20(b) BULLETIN No 2.

BRITISH RAILWAYS.

Mechanical & Electrical Engineer's Department.

Performance and Efficiency Tests with Exhaust Steam Injector.

EASTERN & NORTH EASTERN REGIONS - "B1" CLASS.

2 CYL., 4-6-0 MIXED TRAFFIC LOCOMOTIVE.

August, 1951.

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I. INTRODUCTION.

This Bulletin contains a series of graphs illustrating inter-dependent relationships in performance and efficiency of the particular locomotive tested, with appropriate notes in explanation.

Whereas there is almost no limit to the range of such interesting relationships which can be worked out, an effort has been made to include only those which are necessary to establish, in respect of certain important engine classes -

(a) The price in terms of coal and water of hauling different train loads at different speeds over given routes.

(b) An indication of the level of efficiency of the locomotive.

(c) Means of comparing one locomotive with another on a common basis.

The presentation of the data in the report is divided, therefore, 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 is concerned mainly with efficiency, giving data of more importance in locomotive design.

Indicating was not undertaken in this series of tests.

At a later date it is proposed to issue a bulletin containing a critical comparison of the test results obtained from selected individual locomotive types.

In considering this first series of test bulletins, the following points should be noted -

(1) In all relationships based on coal, the values shown apply to a particular coal. Variations in quality of coal have a direct bearing on the amount consumed irrespective of locomotive design or condition. As far as possible each locomotive type is tested with at least two qualities of coal, one of which is common to the various engines tested.

(2) By the nature of the testing procedure every value shown on the graphs is obtained under constant conditions maintained for a period of time. Data is not yet available to cover periods of rapidly fluctuating power output, such as occur during acceleration or coasting of stopping trains, and the estimates of coal burned when examining different train speeds and loads are, therefore, in this stage of our knowledge, comparative and not absolute.

(3) The tests described have been made under one or other of two methods of locomotive testing. One of these is generally arranged as a combination of stationary plant tests with road Dynamometer Car tests at constant rates of steam production, a method initiated and developed by Swindon. The other is based on the use of the Mobile Testing Plant at constant speeds, a method initiated by the former L.M.S. Railway.

(4) The locomotives tested were in first class condition. It is clearly desirable to establish values also for the engine in run down condition but some reflection will indicate the extreme difficulty of defining this in a manner which will be sufficiently representative for a whole locomotive class and this aspect is the subject of further consideration.

(5) Since one of the purposes of these Bulletins is to explain to the Operating Department the manner in which these particular test results can be applied to a consideration of train schedules, a special section is included, setting out this aspect in simple terms.

The tests were carried out under 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 Department, 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 tests were carried out primarily to establish the performance characteristics of the B. 1 Class and these characteristics were established over virtually the whole of the effective working range of the locomotive, ranging approximately from one fifth to four fifths of full power on the line and up to full power on the stationary test plant.

Circumstances made it necessary to omit indicating, and the Indicated Horsepower and consumptions per I.H.P. hour for this class of engine will be issued as a supplement at a later date. The particular engine selected for test was not fitted with a self-cleaning smokebox.

Some preliminary tests were first carried out with dimensional variations in blast pipe and chimney, but, as these made no improvement, the standard arrangement was used throughout the tests covered by this bulletin, and it proved to be adequate up to the maximum rate of firing possible on the grate. The blast pipe diameter was $5\frac{1}{8}$" and the chimney choke 15" diameter. The taper of the chimney bore was 1 in 26. Blast pipe tip was $10\frac{1}{2}$" below the centre line of the boiler and $34\frac{1}{2}$" below the chimney choke.

III. METHOD OF TESTING

The tests were carried out in accordance with the Swindon method. The essential feature of this method, which combines testing on the stationary plant and testing on the line with a dynamometer car, is that the locomotive should be operated, for each test, both on the plant and on the line, at constant rates of steaming, which also imply constant rates of firing. The rates of steaming are kept constant during the dynamometer car tests by adjusting the cut-off to suit the speed of the train at any time, the adjustment being made in accordance with the indications of the special steam flow meter, developed at Swindon, which had been calibrated for the locomotive concerned during the tests on the stationary plant.

The indicator of this meter consists of a mercury manometer mounted on the driver's side of the locomotive cab and duplicated in the dynamometer car. The height of the mercury column is used as a measure of the feed water rate and although the height is varied according to the rate selected for any test, it is kept constant during any particular test by adjusting the cut-off to suit the train speed as stated above.

The fireman takes coal from a partitioned off part of the shovelling plate of the tender into which the coal increments are tipped as required from previously weighed bags. An observer in the cab signals this operation to the dynamometer car where the time is noted and where the feed water injected up to that moment is read from a water meter.

In particular the boiler relationships are determined on the stationary plant and are used as a guide to facilitate correct firing and a rapid attainment of the required conditions during the tests on the line. The power characteristics measured on the plant also form a guide to the correct loads of the test trains on the line to permit the attainment of the timing, agreed with the Operating Department, for each rate of steaming, but the true drawbar pulls and drawbar horsepowers are measured by the Dynamometer Car during the tests on the line.

t the same time measurements of the amount of coal used during he dynamometer car tests are made and are compared with the elationship, obtained on the stationary plant, between feed ater rate, equivalent evaporation and boiler efficiency and the ate of firing. The agreement between the results obtained on he line and those on the test plant is illustrated in Figs.3 nd 4, which show the actual points obtained during the dynamometer ar tests plotted on the curves previously determined at the esting Station for the relationship between the feed water ate and the rate of firing.

The drawbar horsepowers measured by the dynamometer car re then related to the corresponding water rate at the time. he overall efficiency can then be deduced.

The tests described in this bulletin were carried out t the Locomotive Testing Station, Rugby, and on the line etween Carlisle and Skipton with the No. 1 Dynamometer Car f the Mechanical & Electrical Engineer's Department of the ondon Midland Region.

IV TEST ARRANGEMENTS.

At Rugby the tests covered feed water rates from nder 7,700 to over 20,200 pounds per hour. As the exhaust team injector was used, the steaming rates to cylinders were correspondingly higher, but all the rates of water consumption uoted and plotted on the graphs are feed water rates. With ive steam injector only feed water rates of up to 25,000 lbs/hr. were attained.

The range of speed and cut-off covered during the tests is shown in the following table :-

Nominal Cut-off	NOMINAL SPEEDS. M.P.H.										
	15	20	25	30	35	40	45	50	55	60	70
15%				X				X			X
20%				X			X		X		X
25%			X			X		X	X		
30%		X	X		X	X		X			
35%		X	X	X	X	X					
45%	X		X	X			X+				

+ Using live steam injector.

Tests involving the measurement of coal consumption had durations of 80 to 160 minutes, according to the rate of firing. These times relate to the actual test period after adequate periods of "Warming up" while the test conditions became stabilised.

During the tests on the line, over a route with long gradients of 1 in 100, the train loads varied from 116 to 436 tons according to the selected steaming rate for the test, the timings were approximately the same as those current for express trains at the present time.

The feed water rates ranged from 8,000 to 18,700 lb/hr. e conditions on the line were such that the speed, during the tual test periods, varied between about 20 and 70 m.p.h., whilst e cut-off was reduced to a minimum of 12% during the low power sts and reached a maximum of 45% during the high power tests. On e runs from Carlisle to Skipton the duration of the tests, after warming up period, was approximately 60 minutes and in the reverse rection about 35 minutes, the time being curtailed on account a temporary speed restriction.

All these tests were carried out with the regulator fully en.

THE LOCOMOTIVE.

Locomotive No. 61353 is one of the class B.1 4-6-0 type, signed by the former London & North Eastern Railway, the leading rticulars of which are given on the accompanying diagram Fig. 1.

In order to prevent excessive reciprocating forces on the awbar of the stationary test plant, it was decided to re-balance e locomotive, and as a result the engine was tested, both on the ant and on the line, with 72% of the reciprocating masses lanced instead of the normal 30% for this type.

The locomotive had run a total mileage of 46,000 miles since w.

It was taken into Darlington Shops for preparation for test the course of which the tyres were turned to correct profile, e axleboxes reconditioned and given correct clearances, and new ston and valve rings were fitted.

Live steam injector tests were carried out which are outside e scope of this bulletin and the engine had run a further 7,700 les by the start of the tests described in this report. A tal of 3,150 miles were covered on the test plant and a further 50 during the subsequent tests on the line.

COAL.

The coals used during the tests, and to which the attached aracteristic curves refer, were a grade 1A coal from South Kirkby lliery and a grade 2B coal from Blidworth Colliery. X

For both coals a number of samples showed very little riation in calorific value and in Proximate analysis.

presentative results are given below:-

al	1A Best Hard Steam	2B Small Cobbles.
lliery	South Kirkby	Blidworth
pearance	Dull hard coal with some bright coal.	Mixed dull hard coal and brights. Small amount of visible shale and pyrites.
ze	Large coal. 2'6" in size down to 1'0". Broken down to large cobbles and dust screened for firing.	Small cobbles 4" x 5" to singles in size. The main proportion being small cobbles.

Definitions:-

. Grade 1A. Coal which will give efficiency on the longest through runs (up to 400 miles) with reasonable certainty.

Grade 2B. Coal which will give fair efficiency up to 150 miles running, with reasonable certainty.

	SOUTH KIRKBY		BLIDWORTH	
ALORIFIC VALUE (GROSS)	AS RECEIVED	DRY	AS RECEIVED	DRY
alories/gram	7,670	8,010	7,040	7,590
,Th.U/lb.	13,800	14,420	12,670	13,660
ounds of water at 212°F onverted into steam t same temperature by lb. of coal.	14.23	14.87	13.06	14.08
ROXIMATE ANALYSIS.				
oisture %	4.26	-	7.21	-
olatile Matter %	34.83	36.33	34.31	36.98
ixed Carbon %	57.15	59.74	52.91	57.02
sh %	3.76	3.93	5.57	6.00
ulphur %	0.80	0.83	0.89	0.96
oke. Character	Hard dark grey lustrous.		Hard - very dark grey.	
welling Index. (Ratio of volume to hat of coal).	1.0		1.0	
olour of Ash	Light brown		Light brown	

VII OBSERVATIONS.

The boiler proved to be very free steaming, but rather ensitive to any departure from the correct method or rate of iring and rather slow to recover from the effects of any such ccurrence. During the tests the fire was kept relatively hin, for each condition of working, and of even thickness, and he firehole door was kept in the "closed" position when not ctually firing. It was not closed between each successive hovelful. There is a front damper only on the ashpan and his was open one notch during the lower power tests and two otches for the higher power tests, except for the very highest ower tests on the stationary plant, when it was the full three otches open.

When using the Blidworth coal no tests were carried ut at feed water rates greater than that set by the apacity of exhaust steam injector. The boiler limit as not, therefore, been precisely determined and none is hown on any of the relevant graphs. Such information s was obtained indicated that the limit was well above the 0,000 lbs/hr. actually attained.

The engine rode well on the test plant and on the line, he general riding throughout the tests was satisfactory.

VIII APPLICATION OF TEST RESULTS TO OPERATING CONDITIONS.

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

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 consumption of every locomotive at each point in its working 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.

Since the method used, with its possibilities and limitations, will not be familiar to Operating Departments generally, this section endeavours to explain in simple terms how the data contained in this Bulletin can be applied.

Taking, for example, the Graphs for South Kirkby Coal.

Graphs 1 and 2 indicate the range of power which has been designed into the locomotive in new condition as built. It will perform satisfactorily at any speed, cut-off, drawbar pull or horse-power within the area of these graphs, sufficient test points having been taken to verify this by actual observation. The only variable not connected with the design of the locomotive is the boiler limit which may vary with different qualities of coal.

The cost in coal, the rate of coal consumption per unit of work done, for the various rates of doing work, i.e. different speeds, or different horse-powers, which in turn can be translated directly into actual train loads, is shown in Graph 4. If between two points on the level or on the same gradient on any run, the horse-power required to move the train is calculated based on speed and train resistance, then the rate of coal consumption applicable to those conditions can be derived from Graph 4, and the actual amount of coal used can be calculated. If this is done for each successive change in power demand throughout a whole journey, then the total coal used by that particular engine on that journey can be arrived at, and this can be compared with the amount of coal similarly arrived at which is required to do the same journey with some other load or at different sectional speeds. If the water consumption is required for any reason, this can be similarly arrived at based on Graph 3.

There are different methods by which these calculations can be carried out and after the conditions to be examined have been agreed by the Mechanical Engineering and Operating Departments, the actual working out is better done by the M. E. Department.

In arriving at the final answer, certain commonsense allowances have, of course, to be made, and as more test data and experience accumulates they will be able to be made with increasing exactitude.

For example Graph 4 is based on one particular coal, and adjustments will be necessary if the kind of coal generally available on the particular run to be examined is of different quality. To meet this, the tests which are being carried out with each locomotive class are being made with at least two kinds of coal.

Then Graph 4 is based on an engine in first class condition. Separate tests are to be run to ascertain accurately the increase in coal consumption when an engine is 'run down' but in the meantime based on such experience as is already available, maximum power output may have to be derated by a certain percentage for engines in such condition, and coal consumption at any rate of working may be increased by a like amount.

Again, all the values obtained in locomotive testing are obtained under constant conditions, and these values may require some adjustment where actual conditions on the road do not allow of stable conditions, as for example when an engine is starting away from a terminal before the fire is thoroughly burned through.

Now there are certain features about the data on Graph 4, which considerably assist in relating test results to practical railway operation. It will be seen that the rates of coal consumption per horse-power hour at the drawbar for different speeds take the form of rather flat curves. Consumption is higher at low power output, then it continues at a lower rate over a considerable middle range of powers and finally rises again at the highest powers. To make this clearer, Graph 5 extracts a single line from Graph 4 in respect of a particular speed, namely that applicable to 50 m.p.h. Instead of showing Drawbar Horsepower as a base, this is translated into actual tons of passenger train hauled on the level and up two selected gradients.

It will be seen that there is a considerable range of train loads within which coal consumption does not increase appreciably, i.e. within say, 5%. It will be noted that when running at constant speed on the level, the train loads for most economical working are higher than will be found usually in daily service, but that on the gradients the most economical range is found to agree well with practical operating conditions.

This 'flat characteristic' is a most important feature in the economy of the steam locomotive, for it means that although thermal efficiency may not be great in comparison with other forms of motive power, such efficiency as it has is applicable to a wide range of working. This is shown in another way by the thermal efficiency contours indicated on Graph 1.

Referring again to Graph 4, lines of constant rate of steam production will be noted and it will be seen that the line for 16,000 lb/hr. cuts the lines of 40, 50, 60 and 70 M.P.H. close to their lowest points. Similar diagrams for working up gradients give much the same result for lower speeds. If this rate is chosen, then whatever the speed or gradient, within limits, the engine will be working at or very near its lowest rate of coal consumption all the time it continues to work at that steam rate.

This fact connects with the principle of controlled firing. The greatest economy in the use of fuel is obtained when the engine is worked at a steady rate of shovelfuls every few minutes throughout a run while steam is on, whatever the gradient or speed conditions at the time, this resulting in a constant rate of steam production.

Graph 4, or in a similar manner Graph 1, if the efficiency contours are studied, indicates what steam rate is the most economical. Here again, arising from the 'flat characteristic' feature there is actually a range of steam rates which can be worked to, in this case from 13,500 to 18,500 lb/hr., without appreciable sacrifice of economy at any but the lowest and highest speeds.

To sum up, therefore, schedules and loads can be worked out for any route which will give the lowest range of coal consumption, and it will be found that these are related to a certain constant rate of steam production, which in turn relates to a certain rate of controlled firing.

Graph 6 shows part of an actual test run at the most economical steam rate for this particular engine. Graph 7 shows the operation over the same route at a high rate of steam production.

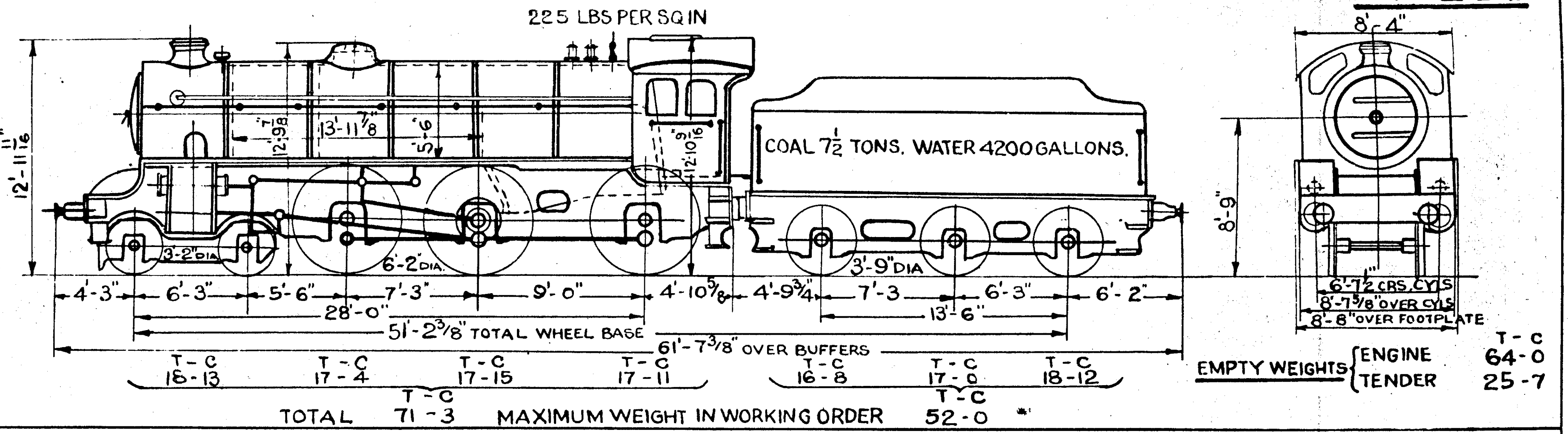
To illustrate the trend which this working out of actual schedules and loads may take, eight additional graphs, Nos. 8 to 15 are included, which give examples of the cost in coal rate, lbs. per D.B.H.P. Hour and lbs. per trailing ton mile, which results from working different train loads, both passenger and freight, at selected speeds on the level and up 1 in 200.

So far as the working of the engine is concerned, certain things must be borne in mind. The data from the actual tests as set out in Graphs 1 and 2 cover working at constant speed and full regulator at different cut-offs down to 15%. While the valve gear will operate over this range it is not always customary for drivers to work engines of this class in service at cut-offs as low as 15%, lower power requirements being covered by partial regulator working at longer cut-offs. This is done mainly because a two cylinder engine operates more easily from a mechanical point of view under these conditions, but also from an instinct, confirmed in practice, that no sacrifice in economy is being made by so doing. In the graphs showing coal consumption related to train load, therefore, (Graphs 8 to 15) where points of cut-off are shown along the various speed lines, no lower cut-off value than 15% is shown and at any train load lower than that which can be covered by working at 20% cut-off with full regulator, it must be understood that appreciably the same values in coal per D.B.H.P.hr or per ton mile can be attained by partial regulator working.

Within the above definition a point clearly brought out by graphs 8 to 15 is that the earliest cut-offs are not necessarily the most economical on a Drawbar Power basis. It is true that the earliest cut-off is the most economical from the point of view of the power developed in the cylinders, but a good part of that power is used for moving the engine itself. When the coal used is related not to the total power output in the cylinders but only to that part of it which is available for hauling the train, then the relationship alters and the most economical cut-off from this latter point of view is found usually to be neither very early nor very late but somewhere in between.

FIG. 1

TYPE B1.



LEADING DIMENSIONS & RATIOS

BOILER:

MAX. DIA. OF BARREL	5'-6"
OVERALL LENGTH OF FIREBOX	9'-7 1/4"
" " " AT BOTTOM	9'-0"
" WIDTH " " " "	4'-0 1/2"
THICKNESS OF BARREL PLATES	11/16"
" " OUTSIDE WRAPPER	9/16"
" " COPPER FIREBOX PLATES WRAPPER & BACKPLATE	9/16"
TUBEPLATE	1" & 9/16"

TUBES:

SMALL	NUMBER	141
	DIA. OUTSIDE	2"
SUPERHEATER FLUE	NUMBER	24
	DIA. OUTSIDE	5 1/4"
SUPERHEATER ELEMENTS	NUMBER	24
	DIA. INSIDE	1.244

GRATE: AREA 27.9 SQ FT

HEATING SURFACE:

FIREBOX	168 SQ FT
TUBES	1033 " "
FLUES	460 " "
TOTAL EVAPORATIVE	1661 " "
SUPERHEATER	344 " "
TOTAL	2005 " "

FREE GAS AREA THRO' TUBES 4.42 " "

AIR OPENING THRO' GRATE 52.9%

CLEARANCE VOLUMES (CYLINDER) FRONT - 8.3%, BACK - 7.5%

SAFETY VALVES: TYPE & DIAMETER TWO ROSS 'POP' 3" DIA

AXLES:

	DIA	LENGTH
JOURNALS: BOGIE	6 1/2"	9"
COUPLED WHEELS	8 3/4"	9"
CRANK PINS: OUTSIDE	5 1/2"	6"
COUPLING PINS: LEADING	4"	4 3/8"
DRIVING	6"	4 1/4"
TRAILING	4"	4 3/8"

CYLINDERS: NUMBER 2; DIAMETER & STROKE 20"x26"

MOTION:

TYPE	WALSCHAERT
TYPE OF VALVE	PISTON
DIAM " "	10"
MAX VALVE TRAVEL	6 5/8" + 1/32"
STEAM LAP	1 5/8"
CUT-OFF IN FULL GEAR	75%

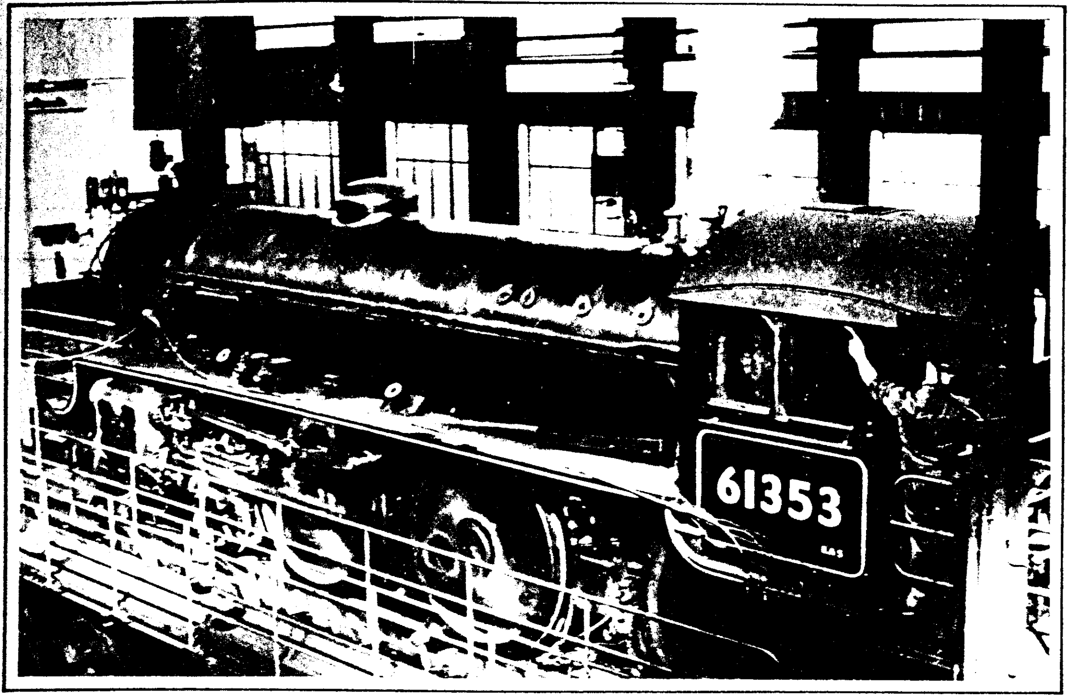
TRACTIVE EFFORT AT 85% BOILER PRESS 26,878 LBS.

TOTAL ADHESIVE WEIGHT: 117600 LBS.

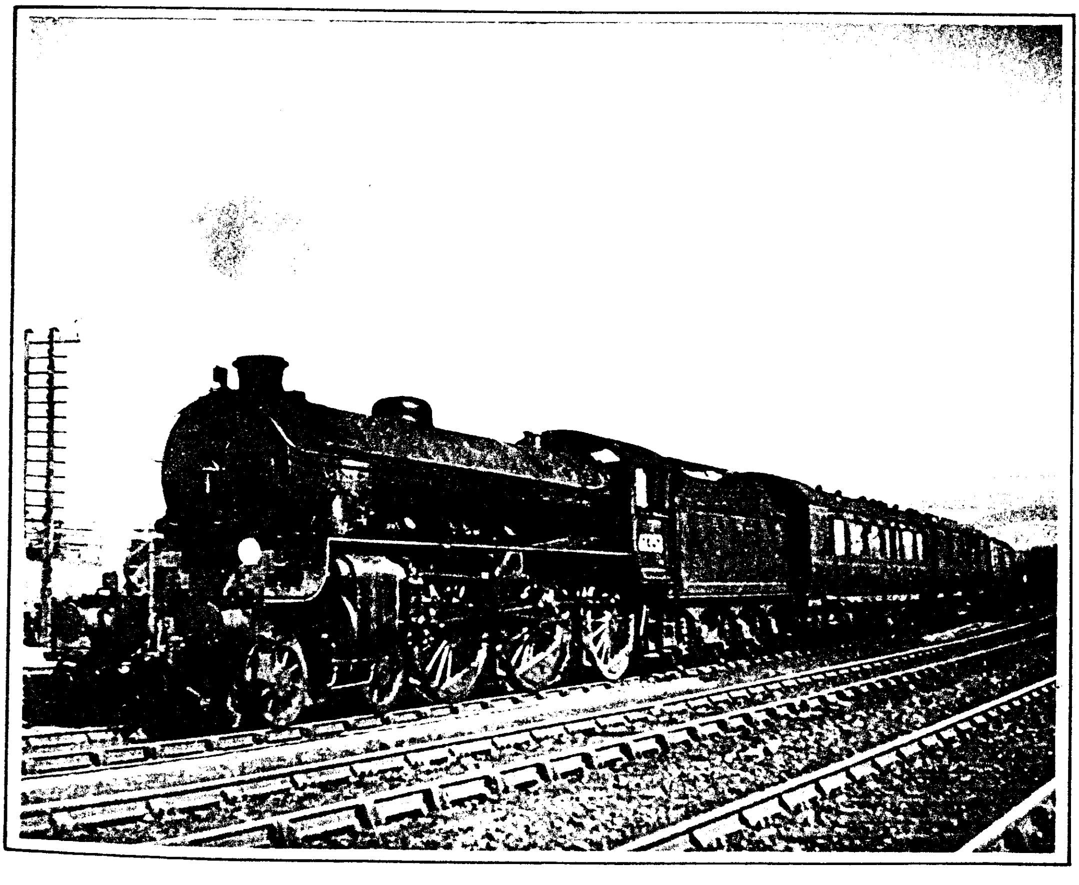
ADHESIVE WEIGHT ÷ TRACTIVE EFFORT 4.375

BRAKE: STEAMBRAKE & VACUUM EJECTOR

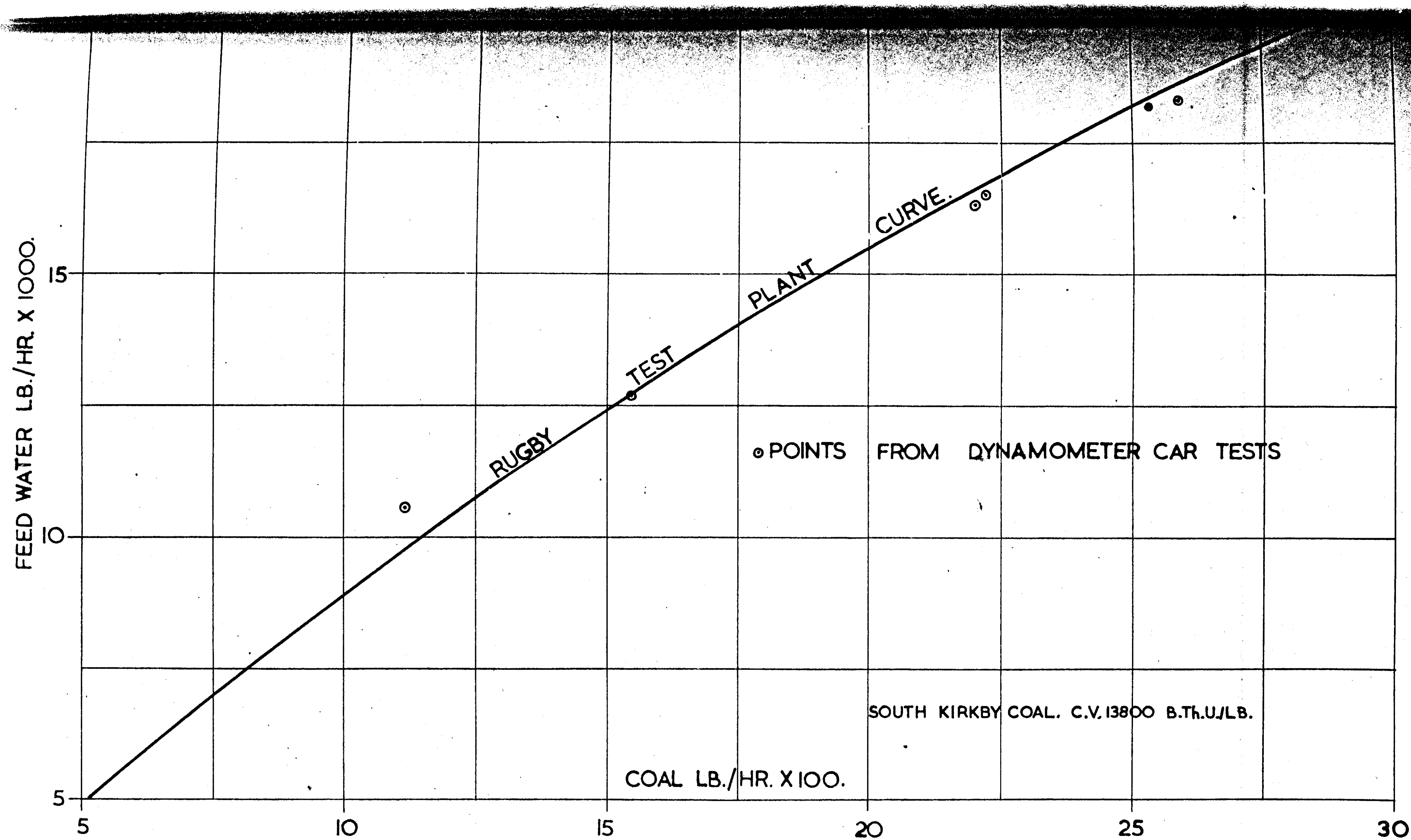
FIG. 2.



ENGINE No. 61353 RUNNING ON THE RUGBY TEST PLANT.



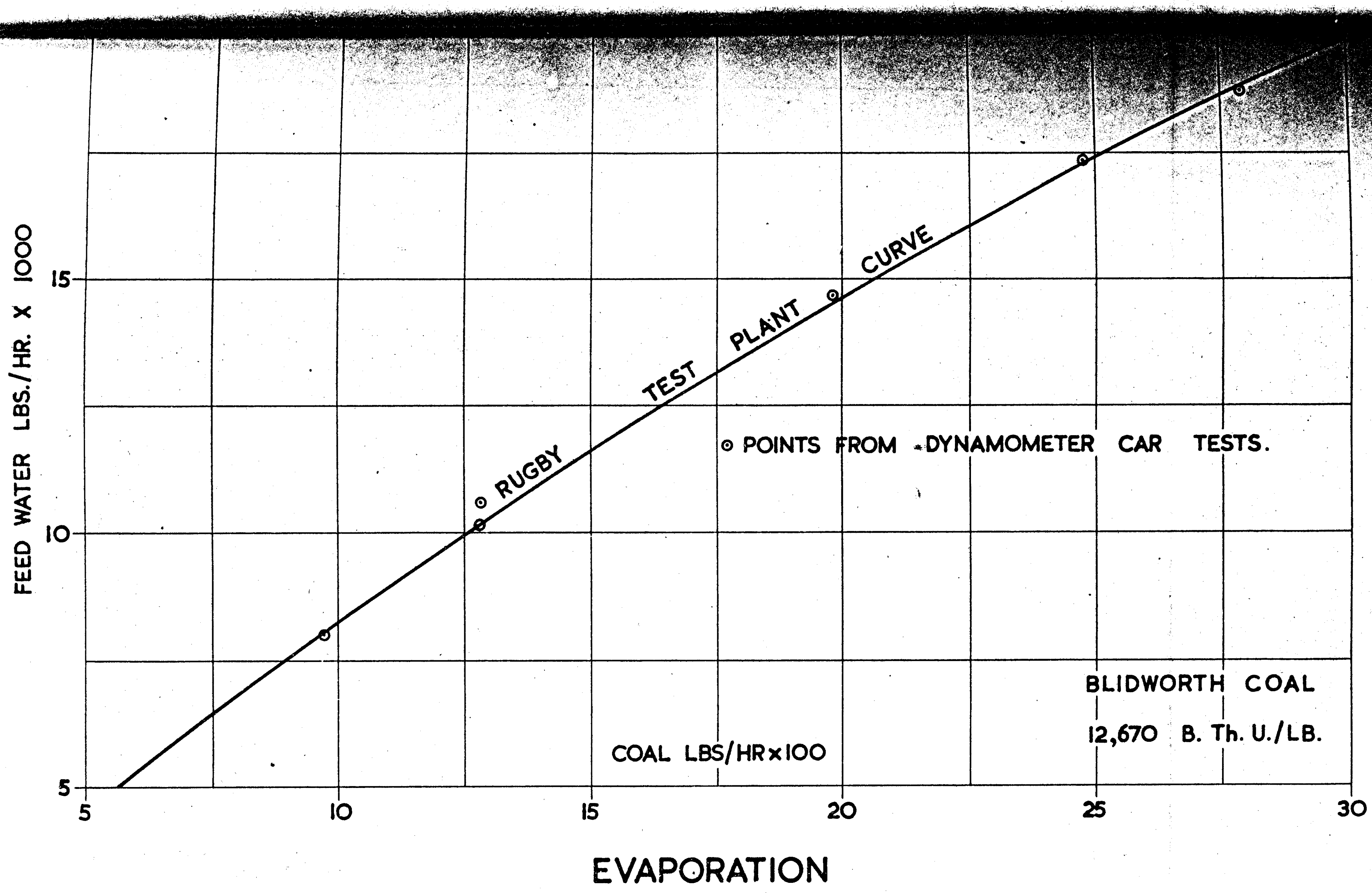
ENGINE No. 61353 AND TEST TRAIN AT SKIPTON. LOAD 15 VEHICLES - 436 TONS.



EVAPORATION

FIG. 3.

FIG. 4.



FEED WATER LBS./HR. X 1000
15
10
5
5
10
15
20
25
30
RUGBY TEST PLANT CURVE
⊙ POINTS FROM DYNAMOMETER CAR TESTS.
BLIDWORTH COAL
12,670 B. Th. U./LB.
COAL LBS/HR×100
EVAPORATION

CUT OFF AT	LEAD		OPENING		CUT OFF %		RELEASE %		COMPRESSION %		PRE ADMISSION %		ANGLE OF RELEASE		ANGLE CRANK MOVES THRO' WHILST PORT IS OPEN.		FULL EXHAUST PORT OPENING 1 3/4"		ANGLE CRANK MOVES THRO' DURING EXPANSION		ANGLE OF CUT OFF		ANGLE OF COMPRESSION	
	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.	F.P.	B.P.
15 %	1/8"	1/8"	7/32"b.	7/32"b.	15	16	66½	66	34½	33½	3/4	3/4	106½°	110½°	53°	59°	+ 3/32"b	+ 3/32"b	62½°	60½°	44°	50°	69°	7
25 %	1/8"	1/8"	5/16"b.	11/32"b.	25	26½	73½	72	27¾	26½	3/8	3/8	116°	119°	64°	72°	+ 7/32"b	+ 3/16"b	58°	54°	58°	65°	61°	6
35 %	1/8"	1/8"	13/32"F.	15/32"	35	35½	78½	76½	23½	21½	1/4	1/4	122½°	124½°	75°	81°	+ 11/32"	+ 9/32"f	52½°	48½°	70°	76°	55½°	57
45 %	1/8"	1/8"	19/32"	21/32"	45	45	82½	80½	19½	17½	1/4	1/4	128½°	130°	85¾°	91°	+ 17/32"	+ 15/32"	46¾°	43°	81¾°	87°	50°	51
55 %	1/8"	1/8"	25/32"	27/32"	55	53¼	86	83¾	16¼	14	1/8	1/8	134°	134½°	96½° *	98½°	+ 23/32"	+ 21/32"	41°	39°	93°	95½°	45¼°	45
65 %	1/8"	1/8"	1 3/32"	1 5/32"	65	61¾	89¼	87¼	12¾	11	1/8	1/8	140°	140¼°	108°	109¼°	+ 1 1/32"	+ 31/32"	35°	34°	105°	106¼°	40°	40
FULL GEAR	1/8"	1/8"	1 21/32"	1 3/4"	76	72	93	91½	8¾	7¼			147½°	147½°	121½°	121½°	+ 1 5/8"	+ 1 17/32"	28½°	28½°	119°	119°	32½°	32

DIE BLOCK CLEARANCE 1 3/32" AT BOTTOM | SLIP 23/32" | LAP 1 5/8" | EXHAUST LAP LINE AND LINE. | MAX. TRAVEL 6 5/8" + 1/32".

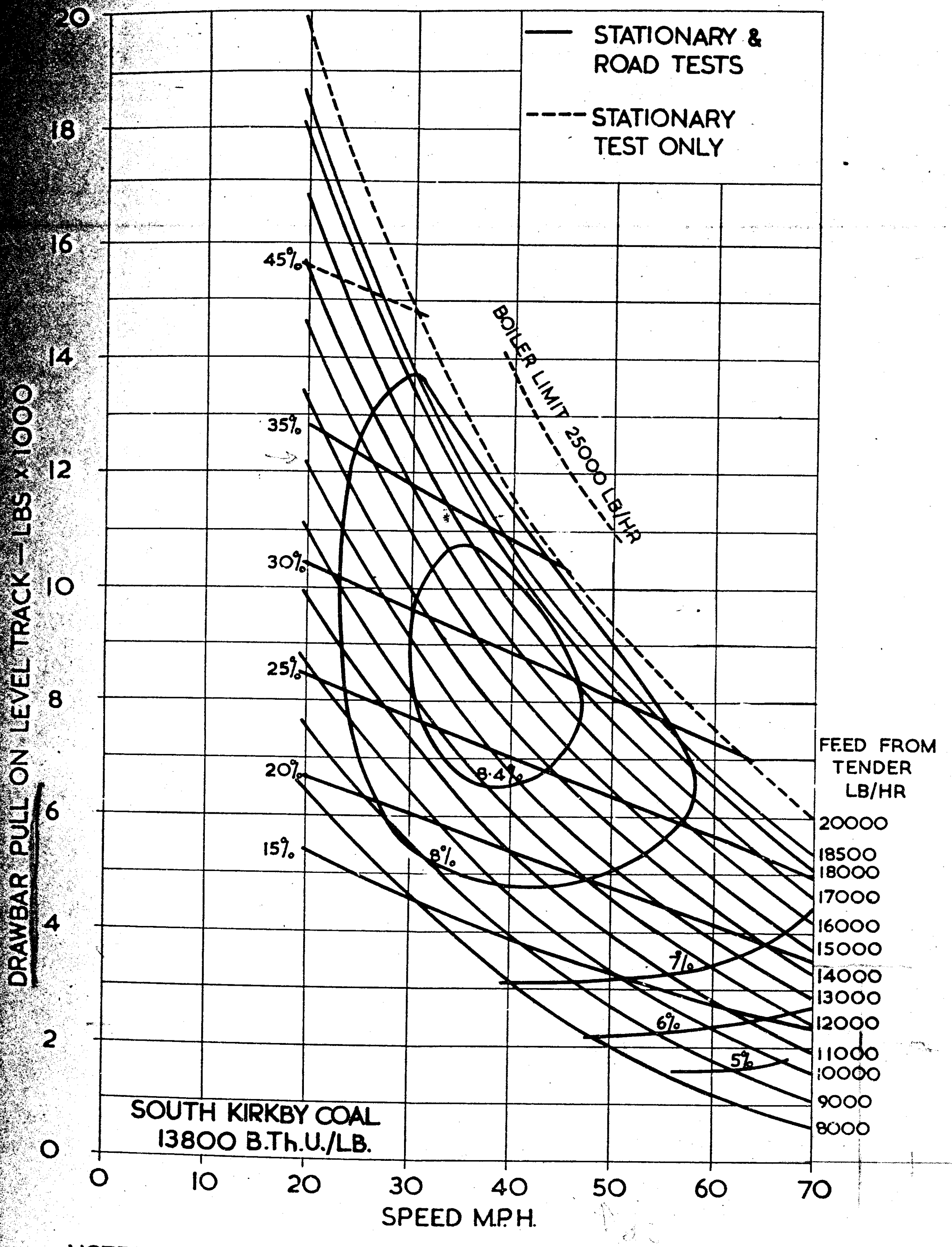
VALVE EVENT TABLE

FIG. 5.

SOUTH KIRKBY COAL.

Performance Data : Graphs 1 to 15.

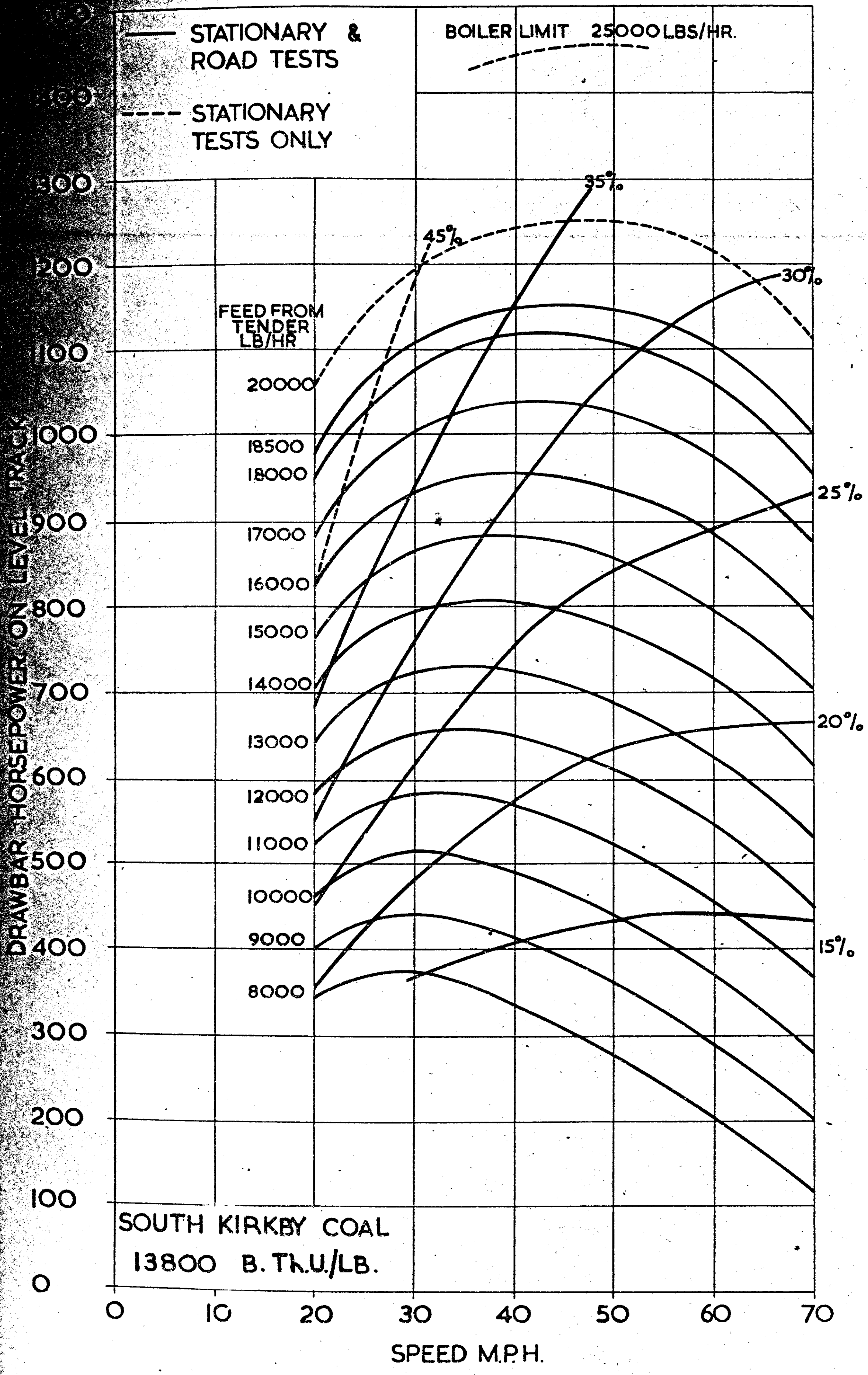
Design Data : Graphs 16 to 20.



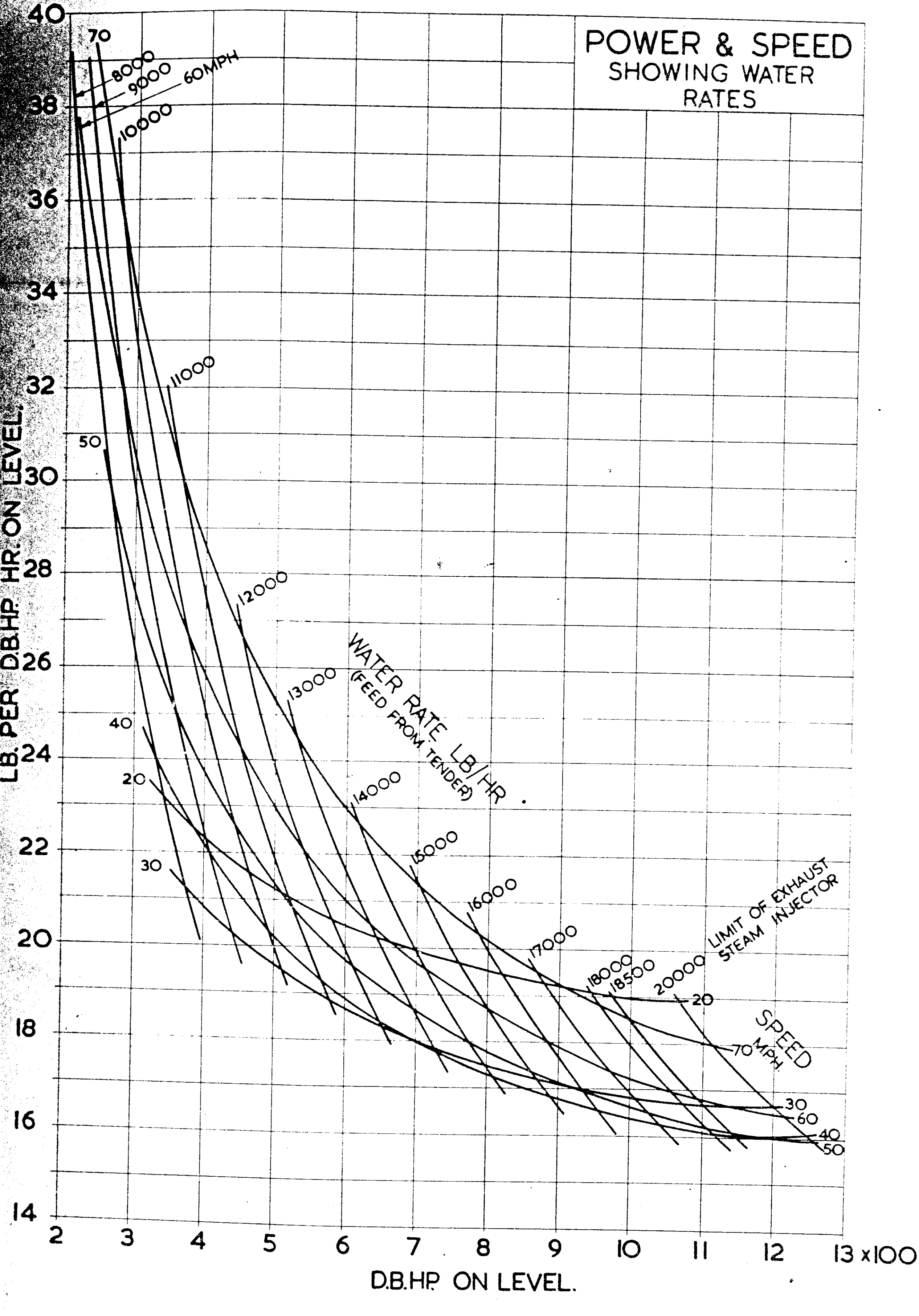
NOTES:- 1 CONTOUR LINES INDICATE CONSTANT OVERALL EFFICIENCY ON LEVEL TRACK.

2 LIMIT OF EXHAUST STEAM INJECTOR 20000 LBS/HR. SUPPLEMENTED BY LIVE STEAM INJECTOR TO REACH BOILER LIMIT

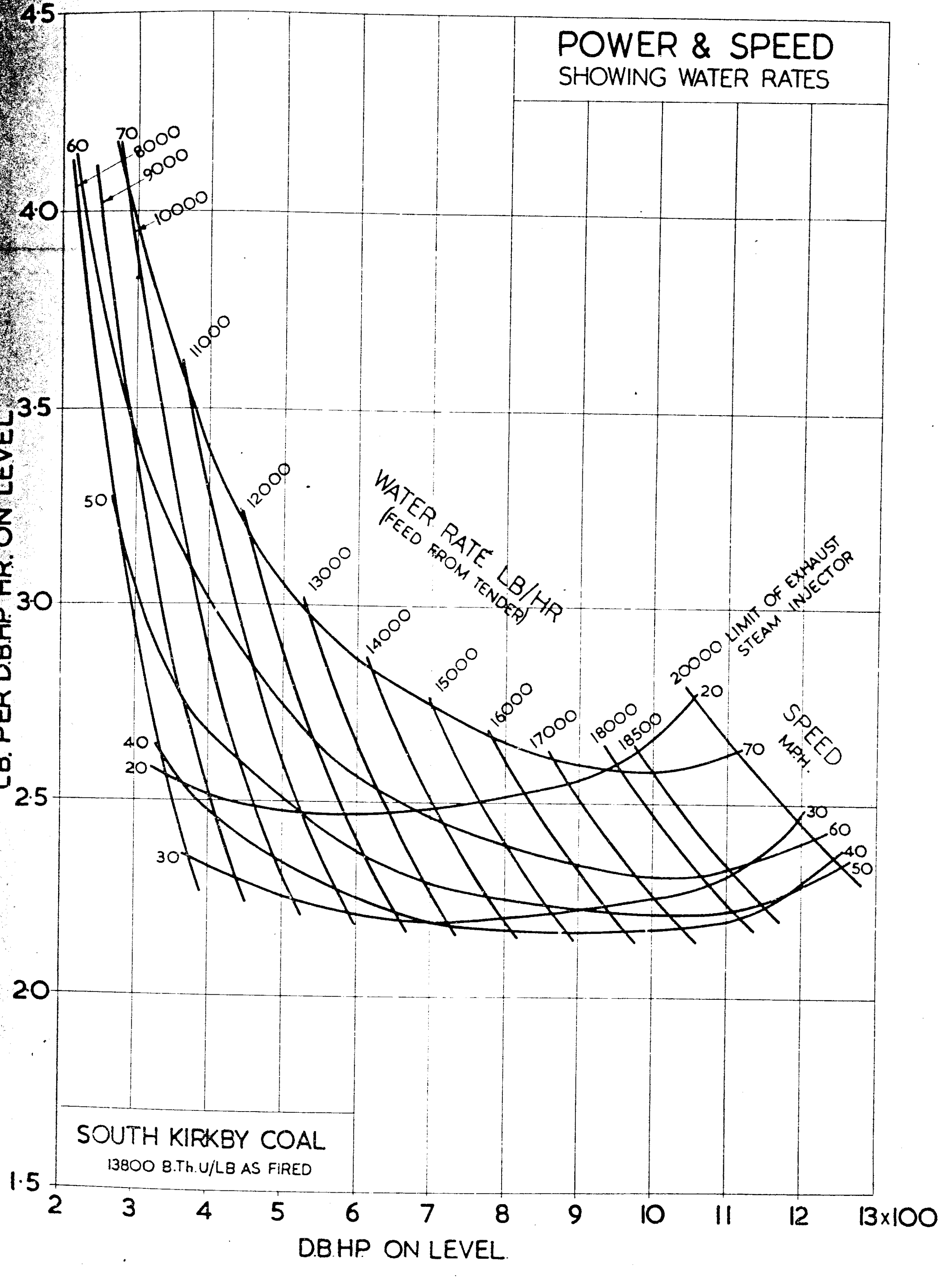
DRAWBAR PULL CHARACTERISTICS



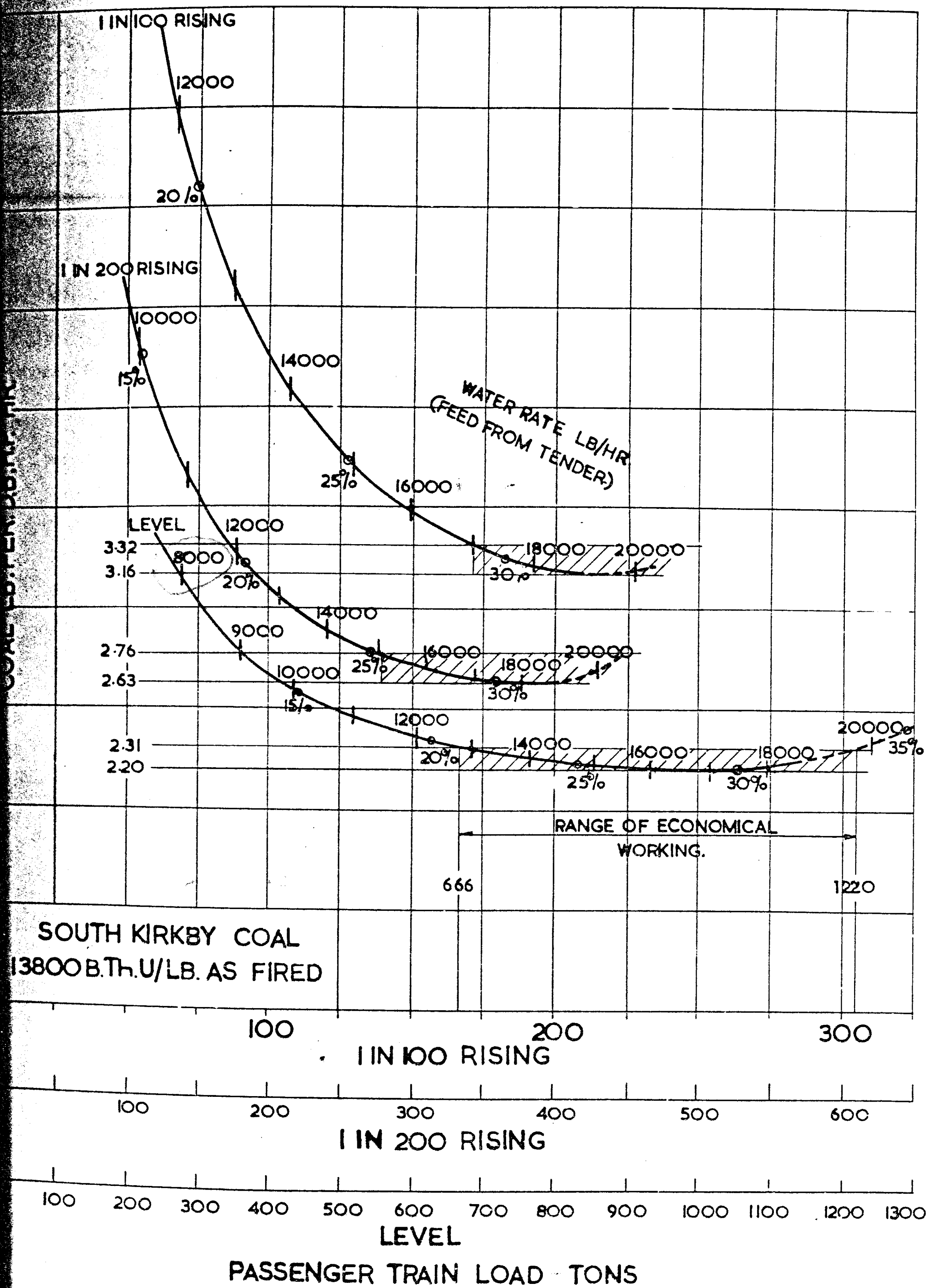
DRAWBAR HORSEPOWER CHARACTERISTICS



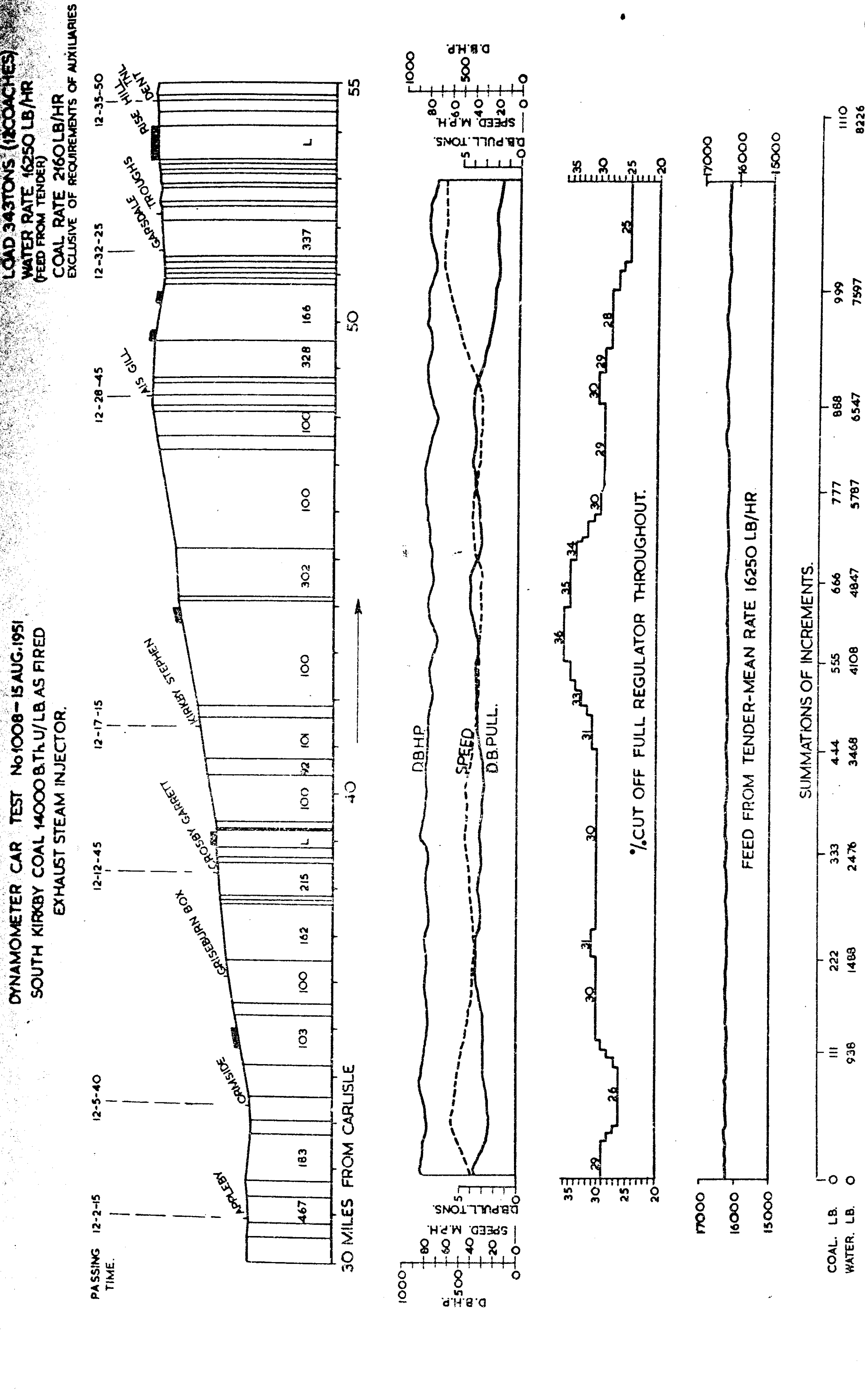
WATER PER D.B. H.P HR.



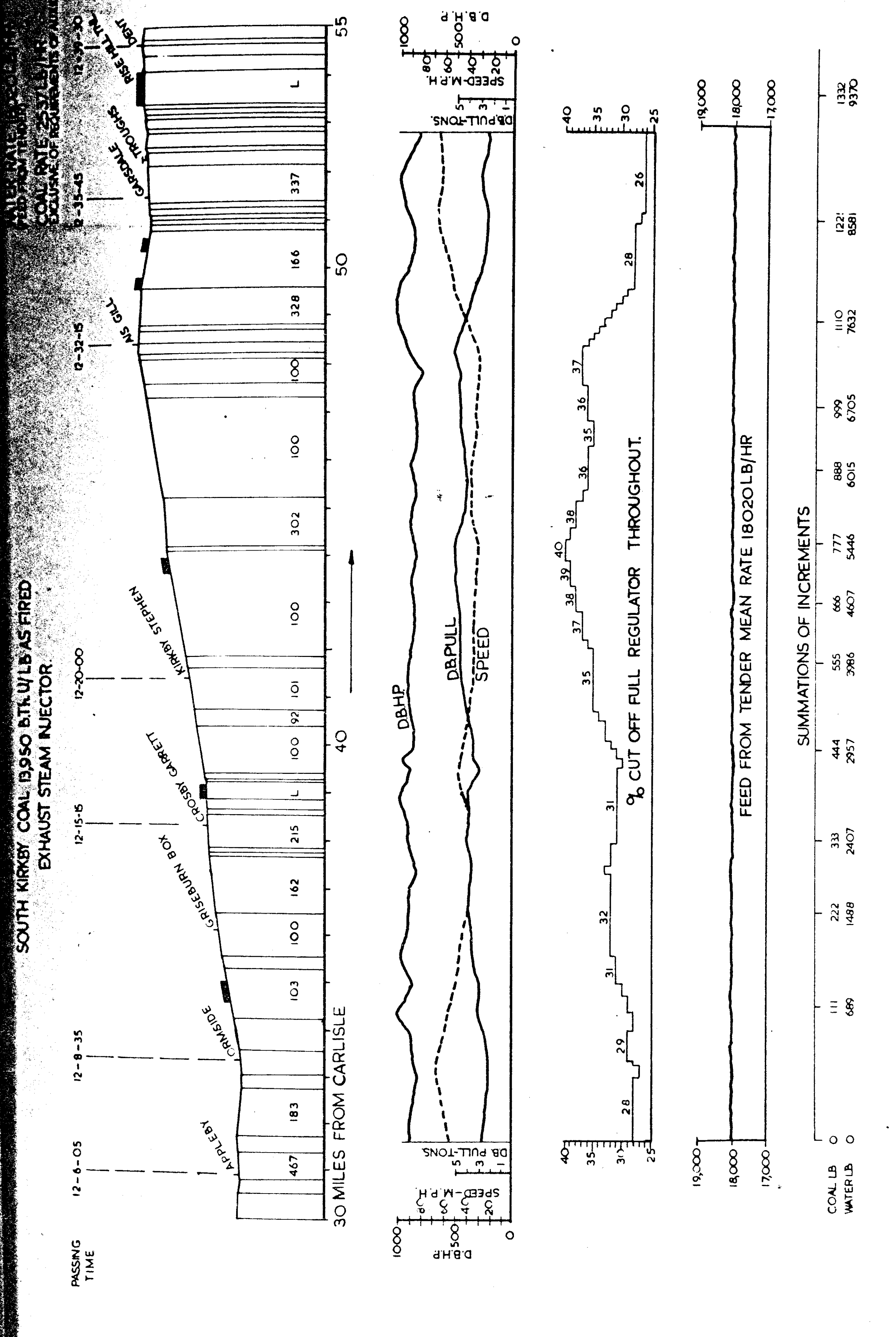
COAL PER D.B.H.P HR.



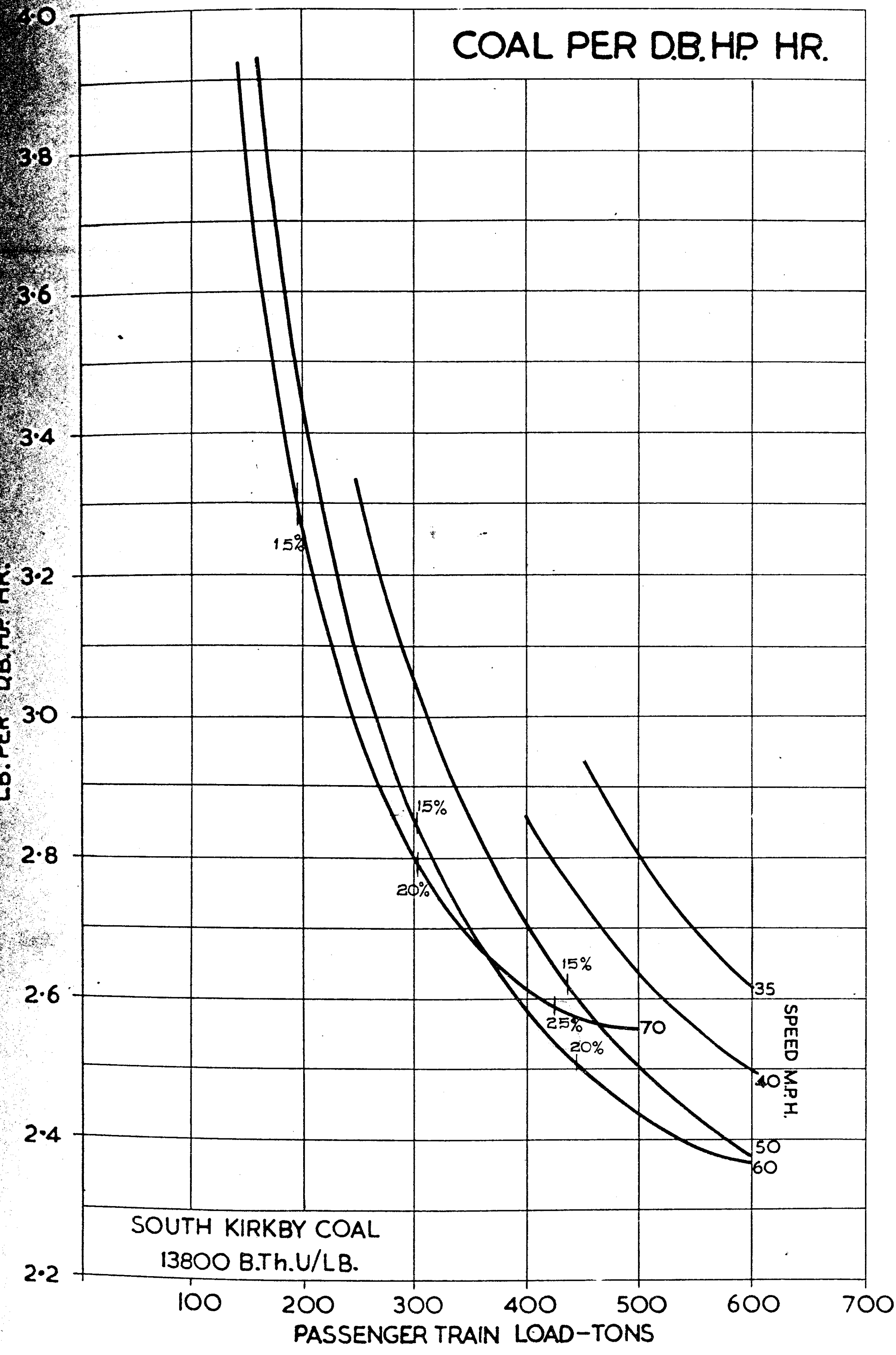
EXAMPLES OF RANGE OF ECONOMICAL WORKING AT 50 M.P.H.



EXAMPLE OF RUN AT CONSTANT EVAPORATION.
UNDER CONDITIONS GIVING MINIMUM RATE
OF COAL CONSUMPTION

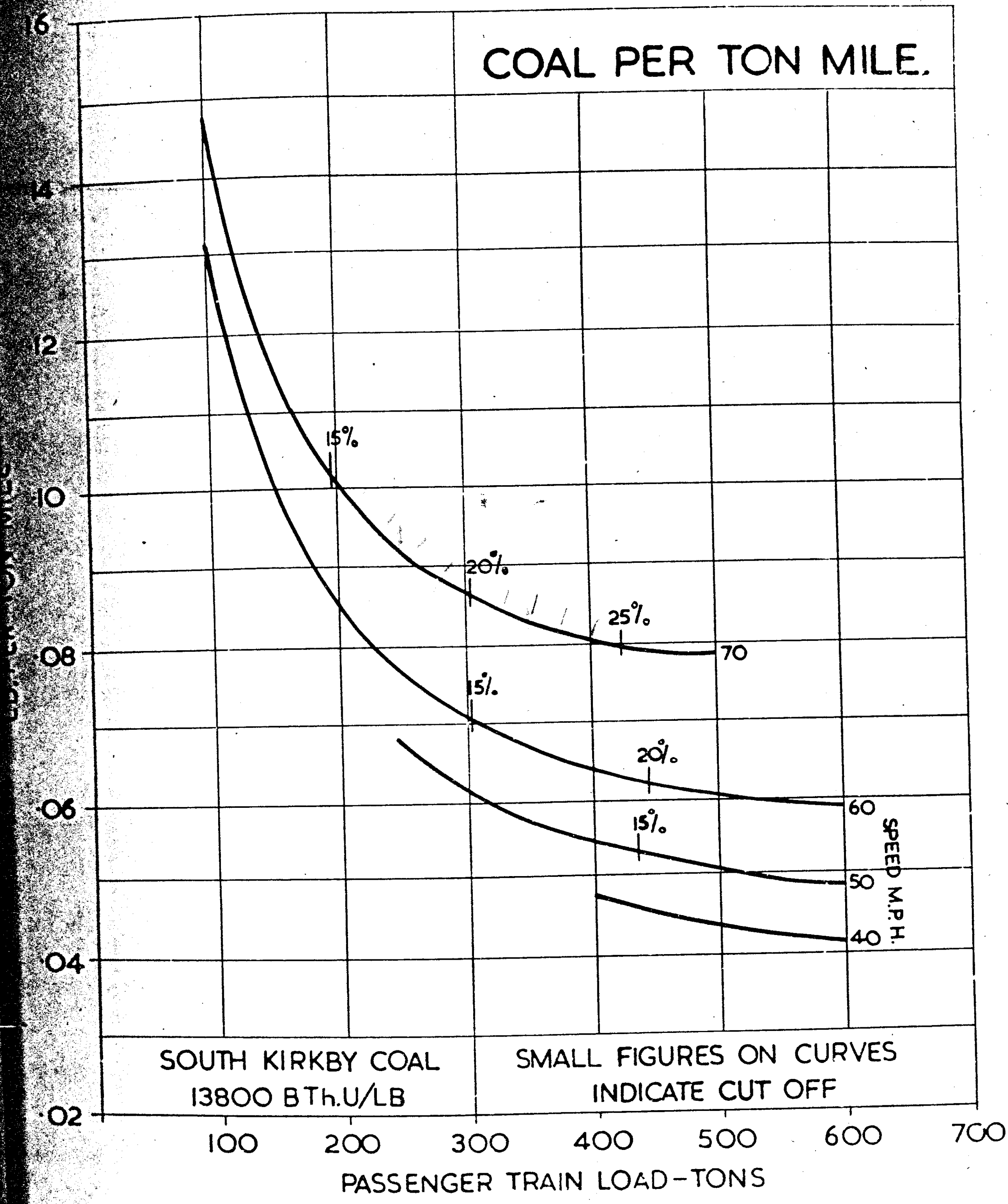


EXAMPLE OF RUN AT CONSTANT EVAPORATION
AT HIGH STEAMING RATE.



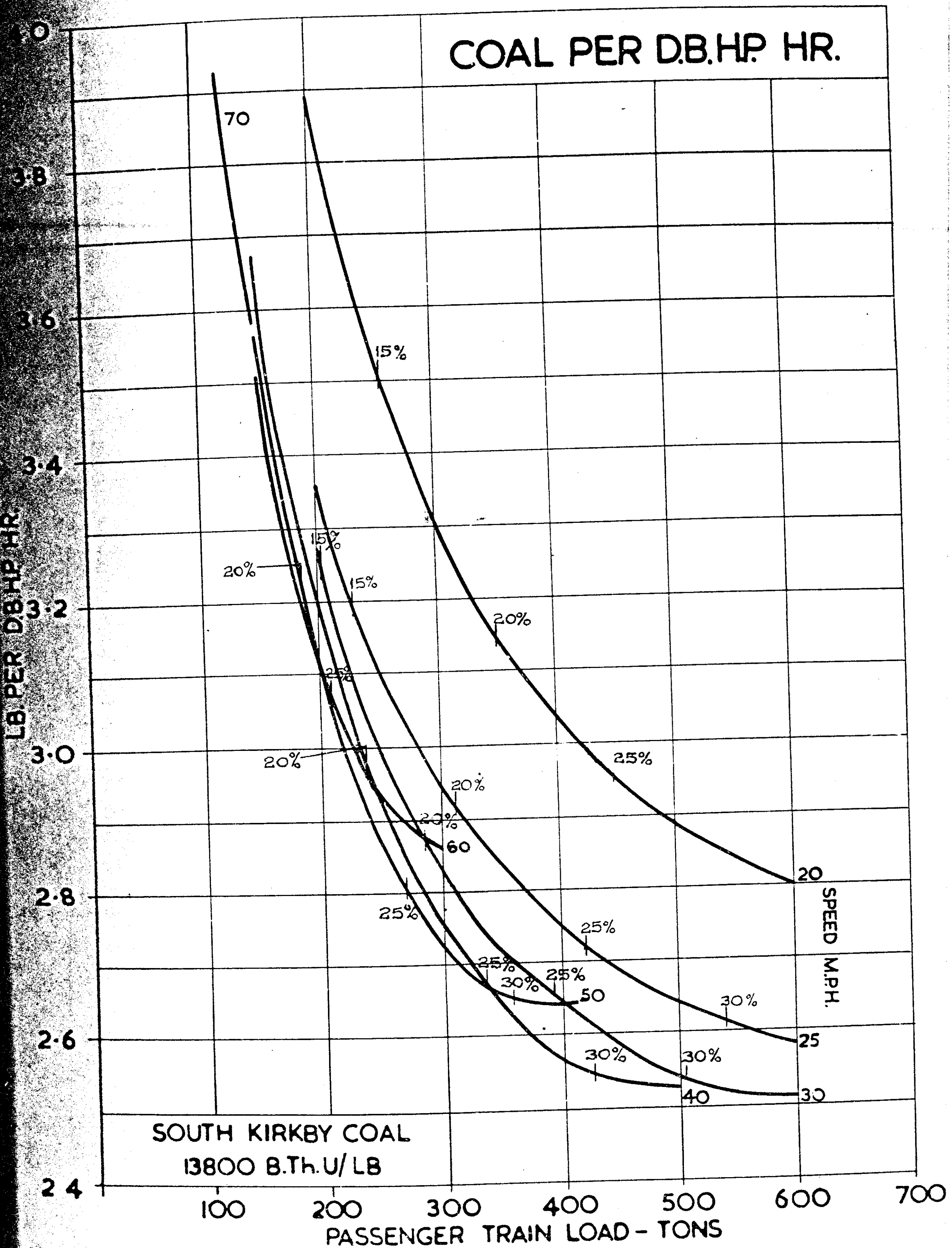
PASSENGER SERVICE LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

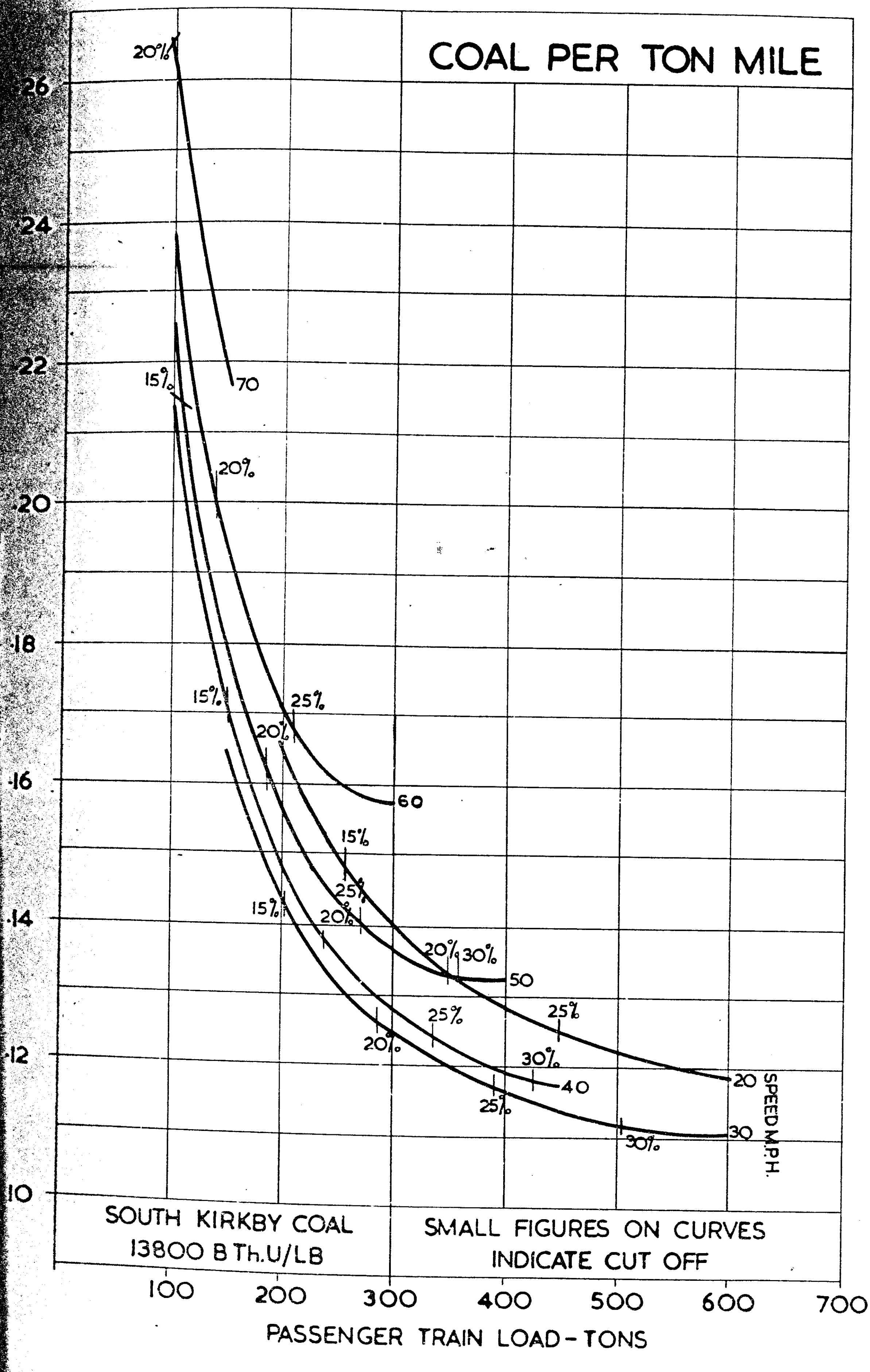


PASSENGER SERVICE LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

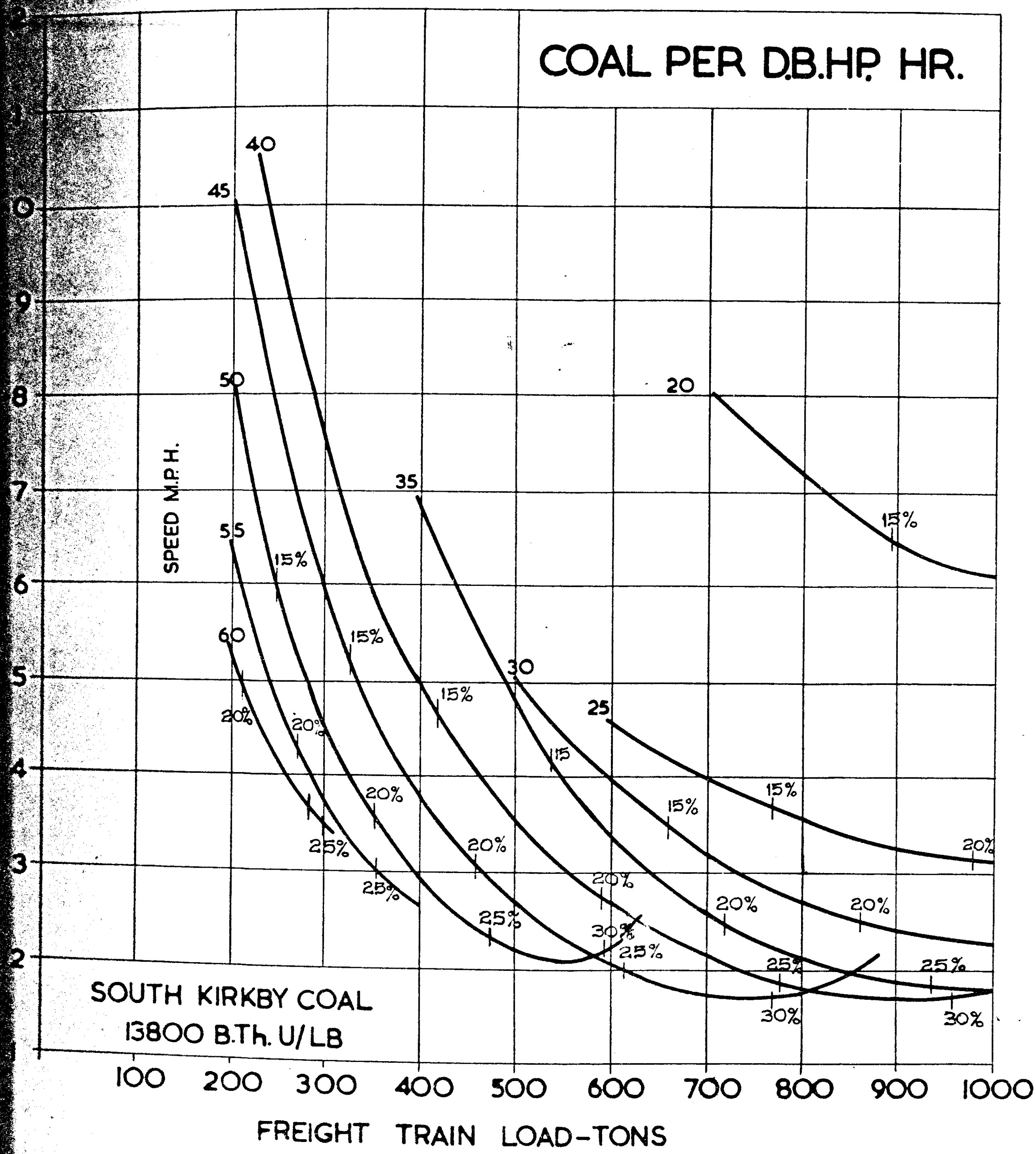


PASSENGER SERVICE 1 IN 200 RISING
EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



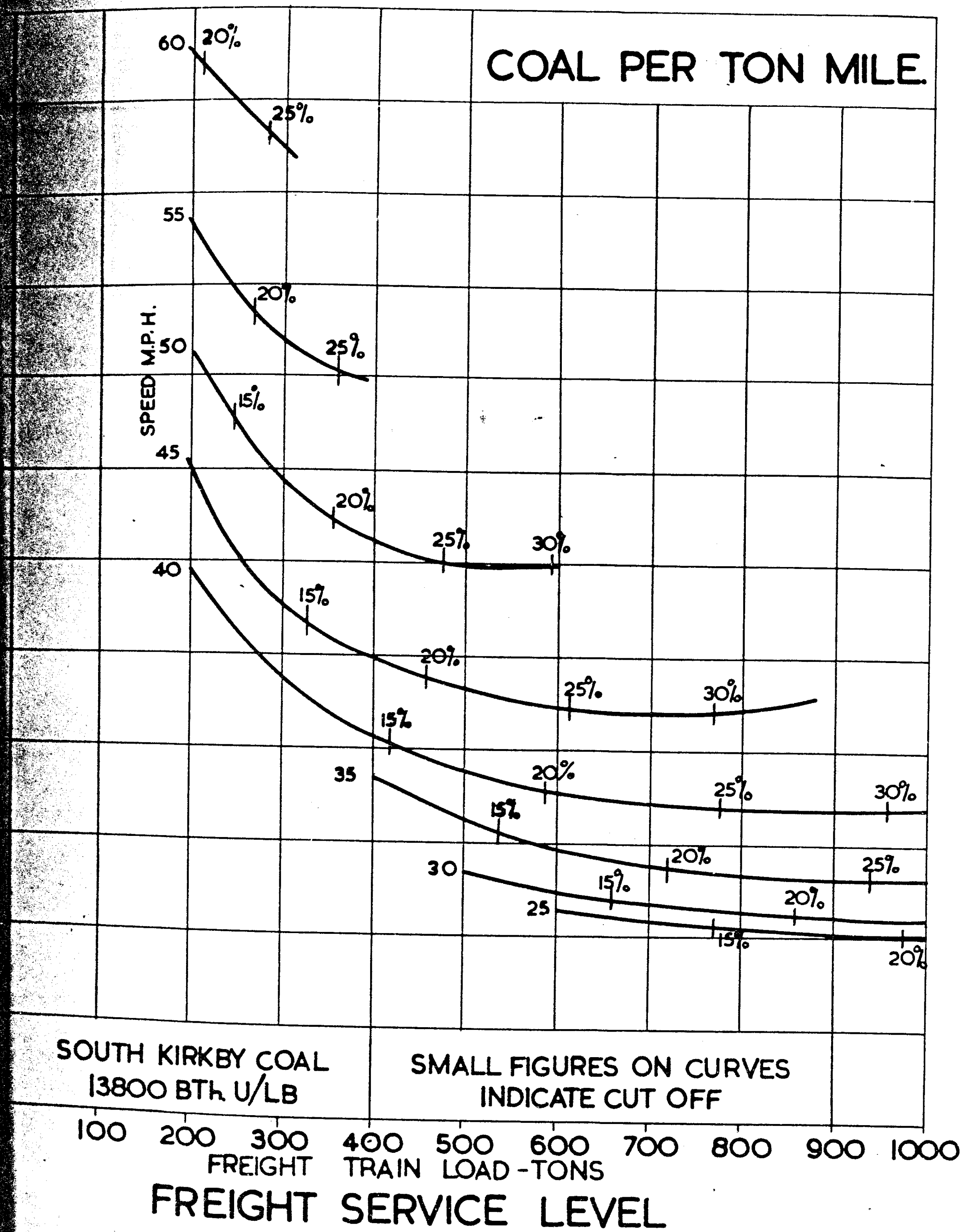
PASSENGER SERVICE – 1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

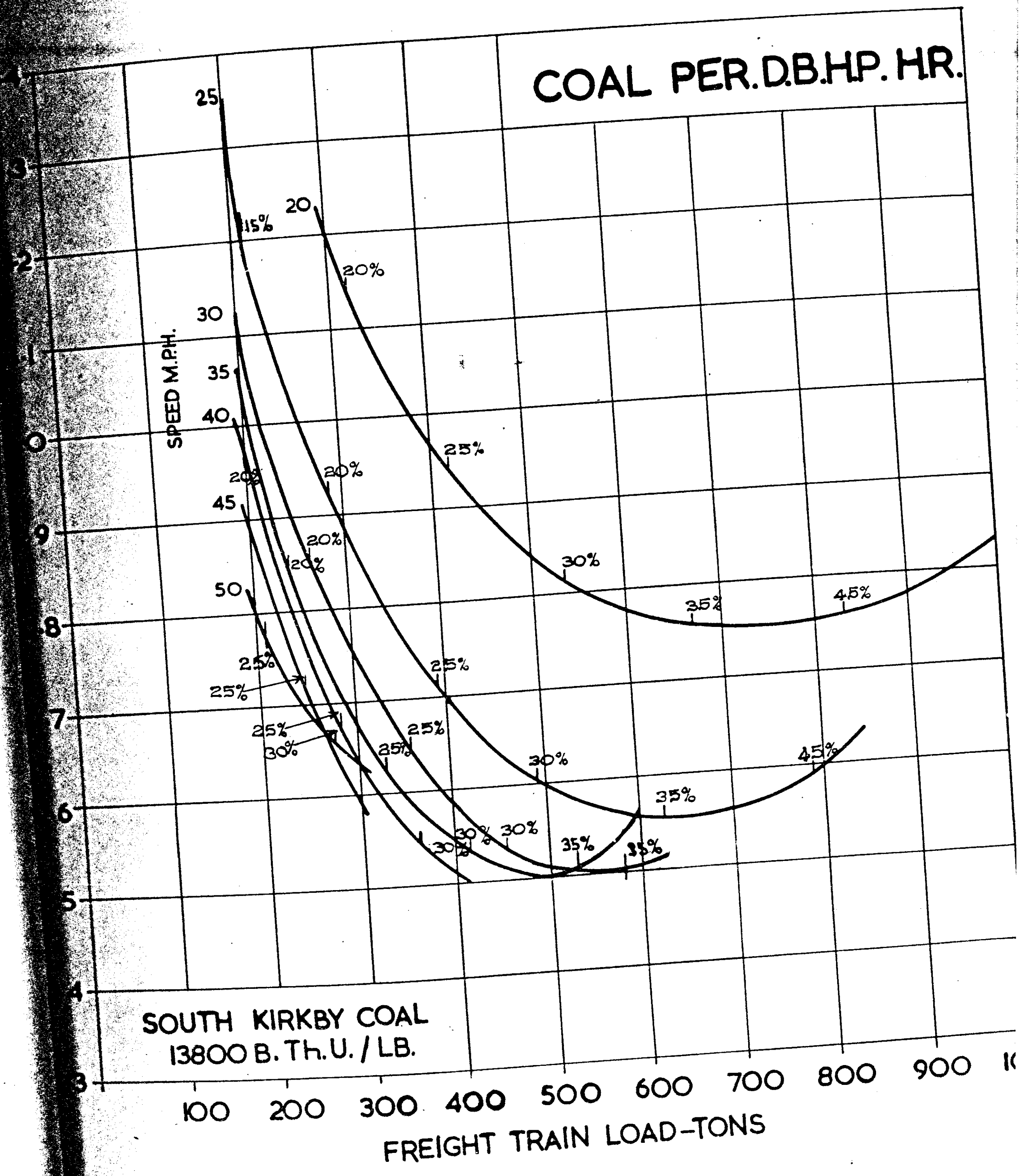


FREIGHT SERVICE LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



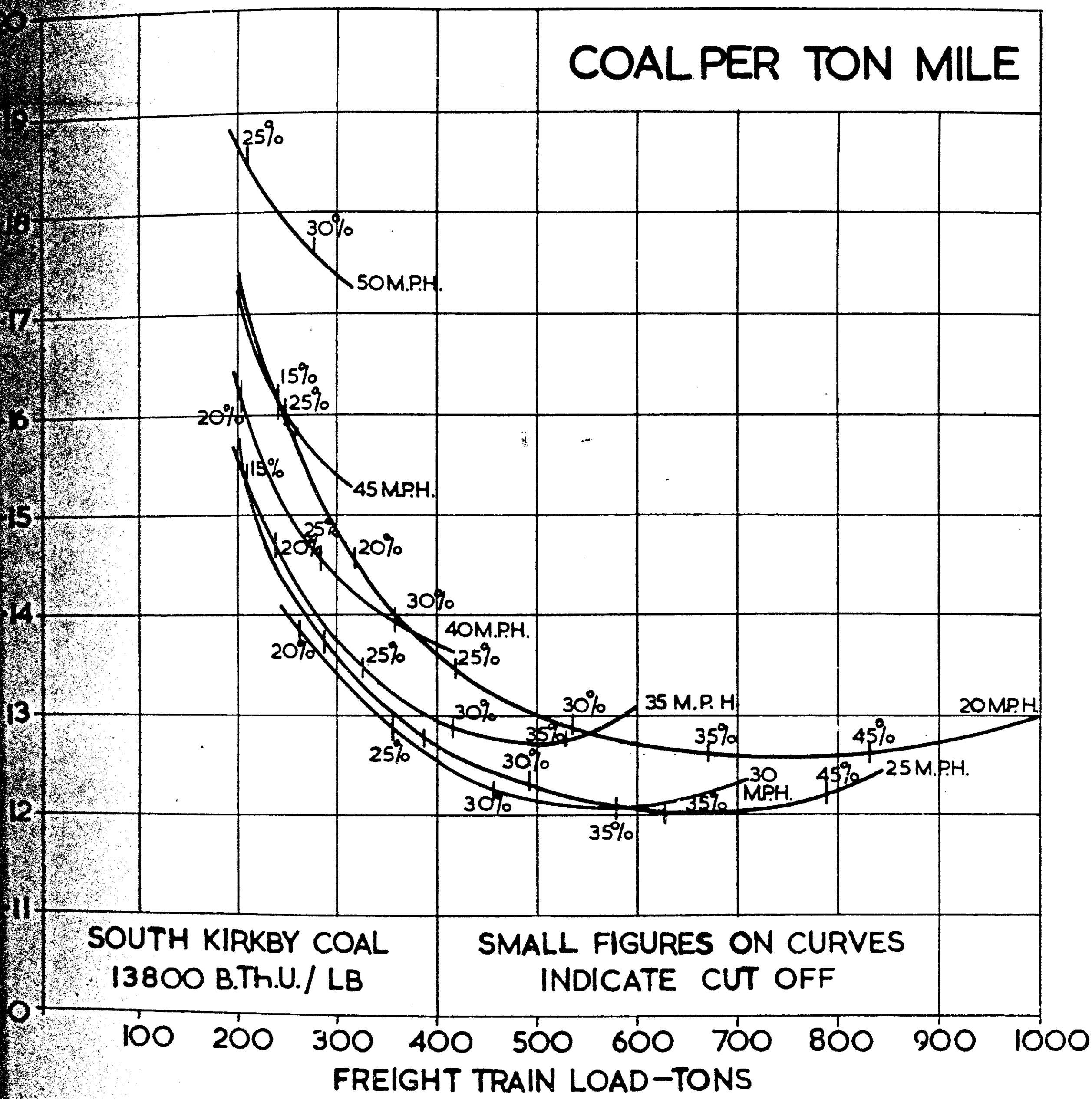
AMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



FREIGHT SERVICE–1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFEREN

TRAIN LOADS & SPEEDS

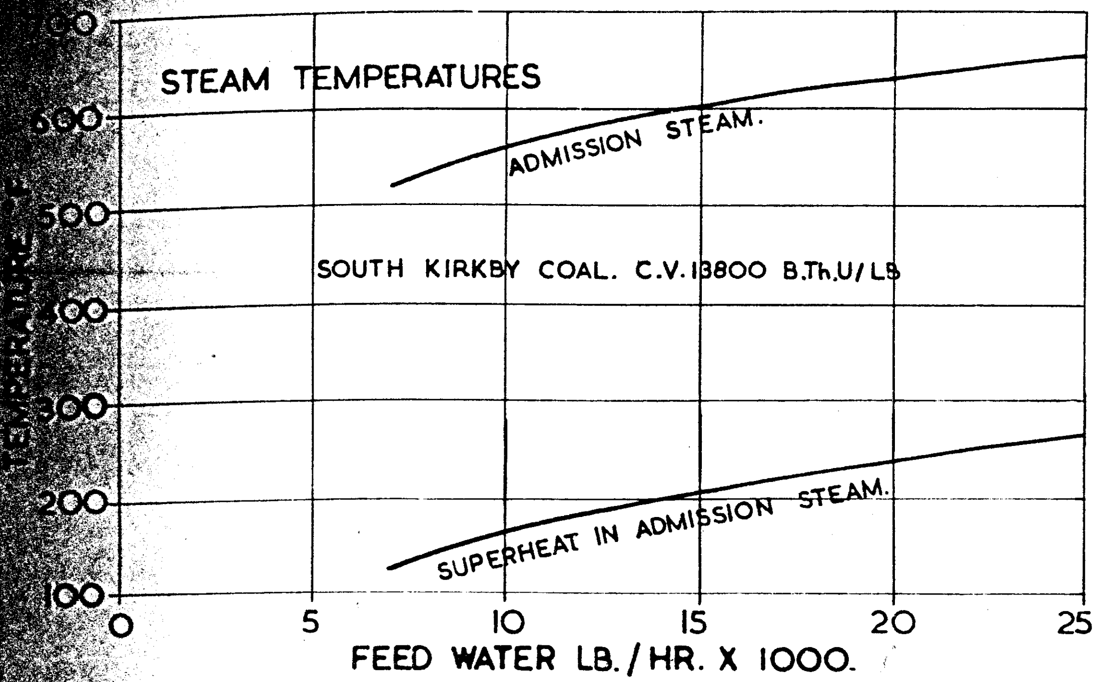


FREIGHT SERVICE–1 IN 200 RISING.

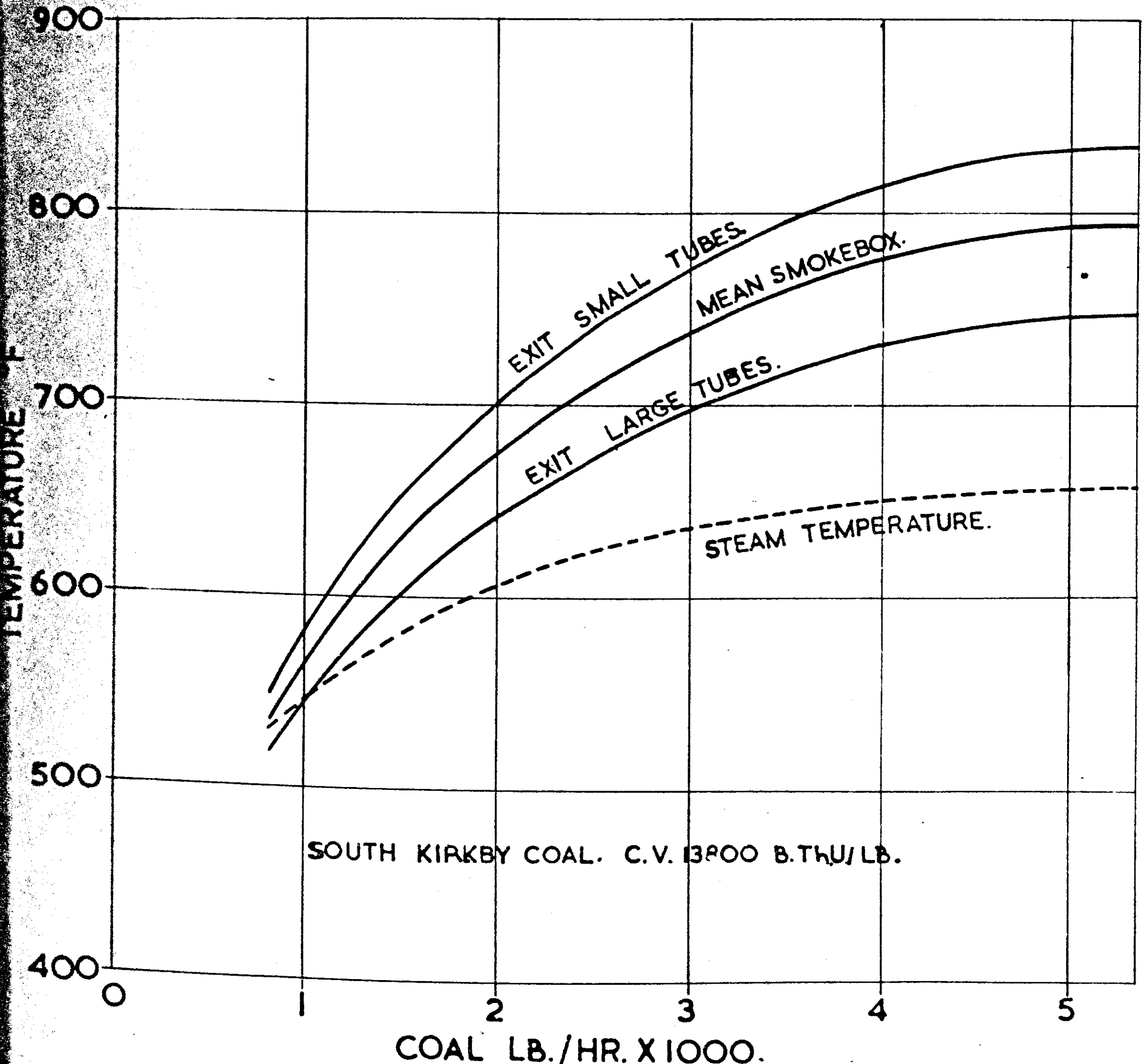
EXAMPLE OF COST IN COAL OF DIFFERENT

TRAIN LOADS & SPEEDS.

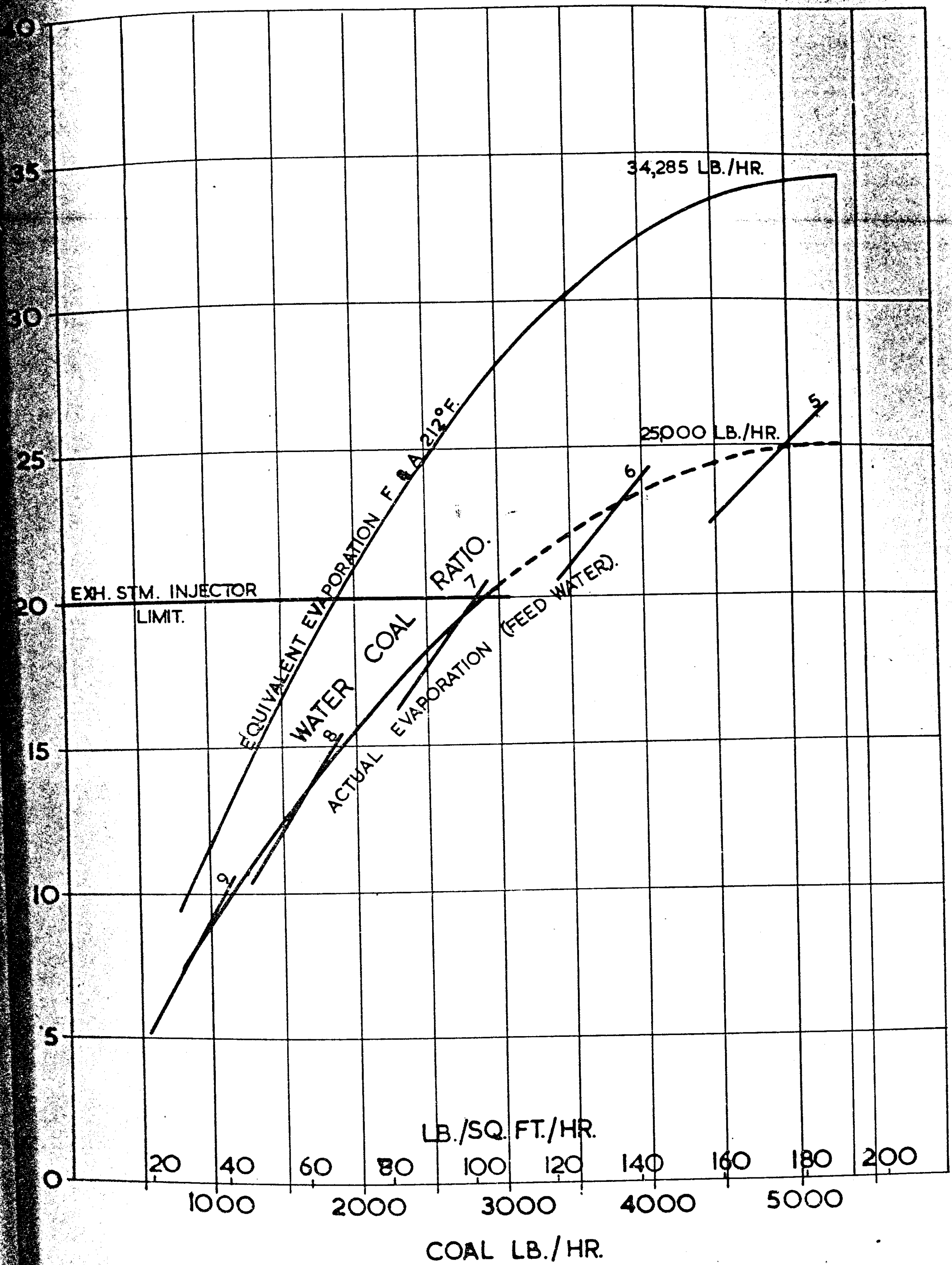
16



17

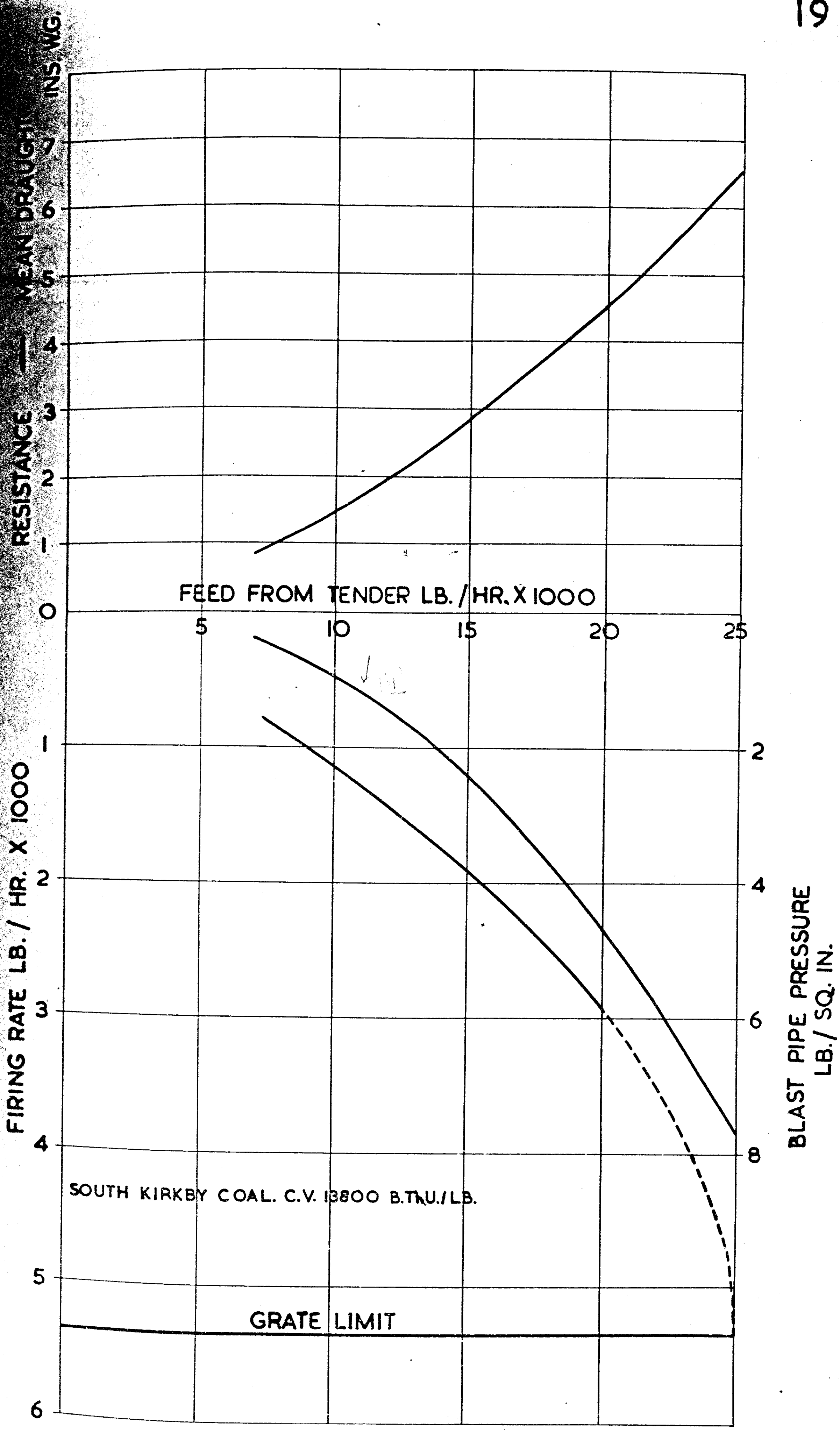


TEMPERATURES

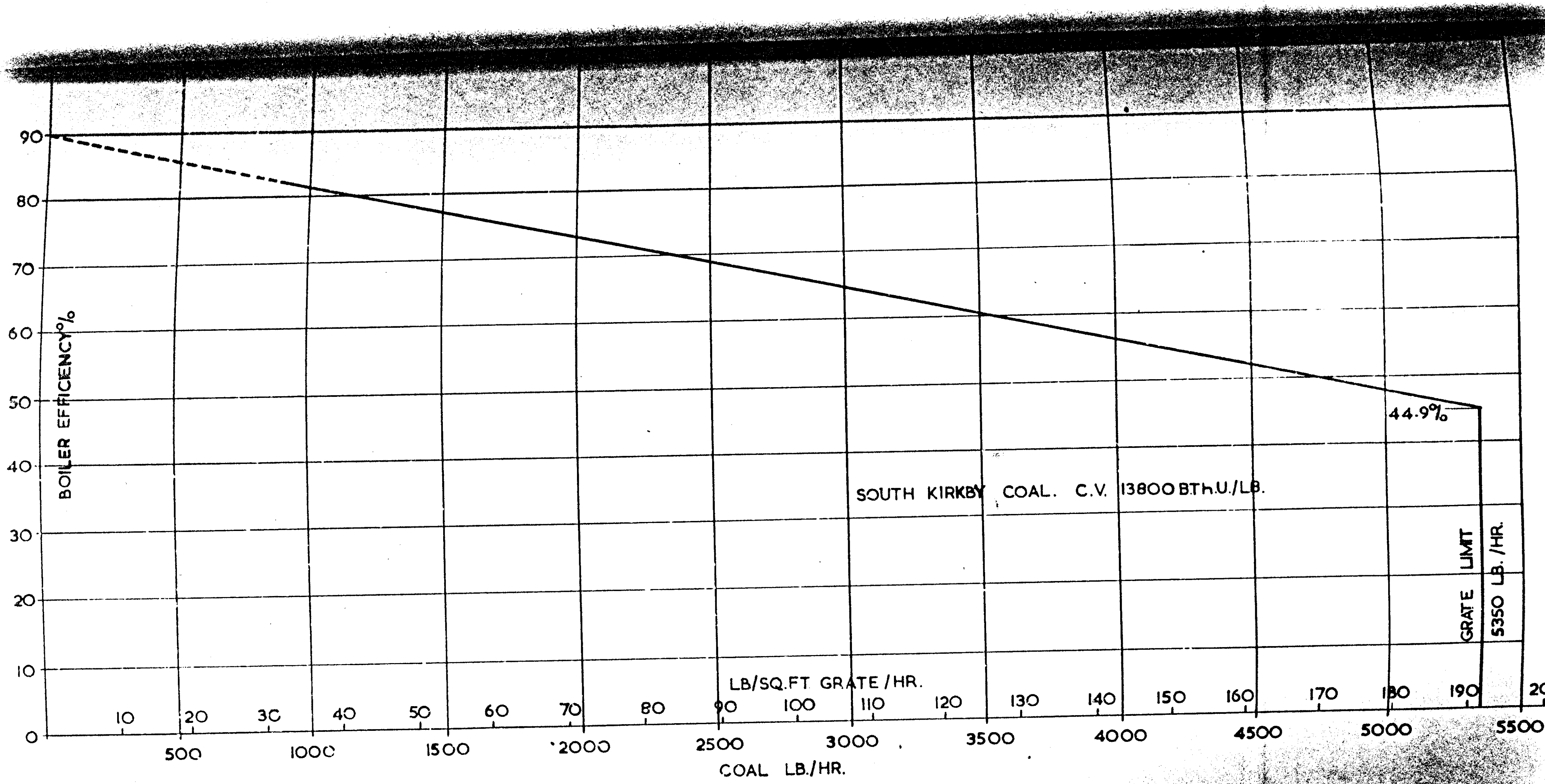


SOUTH KIRKBY COAL. C.V. 13800 B.Th.U./LB.

EVAPORATION


RESISTANCE — MEAN DRAUGHT INS. W.G.
0
1
2
3
4
5
6
7
FEED FROM TENDER LB./HR. X 1000
5
10
15
20
25
FIRING RATE LB./HR. X 1000
1
2
3
4
5
6
BLAST PIPE PRESSURE LB./SQ. IN.
2
4
6
8
SOUTH KIRKBY COAL. C.V. 13800 B.Th.U./LB.
GRATE LIMIT

DRAUGHTS

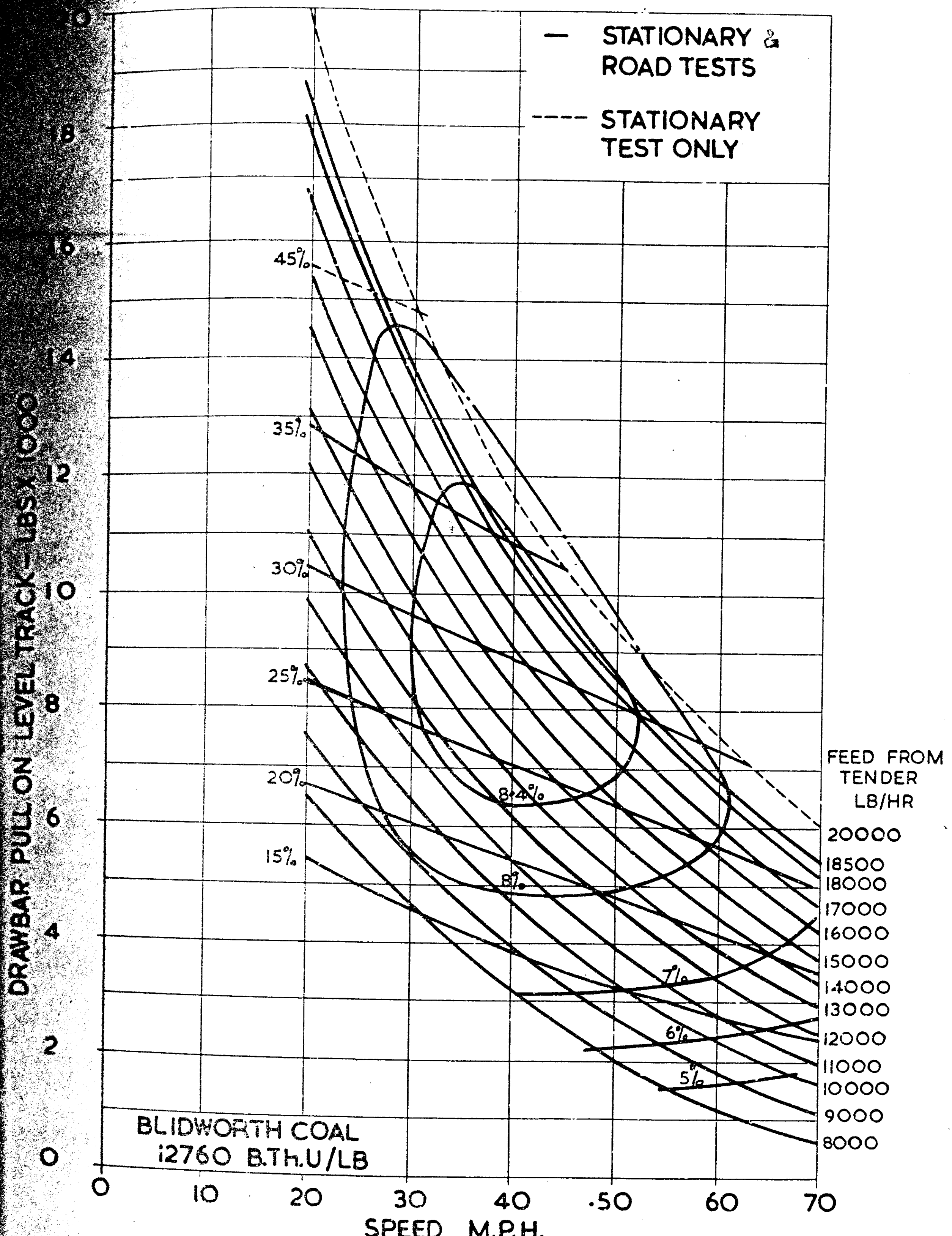


BOILER EFFICIENCY.

BLIDWORTH COAL.

Performance Data : Graphs 21 to 32.

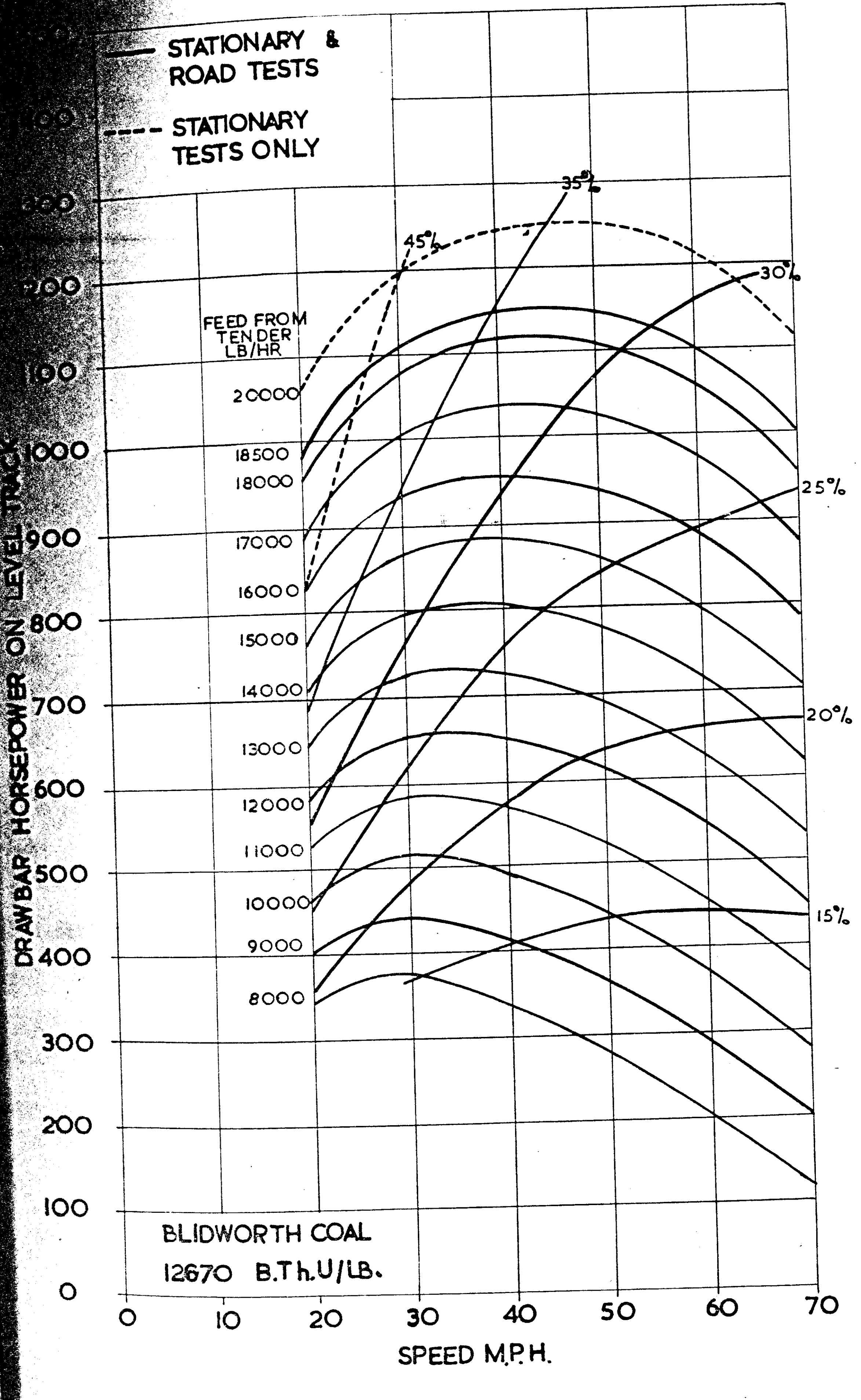
Design Data : Graphs 33 to 37.



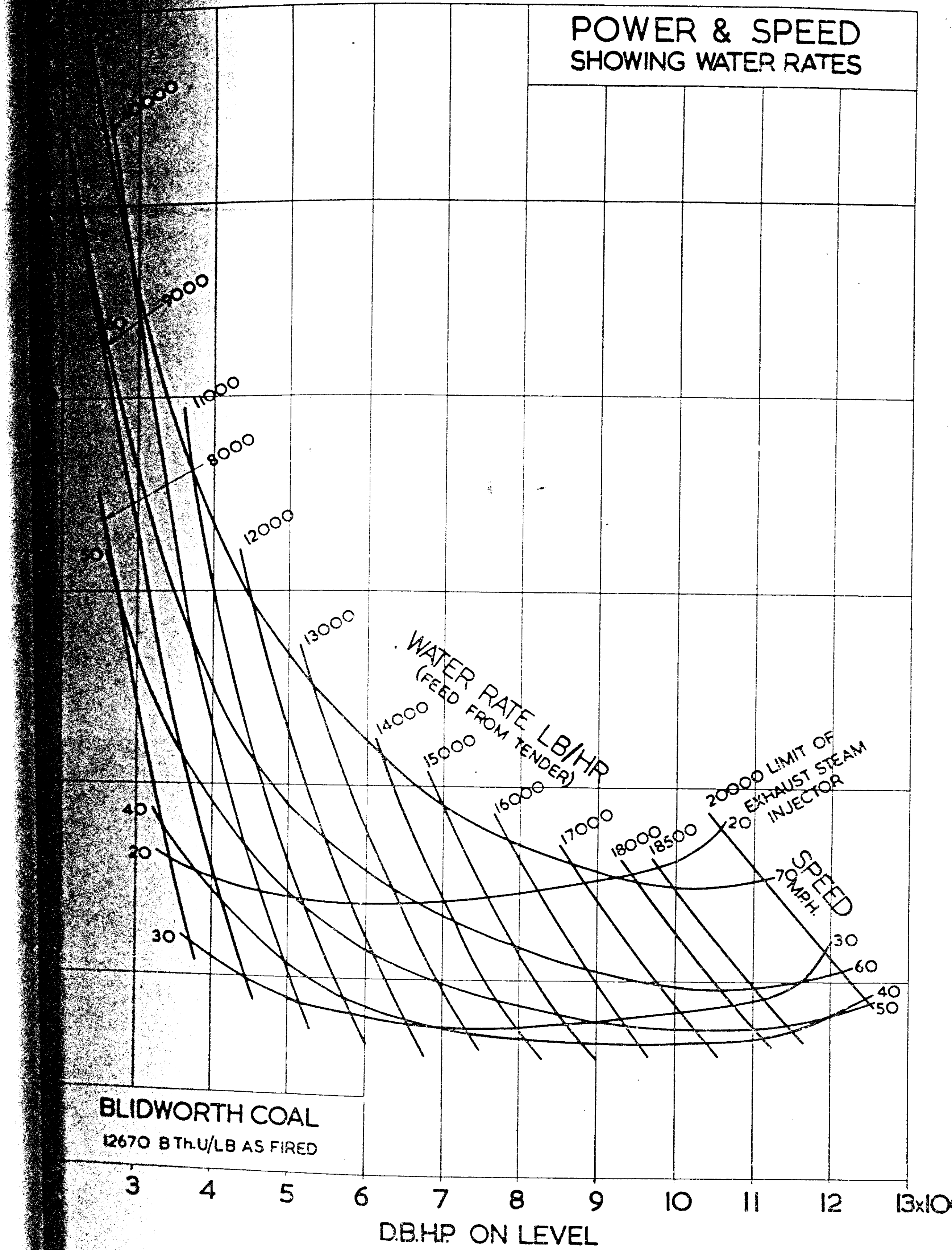
NOTES:- 1 CONTOUR LINES INDICATE CONSTANT OVERALL EFFICIENCY ON LEVEL TRACK

2 LIMIT OF EXHAUST STEAM INJECTOR 20000 LBS/HR

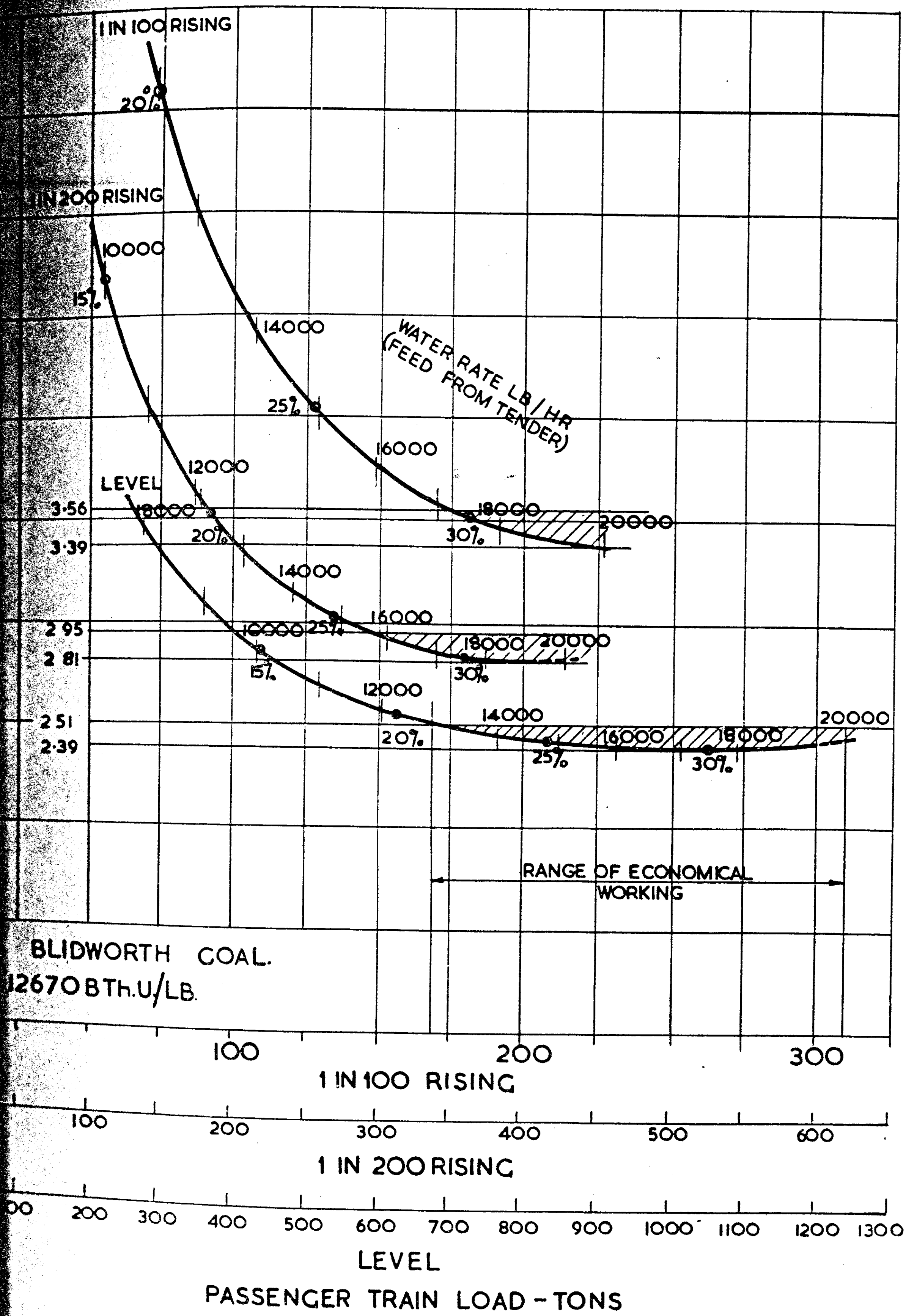
DRAWBAR PULL CHARACTERISTICS



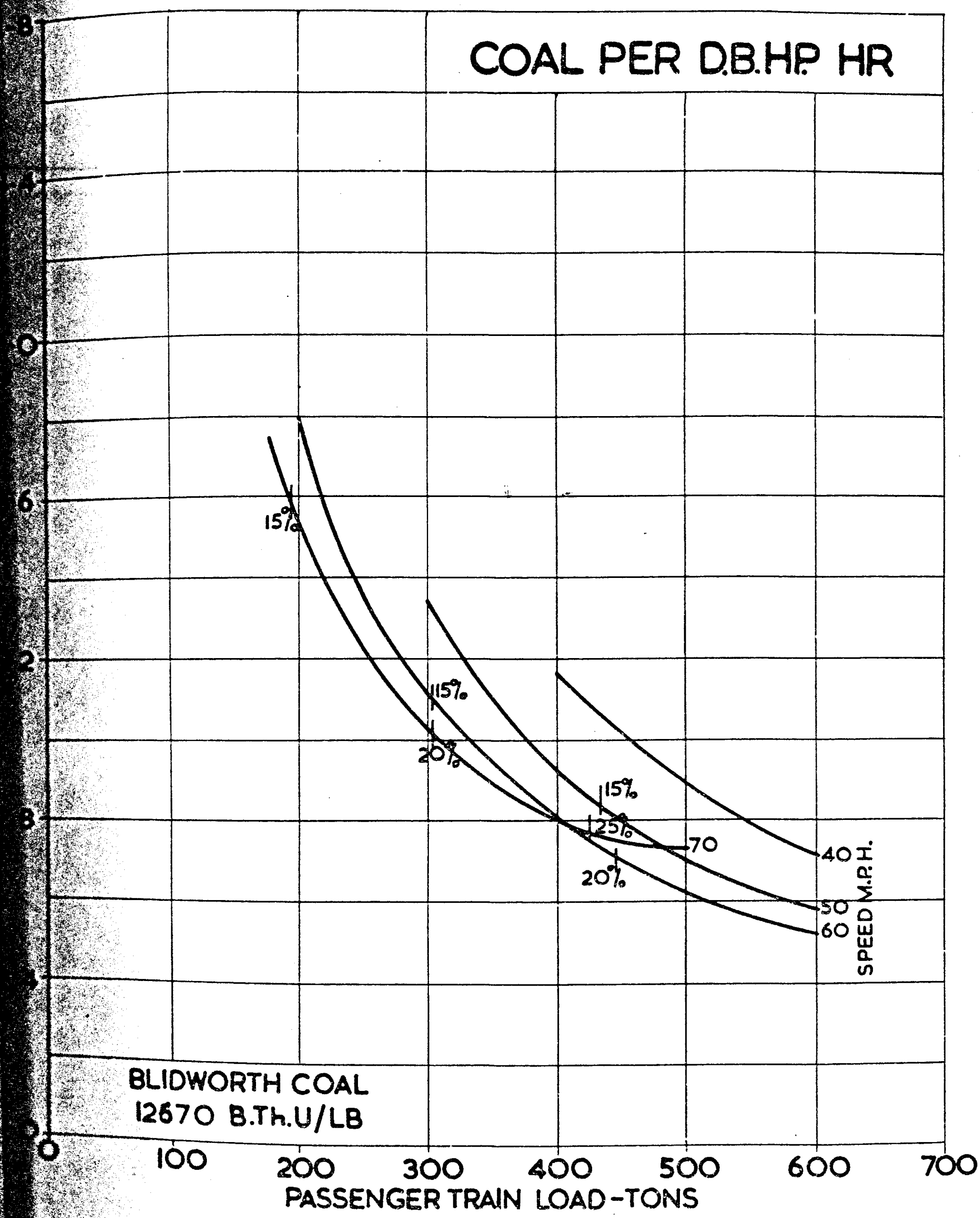
DRAWBAR HORSEPOWER CHARACTERISTICS



COAL PER D.B.H.P. HR.

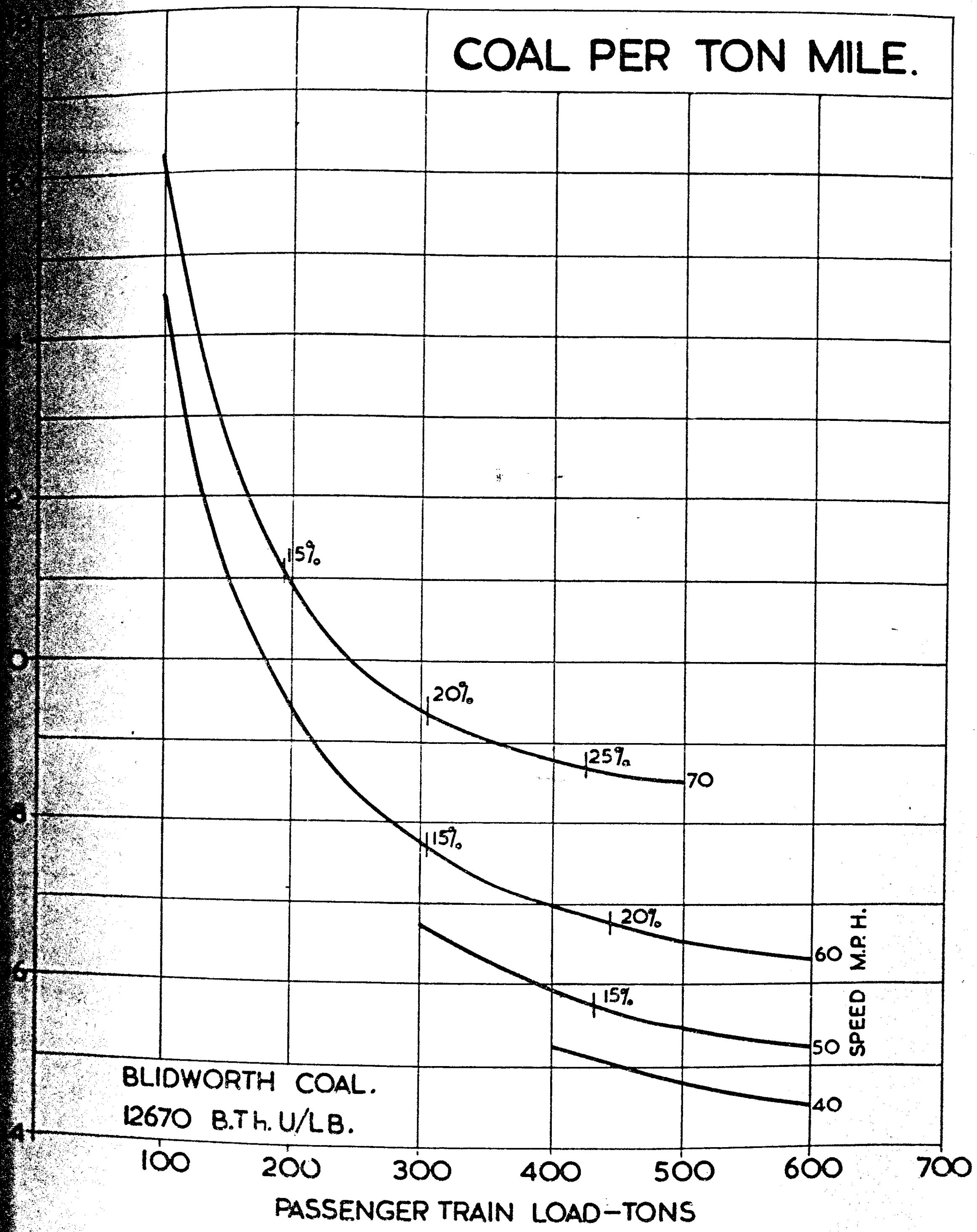


EXAMPLES OF RANGE OF ECONOMICAL WORKING AT 50 M.P.H.



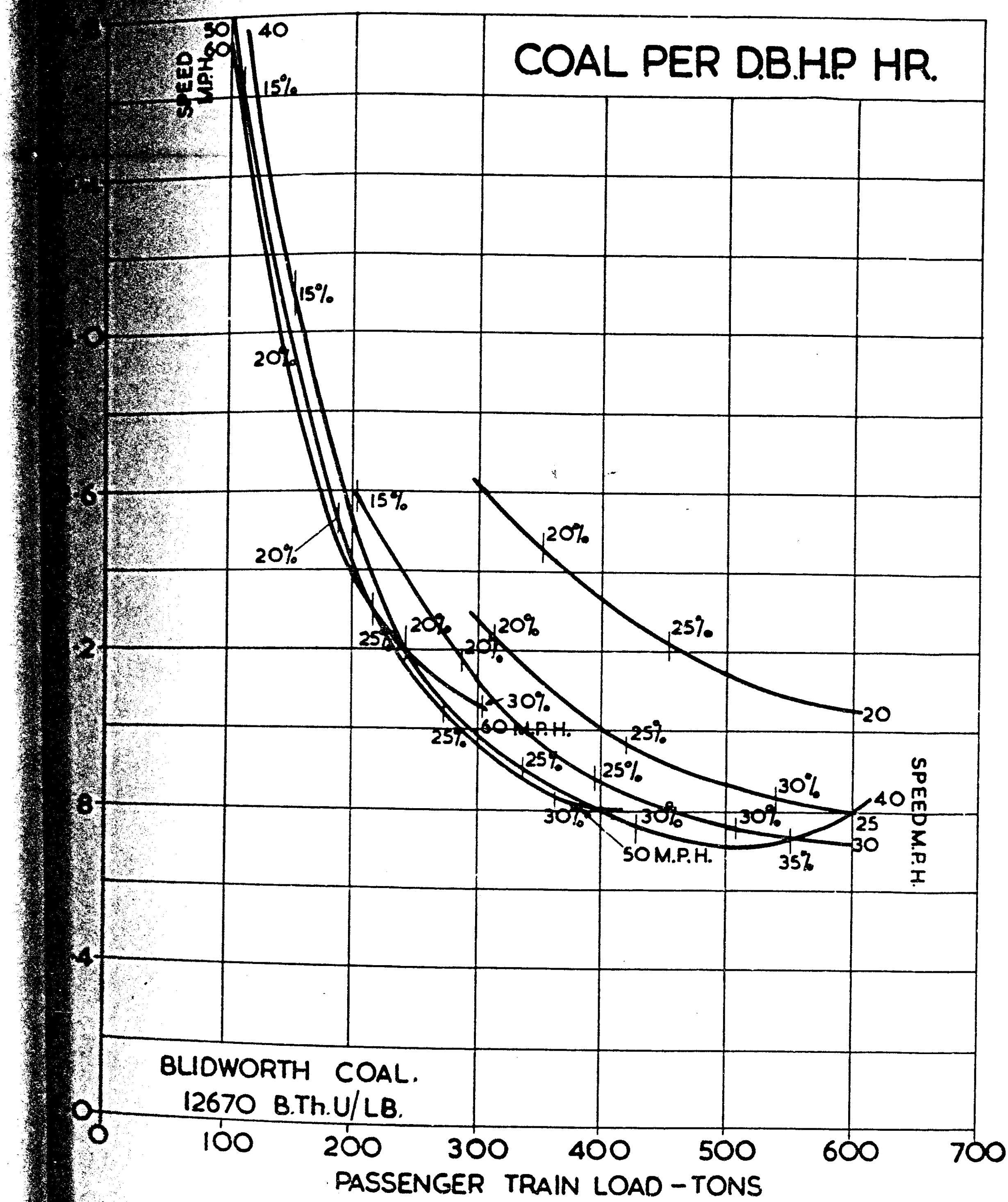
PASSENGER SERVICE LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



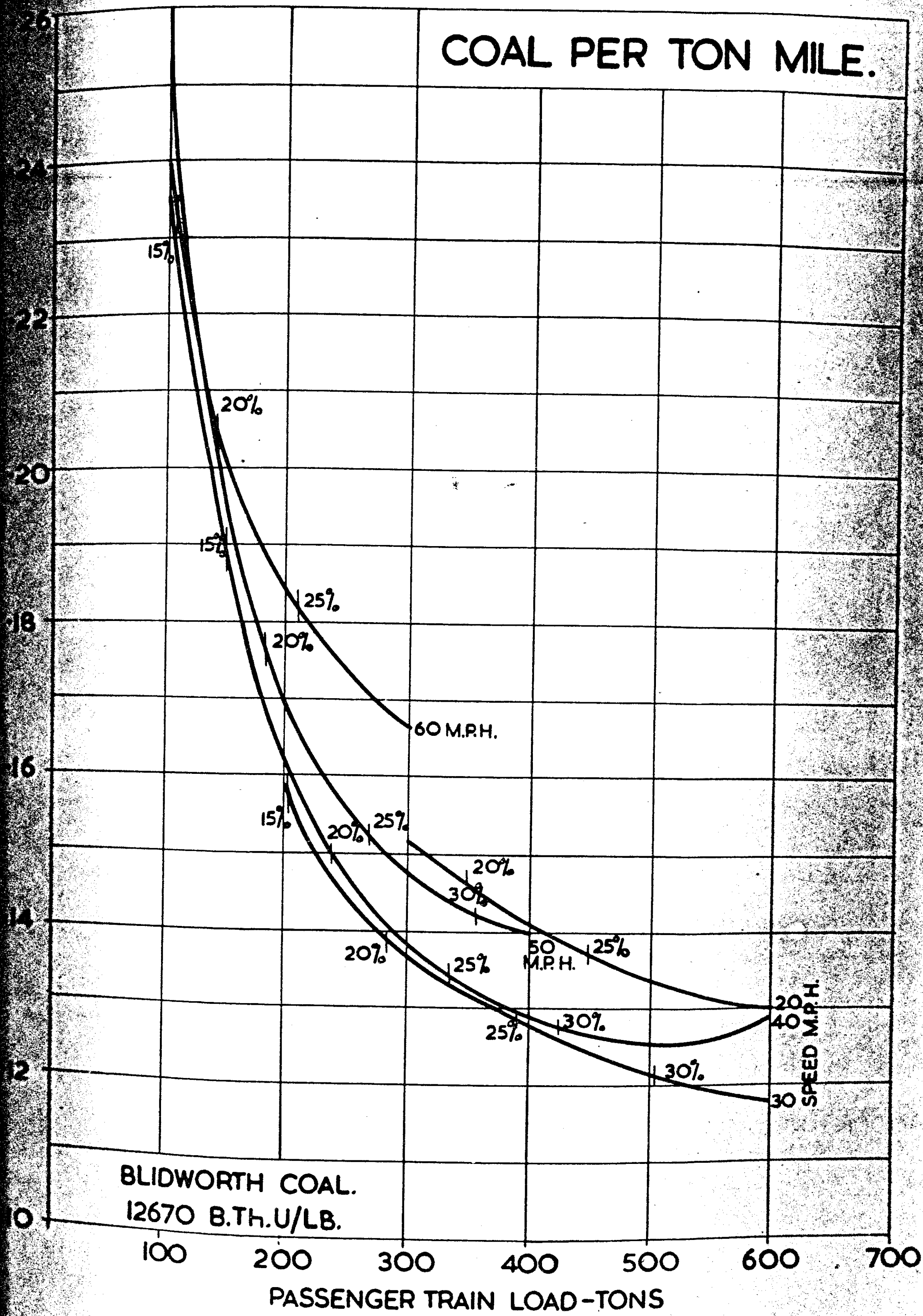
PASSENGER SERVICE-LEVEL

XAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



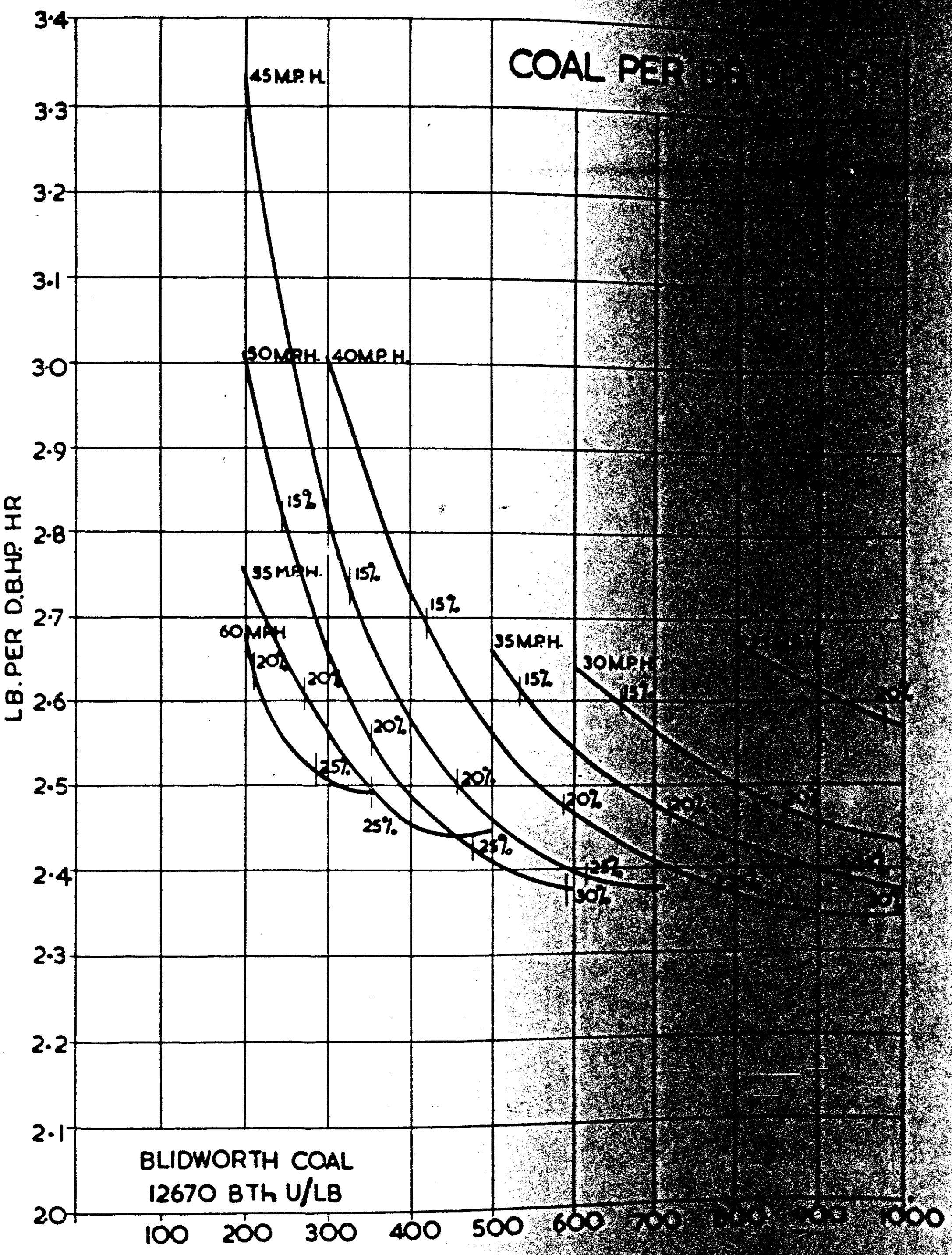
PASSENGER SERVICE 1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



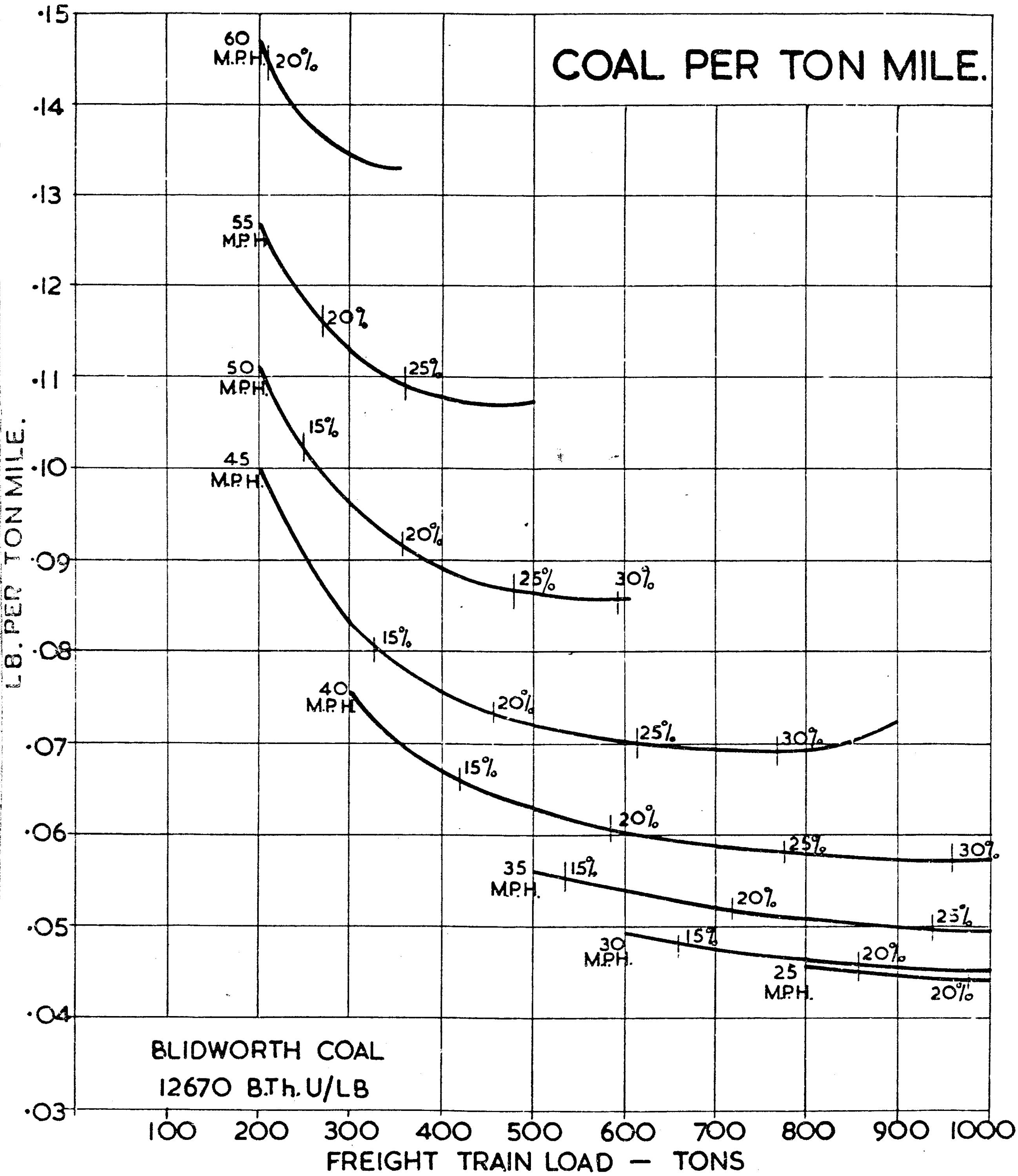
PASSENGER SERVICE 1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



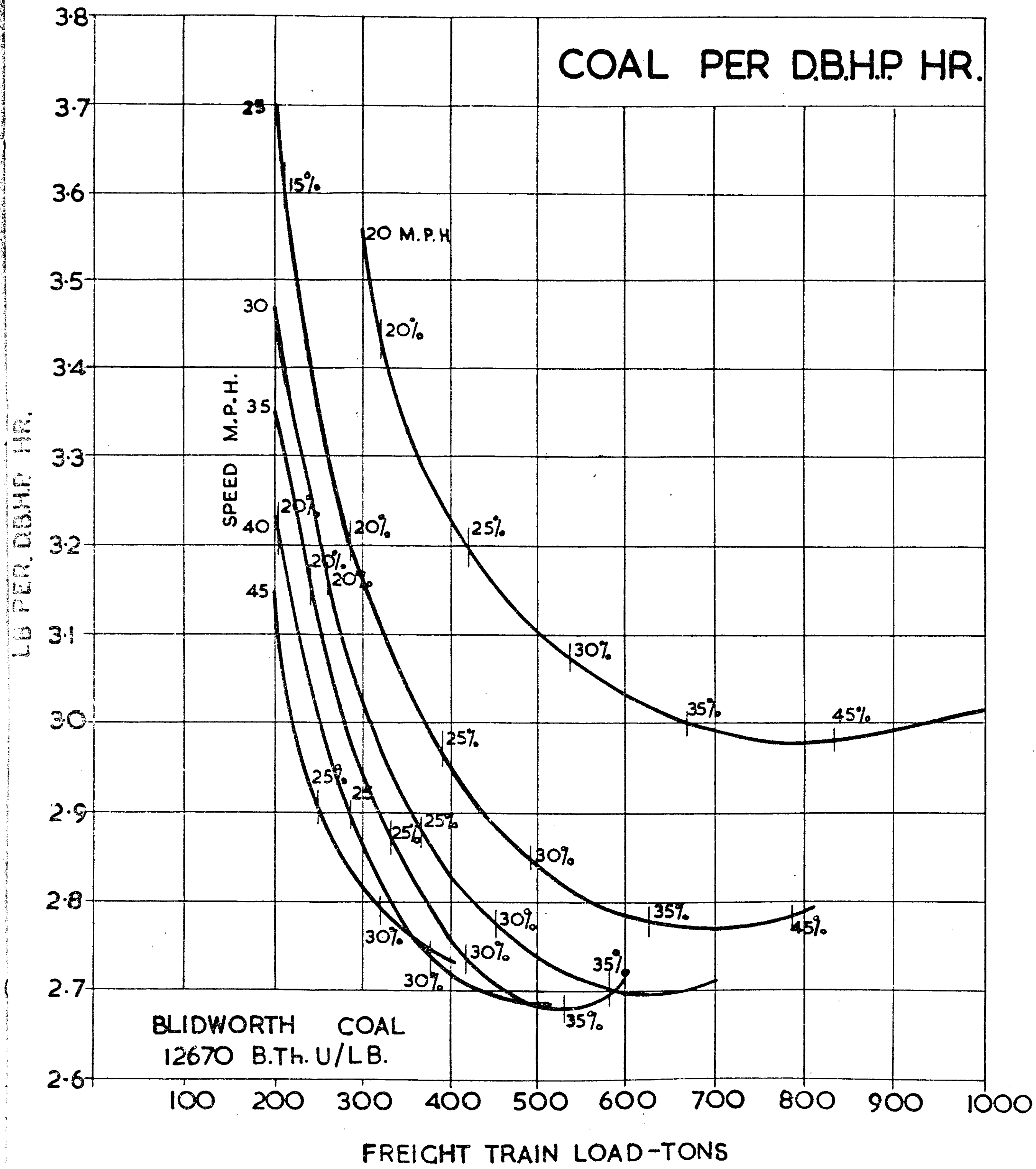
FREIGHT SERVICE LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



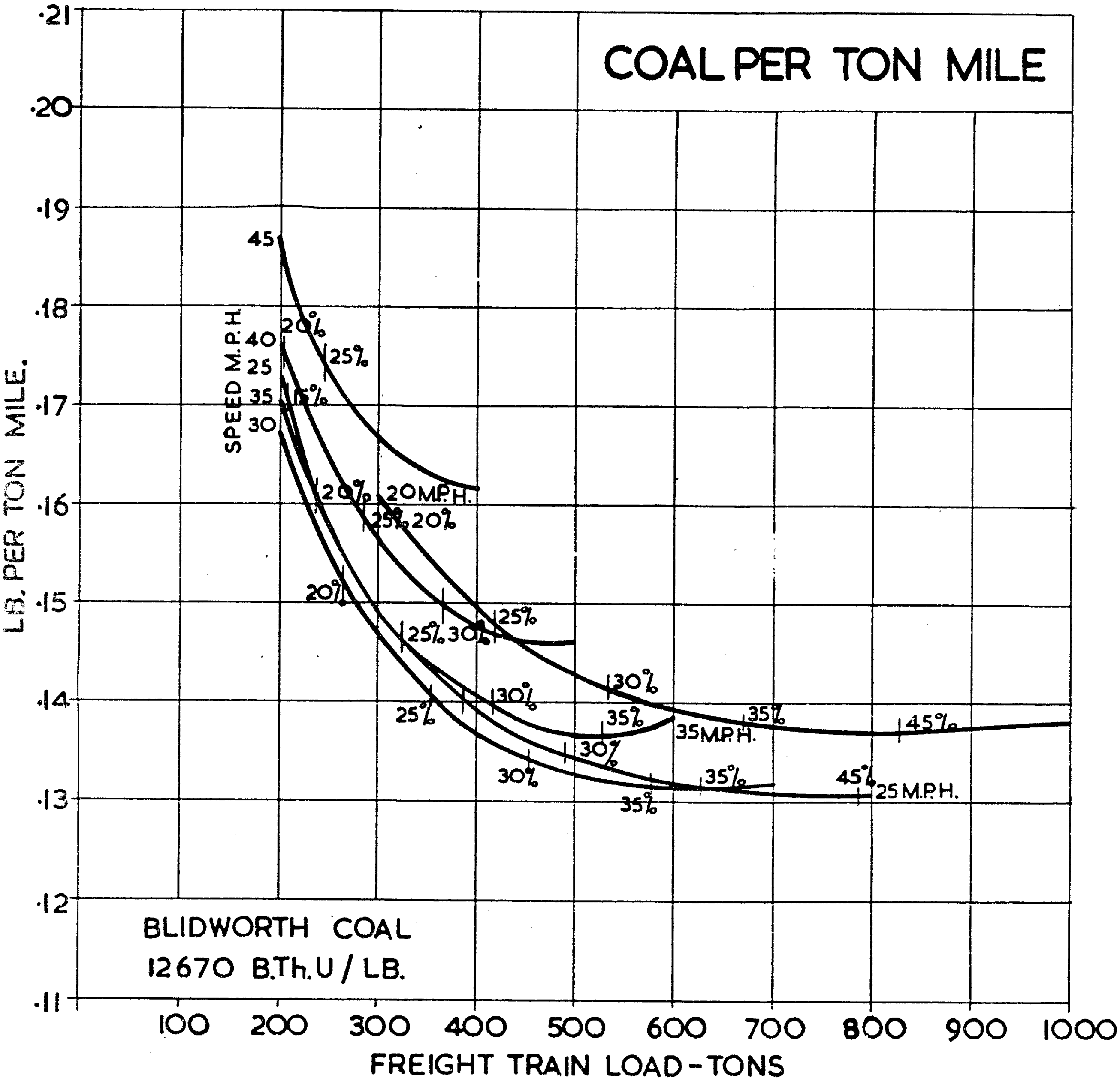
FREIGHT SERVICE-LEVEL

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS



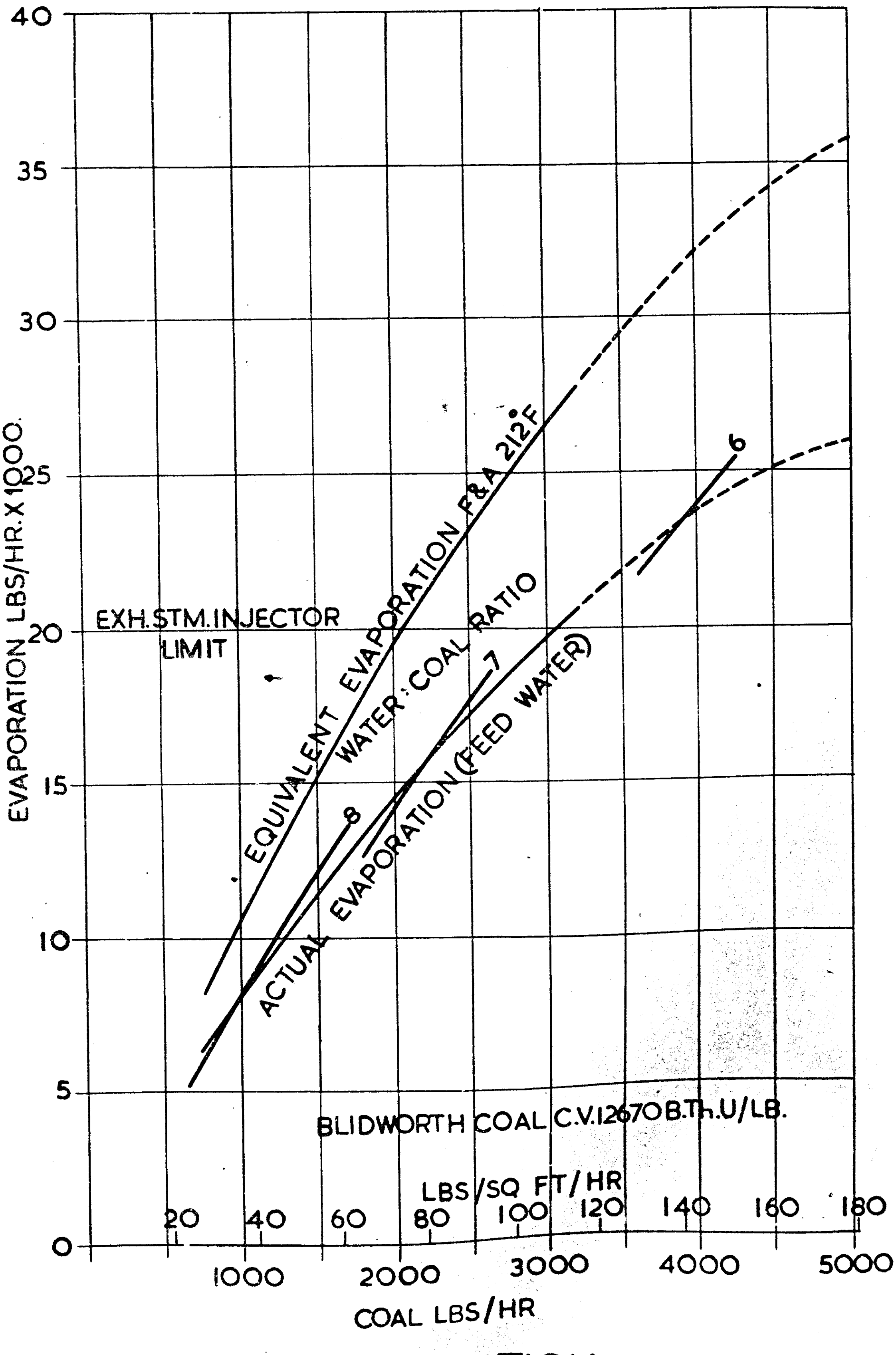
FREIGHT SERVICE-1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

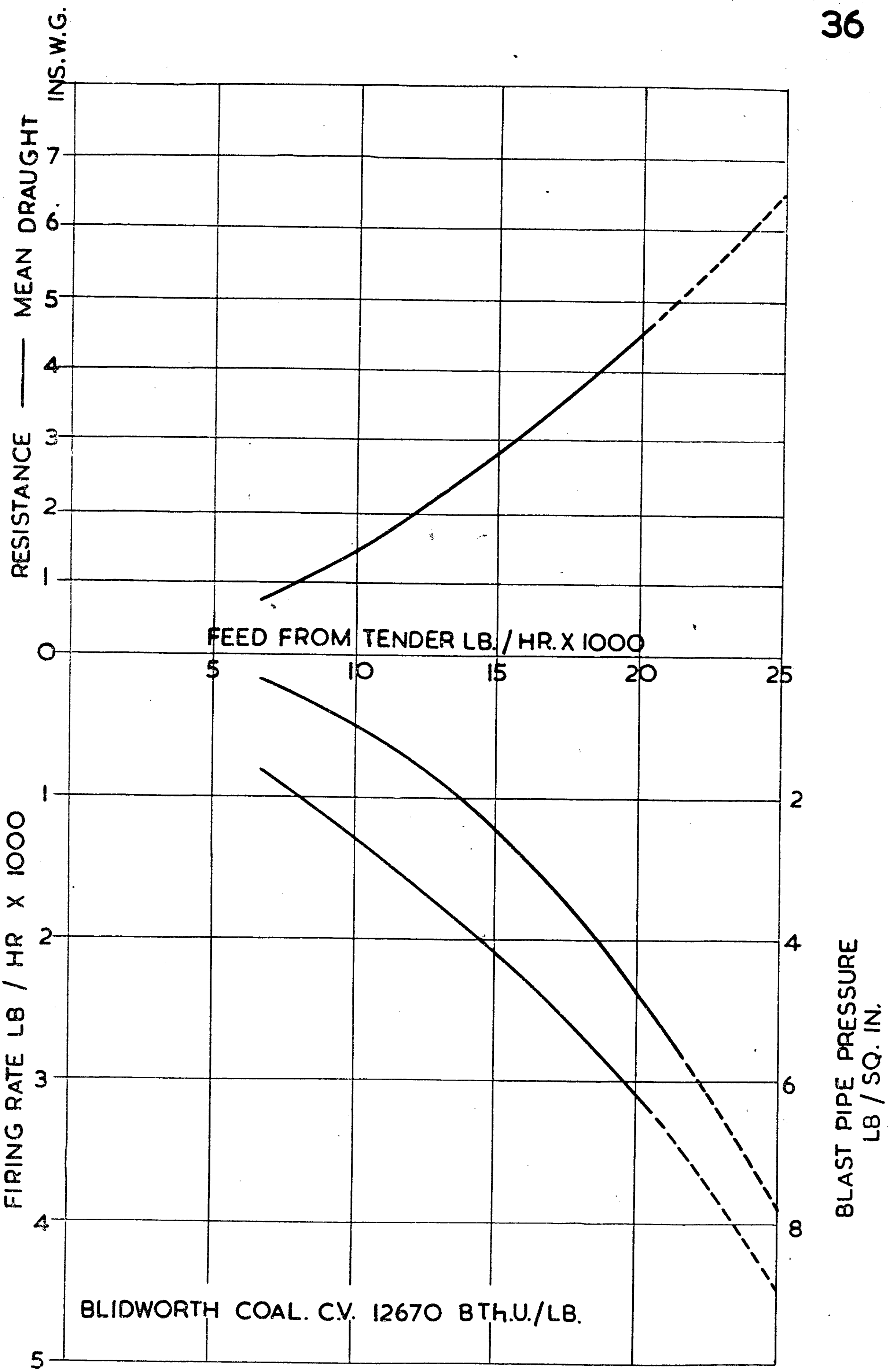


FREIGHT SERVICE 1 IN 200 RISING

EXAMPLE OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

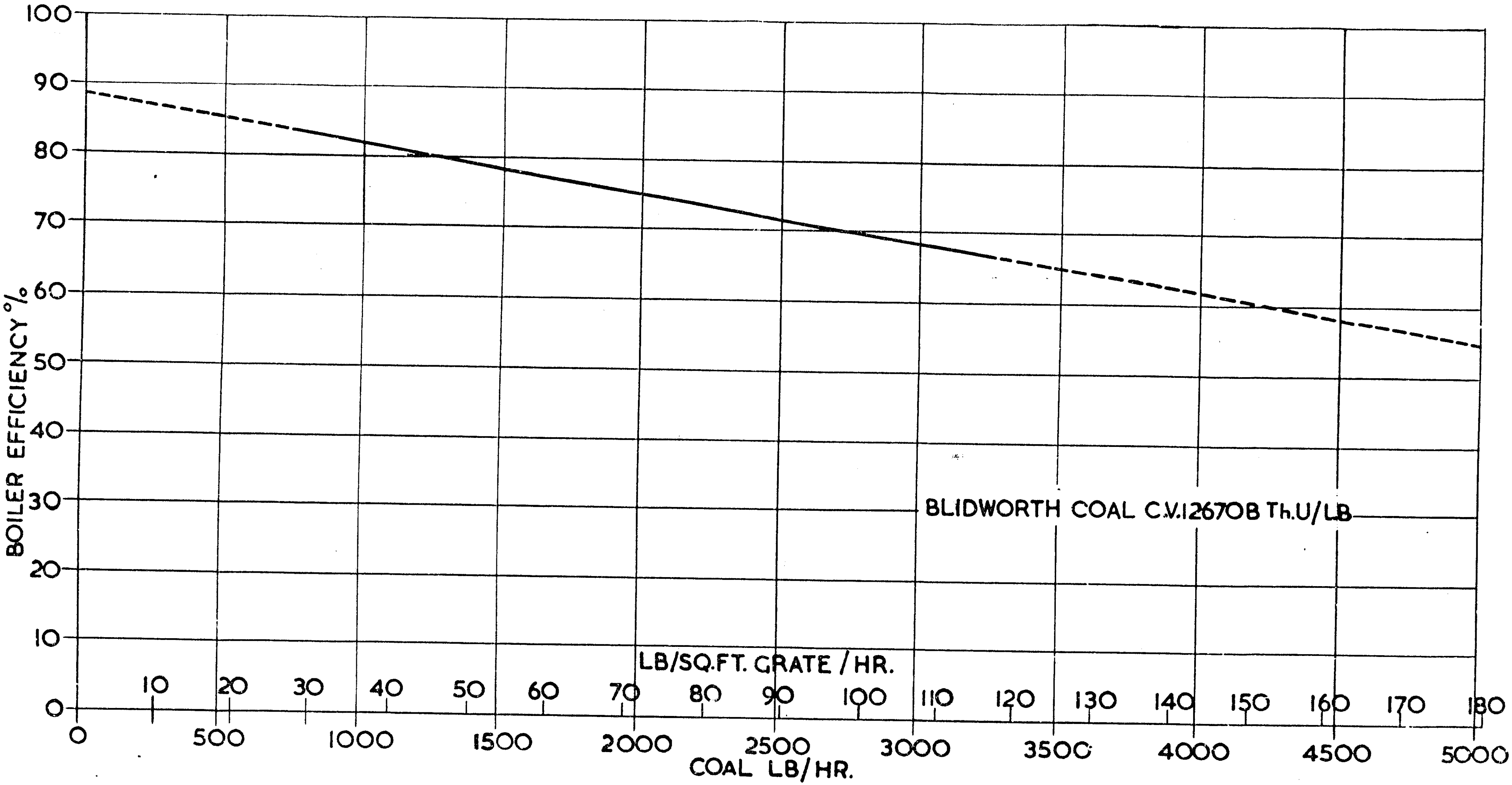


EVAPORATION



INS. W.G.
RESISTANCE —— MEAN DRAUGHT
FEED FROM TENDER LB./HR. X 1000
FIRING RATE LB / HR X 1000
BLAST PIPE PRESSURE LB / SQ. IN.
BLIDWORTH COAL. C.V. 12670 BTh.U./LB.
0
1
2
3
4
5
6
7
5
10
15
20
25
2
4
6
8

DRAUGHTS.



BOILER EFFICIENCY.