

THE GIESL EJECTOR : A PRACTICAL
APPRAISAL OF ITS ABILITY TO IMPROVE
THE PERFORMANCE OF A STEAM LOCOMOTIVE.

A Thesis submitted to
THE UNIVERSITY OF CAPE TOWN

by

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for consideration of the
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FOREWORD.

I am employed by Rhodesia Railways as an Assistant Mechanical Engineer doing design investigations and testing work. During the months of March to July 1963, it became my duty to conduct the fitting and testing of two versions of the Giesl ejector on two Rhodesia Railways steam locomotives. Since I was given a free hand in planning and conducting these tests and in view of the value of the data they produced, I obtained permission from the Rhodesia Railways Administration to use the material in this thesis.

The Rhodesia Railways tests were carried out by a team of four persons; myself in charge, two Draughtsmen to assist in reading instruments and a Locomotive Inspector who conveyed the requirements of the test to the locomotive crew. All special equipment required as part of the instrumentation was designed by myself and built in the Bulawayo Mechanical Workshops of the Rhodesia Railways.

INDEX TO CHAPTERS.

Chapter		Page
1.	Introduction.	4
2.	Some Aspects of the Locomotive Boiler affecting Efficiency.	7
3.	The Development of the Smokebox Ejector.	18
4.	The Giesl Ejector and Superheat Booster.	29
5.	Rhodesia Railways Giesl Ejector Tests.	47
6.	Description of Locomotives and Test Apparatus used on Rhodesia Railways Tests.	50
7.	Procedure Adopted on Rhodesia Railways Tests.	72
8.	Results obtained from Rhodesia Railways Tests.	76
9.	Conclusions drawn from the Rhodesia Railways Tests.	78
10.	Discussion of the Rhodesia Railways Test Results.	80
11.	Subsequent Developments with the two Rhodesia Railways Locomotives.	113
12.	In Conclusion.	116

INTRODUCTION.

1.1. An ejector (jet pump) is a continuous flow pump which utilises the kinetic energy in a high velocity fluid stream, to entrain and extract a second fluid from a given location. Three common variations of the ejector as used on steam locomotives are :-

1.1.1. The live steam operated ejector which creates a partial vacuum throughout the train braking system and allows atmospheric pressure braking.

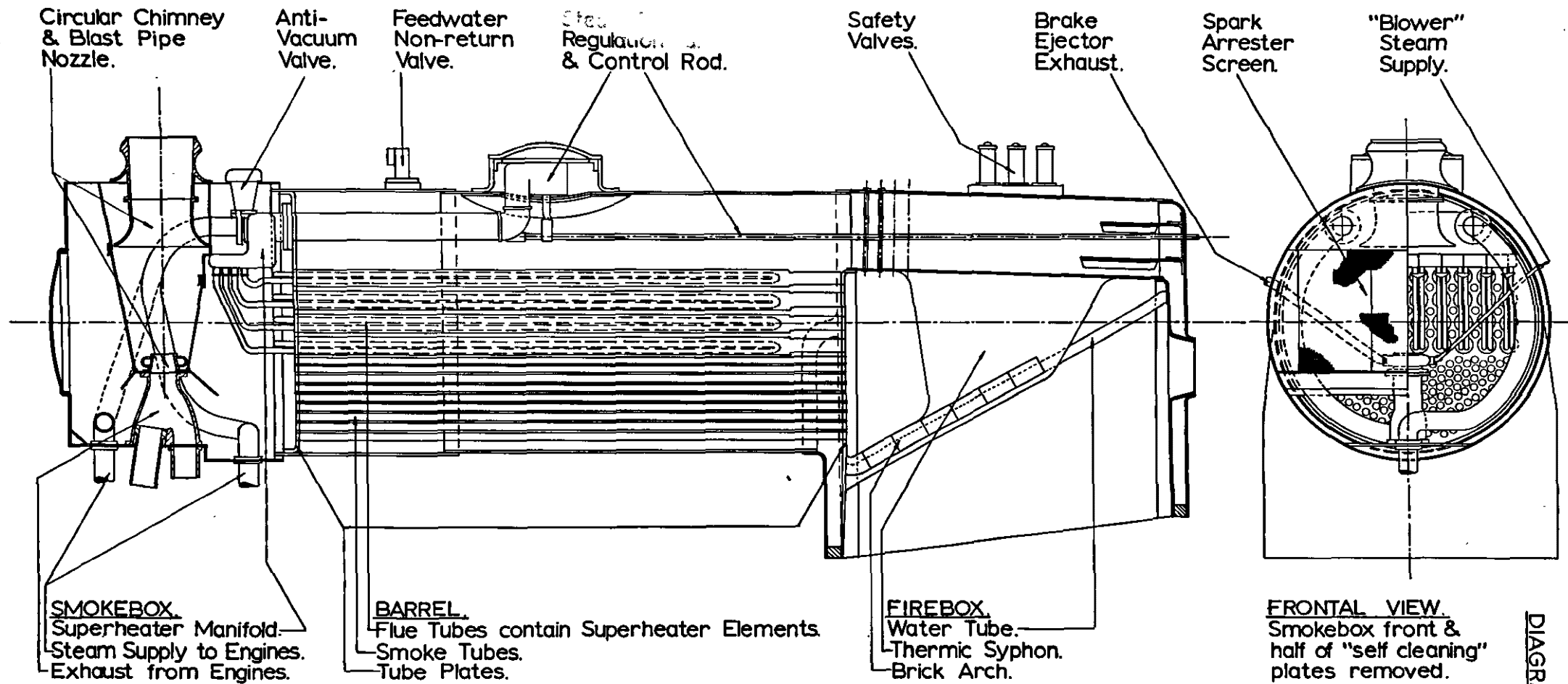
1.1.2. The live steam operated injector which forces feed water into the boiler.

1.1.3. The exhaust steam operated ejector which extracts the products of combustion and air from the smokebox inducing a partial vacuum at this location and thus creating a draught through the boiler and firebed.

1.2. This thesis concerns the last mentioned variation of the ejector in paragraph 1.1. and will attempt to show how this ejector was evolved and how it influences the steam locomotive, the boiler in particular.

1.3. Since George Stephenson's conception of the locomotive boiler, as fitted to the "Rocket" in 1829, this ejector has traditionally consisted of a circular nozzle, fitted to the end of the exhaust pipe from the locomotive cylinders, which accelerates the exhaust steam into a high velocity stream carrying the smokebox gases through the chimney to atmosphere. Although innumerable attempts have been made to improve the efficiency of this arrangement, nothing like the success enjoyed by Dr. A. Giesl-Gieslingen of Vienna with

his ejector on the Austrian Federal Railways in 1951 has heretofore been experienced. The success of the Giesl Ejector in improving boiler efficiency has allowed departures from traditional locomotive boiler practice which were not previously possible.



DIAGRAMMATIC SECTION OF GARRATT TYPE STEAM LOCOMOTIVE BOILER.

2. SOME ASPECTS OF THE LOCOMOTIVE BOILER AFFECTING EFFICIENCY

2.1. The conventional locomotive boiler consists of a firebox or combustion space over the fire grate, where the combustion of the fuel takes place radiating heat to the surrounding water cooled walls and generating steam. From the firebox the hot gaseous products of combustion are transported through large numbers of parallel, water cooled tubes to the smokebox, from which they are exhausted to atmosphere by the action of the exhaust steam ejector, being discussed. During the passage of the hot gases through the tubes they further heat the water in the boiler and in some of the tubes, called flues, the hot gases add heat to steam in adjacent pipes, causing it to become superheated. This steam then passes to the locomotive cylinders where it expands doing work. Once the steam has expended most of its energy in the cylinders it is exhausted through the ejector in the smokebox inducing a draught through the boiler, which stimulates further combustion and produces more steam. This has been termed the closed loop of "air, fire and water" and is in effect a closed loop since a change in the load causes a change in the steam requirements at the cylinder, which in turn influences the draught created by the ejector and hence partly controls the rate of steam production. These basic boiler features are shown on diagram No. 1. This diagram also shows the standard smokebox deflector plate arrangement, as well as the brick arch in the firebox, which is a means of storing heat and forcing the combustion gases to follow a long path through the firebox.

2.2. A steam locomotive boiler is usually restricted in weight and size by track loading considerations and moving structure gauge limitations, hence, since it has to be capable of the greatest possible rate of evaporation

compatible with its size, it must be efficient. Due to the space limitations of the locomotive and the wide range of demand made on the boiler it has always been very difficult to obtain highly efficient steam locomotive boilers. Further, this field of Mechanical Engineering endeavour has seldom been thoroughly investigated from a purely scientific point of view to establish exact rules for boiler proportions, accounting for all the possible variables. Consequently, locomotive boiler design has remained essentially an empirical process, since the early 19th century and the majority of successful boilers have been based on the most successful features of the boilers that preceded. The following extract from the Proceedings of the Institution of Locomotive Engineers serves to illustrate this :

September 1929 : "When getting out new designs, it is the practise to compare the boiler proportions of those regarded as efficient and known to steam well, and from these known facts to deduce the new and improved boiler". (1.)^x

Similar remarks were made in papers presented in January 1938 (2) and January 1945 (3) although by this latter stage boiler design was slightly less empirical being referred to as "tuned" boiler design, which meant that once the heating surfaces had been proportioned by empirical means to allow the maximum transmission of heat from fuel to water, then certain fundamental theoretical considerations could be applied to aspects such as boiler tubes, superheating and draughting before

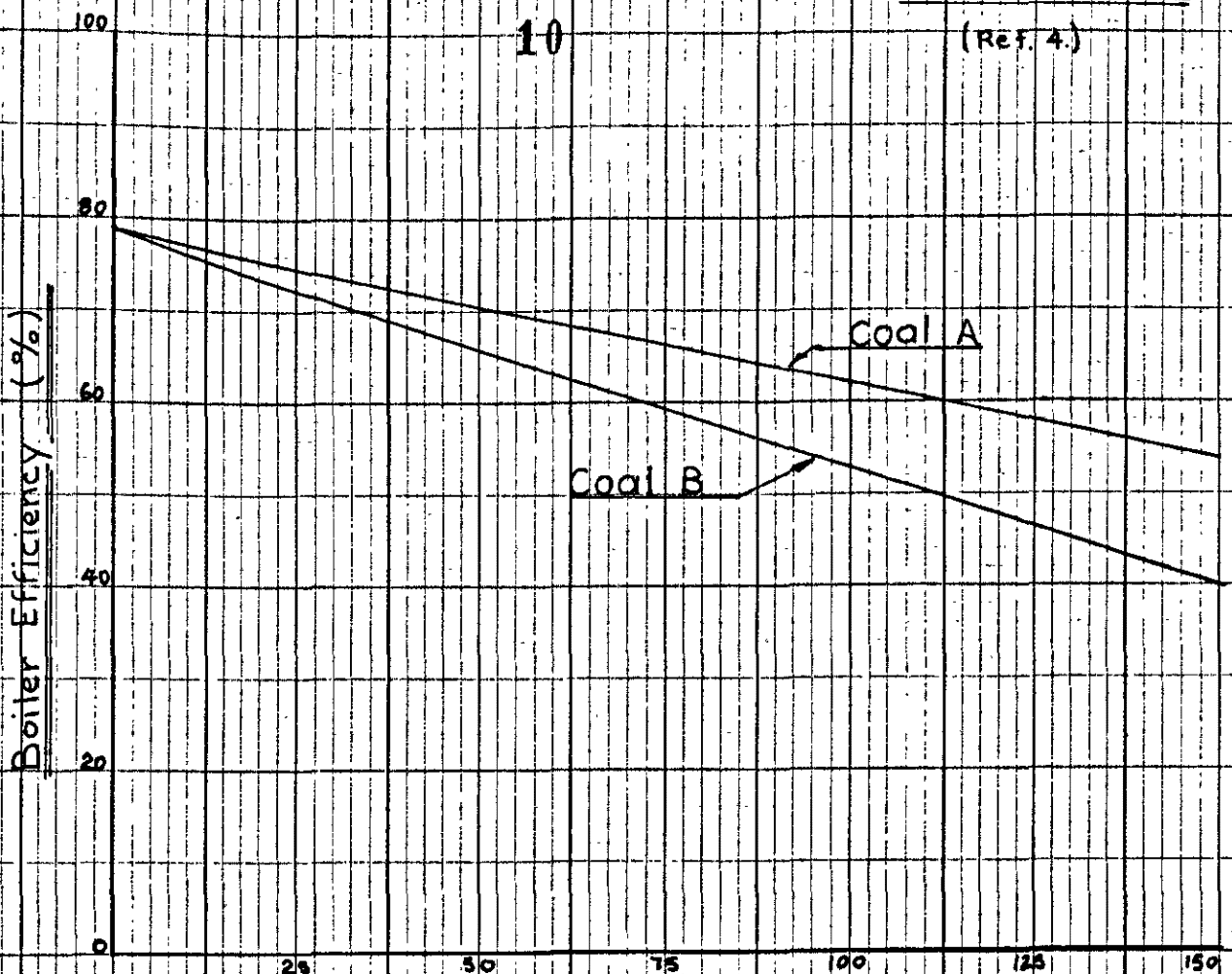
^x A list of references is given in Appendix VI

final selection of dimensions. Once in service this boiler would undergo extensive testing and various trial alterations, particularly to tube size and number, would be made until the most efficient arrangement was determined.

2.3. The majority of Rhodesia Railways steam locomotives are of the Garratt Articulated type and were designed and built in the United Kingdom at a time when the above ideas on design predominated. Unfortunately, the Rhodesia Railways has never been in a position to experiment with these boilers except for minor alterations such as to the brick arch in the firebox and smokebox, ejector and deflector plate arrangement. Consequently there has remained room for improvement in almost all the types in service and a device such as the Giesl Ejector, which is claimed to increase boiler efficiency, could prove to be of value.

2.4. In order to later show how the Giesl Ejector effects increases in efficiency in the locomotive boiler it is first necessary to consider the thermal and dynamic losses which occur with particular reference to the Garratt type ; characterised by the short, large diameter barrel and almost square firegrate.

2.4.1. The measurement of locomotive boiler efficiency is most accurately established from stationary test plant (laboratory) tests where the input and output can be closely balanced. Average efficiencies on mobile tests are determinable but are of little value since conditions change rapidly. Generally only limited data on boiler efficiency is available since very few stationary test plants for steam locomotives have been built and this is one of the reasons why the locomotive boiler has remained relatively undeveloped. In fact only 3 test plants were in operation in the U.S.A. prior to 1939 and one came into operation in the U.K. after 1945. Reference 4 contains data taken from the American



Dry Coal Fired (lb/square foot of grate/hr.)

Relation Between Rate of Firing and Boiler Efficiency

Coal A - Bituminous - Lump

Proximate Analysis: Fixed Carbon 57.7%; Volatile Matter 31.9%;
Moisture 1.2%; Ash 8.5%

Ultimate Analysis: C = 77.7%; H = 4.8%; N = 1.5%; S = 1.1%;
O = 6.8%; Ash = 8.1%

Calorific Value: 14,047 btu/lb.

Coal B - Semi Bituminous - As Mined

Proximate Analysis: Fixed Carbon 72.8%; Volatile Matter 15.2%;
Moisture 3.1%; Ash 8.9%

Ultimate Analysis: C = 81.1%; H = 4.1%; N = 1.0%; S = 0.9%;
O = 3.4%; Ash = 9.5%

Calorific Value: 14,347 btu/lb.

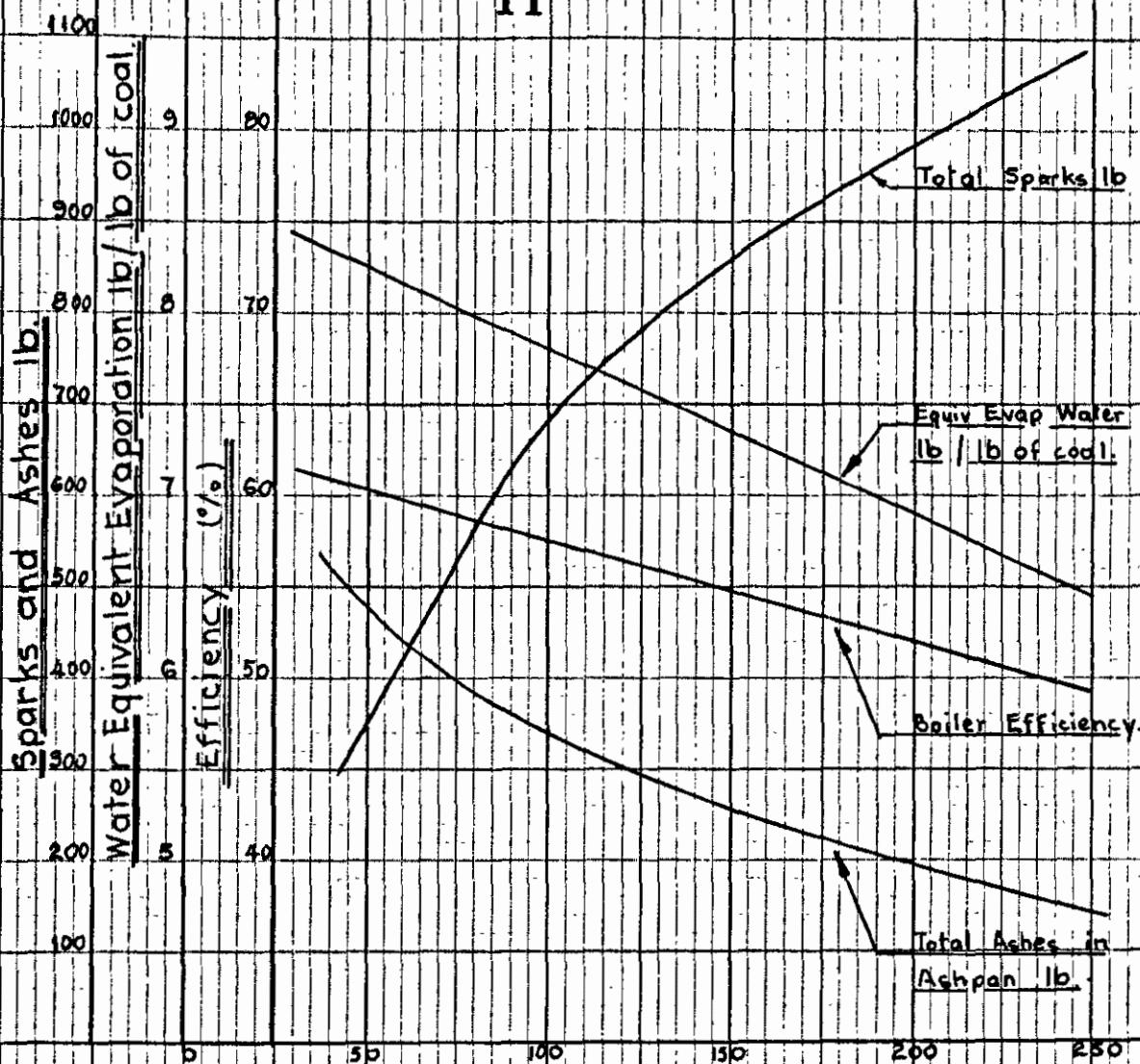
Heat Balance Relative to above curves

	Coal A		Coal B	
Rate of Firing (lb/sq ft./hr.)	49.9	101.1	52.7	99.2
Heat taken up by water and steam.	69.1	63.2	65.7	53.9
Outside losses.	3.5	3.2	3.3	2.7
Unburnt fuel loss.	8.6	13.8	13.4	28.0
Carbon monoxide loss.	1.2	1.4	0.0	0.3
Heat lost to smokebox gas.	17.6	18.4	17.6	15.1
Total	100.0	100.0	100.0	100.0

DIAGRAM 3.

(Ref 5.)

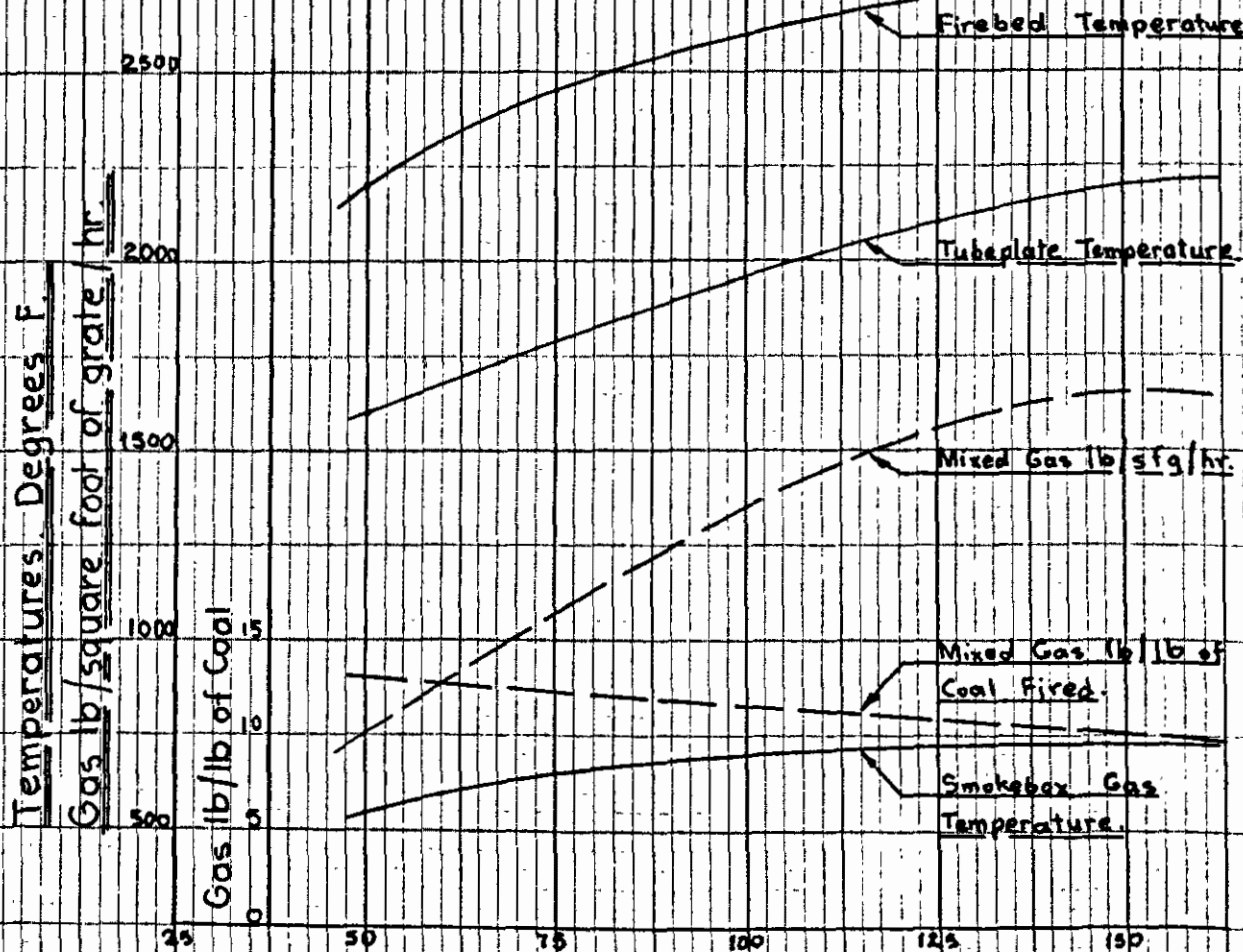
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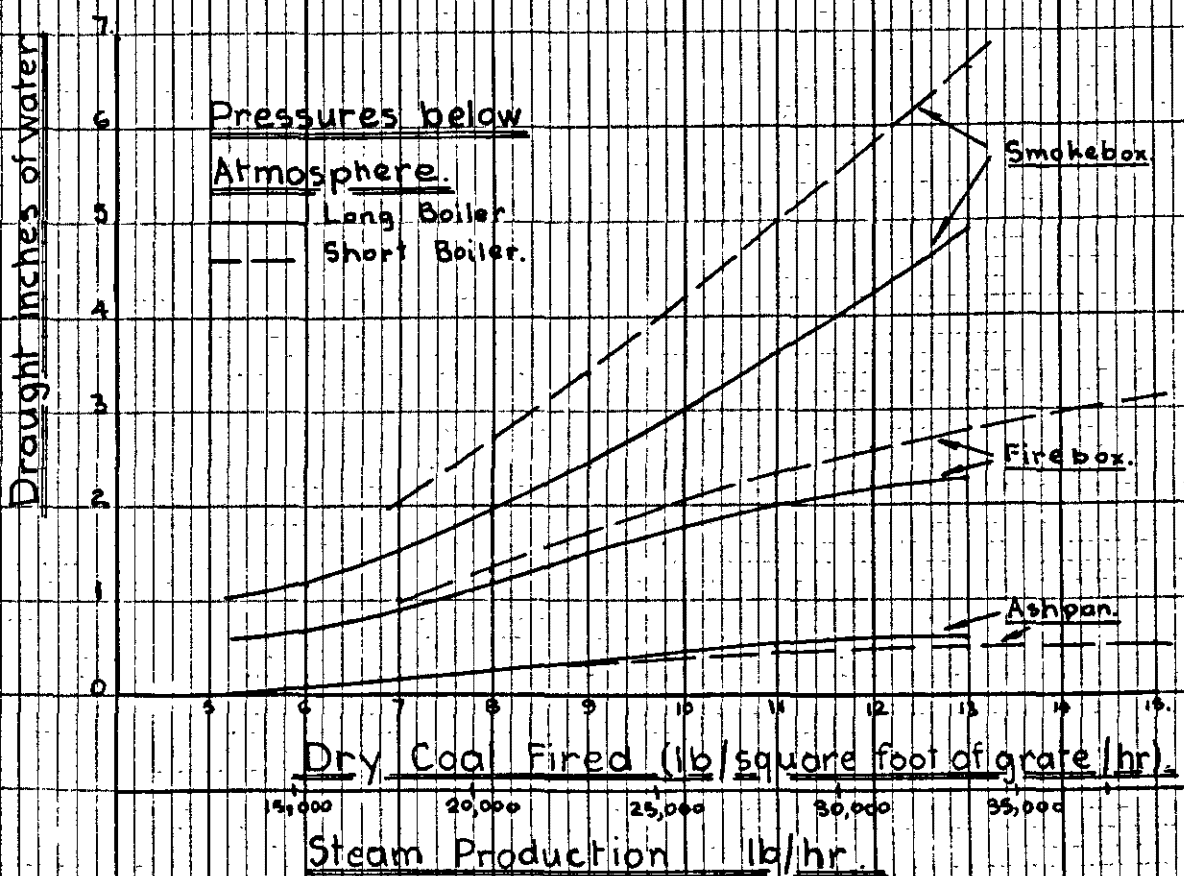
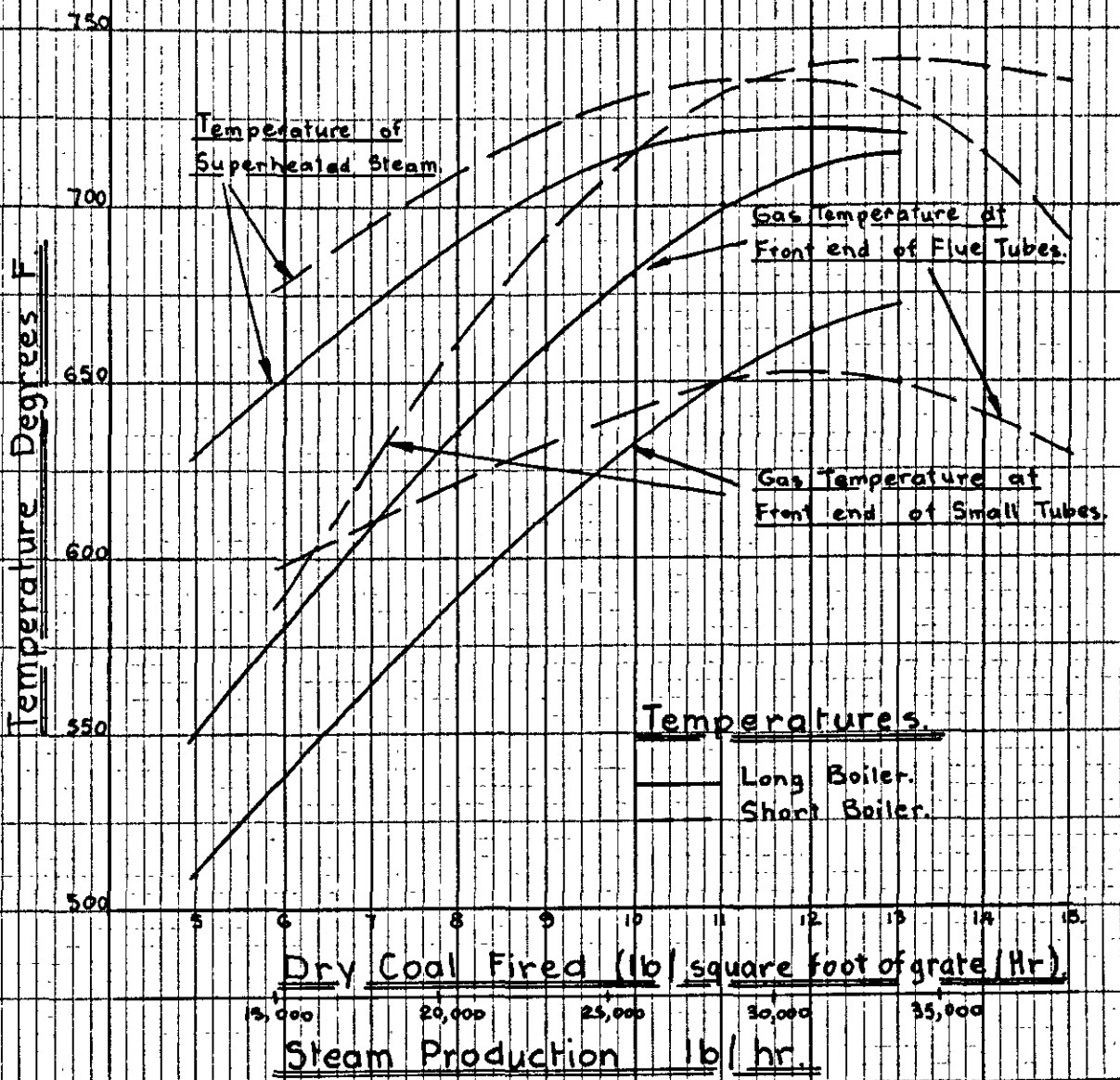
Dry Coal Fired (lb/square foot of grate/hr)

DIAGRAM 4.

(Ref. 5)



Dry Coal Fired (lb/square foot of grate/hr)



test plants for American locomotives and discusses in detail boiler efficiency, this work has been a standard since its publication in 1924 and is still of some considerable value.

2.4.2. Diagram 2 (4) shows the basic relationship between boiler efficiency and rate of firing as well as the influence of different grades of coal. The first most important aspect of this graph is the way in which the efficiency decreases with increasing rate of firing due to decreasing combustion efficiency. At high rates of firing the firebox temperature is higher (see Diagram 4)(5) making for more efficient combustion but the period of contact between the incoming air and incandescent coal is reduced which causes an increase in the quantity of unburned coal. It is therefore desirable to increase the quantity of air in contact with the coal as the rate of firing increases and it is this relationship of quantity of air to rate of firing which determines a good or bad ejecting arrangement. However, at these high rates of firing, the draught and average velocity of gases through the boiler are increased causing an increased carry-over of unburned coal and char to the smokebox (see Diagram 3)(5), hence a balance must be established. Other aspects such as moisture, production of carbon monoxide and boiler design, affect these curves to a lesser extent. It is significant that the lower calorific value coal gives the better efficiency in this case which is put down to (Diagram 2) ;

1. Lump coal as opposed to "as mined" coal, i.e., more uniformity in size and possibly a higher surface area to volume ratio on the average.
2. Increased volatile content and increased oxygen of coal A over Coal B.
3. Less moisture in Coal A than Coal B.

2.4.3. Boiler efficiency can be subdivided into two sections - efficiency of combustion (already

discussed), and efficiency of heat absorption. The latter has been found to be independent of rate of firing but dependent on boiler design. Fry (4) states "It is evident that the design of the boiler will determine the efficiency of heat absorption, but the effect is so complex that it does not seem possible to set up a direct connection". The absorption efficiency is the ratio of the heat taken up by the water plus the heat lost in external radiation from the boiler to the heat released from the coal, i.e., it is the ratio of the heat released less the heat lost in the smokebox gas to the heat released. As the rate of firing increases the exhaust gas temperature increases causing an increase in heat lost but at the same time the quantity of air per pound of coal drawn in decreases causing a decrease in the loss to the smokebox gas, so that the overall relationship remains almost constant and it is for this reason that absorption efficiency appears independent of rate of firing.

2.4.4. Continuing with the influence of boiler design on the efficiency of heat absorption, a field where the Giesl Ejector will be shown to have some influence, it has been found by comparison of boiler characteristics (6) and confirmed by tests (4) that fireboxes with large heating surfaces and having the ratio firebox volume to firegrate area, equal to 6 give high absorption efficiencies and good combustion efficiencies. This is difficult to achieve with the Garratt type boiler since the overall length is restricted and the firebox must be kept shorter than the long narrow more efficient firebox of the non-articulated locomotive. However, some compromise is possible since the Garratt firebox can be made deeper. Most of the heat transmitted to the water is through the firebox hence the correct proportioning of this part has the greatest influence on boiler absorption efficiency. However, once the boiler has been designed and built there is very little possibility of alterations to the

firebox dimensions being made, so that one must look elsewhere in order to improve the boiler efficiency. This leads to the tubes where by changing the plates that support the tube ends, different arrangements of smoketubes (small tubes) and flue tubes can be tried, this is in fact the method of "tuning" a boiler and although it is a simple operation it is usually costly and hence seldom tried. Nevertheless, this has been done and (2) gives four variations of the same boiler where consecutive alterations to tube numbers, sizes and distribution gave increases in efficiency without any changes to the smokebox ejector being made.

COMPARISON OF FOUR VARIATIONS OF THE SAME BOILER				
Boiler Reference No.....	1	2	3 ²	4
No. of small tubes	160	138	159	151
Diameter	2" O.D.	2½" O.D.	1½" O.D.	1½" O.D.
No. of flue tubes	14	21	24	28
Diameter	5½" O.D.	5½" O.D.	5½" O.D.	5½" O.D.
Superheater Elements -				
Number	14	21	24	28
Diameter	1½" O.D.	1½" O.D.	1½" O.D.	1½" O.D.
Length between tubeplate ..	14ft 3in	13ft 3in	14ft 3in	13ft 3in
Heating surface firebox ...	162.4	181.1	162.4	181.1
TOTAL	1624.9	1572.1	1730.4	1661.3
Grate area	29.5	31.0	29.5	31.0
Superheater heating surface	227.5	235	330	358
Free area -				
Small tubes	2.74	2.69	2.34	2.22
Large tubes	1.16	2.03	2.16	2.52
TOTAL	3.90	4.72	4.50	4.74
Total free area as per cent of grate area	13.2	15.2	15.2	15.3
Flue tube free area as per cent of total free area ...	29.8	43.0	52.0	53.1
Quantity of gas flues over total $\frac{QL}{QT}$	8.0	16.5	16.0	19.3
Percentage	27.9	37.7	32.4	35.5
Estimated superheat temperature °F	28.7	43.8	49.4	54.3
A/S ratio -				
Flue tubes	1/440	1/313	1/383	1/354
small tubes	1/387	1/336	1/416	1/387

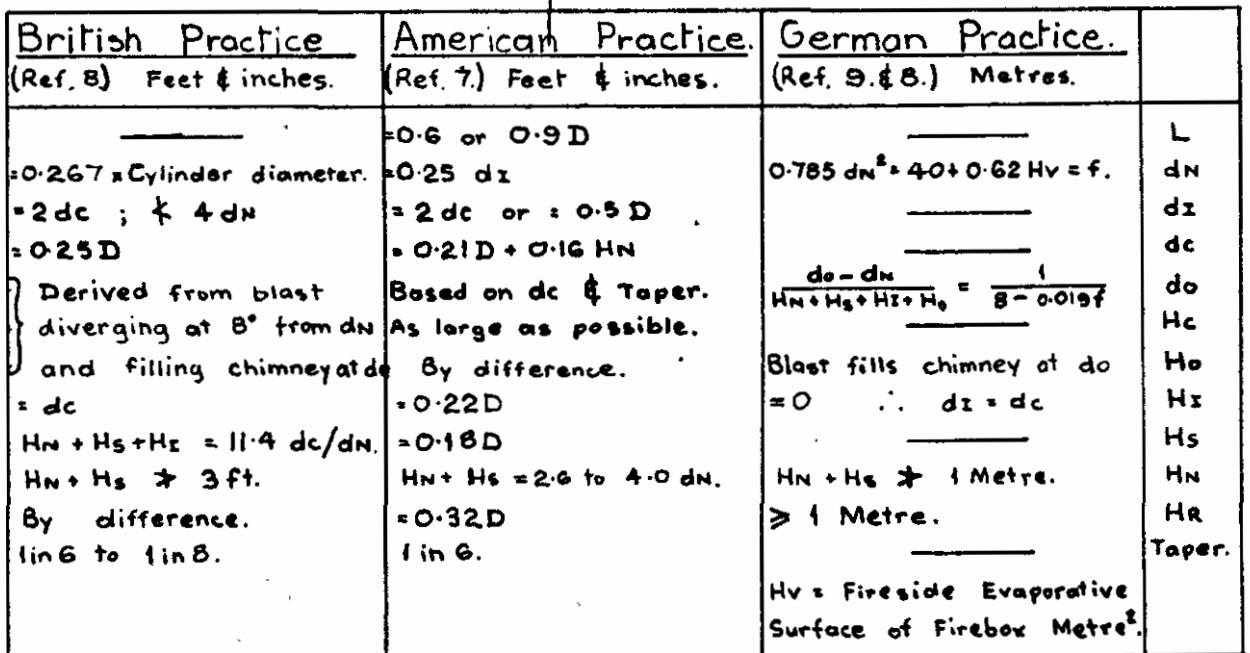
*The same tube arrangement has been used for replacements in either boilers No. 1 or No. 2. The figures given in this column refer to the boiler with 14ft. 3in. long tubes. When used with the 13ft. 3in. long boiler, the ratio of free area/grate area is 14.5 and the superheated steam temperature 590°F.

It is significant to note here that each successive improvement has an increased free area through the tubes, indicating that there was a decrease in resistance to flow of gas through the boiler tubes so that the ejector would create a lower draught through the boiler. It is, however, desirable to create a higher draught through the boiler for more efficient combustion which requires an increase in the tube resistance and a more powerful ejector in the smokebox. Sanford (3) quotes the LMS.5X Class boiler as having been improved by fitting successively $2\frac{1}{2}$ inch, 2 inch, $1\frac{1}{2}$ inch and finally $1\frac{1}{4}$ inch diameter tubes using the most efficient smokebox ejector then known. The conclusion here is that once the arrangement of tubes has been improved to a certain point, further improvement can only be made if the smokebox ejector arrangement is first improved. Note : the above table includes A/S ratios (A is the free area and S the "wetted" surface area of a tube) which for a tube of diameter D and length L is :-

$$\frac{\pi D^2}{4 \pi D L} = \frac{D}{4 L}$$

Although this ratio is found to have an optimum value, basically as it is increased a lower pressure difference across the tube is required to cause flow. For unit length this ratio = $D/4$, a factor called the hydraulic depth and long recognised as being significant in the study of flow of fluids through tubes. This ratio came into its own as a result of the paper (1) which dealt with it in some detail and advocated $1/400$ as the optimum.

Another aspect of the tubes which affects the boiler performance is their length. It is not possible to change this radically once the boiler has been built but it is worth noting here that as in the case of the short Garratt type boiler, where it is possible to obtain higher superheat temperatures with short flues, the exhaust gas temperature and hence losses, are higher. Diagram 5 (1) compares the significant temperatures for similar long and short boilers.



Comparison of Circular Smokebox Ejector Proportions.

3. THE DEVELOPMENT OF THE SMOKEBOX EJECTOR.

3.1. As already explained the smokebox ejector consists of a nozzle, on the end of the steam exhaust pipe from the cylinders and a chimney, whose inner profile is generally initially convergent and then divergent. The nozzle accelerates the exhaust steam into a divergent blast which strikes the inner periphery of the chimney on a line between the throat and the outlet. Friction and turbulence at the surface of this cone of steam cause some of the surrounding gas to be accelerated to the same velocity as the steam and become entrained. This entraining or ejecting action is the basic purpose of the ejector and must be so carried out that the ejector extracts more than the basic products of combustion causing a partial vacuum in the smokebox. This partial vacuum stimulates the flow of air through the firebed and promotes combustion.

3.2. The conventional smokebox ejector consists of a circular chimney and nozzle, the dimensions and disposition of which are based on empirical relationships found to give the largest nozzle diameter necessary to create the desired draught through the boiler at maximum boiler output (see Diagram 6). The main disadvantage of the conventional arrangement is that the high velocity underexpanded steam jet encounters the surrounding gas in the smokebox violently, resulting in a high loss of energy by the steam (shock loss). This means that for the mixture to retain sufficient velocity and pressure energy to pass up the chimney and clear the locomotive the initial velocity of the steam must be high. For the nozzle to impart sufficient velocity to the exhaust steam its cross sectional area has to be small, resulting in the creation of considerable back pressure at the locomotive cylinders which in turn reduces the amount of expansive work that can be done by the steam in the cylinders thus influencing the whole economy of the locomotive. It is therefore desirable to have a smokebox ejector that will do the necessary

pumping of gas and creation of draught with the minimum shock loss and minimum back pressure influence at the cylinders. These requirements have long been recognised and many attempts have been made to find the perfect arrangement.

3.3. Some of the reasons why the conventional arrangement has remained in vogue for so many years are :-

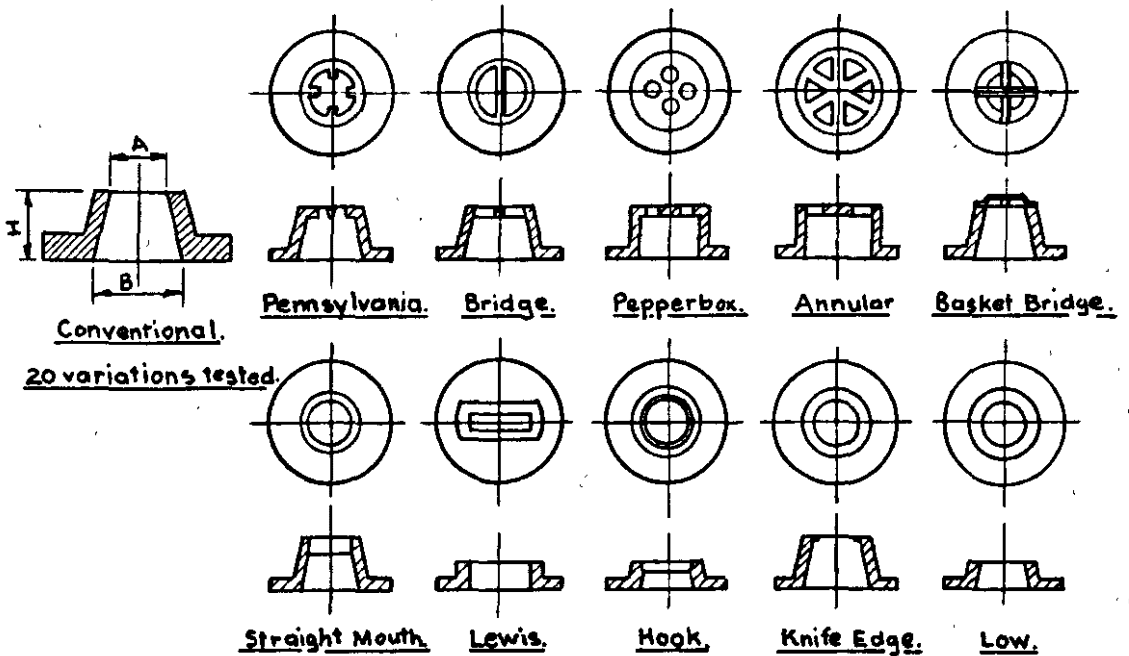
3.3.1. Its simplicity makes for ease of manufacture, erection and maintenance.

3.3.2. In areas where coal is relatively cheap there has been little incentive to improve on this arrangement merely to save a small amount of coal.

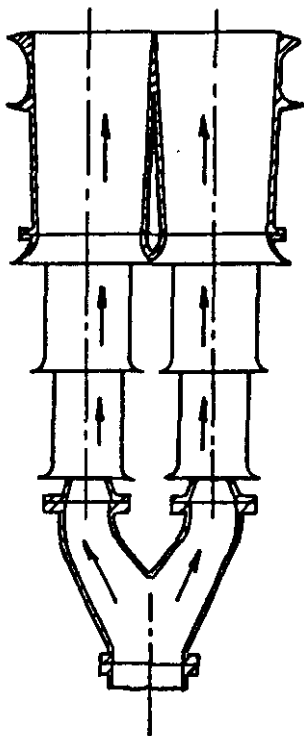
3.3.3. Large numbers of locomotives already work at their limits of adhesion so there is no point in increasing their power by reducing backpressure since they would not be able to start heavier trains.

3.3.4. Since a large amount of unsuccessful experimentation has already taken place and the cost of research of this nature is usually high, very few organisations have the inclination or ability to pursue the matter.

3.4. Although considerable experimentation and trial and error development of the smokebox ejector has taken place, it was not until the principles of the true ejector were applied, as in the Giesl Ejector, that any real success in improving the efficiency of the smokebox ejector was forthcoming. Experimenters in the past have concentrated on increasing the area of the blast pipe nozzle and obtaining the maximum possible surface area for the steam cone issuing from this nozzle, by providing nozzles with large circular and non-circular perimeters but have done little to improve on chimney shapes and proportions.

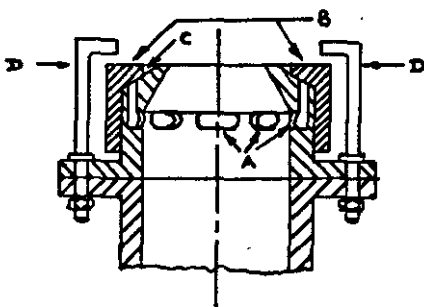


Nozzles used in University of Illinois Tests. (Ref. 7.)



"Kylchap."

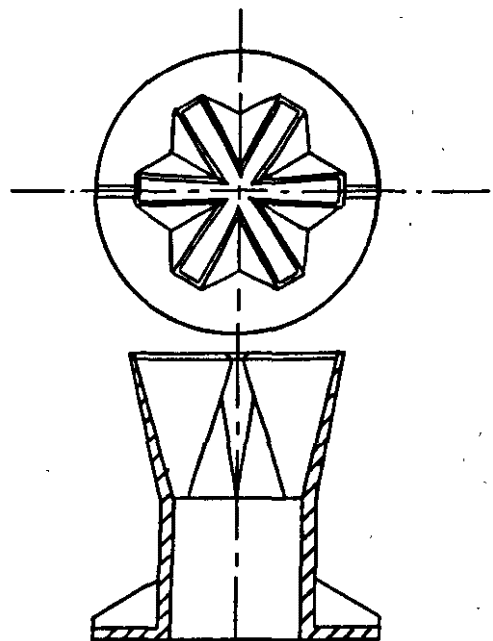
Double Blast-pipe & Chimney.
Shows chimney skirt extensions
or "petticoats"



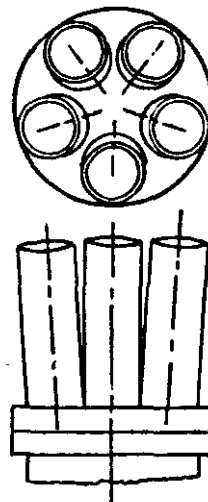
Jumper Top Nozzle.

A = Extra Exhaust Holes.
B = Ring which lifts.
C = Steam tight seat.
D = Lifting ring stop.

DIAGRAM 8.



Kiesel Star
Type Nozzle.



Multiple Jet Nozzle.

The following are some of the types of blast pipe nozzles that have been tried out with varying degrees of success :-

3.4.1. Diagram 7 shows 10 different nozzle models that were used by Professor E.G. Young of the University of Illinois for his experiments in 1933. His conclusions (7) are as follows :-

"Nozzles of the Goodfellow type (see Diagram 10) while superior to the plain circular nozzle, do not compare with nozzles producing a definite division of the jet. The pepperbox type gave the best results with any form of stack, the maximum discharge capacity exceeding that of the circular nozzle by 12%. Where additional perimeter is obtained by the use of a square or rectangular opening, the improvement is negligible."

Despite these remarks, the "pepperbox" or multiple jet type of nozzle does not appear to have found much favour in U.S.A. instead a star type known as the Keisel Nozzle (Diagram 8) was introduced and used extensively. Johnson (7) states :-

"The star nozzle will produce the same draught as the round four-internal projection nozzle (Goodfellow) with approximately 40% less backpressure resulting in 11.5% increase in draw-bar horsepower." (See also paragraph 3.6.)

3.4.2. Up to about 1938 the only major deviation from the circular nozzle in the U.K. had been the use of the Goodfellow nozzle, which is merely a circular nozzle with projections into the steam column. However, at this time the Multiple Jet nozzle was in use on the Southern Railway, the Jumper Top nozzle on the Great Western Railway and "Kylchap" Double Blast Pipe on the London and North-Eastern

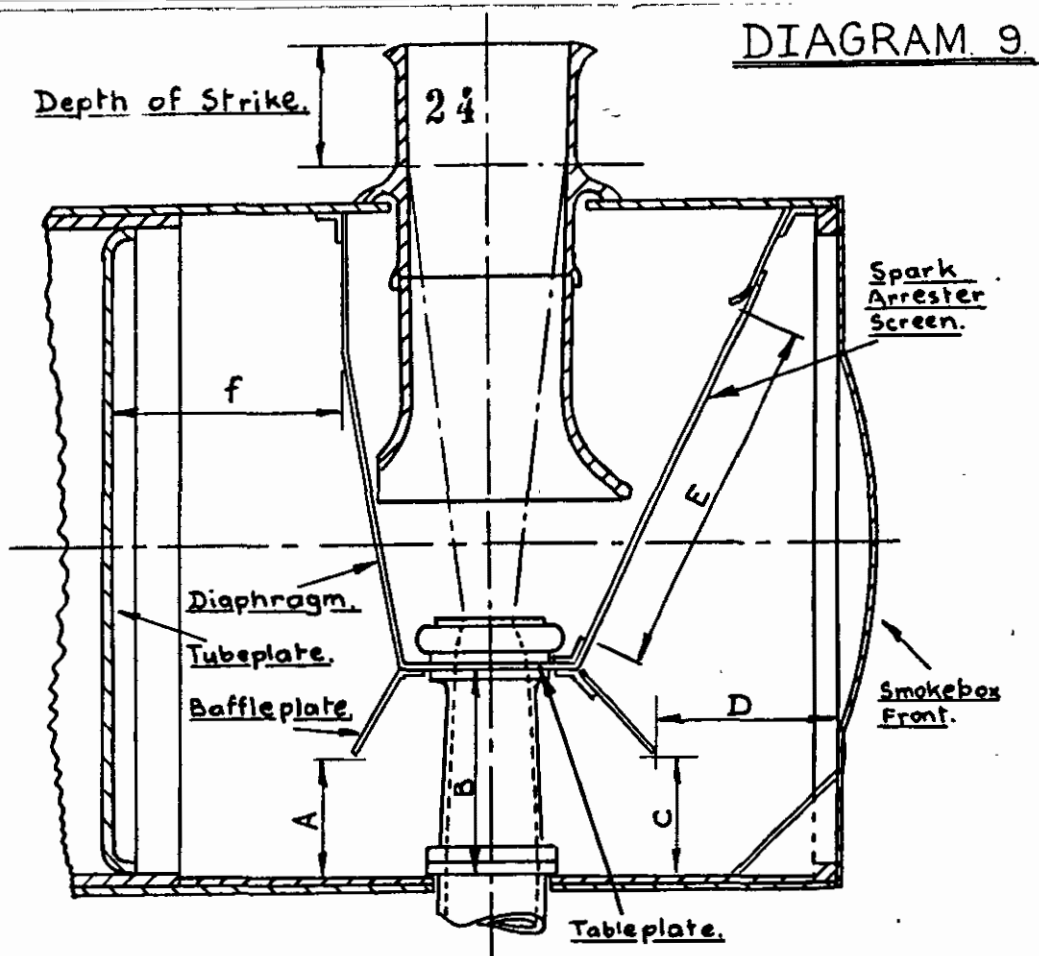
Railway. See Diagram 8 (2 and 10). The properties of each type (10) being :-

1. The multiple jet nozzle, also called Bulleid multiple jet, divides the exhaust in British practice, into 5 jets inclined outwards at 1 in 12 and having a 15% increased free area over the equivalent circular nozzle. This arrangement has the advantages of decreased backpressure and increased draught when compared with the standard circular nozzle although it requires a larger diameter chimney.
2. The jumper blast pipe top is essentially a circular nozzle with an external annular valve device which opens under high steam pressure allowing a larger free area for steam flow. The only advantage of this type of nozzle is the decreased back pressure when the locomotive is "working heavily". In the discussion (2) it is stated that the jumper valve is designed to lift at 3.9 lb/square inch back pressure and although no draught values are given, it is probable that there is an increase in draught when the valve opens due to the increased surface area of steam.
3. The "Kylchap" double blast pipe as shown in Diagram 8 is merely two simple circular nozzles and chimneys in parallel. It achieves reduction in back pressure and increases in draught of the same order as the multiple jet by presenting a larger total free area for steam flow and promoting entrainment by the use of two chimney extensions in series.

3.4.3. In Continental practice the multiple jet, called Lemsitre in France, and variations of the "Kylchap" double blast pipe, e.g., Kylala and Polish double blast pipe, have been extensively

used particularly by Eastern European nations where they are gradually being ousted by the Giesl Ejector. In (3) the above types are mentioned as is a Belgian trial of 1945 with a square nozzle and chimney, which apparently met with some success. Reference (3) is also made to a Lewis Blast Pipe which was in use on the London, Brighton and South Coast Railway in the U.K. in 1920. This consisted of a "long elongated slot working beneath an elongated chimney" and might be considered the forerunner of the Giesl Ejector.

3.5. As yet no reference has been made to the smokebox layout and proportions. This is an important aspect. A good ejector incorrectly placed would be wasted since it would produce an uneven draught across the tubes affecting superheat temperature and boiler steaming, also there would be excessive char deposits in tubes in sluggish areas and in the smokebox. Every effort is therefore made to create an even "distribution" of draught over the tube ends or tube plate in the smokebox. This is usually done by providing a diaphragm in the form of a steel segment between the tube plate and the ejector. This diaphragm was introduced by the American Railway Master Mechanics Association in co-operation with Purdue University Locomotive Laboratory between 1896 and 1902 (7) which, in conjunction with other plates shown in Diagram 9, has come to be known as the Master Mechanics Front End. This arrangement of plates and screens is extensively used in Southern Africa since, by virtue of the circuitous path presented to the combustion gases in the smokebox sparks become extinguished and large pieces of char are broken up and ejected. This means that the slight increase in resistance to flow of the combustion gases is justified by the reduced risk of grass fires being started by sparks. A second advantage of the Master Mechanics Front End is that it keeps the smokebox free of char, which means less "standing time" for the locomotive

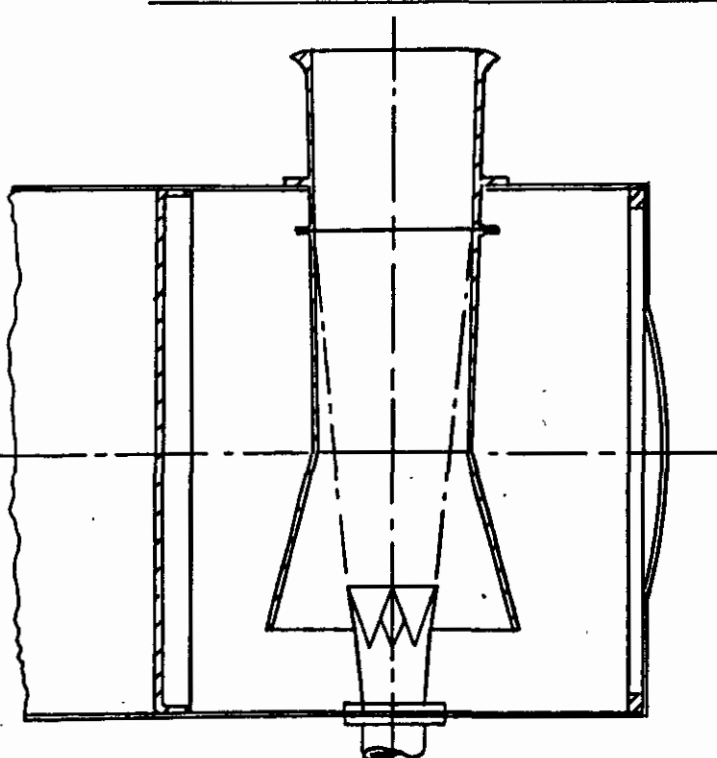


The Master Mechanics Front End
or "Self Cleaning" Smokebox Arrangement

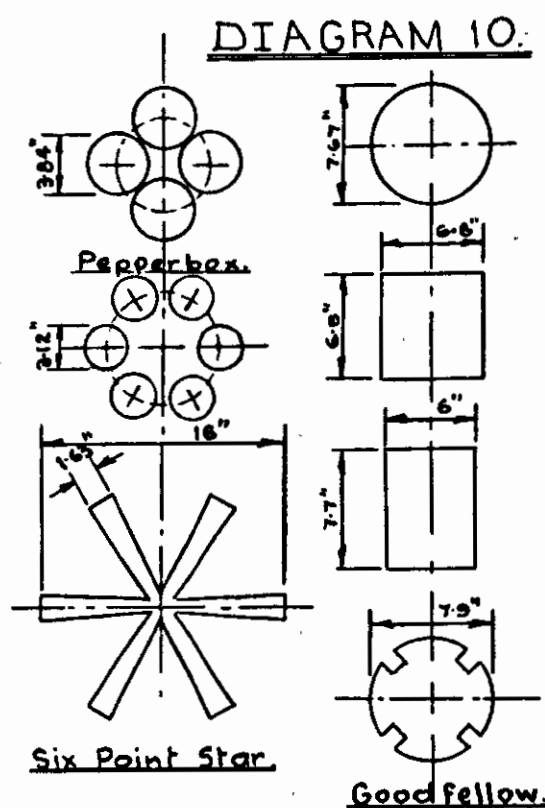
Table of Recommended Proportions based on nett tube & flue gas area.

AREA.	SHAPE.	LIMITS.	PREFERRED
A	Segment of circle.	95% - 110%	95%
B	Segment less blast pipe cross section.	80% - 95%	85%
C	Segment of circle.	65% - 80%	75%
D	Rectangle.	150% - 170%	160%.
E	Rectangle plus two segments (perforated)	120% - 140%	130%

In addition the dimension f should not exceed 30 inches, while in the firebox the brick arch should slope at 30° and the gas area above the brick arch (minimum area) should be between 120% & 130% of nett tube area



Long Skirted Chimney.
(Ref. II.) To scale.
(Kiesel Star Nozzle.)



Comparison of Perimeters of
various nozzles of equal area.
(Ref. II.) To scale.

between trips, to have char removed and a reduced danger of fires or explosions being caused in the smokebox by accumulations of glowing char producing carbon monoxide. Although other means of removing smokebox char automatically have been devised these are not as effective as the Master Mechanics arrangement, which justifies its retention regardless of the type of ejector being used.

3.6. Vincent (11) has analysed the results of tests with seven different American locomotives, using both Goodfellow and Kiesel nozzles with a view to studying the ratio, quantity of gas moved to back pressure at the nozzle, he also relates these two factors to the quantity of exhaust steam utilised. From these results, for identical locomotives, it was noted that at a steam flow 16 lb/second :-

The Goodfellow nozzle and Master Mechanics front end ejected 26 lb/second of gas;

The Kiesel six point star nozzle and Master Mechanics front end ejected 30 lb/second of gas ;

The Kiesel six point star nozzle and long skirt chimney ejected 30 lb/second of gas.

This last chimney arrangement developed at that time, had a very long chimney skirt projecting well over the blast pipe nozzle and was slightly more efficient than the "Kiesel and Master Mechanics" combination at lower steam flows. Elsewhere in (11) reference is made to further model tests carried out by Professor E.G. Young in 1935 (subsequent to those mentioned in (7) and Diagram 7) to compare the nozzles shown in Diagram 10. The results of these tests applied to the locomotives in (11) show that for the Goodfellow nozzle and Master Mechanics arrangement moving 28.8 lb/second of gas at a back pressure of 14 lb/square inch the six (or four) hole "Pepperbox" and long skirt chimney would move 37 lb/second at the same back pressure, i.e., the six and four hole multiple jets of equal free area have equal efficiencies and are considerably more effective than the Goodfellow type.

3.7. From a partly theoretical point of view, Phillipson (8) states that for a conventional circular blast pipe and chimney

$$\left(\frac{G}{W}\right)^2 = \frac{2 \left(\frac{T}{S}\right)^2 \left(1 - \frac{a}{S}\right)}{\frac{a}{S} \left(L + 2 \left(\frac{T}{S}\right)^2\right)}$$

where G = weight of gases displaced, lb/minute
 W = weight of steam discharged, lb/minute
 a = area of blast pipe orifice, square inches
 S = minimum cross sectional area of chimney, square inches
 T = total cross sectional area of tubes, square inches
 L = a constant = 4.

If $\left(\frac{G}{W}\right)^2 = E$, $2 \left(\frac{T}{S}\right)^2 = B$, and $\left(\frac{a}{S}\right) = C$.

then this relationship reduces to

$$E = \frac{\left(\frac{1}{C} - 1\right)}{\left(\frac{1}{B} + 1\right)}$$

which shows that an increase in E could be achieved by a reduction in C or an increase in B . Note, in practice $C < 1$ and $B > 1$. If S remained constant then this increase in E would require a decrease in a and an increase in T . Obviously a decrease in a is undesirable since it increases back pressure but an increase in T is practicable and has already been noted in paragraph 2.4.4. The above relationship is typical of a number of empirical formulae in this field with, as yet, no theoretical backing. They have been used in the past for selection of proportions but are unreliable since there is no clear reference to optimum conditions. The true ejector on the other hand has been more closely studied hence the performance of the Giesl Ejector, which has been designed as a group of true ejectors, has and can be better predicted.

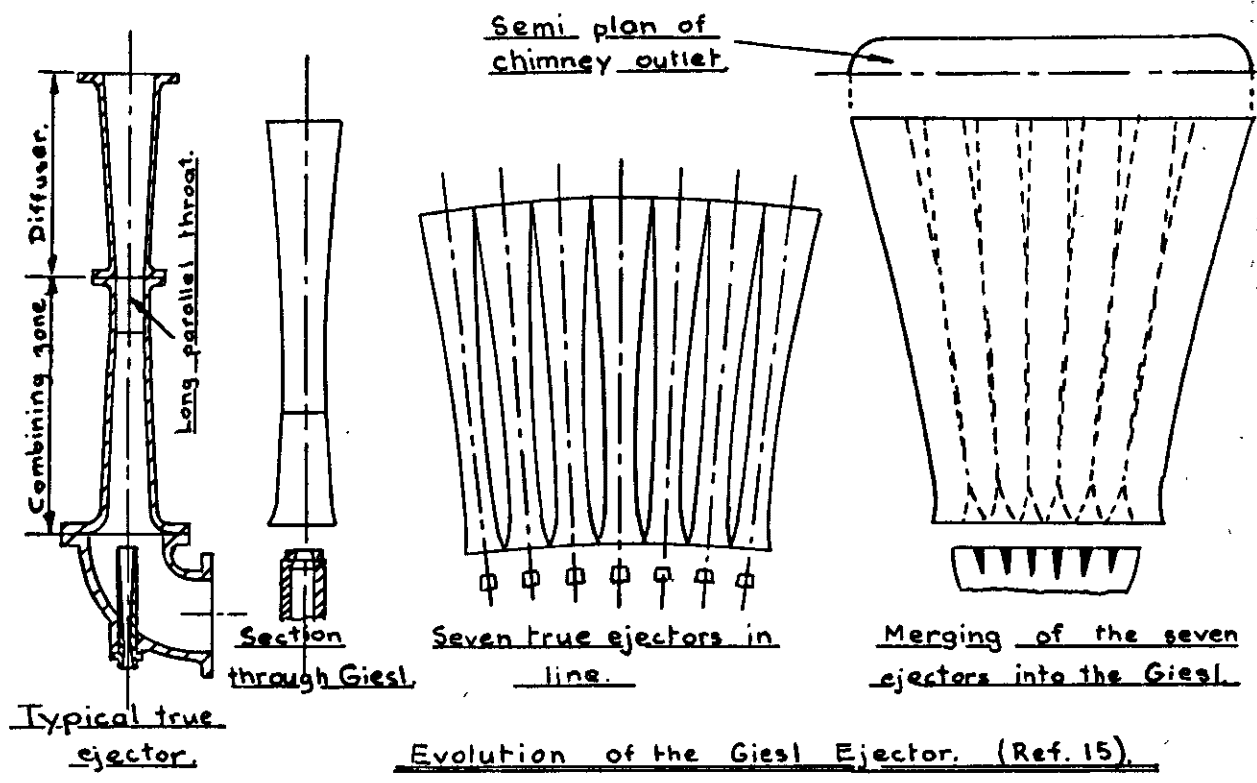
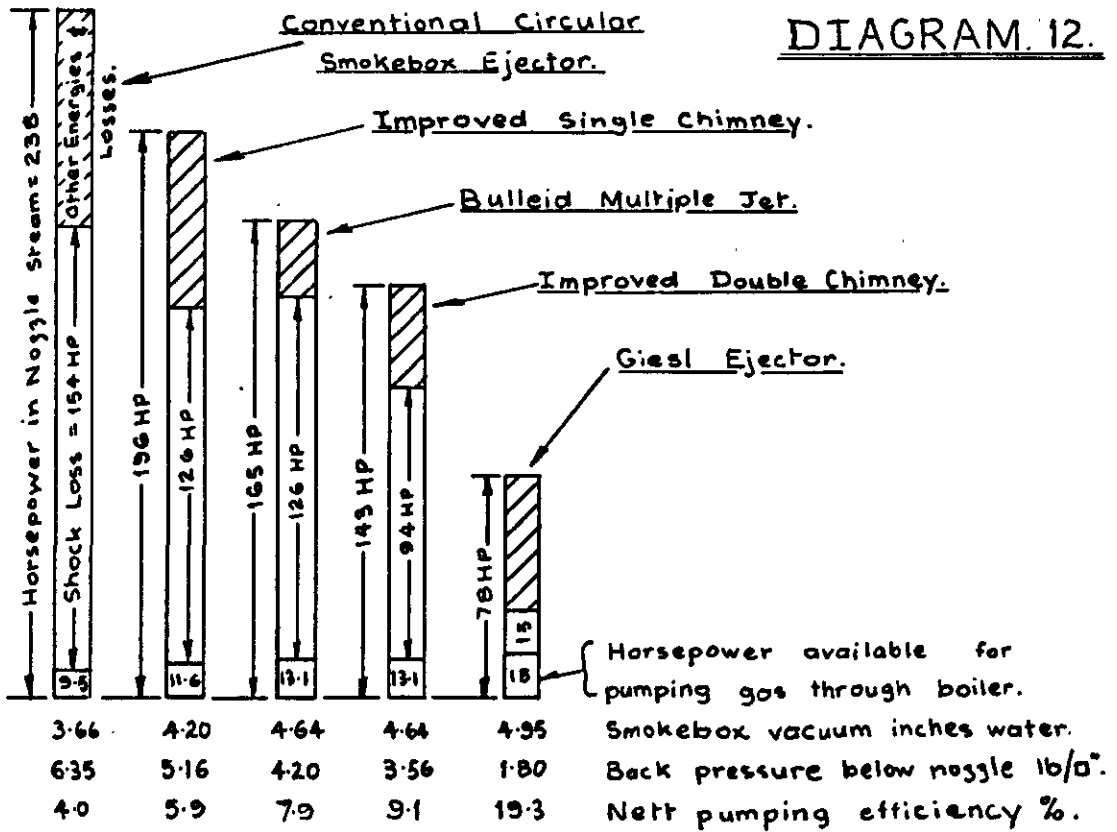


DIAGRAM 12.



Comparison of Performance of some Smokebox Ejectors for an Evaporation of 20,000 lb/hour. (Ref. 15.)

DIAGRAM 13.

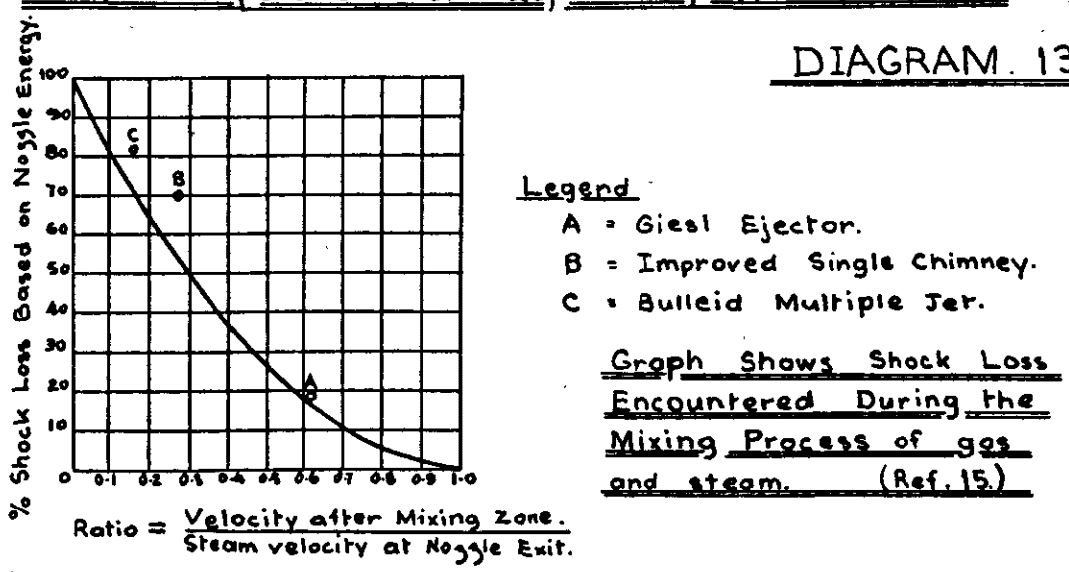
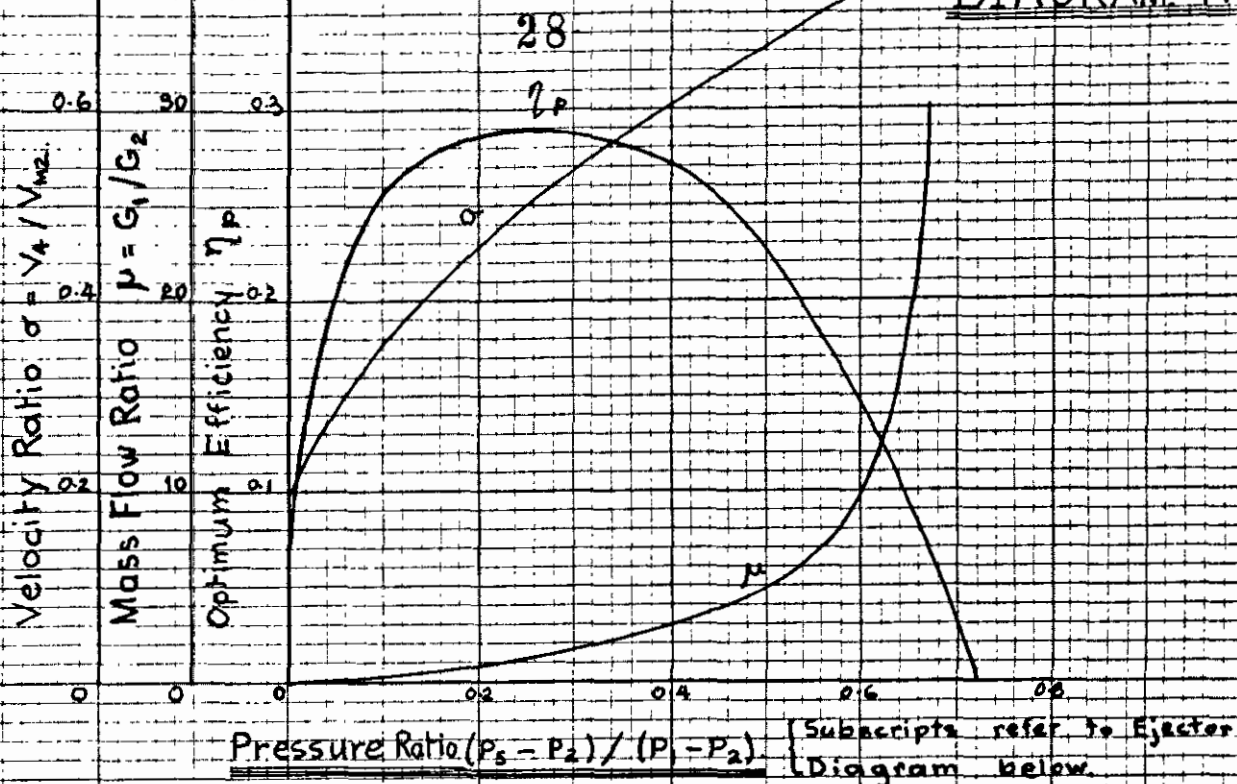


DIAGRAM 14



Typical Ejector Characteristics for a

True Ejector (Ref 14.)

Conditions:

Discharge Coefficients

$[\phi_1]^2 = 0.95; [\phi_2]^2 = 0.85$

Diffuser Efficiency $\eta_d = 0.75$

Velocity Ratio $V_5 / V_{m2} = 0$

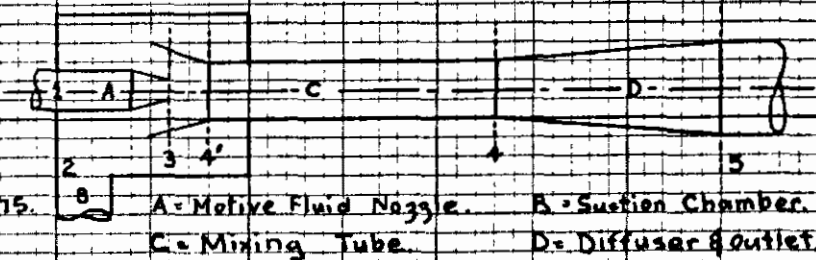
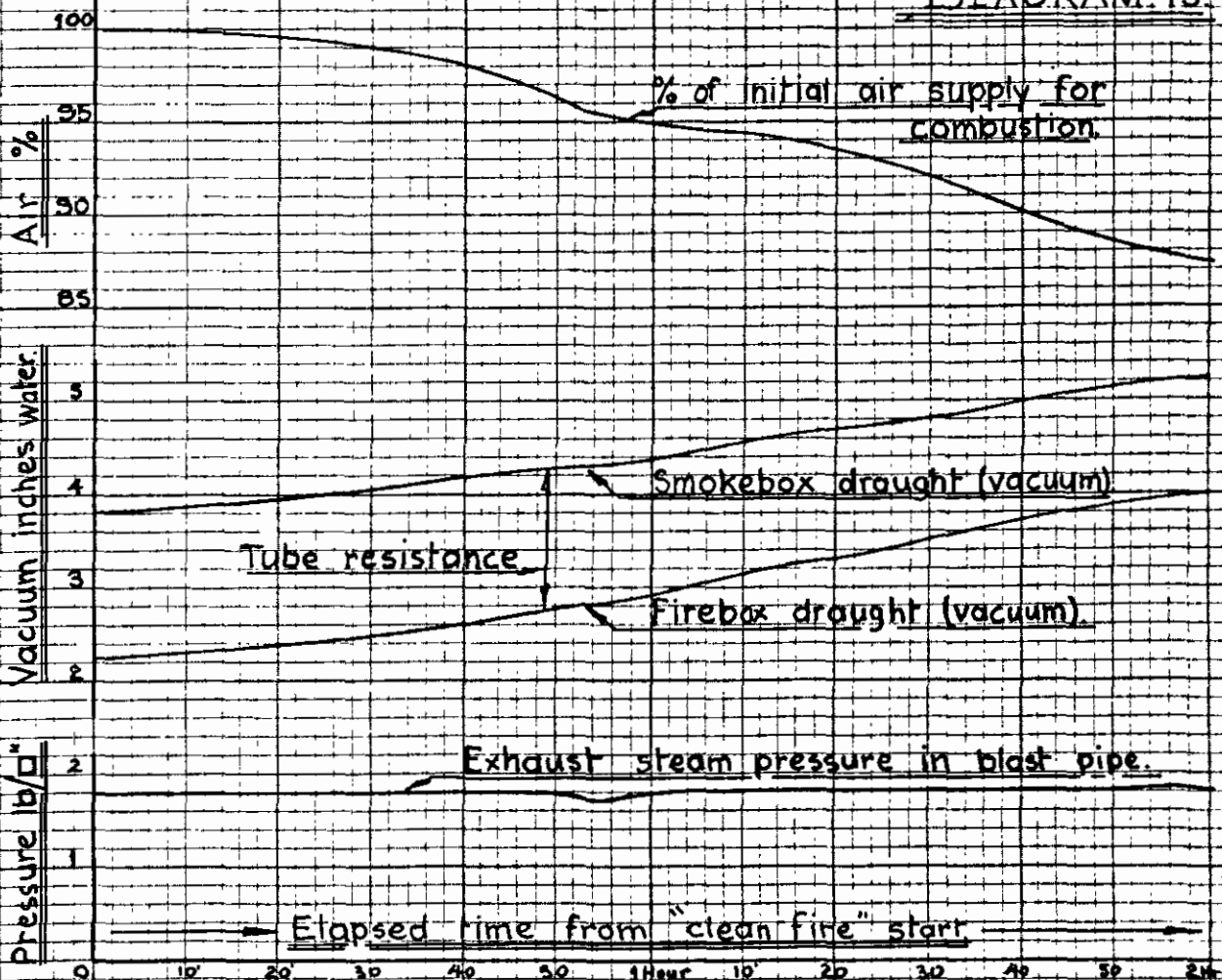


DIAGRAM 15



Effect of Firebox Deterioration During Locomotive Working (Ref 15)

4. THE GIESL EJECTOR AND SUPERHEAT BOOSTER.

4.1. In chapter 3 it was shown how development of the smokebox ejector lead away from the circular nozzle to the more efficient Kiesel six pointed star and multiple jet nozzles. Further, the very long skirted chimney was found to have advantages although the no less efficient but complicated Master Mechanics front end retained its popularity. It is apparent that the Giesl Ejector with its 7 rectangular jets blasting fan-wise into a long oblong chimney fits into this pattern of improved ejectors.

4.2. As already stated the Giesl Ejector was developed and patented by Dr. A. Giesl-Gieslingen of Vienna. It was first tested on an Austrian Federal Railways Class 33 Locomotive in October 1951 and by July 1963 over 2,000 units were in service on 80 steam locomotive classes throughout the world.

4.3. Although the Giesl Ejector embodies many features common to other types of smokebox ejector, e.g., multiple jets and a long chimney, these were not the roots of this development, it being evolved from the principles of the true ejector. Where the true ejector has the inducing flow nozzle close to a short inlet cone and a long parallel mixing tube to allow this process to take place with minimum shock loss, also a long diffusing cone to allow efficient compression of the mixture. If a single circular nozzle and chimney were designed to be a true ejector the combination would be so long that it could not be accommodated in the locomotive smokebox, if however, a number of smaller separate true ejectors were provided they could be accommodated but the complication and expense would be prohibitive. These requirements lead to the in line fan-like arrangement of 7 nozzles, equivalent to 7 separate ejectors and the long oblong shaped chimney of the Giesl Ejector. (See Diagram 11). This combination of 7 ejectors retains the advantages of the true ejector, namely reduction in shock loss in the

mixing zone, by allowing sufficient acceleration of the gas prior to mixing with the steam, i.e., reduced pressure difference between gas and steam at mixing and reduced wall friction in the chimney since there are no dividing walls between the 7 streams. The significance of this reduced shock loss and consequent high efficiency of the Giesl Ejector is shown in Diagram 12, which compares a number of smokebox ejectors at equal boiler output. Diagram 13 further clarifies this point in that the low shock loss encountered in the Giesl Ejector is due to the small drop in velocity between the steam nozzle and the ejector throat, due to steam pressure and gas pressure being nearly equal, which of course, means that throat velocities are very high while pressures are low, which in turn requires an efficient diffuser to overcome atmospheric pressure outside the boiler. As in the case of the conventional smokebox ejector the Giesl Ejector steam nozzles are convergent only and operate below the critical pressure ratio, which means that maximum mass flow occurs with some under-expansion resulting in the mixing shocks already mentioned. They do however, operate closer to the critical pressure ratio than the conventional ejector, which reduces the severity of the shock caused by the expansion of the steam outside the nozzle. Current theories covering the operation of the true ejector are given in (13) and (14), but only the results are of interest here. In (14) the efficiency of the ejector is given as

$$\eta = \frac{G_2 (H_5 - H_2)}{G_1 (H_1 - H_5)}$$

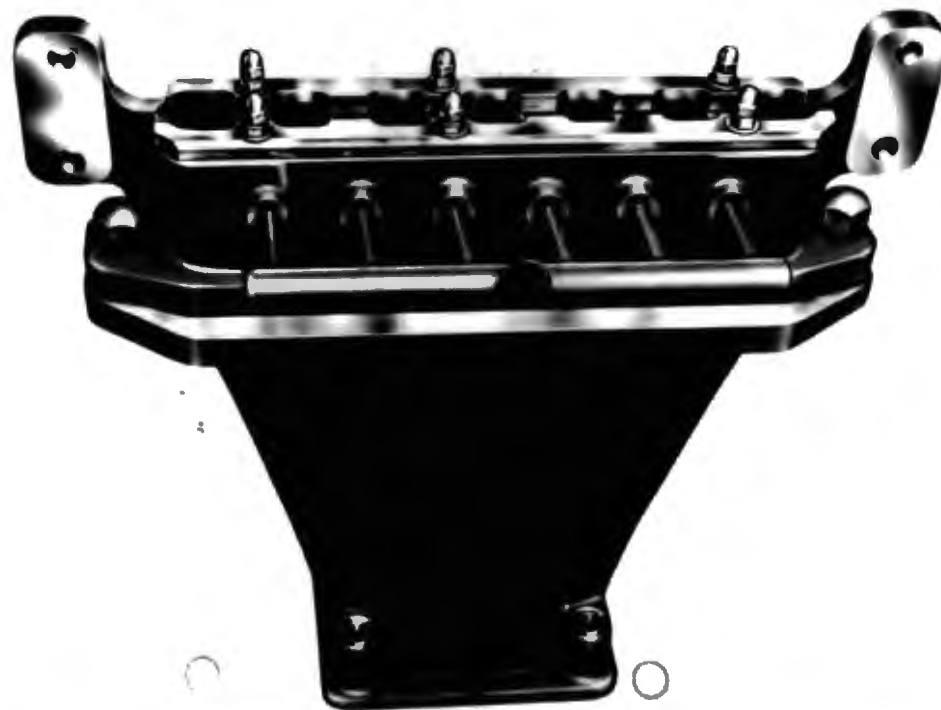
where G is mass flow

H is enthalpy

and suffixes 1 - 5 refer to the ejector zones as shown in Diagram 14. The curves shown in Diagram (14) (includes above efficiency relationship) are derived for the case of entrainment occurring at constant pressure and mixing at constant area (14). These curves have been found to be reasonably accurate in practice and could be applied to the Giesl Ejector. Note that the maximum efficiency of the true ejector coincides with the optimum mass flow ratio G_1/G_2



ASSEMBLED GIESL EJECTOR.



GIESL EXHAUST NOZZLE AND STANDPIPE.

and occurs at a velocity ratio of 0.5 while Diagram 13 shows the Giesl ejector to be operating at a velocity ratio of 0.62, which corresponds to a small amount of underexpansion and a maximum mass flow ratio close to the optimum.

4.4. The photograph on page 31 shows a typical Giesl ejector, with box type spark arrester fitted. The heat resistant steel chimney is made in three parts, the uppermost of which is welded to the smokebox roof while the lower section is coupled to the ejector nozzle. Ease of erection and alignment is assured by the use of accurately fitted pins and tapered cotters at all joints. The ejector nozzle, shown in detail in the photograph on page 32 is made in cast iron and is bolted to the cast iron standpipe which in turn is fixed to the floor of the smokebox. Some adjustment of the nozzle area is provided for by the two steel strips fixed along its top edges. The advantages of this adjustment are that one nozzle size is suitable for a number of slightly different locomotive types and changes in coal or type of train to be handled can be compensated for. Further, the distribution of mixture pressure in the chimney can be varied to be "heavy" back and front and light at the sides, an arrangement which is found to give uniform draughts over the smokebox and firebox tubeplates. However, these slides are not continually adjusted, having once been set for locomotive type, coal and typical load requirement, they are locked in position.

4.5. A feature of the Giesl ejector which, in practice, is very significant is the way in which the pumping efficiency has been found to increase with increasing "boiler resistance". This means that the ejector is able to counter the natural tendency for the fire to be starved of air due to the progressive accumulation of ash on the firegrate as the journey progresses. In Rhodesia Railways practice the fire has to be cleared every 50 to 100 miles, depending on terrain, in order to maintain efficient combustion. Diagram 15 (15) shows how during a special test with a

locomotive held at constant speed and constant cut off for a 2 hour period the smokebox and firebox draughts increased with increasing firebed resistance while back pressure remained constant. In these tests there was a gradual decrease in air supply but nothing as severe as would be experienced with a conventional smokebox ejector. In fact, with a conventional smokebox ejector this decreasing air supply with increasing firebed resistance is so severe that it has proved to be a limitation of steam locomotive capabilities.

4.6. The relationship between ejector performance and "boiler resistance" was mentioned in paragraph 2.4.4. when it was noted that boiler efficiency increased with decreasing boiler tube diameter, i.e., with increased resistance to flow of the gases, but a limit was reached which could be partly overcome by using a more efficient smokebox ejector. This too, applies to "Giesl" equipped locomotives. As the tube diameter is decreased, the number of tubes has to be increased to retain the same total cross sectional area since the same quantity of gas has to pass. For instance, if

there are N tubes of diameter D and the diameter is reduced to XD then the new number of tubes (N') required for the same total cross sectional area is given by

$$\frac{\pi}{4} (XD)^2 N' = \frac{\pi}{4} D^2 N$$

$$\text{i.e., } N' = \frac{N}{X^2}$$

But the heat transferred is proportional to the surface area of the tubes and the increase in total surface area is

$$\frac{\pi (XD) N'}{\pi D N} = \frac{X}{N} \times \frac{N}{X^2} = \frac{1}{X}$$

(an increase since $0 < X < 1$)

Further, when a gas flows through a circular pipe with low pressure drop then the flow (12) is given by

$$\Delta P = 3.36 \times 10^{-6} \frac{f L w Q^2}{D^5} \text{ lb/square inch.}$$

where ΔP = pressure drop or resistance - lb/square inch

f = friction factor dependent on Reynolds number and type of pipe.

L = length of pipe - feet.

w = density of gas - lb/cubic foot.

Q = gas flow rate - cubic feet/hour.

D = pipe diameter - inches.

In the case under consideration f , L and w would remain nearly constant

therefore $\Delta P = \frac{K Q^2}{D^5}$, where K is the "lumped" constant.

Since there are now more tubes each smaller tube would carry less, i.e.,

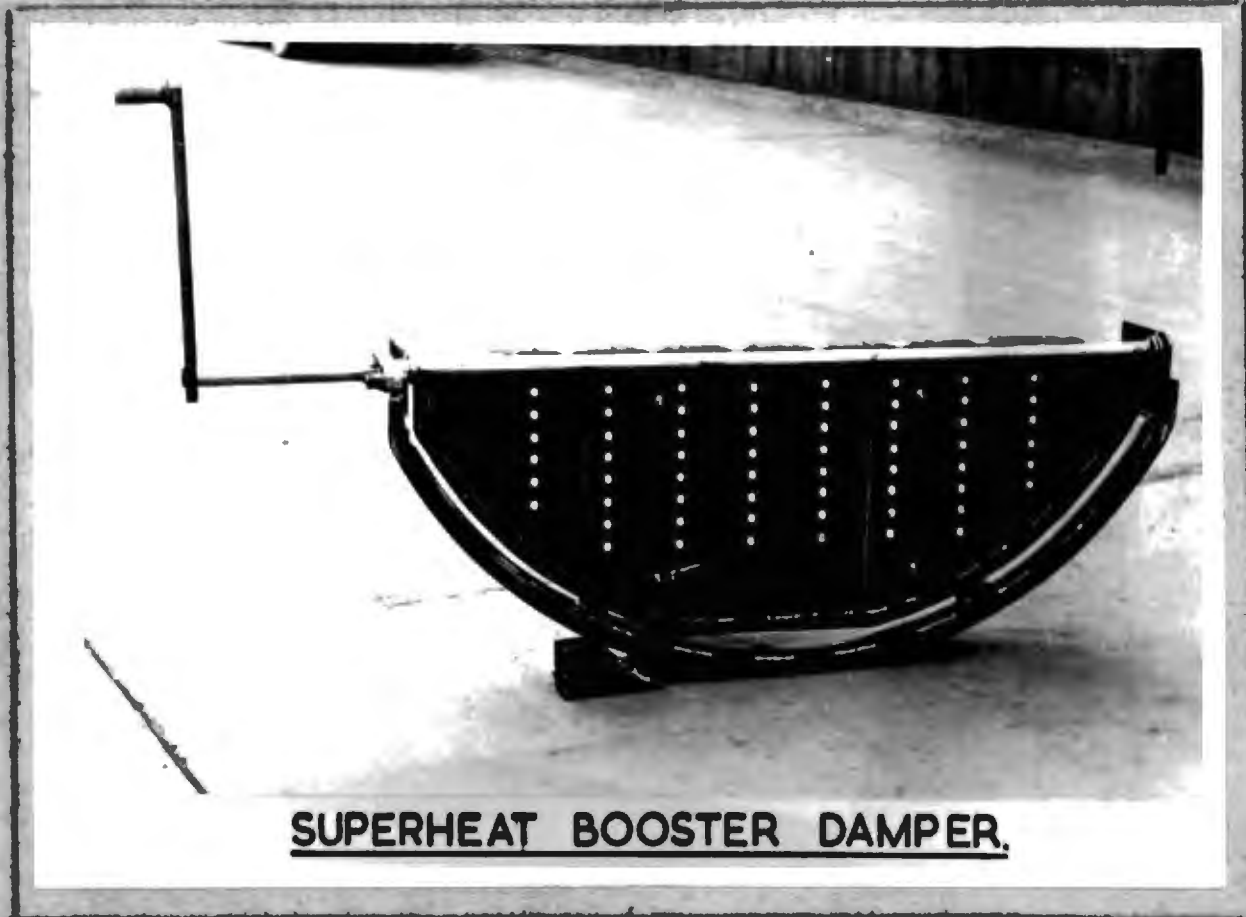
$$Q' = X^2 Q$$

New pressure drop or resistance would be

$$\Delta P' = \frac{K (Q')^2}{(XD)^5} = \frac{K X^4 Q^2}{X^5 D^5} = \frac{K}{X} \frac{Q^2}{D^5}$$

hence $\Delta P' > \Delta P$ since $0 < X < 1$.

The outcome is that by decreasing the diameter of the tubes and increasing their number the total surface for heat transfer is increased, which appears in practice as an increase in evaporative efficiency. A greater pressure drop (increased resistance) is required to move the same quantity of gas through the boiler. There are limits to this in so far as the tubes cannot be made so small that they become structurally unsound or very susceptible to blockage. However, it is desirable to increase the total tube resistance to such a value that the firebed resistance is small in comparison, in which case the increase in firebed resistance due to ash accumulation is less significant and the overall boiler operation is more stable.

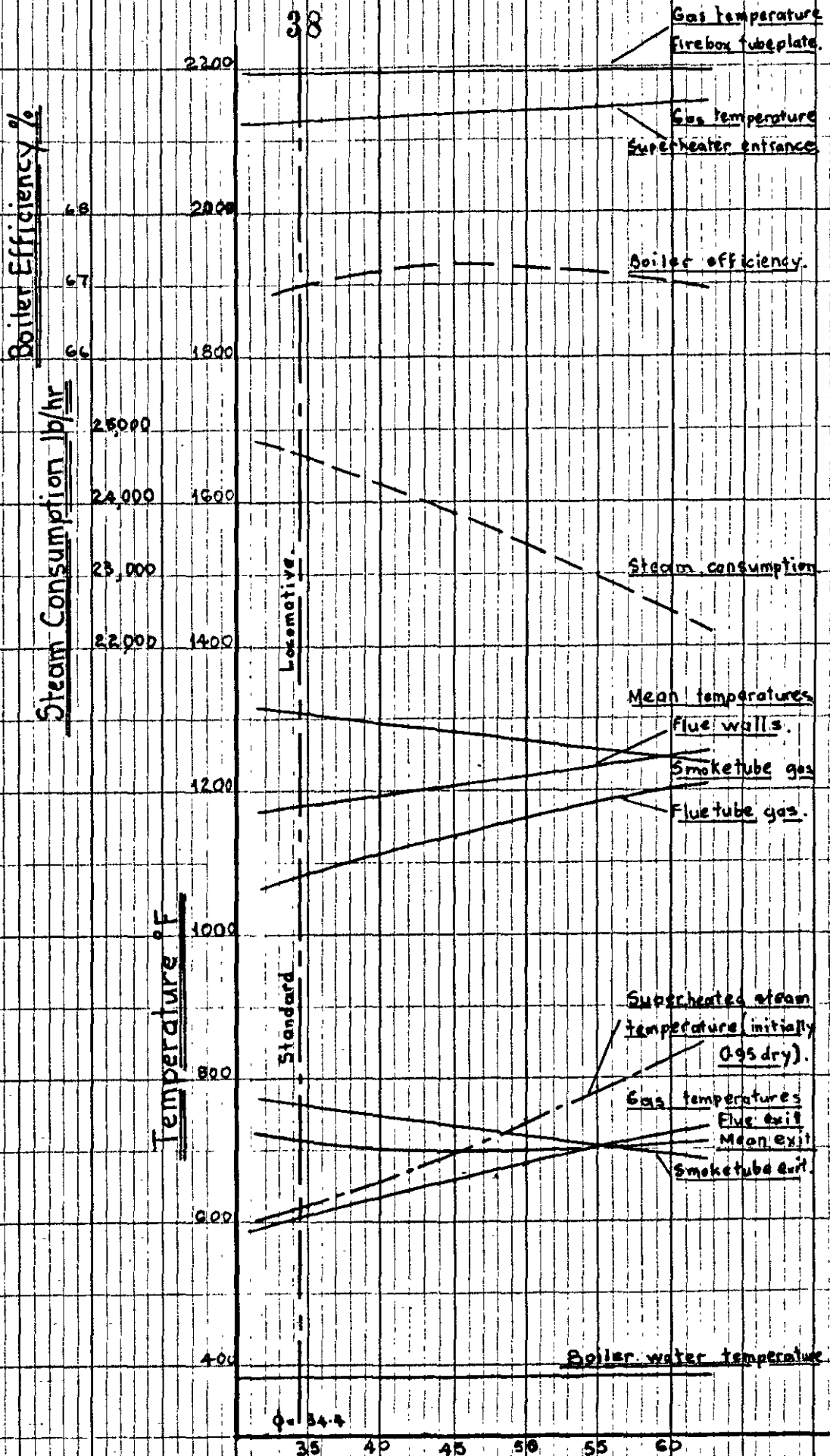


SUPERHEAT BOOSTER DAMPER.

4.7. It is seldom that a Railway Company is in a position to vary the number and diameter of boiler tubes in a boiler at will, since this involves changing the two expensive, inaccessible plates that support the tubes. However, this idea of increasing boiler resistance has another facet in that by placing a damper or throttling plate in the smokebox across the exits from the small boiler tubes more of the combustion gases pass through the flue tubes, which increases the resistance to flow through the boiler and achieves the objective of boiler operating stability. The fitting of the Giesl-Altmann Superheat Booster, as the above damper is called (see photograph of damper or booster), is claimed to increase total barrel resistance by 50 - 160% (giving rises of superheat from 55 to 135°F respectively) which means that firebed resistance is definitely less significant, hence the boiler will give stable operation under varied conditions of handling and coal. This increase in resistance can only be applied where the smokebox ejector is capable of transporting the combustion gases against the increased resistance without causing any substantial increase in back-pressure at the cylinders. A second effect of this damper which is even more important than the first is that it improves the economy and efficiency of the locomotive by increasing superheat temperature. The reasons for this improvement are that condensation in the cylinders is less significant due to the higher steam temperature and less steam is consumed, since increased superheat means greater specific volume and therefore less steam (weight) admitted to the cylinder per stroke. The maximum superheated steam temperature permitted is not limitless but depends on the properties of the cylinder lubricant, since this must not fail under conditions of high temperature.

4.8. The damper referred to above is made from heat and abrasion resisting alloy steel. It is so proportioned that it maintains a definite ratio between the quantities of gas passing through the small and large boiler tubes. The gas allowed through the

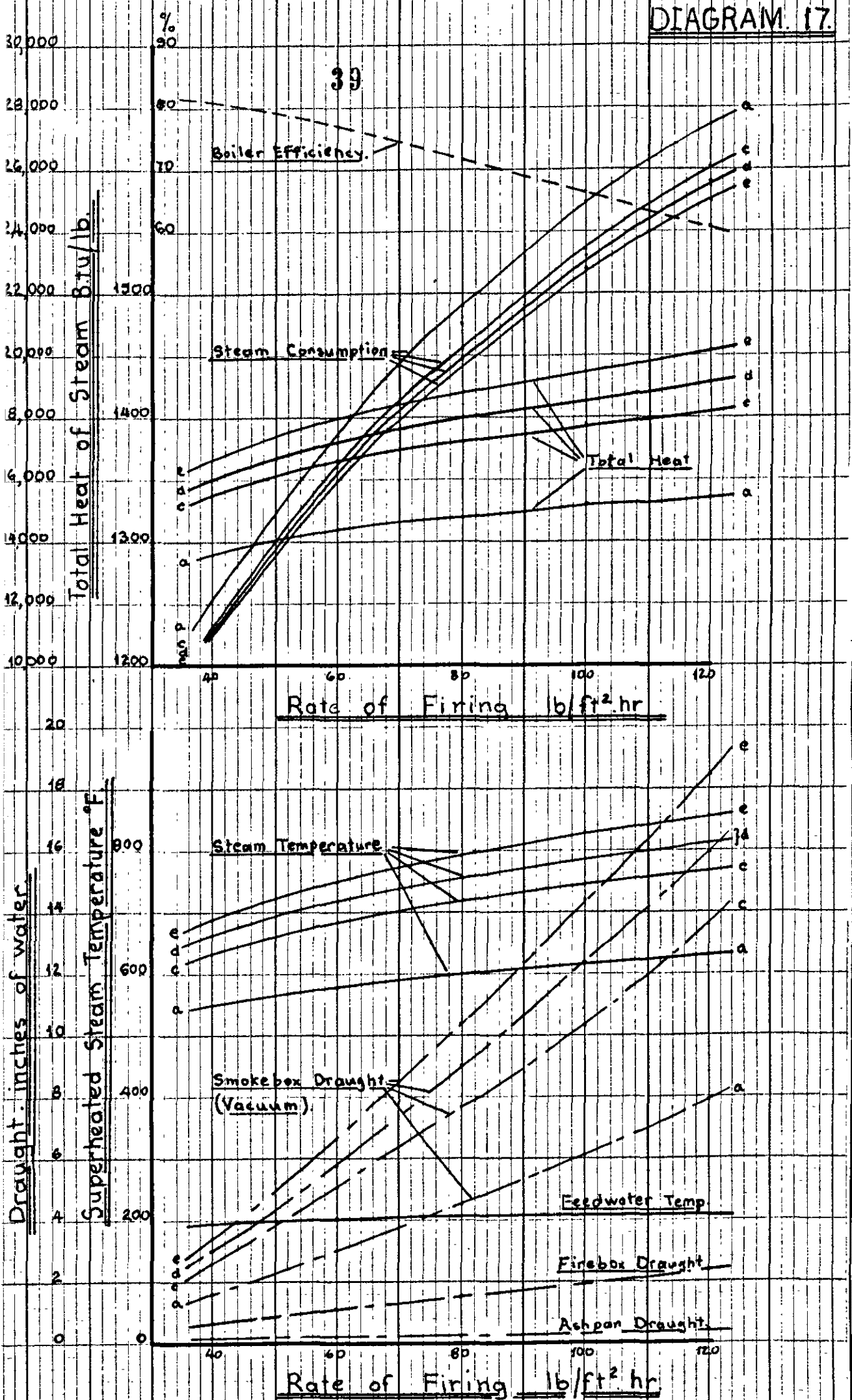
DIAGRAM 16



% of Exhaust Gas Passing through Flues.

i.e. ϕ is fraction of gas past superheater

Curves relate to tests carried out on Austrian railways class 78 4-6-4 locomotive by Dr. A. Giesl-Gieslingen. The standard locomotive had $\phi = 0.344$; this was increased by throttling the flow through the smoketubes (small tubes). Coal of 12,250 Btu/lb was fired at a rate of 3,450 lb/hr of which 3,240 lb/hr was burnt producing 47,300 lb/hr of gas. 45% excess air was provided.

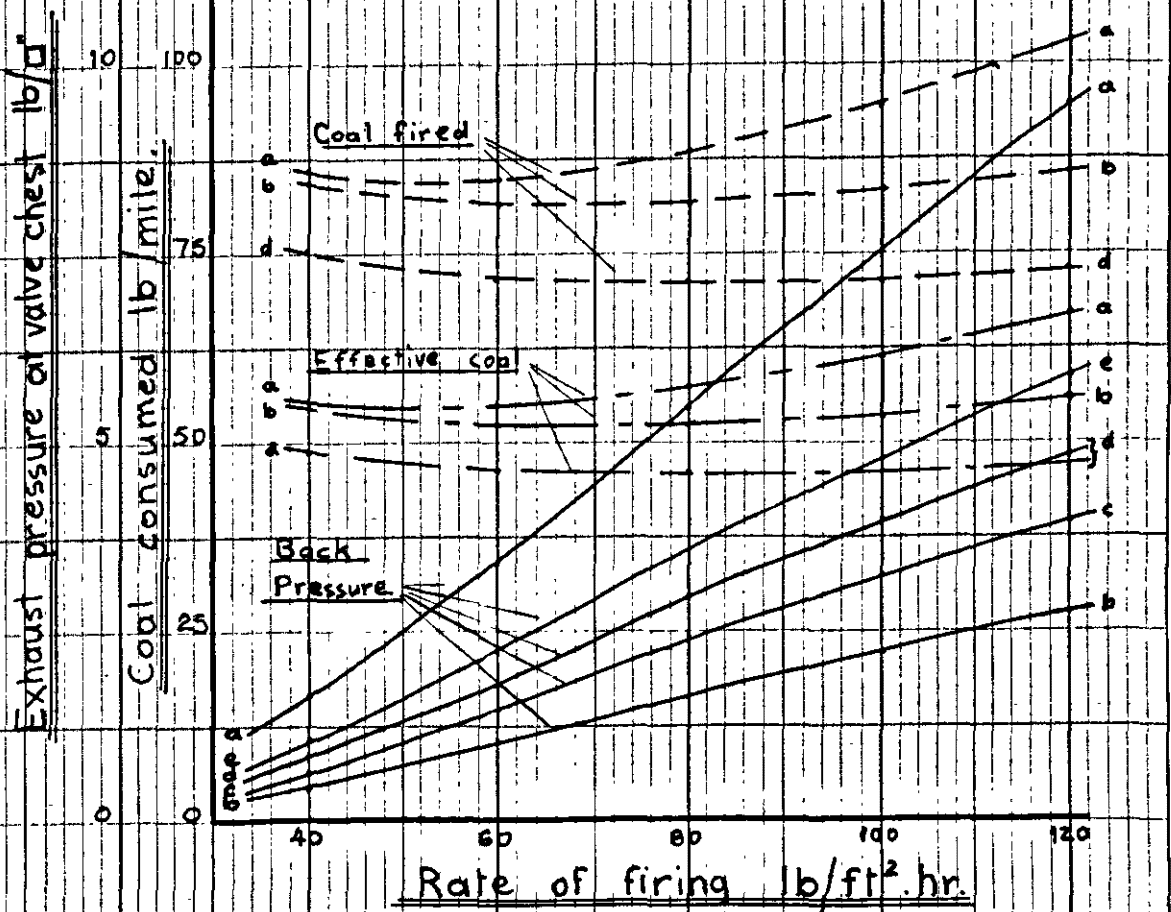
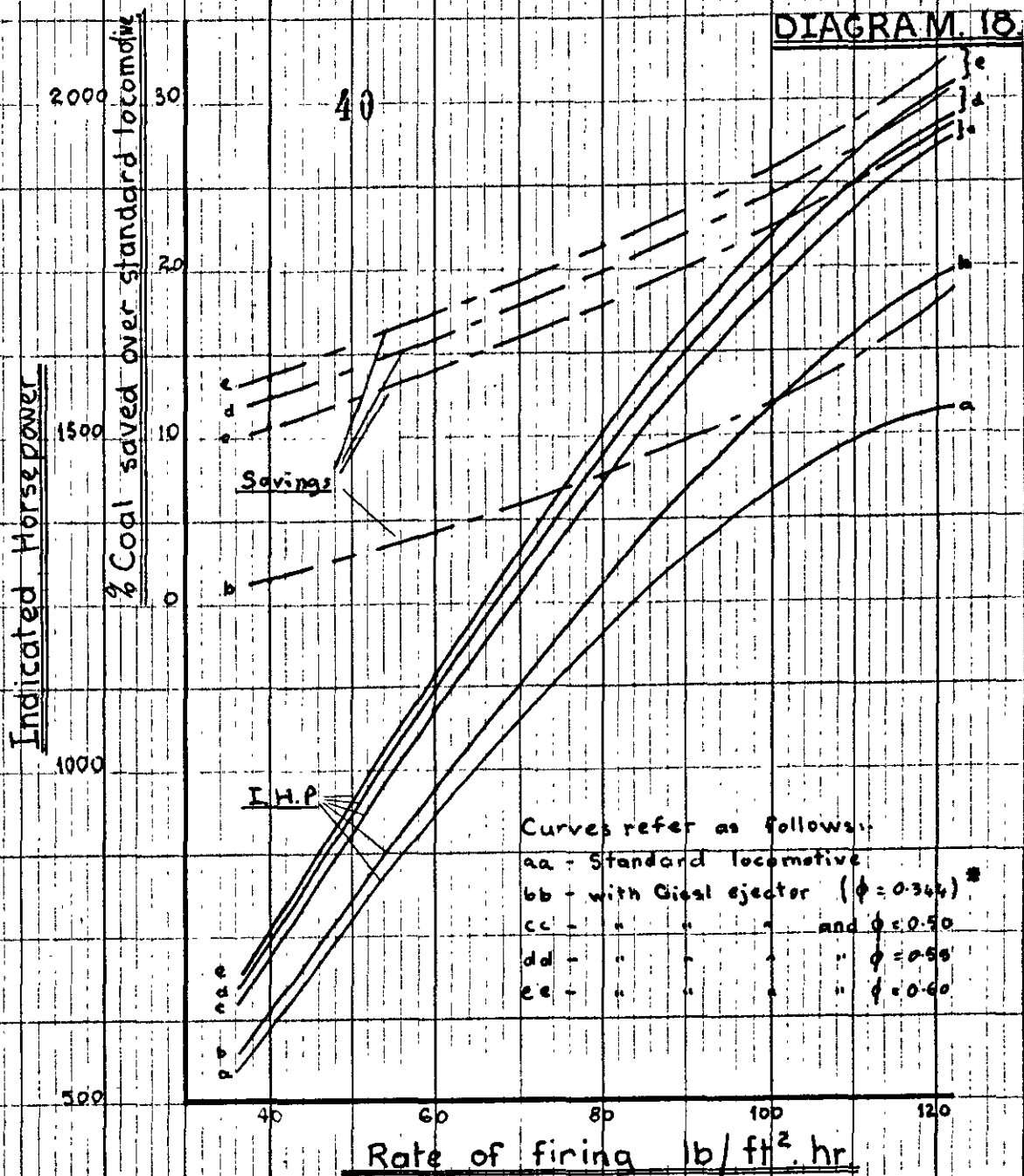


Boiler Trials with Varying degrees of Throttling

Curves represent

aa	- Standard locomotive ($\phi = 0.344$) (Austrian Cl 70)
cc	- Giesl ejector plus $\phi = 0.50$.
dd	- " " " $\phi = 0.55$.
ee	- " " " $\phi = 0.60$.

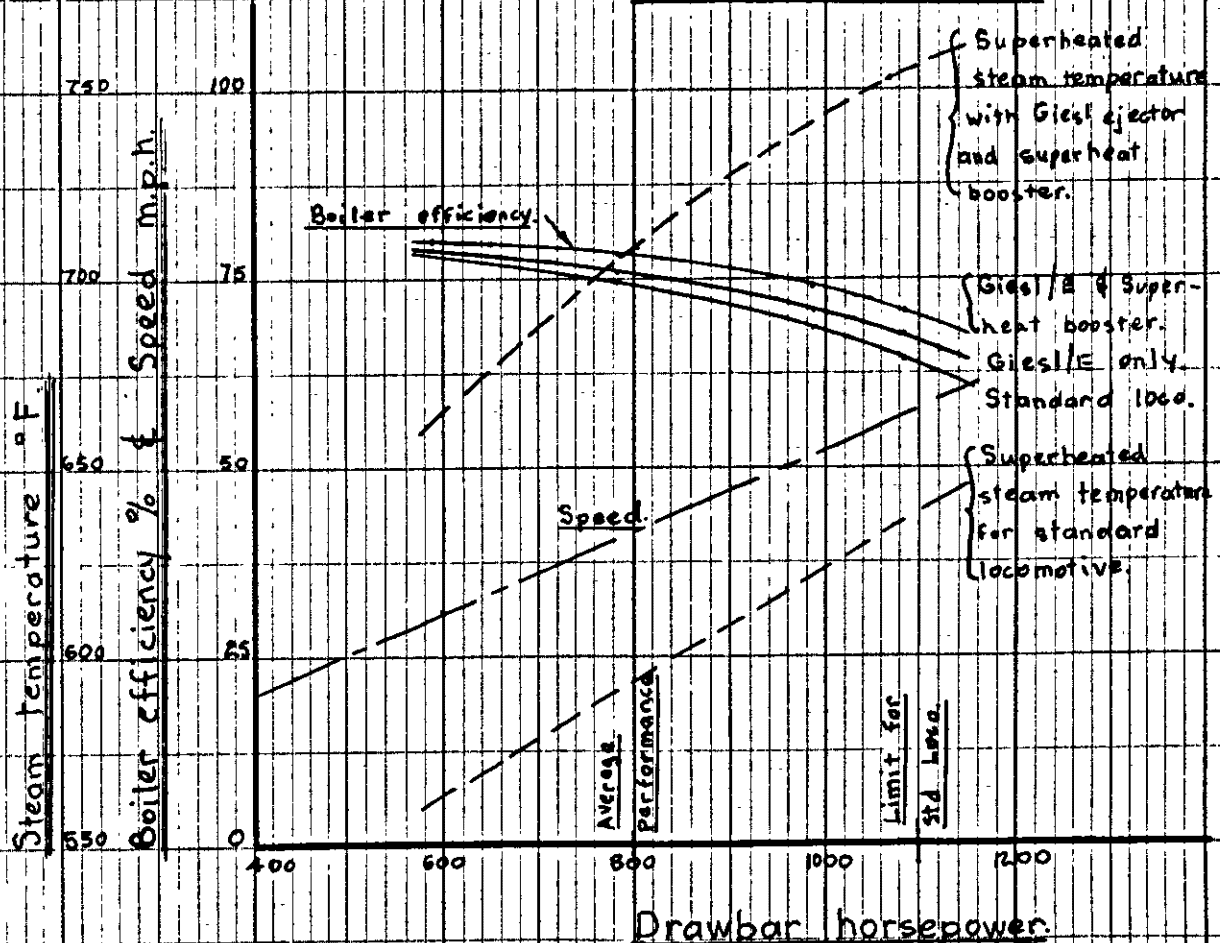
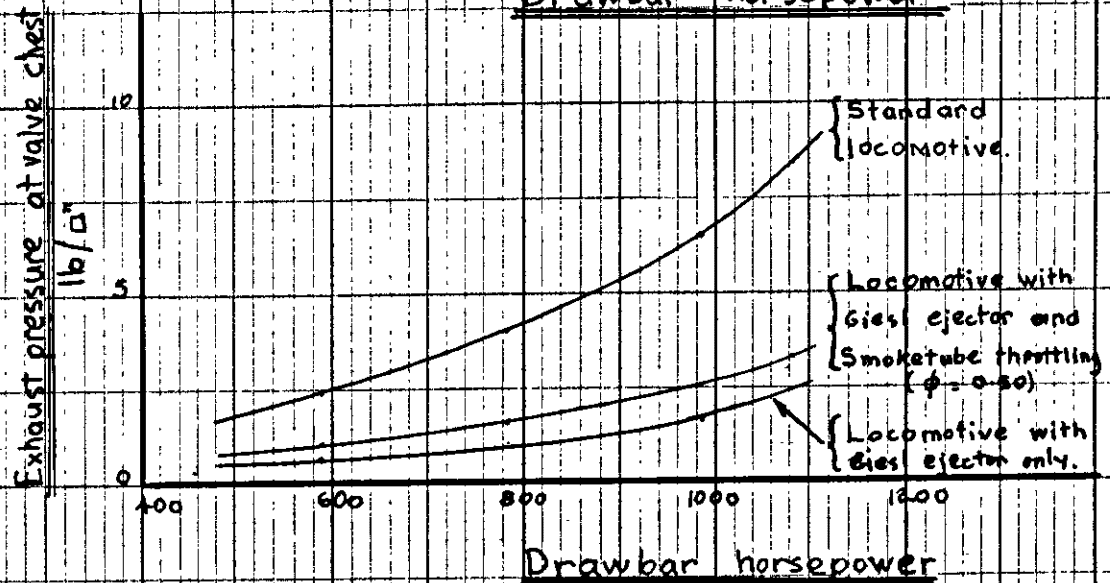
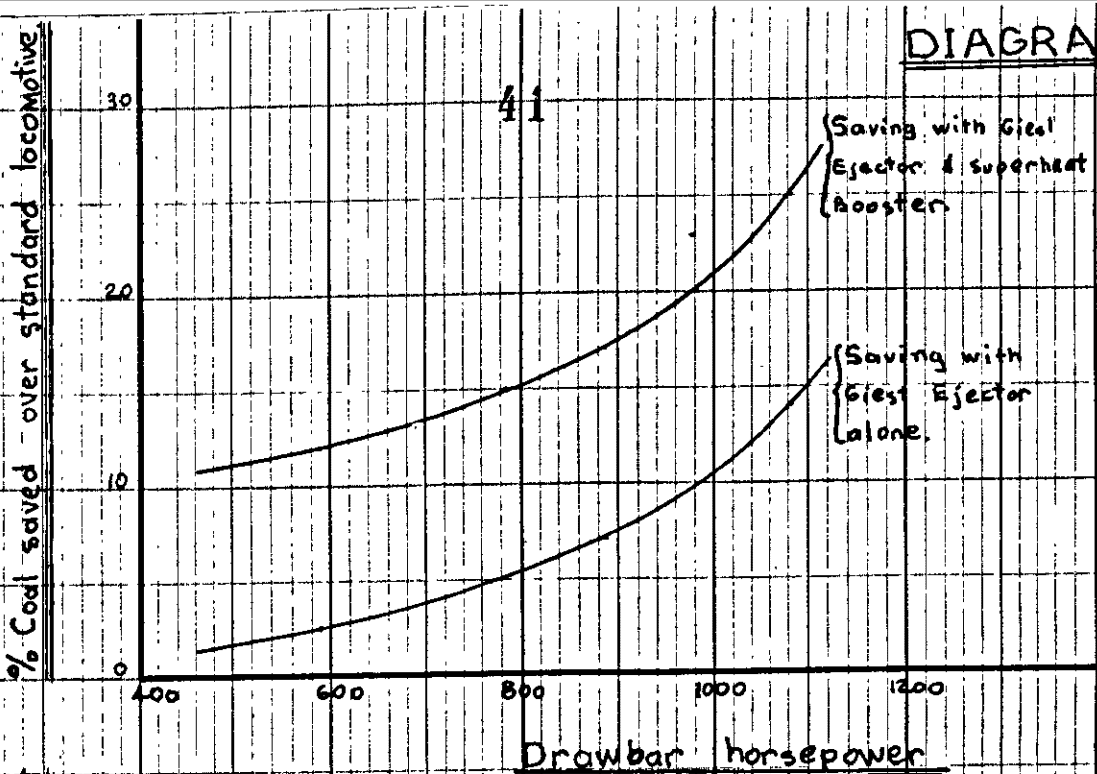
ϕ = portion of exhaust gas through flues (past superheater). Coal had 12,250 Btu/lb.



Curves Derived from Diagrams 16 & 17.

* Coal of 12,250 Btu/lb. ϕ = Portion of exhaust gas passing through flues.
 Note ϕ increased by throttling. Standard loco as built has $\phi = 0.344$.

41



Improved Performance & Economy after fitting Giesl Ejector & Superheat Booster to Austrian class 78 - A-6-4 Locomotive.
 $\phi = 0.344$ (Standard loco) increased to 0.50 by throttling smoke (small) tubes.

smaller tubes is sufficient to keep them free from char and to contribute adequately towards evaporation; once this gas reaches the damper it may either pass through the few holes in the damper or through the space near the periphery of the damper provided for this purpose. This device was developed jointly by Dr. A. Giesl-Gieslingen and D.F. Altmann of the Austrian Federal Railways; the railway on which it was tested and perfected. Diagrams 16, 17, 18 and 19 refer to the actual original tests (15) with the Giesl Ejector and superheat booster during which the optimum degree of throttling was established.

4.8.1. Diagram 16 shows how the gas temperatures at exit from the flues and smoketubes as well as the superheated steam temperature varied with increasing degrees of smoketube throttling. The diagram further shows that within the practical range of throttling considered and for the constant rate of firing adopted, the mean exit temperature from the tubes and hence the boiler efficiency, remained almost constant. The significance of the way increased superheat temperature affected the economy of operation is shown by the decreased steam consumption with increased throttling.

4.8.2. Diagram 17 shows the effects on draught, steam temperature and steam consumption for increasing rates of firing. These curves illustrate the difference between the Giesl Ejector equipped locomotive with varying degrees of throttling and the standard unthrottled locomotive. A significant aspect is the way in which smokebox vacuum (draught) increases with increasing degree of throttling, for which reason a conventional smokebox ejector with associated high back pressure would be unfit for operating the superheat booster.

4.8.3. Diagram 18 is based on diagrams 16 and 17. It shows significant increases in power and economy at the expense of increased back pressure. In addition to the standard locomotive and Giesl Ejector with varying degrees of throttling, the application of the Giesl Ejector to the unthrottled

locomotive is also considered, for which case the considerable reduction in back pressure effected significant increases in economy and power.

4.8.4. Diagram 19 summarises the results demonstrated in the previous three diagrams. In this case, the degree of throttling considered is equivalent to 0.50, i.e., 50% of the exhaust gas passes the superheater elements in the flues while the remaining 50% flows through the throttled smoketubes. The manufacturers of the Giesl equipment maintain that the results shown in Diagram 19 can be fully reproduced for any type of locomotive by calculation and this is the method of selection of ejector and booster proportions for any given application within the limits of locomotive capacity, steam temperature and backpressure.

4.9. Whilst diagrams 16 to 19 illustrate improvements and economies recorded for the Austrian Federal Railways test locomotive they are only quoted to show trends and effects of various phenomena encountered. In general the application of the Giesl Ejector with or without the superheat booster results in varied fuel economies depending on the service. Giesl Ejectors have been fitted for the following reasons; to effect fuel economies only, to effect power increases only, to effect speed increases only, to effect improvements in "steaming" ability or various combinations of the above. The table on page 44 gives details of improvements recorded for various locomotive types after fitting Giesl Ejectors.

4.10. The shortcomings of the steam locomotive have been considered with respect to the gas ejecting arrangements in the smokebox. The development of the smokebox ejector up to the Giesl ejector has been traced culminating in an appraisal of its influence on the steam locomotive, the boiler in particular. Prior to presenting the Rhodesia Railways tests and experiences with the Giesl ejector consideration is given to the following extract (15) which summarises the attributes of the equipment ;

EXTRACTS FROM PUBLICATIONS OF IMPROVEMENTS EFFECTED BY THE GIESL EJECTOR

DATE	RAILWAY	LOCOMOTIVE TYPE	SERVICE	PREVIOUS SMOKEBOX EJECTOR	YEAR LOCO BUILT	FUEL SAVED	TYPE OF FUEL	INCREASE IN POWER	BOOSTER AND/OR G/EJECTOR	INCREASE IN SUPERHEAT
10/1951	Austrian	4-8-0	Passenger	Conventional	-	6%	Coal	-	E	-
12/1957	Czech	2-10-0	Freight	Kylchap	-	5%	Lignite	-	E + B	88°F
10/1959	East African	4-8-2 + 2-8-4	Freight	Conventional	1955	15%	Oil	-	E	-
1958	East African	4-8-2 + 2-8-4	Freight	Conventional	1954	3%	Oil	23%	E	-
1957	Australia	4-6-0	Freight	Conventional	-	8%	Coal	-	E + B	95°F
5/1959	British	2-10-0	Freight	Kylchap	-	5%	Lignite	5.1%	E	-
7/1959	UK Coal Board	0-6-0	Freight	Conventional	-	9%	Coal	27%	E	-
1/1958	East Germany	2-10-0	Freight	Conventional	-	9%	Lignite	30%	E	33°F
4/1958	Jugoslavian	0-10-0	Passenger	Conventional	1911	10%	Coal	-	E + B	150°F
12/1958	Belgian	0-8-0	Freight	Conventional	1920	12%	Coal	30%	E + B	128°F
5/1959	Belgian	4-6-0	Passenger	Conventional	1917	12%	Coal	-	E + B	-
12/1958	Spanish	2-8-2	Mixed	Kylchap	1953	13%	Lignite	35%	E + B	-
1957	Austrian	2-10-0	Freight	Conventional	-	8%	Lignite	-	E + B	40°F
2/1958	Austrian	0-8-0	Ore	Conventional	1941	8%	Lignite	-	E + B	-
5/1959	Austrian	0-8-0	Ore	Conventional	1927	14%	Lignite	33%	E	-
1958	Austrian	2-12-2	Freight	Kylala	1941	-	Coal	-	E + B	90°F
1957	Austrian	2-6-2	Mixed	Conventional	1911	10%	Coal	-	E + B	120°F
7/1960	Jugoslavian	2-8-2	Freight	Conventional	1927	12%	Coal	-	E + B	151°F
3/1961	Spanish	2-6-0	Passenger	Conventional	1921	19%	Coal	-	E + B	-
12/1961	Spanish	2-8-0	Ore	Conventional	1930	24%	Coal	-	E + B	-
8/1962	Angola	4-8-2 + 2-8-4	Freight	Kylchap	1950	13%	Wood	-	E + B	131°F
8/1962	Angola	4-8-0	Freight	Conventional	1930	20%	Wood	-	E + B	167°F
7/1962	Spanish	2-8-0	Ore	Conventional	1926	23%	Coal	-	E + B	-
8/1963	Japanese	2-8-2	Freight	Conventional	-	9%	Coal	-	E + B	-
	AVERAGES				1934	12%				108°F

44

"Claims for the Giesl ejector are reported to have been substantiated by the performance of over 500 locomotives fitted with it. The claims are :

Its use permits a locomotive to operate with 50 - 75% reduction in steam chest back pressure for the same smokebox vacuum or alternatively with much higher smokebox vacuum for the same back pressure, or both in lesser degrees.

Front end limit is eliminated.

Locomotives which have never been free-steainers can be transformed.

Normal locomotives are able to haul greater loads and abnormally low-grade coal can be successfully burnt. Black smoke and exhaust noise are much reduced.

The ejector has a markedly even draw on the fire.

In general, the harder the engine is worked, the better the economy, which has been as high as 25% in some cases. This applies equally to oil-fired and coal-fired locomotives. The high efficiency of the ejector allows the use of the superheat booster which raises the temperature of the superheated steam in some older and less efficient locomotives, so affording economies in both fuel and water".



ENGINE No. 380 FITTED WITH GIESL EJECTOR.

5. RHODESIA RAILWAYS GIESL EJECTOR TESTS.

5.1. The following chapters deal with tests carried out for Rhodesia Railways to determine, the effects of the Giesl ejector on its own and Giesl ejector with superheat booster on their 15th Class type steam locomotive, in traffic. In addition these tests were designed to establish fuel and water savings accrued under normal service conditions also to confirm the reduction in cylinder back pressure, increase in smokebox draught and increase in superheat temperature claimed by the manufacturers of the equipment.

5.2. The 15th Class steam locomotive is of the articulated Garrett type having a wheel arrangement of 4-6-4 + 4-6-4 and other principal characteristics as follows :

Tractive force at 85% B.W.P. = 42,750 lb.

Total length over couplers 92' - 4"

Total weight in full working order 186.74 tons.

Total water capacity 7000 gallons.

Coal capacity 12.5 tons.

4 Cylinders (2 on each unit); 17.5" dia x 26" stroke.

Walschaerts Valve Gear with piston valves

9" dia x 6" travel.

Coupled wheels 4' - 9" diameter.

Boiler ; Superheated ; Working pressure 180 lb/sq.in.

Least diameter of Barrel 6' - 4 9/16"

Length between tubeplates 13' - 3/8"

Grate area 49.6 square feet.

Heating Surfaces :

Flue tubes + Smoketubes	2131 sq.ft.
Arch (water) tubes + Thermic syphons + firebox surface	254 sq.ft.
Superheater	494 sq.ft.
Total	2879 sq.ft.

Locomotives Nos. 380 and 381, built in 1949 were chosen from the fleet of 15th Class locomotives for the proposed tests.

5.3. In the ensuing pages a number of special terms will be met. It is therefore desirable at this stage, to include a short glossary of these terms with their definitions.

5.3.1. In a similar way to most other railways and large transport operators the Rhodesia Railways applies a system of preventive maintenance to its locomotives and rolling stock. The 15th Class locomotive for instance, has a General Repair, which is a complete rebuild of all components including engines and boiler, every 190,000 miles (approximately 3 years). Between general repairs the locomotive has a Wheel Job, when only the wheels, bearings and side rod bearings of the engines are attended to, this occurs at 100,000 miles (approximately 18 months after the General Repair). The pattern is further subdivided to P.15 Examinations which occur every 15,000 miles (3 monthly), at which all bearings and pistons, mainly, are attended to. In addition to attentions given to the boiler at the above scheduled repairs it (the boiler) requires Washing Out once a month to clear the water spaces of sludge accumulations and as a part of the water treatment programme. Also the boiler has a Tube Blow fortnightly at which all gas passages are cleared of soot, char and ash, in addition the fireside of the firebox plates are cleared of all encrustations.

5.3.2. The Regulator is the main valve that allows steam from the boiler through the superheater to the engines.

5.3.3. This class of locomotive is fitted with Walschaerts Valve Gear which regulates the power developed in the locomotive cylinder by controlling the point in the piston stroke at which steam admission to the cylinder is Cut Off. The linkage driving the valve gear can be so positioned that the locomotive will move either forwards or backwards when steam is admitted to the cylinders. All these positioning and controlling movements of the valve gear require some power if they are to be carried out rapidly and precisely, this power is provided by the steam powered Reversing Engine. The controls for which are situated in the cab adjacent to an indicator or Sector Plate which indicates to the driver as to whether the locomotive is in forward or backward gear and at what percentage of the piston stroke the steam admission to the cylinders will be cut off by the valves.

5.3.4. This class of locomotive has too small a firegrate area to warrant automatic stoking. The boiler is therefore Hand Fired by an operator known as a Fireman. To facilitate adequate heating up of the water when the locomotive is stationary or coasting the boiler is fitted with a Blower. This device induces a draught through the boiler by the action of a large number of high velocity jets in the smokebox, drawing gas through the boiler and expelling it through the chimney in much the same way as the exhaust steam ejector under discussion.

5.3.5. The locomotive and train braking system employs vacuum braking, the successful operation of which requires the creation of a partial vacuum in certain cylinders along the train. In the case of the steam locomotive this vacuum is created by a steam ejector, the exhaust from which gives rise to the Vacuum Ejector Exhaust mentioned below.

5.4. This class of locomotive is very versatile being capable of pulling fast light loads as well as heavy slow speed trains and is in fact used for both these duties. The 219 miles section of track, see Appendix IV, between Bulawayo and Thomson Junction includes a wide variety of track grades and curvature, ranging from a 50 miles steeply graded, heavy section through hilly country to a 70 miles flat, straight section. In addition this section of track, chosen for the tests, is controlled entirely by the C.T.C. automatic signalling system which besides being safer allows trains longer runs between crossing stops, thus saving time and fuel compared with other signalling and train control methods. Amongst other things these factors influenced the choice of trains 50 UP and 23 DOWN as test trains. 50 UP, Bulawayo to Thomson Junction is a fast light express goods with a regulation load of 600 tons on 68 axles. 23 DOWN, Thomson Junction to Kpopoma (near Bulawayo) is a slow, heavy goods train with a regulation load of 1300 tons on 104 axles.

6. DESCRIPTION OF LOCOMOTIVES AND TEST APPARATUS
USED ON RHODESIA RAILWAYS TESTS.

6.1. The following two 15th Class locomotives were used.

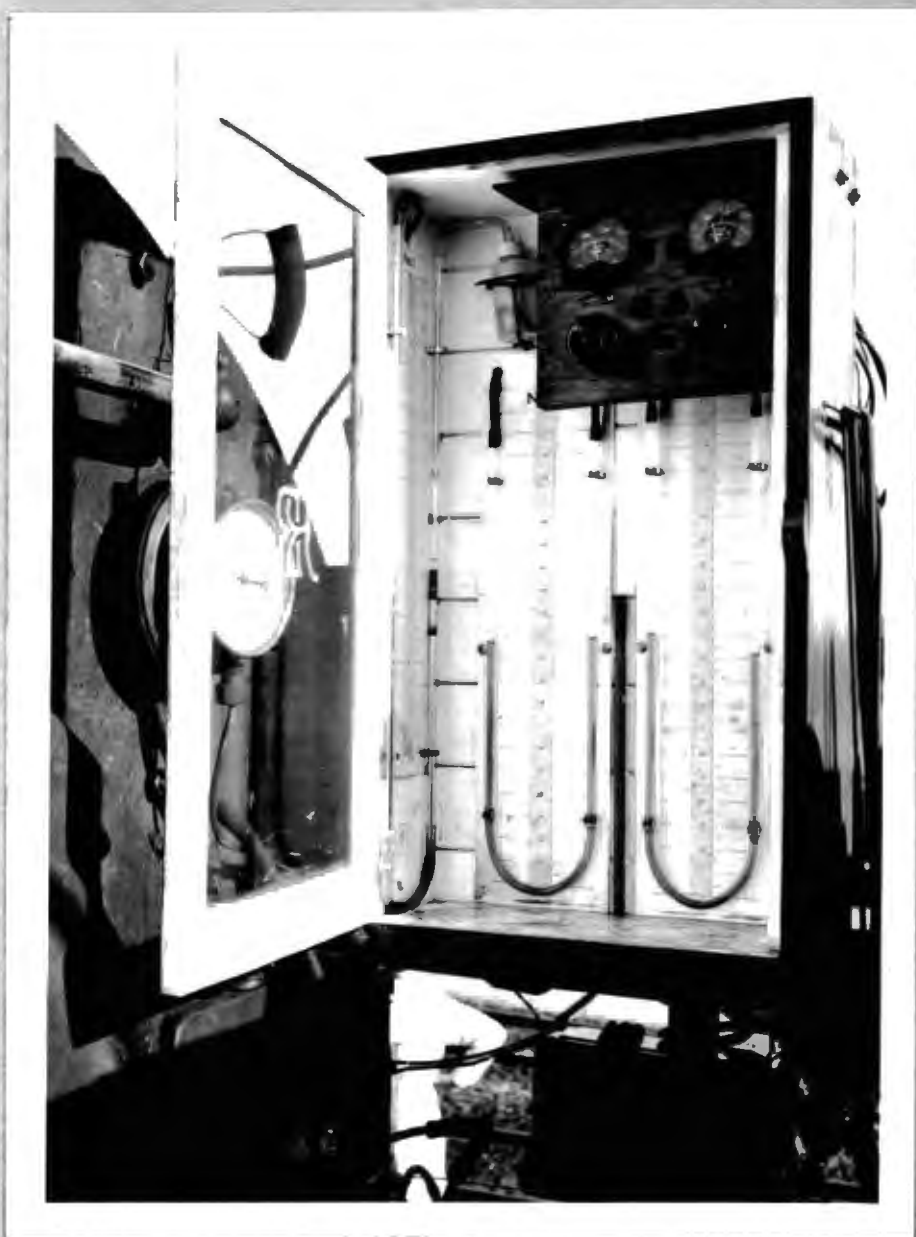
6.1.1. ENGINE NO. 381.

This locomotive received a general overhaul at Umtali during August 1962, being released on 30.8.62. By March 1963 it had completed 20,507 miles of service. Prior to the initial test being carried out on 3.4.63, it had been washed out. A slight regulator leak developed in this engine during the initial tests and had to be rectified before fitting the Giesl Ejector. The mechanical condition of this locomotive was fair, it's previous P.15 examination having been carried out on 10.7.62; it received a P.15 directly after the tests were completed on 3.5.63. This engine was fitted on 17.4.63 with the Giesl Ejector size 2.152.E as shown on Messrs. Schoeller-Bleckmann's drawing No. G-623A (see Appendix 1) The calibration of the reverser sector in the cab was checked using compressed air on 2.5.63 and again under steam on 8.5.63. Further information obtained about the left hind cylinder, prior to fitting the indicator was :

Lead of Valve	: Inner 7/32" ; Outer 1/4"
Cylinder Clearance	: Inner 5/16" ; Outer 3/8"
Piston Rod Diameter	3 15/32"
Cylinder Diameter	17 1/2"

6.1.2. ENGINE NO. 380.

This locomotive received a general overhaul at Umtali during June 1962 being released on 29.6.62. By March 1963 it had completed 26,248 miles of service. The boiler was washed out prior to the initial tests on 14.5.63 and again prior to the tests with the Giesl Ejector on 6.6.63. The mechanical condition of this locomotive was slightly better than 381 its previous P.15 examination having been on 7.11.62. This engine was out of service during February, and March 1963 while a broken boiler frame was repaired. It was fitted on 4.6.63 with the Giesl Ejector with Superheat Booster size F-2-142-1E as shown on Messrs. Schoeller-Bleckmann's



INSTRUMENTS MOUNTED IN FRONT OF THE BOILER.

drawing No. 0-624A (see Appendix II). The calibration of the reverser sector in the cab was checked while under steam on 13.5.63. Further information obtained about the left hind cylinder, prior to fitting the indicator was ;

Lead of valve	: Inner 1/4" ; Outer 7/32"
Cylinder Clearance	; Inner 3/8" ; Outer 3/8"
Piston Rod Diameter	3 1/16"
Cylinder Diameter	17 3/4"

6.2. DESCRIPTION OF INSTRUMENTS USED.

6.2.1. SMOKEBOX DRAUGHT (VACUUM).

This was measured by having a static head probe approximately 18 inches in front of the tube-plate and as close to the axial centre line of the boiler as possible. Where applicable this probe was behind the diaphragm. The probe was connected to a 20" "U tube" water manometer housed in a cabinet in front of the smokebox. (See photograph).

6.2.2. FIREBOX DRAUGHT (VACUUM).

This was measured through an open ended steel tube projecting through a hollow stay just below the horizontal centre line of the boiler, 13 inches from the tubeplate on the left hand side of the firebox. Due to the degree of turbulence in this region the open ended tube was considered reliable for measuring static head. This tube was connected to a 20" "U tube" water manometer housed in a cabinet in front of the smokebox. (See photograph).

6.2.3. BLAST PIPE STEAM PRESSURE OR BACK PRESSURE

This was measured through a pressure tight pipe screwed into the blast pipe so as to be flush on the inside, midway between the incoming exhaust pipes and about 12 inches below the top of the blast pipe cap. The pipe was connected through a cooling coil and tee piece, to a 29" "U tube" mercury manometer, housed in front of the smokebox. The cooling coil allowed condensate to be discharged through the tee piece without being carried over into the manometer. The tee piece was sealed off so as to pressurise the manometer when a reading was taken. Nevertheless, water was often carried over into the manometer and had to be accounted for. A plastic bottle was provided as

on the low pressure side of the manometer so as to collect the mercury if the manometer was subjected to too high a pressure. This precaution was found necessary during a previous series of tests when under the abnormal conditions of high speed, late cut-off, and a fully open regulator, very high pressures were experienced in the blast pipe. During the initial tests with engine No. 381 a long enough manometer was not available (only 22 inches available as against 28 inches later found necessary) so that for these tests an "acetylene" pressure gauge, reading up to 30 p.s.i., had to be used. The longer manometer was later developed and included a restriction to damp out pressure surges.

6.2.4. DEPTH OF STRIKE INDICATOR.

This consisted of a straight copper tube (probe) marked off in inches from the free end for about 30 inches. This tube was connected by a rubber hose to a "U tube" water manometer. The purpose of this instrument was to determine the depth below the top of the chimney at which the steam blast struck the side and sealed the chimney. The operation was by sliding the probe down the inside of the chimney in the exhaust stream and noting the depth at which the pressure indicated by the manometer changed from positive to negative, i.e., probe first influenced by steam blast then by smokebox vacuum (see diagram 9).

6.2.5. BLAST FEELER.

This consisted of a 2 feet length of 3/16 inch diameter brass rod with a piece of 1" x 2" x 1/16 inch copper brazed on the end. The method of operation was to hold this feeler in the exhaust stream just above the chimney and "feel" the distribution of pressure. This was essential in the case of the Giesl chimneys where the blast could be aligned or redistributed by the adjustable slides provided on top of the blast pipe caps. Further, this instrument was necessary to check that the blast filled the chimney and that in the case of the Giesl chimneys the blast was heavy at back and front, lighter down the centre and lighter still at the centre sides. See photograph.



USE OF FEELER TO CHECK BLAST DISTRIBUTION.

6.2.6. COMBUSTION GAS ANALYSIS.

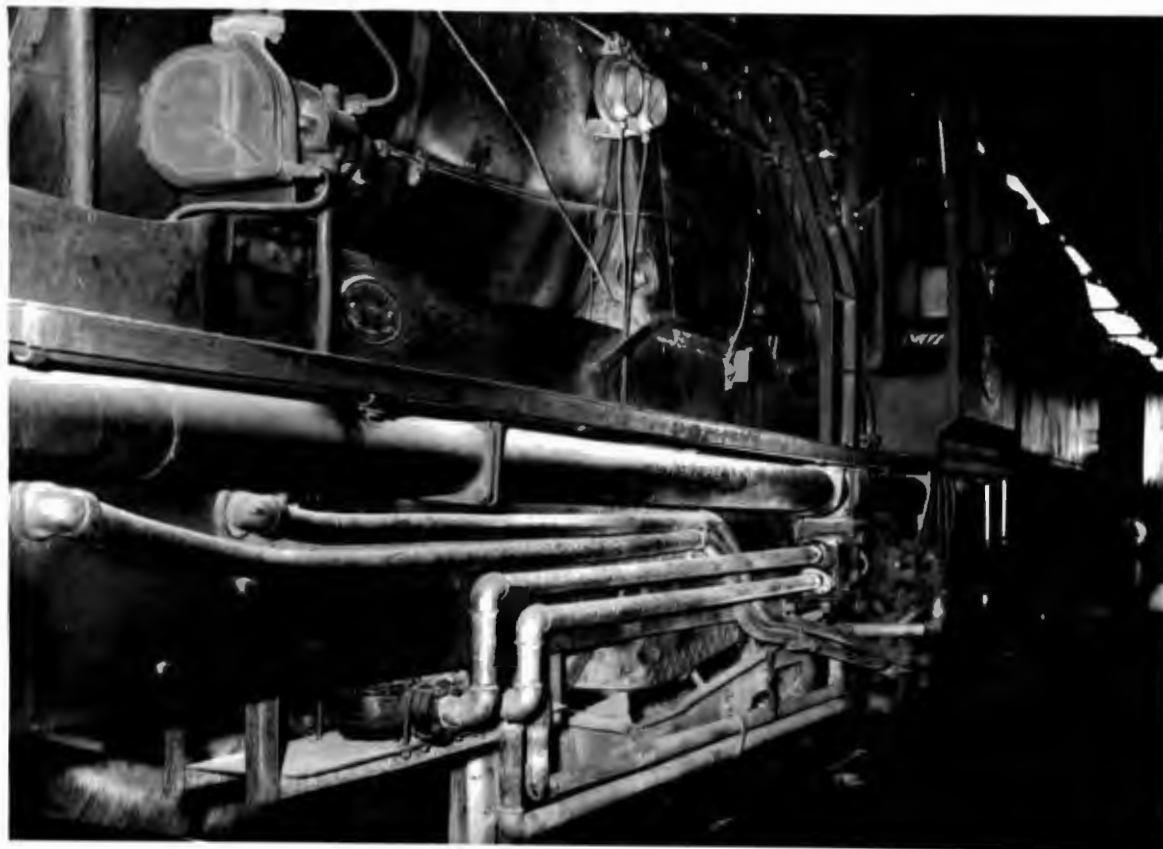
For the purpose of determining the air to fuel ratio and hence efficiency of combustion, a pipe was allowed to project through the front of the smokebox into the gas produced by combustion. Through this pipe samples of gas were drawn into an Orsat apparatus by means of which the percentages by volume of carbon dioxide, oxygen, carbon monoxide and nitrogen in the gas were determined. These samples were only taken from engine No. 380 since the apparatus, which was kindly loaned by the Bulawayo Technical College, was not available earlier. Some inconsistency in the first few gas samples taken from Engine No. 380 led to the thought that the presence of unusually large proportions of sulphur dioxide in the gas were affecting, adversely, the percentage of oxygen determined by the Orsat apparatus. It was therefore arranged to absorb this sulphur dioxide. This, however, was later found to be unnecessary since, in fact, the method of drawing off the gas sample against the partial smokebox vacuum was at fault. When this was overcome by first collecting the sample "over water" and later analysing in the Orsat, better consistency was obtained.

6.2.7. SMOKEBOX GAS TOTAL TEMPERATURE.

This was measured by a thermocouple placed in the gas stream near the blast but in such a position that it measured the total temperature of the gas only, before the gas became entrained. This thermocouple was connected to a meter supplied and calibrated by the Railway laboratory. In all tests the thermocouple was well enough away from the exhaust steam not to be affected by radiation from this source.

6.2.8. SUPERHEATED STEAM TOTAL TEMPERATURE.

This was only recorded on Engine No. 380. and was done by providing a thermometer pocket in the superheater header near the entrance to the steam pipe to the cylinders, on the left hand side of the boiler. A thermocouple connected to a meter, provided and calibrated by the Railway laboratory, was inserted in the pocket which, since it projected into the steam stream indicated the total temperature.



SITUATION OF WATER METERS.

6.2.9. AMBIENT TEMPERATURE.

This was read at intervals from a thermometer held in still air behind the front tank of the locomotive.

6.2.10. SUPERHEATER HEADER PRESSURE.

In the case of Engine No. 380 a pressure gauge was provided on the front of the boiler indicating the steam pressure in the header near the outlets to the cylinders. This gave the observer at this station an indication of the regulator position.

6.2.11. WATER CONSUMPTION.

In the case of Engine No. 381, 2 inch "Measurement" water meter No. 543734 was mounted on the running board just ahead of the cab. A two compartment dividing cell was provided between the upper and lower halves of the feedwell, in such a way that feed water entering one compartment of the cell had to travel through the pipes to the meter and then back to the other compartment from where it was fed to the injectors. The following disadvantages were encountered with this system; a) because of the high position of the meter relative to the tanks it became difficult to work both injectors when the water level in the tanks fell; b) only the sieve in the meter was effective and because of its fine mesh became rapidly clogged, hence restricting the injector operation. As a result of experience with Engine No. 381 it was decided to use two meters on Engine No. 380 and in addition they were mounted on a platform slung under the boiler at the same level as the injectors. The two 2 inch meters were "Measurement" No. 543734 and "George Kent" No. 1612455. By this arrangement it was possible to pipe water from the feedwell through the meters to the injectors; also a sieve of fine mesh and large surface area was made for the feedwell, so that by frequent cleaning of this sieve the meters were kept clean and worked perfectly throughout the test series. On one occasion a check valve stuck open causing steam to flow back through one of the meters causing some distortion and damage, but this was later repaired. See photograph of this second metering arrangement.



COAL ME/TERING DEVICE .

BIN IN RELEASE POSITION.



COAL METERING DEVICE

RESET HANDLE & SPRING SUSPENSION.

6.2.12. INJECTOR PERFORMANCE.

The two pressure gauges visible in the photograph referred to in 6.2.11. were used for a series of injector performance tests carried out while Engine No. 380 was running. These tests recorded the effects of throttling the steam supply to the injectors on their performance and are of no interest to the present case.

6.2.13. COAL CONSUMPTION.

Numerous methods of measuring coal consumption were considered including the use of coal bags, weighed individually and each containing about 150 lbs. of coal but the majority were rejected on the grounds of being either too inaccurate or too time and labour consuming (coal bags) for the extensive test programme contemplated. It was therefore decided to construct a rectangular steel bin of 5.5 cubic feet capacity (about 300 lbs. of coal) so shaped that it fitted in the bunker doorway. The bin was mounted on two columns and suspended from two springs in such a way that it was free to move vertically in the entrance to the bunker. Further, the entrance to the bunker was completely blanked off except for a narrow opening just under the cab roof, opposite an opening in the back-top of the bin. The operation was such that two "Garrett Boys" in the bunker loaded coal into the top of the bin to a predetermined level, the average deflection of the springs from a bin-empty-zero-position was then recorded. By releasing a trap door in the bottom of the bin the weighed coal was dumped onto the shovel plate ready for use. This method of weighing was estimated to be within 2% accurate, by calibration with dead weights; it also had the advantage of being quick and easy to operate and enabled rates of coal consumption as well as totals to be recorded. See photograph of bin in released position, one supporting spring on the side of the bin and the centrally mounted displacement measuring ruler are just visible.

6.2.14. BOILER PRESSURE.

The existing pressure gauge in the cab was used for this purpose.

6.2.15. REGULATOR POSITION.

It was necessary to know the degree of regulator,

opening for which purpose the sector on the regulator in the cab was marked off in fractions, between the closed and fully open positions.

6.2.16. STEAM CUT OFF.

The percentage of the piston stroke in forward or back gear at which steam cut off in the cylinders occurs is set and indicated on the reversing engine controls in the cab. On both engines the reversing engine and cab sector plate were calibrated to allow correction of the readings taken. In the case of Engine No. 380 a calibrated scale was placed adjacent to the reversing rod at the front of the boiler to indicate the cut off to the person observing the manometers and pyrometers and controlling the test procedure.

6.2.17. TRAIN SPEED.

This information was taken from the speedometer in the cab, the accuracy of which was checked against roadside mile pegs with the aid of a stopwatch.

6.2.18. STEAM CHEST TEMPERATURE.

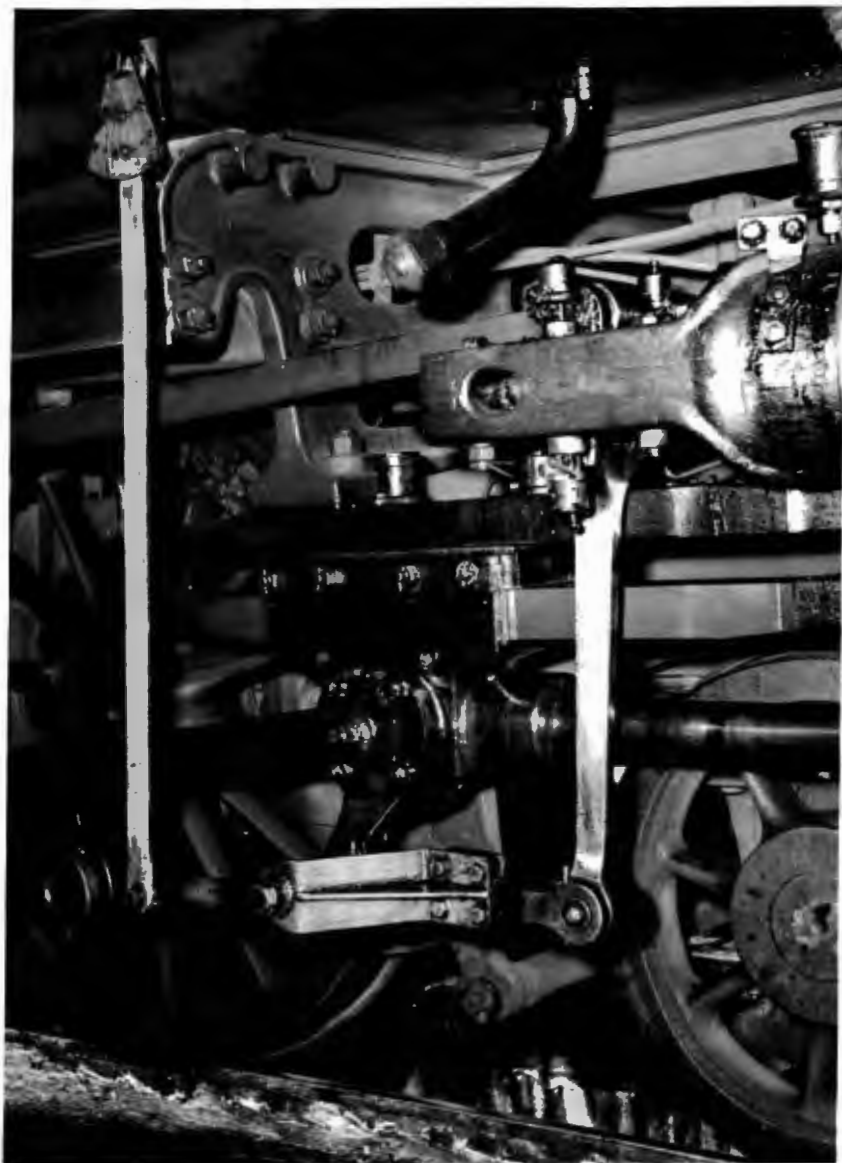
A thermometer pocket was provided in the steam chest of the left hind cylinder which enabled the steam temperature to be measured with the aid of a pyrometer manufactured and calibrated by the Railway laboratory. The pyrometer was mounted behind the hind tank.

6.2.19. STEAM CHEST PRESSURE.

A pressure tapping adjacent to the thermometer pocket in the left hind steam chest was used for this purpose. The pressure gauge was mounted behind the hind tank.

6.2.20. INDICATOR.

For the purpose of indicating steam phenomena in the cylinder a Dobbie McInnes continuous diagram indicator type 3 No. D/3A/6403 was mounted on the left hind cylinder. Two lagged steam pipes of 1/2 inch bore and 4ft. 6inch long piped steam from the steam port inspection hatches to a three way cock mounted under the indicator. It was thus possible to communicate



PISTON STROKE REDUCING MECHANISM FOR INDICATOR.



INDICATOR; STEAM CHEST TEMPERATURE ; STEAM CHEST PRESSURE .

the indicator with the steam either side of the piston (including the clearance space), as well as to atmosphere. An oscillating lever suspended from the engine frame and coupled to the crosshead by a short link was used to reduce the piston stroke by 8.5:1, enabling the indicator string to be driven from a sector mounted on the lever. Special precautions to protect the indicator and string from damage by steam, oil and sharp edges, had to be taken. Johnson (7) points out that steam pipes of 1/2 inch bore and 3ft. 6 inch length used for piping steam from an engine cylinder to an indicator tended to smooth out all pressure changes and in fact, enlarged the diagram due to pressure lag. He then goes on to state that this increase in power (diagram area) was found to vary as follows :-

**"Errors in Mean Effective Pressure caused
by Pipe Connection".**

Speed R.P.M.	Excess of Power shown by Pipe- indicator as compared with that shown by Cylinder-indicator.
134	1.5 %
161	2.1 %
188	2.9 %
215	4.9 %
242	8.4 %
269	14.0 %
296	17.2 %

In view of the similarity of the quoted conditions to the test conditions, the above table has been used verbatim to modify all recorded indicated horse powers. It should however, be noted that all mean effective pressures stated in this report have not been adjusted since the above factor was applied direct to I.H.P. The photographs show the lever reducing mechanism used to drive the indicator, also the position of the indicator and steam chest pressure and temperature gauges.

6.2.21. DRAWBAR PULL.

The saloon end drawbar of private saloon No. 751, which was fitted out for measurements of this kind using strain gauges, in October 1963, was utilised for this purpose. The 220 volts A.C. power supply for

which was derived from an alternator driven by a 24 volt D.C. motor powered by the coach batteries. Although this equipment appeared to be giving consistently reliable readings these have had to be abandoned, all being too low. This indicated that some deterioration of the strain gauges had occurred and was in fact, expected since the only strain gauges available were for a smaller strain range than applied in this case.

6.3.

GIESL EJECTORS.

6.3.1. Giesl Ejector size 2-152E shown on Messrs. Schoeller-Bleckmann's drawing No. G-623A (Appendix I) consisted of an oblong, seven ported exhaust nozzle with exhaust area adjusting slides, the whole being mounted on a conventional standpipe and connected through expansion free joints to an oblong shaped chimney. The throat of the chimney was 6 3/16" wide while the outlet was 11 5/8" wide. This ejector was fitted with basket type spark arrester screens and was not tested with the self cleaning type of front end. The recommended exhaust port width for the arrangement with basket type spark arrester was 2 1/2" front and back and 2 1/8" front and back when fitted with the self cleaning front end, the actual width used is given in 10.6.3. Very little difficulty was experienced when fitting this ejector except that due to a discrepancy in the smokebox floor it was necessary to machine off the stand pipe base a wedge shaped piece equal to 3/8" at the back and nothing at the front. The chimney then came into the correct position in the opening in the smokebox top but rested lightly against the superheater header, this position was accepted. It was noted that the top of this chimney was 13ft. 4 inches above rail level whereas the moving structure gauge allows 13 ft. 6 inches so that the makers might consider raising the whole assembly by a small amount to avoid fouling the superheater header if large numbers of these units were purchased.

6.3.2. Giesl Ejector with Superheat Booster size F-2-142-1E shown on Messrs. Schoeller-Bleckmann's drawing No. G-624A (Appendix II) consisted of an oblong seven ported exhaust nozzle with exhaust area adjusting

slides, the whole being mounted on a conventional standpipe and connected through expansion free joints to an oblong shaped chimney. In addition to which a partly perforated semicircular hinged damper (superheat booster) was fitted across the smoketubes in the smoke-box while 39 throttling rings of $1 \frac{1}{16}$ " bore were expanded into the firebox ends of the smoketubes above the level of the damper. The throat of the chimney was $5 \frac{1}{2}$ " wide while the outlet was $11 \frac{1}{2}$ " wide. The basket type spark arrester supplied with this ejector was not used but instead the self cleaning front end shown on Messrs. Schoeller-Bleckmann's drawing No. G-674 (Appendix III) was constructed and used. The recommended exhaust port width for the arrangement with basket type spark arrester was $2 \frac{5}{32}$ " front and back and $1 \frac{31}{32}$ " front and back when fitted with the self cleaning front end, the actual width used given in 10.6.3. As in the case of the previous ejector during erection, the chimney was inclined to foul the opening in the top of the smokebox at the front, this was overcome by cutting an additional $\frac{1}{2}$ " out of the top of the smoke-box at the front; in this case the chimney when in position did not foul the superheater header. No difficulty was experienced when fitting the damper except that the hinged flap provided in the damper to clear the steam pipe to the hind unit was incorrectly positioned and was in fact not correct to drawing No. G-624A. To overcome this a section of the damper was cut out on a band saw and attached to the flap, it was then possible to open the damper past the steam pipe to allow access to the tube plate except that the damper soon came up against the tableplate and restricted the access to the washout plugs. The following photographs show the conventional 15th Class smokebox arrangement with the circular blast pipe nozzle and chimney and with the self cleaning type front end. Most of the spark arrester screens and part of the diaphragm (see diagram 1) have been removed, to illustrate the superheater elements extending into the flues, also making the ends of the smoke or small tubes visible. The photographs of the smokebox of Engine No. 380 after receiving the Giesl Ejector and superheat booster and before and after fitting the self cleaning front end show a general view with the damper visible in the background, a close-

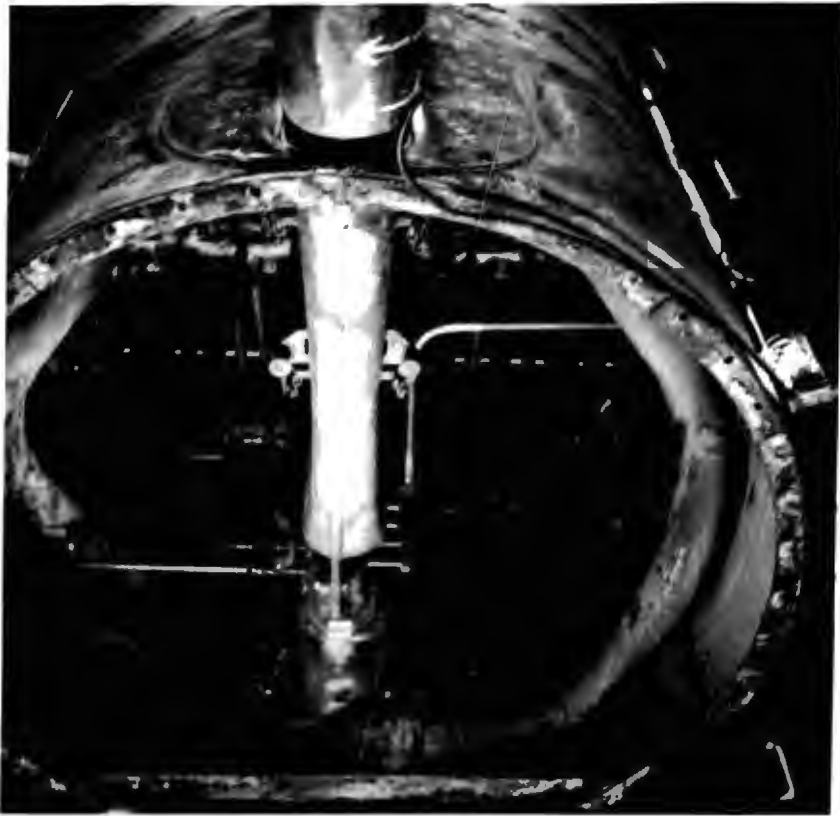
up of the nozzle with the control rods to the adjusting slides and the connection between the nozzle and chimney visible. Other views show a close up of the nozzle in the self cleaning layout with steam issuing from the blower jets, also the damper and adjusting slide controls external to the boiler.



LAYOUT OF SELF CLEANING SMOKEBOX.

PARTS OF DIAPHRAGM AND SPARK

ARRESTER REMOVED.



GIESL EJECTOR IN POSITION.



NOTE. SLIDE CONTROL RODS &
SUPERHEAT BOOSTER DAMPER.



GIESL EJECTOR IN POSITION; ENGINE No. 380.



DAMPER LIFTING ARM; EXHAUST NOZZLE ADJUSTING SLIDE CONTROLS.

7. PROCEDURE ADOPTED ON RHODESIARAILWAYS TESTS.

7.1. So as to bring out the actual differences in the performance of the locomotive in all respects, it was decided that the locomotive should be studied firstly in the standard condition and then when fitted with the Giesl equipment. This meant that for each locomotive a series of four trains were hauled with the standard engine and then as nearly as possible four identical trains were hauled over the same route with the modified engine enabling a comparison to be made.

7.1.1. In order to cover the full range of locomotive working it was decided to carry out all tests on trains 50 UP (fast light goods, Bulawayo to Thomson Junction) and 23 DOWN (slow heavy goods, Thomson Junction to Mpopoma (Bulawayo)). All tests were carried out with the locomotive prepared in the normal way i.e., fully lubricated; tanks, boiler and bunker full; clean bright fire and the trains as near full load as possible.

7.2. On every test train coal meter readings were taken throughout the trip while water meter readings were taken at all watering places and principal stops. Only the coal used while the locomotive was attached to the train was accounted for. Similarly only the water used between the time of departure to just after arrival at the destination, the boiler being full at both instances, was accounted for.

7.3. The instrument reading procedure adopted in the case of Engine No. 381, the first to be tested, was as follows: From a Small Scale Section (route plan a sample of which is shown in Appendix IV) of the Bulawayo/Thomson Junction route a number of more arduous gradients, for both directions, were singled out. Points on these banks were selected where readings would be taken. These points were chosen such that stable conditions of temperature, pressure and speed would be reached. As the locomotive approached the selected point, defined by a mile post, a signal (whistle blast) was given by a member of the test team in the locomotive cab, at the sound of which the following phenomena were observed.

1. Time
2. Place
3. Speed
4. Regulator Opening
5. Reverser Position (Cut Off)
6. Boiler Pressure
7. Steam Chest Steam Temperature
8. Steam Chest Steam Pressure
9. Took Indicator Diagram.
10. Drawbar Pull
11. Steam Pressure in Exhaust Pipe
12. Smokebox Draught
13. Firebox Draught
14. Smokebox Gas Temperature.

As the test series progressed these reading points were altered slightly, since it was found that some were too close to signals and often resulted in the power being shut off during the reading, also stable conditions did not always prevail at the reading point which necessitated selecting a point further up the bank. In taking an Indicator Diagram all the techniques of warming up the indicator, proper lubrication of the mechanism and obtaining one trace only were observed.

7.4. In the case of Engine No. 380 the proven reading points of the previous tests were used. The signalling was however, re-arranged so that the signal could be sounded from in front of the boiler where the instruments gave a better indication of the potential value of the reading. It was also decided that under normal working, insufficient variety of cut offs were used, therefore in order to obtain more information about the engine a series of tests were introduced, where the train was slowed down, on a suitable gradient and the engine worked at a short cut off with a full regulator until stable conditions prevailed, when readings were taken. Once all phenomena had been recorded the cut off was increased by about 10% and the procedure repeated, by this method the full range of cut offs could be recorded, without too much variation in boiler pressure or fire condition. On this Engine (No. 380) the following phenomena were observed at each reading point ;

1. Time
2. Place
3. Speed
4. Regulator Opening
5. Reverser Position (Cut Off)
6. Boiler Pressure
7. Superheater Header Steam Pressure
8. Steam Chest Steam Pressure
9. Steam Chest Steam Temperature
10. Superheater Header Steam Temperature
11. Smokebox Gas Temperature
12. Steam Pressure in Exhaust Pipe
13. Smokebox Draught
14. Firebox Draught
15. Took Indicator Diagram
16. Drawbar Pull

7.5. For both locomotives, after the "standard" locomotive tests but prior to the main tests with the Giesl Ejector fitted, it was necessary to run a short test to obtain the best setting of the Giesl Ejector exhaust nozzle adjusting slides. For this purpose the locomotive was fully instrumented and then made to haul a light load from Mpopora to Heany Junction and back, a total of 40 miles. By starting with the adjusting slides set to the manufacturers recommendations, it was a relatively simple matter to adjust them to give the correct distribution of mixture in the chimney as well as the best combination of draught and back pressure. The setting was such that the average firebox draught with the Giesl equipment was approximately equal to the average draught recorded for the standard locomotive. The position of the slides obtained on these tests was not subsequently altered.

7.6. For engine No. 380 the method used to obtain samples of exhaust gas from the smokebox was to merely draw the sample through a steel tube, which was projecting into the gas stream, into the Great apparatus. This method was satisfactory for the standard engine when smokebox draughts were low but when the locomotive had been fitted with the Giesl Ejector, it became difficult to draw off the sample against the high vacuum and so a method of collecting by displacement

of water had to be used. Generally gas samples were taken while ascending grades soon after the other readings had been taken and while stable conditions prevailed. The samples were analysed later, usually while the train was still moving.

7.7. The procedure used to determine the approximate depth below the top of the chimney at which the exhaust steam impinged and sealed the chimney was as follows. A straight graduated copper pipe connected to a water manometer (called the depth of strike indicator) was lowered into the chimney in close contact with the wall. Initially the manometer registered a positive pressure while the probe was in the blast and then a negative pressure when it projected into the area influenced by the smokebox vacuum. The fairly well defined transition from positive to negative was recorded as the point of strike.

7.8. Because of the distribution of the members of the test team along the locomotive (one in front of the smokebox, two in cab and one behind the bunker) some difficulties in communication were experienced particularly in the case of engine No. 381. Telephonic communication installed on engine No. 380 overcame this.

8. RESULTS OBTAINED FROM RHODESIA RAILWAYS TESTS.

8.1. All coal and water consumption figures have been analysed and are presented in Appendix V Results Sheets 1 to 9. The coal consumption figures indicated on Results Sheets 1 to 4 include the amounts consumed while the test trains were stationary at intermediate halts along the route. Although these results are indicative of the performances normally met in service, they are not completely satisfactory for comparative purposes in this case. Since the time spent at various halts varied rather widely, according to whether passing trains were running to time, the test trains were running to time or the track relaying work being carried out on certain sections disallowed a through run. In view of this the following table of results was derived from Results Sheets 1 to 4, by subtracting the amounts of coal consumed while the train was stationary.

8.2. All readings have been adjusted in accordance with instrument calibrations etc., and are presented together with a number of derived results in Appendix V Results Sheets 10 to 27. For the purposes of discussion and analysis the most important of these results are presented in graphic form below.

8.3. Other sundry results are presented in Appendix V Results Sheets 28 and 29.

8.4. A log of arrival and departure times as well as reasons for delays, called the Trainmen's Journal, was compiled as a normal procedure by the Guard on each test train. Unfortunately, no copies are available for inclusion here, nevertheless reference has been made to them in deciding whether the running times of these trains could be considered typical of normal service.

TOTAL COAL CONSUMPTIONS BASED ON COAL CONSUMED WHILE IN MOTION ONLY.

(Taken from Results Sheets 1 - 4 see Appendix V)

		STANDARD LOCOMOTIVE		LOCOMOTIVE FITTED WITH GIESL EQUIPMENT		AVERAGE GAIN
From Sheet No. 1 For engine No. 381 Bulawayo to Thomson Junction	Train No. Date Total lb. Overall lb/ton Mile	50 Up 3.4.63. 11997 0.0929	50 Up 5.4.63 12210 0.0844	50 Up 23.4.63 9908 0.0776	50 Up 25.4.63 12041 0.0874	+9.32% +4.74%
From Sheet No. 2 For engine No. 381 Thomson Junction to Mpopoma	Train No. Date Total lb. Overall lb/ton mile	23 Down 4.4.63 24178 0.0867	23 Down 6.4.63. 24226 0.0890	23 Down 24.4.63 22575 0.0812	23 Down 26.4.63 23350 0.0860	+5.12% +4.78%
From Sheet No. 3 For engine No. 380 Bulawayo to Thomson Junction	Train No. Date Total lb. Overall lb/ton mile	50 Up 14.5.63 9938 0.0768	50 Up 16.5.63 10924 0.0846	50 Up 6.6.63 10783 0.0742	50 Up 11.6.63 11877 0.0775	-8.61% +6.07%
From Sheet No. 4 For engine No. 380 Thomson Junction to Mpopoma	Train No. Date Total lb. Overall lb/ton mile	23 Down 15.5.63 26765 0.1088	23 Down 17.5.63 26655 0.0960	23 Down 7.6.63 23759 0.0856	23 Down 12.6.63 23448 0.0842	+13.5% +17.1%

9. CONCLUSIONS DRAWN FROM THE RHODESIA RAILWAYS
TESTS.

9.1.1. The Giesl ejector with Superheat Booster is far more beneficial than the plain Giesl ejector. For engine No. 381 fitted with the Giesl ejector the following savings, compared with the standard engine, would be accrued during normal service :

Coal 4.76% in lb/ton mile
 Water 1.66% in gallons/ton mile

Although these are averages the results sheets show that with the plain Giesl ejector the savings in coal are nearly constant and independent of type of train. While the results sheets show greater water savings occurred with heavy slow trains due to the later "cut off" required and hence more significant reductions in back pressure.

9.1.2. For engine No. 380 fitted with the Giesl ejector and Superheat Booster the following savings, compared with the standard engine, would be accrued during normal service :

Coal 11.58% in lb/ton mile
 Water 14.77% in gallons/ton mile

The coal and water savings on the fast light loads showed the same trend as those on the slow heavy trains although the latter were much greater due to higher steam temperatures and greater reductions in back pressure at late cut offs. The standard engine used coal at the rate of 0.0896 lb/ton mile and water at 0.0848 gallons/ton mile.

9.2. When fitted with the Superheat Booster the superheater header steam temperature increased from 605°F to 660°F at half power and from 562°F to 685°F at full power i.e., 123°F maximum. The temperatures reached were still within the limits of the lubricant. The cooling of the steam between the header and cylinders was very severe.

9.3. Comparing both engines working at high power the Giesl ejector reduced back pressure by nearly 60%, producing, in the case of engine No. 381 a 40% increase in smokebox draught and a 7% increase in firebox draught while in the case of engine No. 380 a 34% increase in smokebox draught and a 21% loss of firebox draught resulted. Both engines were undoubtedly "free steaming" and due to the extra power available tended to run faster with a standard load. For this latter reason shorter cut offs in service are essential if speeds are not to be exceeded.

9.4. The basket type spark arrester worked well but was of too light a construction for the arduous conditions of handling and service experienced on the Rhodesia Railways. The self cleaning arrangement was efficient but was too complicated and rendered the smokebox inaccessible for maintenance.

9.5. The blower effect of the Giesl ejector with Superheat Booster was insufficient and should be increased.

10. DISCUSSION OF THE FEDERIAL RAILWAYS TEST RESULTS.

10.1. ROUTES.

10.1.1. It was originally planned to carry out all tests on the Bulawayo/Mahalapye section but at the time of embarking on the test programme the above section was not being overhauled by 15th Class locomotives, it would thus have meant carrying out tests with crews that were not used to working this class of locomotive on the above section. It was therefore decided to carry out all tests on the Bulawayo/Thomson Junction section with one return trip on the Bulawayo/Mahalapye section at a later date. The advantage of the Bulawayo/Thomson Junction section was that the crews were familiar with the operation of 15th Class locomotives over this route as well as the fact that running shed facilities were available at Thomson Junction and not Mahalapye. Generally, because of the easier gradients on the Bulawayo/Thomson Junction section trains were heavier than on the Bulawayo/Mahalapye section where steeper gradients exist, however, the demands made on the locomotive were comparable.

10.1.2. For the purpose of arriving at a reliable overall figure of coal and water saving, to facilitate financial appraisal, it has been necessary to consider the locomotive's performance between various prominent points along the Bulawayo to Thomson Junction to Epopoma route. The subsections chosen were generally between watering points and are described briefly below :
(see Appendix IV)

UP TRAINS.

(BULAWAYO TO THOMSON JUNCTION 219½ MILES)

Bulawayo to Sawmills : 63½ miles, mainly down grade with one 4 mile climb of 1:12½ gradient generally a fast section.

Sawmills to Gwasi : 31½ miles, initially a climb up to Grants containing one 3 mile bank of 1:100 then a run down to Gwasi.

Gwasi to Dett : 72½ miles, almost flat throughout with a slow rise over the whole distance resulting in an overall change in altitude of 400 feet of which most is accounted for by one 3 mile bank of 1:165 out of Gwasi.

Dett to Thomson Junction : 52½ miles, runs down steeply throughout with one 2 mile climb of 1:148 out of Lukosi. Extensive braking throughout and of little value to the test.

DOWN TRAINS.

(THOMSON JUNCTION TO MPOPOMA (NEAR BULAWAYO) 217½ MILES)

Thomson Junction to Lukosi : 21 miles; A very difficult section of predominately 1:120 and 1:140 up gradients. A slow section with a heavy load.

Lukosi to Dett : 31½ miles; A very difficult section composed of long 1:120 up gradients. A slow section with a heavy load.

Dett to Gwasi : 72½ miles; A very gradual down gradient throughout but requires almost continuous "steaming" against resistances.

Gwasi to Sawmills : 31½ miles; Consists of a continuous climb up to Umgusu containing a 12 mile up grade of 1:200. Then down to Sawmills with braking.

Sawmills to Nyamandhlovu : 31½ miles; Contains one 9 mile and one 6 mile climb of 1:130. An excellent test section.

Nyamandhlovu to Mpopoma : 30½ miles; Similar to the previous section containing 15 miles of 1:130 continuous up gradient.

10.2. COAL CONSUMPTION.

10.2.1. Since the Bulawayo to Thomson Junction to Mpopoma trip involved the handling of the locomotive by six different crews and despite the fact that a Locomotive Inspector was almost continuously on the footplate, a wide variety of coal consumptions were recorded for very similar loads and conditions. Hence to try and overcome the errors introduced and in an endeavour to find a common denominator, the elaborate analysis of

coal consumptions shown on results sheets numbers 1 to 4 has been introduced. For the ultimate comparison of the locomotive performances the coal consumed while stationary has been eliminated as stated in paragraph 8.1. It should however, be stated that the method of coal measurement adopted was extremely reliable and worked well throughout the test series.

10.2.2. The coal used throughout these tests was generally of a good standard with negligible inclusions of foreign material such as pyrites, rock, etc; this was substantiated by the small amount of clinker formed as well as the friable nature of the ash. Although "rounds" were used throughout, the size was generally smaller than the recognised +4". The quantity of fines accompanying the coal varied widely and in fact was very high on one or two trips. A survey of the most recent coal analysis figures is given below :

COAL FOR PERIOD SEPTEMBER 1961 - JUNE 1963 ON AIR

DRIED BASIS : FOR ROUNDS ONLY (+4").

No. 2 COLLIERY.

PERIOD	MOISTURE %	ASH %	VOLA- TILES %	FIXED CARBON %	CALORIFIC VALUE btu/lb
Sept 61-Apr 63	0.91	9.1	27.4	62.2	13730
February 1963	1.00	9.4	29.2	60.4	13660
March 1963	1.20	10.0	29.0	59.8	13530
April 1963	1.00	10.0	29.9	59.1	13550
May 1963	1.10	9.2	29.0	60.7	13700
June 1963	1.00	9.2	28.8	61.0	13700

For the period February 1961 - December 1962 Average Sulphur 1.64%, by separate analysis.

NO. 3 COLLIERY.

PERIOD	MOISTURE %	ASH %	VOLA- TILES %	FIXED CARBON %	CALORIFIC VALUE btu/lb
Sept 61-Apr 63	0.81	9.4	27.7	62.1	13480
February 1963	1.10	12.8	26.6	59.5	13000
March 1963	1.00	10.5	27.9	60.6	13430
April 1963	1.00	11.8	27.5	59.7	13210
May 1963	1.20	11.9	26.7	60.2	13200
June 1963	1.00	12.1	26.8	61.1	13130

For the period February 1961 - December 1962 Average Sulphur 2.38%, by separate analysis.

It was not known from which of the two collieries the coal came from for any particular trip, but in either case the slight variation shown above gives an indication of the stable quality of the coal.

10.2.3.

RESULTS SHEET NO. 1.

The overall saving of 6.4% (4.74% neglecting coal consumed while stationary) in lb/ton mile is reliable in view of the similarity of loads hauled and times taken before and after modification of the locomotive. However, this figure was influenced mainly by the performance between Bulawayo and Saxmills, a fast section where not very much is required of the locomotive. Nevertheless, these four trains were hauled without undue hardship and this saving would be realised in practice.

10.2.4.

RESULTS SHEET NO. 2.

Extremely close agreement in train loads and overall times is indicated but an overall loss of 0.2% in lb/ton mile appears. By neglecting the coal consumed while stationary this loss becomes a gain of 4.78%. This change was almost entirely due to considerable differences in "stationary time" on the various tests, due to unforeseen delays.

10.2.5. Considering both the 50 UP and 23 DOWN trains hauled by engine No. 381 the outcome is that a gain of 4.76% (average of 4.74% and 4.78%) in lb/ton mile would be realised in normal service.

10.2.6. RESULTS SHEET NO. 3.

The trains hauled by the modified engine were 15.25% heavier than those hauled by the standard engine consequently the gains that might have been realised were reduced. After accounting for the coal consumed while stationary the overall gain of 10.06% reduces to 6.07% in lb/ton mile, due to some lengthy delays incurred at Sawmills while the track relaying gangs cleared the section. Nevertheless these losses in time were compensated for by the ability of the "Giesl" engine to "run faster" and was demonstrated by the gains in running times recorded between Sawmills and Dett.

10.2.7. RESULTS SHEET NO. 4.

Loads hauled before and after modification were very nearly equal; a slight bettering of the "time taken" was achieved with the modified engine. These four trains were ideal tests and ran "without hitch" resulting in the reliable saving of 18.35% in lb/ton mile, reduced to 17.10% after deducting coal consumed while stationary.

10.2.8. The average of the savings incurred on the 50 UP and 23 DOWN trains hauled by engine No. 380 is 11.58% in lb/ton mile (average of 6.07 and 17.10), considerably higher than engine No. 381.

10.2.9 Rhodesia Railways statistics give the ton miles hauled by 15th Class locomotives for any given period. Therefore the financial saving in coal can only be assessed from an accurate knowledge of the rate of coal consumption, i.e., lb/ton mile, for the class of locomotive concerned. In this case the value of lb/ton mile to be applied to all 15th Class locomotives is the average of all the values obtained for engines 380 and

and 381 before modification; being 0.1040 lb/ton mile for results sheets 1 to 4 or 0.0896 lb/ton mile if coal consumed while stationary were neglected. Once again the latter value is the best that could be expected in service, generally some intermediate value would apply. These values are quite favourable since (16) states :-

"Fuel Consumption : (Engines of modern build :
Coal of average quality)

Main line express and passenger	40 lb/mile or 0.12 lb/ton mile
Main line goods and minerals	65 lb/mile or 0.1 lb/ton mile"

10.2.10. In order to further qualify the coal saving, graph No. 4, ^{page 93,} showing coal consumption as Rate of Firing vs I.H.P., has been derived. The rates of firing values plotted here were selected from the records of coal bin loads and consumption times, in such a way that each figure represents the average continuous rate of firing of at least 900 lb. of coal. These rates of firing were selected to coincide with known values of I.H.P. and speed which, before plotting, have been adjusted according to graph No. 3 (I.H.P. vs Speed) so as to give the average I.H.P. over the period that the "rate of firing" covers. For both engines 380 and 381 the slope of this characteristic for the standard engine gives a specific fuel consumption of 2.22 lb/I.H.P. hour. While for No. 381 "with Giesl" the s.f.c. is 1.91 lb/I.H.P. hour and for No. 380 "with Giesl" the s.f.c. is 1.82 lb/I.H.P. hour. For the significance of these figures to be assessed they must be compared with accepted values. The following extract from (16) shows these values to be good :

"It may be taken that $3\frac{1}{2}$ pounds of good English coal per horse power per hour represents economical working under saturated steam conditions, this quantity being reduced to 2.1 or 2.2 pounds in the case of a well designed superheated engine. With a high superheat (300°F) the coal consumption has been reduced to as low as 1.8 lb per I.H.P. hour."

Elsewhere in (16) "a good coal" is qualified as one giving 14,500 btu/lb which is somewhat higher than the Wankie coal used on these tests. However, the agreement is good and confirms the high savings recorded.

10.3.

WATER CONSUMPTION.

10.3.1. The use of water meters on steam locomotives is unusual, thus very little was known about the feasibility of such a scheme, however, except for a few problems experienced with engine No. 381 this method of measurement worked extremely well and justified the use of these accurate instruments. The two main problems experienced with engine No. 381 were that only the sieve in the water meter was effective, which, due to it's fine nature became readily blocked by the organic film produced by the water treatment (Nalco Balls) and secondly, the mounting of the meter on the running board (level with the bottom of the water tanks and above the level of the injectors) produced a considerable loss of head in the feedwater system. In the case of engine No. 380, two water meters were used and were mounted in such a way that the loss of head produced was negligible, further a special sieve of the same grade as those in the water meters was introduced in the feedwell, upstream of the meters, obviating any further meter blockages. Despite the problems mentioned above all the water entering the boilers was metered throughout the tests. In addition the water consumed while stationary was not affected to the same extent as the coal, by variations in the duration of the halt, so that the analyses given on results sheets 5 to 8 are reliable. It should be noted that overflow water from the injectors was not accounted for separately since the quantity involved was small and consistent.

10.3.2.

RESULTS SHEET NO. 5.

As was pointed out in paragraph 10.2.3. the 50 UP trains hauled by engine No. 381, although slightly lighter with the modified engine gave good results. Hence the adverse

water consumption resulting in an overall loss of -2.92% in gallons/ton mile was fair.

10.3.3.

RESULTS SHEET NO. 6.

The overall gain of 6.25% in gallons/ton mile was typical of the savings accrued on the long heavy section between Thomson Junction and Dett. It was therefore acceptable as an indication of heavy, slow conditions.

10.3.4. Considering both the 50 Up and 23 Down trains hauled by engine No. 381 an average gain of +1.66% in gallons/ton mile (average of -2.92 and +6.25) was experienced and could be expected in normal service.

10.3.5.

RESULTS SHEET NO. 7.

The overall saving of 12.42% in gallons/ton mile is accepted since it was qualified by the similar saving recorded for the fast, light Gwasal to Dett section. The above saving would have been greater if loads had been more nearly equal.

10.3.6.

RESULTS SHEET NO. 8.

As in the case of the first test engine the saving of 17.12% in gallons/ton mile is qualified by the Thomson Junction to Dett performance.

10.3.7. Considering both the 50 Up and 23 Down trains hauled by engine No. 380 an average gain of +14.77% in gallons/ton mile (average of +12.42% and +17.12) was experienced and could be expected in normal service.

10.3.8. In order to assess water savings in terms of ton mile statistics the overall average of all the tests with engines 380 and 381 unmodified gives a rate of 0.0848 gallons/ton mile for 15th Class locomotives.

10.3.9. Since the water meters only recorded total gallons passed the rates of evaporation were not known except for a few instances where with the aid of a stop

watch, rates of water flow were measured; mainly for the purpose of assessing injector performance. By comparing results sheets 5 to 8 some idea of evaporation could be arrived at, however, the more significant ratio of gallons of water evaporated to lbs of coal burned can be assessed by comparison of results sheets 1 to 8 bearing in mind previous remarks about the value of certain tests in view of delays. This has been done considering only the Sawmills to Dett section for 50 Up trains and the Lukosi to Gwasi section for 23 Down trains resulting in the following ;

No. 381	(Standard)	0.826 gals. of water/lb of coal
No. 381	(with Giesl)	0.828 gals. of water/lb of coal
No. 380	(Standard)	0.868 gals. of water/lb of coal
No. 380	(with Giesl)	0.793 gals. of water/lb of coal

Hence there was very little change as far as engine No. 381 was concerned but in the case of engine No. 380 a large decrease is evident. This decrease is not a decrease in efficiency but is an indication of how the damper and additional throttling rings fitted to No. 380 reduced the evaporative power of the boiler, in order to increase the degree of superheat, resulting in an overall gain in efficiency.

10.4. As already stated one return test run was carried out on the Bulawayo/Mahalapye section to confirm that the results of the tests on the Bulawayo/Thomson Junction section would also apply to this section. These results, shown on sheet no. 9, are presented purely for comparison with those shown on sheets 3 and 7 for engine No. 380 "with Giesl" hauling similar loads at similar speeds but over a different route. Train No. 814 (Bulawayo to Mahalapye) is normally a slow goods train but due to the lightness of the load hauled it could be compared with train 50 Up, further, train No. 105 (Mahalapye to Bulawayo) is a mail and definitely compares with 50 Up. This comparison reveals that all consumptions (lb/mile ; lb/ton mile ; lb/hour ; gals/mile ; gals/ton mile and gals/hour) were higher than those for the Bulawayo/Thomson Junction route. This was partly due to the increased distance and overall time between Bulawayo/Mahalapye but mainly due to working similar loads up steeper gradients (considerable distances up 1;80 grades) at similar speeds.

The difference in method of trains working for these two test routes (C.T.C. and "paper working") did not appear to have much effect on the performance.

10.5. RESULT SHEETS 10 TO 27.

10.5.1. General Remarks.

As already stated these results sheets contain all the readings expressed in their corrected form and are best interpreted in terms of the graphs Nos. 1 to 8. It should be noted that a wide range of speeds, cut offs and powers have been recorded enabling accurate graphic representation.

Unfortunately the good practice of having the regulator fully open and driving "on the reverser", i.e., by varying cut off was not always observed by all drivers, therefore the value of some otherwise useful readings has been lessened in addition insufficient information about performance at short cut offs was obtained.

Under full boiler pressure and with the regulator fully open an average pressure drop of 20 p.s.i. between the boiler and superheater header and a drop of 10 p.s.i. between the header and steam chest were recorded throughout; of course, these also varied considerably with speed and cut off.

Although quite large variations in ambient temperature were recorded on each trip these were consistent over the whole series. A very large number of indicator diagrams were taken and contain a wealth of information about phenomena in the 15th Class cylinder however, only the exhaust or back pressures and mean effective pressures were required for this test, nevertheless some samples are included and discussed.

Note: The mean effective pressures given on the above resultsheets have not been adjusted to compensate for the length of the pipe connecting the indicator to the cylinder, as required by paragraph 6.2.20. however, the IHP values shown have been corrected. The indicator is only suitable for speeds up to 250 r.p.m. (42.4 m.p.h.) so that some considerable error was introduced at speeds above this due to the inertias of the mechanisms involved.

Engine N° 361: Boiler Draughts.

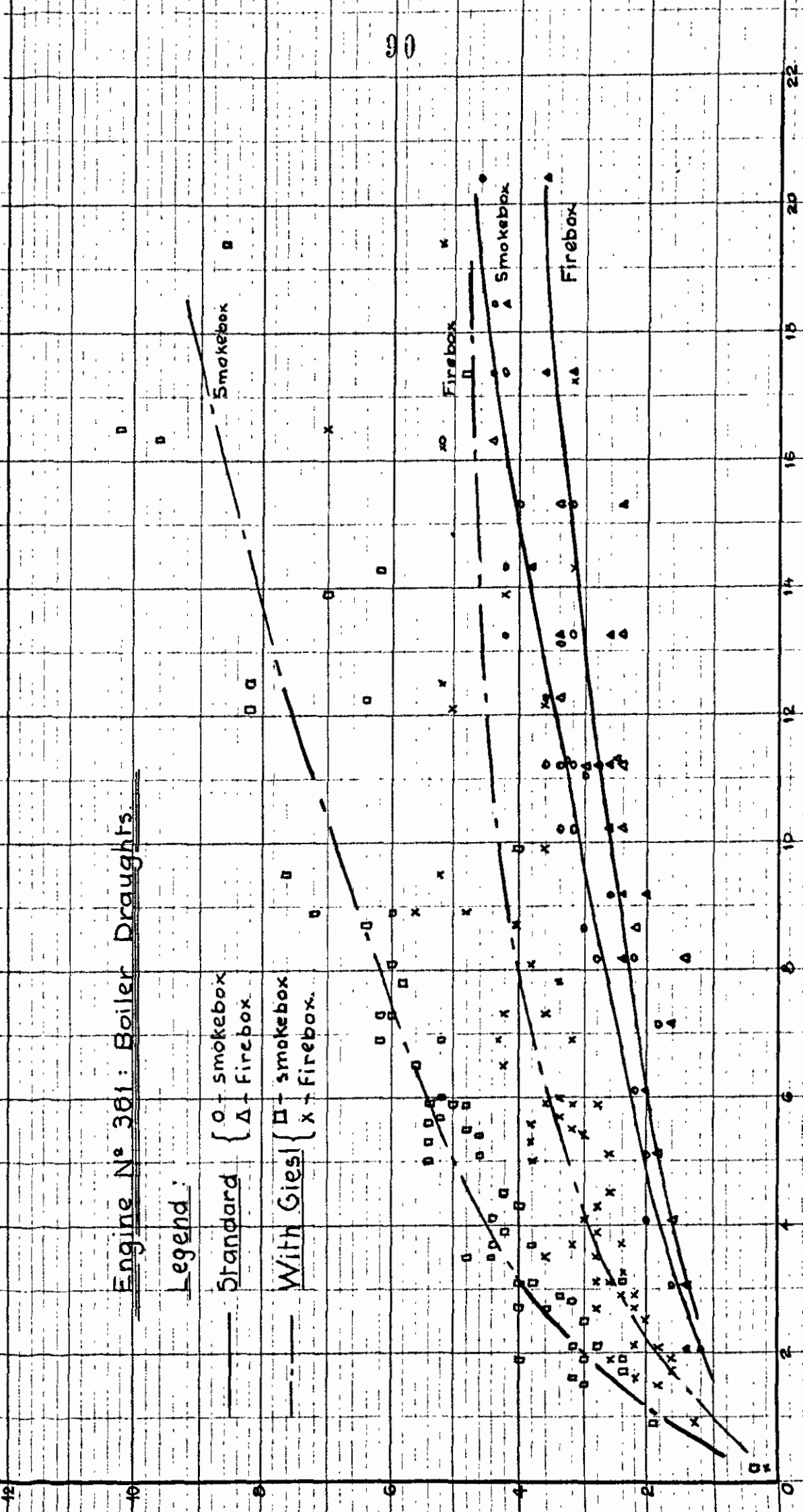
Legend:

Standard {
 ○ - smokebox
 Δ - Firebox

With Giesl {
 □ - smokebox
 x - Firebox.

Draught (inches water gauge)

Steam Pressure in Blast Pipe just below Nozzle (inches of mercury).



Engine No 380 : Boiler Draughts

Legend:

Standard { $\square$ - Smokebox
 Δ - Firebox

With Giesl { $\square$ - Smokebox
 $\times$ - Firebox

Draught (inches water)

2

4

6

8

10

12

14

16

18

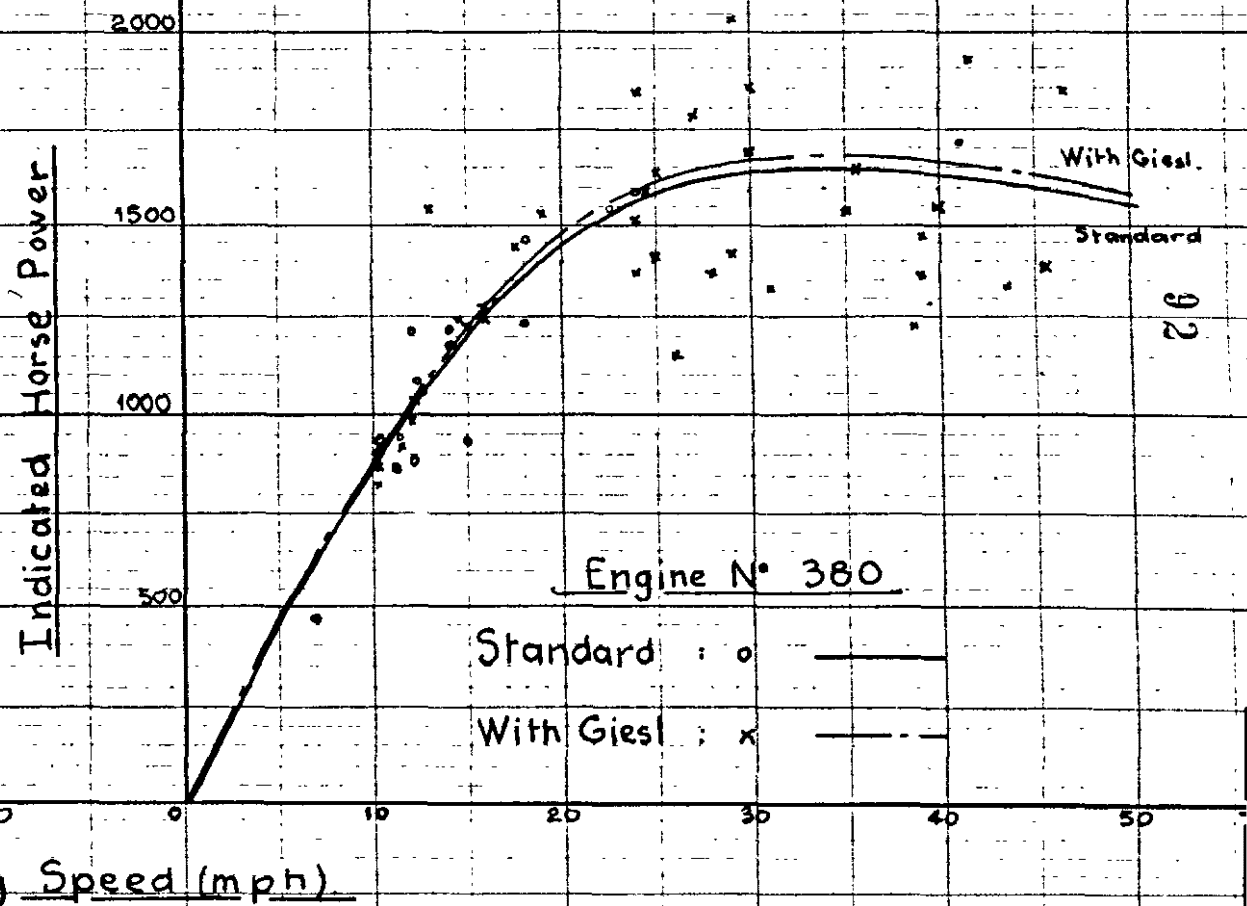
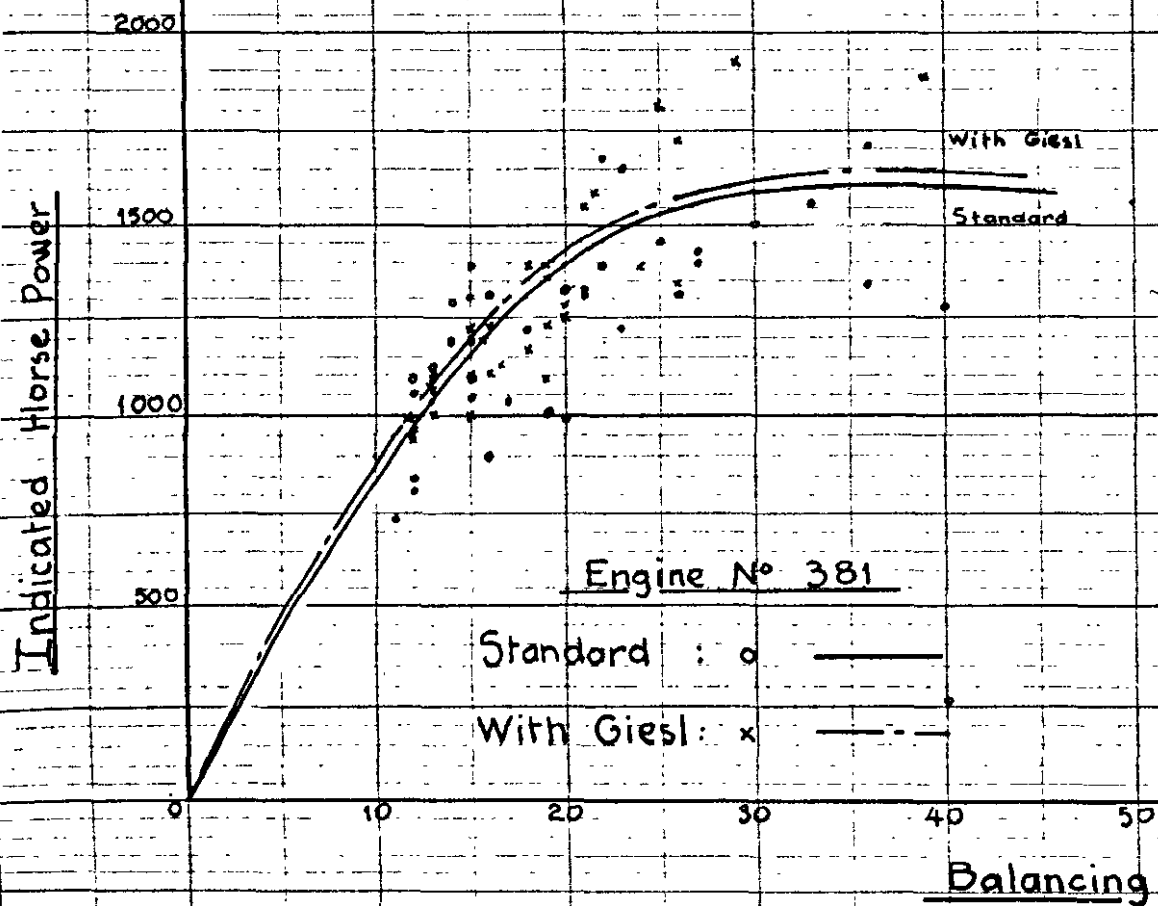
20

22

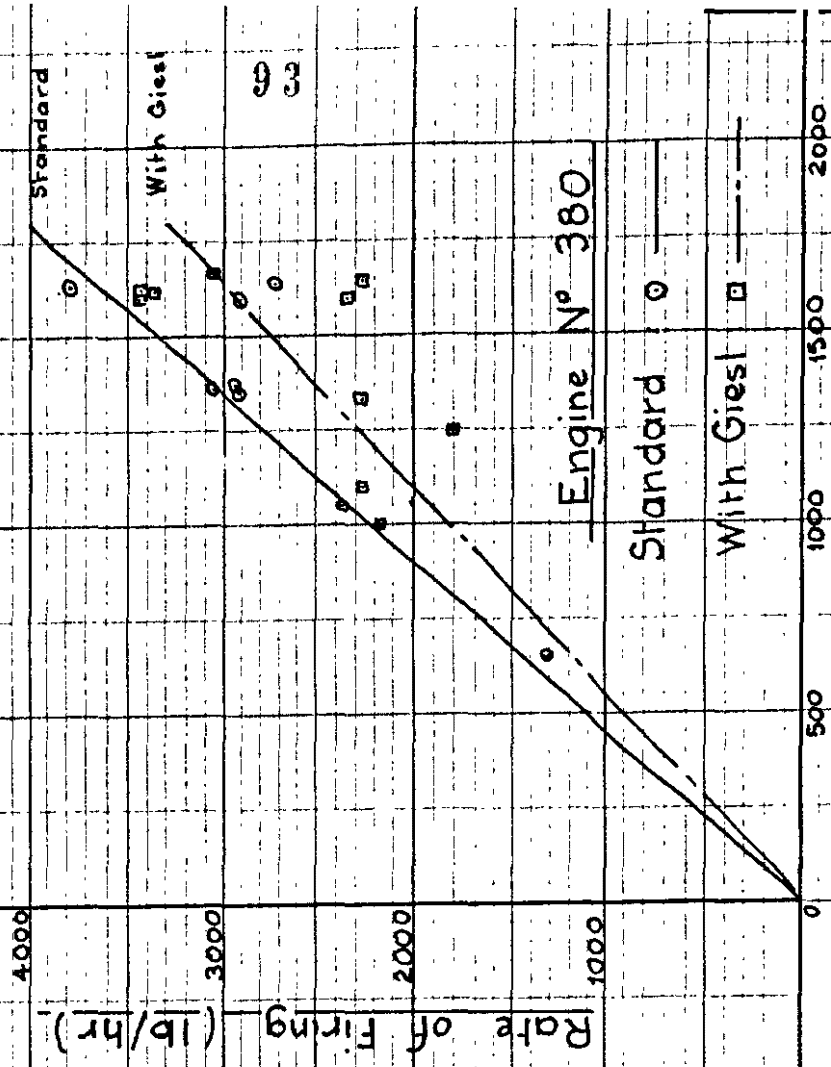
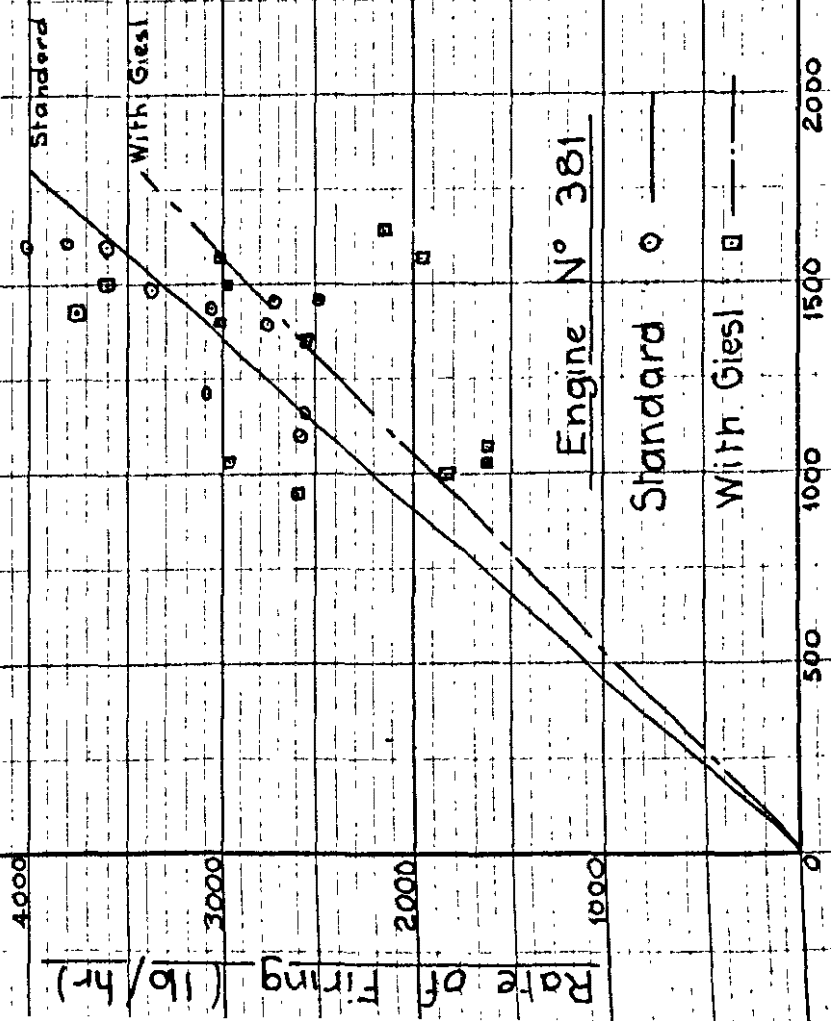
24

Steam Pressure in Blast Pipe just below Nozzle (inches of mercury)

Locomotive Performance.



Coal Consumption



Envelope
With Giesl

Envelope
Standard

700

600

500

400

300

Temperature °F

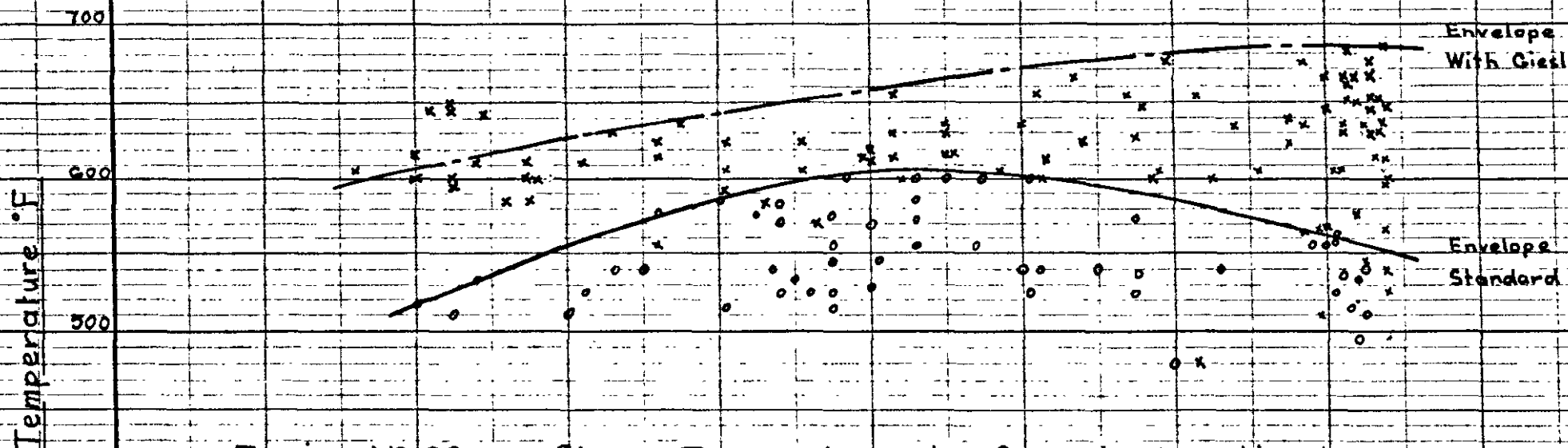
Engine No 380: Smokebox Gas Terminal Temperature

Standard : 0

With Giesl : x

200 400 600 800 1000 1200 1400 1600 1800

Indicated Horse Power



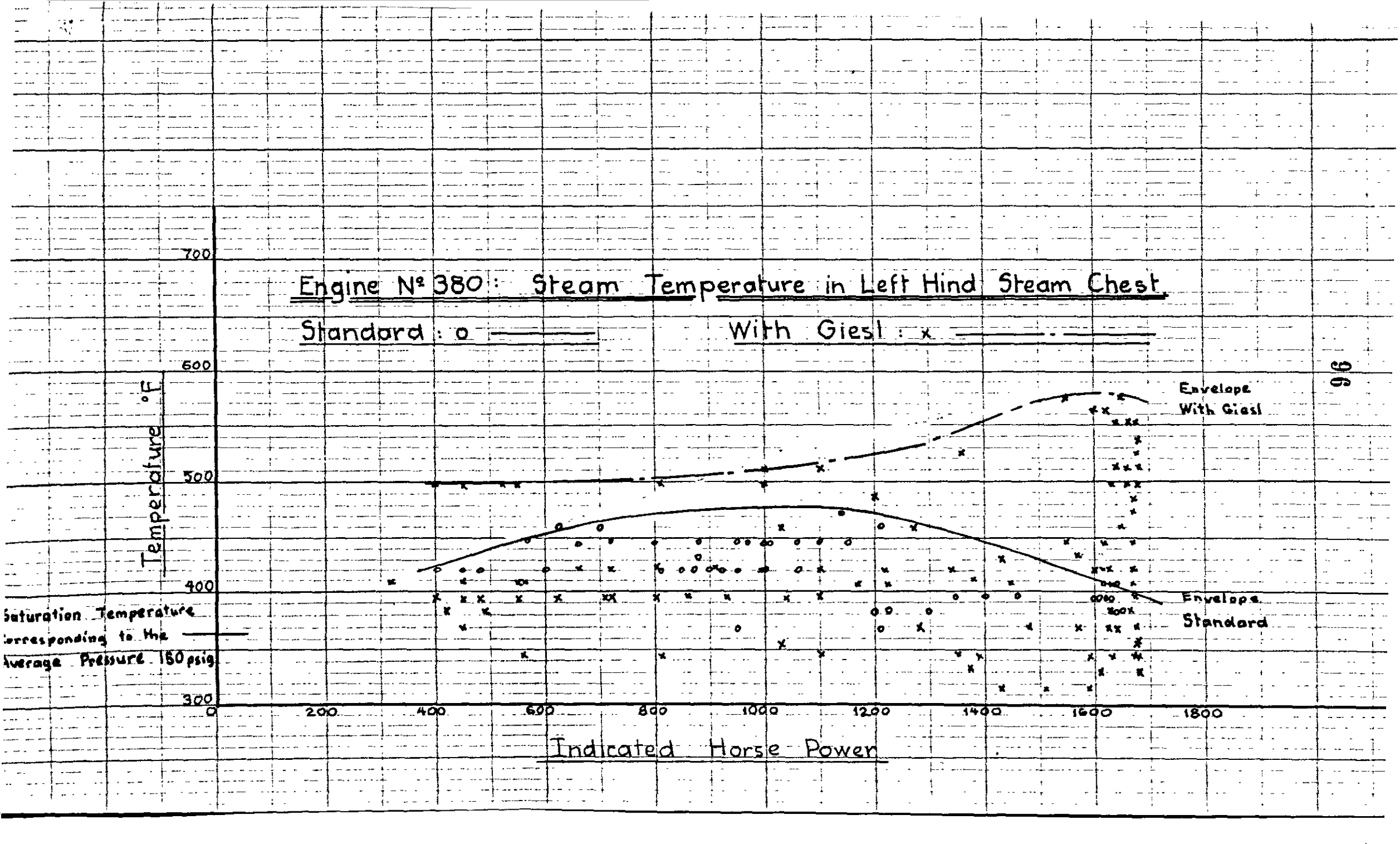
Engine No 380 : Steam Temperature in Superheater Header.

Standard : o ———

With Giesl : x ———

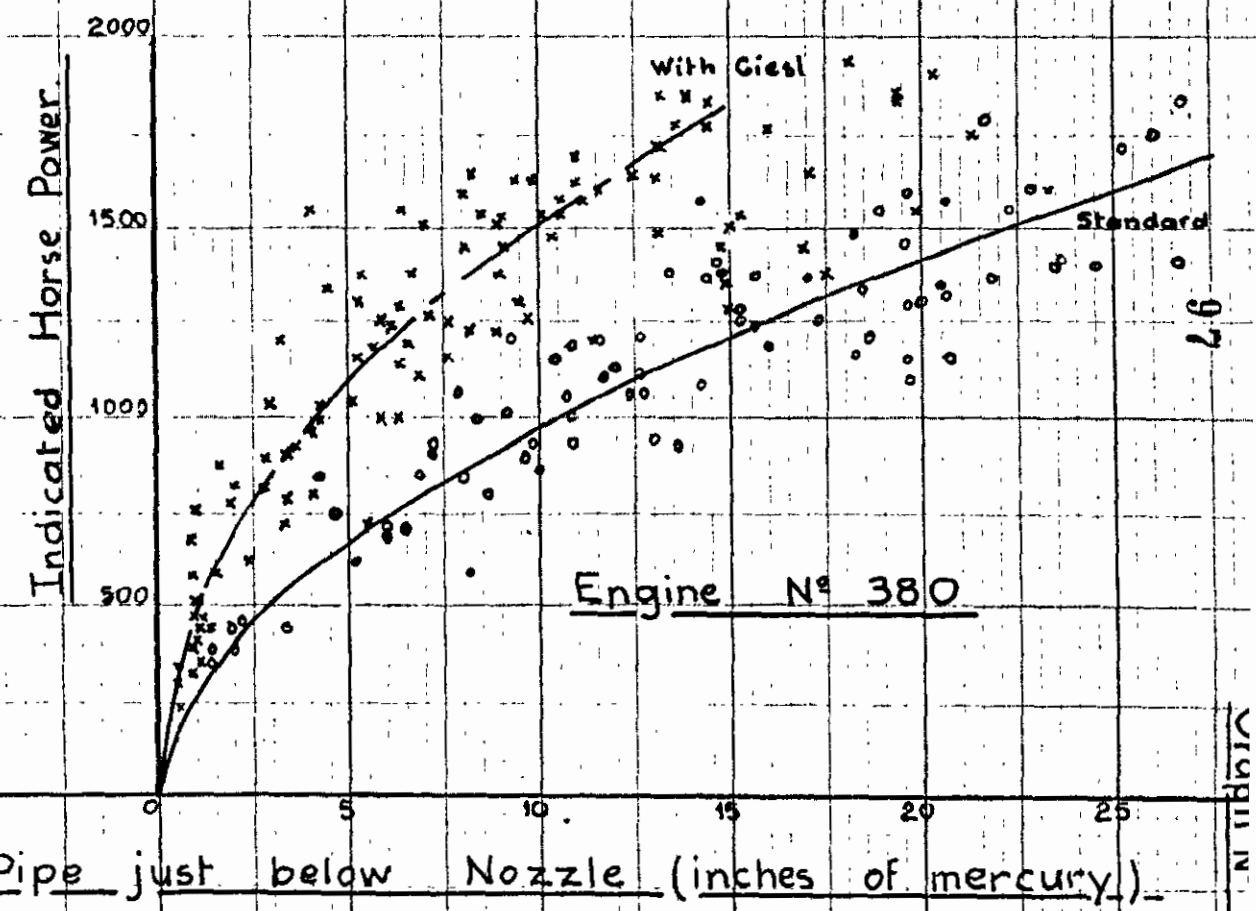
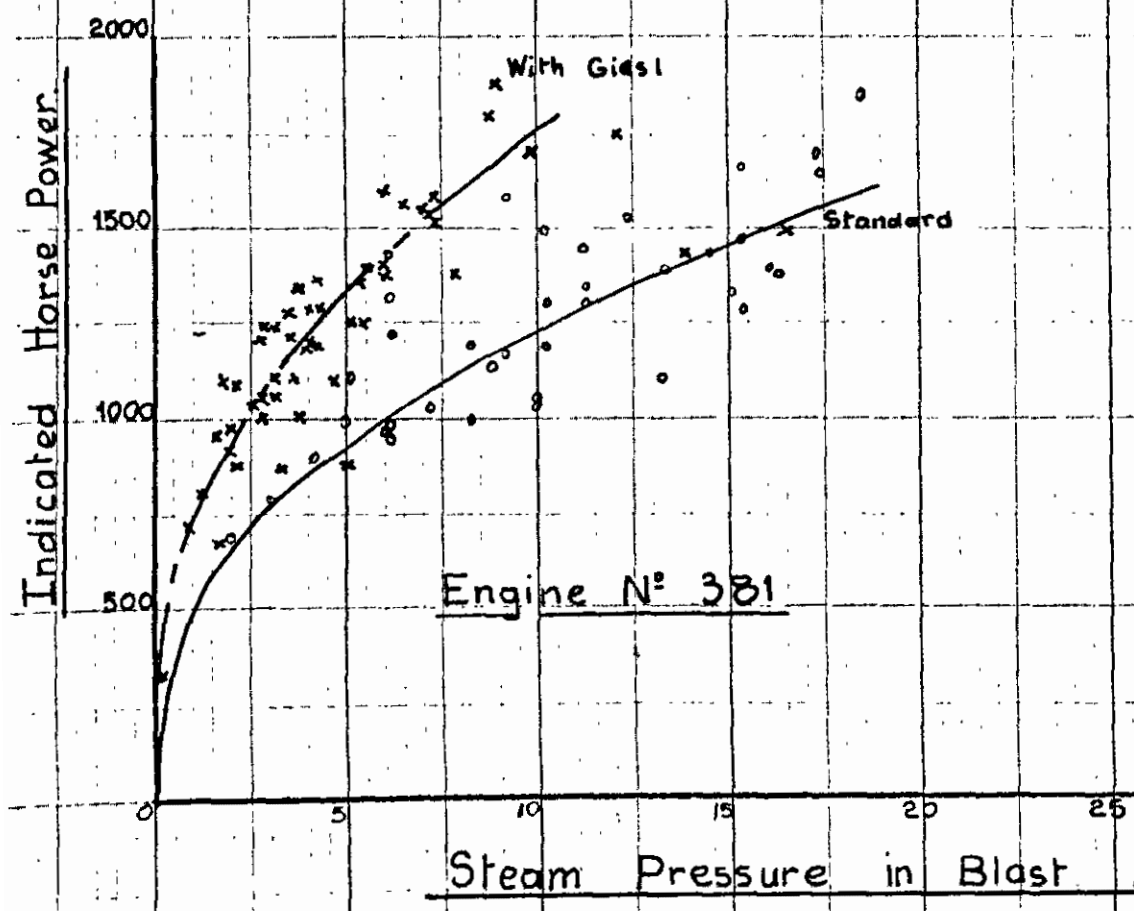
Saturation Temperature
Corresponding to the
Average Pressure 180 psig

Indicated Horse Power



Reduction in Back Pressure

Standard : o ——— With Giesl : x ———



Original

10.5.2. GRAPHS NOS. 1, 2 AND 8.

From graph No. 3 a speed of 20 m.p.h. corresponds to 1430 IHP average for all four engines (380 and 381, standard and with Giesl) and is taken as a basis for comparison. Reading now on graph No. 8 at 1430 IHP for No. 381 there was a reduction in back pressure of (57.6% ; 14.4 to 6.1 "Hg), whilst for No. 380 there was a reduction of (57.1% ; 20.5 to 11.7 "Hg) these reductions being almost constant over the whole range of working. Continuing this line of investigation to graph No. 1, it appears that for No. 381 working at 1430 IHP before and after modification the smokebox draughts were 3.9 and 5.5 inches of water respectively, while the firebox draughts were 3.2 and 3.6 inches of water respectively. In the case of No. 380 (graph No. 2) working at 1430 IHP before and after modification the smokebox draughts were 5.1 and 8.2 inches of water respectively while the firebox draughts were 3.4 and 3.1 inches respectively. Hence, considering both engines running at approximately equal speeds and powers as above shows close agreement between firebox draughts before and after modification, which was the intention of the initial "adjustment tests" mentioned in 7.5.

Considering graphs 1 and 2 from the alternate point of view of increase in draught produced by the same back pressure then it is obvious that very great increases have been effected. The considerable increase in resistance between smokebox and firebox of No. 380 (with Giesl) is also apparent since corresponding to a back pressure of 14 inches of mercury there was a pressure drop of 5.7 inches of water between smokebox and firebox while for 381 (with Giesl) at the same back pressure there was a pressure drop of only 3.5 inches of water between the same points. Note that the resistance introduced by the "self cleaning front ends" of engines 380 and 381 (standard) and 380 (with Giesl) is not apparent from graphs 1 and 2. Further these graphs take no cognisance of the increase in firebed resistance with age of firebed except insofar as this accounts for the dispersion of some of the readings.

GRAPHS NOS. 3 AND 4.

10.5.3. Despite the wide dispersion of readings plotted on these two graphs the characteristics produced are reliable since, in the case of IHP vs Speed (graph 3)

reference has been made to the S.A.R. Dynamometer Car Report of October 1949 on Rhodesia Railways 15th Class engines Nos. 351 and 361 which shows close agreement. While in the case of Rate of Firing vs IHP published information as quoted in paragraph 10.2.10 shows close agreement.

Note : The actual coal consumption recordings were far too bulky to include therefore the selected values on Results Sheet 28 only are included and plotted. As was expected very little increase in IHP between the engines in the standard and "with Giesl" states was recorded, mainly because they were hauling similar loads throughout and similar speeds were adhered to. If higher speeds had been permitted at the expense of economy, then greater IHP differences would have been recorded.

10.5.4. GRAPHS NOS. 5,6 AND 7.

All these graphs show temperatures recorded on engine No. 380. In each case the temperature envelope is shown, since it has been assumed that had the locomotive worked at any given IHP long enough then this (the envelope temperature) would have been the stable temperature reached. The very definite trend at all three stations before and after modifications is significant. In the case of the steam temperature in the left hind steam chest it is felt that the thermometer pocket used did not project far enough into the main body of steam and was consequently strongly influenced by the almost constant temperature of the massive cast iron cylinder casting, so that the apparently high drop in steam temperature between the superheater header and steam chest might not have in fact been the case. The maximum temperature recorded in this steam chest for the modified engine, was 580°F at 1600 IHP and represents 215°F of superheat. While for the standard engine the maximum steam temperature of 480°F (115°F superheat) occurred at 1000 IHP. The lubricant normally used for this application is : "Oil, valve, superheat: code number 73-21-3909" the specification for which demands

Flash Point : Minimum 585°F Open Cup
(Cleveland)

Suitable for : 680°F to 720°F
Superheat

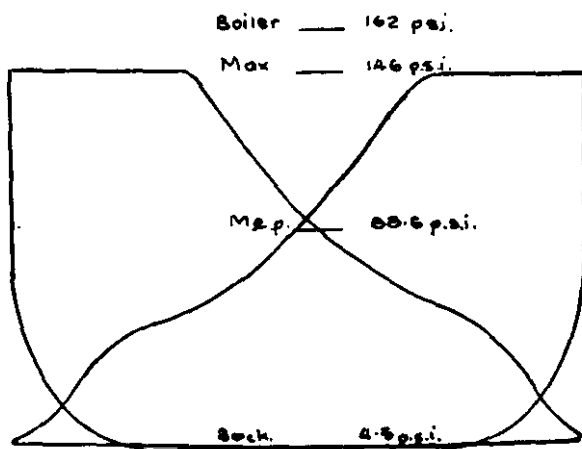


Diagram No 18; 4.4.63; 11 m.p.h.; 733 I.H.P.
Full Regulator; 36% Cut Off; Steam in. 410°F.

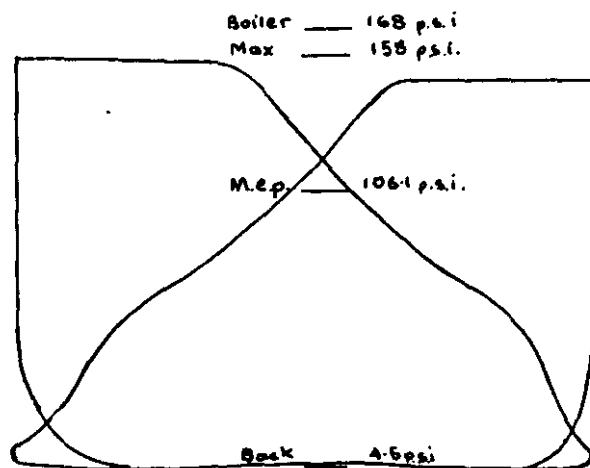


Diagram No 83; 26.4.63; 12 m.p.h.; 958 I.H.P.
Full Regulator; 42% Cut Off; Steam in. 460°F.

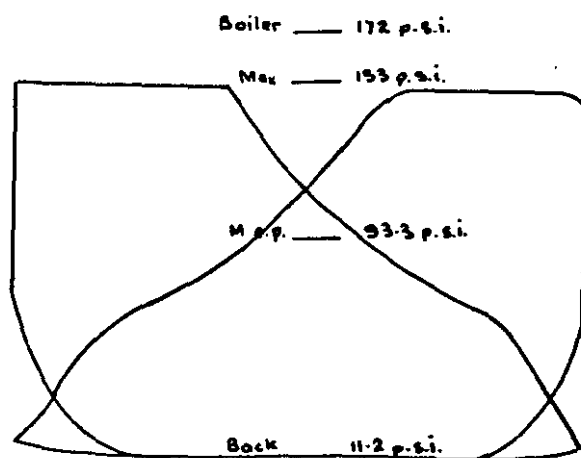


Diagram No 12; 4.4.63; 15 m.p.h.; 1049 I.H.P.
Full Regulator; 47% Cut Off; Steam in. 397°F.

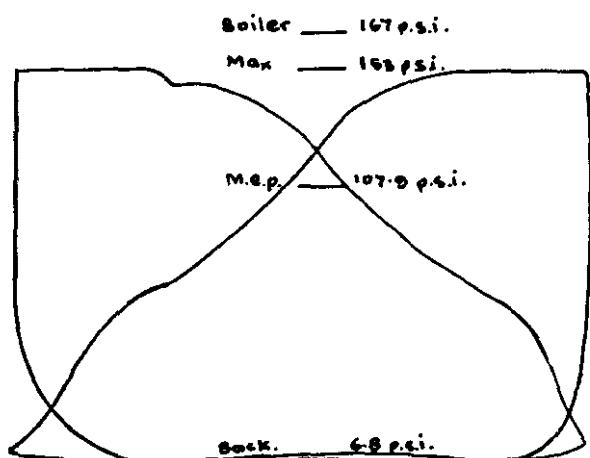


Diagram No 23; 24.4.63; 15 m.p.h.; 1214 I.H.P.
Full Regulator; 47% Cut Off; Steam in. 447°F.

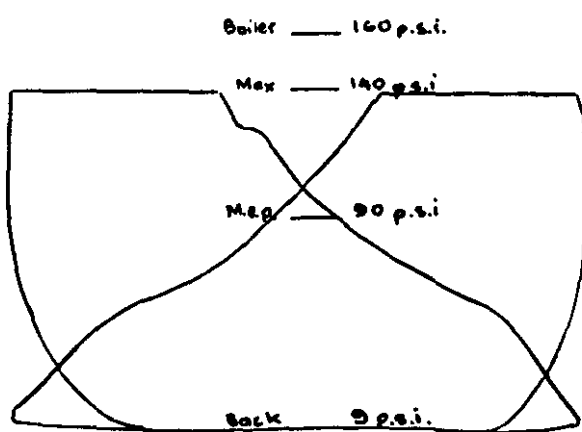


Diagram No 6; 3.4.63; 18 m.p.h.; 1216 I.H.P.
3/4 Regulator; 41% Cut Off; Steam in. 370°F.

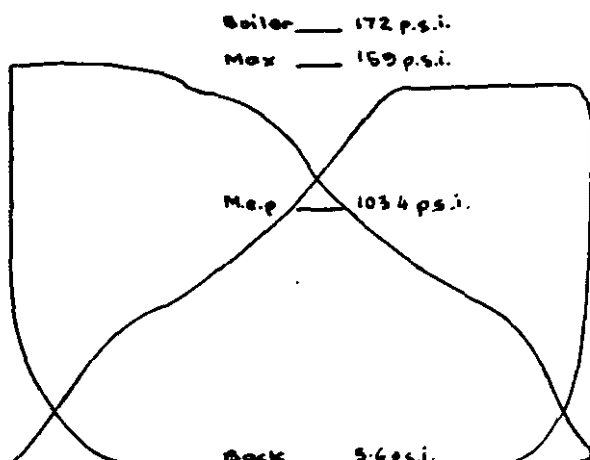


Diagram No 35; 24.4.63; 18 m.p.h.; 1393 I.H.P.
Full Regulator; 43% Cut Off; Steam in. 473°F.

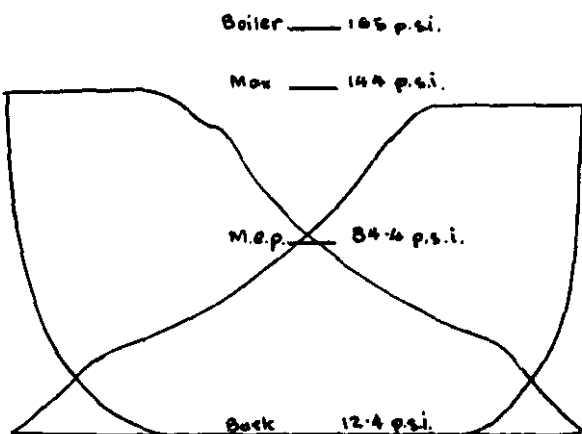


Diagram No C; 5.4.63; 22 m.p.h.; 1384 I.H.P.
Full Regulator; 47% Cut Off; Steam in. 420°F.

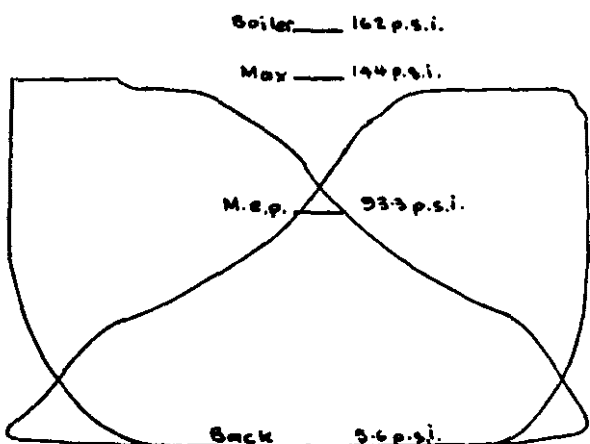


Diagram No 89; 26.4.63; 20 m.p.h.; 1393 I.H.P.
Full Regulator; 47% Cut Off; Steam in. 421°F.

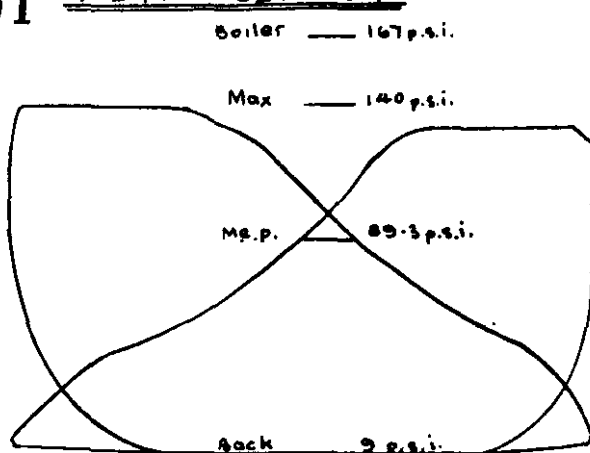
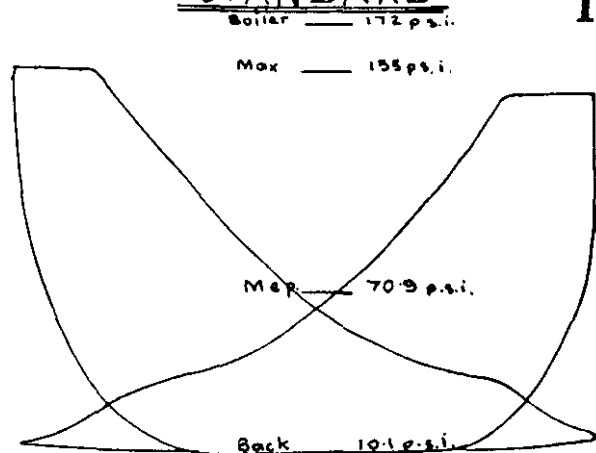


Diagram N° 10; 4.4.63; 27 m.p.h.; 1419 I.H.P.
Full Regulator; 36% Cut Off; Steam in. 410°F.

Diagram N° 27; 24.4.63; 26 m.p.h.; 1720 I.H.P.
Full Regulator; 42% Cut Off; Steam in. 382°F.

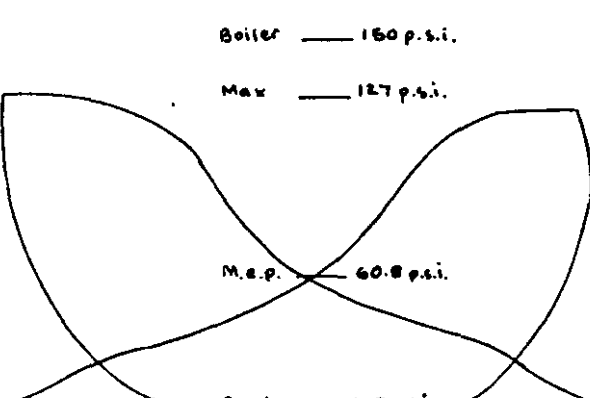
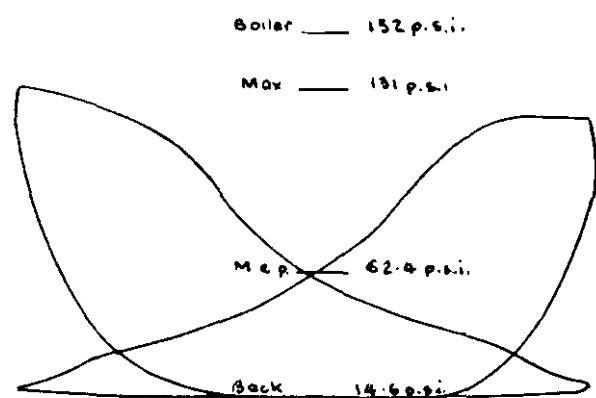


Diagram N° 8; 5.4.63; 35 m.p.h.; 1579 I.H.P.
Full Regulator; 36% Cut Off; Steam in. 370°F.

Diagram N° 6; 23.4.63; 36 m.p.h.; 1568 I.H.P.
Full Regulator; 42% Cut Off; Steam in. 421°F.

INDICATOR DIAGRAMS FOR ENGINE 380.

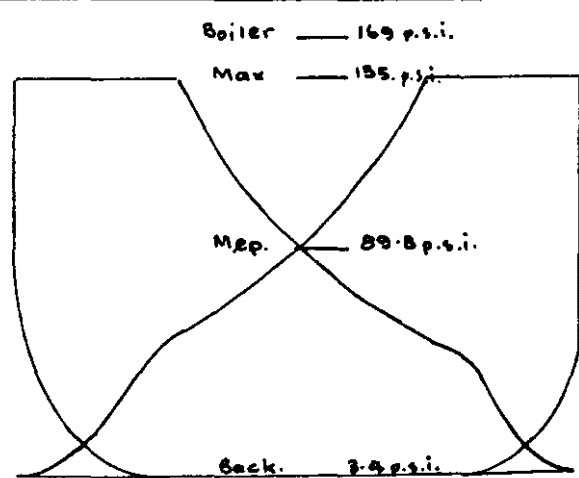
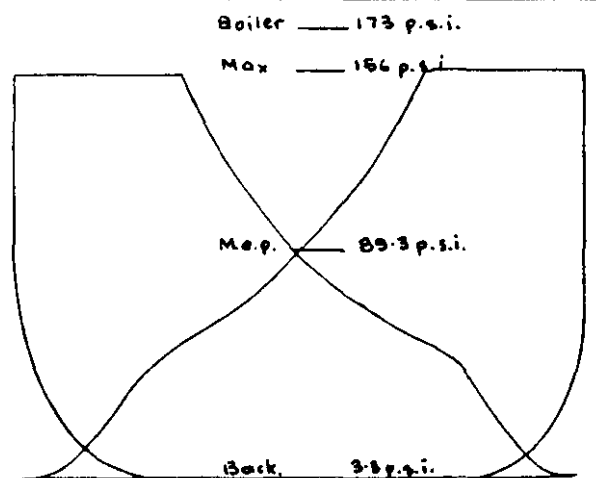


Diagram N° 72; 17.5.63; 6.3 m.p.h.; 443 I.H.P.
Full Regulator; 22% Cut Off; Steam in. 447°F.

Diagram N° A6; 11.6.63; 6.3 m.p.h.; 444 I.H.P.
Full Regulator; 20% Cut Off; Steam in. 343°F.

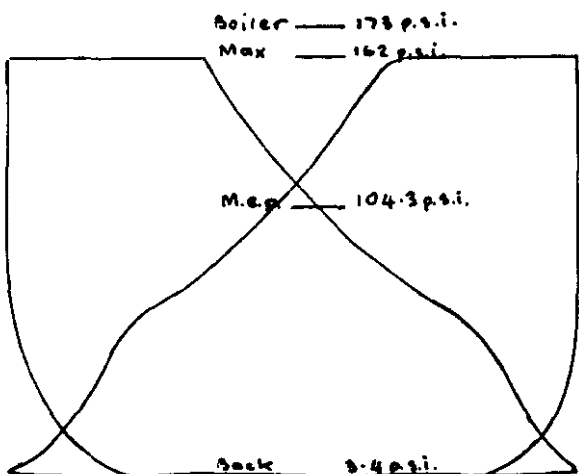
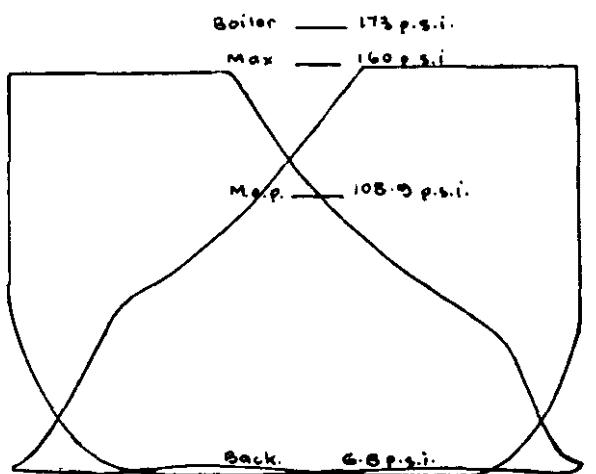


Diagram N° 73; 17.5.63; 8.3 m.p.h.; 705 I.H.P.
Full Regulator; 33% Cut Off; Steam in. 447°F.

Diagram N° 38; 7.6.63; 8.2 m.p.h.; 676 I.H.P.
Full Regulator; 35% Cut Off; Steam in. 421°F.

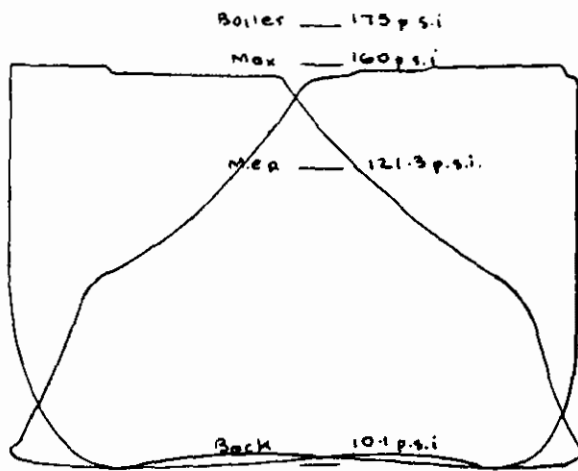


Diagram N° 74; 17.5-63; 11.2 m.p.h.; 1064 I.H.P.
Full Regulator; 43% Cut Off; Steam in. 421°F.

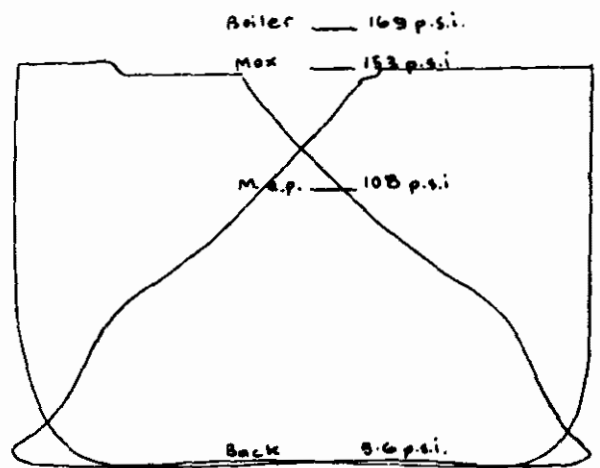


Diagram N° 23; 7.6-63; 12.2 m.p.h.; 1030 I.H.P.
Full Regulator; 44% Cut Off; Steam in. 460°F.

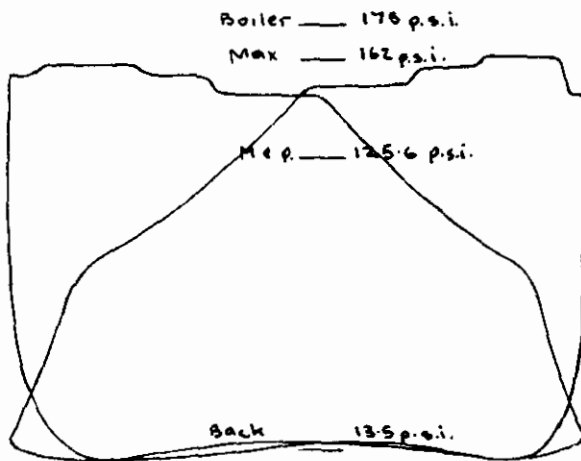


Diagram N° 75; 17.5-63; 12.7 m.p.h.; 1245 I.H.P.
Full Regulator; 53% Cut Off; Steam in. 421°F.

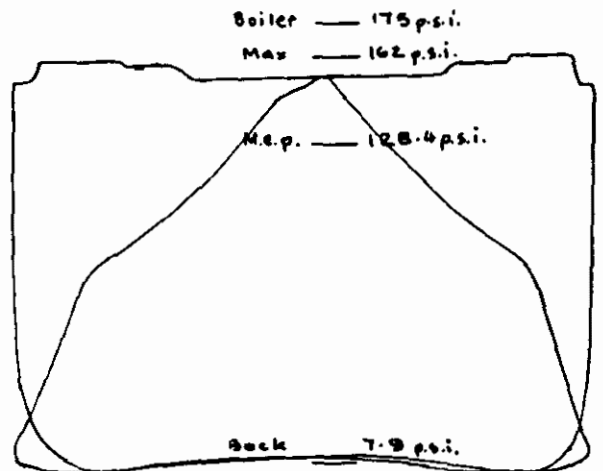


Diagram N° 40; 7.6-63; 10.2 m.p.h.; 1030 I.H.P.
Full Regulator; 52% Cut Off; Steam in. 421°F.

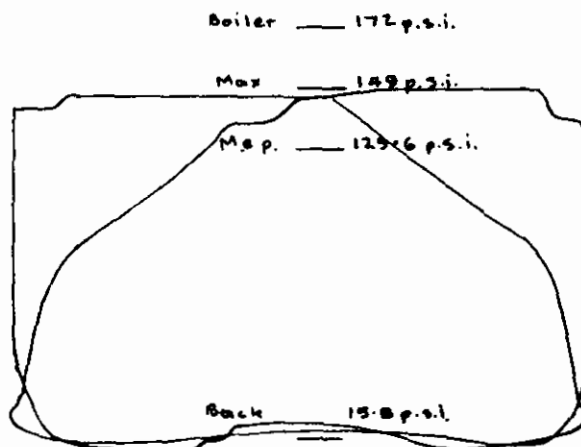


Diagram N° 76; 17.5-63; 13.6 m.p.h.; 1340 I.H.P.
Full Regulator; 62% Cut Off; Steam in. 447°F.

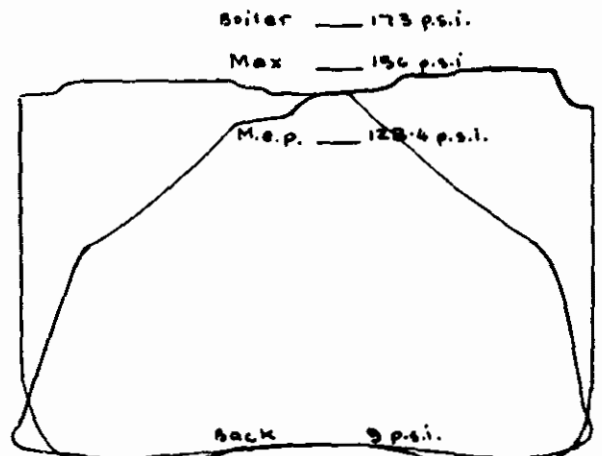


Diagram N° 41; 7.6-63; 13.2 m.p.h.; 1301 I.H.P.
Full Regulator; 62% Cut Off; Steam in. 421°F.

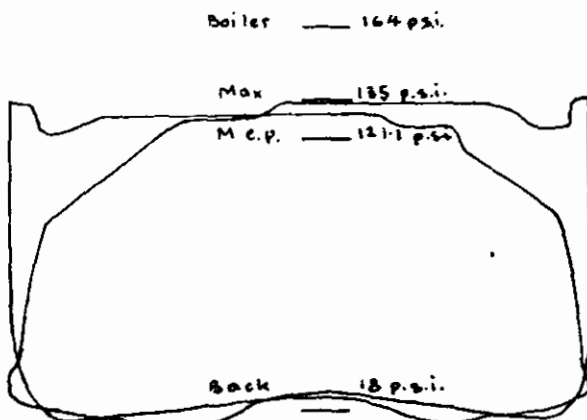


Diagram N° 77; 17.5-63; 15.1 m.p.h.; 1432 I.H.P.
Full Regulator; 72% Cut Off; Steam in. 460°F.

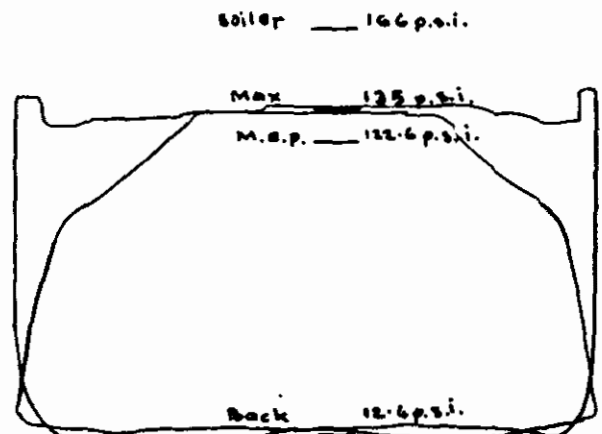
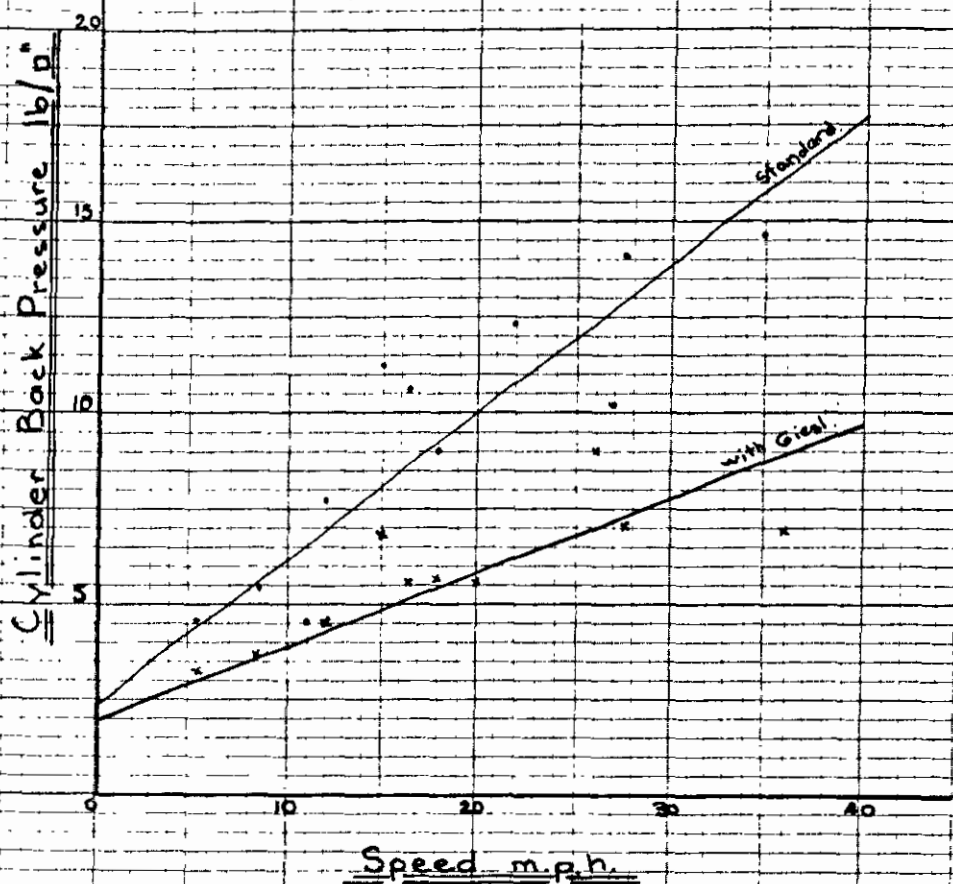
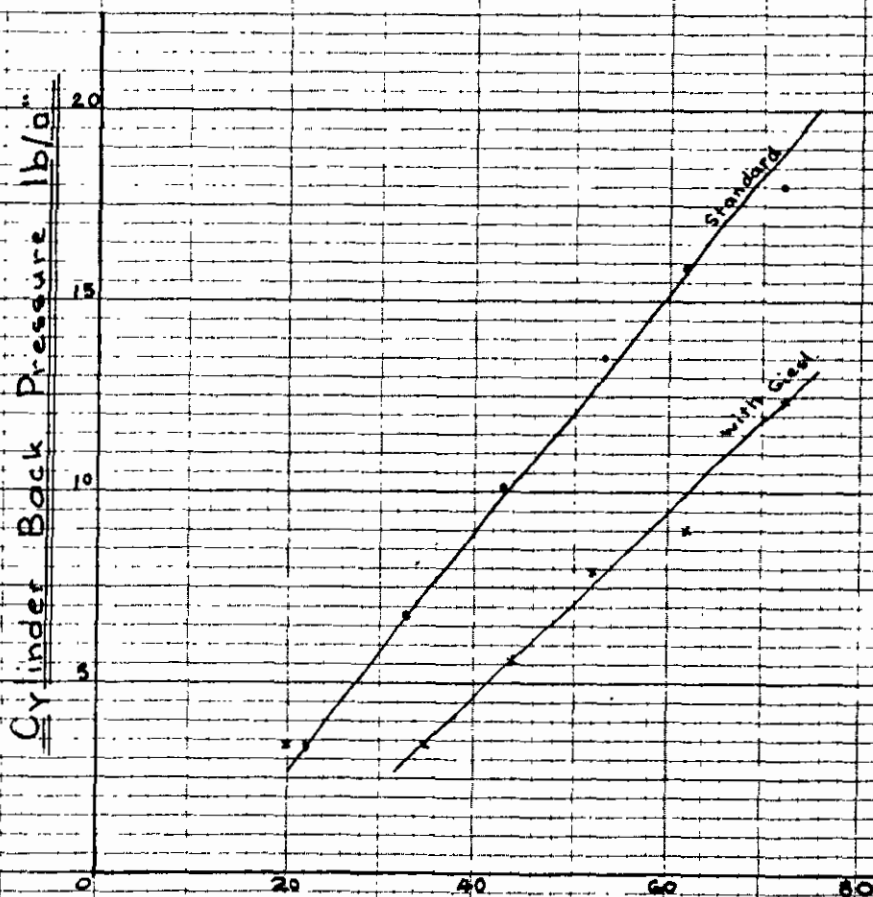


Diagram N° 42; 7.6-63; 15.1 m.p.h.; 1448 I.H.P.
Full Regulator; 72% Cut Off; Steam in. 421°F.



Relationship for Engine N° 381 based on
selected Indicator Diagrams for 40% Cut Off.



Point of Steam Cut Off as % Stroke.

Relationship for Engine N° 380 based on
selected Indicator Diagrams for 11.2 m.p.h.

Hence even if the steam temperatures recorded in the superheater header (graph No. 6) were reached in the steam chest and cylinder, there should be no failure of the lubricant for the engine fitted with the Giesl ejector and Superheat Booster. The points shown outside the "with Giesl" envelope on graph No. 6 were produced by suddenly slowing the engine down from working at a much higher horsepower. It is interesting to note that by comparing graphs 5 and 6 up to about 550 IHP the smokebox gas temperature is actually lower than the steam temperature indicating a very efficient heat exchange at these low powers and low fluid mass flows. Contrary to some of the claims made for the Giesl ejector there was an increased gas exit temperature for the modified engine representing an increased heat loss through the exhaust. This is a bad feature indicating, possibly, that the damping has been "overdone". This temperature could be reduced by removing the throttling rings referred to in paragraph 6.3.2. and hence allow a greater mass flow of gas through these few smoketubes, allowing greater heat transfer to the water and slightly increasing the evaporation.

10.5.5. The selected sets of indicator diagrams on pages 100, 101 and 102 have been chosen so as to enable comparison of the locomotives before and after fitting the respective Giesl ejectors. The series for engine No. 381 show by changes in shape of the diagrams the effect of gradually increasing speed at nearly constant cut off. The most significant feature of the "381" diagrams is the difference in back pressure in the cylinder before and after fitting the Giesl. The cut offs marked against these diagrams were taken from the sector plate in the locomotive cab and are consequently subject to some error. The series of diagrams chosen for engine No. 380 cover a small range of speeds and a high range of cut offs. Again the great reduction in cylinder back pressure of the Giesl equipped engine is visible. It is noted that the two series of back pressures for engine 381 varied at different rates with increasing speed while those for engine 380 varied at equal rates with a nearly equal difference between them (see graphs on page 103). These two phenomena relate to the two respective rates

of steam flow i.e., variation of steam flow with increasing speed at constant cut off and variation of steam flow with increasing cut off (later and later in the stroke) at slow speed. The fitting of the Giesl ejector had no apparent effect on other steam engine phenomena visible from the diagrams i.e., the increasing effect of "wire drawing" with increasing speed was recorded for both 381 sets and in the case of engine 380 both sets showed recompression at 72% cut off as well as undulations of the steam inlet pressure line (top "horizontal" line of indicator diagram) caused by condensation for all the later cut offs, also the variation of back pressure during the stroke due to inter-action of the opposite side cylinder was hardly affected by fitting the Giesl ejector.

10.6. Results Sheet No. 29 contains data obtained from a number of lesser investigations to prove certain specific points or claims.

10.6.1. The draught created by the blower is very important during periods when the locomotive is "making steam" i.e., initial or other warming up periods, hence it was necessary to determine for comparison the effects of the standard blower and the blower provided with the Giesl Ejector. In testing the standard blower the effects of the small and large vacuum brake ejector exhausts were included, producing the result that these contribute a negligible amount towards draught creation. The standard blower produces 0.8 inches of water draught in the smokebox and 0.5 inches of water draught in the firebox while the "Giesl" blower produces 0.6 and 0.2 inches of water draught respectively. The latter is considered too low and warrants improvement. The blower effect from the Giesl nozzles can be increased by enlarging the bores of each jet. While on the subject of vacuum brake ejector exhaust, no provision was made for conducting this exhaust steam into the chimney of the Giesl Ejector. In the case of engine No. 381 it was conducted directly to atmosphere in the vicinity of the clackbox without any ill effects on the brake ejector, i.e., without creating too high a back pressure. In the case of engine 380 it was conducted to atmosphere through a baffle drum or silencer below the boiler just in front

of the ashpan, without any ill effects on the brake ejector. This latter arrangement was later changed in favour of a manifold in front and on top of the chimney, since the previous arrangement allowed steam up around the cab and obscured the crews vision for shunting at night. This method is considered favourable and preferable to a complex manifold on the side of the chimney inside the smokebox.

10.6.2. In order to determine the effects of the increased draught produced by the Giesl Ejector on combustion, a number of exhaust gas samples were taken from the smokebox, of engine No. 380, just in front of the tableplate. For the standard engine there was little difficulty in drawing the sample directly into the Orsat apparatus because of the low smokebox vacuum but in the case of the modified engine, it was found preferable to draw the sample into a bottle, by displacement of water and then to extract some of this sample for analysis. The analysis of each sample is shown on the results sheet corresponding to the train on which the sample was collected. One significant point is that at no stage was any carbon monoxide found in the gas thus indicating that complete combustion had taken place. The high amount of oxygen found in the samples taken from the standard engine was generally not compatible with the percentage volume of carbon dioxide measured, so that these samples were not suitable for calculating air/fuel ratios. These very high oxygen contents were put down to the absorbing solutions being slightly inefficient; there were no apparent leaks in the apparatus. For the later tests with the modified engine all these solutions were renewed and very consistent readings resulted. The percentages of excess air shown on results sheet No. 29 are based on the percentage volumes of carbon dioxide measured and have been taken from empirical results (12). The air fuel ratios have been calculated from the analyses of the gas samples taken. Since 1 lb. coal containing 60% carbon and 28% volatiles requires a minimum of 11.8 lb. of air for complete combustion (based on ultimate analysis of average Wankie coal) it has been possible to check that these values of excess air and air fuel ratio are compatible; this check has been carried out and the values found to be in agreement. As one would expect

the air fuel ratios show a tendency to increase with increasing horsepower output, mainly due to increasing draught with much the same firebed depth. The suitability of using an Orsat apparatus on a steam locomotive has been proved, provided a satisfactory method of sampling is employed. This was one of the objectives in these particular tests.

10.6.3. Normally it is very important that the exhaust blast should strike the internal periphery of the chimney symmetrically and about 12 inches below the top (in the case of 15th Class locomotives) to avoid any leakage of air back into the smokebox. For this reason the alignment of the blast pipe cap (nozzle) and chimney is very important. In the case of the Giesl ejector alignment is more or less assured by the lugs connecting the chimney to the nozzle, nevertheless considerable deflection of the blast is possible by altering the position of the adjusting slides. In fact, on both engines after the Giesl ejectors had been fitted it was found necessary to offset the blasts slightly, since although the slides had been set parallel to and equidistant from the chimney fore/aft centre lines the blasts were found to be over to one side at the chimney exit. As stated earlier preliminary tests were conducted with each engine after the Giesl ejector had been fitted, during which the adjusting slides were set to some intermediate position judged to give the best combination of back pressure and draught. The final positions selected and adopted for all final tests were as follows :

Engine No. 381 (no self cleaning front end fitted)

Distance between adjusting slides (front)	2 7/16"
Distance between adjusting slides (rear)	2 9/32"
Offset of adjusting slides to right of engine (front)	1/32"
Offset of adjusting slides to right of engine (rear)	5/64"

Engine No. 380 (with self cleaning front end fitted)

Distance between adjusting slides (front)	2 1/8"
Distance between adjusting slides (rear)	2 3/32"
Offset of adjusting slides to right of engine (front)	3/32"
Offset of adjusting slides to right of engine (rear)	3/64"

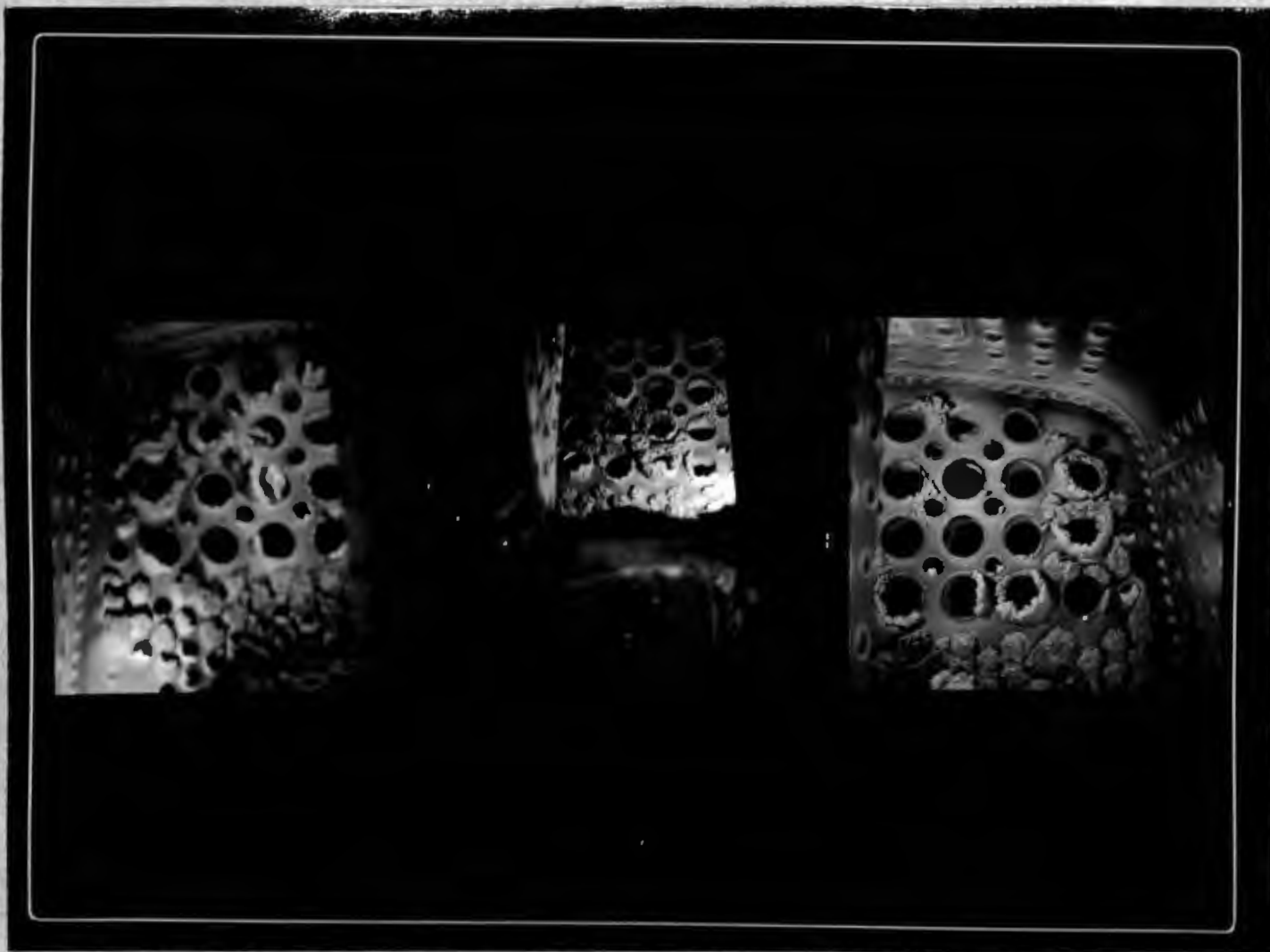
These settings gave the correct distribution of exhaust in the chimney i.e., heavy front and rear and light in the centre. Results Sheet No. 29 includes some information about the depth of strike of the exhaust blast below the top of the chimney. In the case of engine No. 380 (standard) this was fairly easily determined with the aid of the apparatus described earlier (paragraph 6.2.4.). The results show a definite trend in that the higher the back pressure the lower down the blast strikes the chimney, as one might expect. In the case of engine No. 380 fitted with the Giesl Ejector this depth was not easy to determine since due to the distribution of the blast, the striking occurs lower down at the front and back than at the sides, in fact, the depth of strike was found to be so low down in the chimney that under some conditions it dropped out of reach of the instrument probe. One conclusion drawn from these tests was that due to the extreme length of the "Giesl" chimney and in view of the increased depth at which striking occurs these chimneys are less susceptible to drawing air, if the blast is not correctly aligned in the chimney, than the standard chimney.

10.6.4. Results Sheet No. 29 also records the weights of char removed from the smokeboxes of the two engines at various stages, a study of which reveals the efficiency of the Master Mechanics front end compared with the non-self cleaning smokebox. The self cleaning arrangement fitted to engine No. 380 in accordance with Messrs. Schoeller-Bleckmann's drawing No. G-674 (Appendix III) worked very efficiently despite the fact that the area in front of the table plate was very much lower than that recommended by the Association of American Railroads (see Diagram No. 9). The area in front of the table plate (taken from No. 380) expressed as a percentage of the free tube area was 111% whereas the A.A.R. recommends 150% - 170% (Area D, Diagram 9.). The area under the front deflector plate and centre table plate projection (taken from No. 380) expressed as a percentage of the free tube area was 74% the A.A.R. recommendation being 65% - 80% (Area C, Diagram 9). The self cleaning front end shown on drawing No. G-674 was extremely complicated to manufacture and difficult to fit; it will require considerable revision if required in any quantities. Messrs.

Schoeller-Bleckmann did not think it necessary to completely close in the gaps above the diaphragm and front screens at superheater header level but in view of the fact that our standard 15th Class front ends are closed in here and bearing in mind the tendency for gases to short circuit the self cleaning arrangement, as found on other classes of locomotive, these gaps were closed in with plates at the back (diaphragm) and perforated plate in front.



A CLEAN FIREBOX TUBEPLATE.



COMPOSITE OF FIREBOX TUBEPLATE. SHOWS "BIRDSNESTING"



BIRDSNESS; BASE OF ENCRUSTATION.



SUMMIT OF ENCRUSTATION. (UPSTREAM FACE.)

11. SUBSEQUENT DEVELOPMENTS WITH THE TWO RHODESIA RAILWAYS LOCOMOTIVES.

11.1.1. Both engines were returned to normal service after the tests. They have since been examined by myself and the Boilermaker Chergeman at the Bulawayo Running Shed at every "washout" or "tubeblow", approximately every 14 days for the first 6 months after fitting. Engine No. 381 has shown some "birdnesting" on the centre top flue tubes and top three rows of smoketubes but generally this has been less than the average standard 15th Class engine. The tubes themselves have remained very clean with one or two bottom smoketubes containing some char. The smokebox of engine No. 381 has showed signs of regular cleaning out but on one occasion one of the bottom screens in the spark arrester had been burned through and had to be replaced. It would appear that heavier screens are required throughout. The firebox of engine No. 380 had heavier "birdnests" deposits than No. 381, these being concentrated mainly in the high velocity areas at the entrances to the flues with very little on the lower smoketubes. "Birdnesting" is a problem experienced with all Rhodesia Railways steam locomotives basically as a result of the chemical composition of the coal. It is an encrustation consisting of particles of unburnt coal, dust and ash held together by fused ash and tar. The main difficulty is that this mass builds up on the firebox tubeplate and in time completely covers the tubeplate and blocks most of the smoketubes and flues, drastically reducing the steaming ability of the boiler. Whilst chemical dosing of the firebed as well as reduction in ash fusion temperature, by cooling the firebed with steam, have been found to reduce the amount of the build-up, these practices have not been found economic on Rhodesia Railways. Instead the tubeplate is brushed fortnightly (at "washout" or "tubeblow") and the material lying on top of the brick arch removed. It has been noticed that variations in pressure distribution across the tubeplate as well as variations in gas velocity and direction, when entering the tubes from the firebox, affect the distribution of deposit across the tubeplate.

Consequently it was anticipated that some noticeable change in the distribution of the deposit would be evident after fitting the Giesl ejectors as has been noted above. The photograph on page 110 shows a clean 15th Class tubeplate as seen from below with the brick arch removed and the thermic syphons and a water tube visible in the foreground, while the composite photograph on page 111 shows the average condition of the tubeplate of engine No. 381 after fitting the Giesl ejector. The composite photograph shows clearly the way in which the "Birdsnest" builds out conewise from the periphery of the tube end gradually closing the tube off. The centre portion of this photograph was taken through the firehole door and shows a heap of char on top of the brick arch in the foreground. The photographs on page 112 show two views of two pieces of "birdsnest" taken from engine No. 381. The larger piece weighed nearly $3\frac{1}{2}$ pounds and measured 8" x 5" x 5" while the smaller piece taken from the roof of the firebox was 7" long. The first photograph showing the downstream concave side of the larger piece clearly illustrates the way in which this piece had grown, gradually sealing off a flue and adjacent smoketube.

11.1.2. At all examinations of No. 380 it has been apparent that the smoketubes containing the throttling rings have been becoming blocked very rapidly and remaining so for most of the working time between examinations. Further in view of the remarks in paragraph 10.5.4. covering these rings it was decided to remove the throttling rings at a P.15 examination on 15/7/63 this should hardly affect the economies recorded for this engine and should in fact, allow a slight increase in firebox draught - a desirable feature. Subsequent observations have shown these changes to have been justified.

11.1.3. With the increased velocity of the mixture in the Giesl chimney it was thought that rapid erosion might take place. However, to date the chimneys of both engines have retained a polished appearance inside with no evidence of char erosion.

11.1.4. From the maintenance point of view the smokebox of engine No. 381 is ideal since there are few obstructions and the tubeplate and superheater elements are freely accessible. However, in the case of engine

No. 380 the damper can only be opened 50° when it fouls the back centre tableplate leaving no room for the Washoutman to go over or under the tableplate to the tubeplate. Actually the Washoutman has to be under the tableplate before the damper is raised to be able to remove the boiler plugs. Upon examining the situation there seems very little that can be done by modifying the self cleaning arrangement since, in any case, the passages under the tableplate are restricted by steam pipes. However, a modified damper which will be split and hinged segmentally is to be made and fitted allowing relatively free access to the smokebox tubeplate. A further development is that the damper removed from Engine No. 380 will be fitted to engine No. 381 to raise the superheat temperature on this engine. No. 381 still does not have a self cleaning smokebox arrangement so that there will be no difficulty from the point of view of tubeplate access with the damper in place. Nevertheless it is proposed that with the damper fitted to engine No. 381 a false floor sloping down from the smokebox front towards the tubeplate should be fitted. This will restrict the amount of char deposited in the smokebox by compelling it to remain in circulation with the gas, thus rendering the smokebox partially self cleaning. This is only feasible with the damper fitted since the damper allows a stream of gas from the smoketubes to flow along the smokebox floor with a "sweeping" action. It is anticipated that once the damper has been fitted to Engine No. 381 the nozzle adjusting slides will not have to be altered from their present position since, in their present position, the firebox draught is greater than need be and fitting the damper will reduce this draught to a reasonable level.

12.1. By virtue of the fact that the majority of steam locomotives still in service on the worlds railways were designed and built to incorporate the conventional smokebox ejector there is a ready market for the more efficient Giesl ejector. However, although the Giesl ejector and Superheat Booster are recent developments their effects are hardly new. For instance the evolution of smokebox ejectors through numerous configurations employing the largest possible nozzle areas and peripherys culminated in the highly efficient multiple jet types. In addition the principles of "tuned " boiler design employed the practice of "throttling", associated with the Superheat Booster, as the table on page 15 shows. Nevertheless it has taken a development like the introduction of the Giesl ejector and Superheat Booster to "highlight" the desirability of high boiler tube resistance, increased superheat temperature and draught and reduced back pressure, factors which, fortunately, are being incorporated in a few of the new steam locomotives being built today.

12.2. As pump the Giesl ejector is very much more efficient than the conventional circular ejector, in fact so much so that it becomes a very versatile asset. Its use, in particular with the Superheat Booster, allows varying degrees of fuel and water economy as well as increases in continuous power to be experienced. The increased draught available from the Giesl ejector can increase boiler efficiency in two ways :

1. It improves combustion efficiency by ensuring an adequate supply of air at all rates of firing. This was confirmed by measurement of increased excess air at high power on the Rhodesia Railways Tests.
2. In conjunction with the Superheat Booster it improves boiler absorption efficiency by imparting more heat to the steam in the form of superheat.

These effects are limited, since too much excess air cools the fire reducing efficiency. While over throttling, as was experienced with the throttling rings on the Rhodesia Railways tests, reduces the evaporative capacity of the boiler and reduces boiler efficiency by allowing increased mean gas temperature at exit from the tubes and hence a greater thermal loss to the exhaust gases. The optimum throttling adopted after the Austrian Federal Railway tests (paragraph 4.8) was 50% which compares well with the optimum of 54.3% in the table on page 15.

12.3. The important characteristic of the Giesl ejector whereby its pumping efficiency increases with increasing rates of firing and hence power, makes a useful contribution to improved locomotive operation. For instance a more than adequate air supply is guaranteed at all times so that ash accumulates in the firebed the combustion efficiency does not decrease. It is desirable to make the firebed resistance as small a part of the whole resistance as possible since this affects the range of the locomotive and generally makes for more stable boiler operation. This requirement favours increasing the boiler tube resistance by introducing an increased number of smaller smoketubes or Superheat Booster drier, as well as the incorporation of such devices as "self cleaning" plates and spark arresters which add to boiler resistance. Where possible changes in "throttling" i.e., varying the quantity of gas past the superheater by changes in tube sizes and number is preferable to the use of the damper, since, although both systems increase boiler resistance the former has the added advantage of increasing evaporative surface and increasing boiler efficiency due to improved heat transfer. The limit of locomotive range due to the inability of the conventional smokebox ejector to cope with high firebed resistance is known as the "Front End Limit". The claim that with the Giesl ejector the Front End Limit is eliminated is substantially correct.

12.4. Dr. A. Giesl-Gieslingen is quoted as saying that his classification of likelihood of success with the Giesl ejector in descending order is as follows ;

1. Oil Fired
2. Wood Fired
3. Brown Coal Fired (Lignite)
4. Ordinary Steam Coal (Hand) Fired
5. Ordinary Steam Coal (Mechanical stoker) Fired.

The successful applications quoted in paragraph 4.9. gave an overall average saving of 12% fuel giving the following order of success :

- | | |
|------------------|------------|
| 1. Wood fired | 16% saving |
| 2. Coal fired | 13% saving |
| 3. Oil fired | 9% saving |
| 4. Lignite fired | 9% saving |

With such riders as : Oil fired locomotive requires some means e.g., diaphragm plate, to distribute the Giesl ejector draught evenly across the tubeplate ; (East African Railways experience) and mechanical stoker fired locomotives should use washed coal with few fines to avoid chimney erosion (South African Railways experience). Of course the first classification might still be correct since the second is based on relatively few locomotives. Nevertheless one concludes that claims for the equipment are not always realised in practice.

12.5. The Rhodesia Railways tests, although originally designed to "highlight" fuel economy, draught and back pressure changes have supplied considerably more information. As far as realisation of claims is concerned the makers stated that for the Giesl ejectors supplied to Rhodesia Railways :

"Increase in capacity will be at least 20% without booster and 25% with booster ; additional coal and water economy with booster is usually 5 to 8%. 50 to 75% reduction in back pressure will be experienced for the same smokebox vacuum. Black smoke and exhaust noise will be much reduced. Fuel and water economy as high as 25% when working heavily will be experienced".

These claims were met to a greater or lesser degree. Capacity increases were not recorded because the test trains were kept down to regulation speeds, however, one or two "bursts" were permitted when the additional power was noted (accounts partly for dispersion of IHP readings on graphs Nos. 3 and 8). The overall economy in fuel for the Giesl ejector without booster was 4.76% while for the Giesl ejector with booster this rose to 11.58%. Although these fuel economies disagree with the claims the additional economy of 6.82% (11.58 - 4.76) with the booster does agree. A reduction of 60" in back pressure was recorded. The reduction in exhaust noise was noticeable while very little change in smoke colour was recorded since after all, this "lies very much in the hands" of the crew. The superiority of the Giesl ejector with Superheat Booster over the simpler arrangement extended to the water economy field. Should it at any time be possible to run at increased speeds on Rhodesia Railways, then the extra power available with the Giesl ejector due to increased mean effective pressure will be of value.

12.6. Various brochures issued on the Giesl ejector claim amortisation of investment in periods under one year but these seem to neglect variations in fuel costs. For instance, Rhodesia Railways statistics show that each 15th Class locomotive does 44,200,000 gross ton miles of work in one year which for a fuel rate of 0.0896 lb/ton mile amounts to 3,960,000 lb. of coal, which, at a rate of 22/- per ton costs £1,945. The total cost in labour and materials for buying and fitting the Giesl ejector with Superheat Booster to Engine No. 380 was £1,525 while for Engine No. 381 the overall cost was £1,109. Respective fuel savings are :

11.58% of £1,945 = £225 per annum.
and 4.76% of £1,945 = £92.5 per annum.

which means that the Giesl ejector with Superheat Booster will pay for itself in $\frac{1525}{225} = 6.77$ years

and the Giesl ejector without booster will pay for itself in

$\frac{1109}{92.5} = 12$ years.

These figures do not make investment in the Giesl equipment very attractive financially. In Europe on the other hand where coal costs at least five times the Rhodesian price and the Giesl equipment is slightly cheaper the amortisation periods would be reduced to at least $\frac{6.77}{5} = 1.36$ years and $\frac{12}{5} = 2.4$ years respectively.

12.7. It has not been the intention in this thesis to enter a long discourse on the theory of injectors, since this is a very complex subject already dealt with in a number of theses. What is more, most theses deal with ideal ejectors so that their results are hardly applicable to so rough an ejector as the conventional smokebox ejector or anything as complex as the Giesl ejector. In fact these two forms of ejector would require extensive research, not possible at this time, to establish reliable theories covering their performances. Van Der lingen (13) and Engel (14) have formulated and used ejector theories based on constant area, variable area or constant pressure mixing, although both admit that this process is not fully understood, further their ideal ejectors employ predictable fluids such as air and water, air and air or water and water. Hence the vastness of the problem in formulating a theory for an ejector of complex cross section and employing two fluids such as exhaust steam and boiler flue gas becomes apparent. The efficiency of the ejector given in (14) has already been quoted, however, it is interesting to derive a simple efficiency relationship using Bernoulli's equation applied to the steady flow of a compressible fluid.

Consider the work done in pumping gas from the smokebox (station 1) to atmosphere (station 2).

$$\text{Work done } W_g = \int_{P_1}^{P_2} v \, dp + (KE_2 - KE_1)$$

where v is volume of gas at pressure p .

If in the ideal case there is assumed to be no loss of kinetic energy i.e., $KE_2 - KE_1 = 0$, also the compression is assumed to be isothermal following the law $pv = a$ constant, then evaluation gives:

$$W_g = \frac{W_g}{J} R T_1 \log_e \frac{P_2}{P_1} \text{ B.Th.U./min}$$

where W_g is the weight of gas ejector lb/min.
 R is gas constant for smokebox gas.
 T_1 is mean temperature of smokebox gas.
 P_2 is atmospheric pressure.
 P_1 is smokebox pressure.

The work done by the steam is

$$W_s = W_s \Delta H \text{ B.Th.U./min}$$

where W_s is the steam rate in lb/min.
 ΔH is the isentropic heat drop B.Th.U./lb.

$$\text{Ejector efficiency} = \frac{W_g}{W_s} \frac{R}{J} \frac{T_1}{\Delta H} \log_e \frac{P_2}{P_1}$$

This cannot be evaluated since W_g and ΔH are not accurately known, however, consideration of the functions

$$\frac{W_g}{W_s} ; \frac{R T_1}{J \Delta H} ; \log_e \frac{P_2}{P_1}$$

in conjunction with the temperatures and draughts measured on the Rhodesia Railways tests shows the Giesl ejector to be more efficient than the conventional circular ejector. For instance if P_1 only were decreased, corresponding to an increase in smokebox draught then the ejector efficiency would be increased. It is significant that increasing T_1 increases ejector efficiency but of course this is at the expense of boiler efficiency.

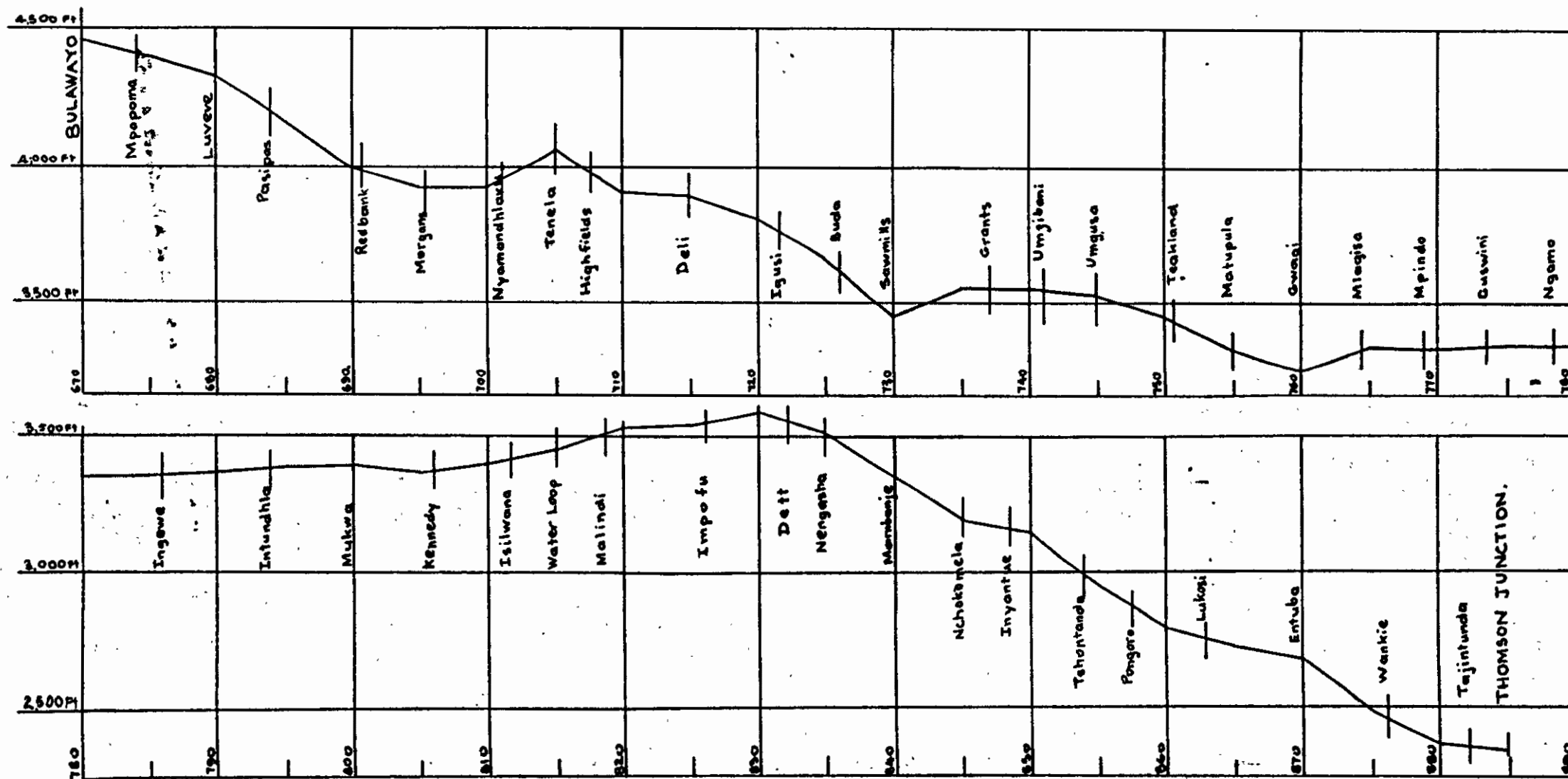
12.8. Generally the Giesl ejector with or without the Superheat Booster meets all claims of improved efficiency and performance, compared with conventional ejectors, to a greater or lesser extent. The unqualified guaranteed fuel economy of at least 10% (15) after fitting the Giesl ejector with Superheat Booster is not entirely commercialism and is frequently realised in practice.

(SEE ALSO BRYER FORCOCK'S MEMO. NO 61/T. 0926/04 OF FILE

THE EXISTING PORTS ARE MAINTAINED WITH THE TRAPPING PARTICIPATIONS AND POWER SOURCES.

3. THE HORIZONTAL CROSS PLATE (TABLE PLATE) IS CUT OUT IN THE CENTER AND A NEW CENTER PLATE PLUS SUPPORTING PLATE IS INSTALLED;
4. THE UPPER BOW-SUPPORTING BOWLS AND PLATE ARE CUT WITH CHAINING AND AN ADJACENT CONNECTING PLATE IS INSTALLED BY WELDING;
5. THE CHAIRS THERE IS INSTALLED AND FITTED WITH A PUNCH; THE TWO BOWS OF BOW ARE TO BE THE NEW PLATE BEHIND THE NEW BOWS AND APPLIED;
6. THE UPPER BOW PLATE IS CUT OUT AT THE CENTER AND BRACED AGAINST THE UNDERBOW BOW PLATE. WHILE THE NEW CHAIRS BEHIND IN THE NEW BOWS, THEREFORE, THE CHAIRS SCISSOR, DISCONNECTED IN HALF, IS REMOVED INSTANTLY AND SUPPORTED BY NEW BOWS IN THE NEW CENTER PLATE IN THE CROSS PLATE;
7. THE NEW BOWS ARE CUT BY THE NEW CHAIRS AGAIN; UNDER THE NEW PLATE, THE NEW BOWS ARE CUT BY THE SUPPORTS TO PLATE THEREIN AND THE REPLACEMENT OF THE CHAIRS, PART OF THE CHAIRS. THE GAP BETWEEN THE NEW BOWS, CLIPPING OF PLATE AND BOWS, NO PLATE AND NO PLATE FOR BOWS THE GAP OF THE TOP (FOUR AND BOW), THEN BEING INSTALLED.

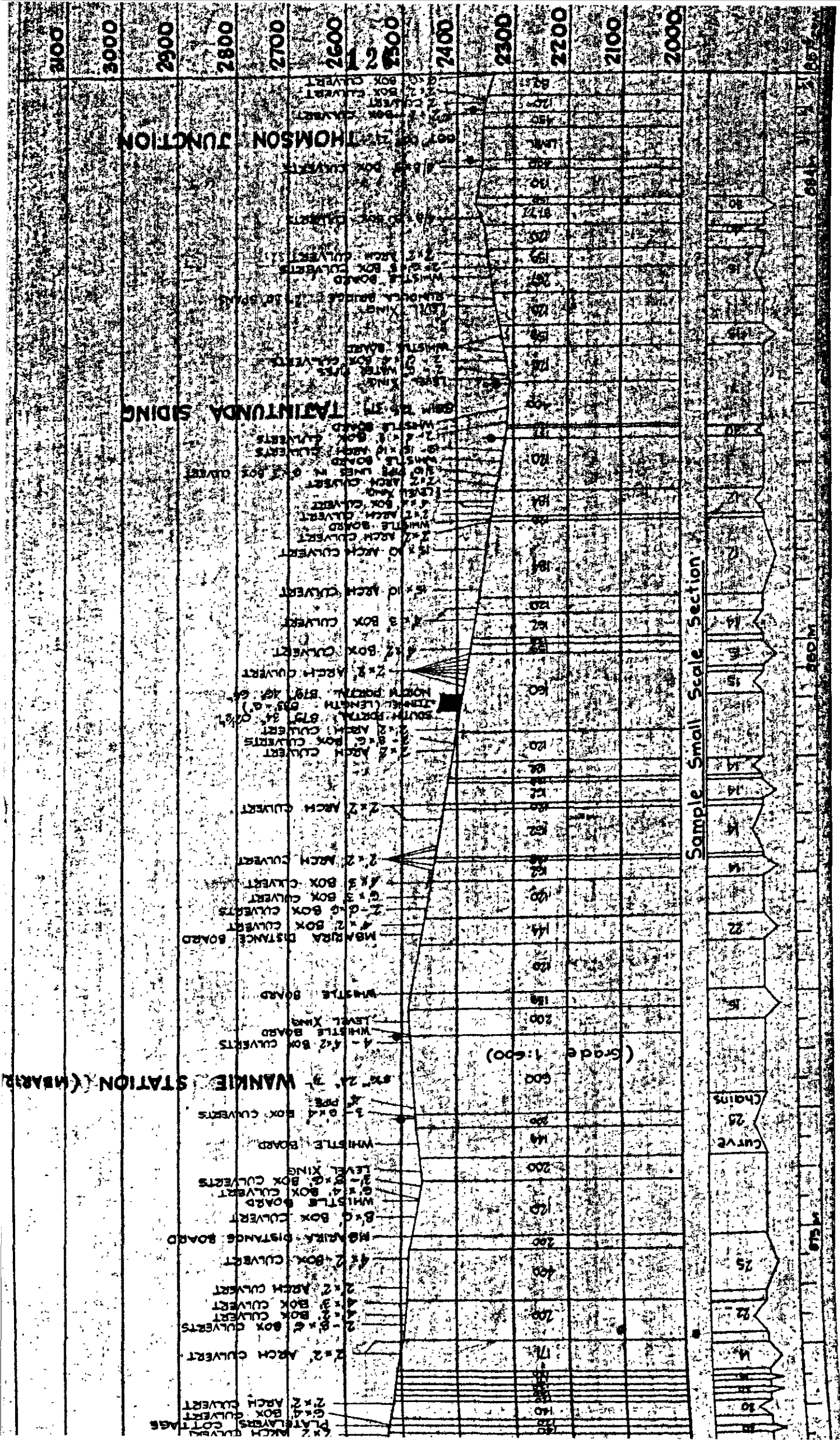


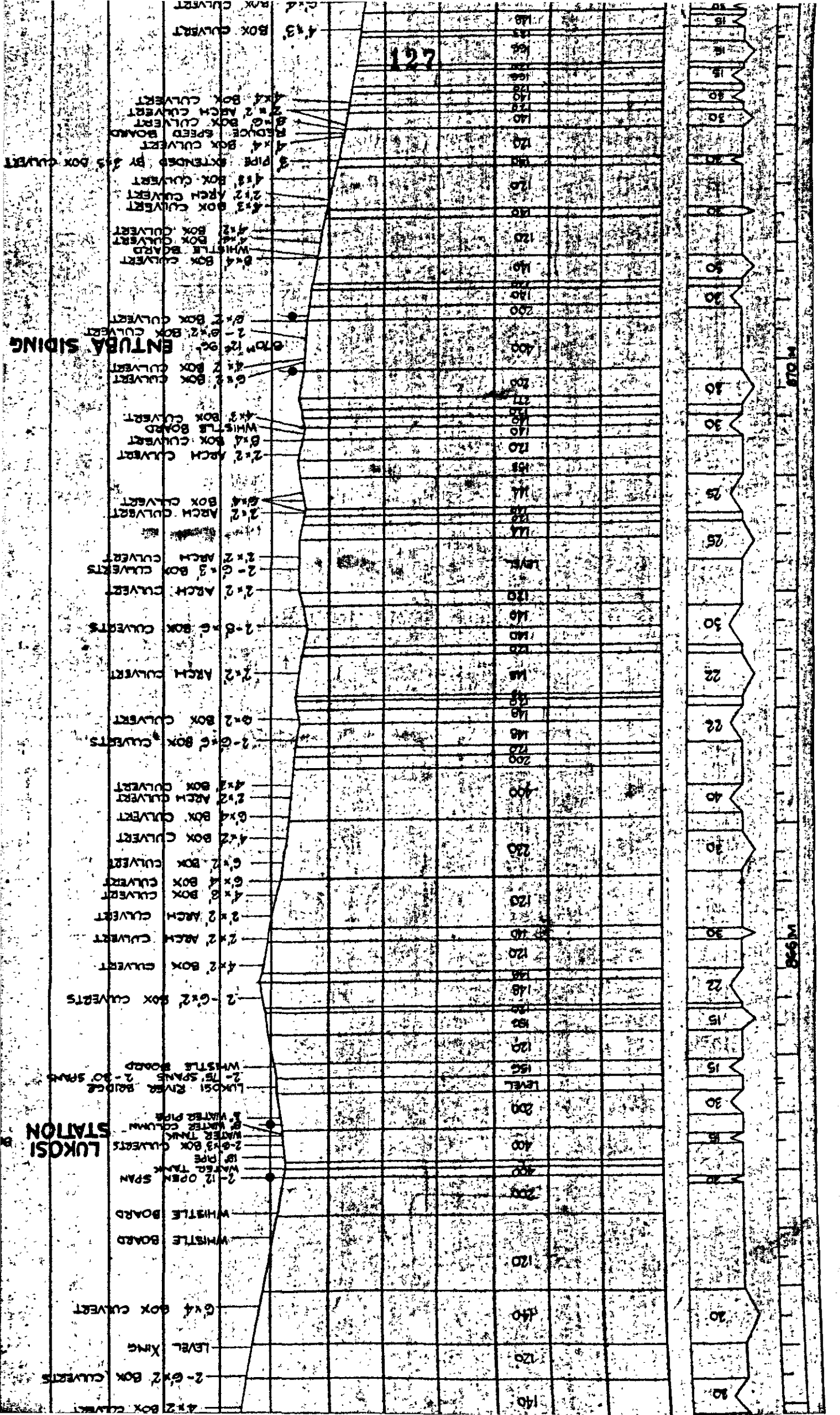


Condensed Altitude/Distance Chart for the Route : Bulawayo to Thomson Junction.

The distance is shown as "Mile Peg" numbers. Numerous re-grades and deviations make the total distance greater than that shown.

Scales: Horizontal, 1 inch = 10 miles. Vertical, 1 inch = 500 feet.





This Appendix includes the following
Rhodesia Railways Giesl Ejector Tests
Results.

Results Sheets 1 - 9 Coal and Water Consumptions.
Results Sheets 10 - 27 Locomotive Performance Data.
Results Sheets 28 and 29 Sundry other Recorded Data.

ENGINE N° 381 : COAL CONSUMPTION
FOR STANDARD LOCOMOTIVE

		FOR STANDARD LOCOMOTIVE		FOR LOCOMOTIVE FITTED WITH GIESL EJECTORS		AVERAGE GAIN:
		50 UP. 590 X 80	50 UP. #	50 UP. 583 X 80	50 UP. 631 X 84	
BULAWAYO TO THOMSON JUNCTION 219 MILES.	TRAIN N°. LOAD: DATE: TOTAL TIME HRS. TOTAL LB. OVERALL LB./MILE OVERALL LB./TON MILE OVERALL LB./HR.	3-4-63 3-88 14027 64-0 0-1085 1418	5-4-63 8-43 13342 60-3 0-0930 1585	23-4-63 8-29 11803 63-8 0-0825 1425	25-4-63 8-80 13298 68-6 0-0861 1612	- 7-19% + 6-66% + 8-31% + 8-31% + 6-40% + 2-20%
BULAWAYO TO SAWMILLS 63-5 MILES.	TOTAL LB. LB./MILE LB./TON MILE. TOTAL HRS. LB./HR.	3580 56-4 0-0956 2-40 1492	3580 56-4 0-0860 1-86 1925	2600 41-1 0-0705 1-37 1320	2710 42-6 0-0677 2-00 1354	+ 25-90% + 25-90% + 23-90% + 6-80% + 21-75%
SAWMILLS TO GWAAI 31-25 MILES	TOTAL LB. LB./MILE. LB./TON MILE. TOTAL HRS. LB./HR.	2680 85-8 0-1455 2-18 1280-1	2042 65-4 0-1000 1-85 1102	2280 72-8 0-1250 1-52 1188	2235 71-5 0-1133 2-22 1007	+ 4-63% + 4-63% + 2-94% - 2-73% + 5-87%
GWAAI TO DETT 72-25 MILES.	TOTAL LB. LB./MILE. LB./TON MILE TOTAL HRS LB./HR.	5070 70-3 0-1191 3-05 1664	5800 80-4 0-1228 2-55 2275	4880 67-1 0-1151 2-53 1918	5730 79-4 0-1256 2-43 2360	+ 3-75% + 3-75% + 0-60% + 11-42% - 8-60%
DETT TO THOMSON JUNCTION 52-25 MILES	TOTAL LB. LB./MILE. LB./TON MILE. TOTAL HRS. LB./HR.	2690 81-5 0-0872 2-25 1195.	2210 42-2 0-0830 2-17 1020	1775 34-0 0-0683 1-87 949	2010 60-0 0-0793 2-15 1215	+ 10-25% + 10-25% + 5-80% + 51-88% + 2-80%

128

LOAD VARIED : 655 X 84 BULAWAYO TO DETT THEN 716 X 80 TO THOMSON JUNCTION

ENGINE No. 381 : COAL CONSUMPTION
FOR STANDARD LOCOMOTIVES

THOMSON JUNCTION. TO MPOPOMA 215 MILES.	TRAIN NO LOAD DATE TOTAL TIME HOURS & M TOTAL LB. OVERALL LB./MILE OVERALL LB./TON MILE OVERALL LB./HR.	FOR STANDARD LOCOMOTIVES		FOR LOCOMOTIVES FITTED WITH GIESL EJECTOR		AVERAGE GAIN.
		23 DOWN 1254 X 52 4-4-63. 14-44 27570 128-0 0-0889 1908	23 DOWN 1264 X 116 6-4-63 13-04 27355 127-1 0-1005 2095	23 DOWN 1253 X 88 24-4-63 12-81 25745 120-0 0-0928 2010	23 DOWN 1263 X 116 26-4-63 14-74 28917 134-5 0-1070 1960	
THOMSON JUNCTION. TO LUKOSI 21 MILES	TOTAL LB. LB./MILE LB./TON MILE TOTAL HRS. LB./HR.	4310 205-0 0-1582 1-80 2350	3360 160-0 0-1268 1-44 2340	3150 150-0 0-1160 1-44 2195	3780 180-0 0-1420 1-39 2725	0-00% - 0-29% + 0-45% + 0-24% - 0-20% + 0-75%
LUKOSI TO DETT. 31-25 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS LB./HRS.	6500 208-0 0-1605 3-03 2143	7060 226-0 0-1780 2-92 2420	5720 1830 0-1410 2-33 2450	4600 206-0 0-1625 2-80 2285	+ 10-58% + 10-58% + 10-35% + 13-80% - 3-77%
DETT TO GWAAL. 72-25 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS. LB./HR.	4840 68-5 0-0529 2-82 1752	5080 70-2 0-0555 2-70 1875	4350 60-3 0-0466 2-83 1540	5250 73-2 0-0680 2-78 1920	+ 3-75% + 3-75% + 3-51% - 1-09% - 4-61%
GWAAL TO UMGUSA 14-75 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS. LB./HR.	3040 206-0 0-1550 1-33 2285	2505 170-0 0-1343 1-07 2335	3170 215-0 0-1660 1-68 1885	2975 202-0 0-1600 1-53 1945	+ 10-65% - 10-65% - 11-15% - 33-80% + 17-10%
UMGUSA TO SAWMILLS. 16-5 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS. LB./HR.	1246 75-5 0-0583 1-05 1187	1500 90-7 0-0717 1-07 1403	1232 74-7 0-0577 1-10 1120	1265 76-6 0-0606 1-18 1100	+ 9-03% + 9-03% + 9-00% - 6-14% + 14-26%
SAWMILLS TO NYAMANDHLOYU 31-25 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS. LB./HR.	5470 175-0 0-1358 2-83 1935	5430 174-0 0-1380 2-12 2560	4685 148-0 0-1150 2-10 2200	4720 151-0 0-1195 2-64 1788	+ 14-33% + 14-33% + 14-33% + 4-25% + 11-28%
NYAMANDHLOYU TO MPOPOMA 38-25 MILES	TOTAL LB. LB./MILE LB. TON/MILE TOTAL/HRS. LB./HR.	3710 97-0 0-0748 1-58 2350	3540 103-0 0-0814 1-72 2290	3500 91-4 0-0706 1-33 2630	4510 118-0 0-0936 2-48 1815	- 4-70% - 4-70% - 5-11% - 15-45% + 4-15%

**** NOTE**

DOES NOT INCLUDE TIME SPENT AT DETT.

ENGINE NO 380 : COAL CONSUMPTION

FOR STANDARD LOCOMOTIVE

FOR LOCOMOTIVE FITTED WITH
GIESL EJECTOR.

AVERAGE GAIN.

BULAWAYO TO THOMSON JUNCTION 21.5 MILES.	TRAIN NO. LOAD. DATE. TOTAL TIME HRS. TOTAL LB. OVERALL LB./MILE OVERALL LB. TON MILE OVERALL LB./HR.	50 UP	50 UP	50 UP	50 UP	
		591 X 84 14.5.63 8.62 12772 58.3 0.0886 1482	590 X 80 16.5.63 9.60 12420 56.7 0.0861 1255	664 X 88 6.6.63 8.22 12263 56.0 0.0843 1450	658 X 92 11.6.63 9.68 13504 63.4 0.0908 1460	
BULAWAYO TO SAWMILLS 63.5 MILES	TOTAL LB. LB. MILE LB. TON MILE TOTAL HRS. LB./HR.	2771 43.6 0.0738 1.93 14.37	2632 41.4 0.0703 1.95 1350	2856 45.0 0.0678 2.27 1258	3425 54.0 0.0772 2.72 1260	+ 15.25% + 2.31% - 3.87% - 3.87% + 10.06% - 5.55%
SAWMILLS TO GWAAI 31.25 MILES	TOTAL LB. LB. MILE. LB. TON MILE. TOTAL HRS. LB./HR.	2444 78.2 0.1325 1.92 1272	2300 73.7 0.1250 2.13 1080	2165 69.5 0.1046 1.65 1376	2013 64.4 0.0922 1.68 1275	+ 11.86% + 11.86% + 23.60% + 20.23% - 9.20%
GWAAI TO DETT. 72.25 MILES	TOTAL LB. LB. MILE LB. TON MILE. TOTAL HRS. LB./HR.	5944 82.3 0.1392 2.78 1260	5138 71.2 0.1208 3.00 1715	5750 79.5 0.1195 2.25 2560	6181 85.5 0.1225 2.76 2220	+ 7.12% - 7.12% + 6.52% + 12.52% - 18.52%
DETT TO THOMSON JUNCTION 52.25 MILES	TOTAL LB. LB. MILE. LB. TON MILE. TOTAL HRS. LB./HR.	1613 30.9 0.0525 2.00 8.06	2350 45.0 0.0763 2.42 371	1488 28.4 0.0428 2.06 722	2285 43.7 0.0626 2.50 914	+ 4.80% + 4.80% + 18.15% - 2.94% + 7.96%

131

ENGINE NO 380 : COAL CONSUMPTION
FOR STANDARD LOCOMOTIVE

**FOR LOCOMOTIVE FITTED WITH
 GIESL EJECTOR**

AVERAGE GAIN.

THOMSON JUNCTION TO MPOPOMA 215 MILES	TRAIN NO. LOAD. DATE. TOTAL TIME HRS. * TOTAL COAL LB. OVERALL LB./MILE OVERALL LB. TON MILE OVERALL LB./HR.	23 DOWN * * 15-5-63 13-70 90770 143 0 0-1251 2245	23 DOWN 1291 X 114 17-5-63 14-14 30582 144 0 0-1115 2190	23 DOWN 1290 X 88 7-6-63 12-02 27347 127 0 0-0584 2270	23 DOWN 1297 X 92 12-6-63 13-30 26492 123 2 0-0548 1995	+ 2.21 % + 9.06 % + 12.82 % + 12.82 % + 18.36 % + 3.83 %
THOMSON JUNCTION TO LUKOSI 21 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	4425 210.5 0-1792 1-68 2680	4894 233.6 0-1810 1-78 2750	3344 159.5 0-1237 1-12 2585	3350 159.7 0-1230 1-70 1975	+ 28.15 % + 28.15 % + 31.50 % + 17.80 % + 8.66 %
LUKOSI TO DETT. 31.25 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	7488 240.0 0-2042 2-50 2585	7300 2340 0-1816 2-32 3150	6469 207.0 0-1605 2-87 2252	5644 180.8 0-1392 2-83 1995	+ 18.10 % + 18.10 % + 22.30 % - 8.43 % + 25.90 %
DETT TO GWAAI 72.25 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	5350 74.1 0-0586 2-93 1825	5094 70.6 0-0546 3-17 1610	5000 69.2 0-0537 2-55 1960	5250 72.6 0-0560 2-75 1908	+ 1.86 % + 1.86 % + 3.69 % + 13.11 % - 12.58 %
GWAAI TO UMGUSA 14.75 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	2754 188.2 0-1488 1-12 2495	1756 119.0 0-0922 1-52 1165	2575 174.6 0-1365 0-73 3530	2494 169.0 0-1501 0-87 2870	- 11.42 % - 11.42 % - 10.21 % + 39.40 % - 75.30 %
UMGUSA TO SAWMILLS 16.5 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	1500 91.0 0-0712 0-95 1680	2244 136.1 0-1065 0-95 2363	1138 69.0 0-0535 0-82 1380	1056 64.0 0-0493 1-03 1025	+ 41.50 % + 41.50 % + 42.00 % + 2.63 % + 38.70 %
SAWMILLS TO NYAMANDHLOUV 31.25 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	5025 161.0 0-1272 2-60 1932	5460 1746 0-1361 2-88 1892	5390 173.0 0-1340 2-30 2350	5356 171.5 0-1322 2-47 2170	- 2.59 % - 2.59 % - 1.49 % + 12.95 % - 18.20 %
NYAMANDHLOUV TO MPOPOMA 98.25 MILES	TOTAL LB. LB./MILE. LB. TON MILE. TOTAL HRS. LB./HR.	4188 109.5 0-0865 1-55 2700	4244 111.0 0-0860 1-52 2785	3431 89.7 0-0895 1-63 2102	3342 87.5 0-0674 1-65 2025	+ 19.65 % + 19.65 % + 20.68 % - 6.84 % + 24.90 %

* NOTE DOES NOT INCLUDE TIME SPENT AT DETT.

* * LOAD VARIED 1156 X 104 TJ TO DETT THEN 1265 X 116 DETT TO MPO.

ENGINE NO. 381 WATER CONSUMPTION

		FOR STANDARD LOCOMOTIVE		FOR LOCOMOTIVE FITTED WITH GESL EJECTOR		AVERAGE GAIN.
		50 UP 530 X 80 DATE 3-4-63 TOTAL GALS. 11026.2 TOTAL TIME HRS. 5.88 OVERALL GALS./MILE 50.4 OVERALL GALS./TON MILE 0.0855 OVERALL GALS./HR. 1118	50 UP * 3-4-63 10850.2 5.43 49.7 0.0718 1252	50 UP 583 X 80 24-4-63 10370.0 8.25 47.3 0.0812 1250	50 UP 631 X 84 25-4-63 11177.6 8.60 51.0 0.0808 1270	
BULAWAYO TO THOMSON JUNCTION 219 MILES	TRAIN LOAD DATE TOTAL GALS. TOTAL TIME HRS. OVERALL GALS./MILE OVERALL GALS./TON MILE OVERALL GALS./HR.	2555.4 40.2 0.0682 2.40 1065	2836.6 44.6 0.0662 1.86 1825	2716.0 42.7 0.0753 1.97 1378	2623.3 41.3 0.0655 2.00 1311	- 7.13 % + 1.69 % + 0.66 % + 1.65 % - 2.92 % - 4.56 %
BULAWAYO TO SAWMILLS 63.8 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE TOTAL HRS. GALS./HR.	2276.1 72.7 0.1230 2.18 1043	1758.8 51.3 0.0784 1.85 851	2032.0 68.0 0.1115 1.82 1058	1857.0 60.6 0.0961 2.22 855	+ 10.47 % + 0.47 % - 3.27 % + 6.80 % - 3.82 %
SAWMILLS TO GWAAI 31.28 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE TOTAL HRS. GALS./HR.	4459.3 61.8 0.1050 3.08 1462	4624.8 64.0 0.0970 2.55 1814	4375.6 60.6 0.1040 2.63 1730	4876.2 67.6 0.1071 2.43 2010	- 1.29 % - 1.29 % - 3.08 % - 2.73 % + 4.06 %
GWAAI TO DETT 72.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE TOTAL HRS. GALS./HR.	1736.1 33.3 0.0565 2.25 771	1670.0 32.0 0.0447 2.17 770	1246.4 23.8 0.0408 1.87 666	1781.1 34.1 0.0540 2.15 828	- 1.83 % - 1.83 % - 4.09 % + 11.42 % - 14.18 %
DETT TO THOMSON JUNCTION 52.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE TOTAL HRS. GALS./HR.					+ 11.33 % + 11.33 % + 6.32 % + 9.05 % + 3.05 %

* LOAD VARIED : 655 X 84 BLK. TO DETT THEN 716 X 80 TO TJ.

ENGINE N° 381 : WATER CONSUMPTION

		FOR STANDARD LOCOMOTIVE		FOR LOCOMOTIVE FITTED WITH GIESL EJECTOR		AVERAGE GAIN
THOMSON JUNCTION TO MPOFOMA 21.5 MILES	TRAIN N° LOAD DATE TOTAL GALS. ‡ TOTAL TIME: HRS. ‡ OVERALL GALS./MILE OVERALL GALS./TON MILE OVERALL GALS./HR.	23 DOWN 1294 X 92 4.4.63 22055.3 14.44 102.5 0.0792 1528	23 DOWN 1264 X 116 6.4.63 22370.0 13.04 104.0 0.0822 1715	23 DOWN 1294 X 88 24.4.63 20345.8 12.81 94.6 0.0731 1591	23 DOWN 1263 X 116 24.4.63 21245.3 14.74 98.8 0.0782 1441	0.00 % + 6.38 % - 0.29 % + 6.38 % + 6.26 % + 6.51 %
THOMSON JUNCTION TO LUKOSI 21 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	3000.8 143.0 0.1108 1.80 1668	2866.0 136.8 0.1080 1.44 1988	2865.8 136.6 0.1055 1.44 1989	2802.5 123.6 0.1060 1.39 2016	+ 3.38 % + 3.38 % + 3.34 % + 12.65 % - 9.55 %
LUKOSI TO DETT 31.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	4721.8 151.0 0.1160 3.03 1558	5444.0 174.2 0.1380 2.92 1865	4160.0 133.3 0.1030 2.33 1784	4580 146.8 0.1162 2.80 1638	+ 14.03 % + 14.03 % + 13.82 % + 13.80 % 0.00 %
DETT TO GWAAI 72.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	4467.0 61.8 0.0478 2.82 1681	4163.1 57.6 0.0485 2.70 1541	3870.0 53.6 0.0418 2.83 1368	4188.0 58.0 0.0459 2.75 1522	+ 6.63 % + 6.63 % + 6.33 % - 1.09 % + 7.44 %
GWAAI TO SAWMILLS 31.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	3115.0 95.6 0.0768 2.38 1310	2968.4 95.0 0.0752 2.14 1387	3607.0 115.0 0.0893 2.78 1299	29178.0 93.3 0.0739 2.68 1090	- 7.08 % - 7.08 % - 7.36 % - 20.80 % - 11.41 %
SAWMILLS TO NYAMANDHLOVU 31.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	3896.0 124.8 0.0962 2.83 1375	3596.3 128.0 0.1012 2.12 1685	2963.0 85.0 0.0735 2.10 1412	36720 114.2 0.0904 2.64 1353	+ 17.18 % + 17.38 % + 16.88 % + 4.25 % + 15.18 %
NYAMANDHLOVU TO MPOFOMA 38.25 MILES	TOTAL GALS. GALS. MILE GALS. TON MILE. TOTAL HRS. GALS./HR.	2860.0 74.8 0.0578 1.58 1810	2932.2 76.6 0.0606 1.72 1706	2880.0 75.3 0.0587 1.33 2170	31850 63.3 0.0660 2.48 1285	- 4.76 % - 4.76 % - 5.32 % - 15.45 % + 1.74 %

‡ DOES NOT INCLUDE STANDING AT DETT.

ENGINE NO 300 WATER CONSUMPTION.

		FOR STANDARD LOCOMOTIVE		FOR LOCOMOTIVE FITTED WITH GIESL EJECTOR		AVERAGE GAIN.
		50 UP. 591X84 14.5 G3 10732.5 8.62 45.0 0.0830 1246	80 UP. 590X80 16.5 G3 12146.4 9.60 55.5 0.0940 1266	50 UP. 664X88 6.6 G3 10227.5 8.22 45.0 0.0737 1245	60 UP. 698X92 11.6 G3 12445.0 5.58 56.9 0.0813 1298	
BULAWAYO TO THOMSON JUNCTION 219 MILES.	TRAIN NO. LOAD. DATE. TOTAL GALS. TOTAL TIME HRS. OVERALL GALS./MILE OVERALL GALS./TON MILE OVERALL GALS./HR.					+ 15.25 % + 0.90 % + 2.31 % + 0.90 % + 12.42 % - 1.24 %
BULAWAYO TO SAWMILLS 63.5 MILES	TOTAL GALS. GALS./MILE GALS./TON MILE TOTAL HRS. GALS./HR.	2664.3 42.0 0.0710 1.93 1380	2356.4 37.1 0.0630 1.95 1208	2855.5 45.0 0.0677 2.27 1258	31475 49.6 0.0710 2.72 1158	- 19.55 % - 15.55 % - 3.51 % - 28.60 % + 6.64 %
SAWMILLS TO GWARI 31.25 MILES	TOTAL GALS. GALS./MILE. GALS./TON MILE. TOTAL HRS. GALS./HR.	1916.2 61.3 0.1038 1.92 998	3164.5 101.2 0.1720 2.13 1488	1670.0 53.4 0.0804 1.65 1012	2168.7 69.4 0.0894 1.58 1375	+ 24.42 % + 24.42 % + 34.80 % + 20.23 % + 4.46 %
GWARI TO DETT 72.25 MILES	TOTAL GALS. GALS./MILE GALS./TON MILE TOTAL HRS. GALS./HR.	4604.5 63.7 0.1080 2.75 1675	4616.0 64.0 0.1085 3.00 1540	4252.2 59.0 0.0886 2.25 1890	4567.0 63.2 0.0908 2.78 1640	+ 4.30 % + 4.30 % + 17.30 % + 12.52 % - 8.80 %
DETT TO THOMSON JUNCTION 52.25 MILES.	TOTAL GALS. GALS./MILE. GALS./TON MILE. TOTAL HRS. GALS./HR.	1547.5 29.6 0.0501 2.00 775	2009.5 38.6 0.0653 2.42 830.	1449.8 27.8 0.0418 2.05 708	2561.8 49.0 0.0702 2.80 1027	- 12.77 % - 12.77 % + 2.94 % - 2.94 % - 8.10 %

ENGINE N° 380 WATER CONSUMPTION

		FOR STANDARD LOCOMOTIVE		FOR LOCOMOTIVE FITTED WITH GIESL EJECTOR		AVERAGE GAIN.
		23 DOWN * * DATE TOTAL GALS * TOTAL TIME HRS * OVERALL GALS/MILE OVERALL TON MILE OVERALL GALS/HR.	23 DOWN 1291 X 114 17.5.63 23279.2 14.14 108.2 0.0838 1655	23 DOWN 1290 X 88 1297 X 92 7.6.63 20927.2 12.02 97.3 0.0754 1740	23 DOWN 1297 X 92 21267.9 13.30 98.9 0.0761 1600	
THOMPSON JUNCTION TO MPOPOMA 219 MILES	TRAIN N° LOAD DATE TOTAL GALS * TOTAL TIME HRS * OVERALL GALS/MILE OVERALL TON MILE OVERALL GALS/HR.	23 DOWN * * 15.5.63 24058.4 13.70 111.8 0.0890 1756	23 DOWN 1291 X 114 17.5.63 23279.2 14.14 108.2 0.0838 1655	23 DOWN 1290 X 88 1297 X 92 7.6.63 20927.2 12.02 97.3 0.0754 1740	23 DOWN 1297 X 92 21267.9 13.30 98.9 0.0761 1600	+ 2.21% + 10.88% + 9.06% + 10.88% + 17.12% + 2.08%
THOMPSON JUNCTION TO LUKOSI 21 MILES	TOTAL GALS. GALS./MILE GALS.TON MILE. TOTAL HRS. GALS/HR.	3363.4 160.5 0.1360 1.65 2040	3589.1 171.1 0.1325 1.78 2018	2827.0 134.5 0.1042 1.12 2525	3570.8 170.0 0.1310 1.70 2100	+ 8.17% + 8.17% + 12.60% + 17.80% - 14.00%
LUKOSI TO DETT 31.25 MILES	TOTAL GALS. GALS./MILE GALS.TON MILE. TOTAL HRS. GALS. HR.	5710.0 182.5 0.1551 2.90 1970	4921.7 157.5 0.1218 2.32 2120	4603.2 147.5 0.1142 2.87 1604	4008.0 128.2 0.0988 2.83 1415	+ 18.90% + 18.90% + 23.10% - 8.43% + 26.36%
DETT TO GWAAI 72.25 MILES	TOTAL GALS. GALS. MILE. GALS. TON MILE. TOTAL HRS. GALS HR.	4523.0 60.0 0.0437 2.93 1477	4488.9 62.2 0.0481 3.17 14.20	4151.0 57.5 0.0445 2.55 1626	3983.7 55.2 0.0425 2.75 1448	+ 7.77% + 7.77% + 5.23% + 13.11% - 6.11%
GWAAI TO SAWMILLS 31.26 MILE	TOTAL GALS. GALS. MILE. GALS. TON MILE. TOTAL HRS. GALS HR.	3532.0 113.0 0.0893 207 1706	3422.9 110.0 0.0862 2.47 1388	3100.0 99.3 0.0770 1.55 2000	3120.0 100.0 0.0772 1.80 1643	+ 10.62% + 10.62% + 11.67% + 24.00% - 17.80%
SAWMILLS TO NYAMANDHLOVU 31.26 MILES	TOTAL GALS. GALS. MILE. GALS. TON MILE TOTAL HRS. GALS. HR.	3941.0 125.8 0.0994 2.60 1515	3810.0 121.8 0.0993 2.88 1322	3649.2 116.7 0.0904 2.30 1588	3821.0 122.4 0.0944 2.47 1546	+ 3.44% + 3.44% + 4.60% + 12.95% - 10.48%
NYAMANDHLOVU TO MPOPOMA 38.25 MILES	TOTAL GALS. GALS. MILE. GALS. TON MILE. TOTAL HRS. GALS HR.	387.0 83.4 0.0660 1.55 2056	3046.6 79.7 0.0617 1.62 2010	2596.8 67.8 0.0526 1.63 1592	2764.4 72.4 0.0557 1.65 1675	+ 14.05% + 14.05% + 15.20% - 6.84% + 15.66%

130

* DOES NOT INCLUDE STANDING AT DETT.

* * LOAD VARIED: 1176 X 104 THOMPSON JUNCTION TO DETT THEN 1265 X 116 DETT TO MPOPOMA.

RESULTS SHEET N° 8.

**ENGINE No 380 COAL & WATER CONSUMPTION
FOR LOCOMOTIVES FITTED WITH GIESL EJECTOR BETWEEN BLR + MAHALAPYE.**

		COAL (LB)	WATER (GALS)	COAL (LB)	WATER (GALS)
BULAWAYO TO MAHALAPYE 268.16 MILES	TRAIN NO LOAD DATE TOTAL TIME HRS TOTAL CONSUMED OVERALL CONSUMED / MILE OVERALL CONSUMED / TON MILE OVERALL CONSUMED HOUR	814 UP * 13.6.63 14.10 21001 78.4 0.1232 1488	814 UP * 13.6.63 14.10 17383.9 64.9 0.1023 1234	108 DOWN 711 X G4 14.6.63 10.15 23895 85.3 0.1256 2335	108 DOWN 711 X G4 14.6.63 10.15 17803.8 66.4 0.0934 1784
BULAWAYO TO FIGTREE 22.60 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED / HOUR	2238 98.6 0.1428 1.00 2238	1758.0 78.7 0.1140 1.00 1785	1575 69.4 0.0917 0.92 1712	1479.8 65.2 0.0917 0.92 1610
FIGTREE TO PLUMTREE 40.18 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HOUR	3406 84.6 0.1228 1.72 1980	2846.5 70.7 0.1028 1.72 1655	3288 81.8 0.1150 1.38 2586	2358.6 58.6 0.0825 1.30 1708
PLUMTREE TO TSESSEBE 26.06 MILE	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HOURS	2875 48.6 0.0705 2.62 1098	2875.9 48.5 0.0705 2.62 1098	3106 119.1 0.1675 1.17 2650	2303.0 88.6 0.1247 1.17 1970
TSESSEBE TO FRANCISTOWN 33.19 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HOURS			3519 106.0 0.1492 1.57 2240	2532.4 76.1 0.1071 1.67 1611
FRANCISTOWN TO SHASHI 16.25 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HRS	2025 124.5 0.1808 1.67 1212	1856.5 114.6 0.1650 1.67 1111	1956 120.3 0.1696 0.88 2224	1494.0 91.7 0.1291 0.88 1700
SHASHI TO SERULI 38.64 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HRS	3475 89.0 0.1302 2.35 1480	2561.6 66.2 0.0960 2.35 10.20	3769 97.5 0.1371 1.33 2835	2580.7 72.5 0.1020 1.33 1940
SERULI TO PALAPYE 46.19 MILES	TOTAL CONSUMED / MILE CONSUMED / TON MILE TOTAL HRS CONSUMED HRS	3388 73.4 0.1032 2.47 1372	2622.0 86.7 0.0796 2.47 1061	3738 81.0 0.1140 1.53 2445	2508.3 84.2 0.0762 1.53 1636
PALAPYE TO MAHALAPYE 44.91 MILES	TOTAL CONSUMED MILE CONSUME TDM MILE TOTAL HRS CONSUMED HRS	3554 80.0 0.1125 2.27 1984	2830.4 63.1 0.0885 2.27 1850	2844 66.6 0.0923 1.37 1260	2550.0 56.8 0.0799 1.37 1860

137

* LOAD VARIED: 600 X 88 WESTGATE TO SERULI THEN 712 X 92 SERULI TO MAHALAPYE

RESULTS SHEET No 2.

ENGINE NO 381 (STANDARD) DATE 3-4-63 TRAIN 50 UP BLR TO TT: LOAD 590 X 80

TIME	PACE MILE/PEG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM NO	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
10:07	BLR	PULL OFF	5	75	180	140	-	1.6	2.8	560	345	-	1	0	86.9	-
10:25	677.5	27	.75	36	145	-	-	1.6	2.4	515	345	78	3	-	62.9	-
11:00	697.5	31	.75	36	165	105	-	2.6	3.2	575	345	-	4	189.4	45.8	1045
11:14	704.5	21	FULL	36	155	140	-	2.8	3.4	592	395	-	5	128.3	71.8	1130
11:53	714.5	18	.75	41	160	145	-	-	-	-	370	-	6	110.0	90.0	1216
12:57	732.7	34	.75	36	160	120	-	2.8	3.6	592	370	81	7	207.7	53.8	1331
13:04	734.0	21	FULL	47	160	140	-	2.2	2.6	606	380	-	8	128.3	66.8	1051
14:54	763.0	27	.75	36	163	150	-	3.4	4.0	606	395	-	9	166.0	69.8	1399
14:59	766.0	37	FULL	18	155	145	-	1.8	2.2	575	395	-	10	226.1	39.6	1041
15:51	791.7	36	FULL	24	160	145	-	3.6	4.0	620	380	-	11	220.0	52.0	1343
16:50	810.7	40	.875	24	167	155	-	3.0	3.2	606	395	-	12	244.4	46.1	1272
17:04	820.0	35	FULL	24	154	140	-	2.8	2.8	560	395	-	13	213.9	42.8	1092

ENGINE 381 (STANDARD) DATE 4-4-63; TRAIN 23 DOWN; TJ-MPO; LOAD 1294 X 32

TIME	PACE MILE/PEG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM No	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
03-09	881.25	20	FULL	47	150	130	6.1	2.8	3.4	652	395	60	1	122.2	81.4	1215
03-54	871.0	12	FULL	58	157	140	6.1	2.4	2.8	575	420	-	2	73.3	105.8	953
05-04	858.75	12	FULL	52	173	165	-	2.4	2.6	592	420	-	3	73.3	89.6	808
05-07	858.5	12	FULL	47	174	160	5.0	3.2	3.6	592	420	-	3 A	73.3	109.8	988
06-11	847.5	15	.875	36	147	150	-	2.0	2.4	575	370	-	4	16.1	70.6	1003
07-10	836.25	12	FULL	52	175	160	10.2	3.0	3.4	606	395	-	5	73.3	117.4	1058
07-24	832.75	13	.75	47	173	150	-	2.6	3.0	592	420	-	6	79.4	106.5	1030
11-08	793.0	23	.75	29	175	160	-	2.2	2.8	592	395	80	7	140.6	71.3	1221
13-20	749.0	22	.875	47	175	150	15.3	4.4	5.4	652	450	-	8	134.4	101.8	1670
13-26	746.5	28	.75	22	175	130	-	2.4	4.6	592	450	-	9	171.1	57.0	1180
14-12	738.0	27	FULL	36	172	165	6.1	3.4	4.0	620	410	-	10	165.0	70.9	1419
14-25	731.5	30	.75	24	150	125	-	2.8	2.8	485	370	-	11	183.3	51.0	1128
15-12	7268.8	15	FULL	47	172	165	-	2.0	3.2	592	397	83	12	91.7	93.3	1049
15-34	723.25	17	FULL	47	165	150	10.2	3.0	3.8	606	435	-	13	103.9	112.6	1034
16-02	717.5	26	FULL	36	170	150	6.1	3.2	3.6	592	420	-	15	158.9	68.3	1817
16-54	703.0	12	FULL	47	156	145	-	2.4	3.0	575	395	-	16	73.3	93.5	843
17-05	706.75	15	FULL	47	160	145	-	2.6	3.4	592	420	79	17	91.7	96.0	1082
18-12	687.0	11	FULL	36	162	155	-	1.8	2.0	545	410	-	18	67.2	88.6	733
18-34	681.0	40	FULL	41	168	155	-	2.4	2.8	575	420	-	19	244.4	95.0	2262

139

ENGINE NO. 381 (STANDARD): DATE 5.4.63 TRAIN 50 UP BLR-TJ: LOAD 665 X 84 (716 X 80)																
TIME	PACE MILE/EG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM NO	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
10.42	677.25	37	.75	24	172	80	2.0	14.4	1.2	630	370	78	A	226.1	25.0	685
11.16	697.5	35	FULL	36	152	130	5.2	2.4	2.0	606	370	-	B	213.9	22.4	1579
11.31	704.2	22	FULL	47	166	160	13.3	3.4	4.2	652	420	-	C	134.4	84.4	1384
11.50	714.5	33	FULL	36	176	160	13.3	2.6	3.4	637	395	-	D	201.6	62.8	1506
12.40	732.75	36	FULL	36	170	160	17.4	3.6	4.4	607	395	80	E	220.0	66.0	1706
12.41	734.0	36	FULL	47	166	145	20.4	3.6	4.6	652	395	-	F	220.0	85.8	2262
14.24	763.0	27	FULL	38	138	120	15.3	3.4	4.0	620	395	-	G	165.0	73.6	1473
14.30	766.0	40	.75	37	160	95	14.3	3.8	4.2	667	420	-	H	244.4	52.8	1451
15.23	791.75	37	.75	37	145	105	11.2	3.0	3.4	592	385	-	I	226.1	53.1	1338
16.06	810.75	43	.75	37	164	110	12.3	3.4	3.6	652	420	80	J	262.7	53.3	1516
16.19	820.0	43	.875	37	170	140	18.5	4.2	4.4	652	435	-	L	262.7	65.5	1863
18.07	864.5	30	.875	29	175	150	10.2	2.6	3.4	575	345	-	N	183.3	67.6	1497
18.28	876.25	30	.75	29	167	120	5.2	2.4	2.6	545	345	-	O	183.3	52.5	1160
18.48	883.5	25	FULL	36	145	120	16.3	-	-	530	370	75	Q	152.8	73.8	1370

ENGINE: 381 (STANDARD) DATE 6-4-63: TRAIN 23 DOWN: TJ - MPO. LOAD 1264/116

TIME	PACE MILE/EG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F	INDICATOR DIAGRAM Nº	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
03:39	881.25	20	FULL	36	164	150	6.1	2.0	2.2	575	335	60	30	122.2	65.0	985
03:57	877.5	12	FULL	58	170	155	13.3	2.4	3.2	662	420	—	31	73.3	121.8	1098
04:31	871.0	14	FULL	58	177	160	15.3	2.4	3.2	667	435	—	32	86.5	122.0	1282
05:55	858.5	15	FULL	58	174	160	11.2	2.6	3.2	632	448	—	33	91.7	115.8	1303
06:37	847.5	22	.75	47	172	85	8.2	2.4	2.8	606	420	—	34	134.4	60.0	985
07:36	836.25	15	FULL	68	165	150	16.3	4.4	5.2	652	435	—	35	91.7	122.8	1353
07:47	832.75	—	—	—	—	135	9.2	2.0	2.6	592	448	—	36	—	96.5	—
11:06	793.0	23	FULL	41	167	145	17.4	3.2	4.2	620	370	80	37	140.5	87.5	1653
11:13	789.0	35	.75	24	148	105	7.1	1.6	1.8	530	370	—	38	213.9	40.1	1015
12:53	753.75	21	.875	36	161	145	10.2	2.6	3.2	592	420	—	39	128.3	83.1	1308
12:57	752.25	20	.875	36	172	155	11.2	2.4	3.0	592	420	—	40	122.2	88.4	1324
13:07	749.0	21	.875	36	164	145	11.2	3.0	3.6	606	435	—	41	128.3	84.1	1324
13:13	746.5	28	.66	31	155	130	5.1	1.8	2.0	560	448	—	42	171.1	53.0	1098
13:58	738.0	23	.75	15	162	147	3.1	1.4	1.6	525	395	—	43	140.5	48.9	787
14:50	726.6	15	FULL	29	178	165	8.2	1.4	2.2	606	420	—	46	91.7	104.8	1180
15:17	723.25	13	FULL	47	177	162	8.7	2.2	3.0	620	448	83	47	79.4	114.8	1120
15:35	717.5	25	FULL	29	174	160	11.2	2.8	3.4	637	460	—	48	152.8	77.8	1446
15:52	709.0	16	.75	29	171	157	4.1	1.6	2.0	560	435	—	49	77.8	74.5	895
16:13	706.75	12	.75	44	173	150	6.1	2.6	3.6	652	410	—	60	73.3	108.3	968
17:23	687.0	16	.875	41	169	150	11.2	2.5	3.3	606	435	78	51	97.8	108.8	1306
17:43	681.0	14	.875	41	170	153	10.2	2.4	3.2	606	435	—	52	85.5	113.0	1181

RESULTSHEET Nº 13

ENGINE NO 381 (PLUS GILL) DATE 24.4.63 TRAIN 50 UP BLR TO TJ LOAD 583x80

TIME	PACE MILE/EG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM NO	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
10.17	677.25	38	.75	38	166	120	13.9	4.2	7.0	606	343	64	1	232.2	53.5	1430
11.03	697.5	39	FULL	28	146	120	5.1	2.6	4.6	575	343	-	2	238.3	46.1	1251
12.22	732.75	39	FULL	33	161	145	8.9	5.6	6.0	667	382	80	4	238.3	60.3	1877
12.34	736.0	19	.75	42	166	105	1.9	1.6	3.0	575	408	-	5	116.1	60.1	984
14.12	763.0	36	FULL	42	150	130	6.5	4.2	5.6	652	421	-	6	220.0	60.8	1568
14.16	766.0	27	.75	40	170	105	4.3	2.8	4.0	606	395	78	7	165.0	63.8	1275
15.08	791.75	34	.75	36	165	800	2.1	1.8	2.8	592	395	-	8	207.7	36.0	880
16.40	810.75	36	.66	36	157	90	2.5	2.0	3.0	575	382	-	9	220.0	38.8	1025
16.03	820.0	34	.75	36	154	155	3.9	2.6	4.0	606	395	-	10	207.7	49.9	1181
16.23	831.5	27	.66	36	173	50	-	0.2	0.6	555	395	-	11	165.0	21.9	428
17.44	864.5	32	FULL	41	139	115	5.9	3.2	5.0	560	369	-	12	156.5	58.3	1367
18.03	876.25	31	.75	31	147	90	1.9	1.6	2.4	364	330	76	13	180.4	40.4	918

142

ENGINE 3B1 (PLUS GIESL) DATE 254-63 TRAIN 50UP BLR -TJ, LOAD 631 X B4.

TIME	PACE MILE/EG.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM No	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER H.P.
09:56	WG	24	FULL	44	169	150	5.9	2.8	4.8	545	382	74.5	61	146.6	78.1	1394
10:07	677.5	34	.66	44	170	80	2.7	2.2	3.6	515	343	-	62	207.7	48.6	1202
10:59	657.5	-	-	-	-	140	5.7	3.4	5.2	608	395	-	63	-	54.9	-
11:01	698.5	43	.75	26	172	140	-	-	-	-	408	-	64	262.7	54.6	1550
11:13	704.5	26	FULL	33	173	160	3.7	2.4	3.8	575	421	-	65	158.9	69.4	1338
11:30	714.5	32	.75	33	166	135	5.9	3.6	5.4	560	395	-	66	195.5	68.6	1609
12:26	732.75	34.5	.75	33	170	125	4.7	3.8	5.8	606	382	-	67	210.7	62.1	2218
12:28	734.25	11	.66	33	163	110	-	-	-	-	382	-	68	67.2	60.3	498
12:35	735.625	23	FULL	36	153	135	3.9	2.8	4.2	560	395	-	70	140.5	89.0	1526
14:30	763.0	20	.875	19	150	135	3.2	2.5	5.8	500	343	86	71	122.2	58.6	874
14:38	766.0	34	.66	28	150	100	3.7	3.2	4.4	515	343	-	72	207.7	41.1	1013
16:08	810.75	46	.66	33	142	95	3.3	3.8	5.0	515	447	-	74	281.1	41.0	1206
16:20	820.0	44	.66	33	171	100	3.5	3.6	4.8	454	447	-	75	268.8	45.3	1271
16:35	830.5	48	.66	33	160	95	2.9	2.2	-	-	447	85.5	76	293.3	41.0	1240
17:53	864.5	27	.80	41	137	110	5.3	3.8	5.4	303	382	77	78	165.0	67.5	1350
18:24	876.26	20	FULL	75	150	115	10.5	7.0	10.2	303	317	-	79	122.2	100.3	1500
18:41	883.5	12	.75	36	160	120	1.7	1.6	2.4	151	343	74	80	73.3	73.6	675

ENGINE 381 (PLUS GIESL): DATE 26-4-64 TRAIN 23 DOWN TJ- MPO. LOAD 1263 X 116																
TIME	PACE MILE PER.	SPEED MPH	REGU- LATOR OPENING	CUT OFF %0	BOILER PRESSURE P.S.I.	STEAM CHEST PRESSURE P.S.I.	BLAST PIPE PRESSURE INS. HG.	FIREBOX DRAUGHT INCHES WATER	SMOKEBOX DRAUGHT INCHES WATER	SMOKEBOX GAS TEMPER- ATURE °F.	STEAM CHEST TEMPER- ATURE °F.	AMBIENT TEMPER- ATURE °F.	INDICATOR DIAGRAM NO	SPEED R.P.M.	MEAN EFFECTIVE PRESSURE P.S.I.	POWER I.H.P.
02-44	881.25	20	FULL	36	174	155	5.4	3.0	4.6	592	382	57.5	81	122.2	83.9	1254
03-00	877.5	13	FULL	39	175	160	3.6	2.4	3.8	569	460	-	82	79.4	113.0	1106
03-25	871.25	12	FULL	42	168	155	1.6	2.2	3.2	539	460	-	83	73.3	106.1	958
04-34	858.5	13	FULL	47	174	162	2.8	2.2	3.2	584	460	62.5	84	79.4	102.6	1002
05-29	847.5	22	.875	41	152	135	5.0	3.8	5.4	608	421	-	85	134.4	88.3	894
06-24	836.25	16	FULL	41	174	160	2.8	3.2	4.4	569	460	60.0	86	97.8	103.0	1233
06-36	833.0	15	.66	41	175	160	1.8	2.8	4.0	551	460	-	87	91.7	97.1	1083
10-59	793.0	19	.75	44	167	150	3.4	2.3	3.6	575	369	78.0	88	116.1	75.3	1072
12-48	753.75	20	FULL	47	162	140	6.0	3.4	5.2	625	421	-	89	122.2	93.3	1393
12-52	752.25	20	FULL	41	169	155	4.1	2.6	4.1	606	447	-	90	122.2	85.3	1276
13-27	749.0	19	.75	44	164	140	7.8	3.4	5.8	592	395	-	91	116.1	98.6	1370
13-34	746.5	26	.75	44	159	140	4.2	2.8	4.8	643	421	-	92	138.9	70.3	1358
14-00	737.75	27	.66	33	162	80	1.2	1.2	1.8	545	421	-	93	165.0	40.6	813
14-32	731.25	27.5	.75	36	161	100	4.6	2.8	4.2	485	330	82.0	95	168.0	53.1	1080
15-40	726.5	15.5	.875	40	175	160	4.0	2.4	3.8	620	447	-	96	54.7	102.6	1192
16-59	723.25	15	.875	41	172	160	3.0	2.2	3.6	606	460	-	97	91.7	99.4	1000
16-18	717.5	18	.625	33	175	45	0.2	0.2	0.4	485	447	-	98	110.0	24.9	335
16-59	709.0	19	.875	46	177	150	5.6	3.8	5.4	629	421	74.0	99	116.1	98.0	1304
17-07	706.75	19	.875	46	173	152	4.8	3.6	5.2	606	460	-	100	116.1	95.6	1360
18-58	687.0	-	-	-	-	130	5.8	2.1	4.1	637	460	-	101	-	105.1	-
19-15	681.0	15	.875	47	168	130	3.6	2.4	3.6	592	460	-	102	91.7	99.4	1120

ENGINE 380 (STANDARD); DATE 14.5.63. TRAIN 50 UP BLR.-TJ. LOAD 591X84.

TIME HRS. MINS	PLACE MILE/PG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPER- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER I.H.P.
10.10	WG	21.0	•625	41	158	120	120	20.0	2.8	4.5	555	606	395	75	1	129.8	79.4	1300
10.58	697.5	39.7	•625	33	160	120	120	16.6	2.6	3.7	525	560	395	-	2	244.2	48.3	1372
11.11	704.5	23.0	•625	33	148	100	118	18.4	3.0	4.4	555	575	408	-	3	141.8	74.4	1328
12.39	733.25	16.1	FULL	14	170	160	160	8.0	1.4	1.7	540	545	382	-	4	99.1	54.4	684
12.40	733.375	15.1	FULL	24	172	160	160	9.8	1.9	2.7	540	545	382	-	5	93.2	78.8	934
12.41	733.625	16.6	FULL	33	175	150	160	10.6	2.8	4.5	540	545	382	-	6	102.1	99.4	1289
12.42	734.5	20.5	FULL	43	162	140	140	23.6	3.4	5.1	540	545	395	-	7	126.7	88.0	1408
12.43	735.25	26.9	FULL	53	151	140	120	23.6 +	4.0	6.3	525	575	395	-	8	166.0	89.8	1868
12.47	736.625	15.1	•5	53	140	40	40	-	0.8	1.1	-	-	382	-	9	93.2	31.7	375
14.17	761.5	31.8	FULL	24	153	-	140	14.8	2.6	3.7	540	560	382	-	10	156.1	56.8	1381
14.19	762.625	25.9	FULL	24	147	140	130	11.6	2.3	3.1	555	575	395	-	11	160.0	60.0	1205
15.52	808.25	43.6	•5	24	178	115	120	9.1	2.0	2.6	546	581	395	82.5	12	268.5	34.3	1013
16.21	820.0	39.7	•75	18	178	160	160	13.4	2.7	3.8	565	606	408	-	13	244.2	48.1	1379
18.02	864.5	27.9	•625	33	150	120	120	14.2	3.2	4.5	525	592	369	71	14	172.1	73.6	1583
18.23	876.25	24.0	•5	39	135	50	60	5.2	0.9	1.2	540	430	317	-	15	147.9	33.3	618
18.38	882.75	21.0	•625	43	166	90	85	12.8	2.7	3.9	540	589	317	67	16	125.8	64.7	1062

*1 GAS SAMPLE TAKEN! CO₂ 13.5%; O₂ 22.2%; CO NIL; N₂ 64.3% BY VOLUME.

RESULTS SHEET N° 13

146

ENGINE 380 (STANDARD) DATE 15-5-63 TRAIN 23 DOWN T.J. TO MPO: LOAD 1176 X 104 (1265 X 116)

TIME HRS. MINS	PLACE MILE/PG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER H.P.
03.04	881.25	16.1	.625	43	173	135	130	10.8	2.3	3.6	540	592	395	55	A	99.1	93.8	1178
03.23	877.5	10.2	.75	53	167	145	150	7.2	2.0	3.0	555	592	434	-	B	62.9	116.3	933
04.10	871.0	10.2	FULL	53	160	140	145	7.2	4.2	3.6	534	600	421	-	C	62.9	114.8	920
05.06	858.5	12.2	.5625	43	168	130	135	11.6	2.2	3.4	570	606	473	56	D	75.0	106.7	1102
05.37	851.0	13.6	FULL	24	170	-	160	-	-	-	-	-	473	-	E	84.1	86.3	923
05.38	850.625	8.2	FULL	33	167	-	160	2.2 P	0.8	1.4	640 P	515	460	-	E1	50.8	87.6	568
05.39	850.375	7.3	FULL	43	167	-	160	2.8 P	1.2	2.0	625 P	530	460	-	E2	44.8	109.6	626
05.40	850.125	7.3	FULL	53	167	-	155	3.8 P	1.8	2.6	625 P	548	460	-	E3	44.8	119.4	719
05.42	850.0	10.2	FULL	62	165	-	150	6.2 P	3.4	5.0	625 P	578	447	-	E4	62.9	128.4	1030
05.44	849.75	11.2	FULL	72	168	-	160	9.2 P	4.2	6.2	625 P	652	447	-	E5	68.9	137.4	1205
05.45	849.25	13.2	FULL	75	166	-	155	13.6 P	4.5	6.8	655 P	652	447	-	E6	81.0	130.0	1337
06.51	836.25	11.2	FULL	43	156	140	140	-	2.6	3.8	543 P	575	447	51	F	68.9	108.5	955
07.20	833.0	12.2	FULL	46	168	150	155	14.2	3.0	4.2	546 P	581	447	-	G	75.0	113.3	1080
11.07	793.0	24	FULL	43	162	140	135	26.8	5.1	7.5	570	643	395	-	H	147.9	98.6	1835
11.09	792.0	31.8	FULL	32	157	-	135	21.6	3.6	5.4	555	560	421	84	I	196.1	73.6	1790
12.50	753.75	24.0	FULL	31	171	150	155	19.6	3.8	5.2	585	620	460	-	K	147.9	86.8	1596
12.54	752.25	22.5	FULL	31	172	150	155	18.8	3.6	5.1	555	620	473	87	L	138.7	88.6	1548
13.24	749.0	18.1	.875	32	170	145	150	19.6	3.6	5.6	573	620	395	-	M	111.2	103.6	1459
13.30	746.5	25.9	.625	32	162	130	110	22.2	3.4	5.4	600	620	460	-	N	160.0	77.6	1555
13.49	736.0	28.9	.5625	32	166	100	105	14.8	2.8	4.0	573	581	460	-	O	178.0	62.3	1382
14.15	731.25	7.3	.5	75	171	110	115	8.2	1.9	2.8	510	518	369	87	P	44.8	102.2	584
16.45	725.0	11.7	FULL	45	168	155	160	10.8	1.6	2.8	600	575	447	-	R	72.0	102.4	937
16.47	724.875	31.1	FULL	24	166	155	155	8.0	1.3	2.0	600	560	447	-	S	81.0	82.5	848
16.49	724.75	10.2	FULL	33	166	160	165	6.0	1.2	1.8	585	530	447	-	T	62.9	90.1	723
16.50	724.625	9.2	FULL	43	177	165	165	8.6	1.8	2.0	585	551	447	-	U	56.9	110.1	797
16.51	724.563	9.7	FULL	53	176	160	165	13.6	2.2	3.5	576	592	421	-	V	59.9	122.2	933
16.52	724.375	11.2	FULL	62	172	145	160	20.6	2.8	4.6	576	606	421	-	W	68.5	131.4	1053
16.54	724.25	13.1	FULL	72	162	140	140	26.6	3.8	6.1	585	652	447	-	X	81.0	127.4	1412
16.55	724.125	14.1	FULL	75	162	135	140	-	3.8	6.0	600	643	447	-	Y	87.2	124.8	1371

* GAS SAMPLE TAKEN CO₂ 8.6%; O₂ 15.7%; CO NIL; N₂ 75.7% BY VOLUME

ENGINE 380 (STANDARD) DATE 16.5.63 TRAIN 50UP, BLR - TJ : LOAD 590 X 80.

TIME HRS. MINS	PLACE MILE/PEG	SPEED MPH.	REGU - LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI.	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER IHP.
9.54	WG.	21.5	.625	32	140	115	115	12.0	2.2	3.6	486	539	369	68.5	20	132.7	66.9	1115
10.07	677.375	30.7	.5	28	166	60	55	4.0	1.1	1.6	513	500	343	—	21	238.2	26.8	754
10.44	657.5	34.8	.5	24	171	100	90	8.4	1.6	2.4	480	509	366	—	22	214.1	38.1	998
10.56	704.0	23.0	.625	31	172	140	140	10.4	2.2	3.2	540	563	395	—	23	141.8	64.3	1149
11.45	713.875	37.7	FULL	23	153	130	130	26.0	3.4	5.6	495	509	382	—	24	232.2	63.2	1749
12.22	733.25	15.1	FULL	24	170	160	160	15.2	2.8	2.4	525	592	369	—	25	93.2	92.4	1279
12.23	733.375	18.1	FULL	33	175	160	160	15.2	2.8	2.4	525	592	395	—	26	111.2	90.0	1256
12.35	735.25	11.2	FULL	24	175	—	160	9.6	2.3	3.7	513	575	369	—	27	68.9	90.9	897
12.37	735.75	19.0	FULL	33	182	—	160	20.6	3.4	5.8	480	620	395	—	28	118.3	88.2	1319
14.15	761.5	31.8	FULL	28	158	—	140	20.6	3.4	5.4	510	592	382	—	29	196.1	65.4	1584
*3.14.13	763.0	28.9	FULL	28	145	130	130	14.6	2.8	4.2	516	560	395	86.0	30	178.0	63.4	1407
14.25	766.25	36.7	FULL	14	146	130	130	9.2	2.4	3.4	634	545	408	—	31	226.3	44.4	1209
16.23	808.25	41.1	FULL	24	165	140	145	25.2	4.0	6.2	546	620	395	—	32	263.3	59.6	1720
16.26	810.0	41.6	FULL	16	164	150	155	6.0	1.6	2.4	567	563	408	81.0	32 A	256.3	33.9	986
16.40	820.0	42.6	FULL	14	170	160	164	4.2	1.2	1.8	658	560	434	—	33	262.7	28.4	854
16.43	821.75	46.6	FULL	19	173	160	162	7.8	2.0	3.0	665	578	434	—	33 A	287.0	34.3	1057
18.34	864.5	23.0	.5625	43	160	80	80	18.2	4.8	4.4	450	521	343	—	34	141.8	64.9	1158
19.06	876.25	12.2	.75	43	171	120	150	18.6	3.4	5.4	435	530	317	—	35	75.0	93.8	894
19.20	882.75	24.0	.5625	43	180	90	85	12.6	3.2	4.8	483	578	317	74	36	147.9	59.6	1110

* GAS SAMPLE TAKEN :

CO₂15.6%, O₂

13.6%; CO NIL

N₂

70.8% BY VOLUME.

RESULTS SHEET NO 20

148

ENGINE 380 (STANDARD) DATE 17.5.63 TRAIN 23 DOWN TJ - MPO LOAD 1291 X 114.

TIME HRS. MINS	PLACE MILEPEG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER HP.
02.41	861.25	13.1	FULL	36	172	160	155	15.6	2.8	4.2	537	612	395	59	50	111.2	87.9	1238
02.58	877.5	11.2	FULL	65	160	140	140	19.6	3.4	5.2	555	641	447	-	51	68.9	131.3	1150
03.20	71.375	12.2	FULL	53	166	150	150	18.0	2.8	4.4	570	637	447	-	52	75.0	127.3	1214
04.47	858.5	14.1	FULL	37	176	160	160	12.6	2.4	3.8	555	612	473	65	53	87.2	109.4	1211
05.12	852.0	7.3	FULL	19	168	160	160	2.2	1.0	3.3	540	491	447	-	54	44.8	80.6	461
05.13	851.875	5.3	FULL	24	167	160	160	1.4	0.6	1.0	534	475	421	-	55	32.6	85.4	356
05.14	851.75	4.3	FULL	33	167	160	160	2.0	0.8	1.2	516	485	421	-	55A	26.6	115.5	392
05.15	851.625	4.8	FULL	43	167	160	160	3.4	1.2	1.8	510	515	421	-	56	29.8	115.9	438
05.16	851.5	6.8	FULL	53	170	160	160	6.6	1.8	3.0	510	569	421	-	57	21.8	124.8	347
05.17	851.375	9.2	FULL	62	172	155	155	13.0	2.8	4.2	516	612	421	-	58	56.9	131.4	953
05.17.30	851.25	10.7	FULL	72	170	150	150	19.6	3.4	5.2	525	620	421	-	59	65.9	130.3	1092
05.18	851.125	12.2	FULL	75	160	140	140	22.0	3.4	5.4	528	620	421	-	60	75.0	122.1	1163
06.08	836.25	11.2	FULL	38	170	160	160	6.8	2.2	2.6	555	592	421	56	61	68.9	98.6	865
06.27	833.0	10.2	FULL	55	149	135	135	10.0	2.2	3.4	540	581	421	-	62	62.9	108.6	870
11.01	793.0	15.5	563	43	175	100	105	16.0	2.5	4.0	525	600	382	-	63	121.4	77.0	1183
11.03	792.0	25.9	563	43	167	90	85	17.0	2.6	4.1	546	600	395	71	64	160.0	67.8	1362
12.49	753.75	24.0	563	33	175	140	135	22.8	3.9	5.6	576	620	473	-	65	147.9	87.1	1621
12.53	752.25	22.0	563	33	167	130	130	18.2	3.4	4.9	576	600	473	79	66	135.5	86.0	1482
13.36	749.0	17.1	FULL	33	160	140	140	21.8	3.6	5.4	573	670	395	-	67	105.1	102.2	1372
13.43	746.5	21.0	5	33	180	80	80	10.7	2.5	3.6	585	600	421	-	68	129.8	61.1	1002
14.03	738.0	28.9	563	33	172	105	105	14.3	3.4	4.8	585	600	434	-	69	178.0	61.4	1363
15.30	726.5	12.7	875	33	174	165	160	10.7	2.4	3.8	573	592	421	82	70	78.0	105.5	1047
15.43	725.0	6.3	FULL	18	176	165	165	1.3	0.5	0.8	600	509	447	-	71	38.7	77.5	384
15.44	724.875	6.3	FULL	22	173	165	165	1.9	0.7	1.1	588	508	447	-	72	38.7	89.3	443
15.45	724.75	8.3	FULL	33	173	160	160	6.5	1.7	2.8	576	560	447	-	73	50.8	108.0	750
15.46	724.625	11.2	FULL	43	175	160	160	12.3	2.6	4.1	576	595	421	-	74	68.9	121.3	1064
15.46.30	724.563	12.7	FULL	53	175	150	155	17.3	3.2	4.8	585	620	421	-	75	78.0	125.6	1248
15.47	724.375	13.6	FULL	62	172	145	150	20.5	3.6	5.6	600	637	447	-	76	84.1	125.6	1340
15.48	724.25	15.1	FULL	72	164	135	145	23.5	4.0	6.2	600	643	460	-	77	93.2	121.1	1432
15.48.30	724.125	15.1	FULL	75	157	125	130	24.5	3.8	6.0	600	626	460	-	78	93.2	118.8	1403

* 4 GAS SAMPLE TAKEN CO₂ 4.2% O₂ 15.4% CO NIL N₂ 80.4% BY VOLUME

RESULTS SHEET N° 21

ENGINE 380 (PLUS GIESL) DATE 6-6-63 TRAIN 50 UP BLR - TJ LOAD 664 X 88

TIME HRS. MINS	PLACE MILE/PEG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLACK PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER IHP.
10:04	WG.	26.9	75	32	166	140	135	16.8	3.4	8.4	585	620	382	64	1	166.0	85.3	1773
10:15	677.375	34.8	563	37	163	82	60	6.8	1.8	4.4	600	551	369	-	2	214.1	42.4	1107
10:51	697.5	40.6	563	33	162	85	80	7.6	2.0	3.2	605	581	382	-	3	250.2	43.3	1248
11:02	703.5	28.9	FULL	28	162	150	140	13.4	3.4	8.0	630	652	408	-	4	176.0	80.3	1183
11:20	713.5	40.6	625	28	163	118	115	10.6	2.6	6.4	606	602	395	71	5	250.2	54.1	1575
12:50	733.375	12.2	FULL	24	175	160	165	2.8	1.7	4.0	600	560	395	-	6	76.0	93.9	895
12:51	733.75	15.1	FULL	33	174	160	160	7.6	2.5	5.8	600	620	408	-	7	93.2	98.3	1163
12:52	734.0	18.1	FULL	43	175	160	160	10.4	3.0	7.4	606	673	421	-	8	111.2	104.6	1476
12:53	734.375	22.0	FULL	52	173	140	150	19.4	4.4	10.4	624	697	447	-	9	135.5	108.8	1858
12:54	734.625	27.9	FULL	61	167	120	130	27.6+	5.0	13.0	636	692	460	-	10	172.1	105.6	2275
12:55	734.75	30.8	FULL	71	154	110	110	-	5.0	13.0	630	667	473	-	11	190.0	93.2	2200
12:56	755.125	30.3	FULL	75	140	100	100	-	4.6	11.8	615	643	473	-	12	187.0	84.2	1960
14:10	761.5	38.7	FULL	33	122	100	95	17.1	3.6	8.8	567	606	395	-	13	220.0	61.8	1648
14:12	762.75	24.9	563	33	138	88	80	8.3	2.6	5.6	588	606	408	78	14	153.8	59.1	1141
14:20	766.25	38.7	FULL	16	174	167	160	3.3	1.6	3.6	630	602	447	-	15	238.2	42.7	1202
15:32	808.25	46.5	FULL	19	170	147	150	13.1	2.8	7.4	606	581	447	75	16	287.0	55.8	1845
15:52	820.0	45.6	FULL	21	170	168	165	5.3	2.0	4.8	615	649	489	-	17	281.0	45.2	1371
15:55	821.75	43.6	FULL	19	170	160	160	4.5	1.6	4.0	615	606	512	-	18	268.5	44.8	1328
17:38	864.625	32.8	FULL	43	146	120	120	18.1	4.0	18.2	606	606	395	-	19	202.0	77.6	1340
17:58	876.25	31.8	75	33	171	140	140	13.1	3.2	7.8	540	575	369	-	20	196.1	70.7	1718
18:10	882.75	24.0	FULL	24	171	150	150	8.9	2.4	6.4	510	551	317	-	21	147.9	73.7	1371
RESULTS SHEET NO 22																		

150

ENGINE NO 380 (PLUS GIESL) DATE 7-6-63 TRAIN 23 DOWN TJ - MPO LOAD 1250 X 80.

TIME HRS. MINS	PLACE MILEPEG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	READER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER IHP.
02:48	881.25	25.9	875	45	160	120	125	19.3	3.4	9.6	636	667	421	59	22	160.0	91.8	1642
03:10	877.5	12.2	FULL	44	169	180	155	2.9	1.4	4.2	630	643	460	-	23	75.0	108.0	1030
03:12	871.5	14.6	FULL	43	170	160	155	6.1	2.4	5.8	636	662	486	-	24	90.0	108.5	1242
04:22	858.5	17.6	75	33	175	160	155	8.1	2.8	6.4	648	662	625	60	25	108.2	106.3	1445
04:48	851.25	4.3	FULL	24	166	160	160	0.5	0.6	1.6	600	536	499	-	26	22.6	94.8	322
04:49	850.75	4.8	FULL	33	170	160	160	1.1	0.6	1.8	584	540	499	-	27	23.6	96.3	364
04:50	850.625	5.8	FULL	43	171	155	163	1.5	1.0	2.4	585	560	499	-	28	35.7	126.6	593
04:50:30	850.625	7.3	FULL	53	173	160	163	3.3	1.8	4.4	585	606	499	-	29	44.8	126.1	720
04:51	850.5	9.2	FULL	62	175	160	160	6.3	3.4	7.4	591	673	499	-	30	56.9	137.8	958
04:52	850.375	11.7	FULL	72	175	155	155	9.7	4.4	9.6	612	697	499	-	31	72.0	137.5	1288
04:53	850.25	13.1	FULL	75	171	147	150	14.9	4.8	10.6	630	697	512	-	32	81.0	130.9	1345
05:54	836.25	11.7	FULL	41	170	160	160	33	2.0	4.4	615	606	512	52	26A	72.0	99.4	909
06:25	833.0	11.7	FULL	43	155	140	140	5.1	3.4	6.8	615	643	421	-	27A	72.0	113.8	1041
10:47	793.0	23.0	FULL	43	158	125	130	21.3	5.2	12.2	564	581	369	-	28A	141.8	97.9	1747
10:48	792.375	30.3	1625	33	146	115	110	9.1	3.4	7.2	540	560	395	69	29A	187.0	92.1	1447
12:17	753.75	29.8	FULL	36	161	145	140	14.3	3.8	9.2	651	688	486	-	30A	184.0	88.3	2022
12:20	752.25	28.9	FULL	36	167	148	145	15.7	3.8	9.6	645	691	512	76	31A	178.0	91.5	2034
12:26	749.0	31.8	FULL	37	166	142	140	19.1	4.6	11.0	645	692	625	-	32A	136.1	94.1	2275
12:32	746.5	36.7	FULL	38	148	120	120	18.9	4.4	10.0	635	682	525	-	33	226.3	73.6	2000
14:12	726.3	15.0	FULL	43	166	150	150	10.1	3.8	8.0	654	667	434	78	34	115.3	102.6	1535
14:51	721.625	16.1	FULL	39	175	160	160	5.8	2.2	5.6	666	652	460	-	35	99.4	99.4	1249
15:19	709.5	7.3	FULL	24	168	160	160	0.8	0.8	2.4	630	575	421	-	37	44.8	100.5	575
15:20	709.375	8.2	FULL	35	173	160	165	0.8	0.8	2.6	624	592	421	-	38	50.8	104.3	676
15:21	709.25	9.2	FULL	43	176	165	165	1.0	1.0	3.0	624	602	421	-	39	56.9	105.2	763
15:21:30	709.125	10.2	FULL	62	175	160	160	4.2	2.2	5.8	624	655	421	-	40	62.9	128.4	1030
15:22	709.0	13.2	FULL	62	173	150	155	9.5	3.2	8.0	636	682	421	-	41	81.0	126.4	1301
15:23	708.875	15.1	FULL	72	166	140	140	16.9	3.8	10.0	654	688	421	-	42	93.2	122.6	1448
15:24	708.75	17.1	FULL	75	158	140	130	19.9	4.0	10.4	654	673	421	-	43	106.1	115.9	1552
15:32	706.5	23.0	75	48	162	140	135	13.1	3.8	8.2	675	712	434	75	44	141.8	92.0	1642

RESULTS SHEET N° 23

ENGINE 380 (PLUS GIESL) DATE 11.6.63 TRAIN 50 UP:BLR-TJ, LOAD 698 X 92

TIME HRS. MINS	PLACE MILEPG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPER- TURE ° F.	SMOKEBOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°.	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER HP.
10.04	WG	24.0	FULL	51	127	105	105	14.7	3.4	9.0	567	581	343	72	A1	147.9	78.0	1451
10.16	677.25	34.8	FULL	19	173	160	160	8.5	2.4	6.2	615	643	343	-	A2	214.1	88.9	1540
10.54	697.5	43.6	FULL	20	150	133	130	12.5	2.6	7.4	540	545	382	-	A3	266.5	55.6	1647
11.05	703.75	19.5	FULL	33	160	142	140	15.1	3.4	9.0	600	630	408	-	A4	121.4	83.6	1283
11.24	713.5	34.8	FULL	24	153	140	137	8.9	2.6	6.6	525	592	356	78	A5	214.1	57.6	1510
13.08	733.375	6.3	FULL	20	169	160	165	1.1	1.2	3.0	600	557	343	83	A6	38.7	89.8	444
13.09	733.5	9.2	FULL	24	178	165	167	2.7	1.8	4.4	606	602	343	-	A7	56.9	112.0	812
13.09.30	733.625	13.1	FULL	33	177	160	160	8.9	3.2	7.8	618	662	343	-	A8	81.0	118.1	1216
13.10	733.75	17.1	FULL	43	176	-	155	13.1	3.6	9.4	633	673	343	-	A9	105.1	111.1	1485
13.10.30	734.0	20.0	FULL	53	175	-	150	18.5	4.3	11.2	636	682	369	-	A10	123.5	110.3	1720
13.11	734.25	23.0	FULL	62	170	140	135	22.5	5.0	13.6	636	673	369	-	A11	141.8	111.8	2013
13.11.30	734.5	25.9	FULL	75	164	-	125	24.5	5.2	14.4	630	667	369	-	A12	160.0	102.3	2057
14.35	761.5	32.8	FULL	29	161	140	140	14.1	3.4	9.0	612	617	330	-	A13	202.0	69.4	1730
14.37	762.5	30.8	FULL	29	156	140	135	11.9	3.0	7.6	615	602	343	-	A14	190.0	71.3	1680
14.44	766.25	38.7	FULL	19	167	160	155	6.1	2.4	5.4	636	634	369	-	A15	238.2	48.2	1361
16.31	808.25	43.6	FULL	32	155	130	125	20.7	5.0	12.4	576	620	369	-	A16	268.5	74.6	2210
16.48	820.0	44.6	FULL	32	166	150	145	15.1	4.4	10.0	660	703	382	-	A17	275.0	65.6	1970
17.00	828.25	38.7	FULL	14	171	160	160	6.1	2.6	15.8	636	643	395	81	A18	238.2	62.3	1468
18.53	864.5	24.9	FULL	29	174	166	160	7.2	2.4	6.2	606	640	330	67	A19	153.8	72.9	1408
19.15	876.25	25.9	FULL	29	162	116	120	7.0	2.0	5.0	492	488	291	-	A20	160.0	56.6	1137
19.33	882.75	19.0	FULL	33	126	134	110	6.6	2.4	6.0	480	530	317	68	A21	118.3	67.8	1013

ENGINE NO 380 (PLUSGIESL) DATE 12.6.63 TRAIN 23 DOWN; TJ.-MPO. LOAD 1297 X92

ENGINE N° 380 (PLUS GIESL) DATE 12.6.63 TRAIN 23 DOWN TJ. - MPO. LOAD 1297 X92																		
TIME HRS. MINS	PLACE MILEPEG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER HP.
03.01	881.25	21.0	FULL	38	150	125	125	15.2	3.0	3.4	606	640	317	54	B1	129.8	93.9	1538
03.17	877.5	10.2	FULL	37	178	166	165	1.6	1.1	3.2	624	606	395	-	B2	62.9	109.1	876
04.09	871.0	10.2	FULL	33	167	160	155	2.0	1.2	3.2	606	575	395	-	B3	62.9	102.8	822
05.11	858.5	14.1	FULL	38	175	160	160	5.6	1.6	4.6	606	620	408	-	B4	87.2	102.5	1173
05.37	851.0	3.3	FULL	16	176	170	167	0.6	0.0	1.0	606	630	408	-	B5	20.6	86.1	227
05.39	850.875	4.8	FULL	24	175	166	167	1.0	0.2	1.6	600	551	408	-	B6	29.6	103.3	409
05.40	850.75	5.8	FULL	33	174	165	167	0.8	0.3	1.7	600	551	408	-	B7	35.7	104.6	475
05.41	850.625	6.3	FULL	43	172	-	165	1.0	0.4	2.0	600	551	408	-	B8	38.7	103.2	511
05.42	850.375	8.2	FULL	53	169	160	155	1.8	1.2	3.8	555	557	395	-	B9	50.8	120.6	781
05.43	850.25	9.7	FULL	62	162	148	145	3.6	1.6	4.9	582	592	395	-	B10	59.9	119.6	914
05.44	850.125	10.7	FULL	75	152	135	135	5.8	2.2	6.4	570	589	395	-	B11	65.9	119.1	1002
06.47	836.25	13.1	025	33	175	153	150	4.0	2.0	5.0	636	640	421	-	B12	81.0	113.4	1545
07.09	833.5	12.2	FULL	33	168	159	155	4.2	2.0	5.0	615	640	356	-	B13	75.0	103.3	986
10.44	793.0	24.0	FULL	33	163	145	145	11.2	3.2	8.2	567	623	343	-	B14	147.9	84.8	1580
10.46	792.25	31.8	FULL	33	156	135	135	14.4	3.6	9.4	597	634	356	71	B15	196.1	75.8	1840
12.28	783.75	25.8	FULL	33	160	140	140	9.4	2.4	6.8	663	634	408	-	B16	160.0	81.6	1637
12.31	782.25	24.0	FULL	33	158	145	140	9.0	2.6	6.9	666	658	421	84	B17	147.9	81.9	1524
12.45	749.0	24.0	FULL	43	170	150	150	14.4	3.4	9.0	666	647	421	-	B18	147.9	98.6	1835
12.53	744.5	36.7	025	33	158	122	120	12.6	3.6	8.8	675	673	447	-	B19	226.3	63.4	1647
13.10	738.0	32.8	025	24	151	125	120	11.0	3.4	8.0	636	640	421	-	B20	202.0	65.2	1630
13.46	731.25	24.4	FULL	24	145	130	130	6.6	2.2	5.4	558	545	330	81	B21	150.9	63.1	1196
14.35	726.5	16.1	FULL	33	146	160	152	7.4	2.0	5.8	624	631	369	-	B22	99.1	109.6	1263
16.38.30	709.5	4.3	FULL	19	176	160	167	0.8	0.4	1.4	618	512	395	-	B23	26.6	93.9	319
16.00	709.375	5.3	FULL	24	175	165	167	0.8	0.4	1.6	612	521	395	-	B24	32.6	94.9	395
16.00.30	709.25	5.8	FULL	33	176	166	167	1.2	0.5	1.8	612	530	395	-	B25	38.7	94.6	431
16.01	709.125	6.8	FULL	43	177	165	167	2.4	1.0	3.2	612	575	395	-	B26	41.8	117.1	625
16.02	708.75	8.2	FULL	53	177	165	165	3.3	2.0	5.2	618	620	395	-	B27	50.8	121.6	787
16.02.30	708.625	11.7	FULL	62	176	160	160	8.1	3.0	8.0	618	640	395	-	B28	12.0	133.5	1223
16.03	708.375	13.1	FULL	75	174	150	150	17.5	4.0	11.0	618	640	395	83	B29	81.0	132.0	1365
* 3 GAS SAMPLE TAKEN: CO ₂ 0.1%; O ₂ 8.0%; CO NIL; N ₂ 82% BY VOLUME.																		
RESULT SHEET N° 25.																		

ENGINE 380 (PLUS GIESL) DATE 13.6.63 TRAIN 814 UP : WG-MAG: LOAD 685 XBB (712 X 92)

TIME HRS. MINS	PLACE MILE/PG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPER- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER IHP.
11.58	1348	18.1	FULL	52	158	140	135	15.0	3.1	-	675	682	343	73	C1	111.2	107.5	1513
12.15	1341.5	25.5	FULL	33	155	140	135	11.6	2.8	8.2	660	631	343	-	C2	160.0	80.0	1606
12.53	1327.5	26.4	FULL	37	155	130	125	20.3	4.4	11.4	681	692	369	-	C3	163.0	73.0	1500
12.57	1325.5	4.8	FULL	19	167	160	160	0.5	0.9	0.2	645	546	369	-	C4	29.6	80.3	304
12.57.30	1325.375	4.8	FULL	24	169	160	160	0.5	0.4	1.5	648	540	382	-	C5	29.6	92.3	349
12.58	1325.25	4.3	FULL	33	167	160	160	0.5	0.4	1.4	645	540	382	-	C6	29.6	92.6	315
12.59	1325.125	5.3	FULL	43	167	160	160	1.1	0.9	2.8	642	560	382	-	C7	32.6	110.9	462
12.59.30	1325.0	8.2	FULL	53	167	155	155	4.1	2.0	5.6	636	643	395	-	C8	50.8	123.9	802
13.00	1324.875	12.2	FULL	62	170	150	150	11.6	3.6	5.4	654	677	395	-	C9	76.0	127.2	1214
13.01	1324.75	16.1	FULL	75	170	145	145	23.2	5.0	13.4	663	715	395	-	C10	99.1	128.3	1614
13.12	1320.25	28.9	5G3	26	159	125	125	5.2	1.6	5.2	666	637	395	-	C11	178.0	58.3	1297
19.35	1214.125	27.9	FULL	25	168	160	153	6.6	1.8	5.4	630	630	291	-	C12	172.1	63.6	1369
* 19.45	1209.125	25.9	FULL	24	170	160	155	5.2	1.4	4.2	636	620	369	67	C13	160.0	57.2	1149
21.39	1172.5	17.6	FULL	33	171	160	160	4.0	1.8	4.4	600	606	343	61	C14	108.2	69.8	969
21.62	1166.0	28.9	FULL	19	165	155	150	7.2	3.1	6.8	630	643	382	-	C15	178.0	63.9	1420
22.09	1157.5	30.8	FULL	16	166	145	150	4.6	2.0	4.4	630	602	356	-	C16	190.0	56.4	1381

* 6 GAS SAMPLE TAKEN! CO₂ 7.2%, O₂ 11.0%, CO NIL N₂ 81.8%; BY VOLUME.

RESULTS SHEET No. 26

ENGINE 380 (PLUS GIESL) DATE 14.6.63 TRAIN 150 DOWN MAG - BLR LOAD TIX 64

TIME HRS. MINS	PLACE MILE/PEG	SPEED MPH.	REGU- LATOR OPENING	CUTOFF %	BOILER PRESSURE PSI	HEADER PRESSURE PSI	STEAM CHEST PRESSURE PSI IN.	BLAST PIPE PRESSURE INS. HG.	FIRE DRAUGHT INS. WATER	SMOKE BOX DRAUGHT INS. WATER	HEADER TEMPERA- TURE ° F.	SMOKE BOX GAS TEMPER- ATURE ° F.	STEAM CHEST TEMPERATURE ° F.	AMBIENT TEMPERATURE ° F.	INDICATOR DIAGRAM N°	SPEED RPM	MEAN EFFECTIVE PRESSURE PSI	POWER I.H.P.
06.47	1087.25	15.1	FULL	43	170	160	150	11.2	3.4	5.0	612	634	296	41	C17	93.2	103.3	1222
* 06.59	1093.25	35.7	FULL	19	173	164	160	6.4	2.6	6.2	654	667	395	-	C18	244.2	54.9	1550
08.35	1143.75	41.6	FULL	19	172	158	157	11.2	3.8	8.6	645	667	499	-	C19	256.3	65.9	1917
08.43	1149.75	34.8	FULL	29	162	135	142	21.2	4.2	11.2	636	670	499	58	C20	214.1	82.4	2155
08.50	1153.25	22.0	FULL	33	154	140	133	10.6	3.2	7.8	639	667	577	-	C21	135.5	90.3	1543
08.58	1157.125	41.6	FULL	15	152	140	137	8.0	2.5	6.2	636	643	577	-	C22	256.3	65.9	1598
10.30	1201.5	37.7	FULL	33	170	150	140	19.8	5.0	12.4	684	715	551	-	C23	232.2	81.6	2255
12.09	1235.25	29.8	FULL	34	163	155	148	11.0	3.2	8.2	675	670	473	68	C24	184.0	73.6	1690
* 12.28	1247.25	35.7	FULL	19	167	155	153	8.2	2.8	5.8	648	652	512	-	C25	220.0	61.8	1648
13.40	1268.25	22.0	625	30	170	150	146	6.4	2.4	6.8	642	617	460	-	C26	135.5	74.8	1278
14.01	1279.75	38.7	FULL	32	164	150	147	11.6	3.2	8.2	615	652	551	-	C27	238.2	76.4	2141
14.05	1282.125	24.0	FULL	32	170	160	155	7.0	2.5	6.0	645	655	564	-	C28	147.9	81.0	1508
14.12	1284.125	24.9	FULL	32	165	155	150	9.8	3.0	7.6	666	643	564	-	C29	153.8	84.8	1640
14.54	1296.25	29.8	FULL	24	173	160	150	13.8	3.6	9.6	654	679	421	83	C30	184.0	80.5	1848
15.06	1303.25	26.3	FULL	24	173	160	155	14.4	4.0	9.6	666	692	551	-	C31	166.0	85.5	1780
15.13	1307.5	34.8	FULL	14	166	160	157	3.2	1.6	4.0	645	620	538	-	C32	214.1	47.6	1242

* 7 GAS SAMPLE TAKEN CO₂ 9.0% O₂ 5.0% C.O. NIL N₂ 82% BY VOLUME.

* 8 GAS SAMPLE TAKEN (13.15 AT 1261.25 MILES) CO₂ 9.0%; O₂ 7.7%; C.O. NIL; N₂ 87.3% BY VOLUME

RATES OF FIRING (EXTRACTED FROM ORIGINAL READINGS)

STANDARD LOCOMOTIVE					EJECTOR				
ENGINE 381									
DATE.	TIME HRS. MIN.	RATE LB. / HR.	I. H. P.	DATE.	TIME MIN. HRS.	RATE LB. / HR.	I. H. P.		
4.4.63	18.30	3600	1600	23.4.63	16.03	2129	1640		
5.4.63	11.16	2700	1610	24.4.63	02.34	3600	1500		
5.4.63	11.30	2450	1460	24.4.63	02.48	1620	1070		
5.4.63	16.07	4015	1600	24.4.63	03.02	1620	1000		
6.4.63	08.00	2760	1400	24.4.63	16.50	2540	1350		
6.4.63	08.50	2650	1160	25.4.63	12.25	2530	1350		
6.4.63	08.35	2715	1460	25.4.63	14.30	3745	1430		
6.4.63	11.06	3260	1460	25.4.63	11.13	1243	1570		
6.4.63	12.50	3063	1430	26.4.63	05.25	2960	1500		
6.4.63	17.23	3060	1210	26.4.63	03.20	2970	1030		
6.4.63	17.43	2875	1100	26.4.63	13.30	3020	1490		

156

ENGINE 380.

DATE.	TIME HRS. MIN.	RATE LB. / HR.	I. H. P.	DATE.	TIME MIN. HRS.	RATE LB. / HR.	I. H. P.
14.5.63	10.56	2920	1370	6.6.63	10.50	1807	1248
15.5.63	13.24	2800	1300	6.6.63	12.35	2262	1640
15.5.63	13.30	2900	1600	6.6.63	14.20	2064	1470
16.5.63	14.15	1905	1450	6.6.63	15.32	3390	1634
16.5.63	11.10	1710	1640	7.6.63	10.47	2320	1600
16.5.63	14.18	3768	1630	7.6.63	14.50	2275	1330
17.5.63	02.40	3050	1300	11.6.63	10.04	3415	1620
17.5.63	15.40	2360	1060	12.6.63	06.40	2270	1100
				12.6.63	16.10	2163	1000

SUNDRY RESULTS.

ANALYSIS OF EXHAUST GAS SAMPLES.

I

ENGINE.	SAMPLE N°	DATE.	TRAIN N°	I.H.P.	CO ₂ % BY VOL.	EXCESS AIR %.	AIR/FUEL BY WT.
ENGINE N° 380 STANDARD	1	14.5.63	50 UP	1600	13.5	43	16.8?
	2	15.5.63	23 DOWN	1000	8.6	120	23.5?
	3	16.5.63	50 UP	1640	18.6	24	14.5?
	4	17.5.63	23 DOWN	860	4.2	350	66.1
	AVERAGE.			1275		133	28.2?
ENGINE N° 380 WITH GIESL.	5	12.6.63	23 DOWN	1100	9.1	110	24.2
	6	13.6.63	814 UP	1650	7.2	164	30.0
	7	14.6.63	103 DOWN	1225	9.0	113	24.5
	8	14.6.63	103 DOWN	1470	5.0	178	31.6
	AVERAGE.			1411		166	27.6

II

CHAR REMAINING IN SMOKEBOX AFTER EACH GROUP OF TESTS.

ENGINE.	CHAR REMOVED DATE & PLACE	NUMBER OF TRIPS PRIOR TO REMOVAL.	ACCUMULATED WEIGHT LB.
N° 381 WITH STANDARD SELF-CLEANING FRONT END.		50 UP BLR-TJ	
		23 DN TJ-MPO	
		50 UP BLR-TJ	
	6.4.63 BLR	23 DN TJ-MPO	32.6
N° 381 WITH GIESL NON SELF-CLEANING.	24.4.63 BLR	50 UP BLR-TJ	442.5
	25.4.63 TJ	23 DN TJ-MPO	224.0
	25.4.63 BLR	50 UP BLR-TJ	461.0
		23 DN TJ-MPO	
N° 380 WITH GIESL & SELF-CLEANING FRONT END.		50 UP BLR-TJ	
		23 DN TJ-MPO	
		50 UP BLR-TJ	
		23 DN TJ-MPO	
		814 UP BLR-MAG	
	14.6.63 BLR.	103 DN MAG-BLR	83.0

III

DRAUGHT CREATED BY THE BLOWER.

ENGINE.	TEST.	FIREBOX DRAUGHT INCHES WATER.	SMOKEBOX DRAUGHT INCHES WATER.
N° 380 - STANDARD. STATIONARY AT IGUEL. 16.00 HOURS ON 17.5.63. FULL BOILER PRESSURE OF 150 PSI.	ALL OFF.	0.0	0.0
	BLOWER ONLY.	0.5	0.8
	SMALL EJECTOR ONLY.	0.0	0.2
	BLOWER + SMALL EJECTOR.	0.5	0.8
	BLOWER + SMALL + LARGE EJECTOR.	0.5	0.8
N° 380 - WITH GIESL STATIONARY AT PLUMTREE. 14.42 HOURS ON 14.6.63. FULL BOILER PRESSURE OF 180 PSI.	BLOWER ONLY (ALTERNATIVE ARRANGEMENT FOR EJECTOR EXHAUSTS.)	0.2	0.6

IV

DETERMINATION OF DEPTH OF STRIKE OF BLAST BELOW TOP OF CHIMNEY.

ENGINE N° 380	EXHAUST PIPE BACK PRESSURE INCHES OF MERCURY.	DEPTH OF STRIKE INCHES.	ENGINE N° 380 WITH GIESL. TRAIN 103 DOWN
STANDARD	10.6	16.5	14.6.63. ONE TEST ONLY AT 10.30 HOURS.
TRAIN 50 UP	13.6	14.0	
16.5.63.	7.6	10.0	BACK PRESSURE 13.5 INCHES OF MERCURY.
	7.6	11.0	
	7.6	10.0	DEPTH OF STRIKE 83" AT CENTRE SIDES, LOWER AT FRONT & BACK.

RESULTS 6MGT N° 23.

REFERENCES.

1. WAGNER, R.P. "Some New Developments of the Stephenson Boiler". Journal of Institution of Locomotive Engineers, 1930, No. 93, Paper 253.
2. LOUBSER, M.M. and COX, E.S. "Locomotive Boiler Design : Theory and Practice". Journal of Institution of Locomotive Engineers, 1938, No. 144, Paper 388.
3. SANDFORD, D.W. "The Relationship between Smokebox and Boiler Proportions". Journal of Institution of Locomotive Engineers, 1945, No. 183, Paper 451.
4. FRY, L.H. "A study of the Locomotive Boiler". Simmons-Boardman Publishing Company, New York, 1924.
5. WEBBER, A.F. "The Proportions of Locomotive Boilers". Journal of Institution of Locomotive Engineers, 1937, No. 140, Paper 378.
6. TURNER, J. "The Locomotive Boiler". Journal of Institution of Locomotive Engineers, 1937, No. 138, Paper 375.
7. JOHNSON, R.P. "The Steam Locomotive". Simmons-Boardman Publishing Corporation, New York, 1945.
8. PHILLIPSON, E.A. "Steam Locomotive Design : Data and Formulae". The Locomotive Publishing Company, London, 1936.
9. "HENSCHEL LOCOMOTIVE ENGINEERS MANUAL". VDI-Verlag, GMBH, Dusseldorf, 1960.
10. LOW, D.A. "A Pocket Book for Mechanical Engineers". Longman, Green and Co., London, 1953.

11. VINCENT. H.S. "The Locomotive Front End". Railway Mechanical Engineer, Volume 112, Nos. 1,2 and 3, Simmons-Boardman Publishing Corporation, New York, 1938.
12. "THE EFFICIENT USE OF FUEL". Her Majesty's Stationary Office, London, 1958.
13. VAN DER LINGEN. T.W. "A Jet Pump Design Theory". Council for Scientific and Industrial Research, Pretoria, Publication No. RN 104, 1960.
14. ENGEL. M.O. "Some Problems in the Design and Operation of Jet Ejectors". Proceedings of Institution of Mechanical Engineers, 1963, Volume 177, No. 13.
15. "THE GIESL EJECTOR". The Railway Gazette, March 20, 1959.
"GIESL EJECTOR PROGRESS". The Railway Gazette, July 12, 1963.
"GIESL-GIESSLINGEN. A. "Adapting Steam Locomotive Boilers to Lower-Grade Coal". "Indian Railways", February 1961.
16. "THE LOCOMOTIVE ENGINEERS POCKET BOOK". 42nd Edition. Locomotive Publishing Company, London.