BULLETIN No.8

BRITISH RAILWAYS

Performance and Efficiency Tests with Exhaust Steam Injector

EASTERN & NORTH EASTERN REGIONS - V2 CLASS
3 CYL. 2-6-2 MIXED TRAFFIC LOCOMOTIVE

March 1953

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LIST OF TABLES

LIST OF GRAPHS AND DIAGRAMS.

LIST OF GRAPHS AND DIAGRAMS (Contd.)

1. INTRODUCTION

This class of locomotive was first placed in service in June 1936 and 184 units have been built to deal with heavy mixed traffic working.. As originally designed they have a long record of successful performance. In order to assist in their more intensive utilisation. self-cleaning plates were introduced into the smokebox from 1946, which resulted in a deterioration in steaming capacity far below the previous standard, which could not be recovered in spite of a number of trial variations in the blastpipe and chimney proportions, including reduction of the blastpipe orifice from $5\frac{1}{4}$" to 5". Since similar trouble had been experienced elsewhere in applying self-cleaning plates to the smokeboxes of 3-cylinder as distinct from 2-cylinder engines, it was decided to send a representative engine to the Swindon Test Plant for steaming tests as then running and with such modification as would result in improved performance.

As a result of relatively small modifications to blastpipe and chimney dimensions, the rate of continuous evaporation which could be sustained was more than doubled, and in its final condition opportunity was taken to carry out a series of full scale performance and efficiency test which are the subject of this Bulletin.

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 horsepower 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) Former Railway Executive, the work being controlled by the Locomotive Testing Committee consisting of :-

Mr. E.S.Cox (Chair)	- Executive Officer(Design)former R.E.
Dr. H.I.Andrews	- Electrical Engineering, New Works & Development Section Former R.E.
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)Former R.E
Mr. T.M.Herbert	- Director of Reasearch Former R.E.
Mr. R.G.Jarvis	- S.R. Brighton
Mr. B. Spencer	- E.&.N.E.R. Doncaster

II. NATURE OF THE TESTS

The draughting arrangements of the engine as received, diagram 2A, was first examined for efficiency on the Stationary Plant, where it was found to be unsatisfactory, the air supply being insufficient to maintain continuously a rate of evaporation higher than 14,000 lb./hr. Removing the self-cleaning plates enabled the maximum rate of evaporation to be raised to 24,000 lb. of steam per hour, but emission of black smoke in considerable quantity was characteristic of the general combustion conditions.

It was thereupon decided to modify the blast pipe and chimney design to that shown also on diagram 2.B. The chimney was altered to convergent-divergent form and the choke lowered to enable the divergent portion, which tapers at the rate of 1 in 14, to be made 2' 2" long. The diameter of the choke remained unaltered at 1' 3". The blast pipe orifice was increased by 3/8" to 5.3/8" in diameter, or 1/8" in diameter over the size which was the standard previous to the fitting of self-cleaning plates. To enable the top of the new chimney to remain in the same position as before, and to avoid replacing the existing exhaust pipe by a special pipe, the new blast pipe orifice was made from a flat steel plate with a skirt welded to its underside for the purpose of guiding the steam into the orifice.

With this arrangement, and with the self-cleaning plates back into position, the boiler was eventually found to be capable of maintaining continously a rate of evaporation of over 30,000 lb. of steam per hour on Blidworth Grade 2B coal, with live steam injectors only in operation, entirely free from emission of the dense smoke which was associated with the former draughting arrangement.

Having achieved this, the boiler and cylinder performances and efficiencies were then fully established whilst still on the stationary plant, these yielding data of value in respect to design. They were followed by Controlled Road Tests at constant rates of evaporation and variable speed with natural loads up to 762 tons behind the tender and rates of firing up to 5,300 pounds per hour of the Blidworth Grade 2B coal which was exclusively used throughout both plant and road trials. On these tests the boiler and cylinder performances which had been established on the stationary plant were reproduced and their efficiencies confirmed, and the relating of the coal and steam rates to the horse power at the drawbar gave the data on operational performance and efficiency which is embodied in this Bulletin.

III. METHODS OF TESTS.

The Stationary Plant tests were carried out on the Swindon Locomotive Testing Plant and the Controlled Road Tests on the Reading-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 in the manner described in Bulletin No. 1.

Coal and water rates were established by direct measurement by the Summations of Increments Method, in conjunction with which the Swindon Steam Flow Indicator was used to control the rates of evaporation and firing 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. The tests establishing the I.H.P. characteristics were, in all cases, tests in which the coal and water relationships conformed to the representative boiler efficiency characteristic, that is to say, each indicator diagram, besides being associated with a definite speed and cut off, was related also to a definite steam rate, with its corresponding pressure and temperature, and to a definite coal rate. Separate tests were made to establish the economy in fuel and feed water which resulted from the use of the exhaust steam injector; these were constant speed tests in which the exhaust steam injector was used in the first part and the live steam during the second. Based on the development of equal power in the cylinders, the savings were demonstrated by the differences in slopes of the summations of increments lines during the two periods.

As part of the variable speed testing technique, modern piston type diesel engine indicators were used, one for each end of each cylinder indicated. Since the indicating arrangements had to be used also on the Controlled Road Tests which followed, short pipes to the indicators were unavoidable, but the cross sectional area of each of these was $3\frac{1}{2}$ times the area of the single indicator piston it served. All fixed points of the reducing motion and its two indicators were carried on a single member which was secured to the cylinder in such a way as to become virtually an integral part of it. In the design of the gear, great attention was paid to maintain geometric similarity in piston and drum movements and the fit of all pins was maintained in first class condition throughout the tests. The inside and one outside cylinder were indicated in this way.

Controlled Road Tests.

The Controlled Road Tests were conducted in the manner described generally in Bulletin 1 with natural loads. The cylinders were indicated on all tests. One of these is shown diagramatically in Graph 11; the plot of the Summations of Increments of Coal and Water for this test is given by Graph 12 from which it can be seen that the constant demand made on the boiler by the cylinders (as controlled by the driver working to his special flow indicator) was balanced by the water injected and that the coal consumption rate was also significantly constant. Hence the efficiency with which the fuel was converted into work in the cylinders and at the drawbar was directly proportional at all times to the I.H.P. and available D.B.H.P. respectively. Similarly the coal per mile and per ton mile at all times were inversely proportional to the train speed because the train weight was constant.

Special scales have been incorporated in Graph 11 to permit the efficiencies and consumptions to be evaluated for any point in the test. It will be noted that on this typically undulating route, running to a representative passenger train time schedule the locomotive converted energy in the fuel to mechanical energy at the drawbar at a fairly constant level of efficiency; the coal per mile and per ton mile however varied considerably.

For each test a curve of actual drawbar tractive effort against train speed, unadjusted for gradient or acceleration, was produced from the efforts registered by the Dynamometer Car, this representing the effort with displaced the trailing load.

Train resistances at various speeds were evaluated which mathematically permitted the mass of the test train under the above tractive efforts to be displaced along the test route in the same time as in the actual test run with very close agreement in train speeds at all intermediate points. These resistance values then enabled the tractive effort-speed curve to be directly adjusted to give equivalent efforts at constant speed on the level. The difference between this curve and the curve on the same base through the mean of the indicated tractive efforts represents the engine resistance.

Co-ordination of Test Results

For each test the mean indicated tractive efforts at speeds selected at 10 m.p.h. intervals were plotted against steam rate to construct the well-known "Willans'Lines" from which the Indicated Characteristics of the locomotive Graphs 22 and 25 were produced. Similarly Willans' Lines were constructed from the equivalent drawbar tractive efforts of the tests after adjustments for the effect of the varying wind conditions. From these the Drawbar Characteristics of the locomotive, Graphs 7 and 8 were produced. These and their derivitives, Graphs 9, 10, 13 to 18, relate to wind conditions defined as having a natural velocity of 7.5 m.p.h. with an angle of approach to the direction of the train of 45°, the resistances of the coaches relating to the random selection from available stock which formed the test trains.

IV. TEST ARRANGEMENTS

The steam rates and speeds at which the locomotive was tested fairly covered the range between the limits of evaporation and speed given in a 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 65-75 minutes of unrestricted steaming on fully stabilised evaporation and combustion conditions.

The trials on the plant took place during hot weather and two firemen took turns to fire the engine on the high rates in order to avoid undue strain due to the heat and relatively poor ventilation.

Fog with winds so light as to be unrecordable in strength and direction at the wind stations prevailed throughout most of the period of the Controlled Road Tests though at the end of the period winds of 10.7 and 12.6 m.p.h. were experienced. Two tests were rendered invalid by operating difficulties due to the foggy weather. On all runs two firemen were employed to allow one to concentrate only on firing whilst the other attended to the other normal duties of the fireman, some of which were made particulary onerous by the prevailing weather conditions. The highest rate of 5,300 lb. of coal per hour was kept without undue fatigue by the one fireman only, but this rate was much in excess of the practical maximum for continuous working. The engine was manned by a driver and firemen from Swindon Motive Power Depot though neither man had worked an engine of this class before or had had previous experience of this form of road testing.

V. LOCOMOTIVE

The locomotive sent for testing was No. 60845 which had run 4,252 miles in traffic since it was last given a heavy repair. By the end of the tests the mileage had increased to 8,305.

During the initial stages of the stationary plant trials, continual trouble was experianced from hot boxes. Slight misalignment of engine wheels with respect to the plant rollers caused a continuous interpressure between wheel bosses and box faces on one side and prevented oil from the bearings reaching the rubbing surfaces. This trouble so interfered with testing that the engine was returned to the owning Region for provision of positive oiling arrangements to these surfaces. At the same time the regulator, of obsolescent design, which had also given trouble, was replaced with one of later design. When testing was resumed, no further delay was caused by these items.

The "pop" valves were found to lift at 225 lbs. per sq. inch and close at 205 lbs./sq.in. discharging meanwhile steam in such quantities as to fill the plant, making testing very difficult and hazardous. The pressure therefore had to be kept below that normally maintained on engines of this nominal working pressure.

Injectors gave trouble through instability at maximum working pressures and the road trials were not as free from brake trouble as is usual. In all other respects the mechanical condition of the engine was satisfactory. The self cleaning plates were efficient at all rates of working.

Elsewhere in this Bulletin will be found a table (Table 1) setting out the dimensional details and ratios of the engine, a diagram (Diagram 1) giving its leading particulars, and a table (Table 2) of the actual valve setting of the engine as provided by Doncaster Works. The available capacity of the tender was found to be 3,800 gallons.

VI. COAL

The engine was tested on one coal only - Blidworth Cobbles of Grade 2B., a coal common to all locomotive testing. Its price per ton as delivered on the tender at Swindon Motive Power Depot at the time of the tests was 57s. 9d. per ton, exclusive of haulage but inclusive of departmental charges.

The coal was mainly dull grey in appearance, containing some bright veined pieces and a little slate. Very hard. Its size varied from 6" in greatest dimensions down to 1" with a little dust; average size 4" to 5" Table 3 gives the calorific values and proximate analyses of a representative sample. Various samples showed little variation in calorific value or proximate analysis.

VII. OBSERVATIONS

1. On Blidworth coal maximum boiler capacity is limited by draughting to a continuous evaporation of 30,400 lb. of cold feed per hour into steam at nominal boiler pressure and at 735°F., the latter representing a superheat of 341°F. The boiler efficiency is then 58%. The exhaust steam injector fitted was found to be limited in capacity to 20,000 lb. of feed per hour. When used, and supplemented by the live steam injector, the cylinders can be supplied with steam at a maximum continuous rate of 31,000 lb./hr. Although draughting actually limits the evaporative capacity, consideration of the measured pressure and condition of steam at discharge from the orifice at this limit indicates that the orifice discharge limit for controlled expansion is nearly reached at the draught limit.

2. At a firing rate of 3000 lb. of Blidworth coal per hour, the boiler evaporates 20900 lb. of cold feed per hour into steam at nominal boiler pressure and at 680°F. The boiler efficiency is then 73%. When the exhaust injector is used, the cylinders can be supplied continuously with 21,500 lb. of steam per hour.

3. Increases in the rates quoted in 1 and 2 above could be expected with coals of higher calorific value.

4. At the practical limit for continuous hand firing (3000 lb./hr.) and on Blidworth coal, the exhaust steam injector effects a saving of 3% in feed water and 4.5% in coal over the live steam injector for the development of the same power in the cylinders. These are lower than usual, possibly due to the condition of the particular injector.

5. Cylinder thermal efficiency reaches a maximum value of 14.6% when the speed is 80 m.p.h. and the steam rate is 18,000 lb./hr. and its temperature is 650°F.; the I.H.P. developed is then 1,360, and the specific steam consumption falls to its minimum value of 13.2 lb. per I.H.P. hr. This efficiency is 73.2% of the efficiency of an ideal engine working on the Rankine Cycle between the same initial pressure and temperature conditions and the same final pressure condition.

At 60 m.p.h., however, the maximum cylinder thermal efficiency is but 14% at the same steam rate and temperature; 1308 I.H.P. is developed in the cylinders and the specific steam consumption is 13.8 lb. of steam per I.H.P. hr. This efficiency is 70.0% of that of an ideal engine working on the Rankine Cycle.

Cylinder thermal efficiency tends to reach its maximum for the speed at a steam rate of 18,000 lb./hr. at the higher speeds and 20,000 lb./hr. in the lower. Minimum specific steam consumption follows the same tendency.

6. The valve gear conjugation is responsible for the unevenness of the steam distribution to the inside cylinder. Reference to the representative indicator diagrams shown in diagrams 30, 31 and 32 indicates that on neither stroke of the inside cylinder is steam used as economically as in the outside cylinder; the distribution is best at the highest speeds when the specific steam consumptions attain their lowest values.

Because of this feature the cut offs cannot be taken as other than nominal, power being defined in terms of speed and steam rate with maximum practicable steam chest pressure.

7. When the unevenness of steam distribution (and beat) is most pronounced, longitudinal oscillation of the tender drawbar is marked, often corresponding to a periodic variation in pull of ±.5 ton. It disappears at or just before a speed of 40 m.p.h. is reached. Experience of cases of a similar nature in other locomotives suggests that it may be possible to practically eliminate these effects by redesign of intermediate and tender drawgear details.

8. On some occasions, when the engine stopped with the cranks in certain positions, difficulty in starting was experienced. In one instance on the main line, 13 mins. was spent in alternate bunching and straining before the train could be started.

TABLE I

DIMENSIONAL DETAILS AND RATIOS OF THE LOCOMOTIVE

Cylinders and Steam Chests

Piston swept volume	cu.ft.	4.04
Cylinder clearance volume as % of piston swept volume. Outside		8.3
Cylinder clearance volume as % of piston swept volume. Inside		8.6
Steam chest volume (Between valve heads and with assumed length 7" to steam chest flange face) as % of piston swept volume.		23

Piston Valve

Nominal diameter		ins	9
Steam lap.	Outside	ins	1.5/8
" "	Inside	ins	1.11/16
Lead	Outside	ins	1/8
"	Inside	ins	1/16
Exhaust lap			Nil
Maximum cut off. Foregear.	Outside	%	66.8
" " " "	Inside	%	63.6
" " " Backgear	Outside	%	65.6
" " " "	Inside	%	-

For actual valve setting see separate sheet.

Boiler

Barrel diameter, outside minimum			5'-9.3/16"
" " " maximum			6'-5"
Small Tubes,	number		121
	outside dia.	ins	2.1/4
	thickness	SWG	10
Large tubes,	number		43
	outside dia.	ins	5.1/4
	thickness	ins	5/32
Superheater elements (double return loop)	outside dia.	ins	1.1/2
	thickness	SWG	9
Length between tubeplates.			16'-11.5/8"

Heating Surfaces / Grate Area } See engine diagrams		
Water suface at half glass	sq.ft	106
Volume of steam above water at half glass	cu.ft	78.5
Total piston swept volume as % of steam volume		15.47
Firebox volume/grate area		6.18
Firebox volume/ Firebox heating surface		1.24
$\frac{A}{S}$ Large Tubes		$\frac{1}{439}$
$\frac{A}{S}$ Small Tubes		$\frac{1}{417}$

<u>Steam Circuit</u>

Regulator area through valve(balanced single seat)	sq.ins.	29.23
Main steam pipe through boiler dia.	ins.	7
cross sectional area.	sq.ins.	38.48
Superheater elements: area through spherical ends	sq.ins	52.76
area through tubes	sq.ins.	49.62
Steam pipes to cylinders,bore	ins	5
cross sectional area	sq.ins.	19.63
Steam chest,cross sectional area through liner	sq.ins	60.34
Ports, width	Ins	1.3/4
Cross sectional area	sq.ins	37.28
Passage, steam chest to cylinder, minimum cross sectional area	sq.ins	31.06
Exhaust Passage, adjacent to steam chest maximum cross sectional area	sq.ins	40.25
at base of blast pipe	sq.ins	126
Blast Pipe cap, see Draughting arrangements		

<u>Gas Circuit</u>

Area through ashpan dampers,front	sq.ft	2.8
Air space through grate as % of grate area		36.55
Free area through tubes, large	sq.ft	3.61

Free area through tubes, small	sq.ft	2.62
total	sq.ft	6.23
Area through large tubes as % of total free area.		57.9
Total free tube area as % of grate area		15.1

Chimney choke. See Draughting Arrangements.

DRAUGHTING ARRANGEMENTS.		Before Modification.	After Modification
Blast pipe orifice, dia.	ins	5.	5.375
area	sq.ins	19.63	22.7
Chimney, diameter at choke	ins	15	15
area at choke	sq.ins	176.7	176.7
diameter at top	ins	15.5	16.875
Chimney bell, dia. at bottom	ins	24	21.8
Blast pipe orifice, below smokebox centre line.	ins	7	11.625
Chimney choke above blast pipe orifice	ins	33.5	30.31
Height of chimney, choke to top	ins	18	26
Chimney sides, taper		1 in 28	1 in 14
Chimney bell, depth below choke	ins	14.5	9.5
$\frac{\text{Chimney choke dia.}}{\text{Blast pipe orifice dia}}$		3	2.79
$\frac{\text{Height of choke above orifice}}{\text{Dia. of choke}}$		2.23	2.02
$\frac{\text{Height of bottom of bell above orifice}}{\text{Dia. of choke}}$		1.27	1.39

TABLE 2.

VALVE EVENTS - FORE GEAR

ENGINE NO. 60845 Class V.2 MARCH 1952

Walschaerts Valve Gear for outside cylinders with Gresley Type conjugation for the inside cylinder.

Steam Lap. 1.5/8" Outside Cylinders. 1.11/16" Inside Cylinder.
Exhaust Lap. Outside and Inside Cylinders - Line on Line.

% Cut Off	Cyl	Pre-ad %		Lead		Port Open		Cut-Off %		Exhaust Opens %		Exhaust Closes %	
		FP	BP	FP	BP	FP	BP	FP	BP	FP	BP	FP	BP
15	R	99.25	99.5	8/64	7/64	7/32	7/32[B]	15.5	16.5	66	65.1	35.9	34
15	L	99.25	99.5	8/64	7/64	7/32	7/32[B]	15.5	16.75	65.8	64.9	35.1	34.2
15	M	99.5	99.8	3/64	3/64	5/32	9/64	14.5	15	65	63	37	35
25	R	99.6	99.5	8/64	7/64	19/64	21/64	24.5	26	74	71	29	26
25	L	99.6	99.5	8/64	7/64	19/64	21/64	24.5	26	73.2	71.5	28.5	26.8
25	M	99.7	99.6	3/64	3/64	16/64	17/64	22	26	73	72	28	26
35	R	99.6	99.6	8/64	7/64	3/8	7/16	35	36	77	75	25	23
35	L	99.7	99.6	8/64	7/64	3/8	7/16	35	35.5	77.5	74.5	24.5	22.5
35	M	99.6	99.6	3/64	3/64[F]	5/16	3/8	32	36.5	76.5	75.5	24.5	23.5
45	R	99.7	99.6	8/64	7/64	9/16	21/32	44.5	46	82.5	81	19	17.5
45	L	99.7	99.6	8/64	7/64	9/16	21/32	44.5	45	82.5	80.5	19.5	17.5
45	M	99.6	99.6	4/64	4/64	1/2	19/32	40	46	83	77	23	17
55	R	99.8	99.8	8/64	7/64	13/16	15/16	56	53	86.5	84	16	13.5
55	L	99.8	99.8	8/64	7/64	13/16	15/16	56	53.5	87	84	16	13
55	M	99.8	99.8	4/64[F]	4/64[F]	3/4	7/8	51	51.5	87.5	85.5	14.5	12.5
65	R	99.9	99.9	8/64[F]	7/64[F]	1.7/64	1.19/64	67	63	90	86.5	13.5	9.5
65	L	99.9	99.9	8/64[F]	7/64[F]	1.3/32	1.1/4	67	64.5	90	87.5	12.5	10
65	M	L/L	L/L	5/64	5/64	1.3/64	1.17/64	63.5	61	90	88.5	11.5	9.5

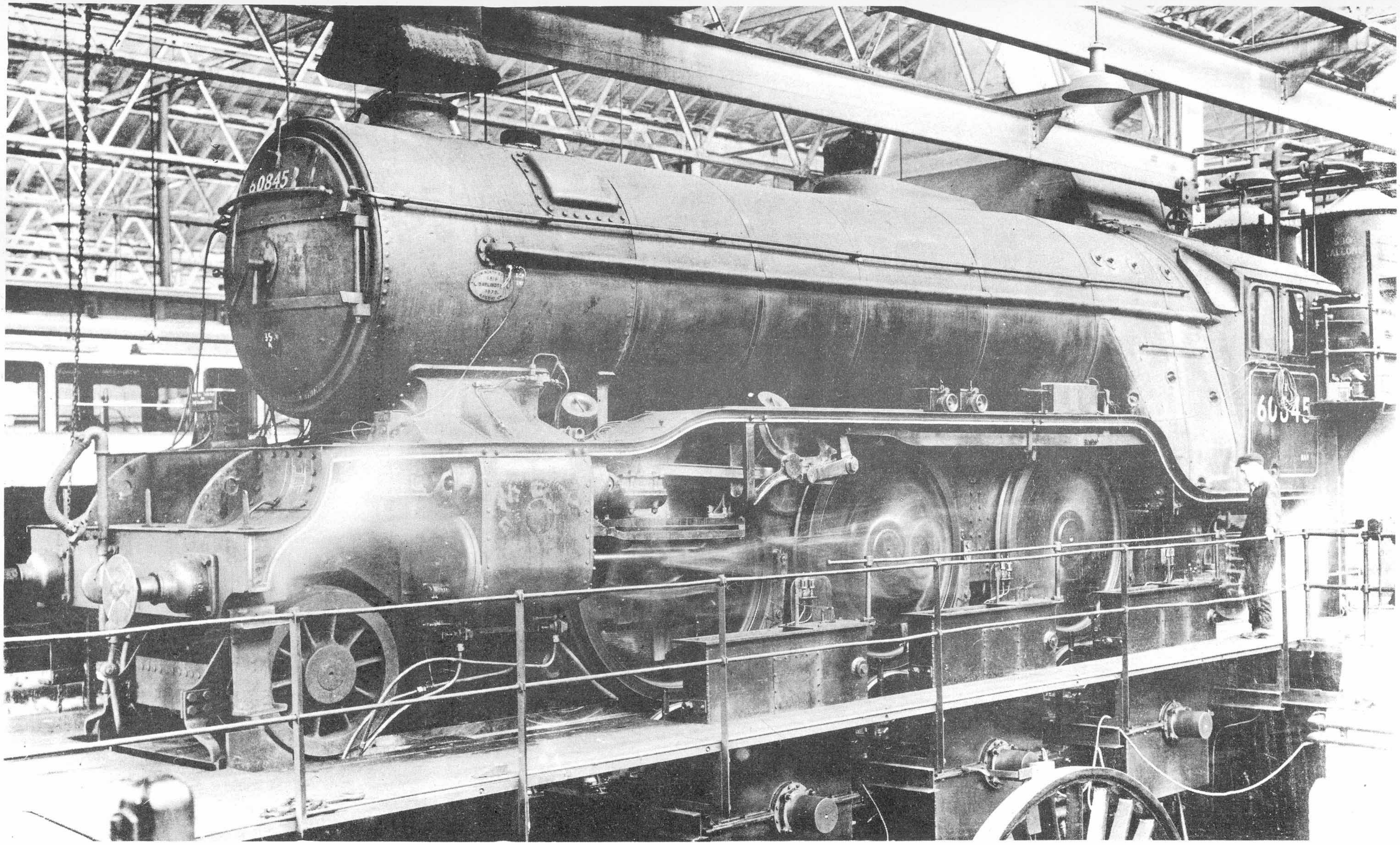
F.P. = Front port

B.P. - Back port

TABLE 3.

CALORIFIC VALUES AND PROXIMATE ANALYSES
OF A REPRESENTATIVE SAMPLE OF COAL

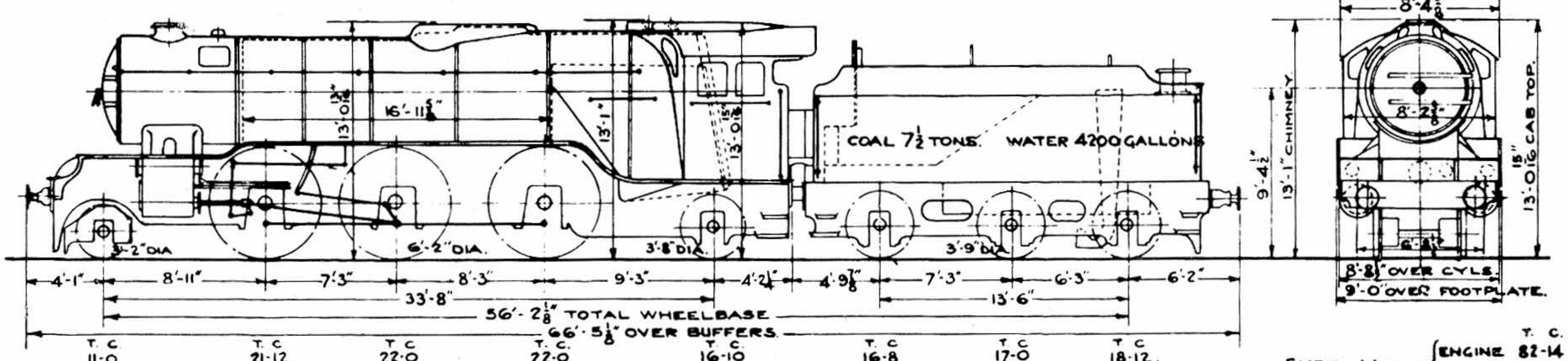
Coal		Blidworth Cobbles Grade 2B	
Calorific Value (Gross)		As received	Dry
British Thermal Units per lb.		12,680	13,470
Proximate Analysis			
Moisture	%	5.9	—
Volatile matter, less moisture	%	33.3	35.5
Fixed Carbon	%	53.7	57.0
Ash	%	7.1	7.5
Total Sulphur	%	1.2	1.29



Efficiency Trials with the Improved Draughting Arrangements on the Swindon Stationary Plant

A Controlled Road Test with the W.R.
Dynamometer Car Load 610 Tons Speed 60 M.P.H.
near Swindon W.R.

TYPE V2.



EMPTY WEIGHT { ENGINE T. C. 82-14; TENDER 25-7.

BUILT FROM 1936

LEADING DIMENSIONS & RATIOS.

BOILER:- MAX. DIA. OF BARREL. 6'-5"
OVERALL LENGTH OF FIREBOX. 9'-5 3/8"
" " " " " AT BOTTOM 6'-8 1/4"
" WIDTH " " " " 7'-9"
THICKNESS OF BARREL PLATES. 23/32" & 25/32"
" " OUTSIDE WRAPPER. 9/16"
" " COPPER FIREBOX PLATES.
WRAPPER & BACKPLATE. 9/16"
TUBEPLATE. 9/16" & 1 1/4"

TUBES. SMALL.
NUMBER. 121.
DIA. OUTSIDE 2 1/4"
SUPERHEATER FLUE. NUMBER 43.
DIA. OUTSIDE 5 1/4"
SUPERHEATER ELEMENTS. NUMBER 43.
DIA. OUTSIDE 1·244"

GRATE:- AREA 41·25 SQ. FT

HEATING SURFACE
FIREBOX. 215. SQ. FT.
TUBES. 1211·57. " "
FLUES. 1004·5 " "
TOTAL EVAPORATIVE 2431 " "
SUPERHEATER 679·67 " "
TOTAL. 3110·74 " "

WORKING PRESSURE. 220 LBS/SQ. IN.

SAFETY VALVES.
TYPE & DIAMETER. TWO ROSS POP 3 1/2" DIA.

AXLES

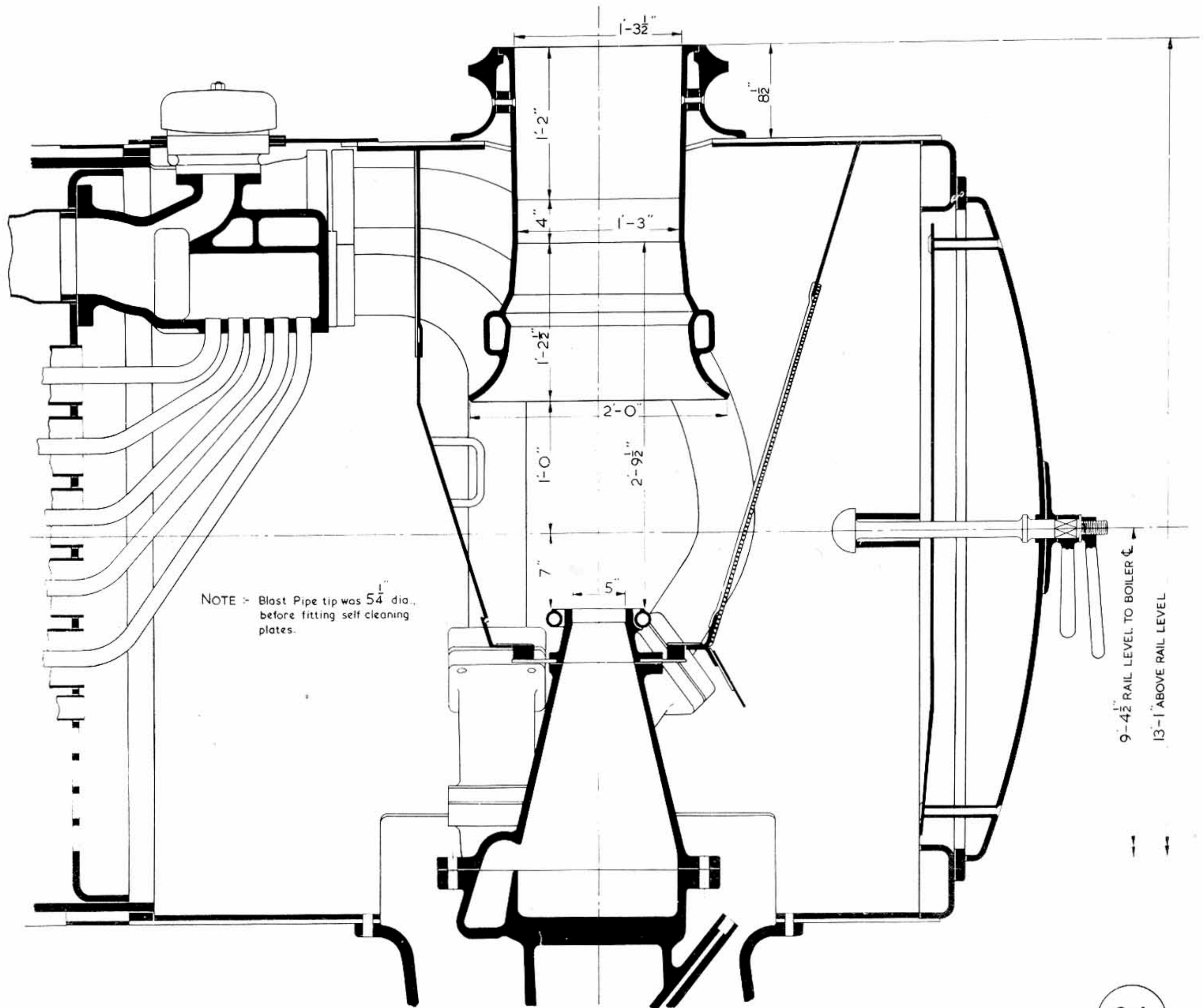
		DIA. LENGTH
JOURNALS	PONY	6 1/2" x 9"
	COUPLED WHEELS	9 1/2" x 11"
	TRAILING "	6" x 11"
CRANK PINS.	OUTSIDE	5 1/2" x 6"
	INSIDE.	8 1/4" x 6"
COUPLING PINS.	LEADING	4 3/4" x 3 1/2"
	DRIVING.	6" x 4 1/4"
	TRAILING	4" x 4 1/4"

CYLINDERS:- NUMBER 3.
DIAMETER & STROKE 18 1/2" x 26"

MOTION:- TYPE: OUTSIDE. WALSCHAERT
INSIDE. GRESLEY.
TYPE OF VALVE. PISTON.
DIA. " " 9"
MAX. VALVE TRAVEL 5 3/8"
STEAM LAP INSIDE CYLS. 1 5/16"
" " OUTSIDE " 1 5/8"
CUT OFF IN FULL GEAR. 65%

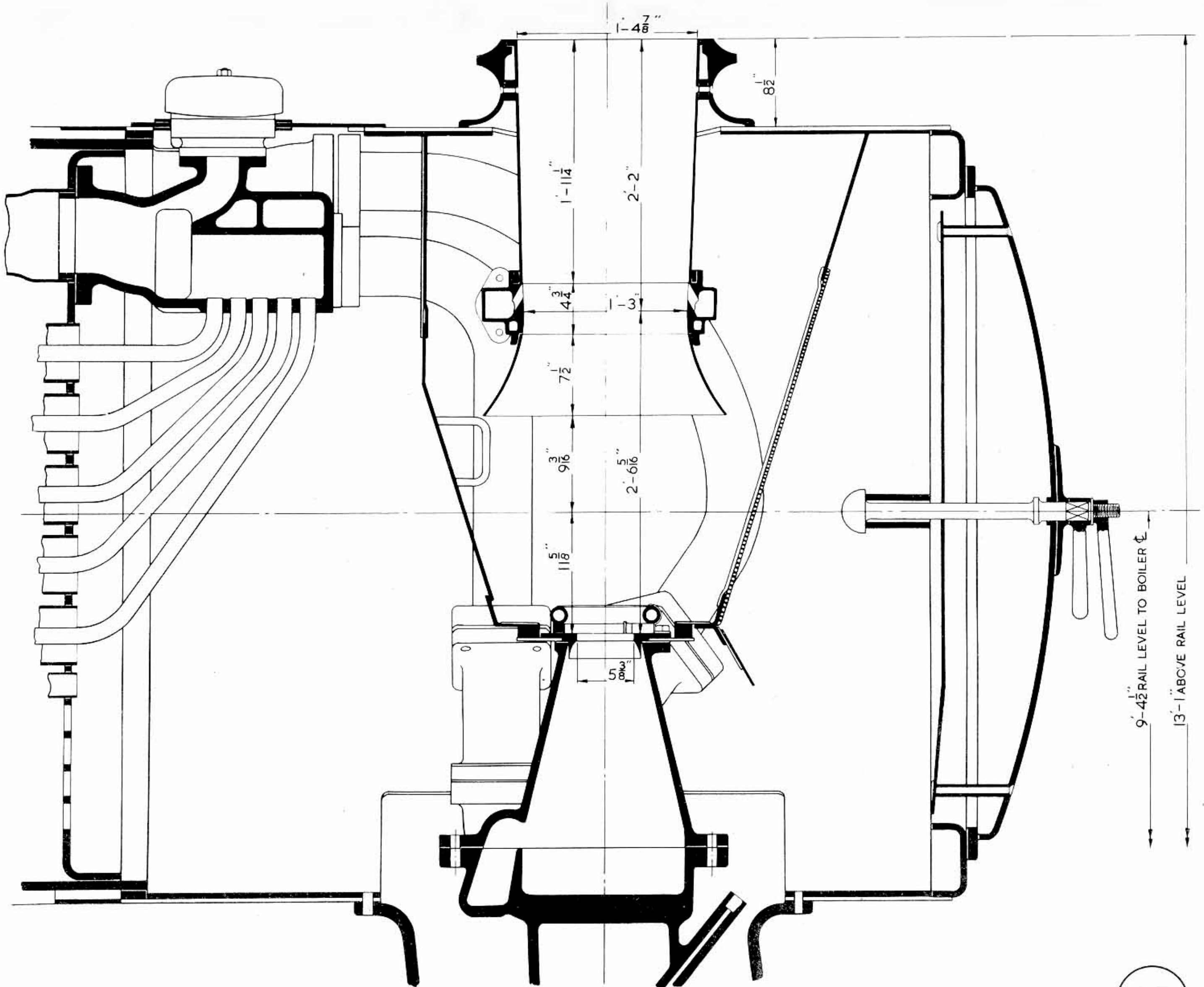
TRACTIVE EFFORT AT 85% BOILER PRESS. 33730 LBS.
TOTAL ADHESIVE WEIGHT. 146944 LBS
ADHESIVE WEIGHT ÷ TRACTIVE EFFORT 4·3
BRAKE - VACUUM; OR STEAM & VACUUM EJECTOR

1


1'-3½"
8½"
1'-2"
4"
1'-3"
1'-2½"
2'-0"
1'-0"
2'-9½"
7"
5"
NOTE :- Blast Pipe tip was 5¼" dia., before fitting self cleaning plates.
9'-4½" RAIL LEVEL TO BOILER ℄
13'-1" ABOVE RAIL LEVEL

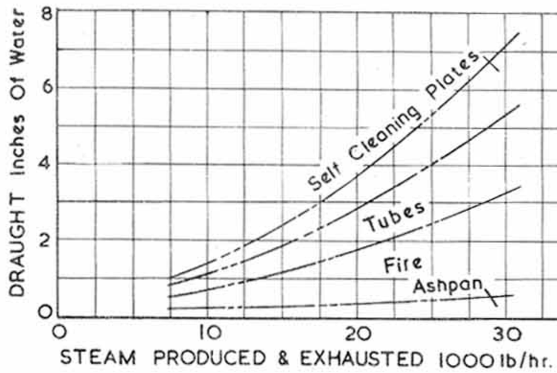
ORIGINAL

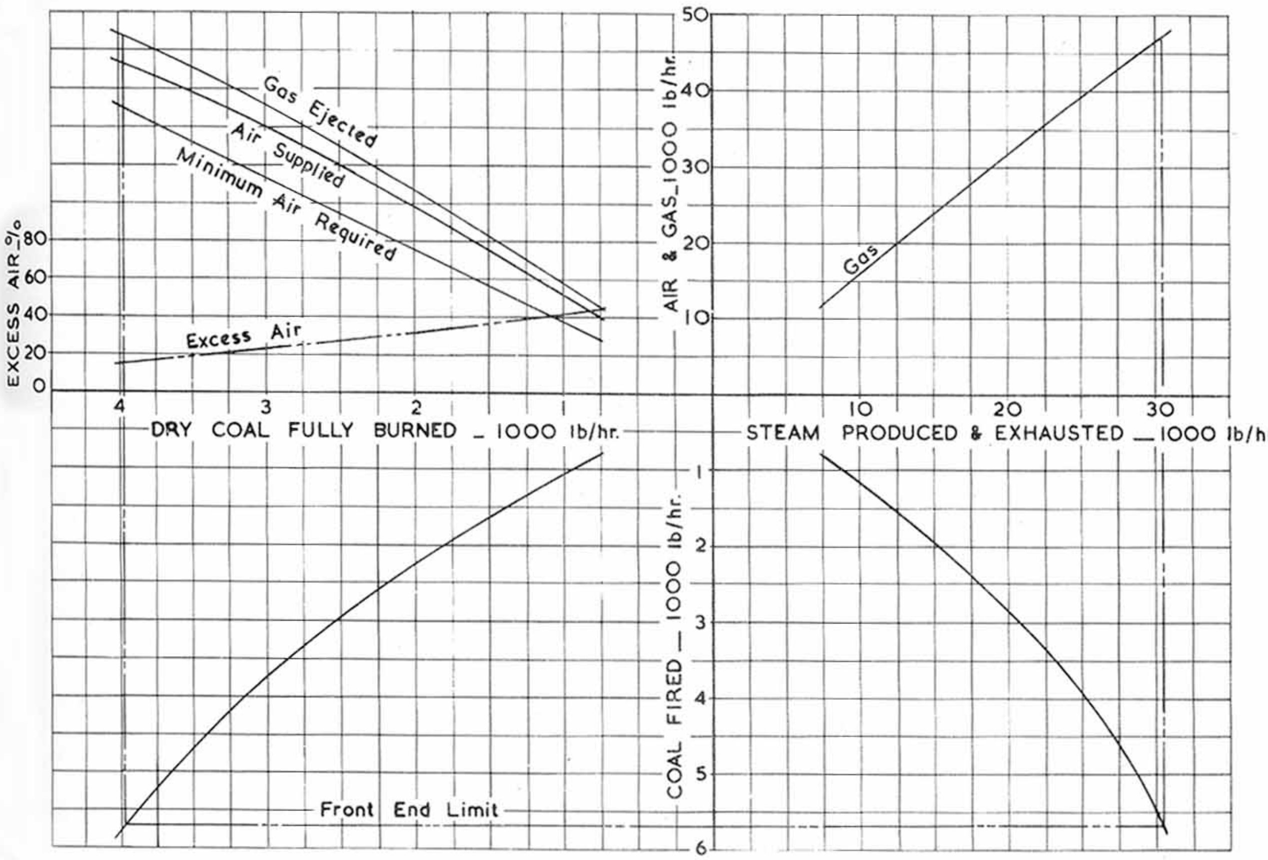
2A


1'-4 7/8"
8 1/2"
1'-11 1/4"
2'-2"
4 3/4"
1'-3"
7 1/2"
9 3/16"
2'-6 5/16"
11 5/8"
5 3/8"
9'-4 1/2" RAIL LEVEL TO BOILER ℄
13'-1" ABOVE RAIL LEVEL

IMPROVED

2B

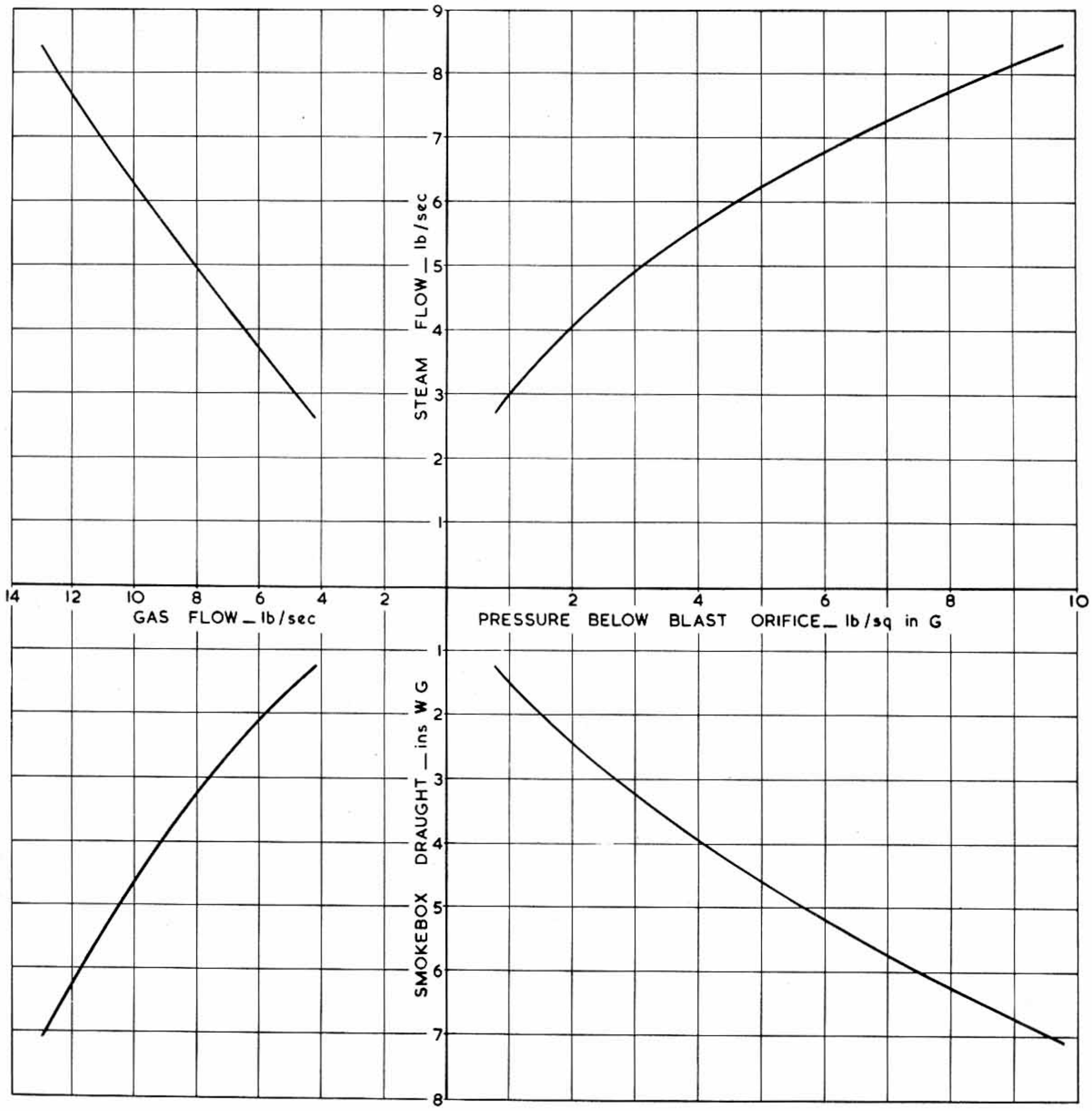




STEAM—AIR—COMBUSTION

BLIDWORTH COAL__12680 BThU/lb

NE/60845/53

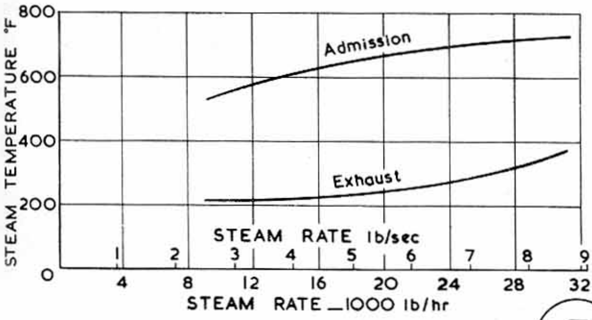


STEAM _ GAS _ DRAUGHT & BLAST PIPE PRESSURE

BLIDWORTH COAL _ 12680 BThU/lb

4

NE/60845/53



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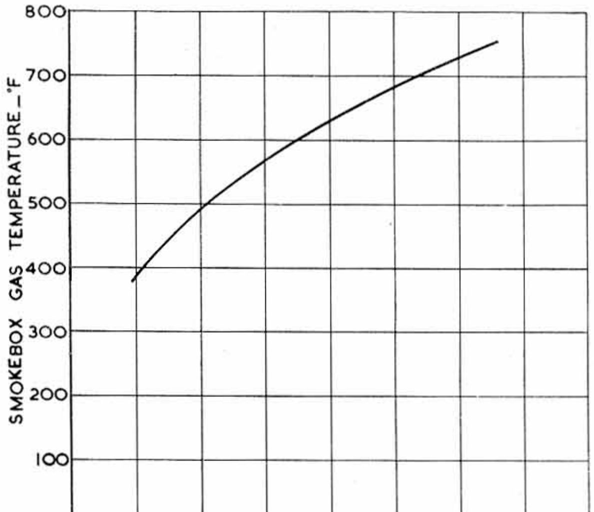
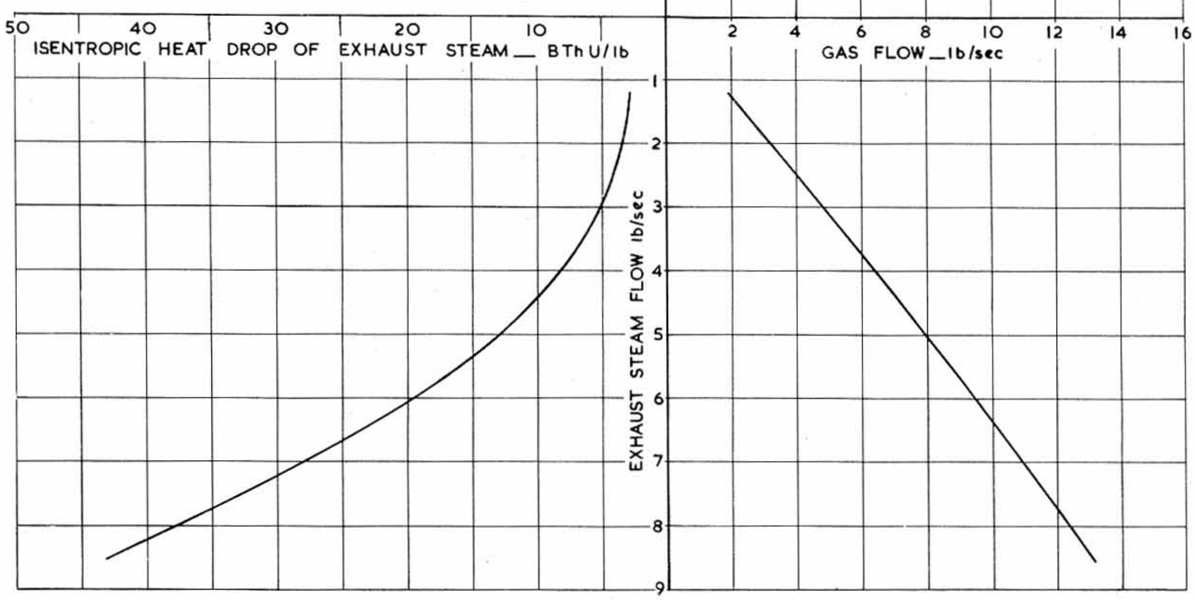




STEAM TEMPERATURES

RELATION: HEAT DROP OF EXHAUST-STEAM FLOW—

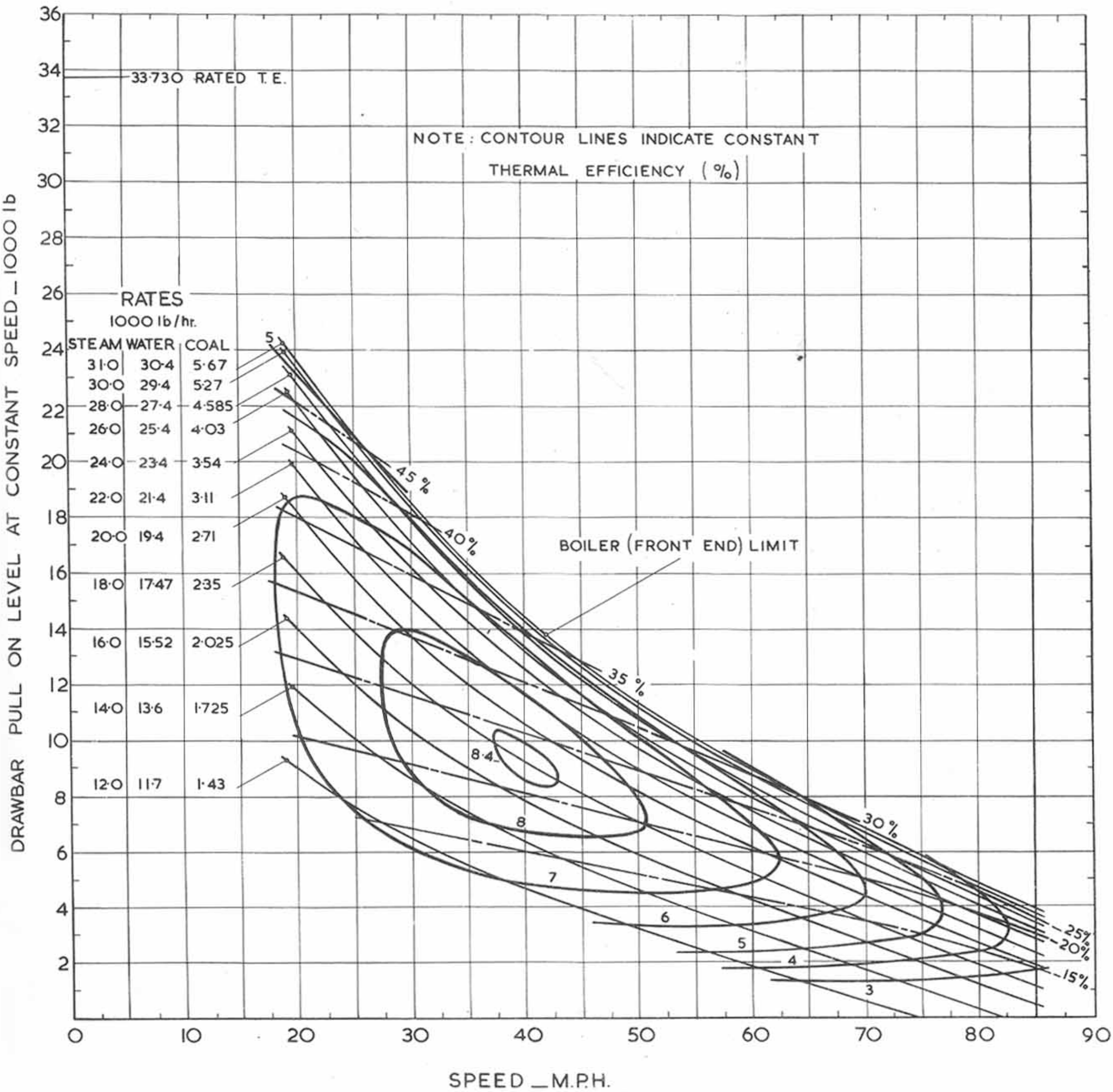
GAS FLOW-GAS TEMPERATURE

BLIDWORTH COAL _ 12680 BThU/lb

6

NE/60845/53

Cut Offs Shown refer to Maximum Steam Chest Pressure

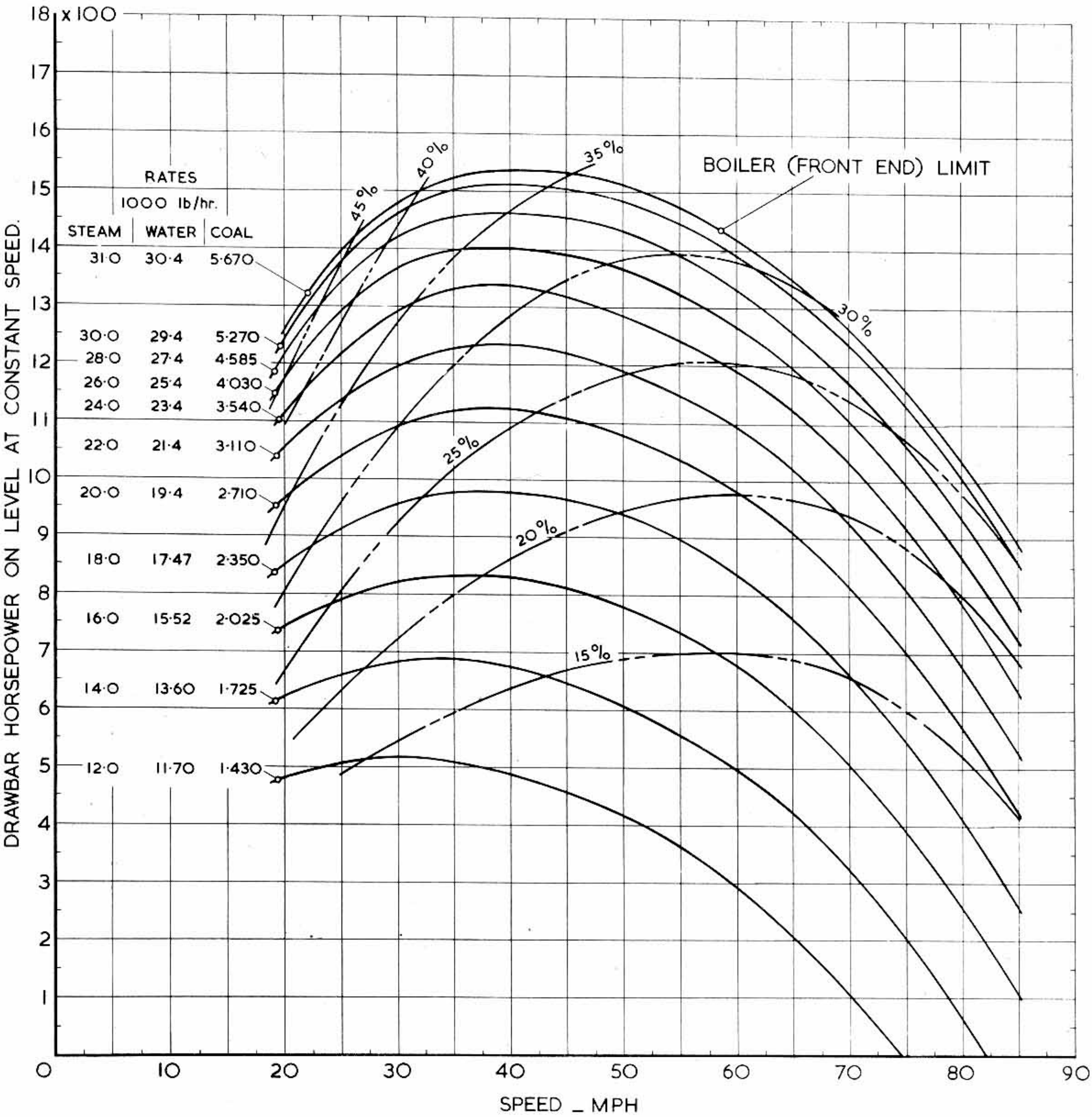


BLIDWORTH COAL _ 12680 BThU/lb

EXHAUST STEAM INJECTOR

DRAWBAR TRACTIVE EFFORT CHARACTERISTICS

NE/60845/53



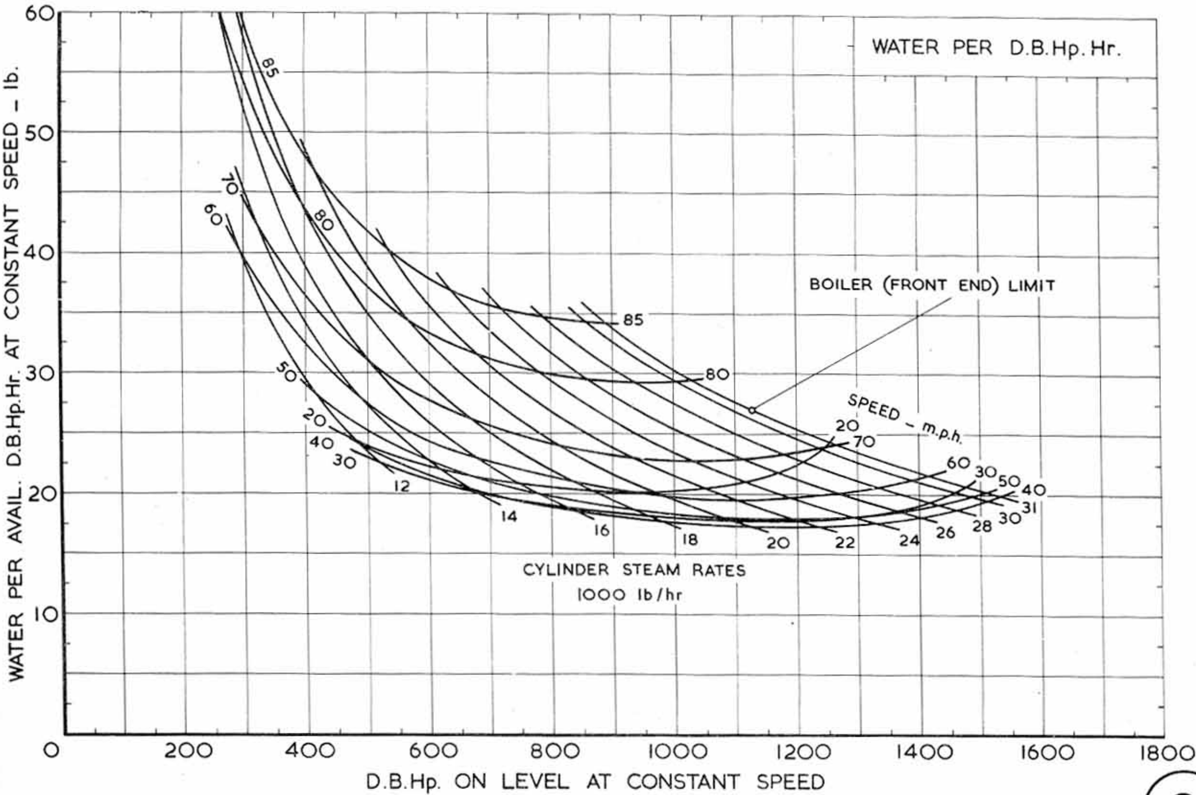
BLIDWORTH COAL _ 12680 BThU/lb

EXHAUST STEAM INJECTOR

DRAWBAR HORSEPOWER CHARACTERISTICS

8

NE/60845/53



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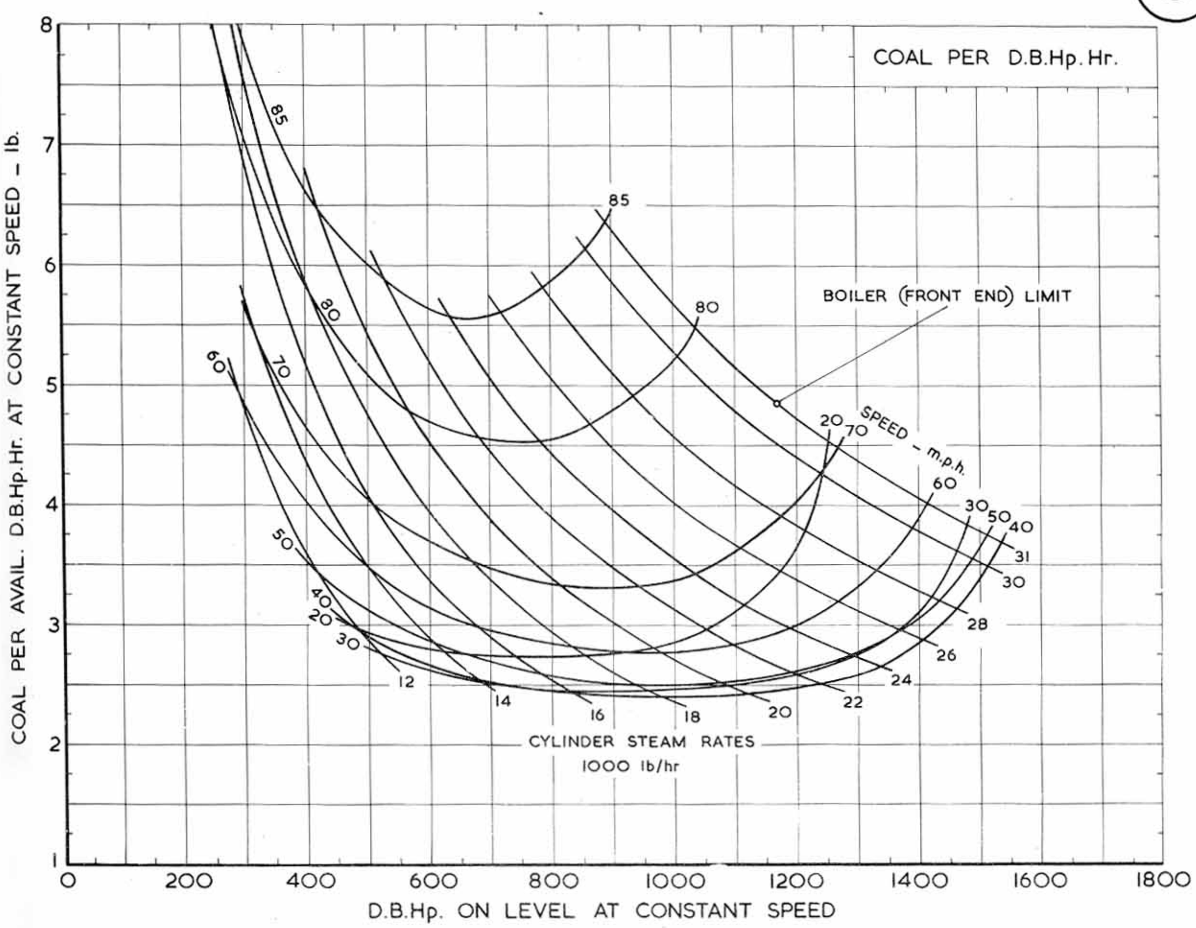


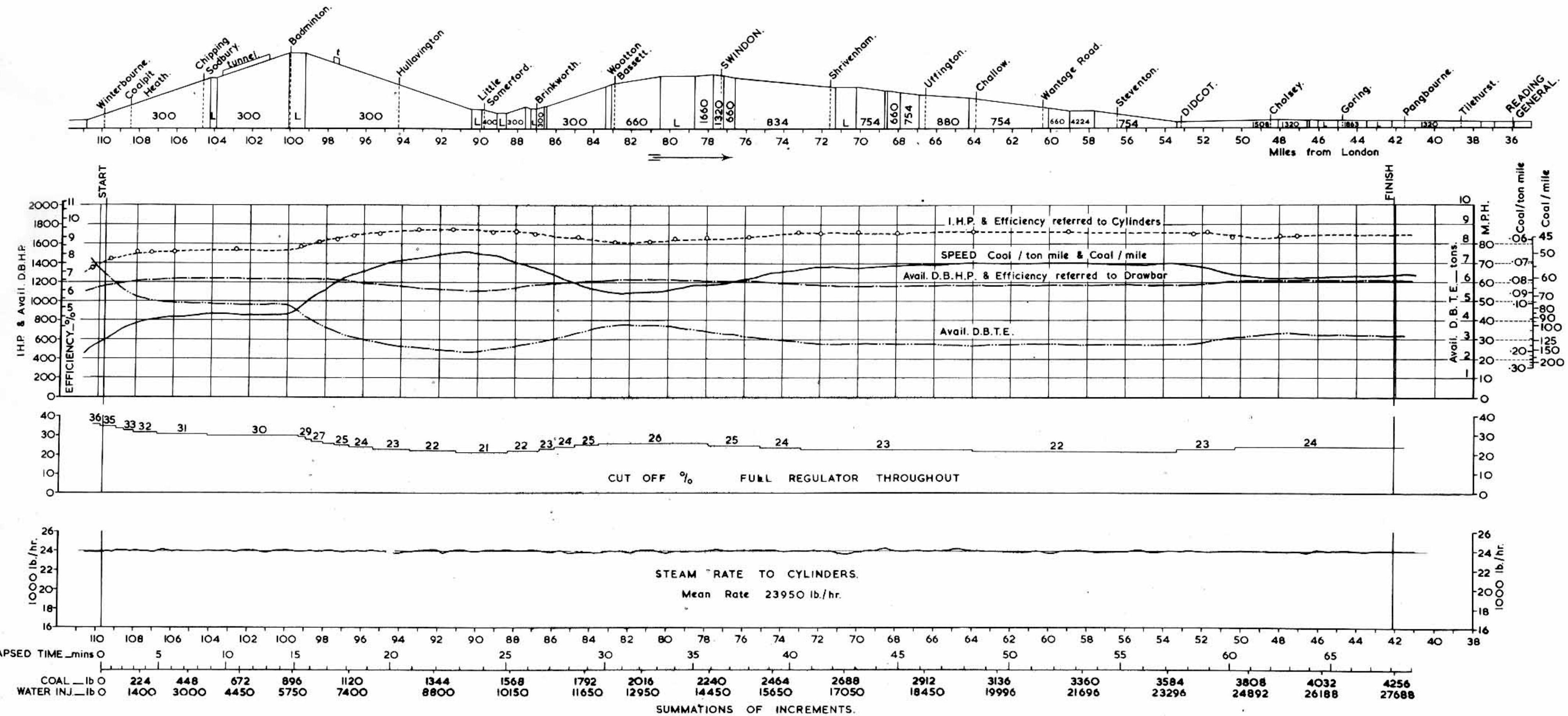
BLIDWORTH COAL _ 12680 BThU/lb

EXHAUST STEAM INJECTOR

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

10

NE/60845/53



CONTROLLED ROAD TEST NO.12.R. 5-3-53.

Testing Unit _ W.R. Dynamometer Car.
Blidworth Coal of 12600 B.Th.U./lb. as fired.
Live Steam Injector only.
Load 761·7 tons (25 coaches)
Natural wind _ Velocity _ Low and indeterminate.
Direction _ Random.

Mean Steam and Water Rates_lb./hr.

	Actual	Equiv. fea 212°F
Cylinder Steam	23950	33400
Ejector Steam	400	488
Total	24350	33888

	Temps. °F
Admission Steam	690
Ejector Steam	385
Feed Water	44

Mean Coal Rates __ lb./hr.

Evap. of Cylinder Steam	3695
Ejector Steam	55
Total	3750
lb./sq. ft. grate / hr.	91
Boiler Efficiency __ %	69·6

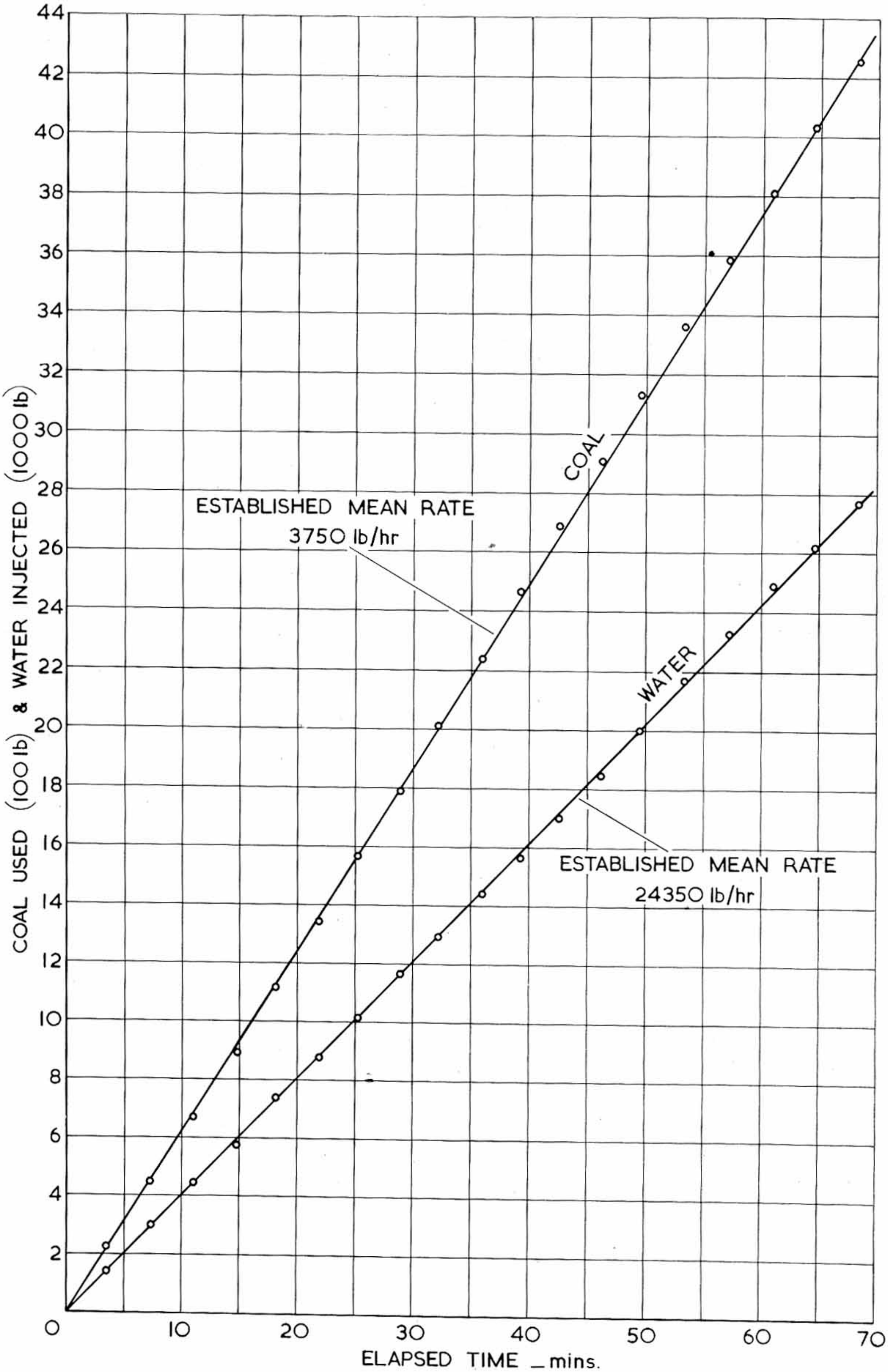
Average Consumptions _ lb.

	inclusive	nett for power
Coal per avail. D.B.H.P. hr.	3·175	3·125
Coal per I.H.P. hr	2·26	2·225
Water per avail. D.B.H.P. hr.	20·6	20·25
Water per I.H.P. hr.	14·68	14·43

Average Speed __ 64·5 m.p.h.

Adjustment for Exhaust Steam Injector

Reduce feed water consumption by 2·46 %
" coal " 3·74 %
Multiply efficiency and divide coal / ton mile and coal / mile by 1·037.

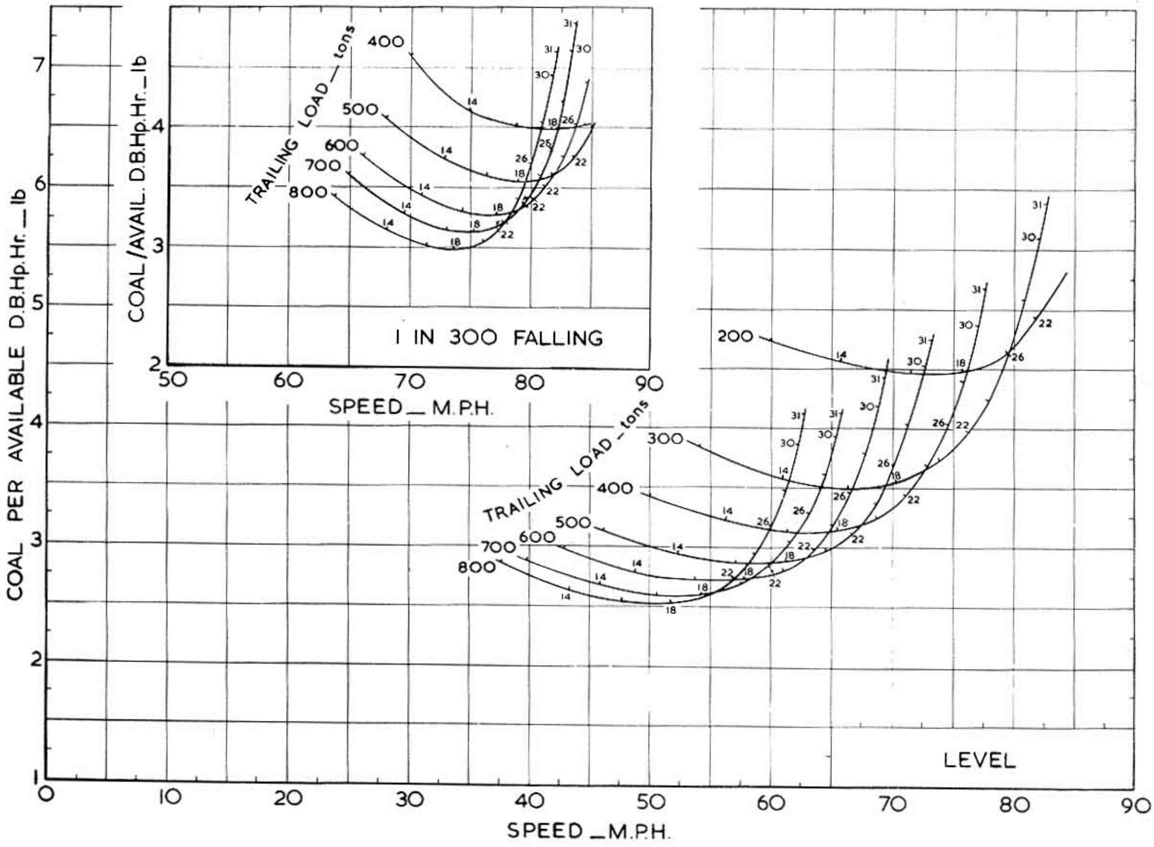


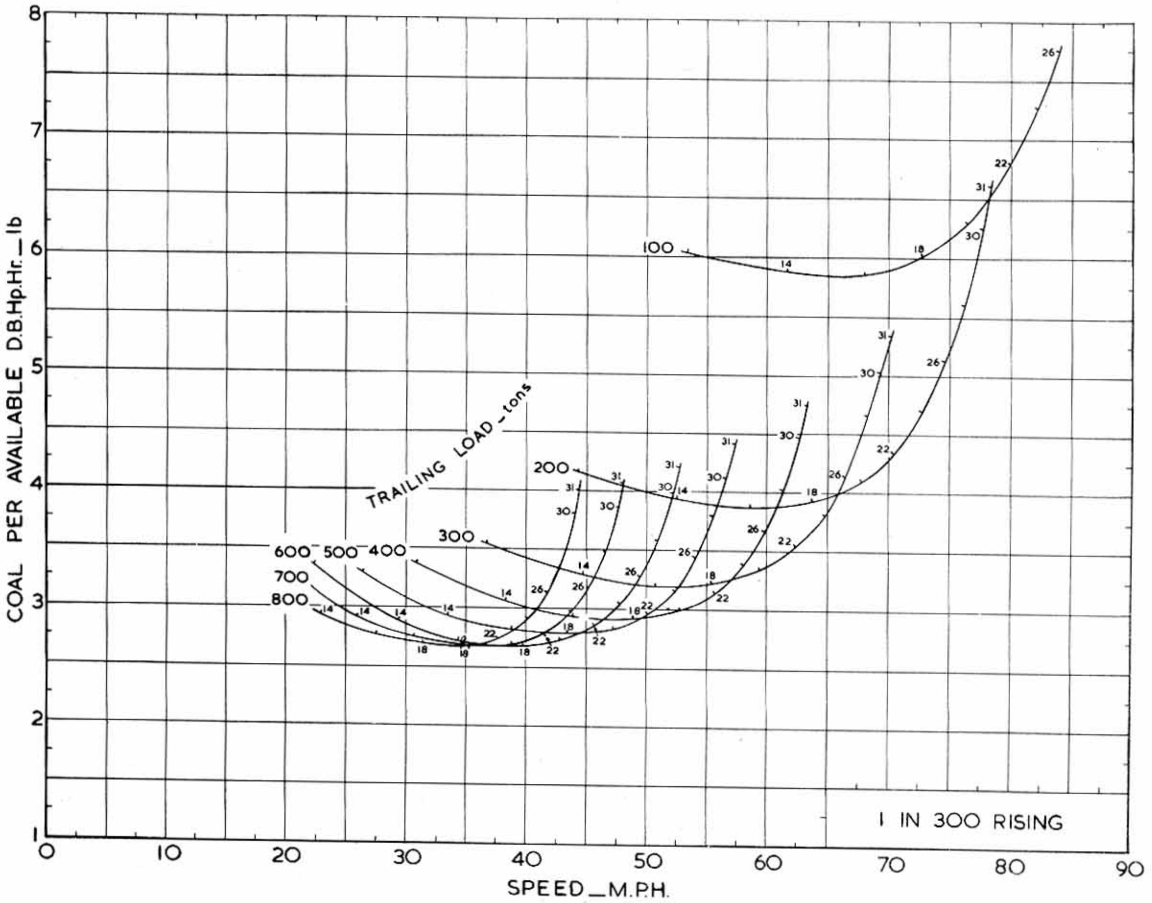
SUMMATIONS OF INCREMENTS
CONTROLLED ROAD TEST 12 R

BLIDWORTH COAL _ 12680 B.Th.U./lb.

NE/60845/53

12





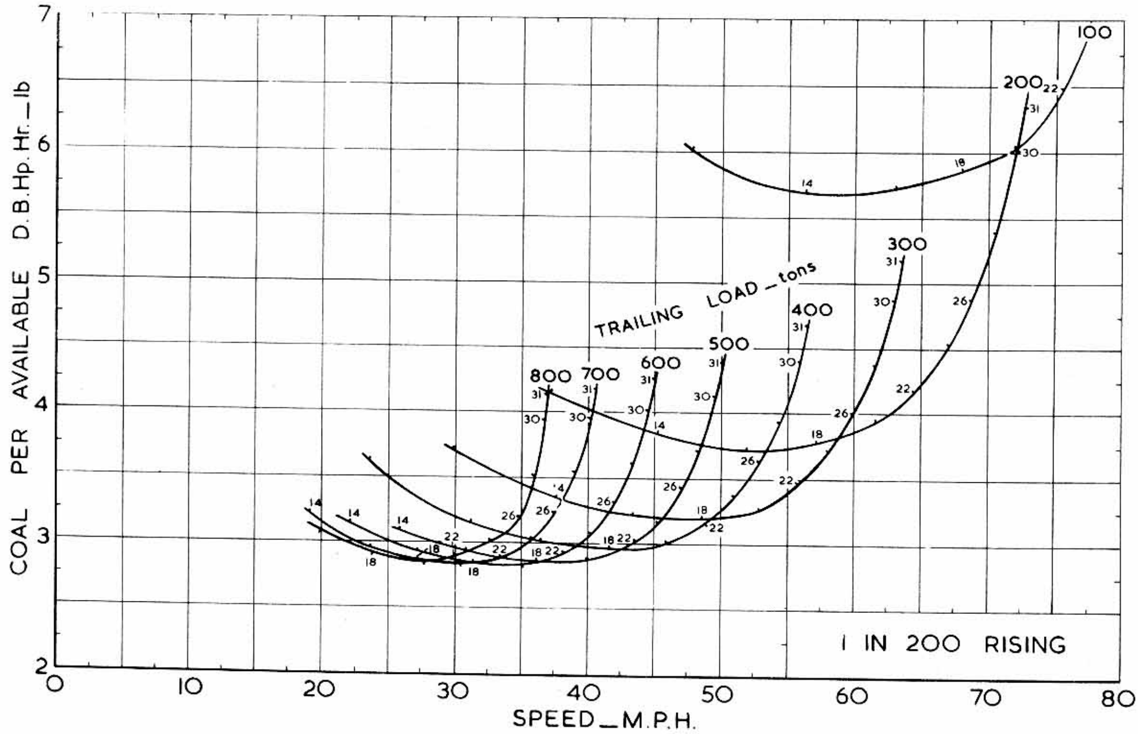
Small figures on curves refer to steam rates in Thousands lb/hr.

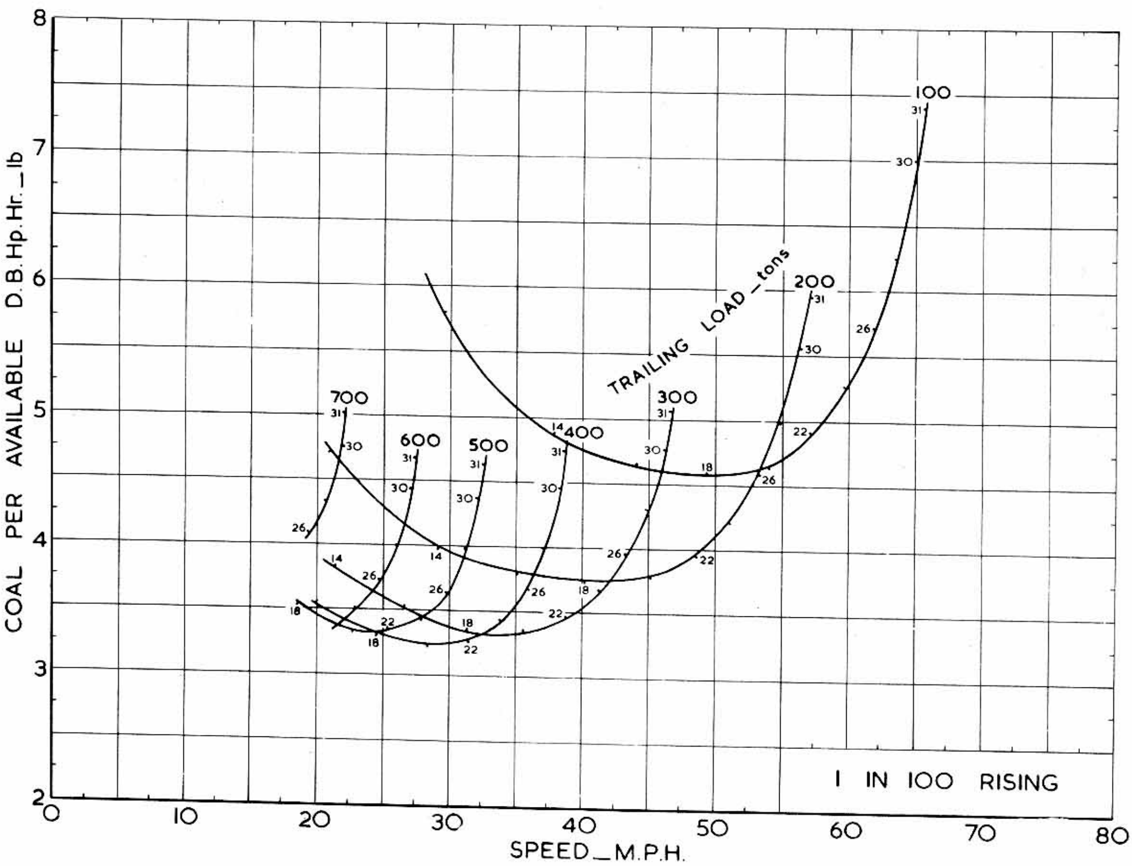
For cut offs relative to steam rate see graph No.7

BLIDWORTH COAL_12680 B.Th.U./lb

EXHAUST STEAM INJECTOR

PASSENGER SERVICE



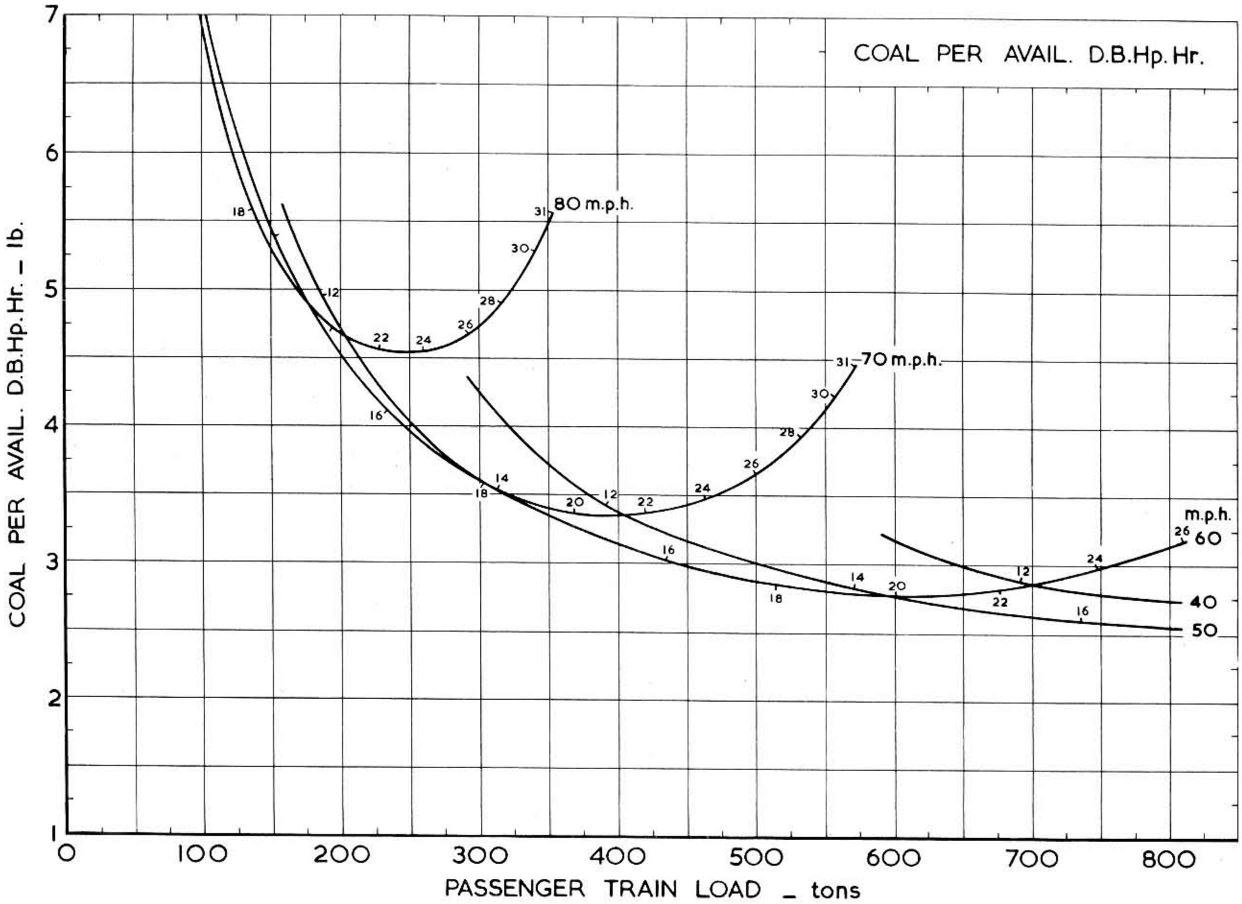


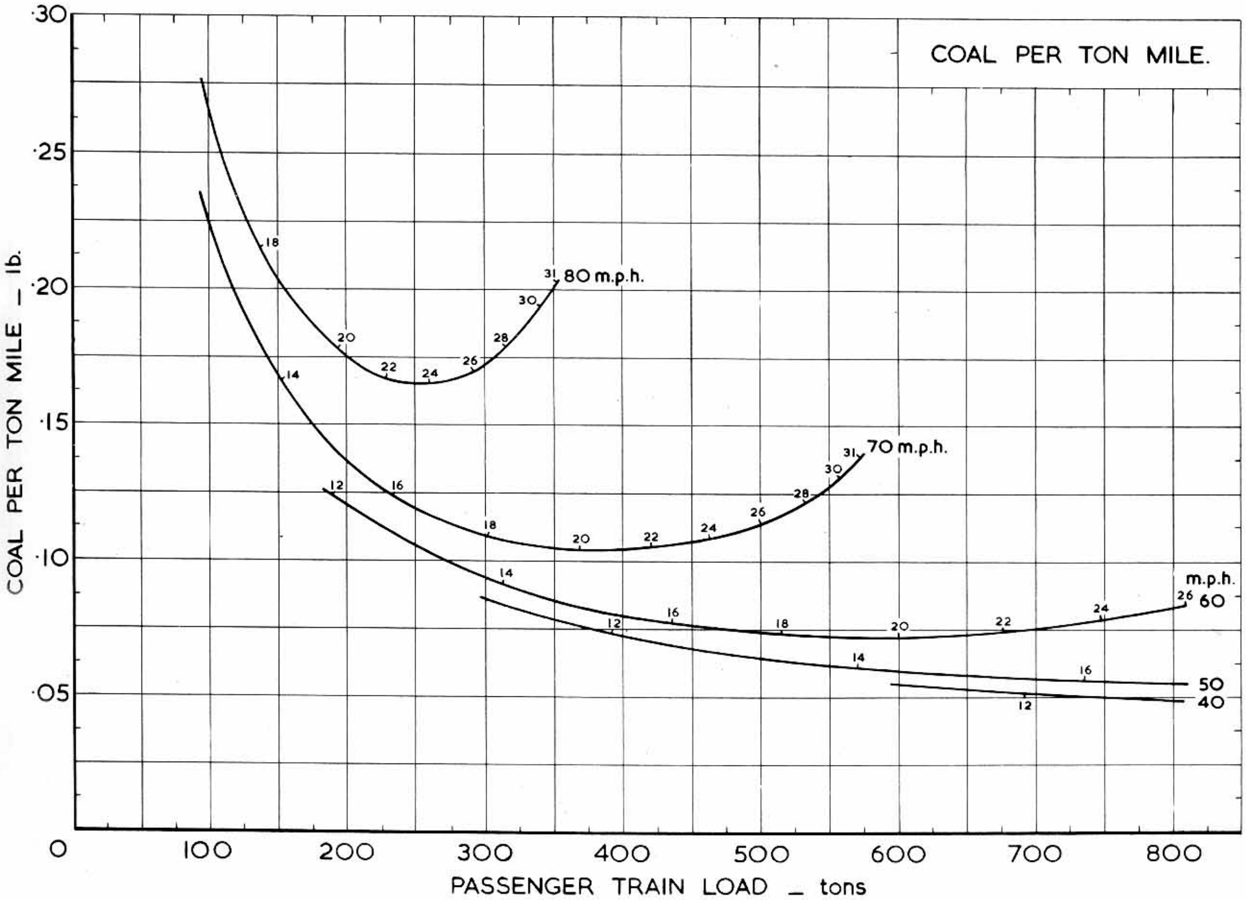
Small figures on curves refer to steam rates in Thousands lb/hr.
For cut offs relative to steam rates see graph No 7.

BLIDWORTH COAL _ 12680 B.Th.U./lb. EXHAUST STEAM INJECTOR

PASSENGER SERVICE

NE/60845/53





Small figures on curves refer to steam rates in Thousands lb/hr.
For cut offs relative to steam rates see graph No 7.

BLIDWORTH COAL _ 12680 BThU/lb

EXHAUST STEAM INJECTOR

PASSENGER SERVICE _ LEVEL

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

15

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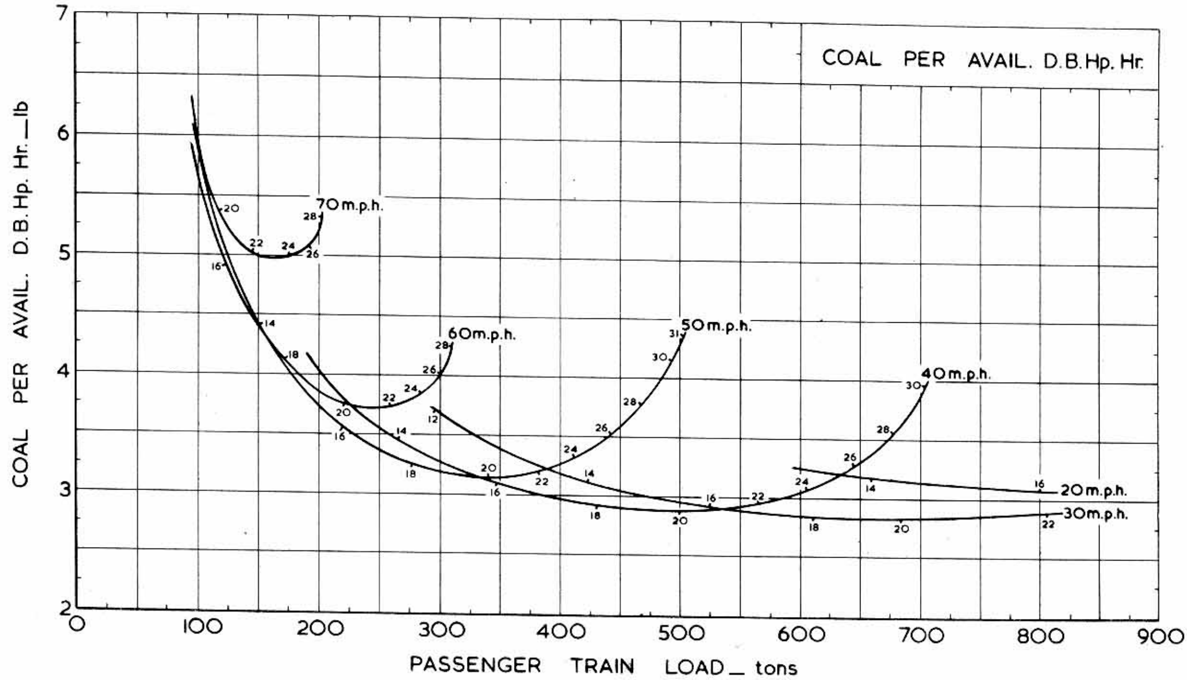
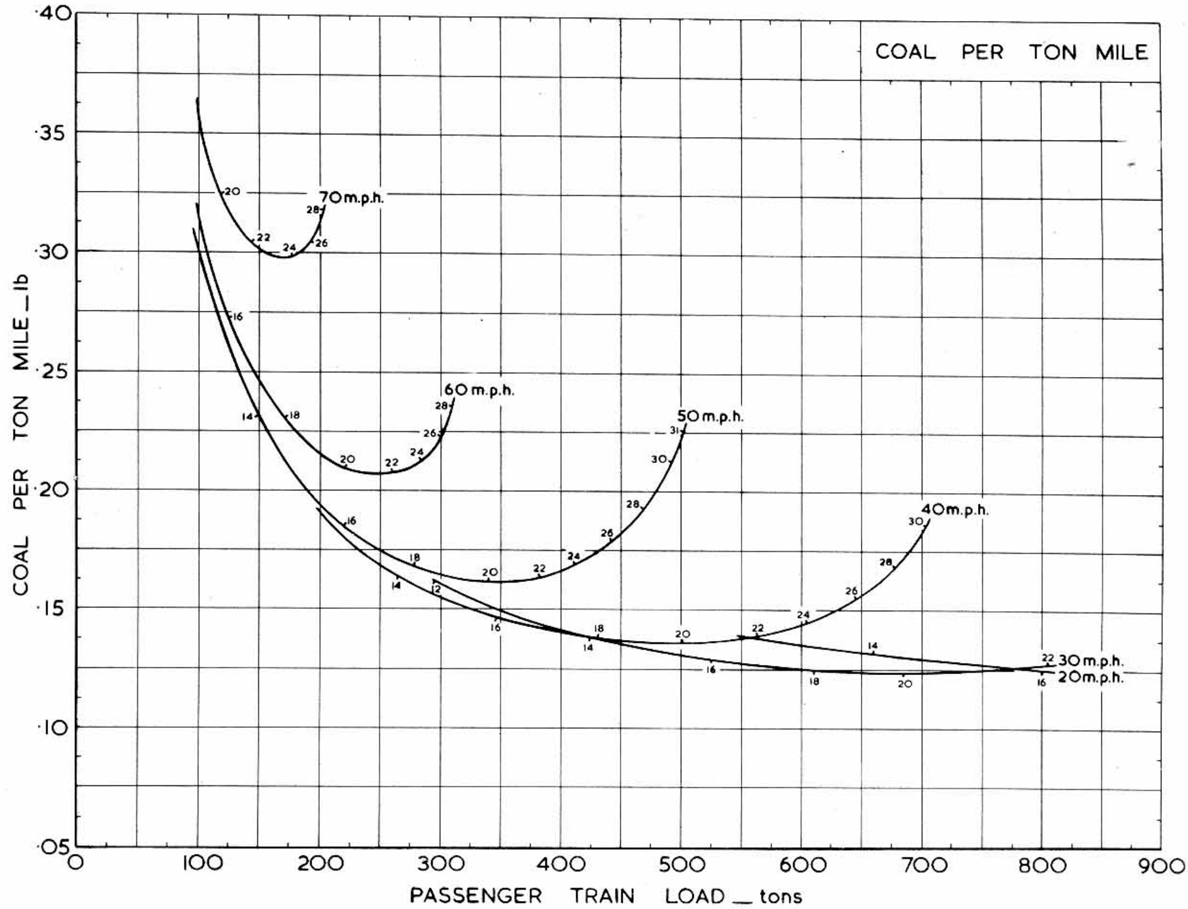




Small figures on curves refer to steam rates in Thousands lb/hr.
For cut offs relative to steam rates see graph No 7

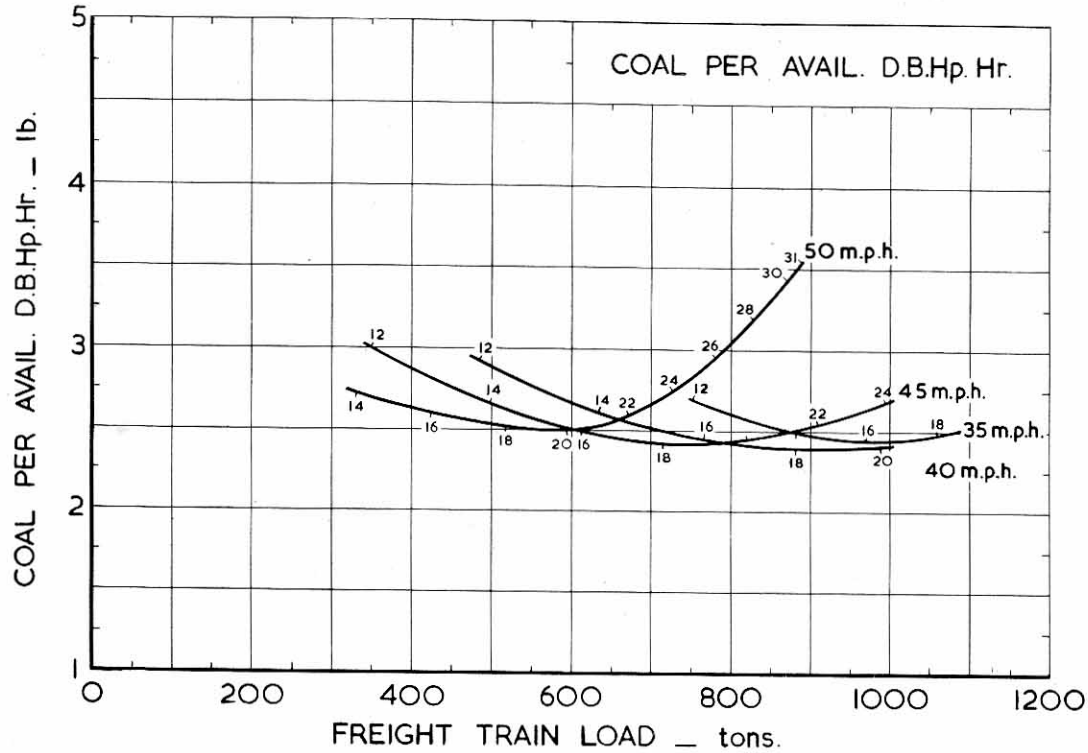
BLIDWORTH COAL _ 12680 B.Th.U./lb. EXHAUST STEAM INJECTOR

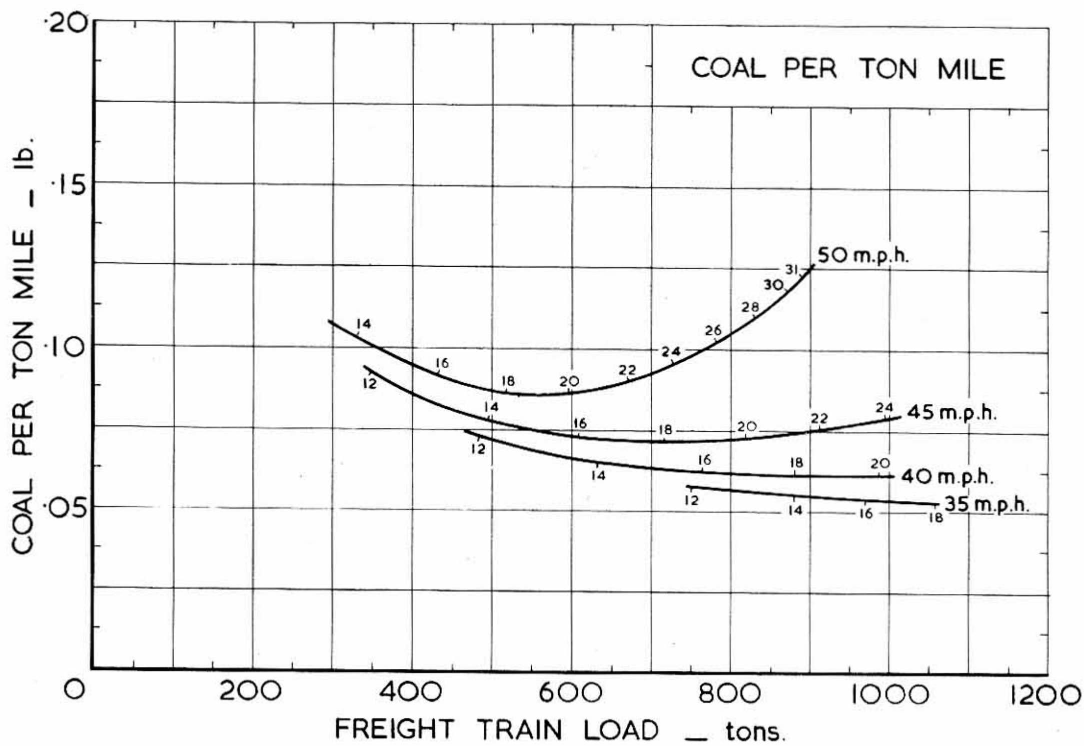
PASSENGER SERVICE _ 1 IN 200 RISING

EXAMPLES OF COST IN COAL OF DIFFERENT
TRAIN LOADS & SPEEDS

NE/60845/53

16





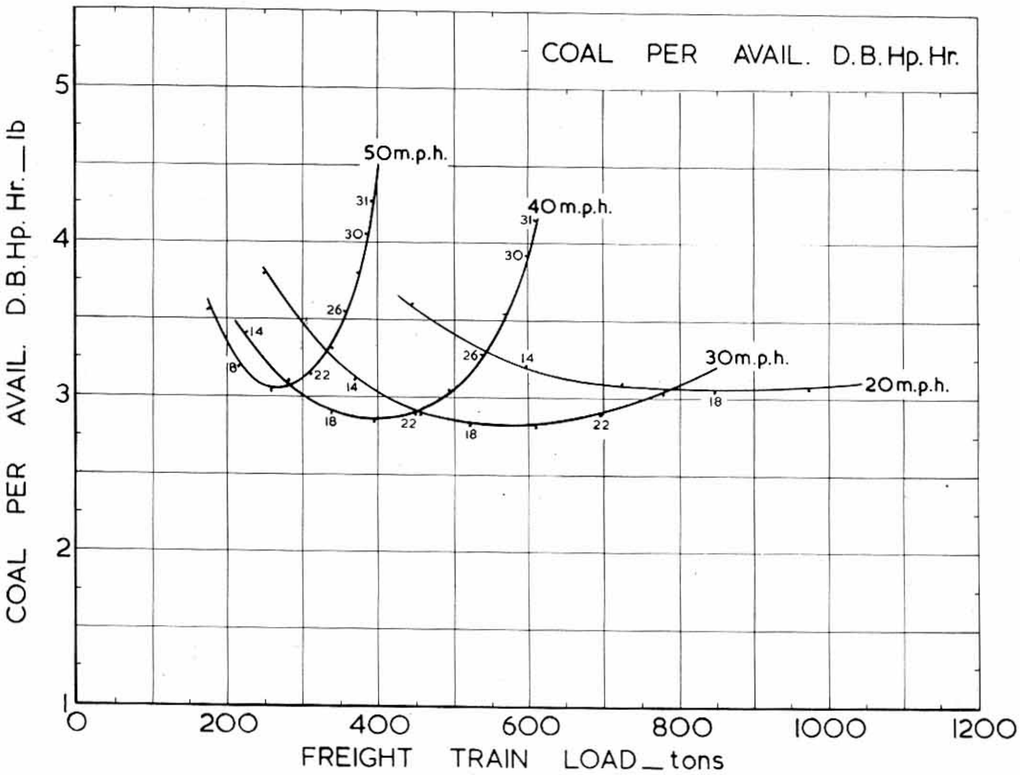
Small figures on curves refer to steam rates in Thousands lb/hr.
For cut offs relative to steam rates see graph No. 7.

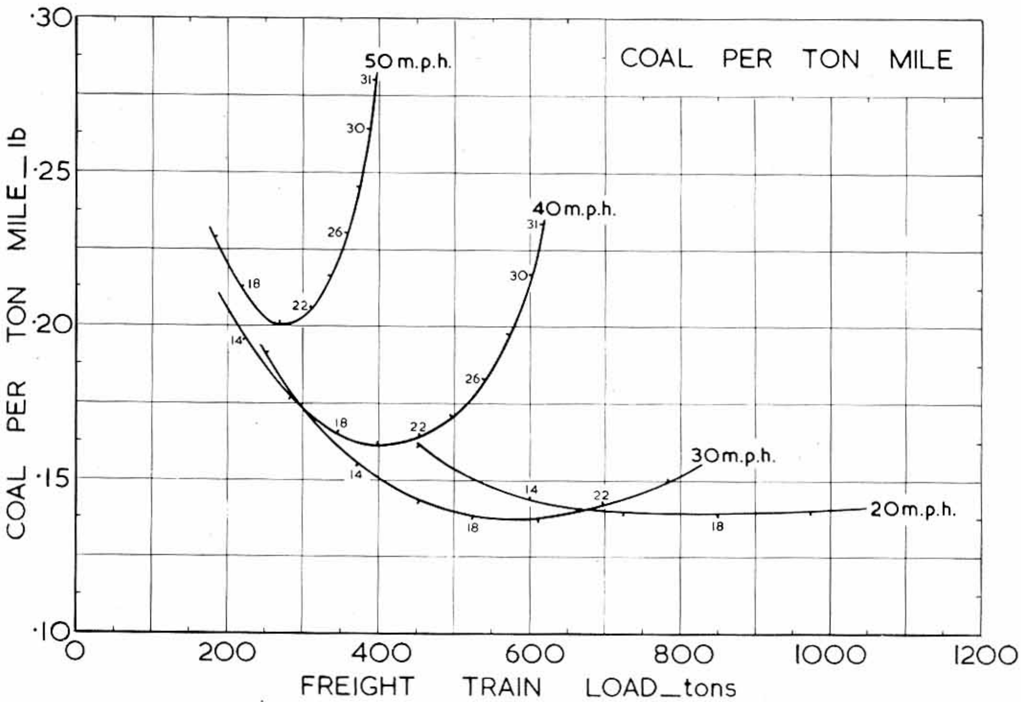
BLIDWORTH COAL _ 12680 BThU/lb EXHAUST STEAM INJECTOR

FREIGHT SERVICE _ LEVEL

EXAMPLES OF COST IN COAL OF DIFFERENT
TRAIN LOADS & SPEEDS

NE/60845/53





Small figures on curves refer to steam rates in Thousands lb/hr.

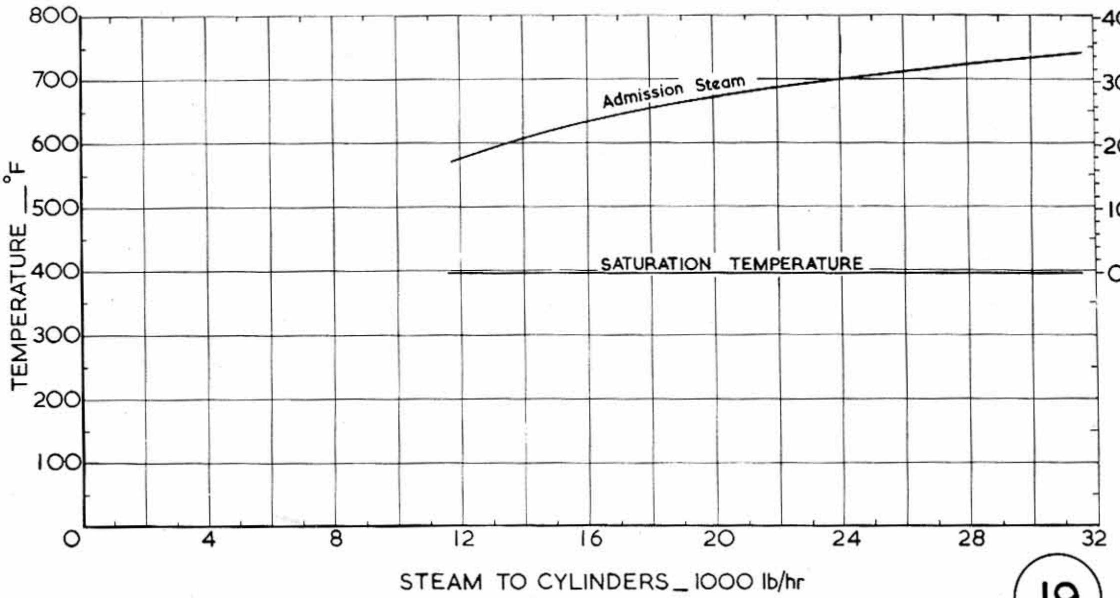
For cut offs relative to steam rates see graph No 7.

BLIDWORTH COAL_12680 B.Th.U./lb. EXHAUST STEAM INJECTOR

FREIGHT SERVICE_1 IN 200 RISING

EXAMPLES OF COST IN COAL OF DIFFERENT TRAIN LOADS & SPEEDS

NE/60845/53



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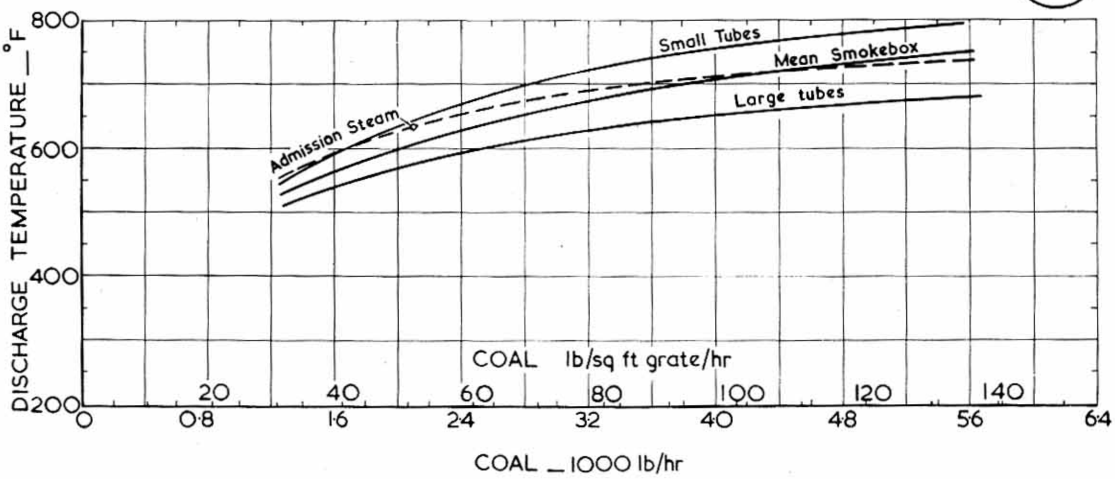

BLIDWORTH COAL 12680 BThU/lb

TEMPERATURES

NE/60845/53

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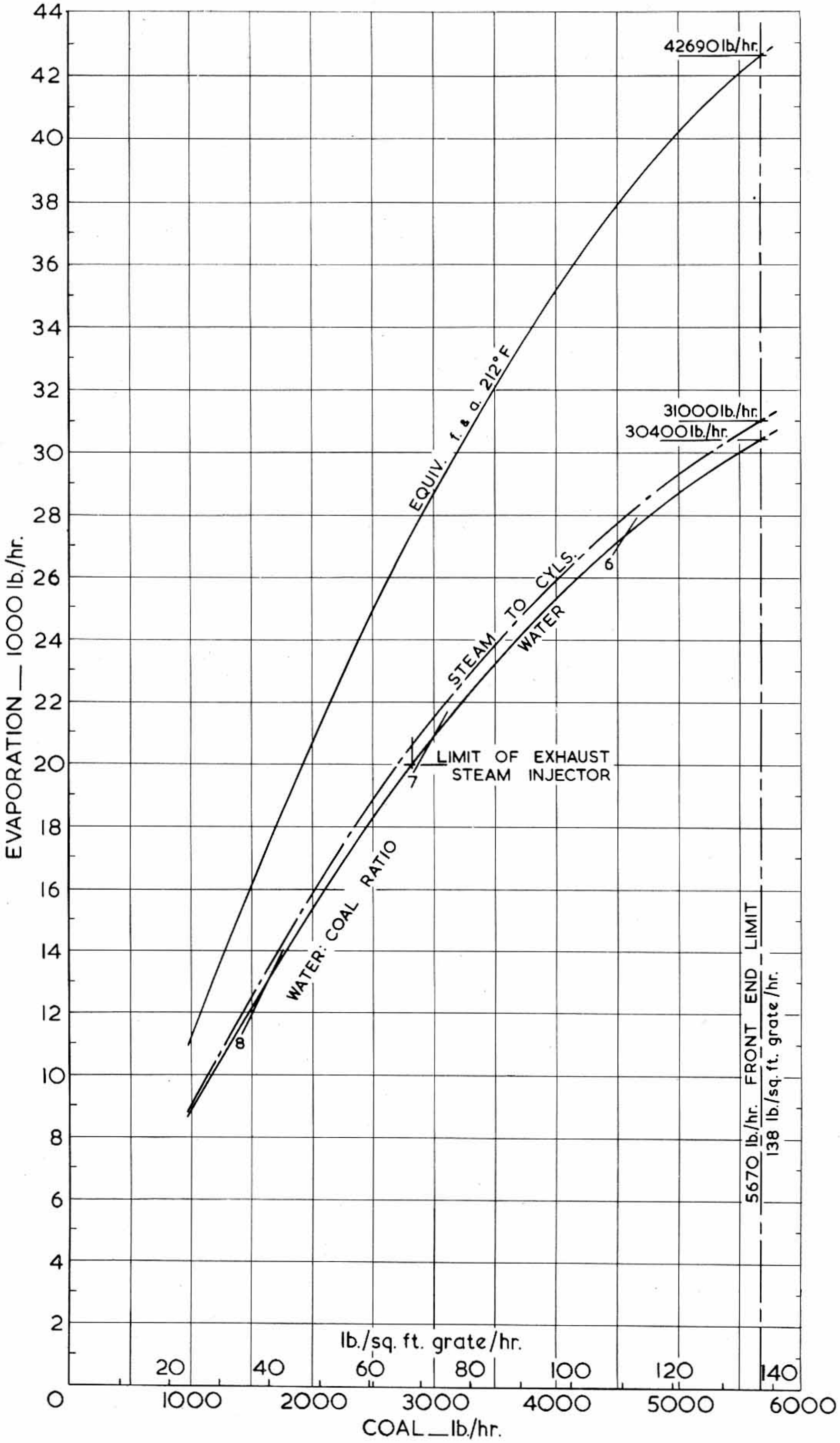

BLIDWORTH COAL 12680 B.Th.U./lb.

EXHAUST STEAM INJECTOR

EVAPORATION

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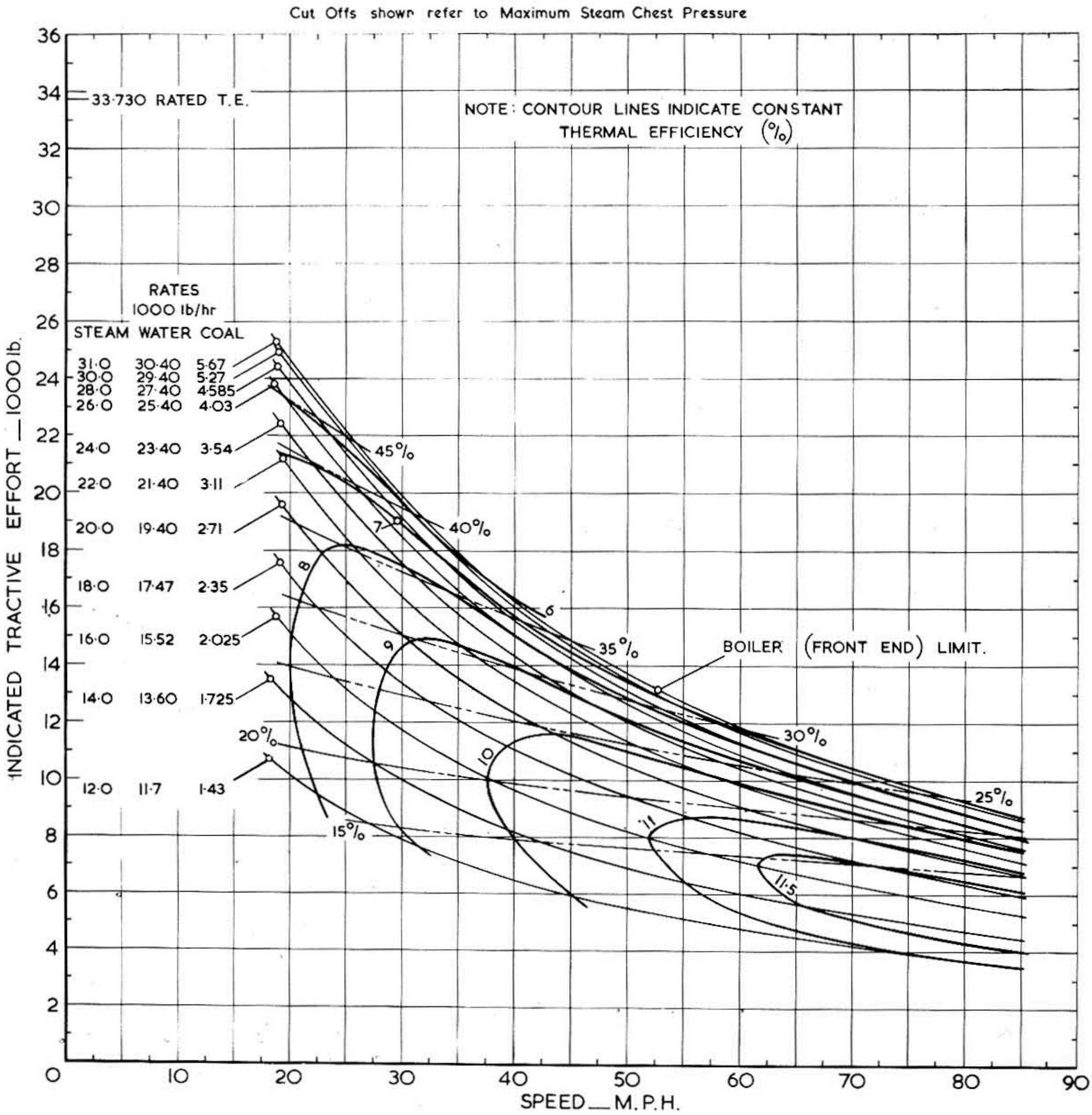
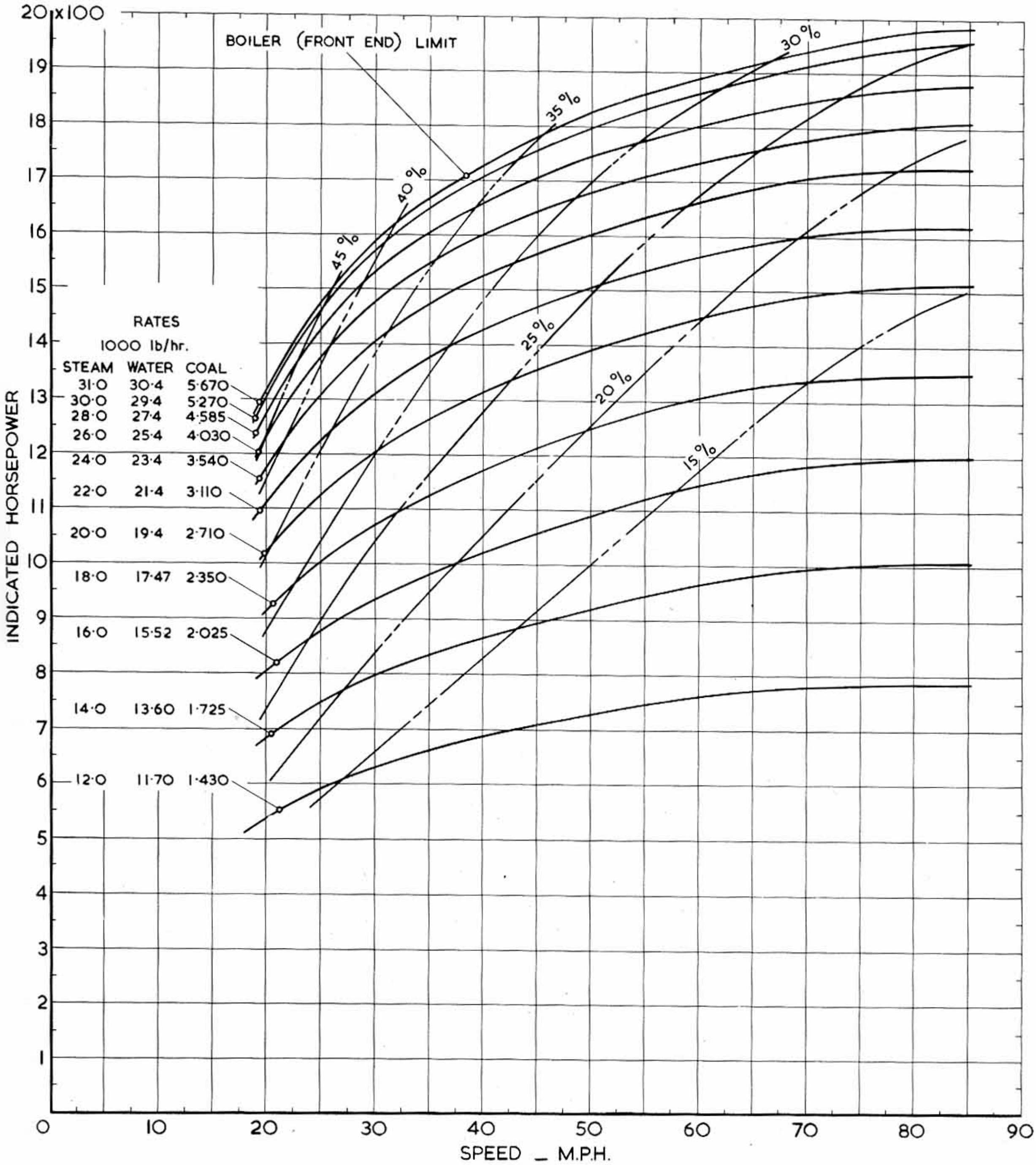


BLIDWORTH COAL — 12680 B.Th.U./lb. EXHAUST STEAM INJECTOR

INDICATED TRACTIVE EFFORT CHARACTERISTICS & OVERALL EFFICIENCY REFERRED TO CYLINDERS

22

NE/60845/53



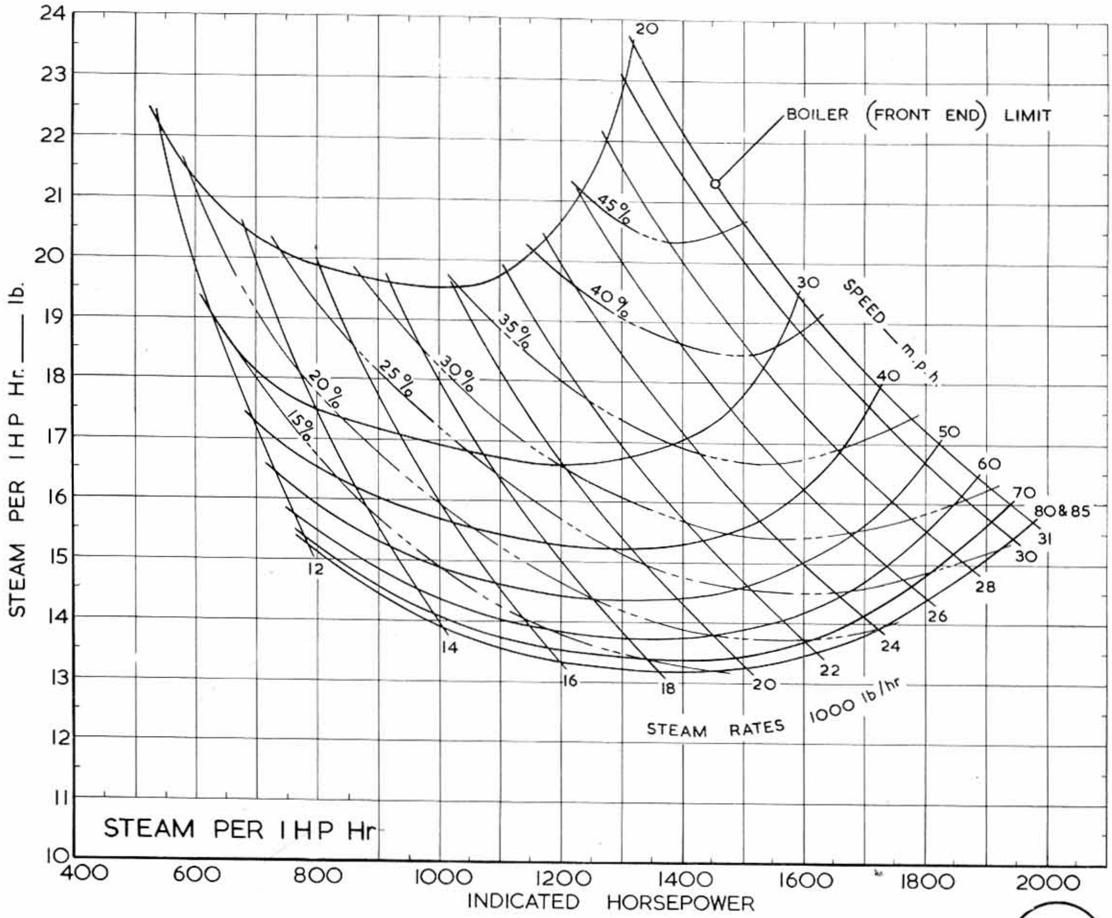
BLIDWORTH COAL _ 12680 BThU/lb.

EXHAUST STEAM INJECTOR

INDICATED HORSEPOWER CHARACTERISTICS

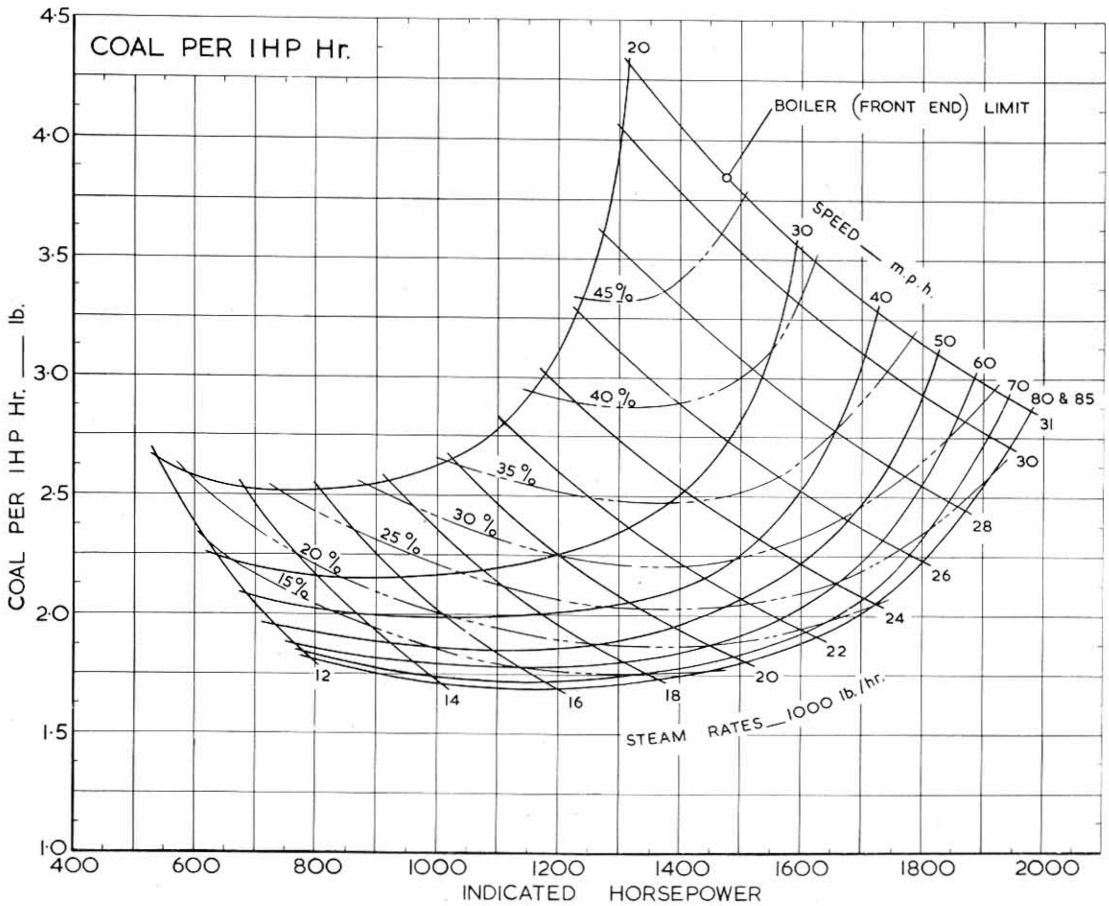
23

NE/60845/53



24

Cut Offs shown refer to Max. Steam Chest Pressure



BLIDWORTH COAL _ 12680 BThU/lb

EXHAUST STEAM INJECTOR

STEAM & COAL PER IHP Hr

25

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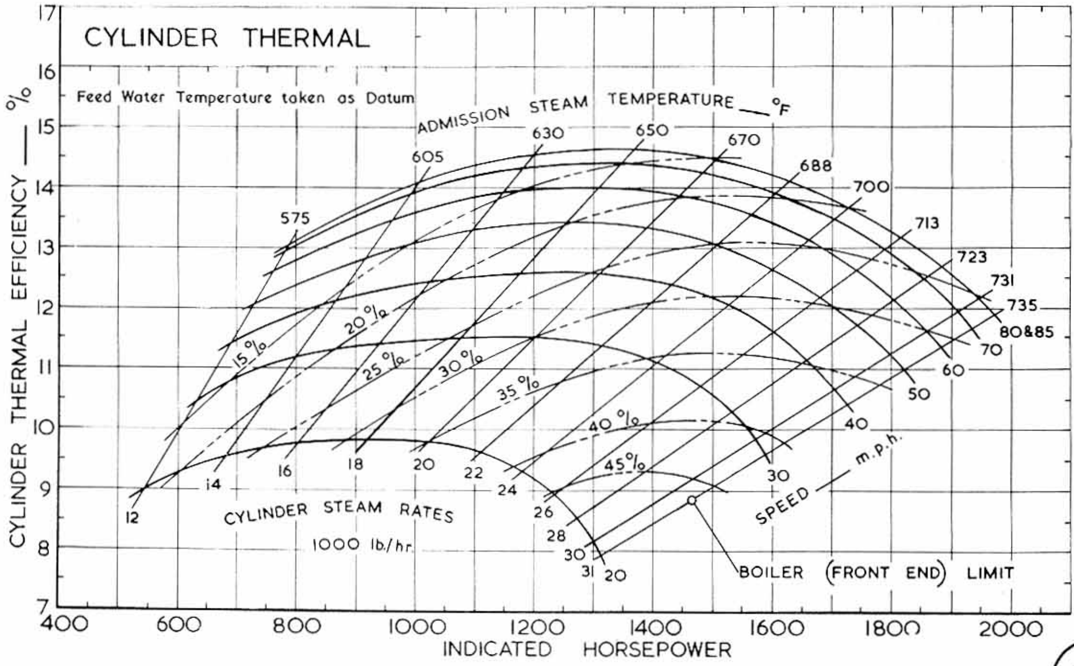
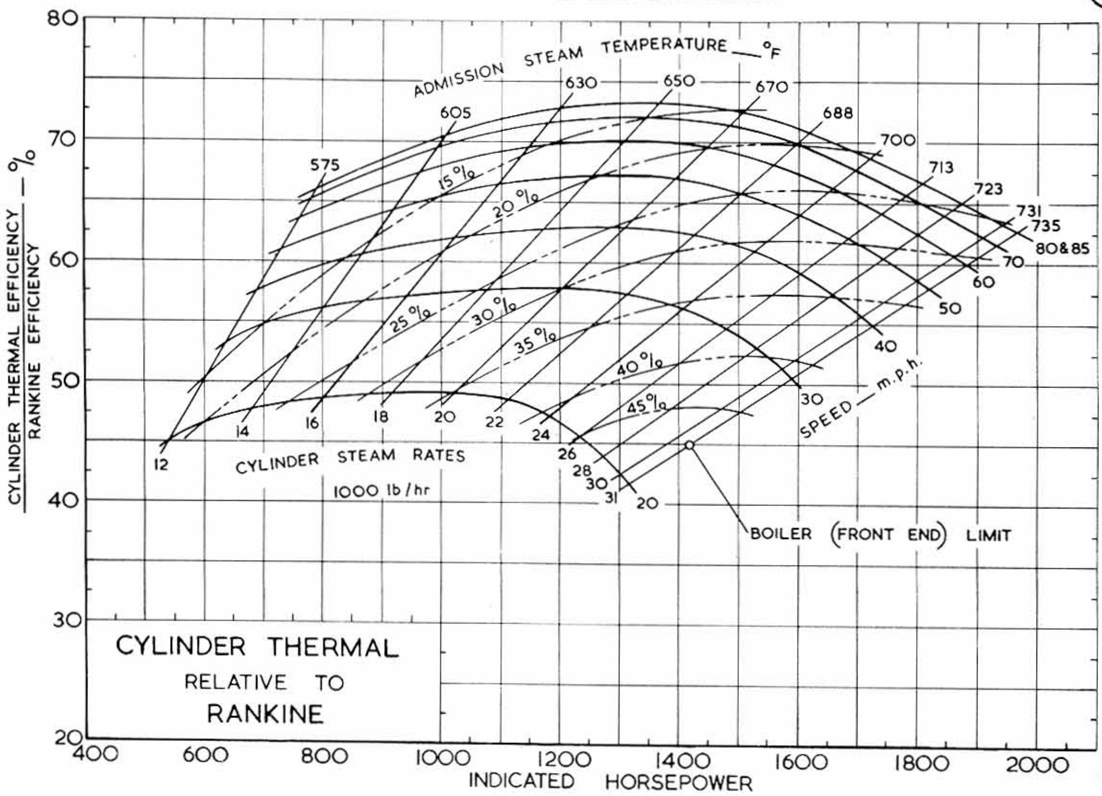


Cut Offs shown refer to Max. Steam Chest Pressure

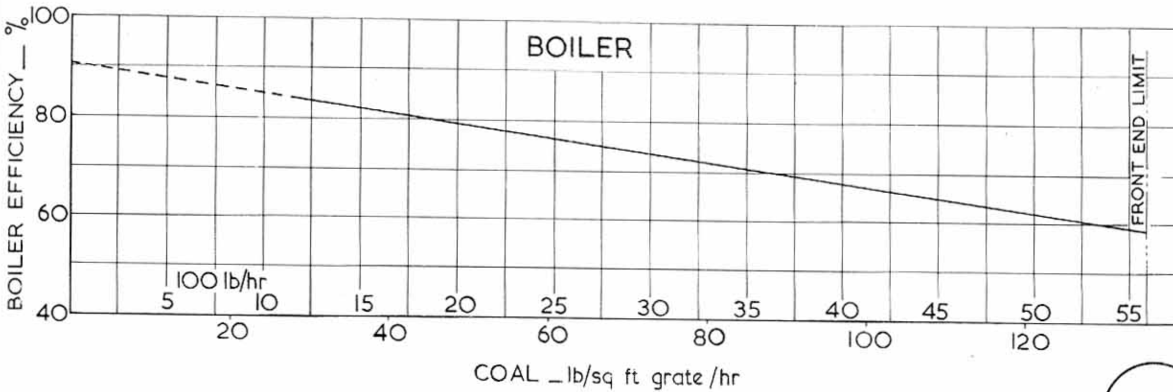


BLIDWORTH COAL — 12680 B.Th.U./lb.

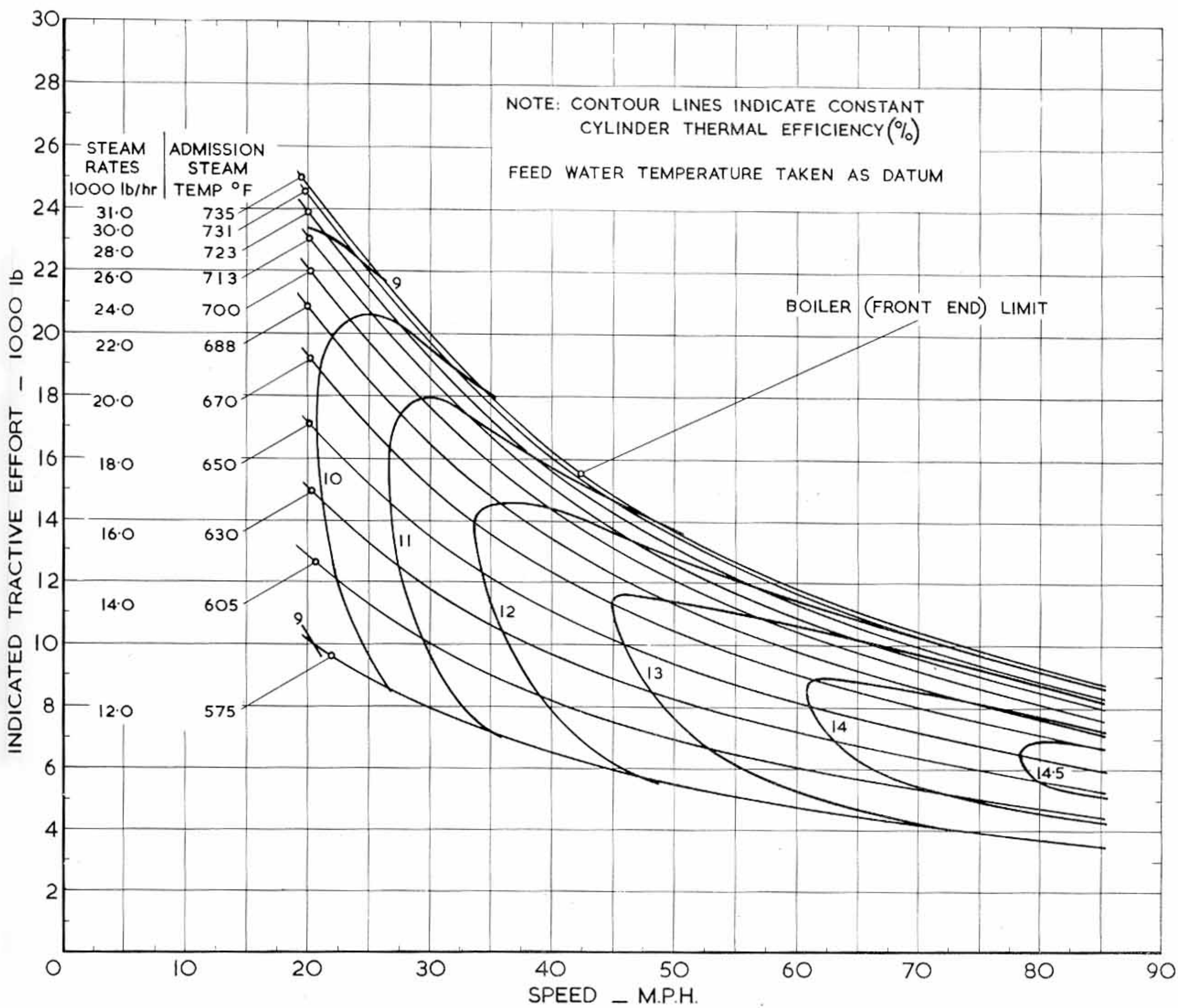
EXHAUST STEAM INJECTOR

EFFICIENCIES

NE/60845/53



28



BLIDWORTH COAL _ 12680 B ThU/lb

EXHAUST STEAM INJECTOR

CYLINDER THERMAL EFFICIENCY RELATIVE TO INDICATED TRACTIVE EFFORT

29

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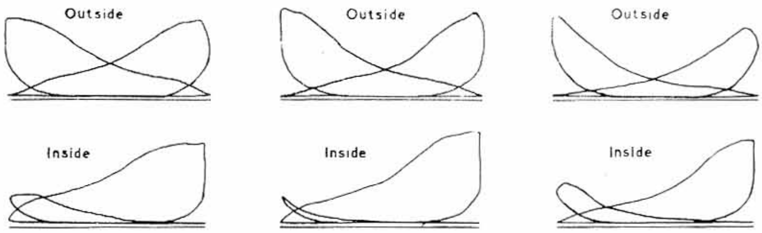
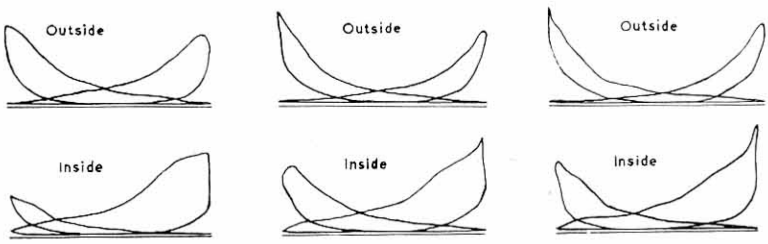
MEAN STEAM RATE 16000 lb/hr FULL REGULATOR



22 m.p.h. 26% C.O. — 845 I.H.P.

25·5 m.p.h 24% C.O. — 895 I.H.P.

39 m.p.h. 20% C.O. — 1010 I.H.P.



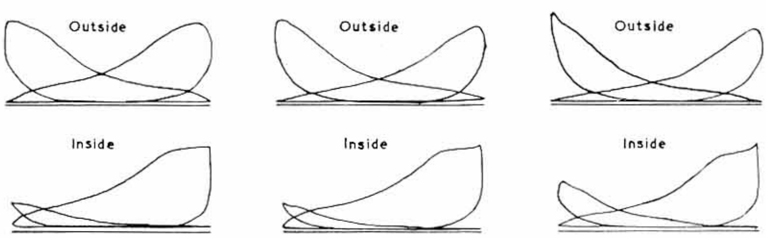
51 m.p.h. 17% C.O. — 1100 I.H.P.

63 m.p.h. 14% C.O. — 1157 I.H.P.

70 m.p.h. 12·5% C.O. — 1185 I.H.P.

PRESSURE SCALE (lb/sq. in.): 200, 100, 0

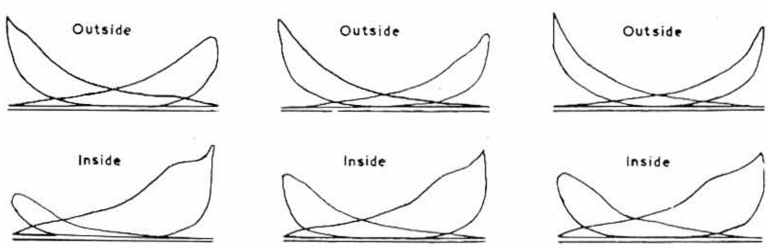
MEAN STEAM RATE 18000 lb/hr. FULL REGULATOR.



28 m.p.h. 27% C.O. — 1064 I.H.P.

38 m.p.h. 23% C.O. — 1162 I.H.P.

46 m.p.h. 21% C.O. — 1222 I.H.P.



53 m.p.h. 19% C.O. — 1282 I.H.P.

62·5 m.p.h. 17% C.O. — 1312 I.H.P.

72 m.p.h. 14·5% C.O. — 1338 I.H.P.

EXAMPLES OF INDICATOR CARDS.

NE/60845/53

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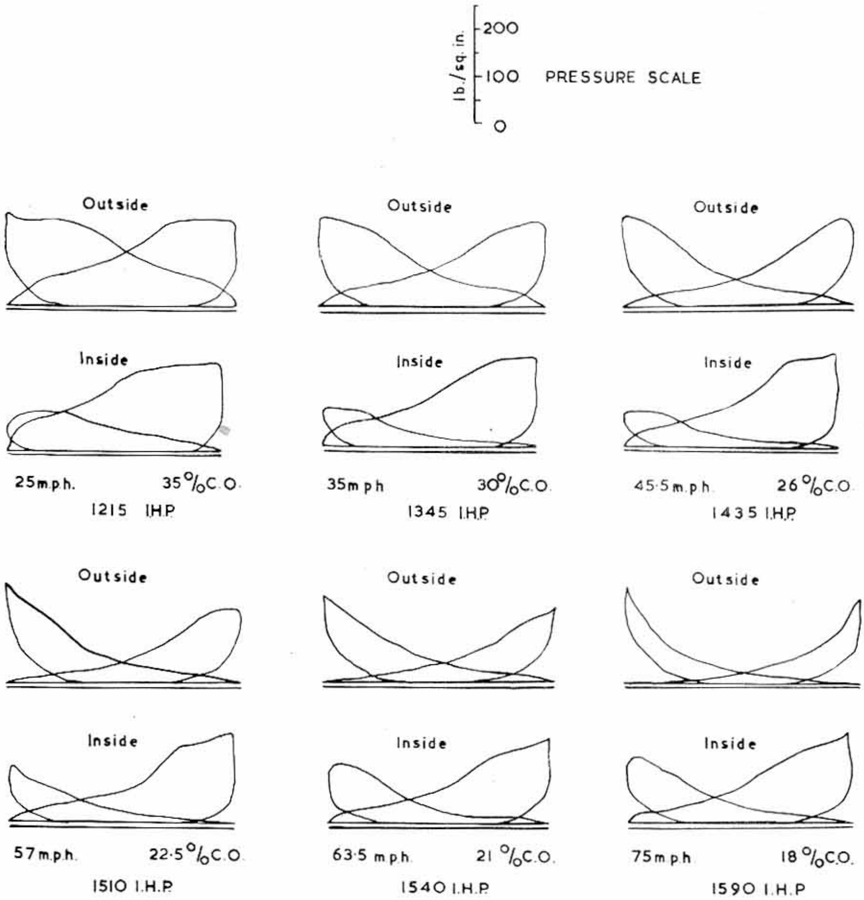
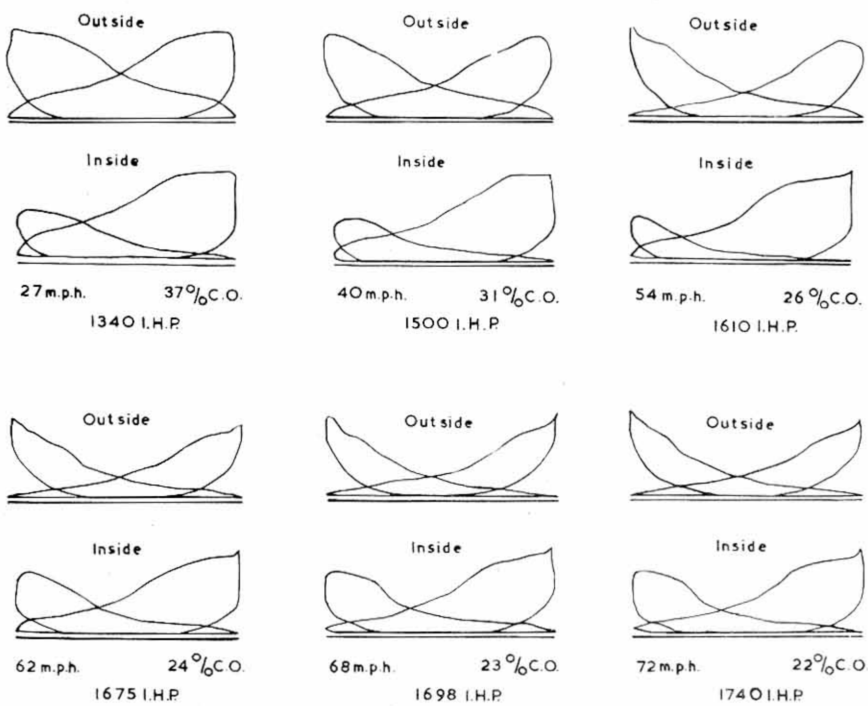
MEAN STEAM RATE 21550 lb./hr. FULL REGULATOR

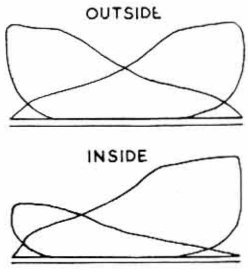


MEAN STEAM RATE 23950 lb./hr. FULL REGULATOR



EXAMPLES OF INDICATOR CARDS

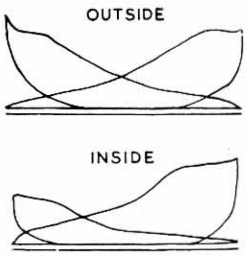
NE/60845/53



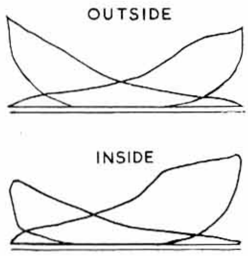
MEAN STEAM RATE 28400 lb/hr.

FULL REGULATOR

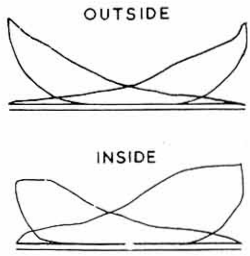
33 m.p.h. 38 % C.O.
1590 I.H.P.



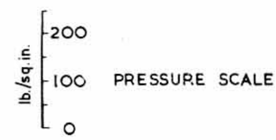
54·5 m.p.h. 30 % C.O.
1790 I.H.P.

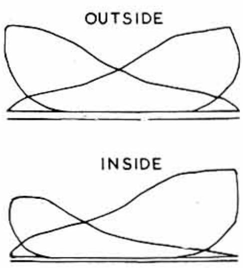


63 m.p.h. 28 % C.O.
1825 I.H.P.



74·5 m.p.h. 25 % C.O.
1870 I.H.P.

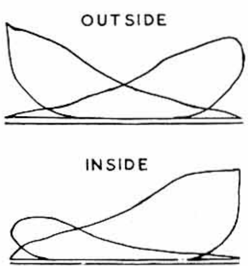




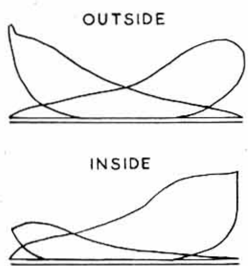
MEAN STEAM RATE 29040 lb/hr.

FULL REGULATOR

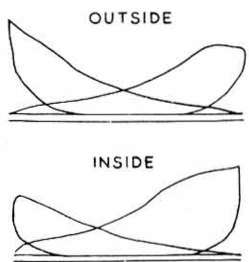
38 m.p.h. 36 % C.O.
1650 I.H.P.



45·5 m.p.h. 34 % C.O.
1730 I.H.P.



53 m.p.h. 31 % C.O.
1800 I.H.P.



60·3 m.p.h. 29 % C.O.
1817 I.H.P.

EXAMPLES OF INDICATOR CARDS.

NE/60845/53