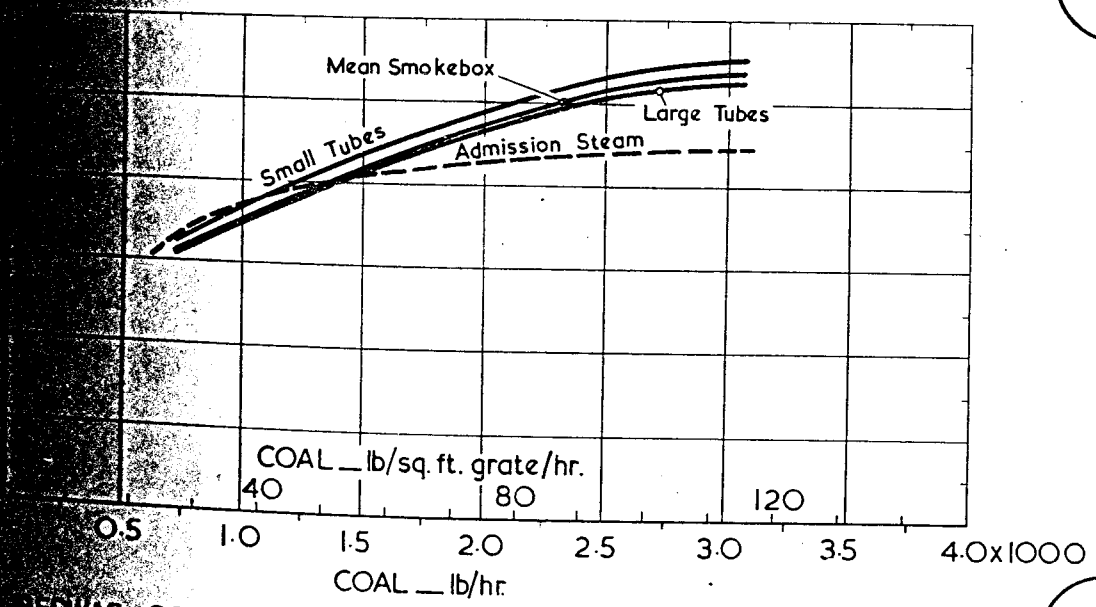
BEDWAS COAL — 13970 B.Th.U/lb.

FREIGHT SERVICE — 1 IN 200 RISING.

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



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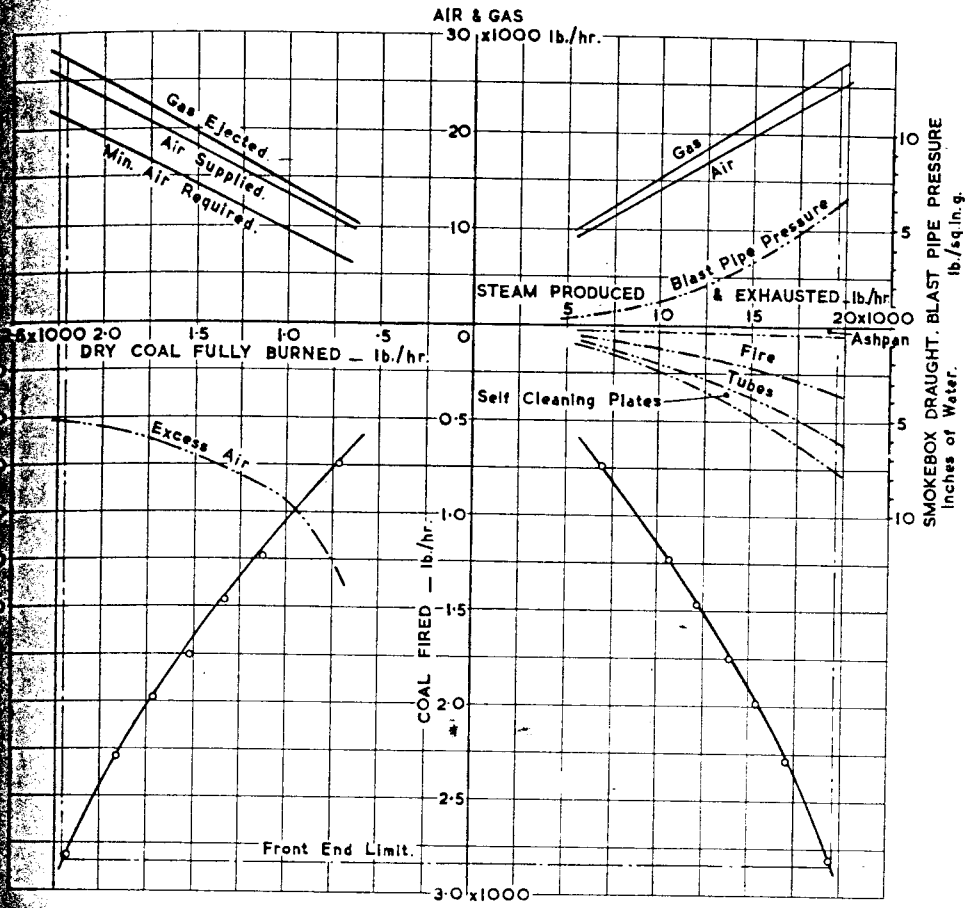


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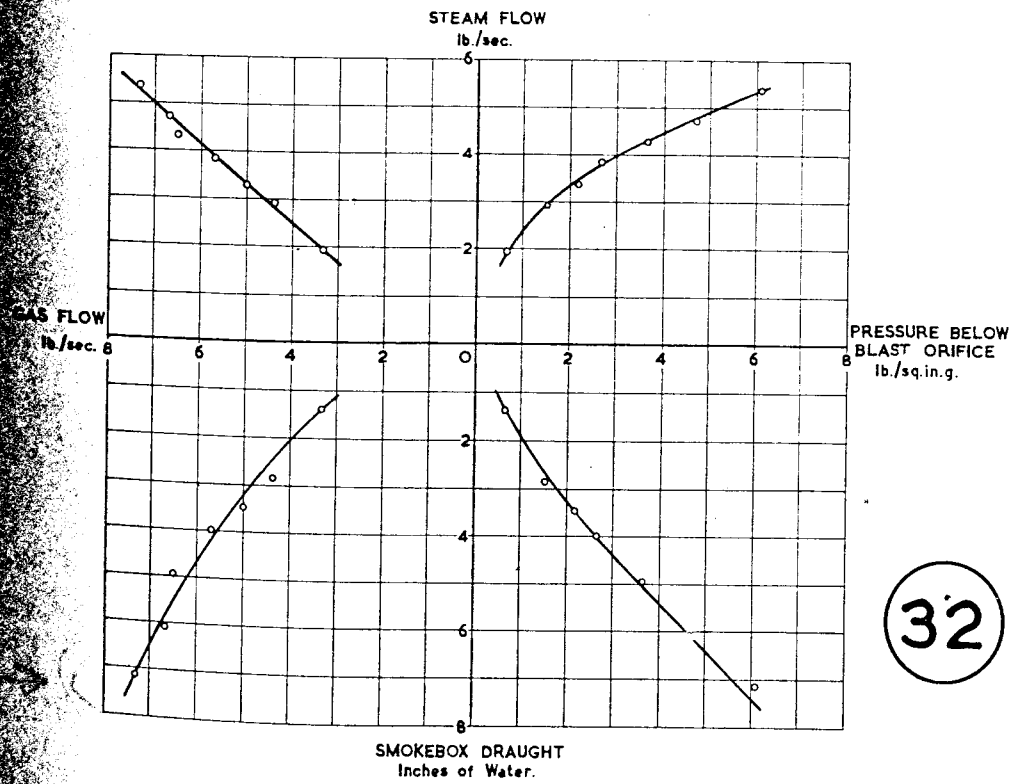
BEDWAS COAL.
10970 B.Th.U./lb.

TEMPERATURES.

RA175006/51.



STEAM - AIR - COMBUSTION.

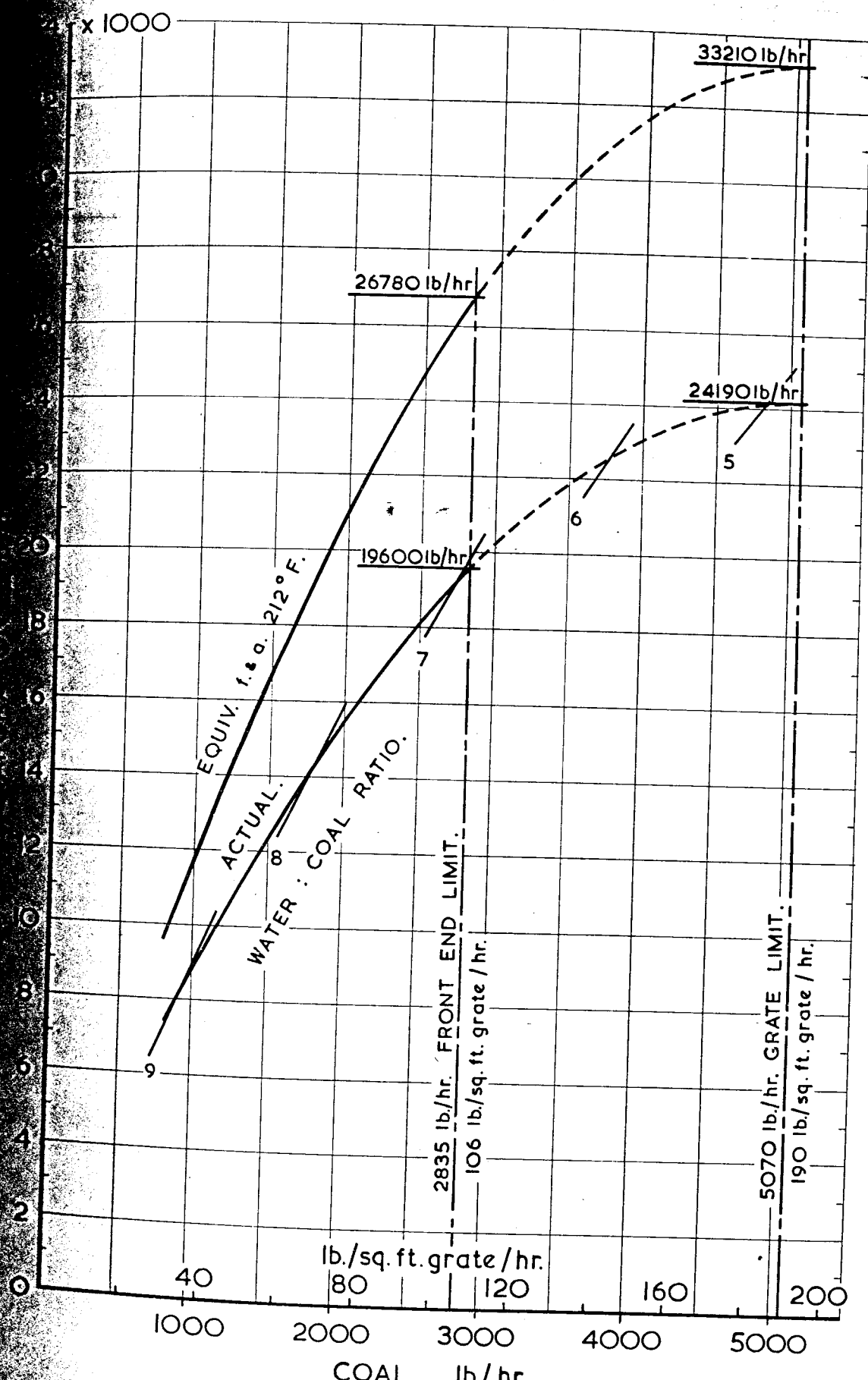


STEAM - GAS - DRAUGHT & BLAST PIPE PRESSURE.

BEDWAS COAL - 13970 B.Th.U./lb.

BRA/75006/51.

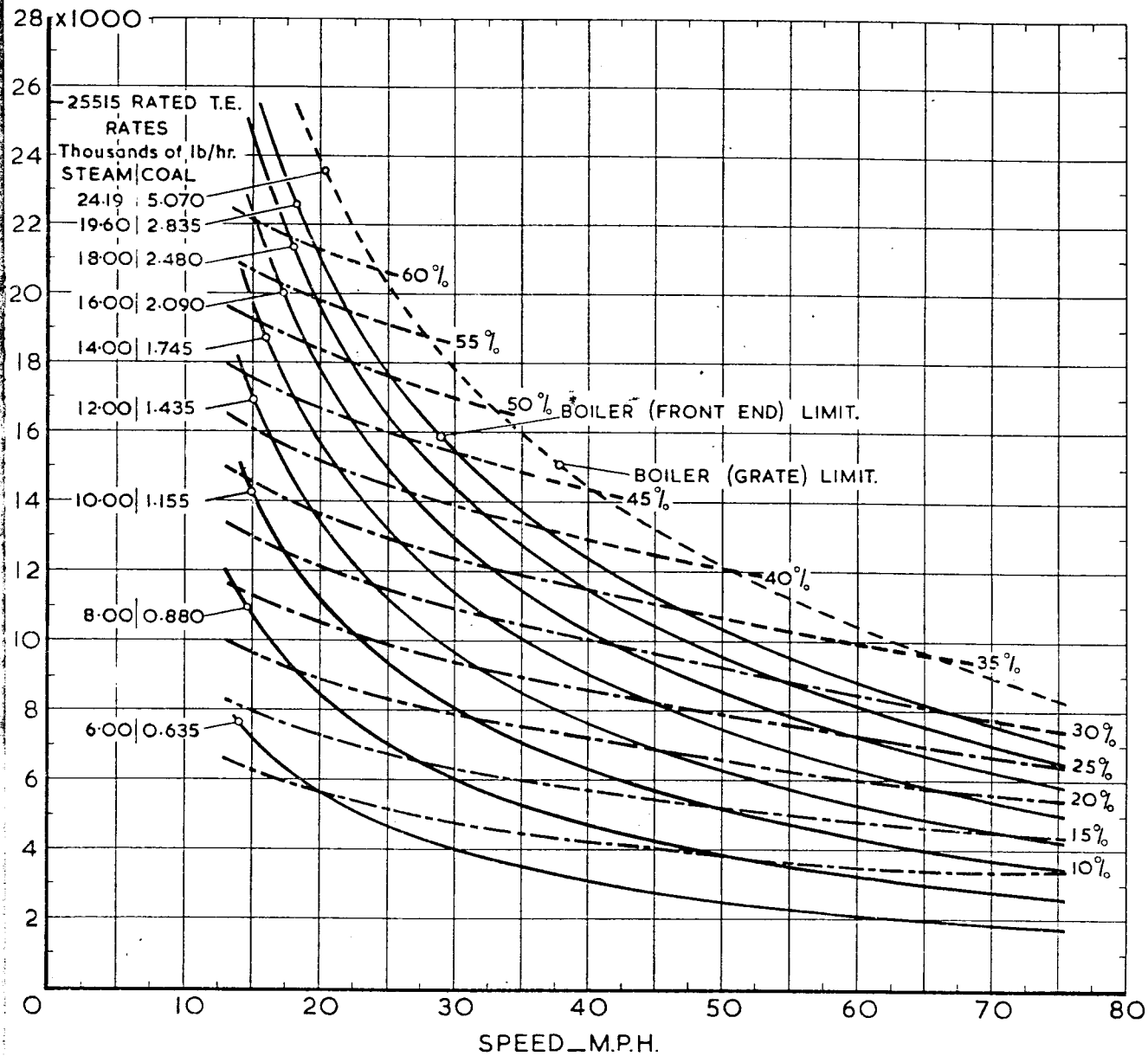
32



BEDWAS COAL — 13970 B.Th.U./lb.

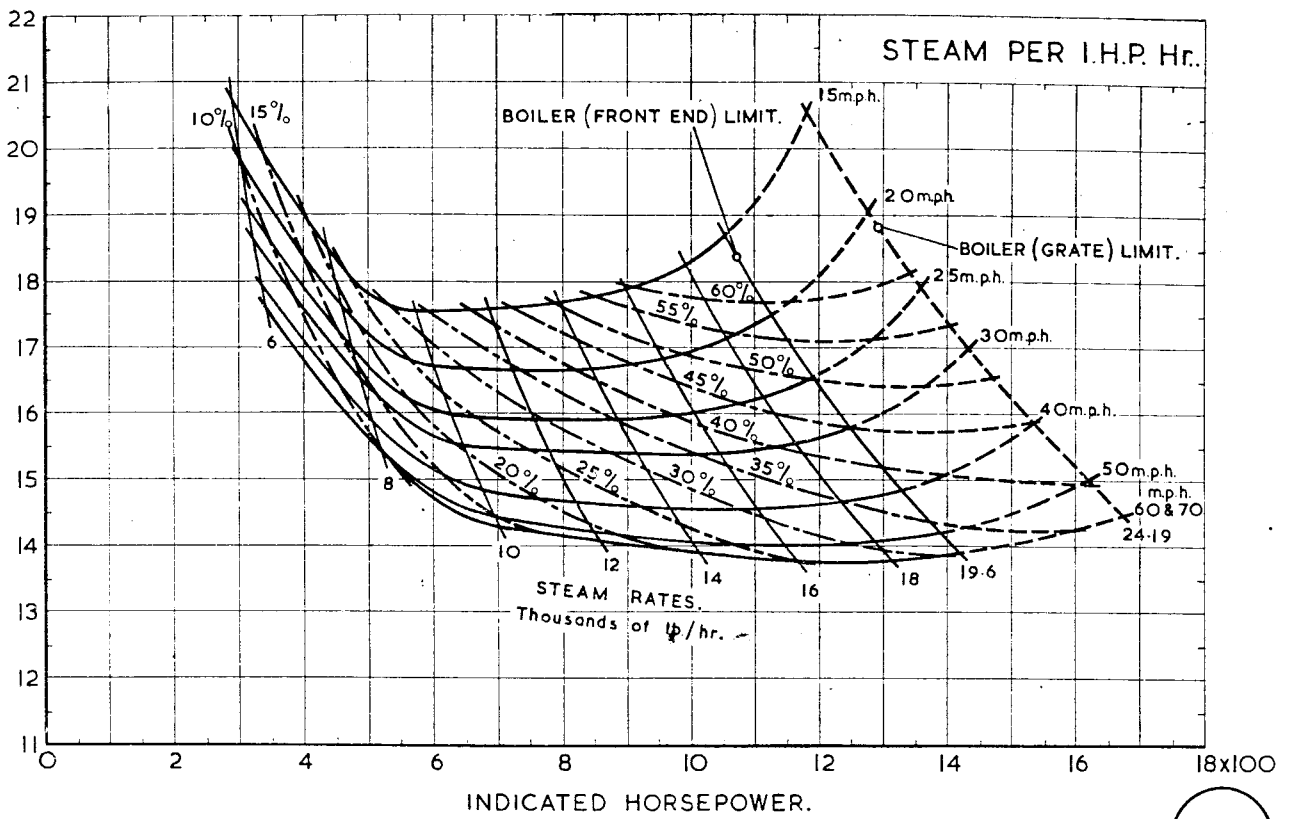
EVAPORATION.

Cut Offs shown refer to Maximum Steam Chest Pressure.



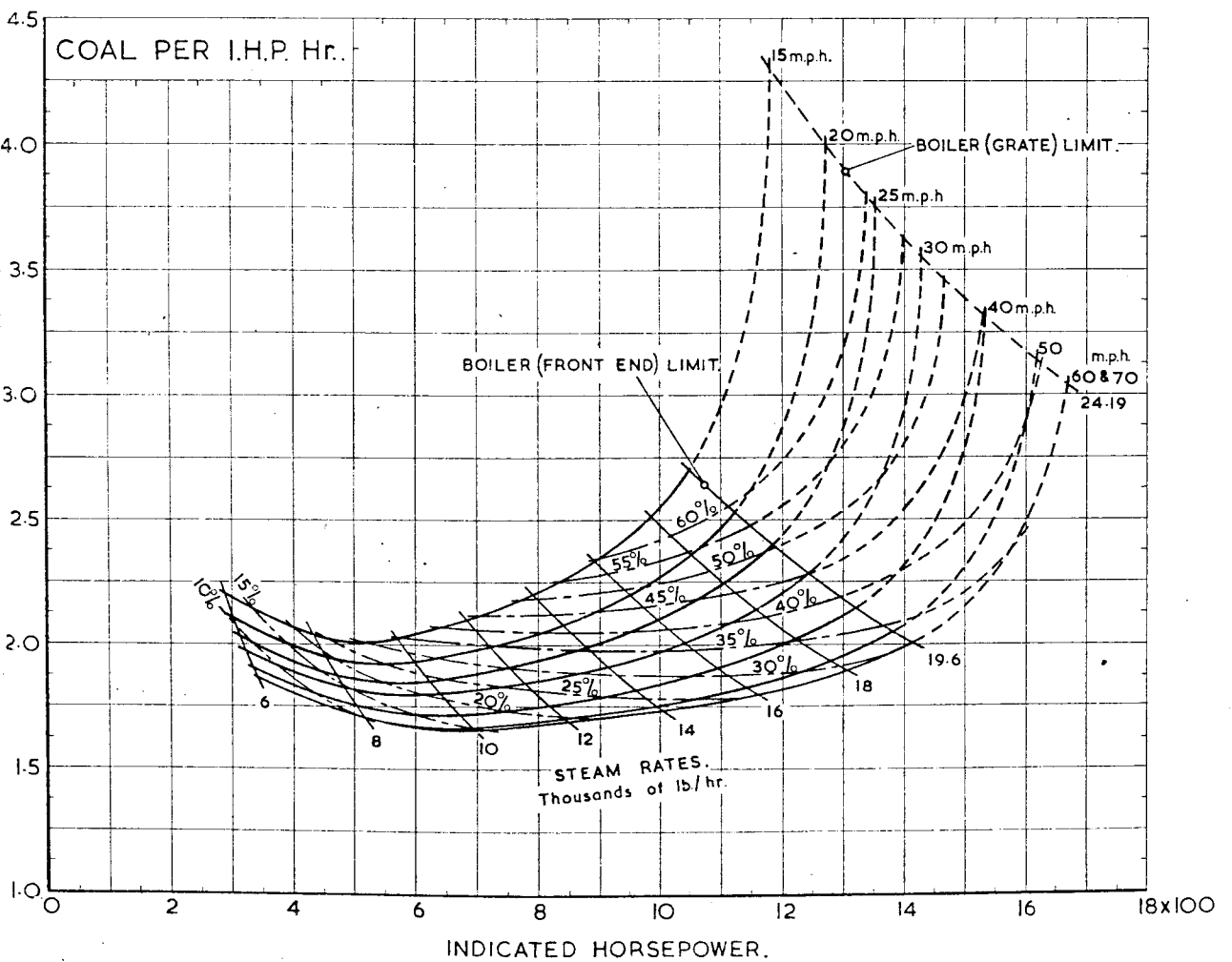
BEDWAS COAL — 13970 B.ThU./lb.

INDICATED TRACTIVE EFFORT CHARACTERISTICS.



Cut Offs shown refer to Maximum Steam Chest Pressure.

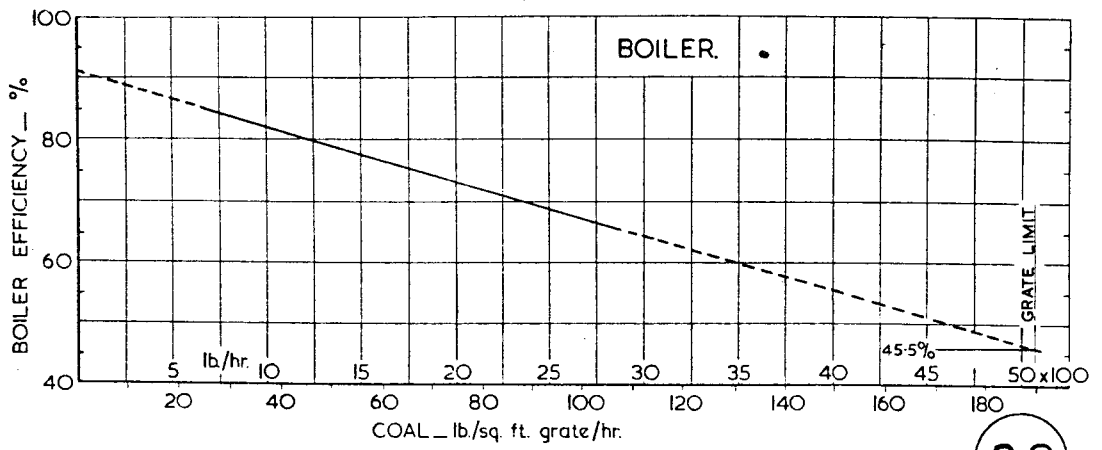
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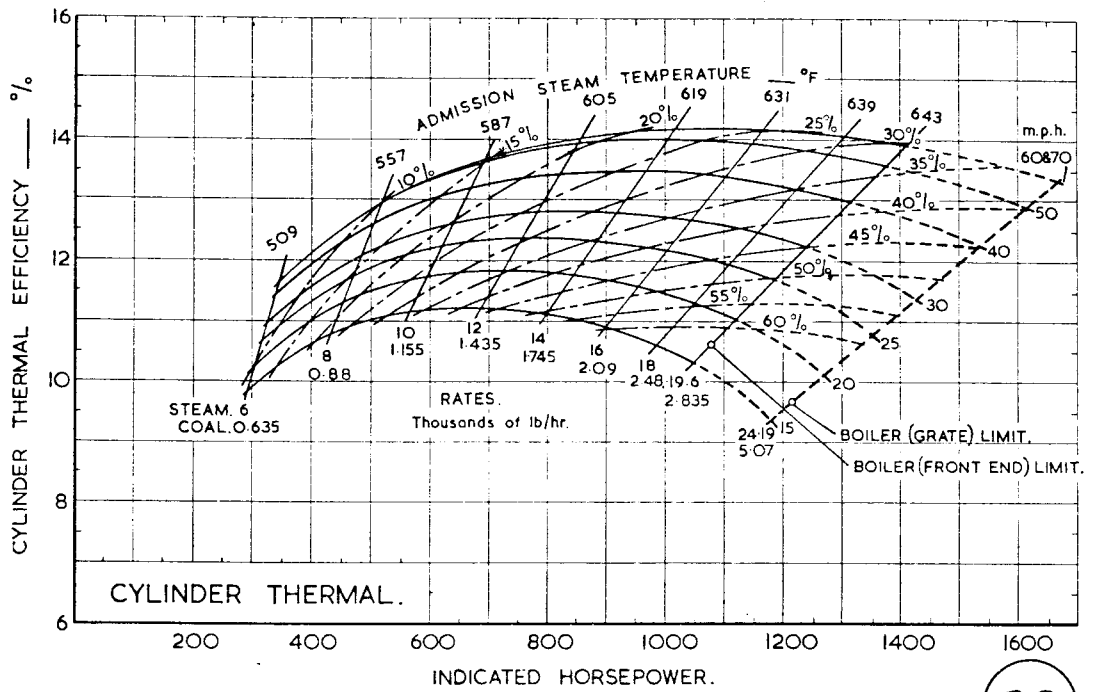
BEDWAS COAL — 13970 B.Th.U./lb.

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

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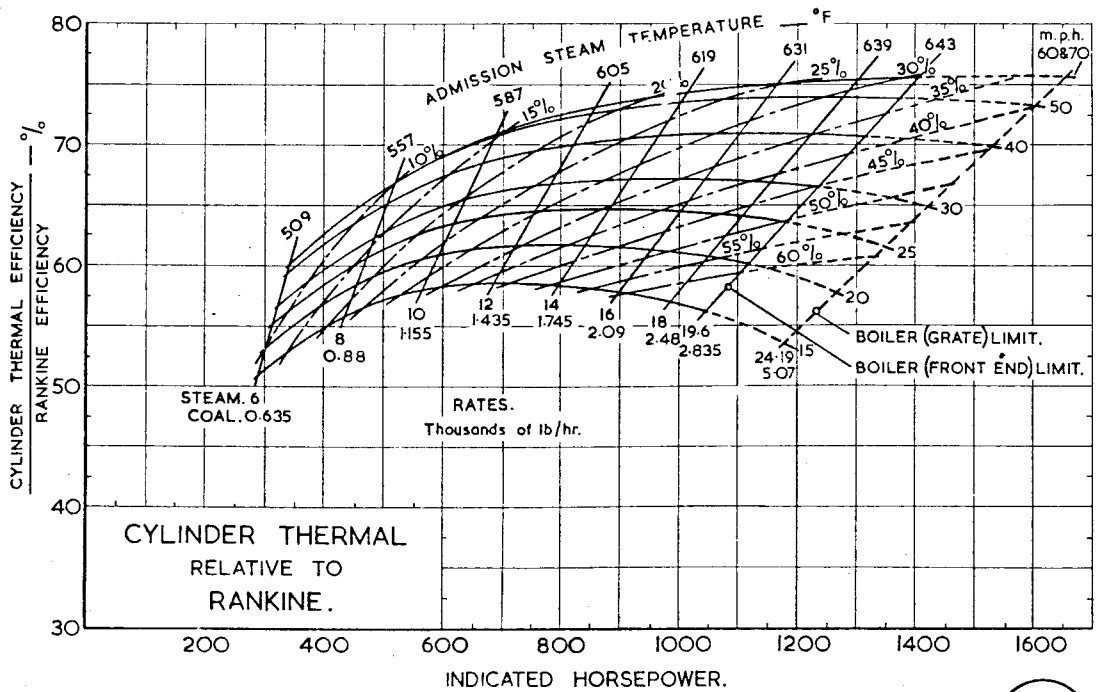


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Cut Offs shown refer to Max. Steam Chest Pressure.

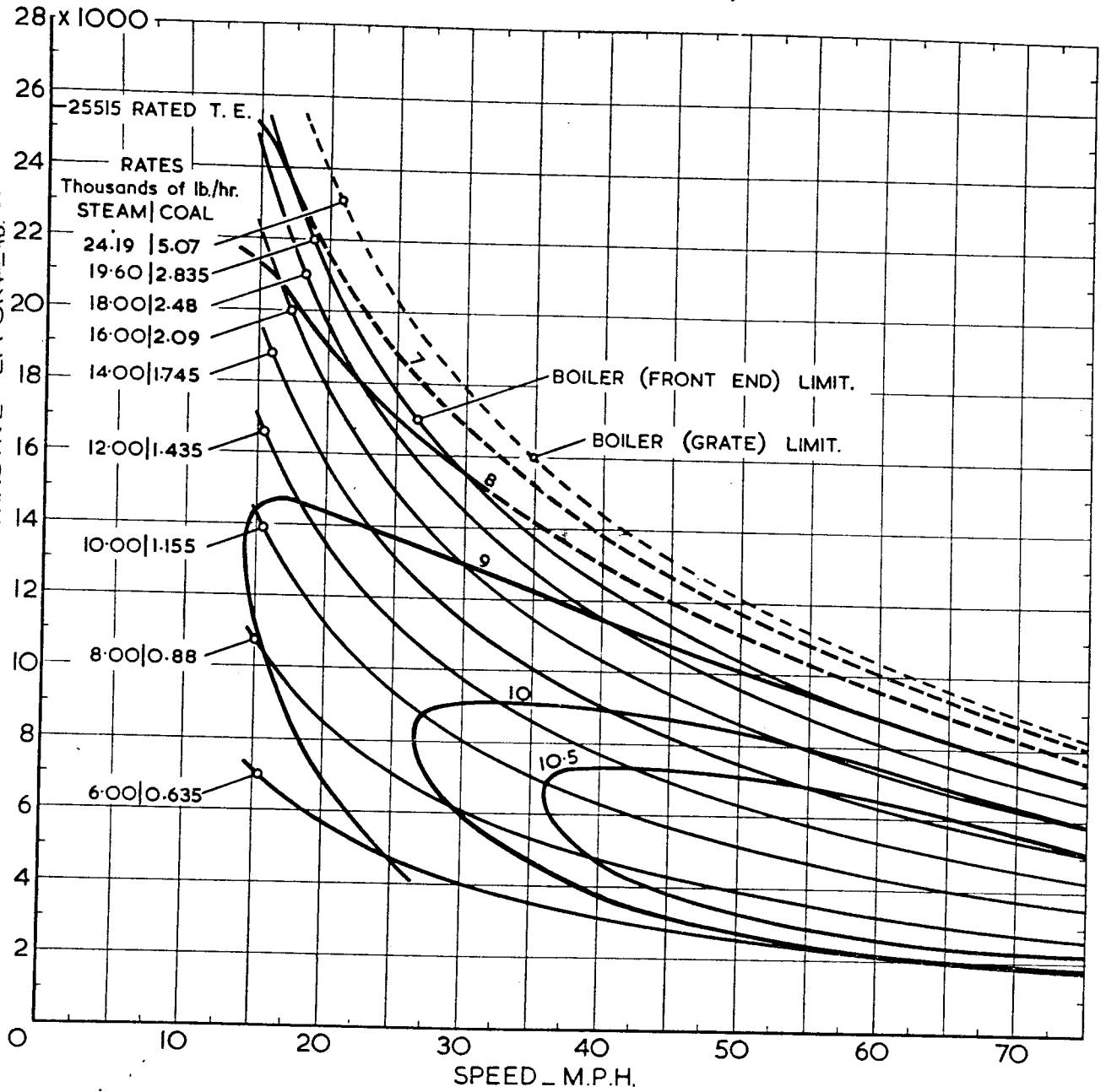


BEDWAS COAL — 13970 B.ThU./lb.

40

EFFICIENCIES.

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

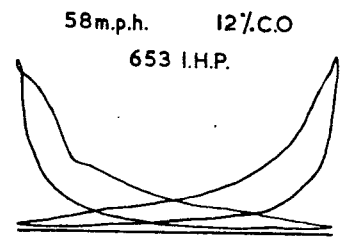
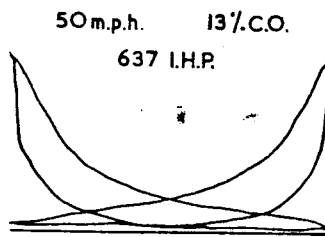
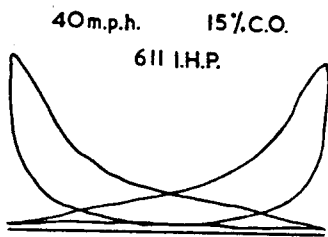
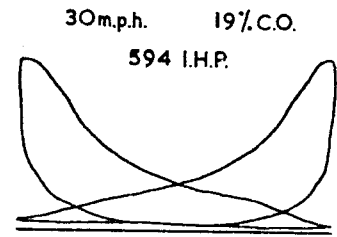
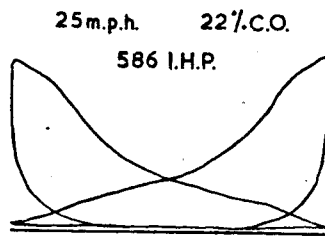
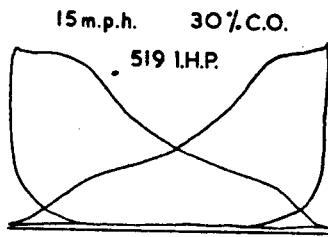


BEDWAS COAL — 13970 B.Th.U./lb.

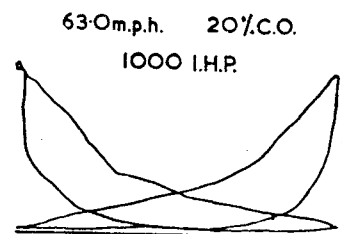
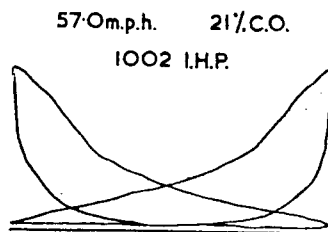
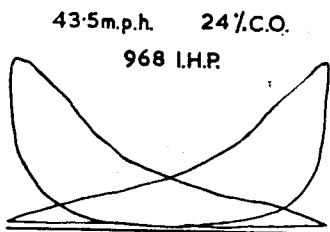
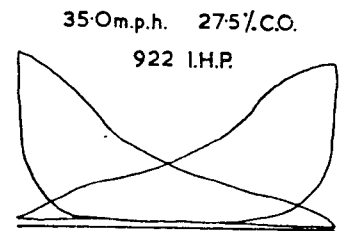
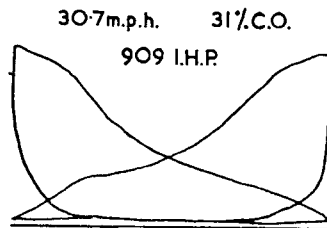
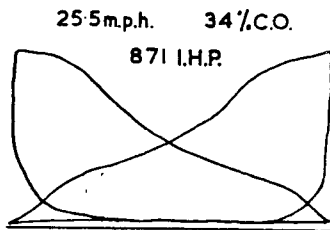
OVERALL EFFICIENCY REFERRED TO CYLINDERS.

EXAMPLES OF INDICATOR CARDS.

MEAN STEAM RATE 9300 lb./hr. FULL REGULATOR.

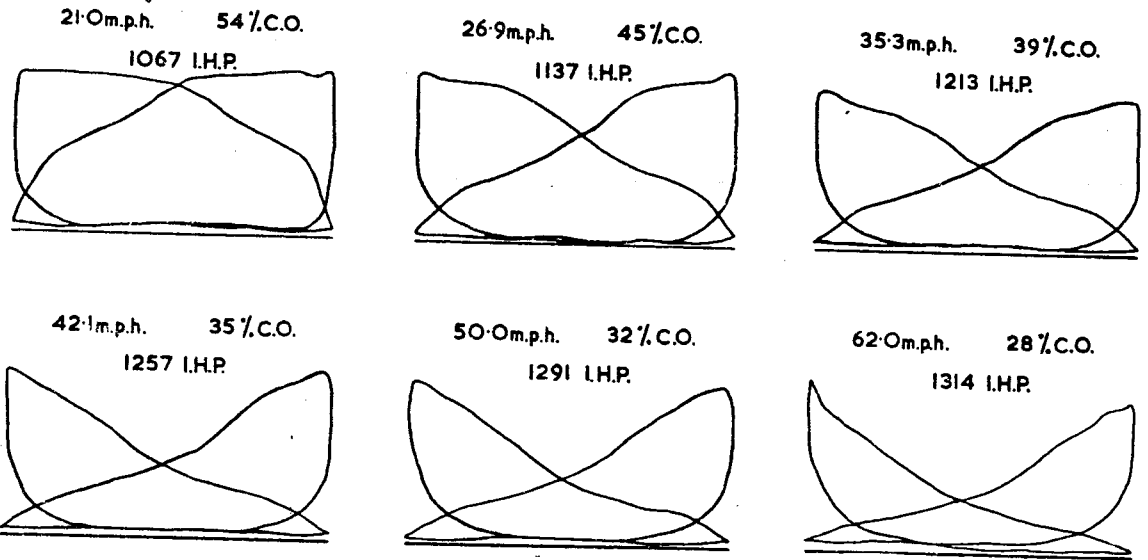


MEAN STEAM RATE 13850 lb./hr. FULL REGULATOR.

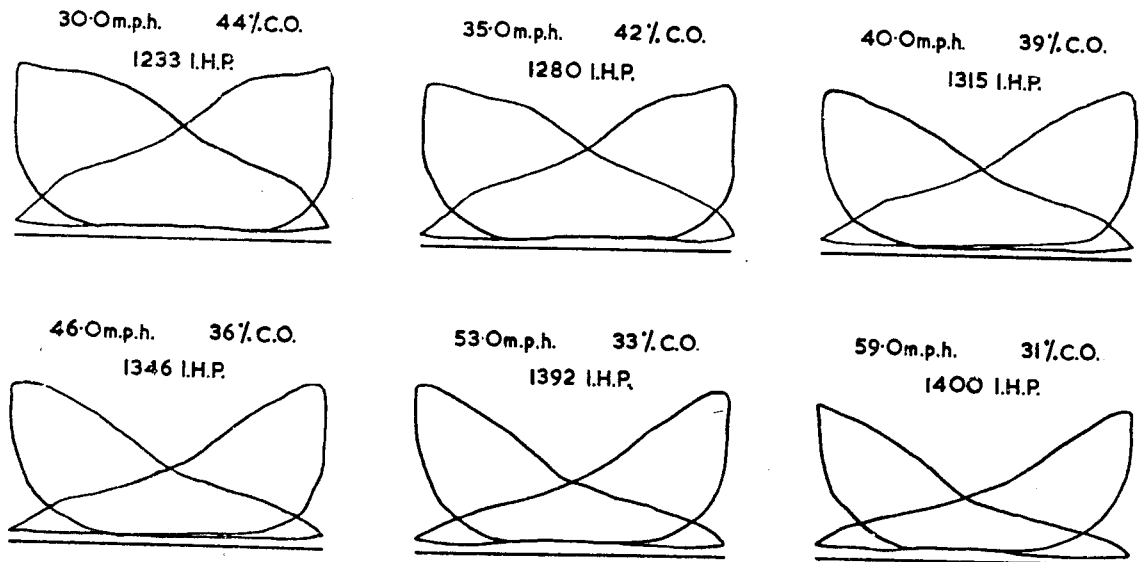


EXAMPLES OF INDICATOR CARDS.

MEAN STEAM RATE 18200 lb./hr.. FULL REGULATOR.



MEAN STEAM RATE 19400 lb./hr.. FULL REGULATOR.



EXAMPLES OF INDICATOR CARDS.