DR/CM/9.1/716.

RESEARCH CENTRE ADVANCE INFORMATION SHEET

RUSTON ENGINE DEVELOPMENT DEPARTMENT.

DATE: 6th October 1970.

A.I.S. No: 70/71-RA-040005

CIRCULATION:

CROSS REF: RK/EF/PC/PI

Dr. H. Watson.
Mr. L. Gibson.
Mr. W.W. Luckman.
Mr. R. Hunt.
Mr. D.A. Wight.
Mr. T. Hemingway.
British Rail.
Dr. D.H. Taylor.

JOB NO: D.D.O. 02404

THIS DATA WILL BE INCLUDED IN A FINAL REPORT.

SERVICE PERFORMANCE MEASUREMENTS ON B.R. TYPE 4 LOCOMOTIVES.

1. INTRODUCTION.

1.1. Recent service experience with the 16 CSVT MK 2 Engines in Type 4 (2700 bhp) locomotives on B.R. has included a number of piston seizures. Examination of the piston assemblies from several engines, some with and some without piston seizure history, has revealed heavier than expected piston ring wear and cracking in the piston crown bowls transverse to the gudgeon pin axis.

1.2. Measurements of engine performance during service were requested in order to determine the type and severity of loading on the pistons and the degree of performance deterioration from new.

1.3. This report gives results obtained from service measurements on two locomotives, Nos. D.409 and D.413, during July and August 1970. The report also refers to examinations of the blowers, aftercoolers and pistons from D.413, shortly after completion of the service trials, the results of which have already been circulated.

2. ENGINE BUILD AND INSTRUMENTATION.

2.1. Engine Build.

The engines involved in these tests were as follows :-

	Locomotive	Engine.
First run -	D.409	IH 6934
Second run -	D.413	IH 6940

They had run for 11060 and 11068 hours respectively since entering service.

Appendix I to this report gives details of engine build and settings.

2.2. INSTRUMENTATION.

Instruments were arranged to measure the following quantities :-

Engine Speed.
Main generator output.
Fuel Pump rack.
Air temperatures at blower suction, delivery and aftercooler outlet.
Aftercooler water inlet.
Blower speed.
Blower delivery air pressure.
Blower intake filter suction drop.
Cylinder exhaust and turbine inlet gas temperatures.
Engine water outlet temperature.
Engine lub. oil outlet temperature.
Governor control air pressure (2nd run only).

In addition, locomotive speed and position on route were noted at suitable times.

Appendix II gives more detail of the instruments concerned and notes on measuring procedure, engine output estimation, etc.

3. PROCEDURE.

3.1. In each case the instrumentation was fitted to the locomotive at the diesel Depot at Crewe during a scheduled service withdrawal for 48 hours. A longer time would have been preferred, because difficulties in installation and the cramped working conditions resulted in very long hours being worked in order to meet the departure times.

3.2. The runs with loco D.409 took place on Wednesday, 8th July, working the 9.25 train from Crewe to Glasgow Central and the 16.00 train back to Crewe. Those with D.413 took place on Thursday, 13th August, taking the same train northwards and the 15.30 train back. Both tests were double headed, the coupled loco being D.426 with D.409, and D.415 with D.413. The train weight was stated to be 455 Tons for each of the tests.

3.3. On the runs north the instrumented loco was in the leading position, with the observers and instruments in the rear cab. During the intervals between trains at Glasgow the locos ran light to Polmadie Depot for fuelling but were not turned, so that the observers were in the forward cab of the trailing loco for the return journeys.

3.4. For the tests on both locos, the Honeywell recorders - measuring gas, air and water temperatures and fuel pump rack - were operated throughout the journeys. Manually recorded readings were taken whenever a period of sufficient length on full power occurred. In fact, the continuous periods at full power were found to be very short, usually only 2 - 3 minutes, with the exception of the climbs up Shap and Beattock inclines and even these were interrupted by several checks on three out of the four occasions.

4. RESULTS.

4.1. Typical sections of the recorder traces are reproduced in Figs. 1 and 2. From the traces the individual readings have been extracted at times corresponding to the manual recordings at times of full power.

4.2. The times at full power were very short, usually only 2 - 3 minutes. Temperatures took 4 - 5 minutes to settle and a similar time was necessary to get from the cab to the engine room and take blower-speed, having noted that the electrical meters indicated full power. For these reasons (amplified in Appendix II) very few full sets of readings at full power are available. However, the gas temperatures repeatedly reached to within 10 - 20° C. of the results tabled below which were taken from the longest periods at full power, on Shap and Beattock inclines. These results are therefore considered to be fully representative.

4.3. For each locomotive, the most representative sets of readings at full power have been tabled, Table I, together with the corresponding new engine performance. For comparison, the performance of the original development engine is also shown, both new and after running for about 150 hours. Typical individual cylinder exhaust and turbine inlet temperatures for each locomotive are shown in Table II.

4.4. For loco D.409 the measured maximum output diminished during each journey. Since it is almost certain that the driver was demanding full power for most of the train accelerations, it is fairly certain that the maximum speed and power given by the engine at a repeated constant control lever setting did diminish with time from journey start. Results which demonstrate this are shown in Table III.

4.5. The measured blower speed on loco D.409 was very low compared with the observed boost pressure. It seems likely that the blower selected was running slower than the others on this engine. Two blowers measured on D.413 showed a difference of 1500 to 2000 rpm under constant load conditions.

4.6. Table IV shows an estimation of the time spent on full power, taken from the fuel pump rack recording on the first test. The overall figures were 26% northwards and 33% southwards. The most notable difference between the two runs was the much higher figure of 53% for the Preston-Crewe stretch on the return journey. The gradients on this stretch are only light but there were hardly any (if any) signal checks. The overall load factor could be a little higher because no account has been taken in this estimation of the times at ower powers.

5. DISCUSSION.

5.1. The results at maximum power, Tables I and II, show obvious high gas temperatures with much more than the normal scatter between cylinders. These are consistent with fouling of the turboblower compressors and/or aftercoolers. A similar trend was demonstrated on the original development engine after only 150 hours' running in a fairly oily atmosphere, which was largely recovered by cleaning the blower compressors and air filters.

5.2. Examination of the blower compressors and aftercoolers fully confirmed these deductions. Three out of the four blower/cooler groups were heavily fouled though on some the fouling was on the blowers while on others it was on the coolers. The magnitude of the deterioration was considered to be sufficient to cause the degree of performance deterioration recorded.

5.3. These locomotives were provided with two stage inlet air filtration and water washing facilities for the compressors to prevent fouling reaching significant proportions. In view of this the degree of fouling found was unexpected. Because the inlet filters and ducts were clean and the deposits on the coolers were on their inlet faces, the oil fouling must have originated from the blowers. It is most likely that the cause was running with turboblower sump breathers blanked off, a modification introduced on all locos to reduce fuming in the engine room. During the recent trial on D.413, the pressure in the sump blew oil out of the compressor end axial plug hole when the plug was removed for speed measurement, so that it is highly likely that oil was also blown into the compressors and thence to the coolers.

5.4. Examination of other components on the engine, such as the fuel equipment condition and settings, valve timing, etc. did not show variations of sufficient magnitude to affect the engine performance seriously.

5.5. The diminishing of full speed and power at constant control lever setting on D.409 is most likely to have been due to a fault in the control system or governor and not in the engine itself. Allowing for the generally lower powers called for on this locomotive the deterioration in engine performance of both engines was similar. It seems very likely that this deterioration is common throughout the fleet to a greater or lesser degree.

5.6. The high gas temperatures measured are indicative of piston thermal conditions well in excess of those anticipated during normal service. The comparatively short periods at these maximum conditions have probably saved the pistons from seizure in most cases but the piston crown cracking must be largely attributed to these conditions. They could also adversely affect the running and lubrication conditions of the piston rings and hence increase the ring wear rate.

5.7. Examination of the piston assemblies from D.413 showed the typical high rate of piston ring wear; four piston crowns were cracked, on lines B1, B2, B3 and B4. Fig. 3 at the end of this report shows these in relation to the measured temperatures, from which it will be seen that the cracked pistons were on four of the highest temperature lines including the three highest.

5.8. The average of 30% of the journey time at full power is not excessive. Comparable figures of 30 - 35% were measured on the S.R. 4SRKT rail car sets. On E.A.R. '90' class locos checked some years ago, while the overall factors were much lower the duties on certain sections did involve periods of two hours on continuous full power.

6. CONCLUSIONS.

6.1. Measurements on two locomotives have shown gas temperatures to be well in excess of those anticipated in normal service. They indicate excessive thermal conditions for the piston assemblies. These would be expected seriously to affect the piston and ring life.

6.2. Subsequent examination of the pistons from one of these engines has shown crown cracking associated with the highest temperatures, supporting the above.

6.3. Examination of the turboblowers and aftercoolers has revealed severe fouling of the air side of three out of four of the blower/cooler groups. This would certainly cause the type of performance deterioration found and was probably sufficient to give the degree of deterioration measured.

6.4. Fouling appears to have originated at the blowers and is probably connected with blanking of the blower sump breathers to reduce engine room fumes. Water washing of the compressors does not appear to have proved successful in keeping the assemblies clean under these abnormal circumstances and may well have made matters worse by transferring deposits from the blowers to the coolers.

6.5. Deterioration of other components, such as fuel equipment, may be contributory to the performance deterioration but is not thought to be a major cause. On the one engine thoroughly examined so far, relevant components, other than the blowers and coolers, showed no seriously significant defects.

6.6. It seems likely that these conditions apply to a greater or lesser extent to all this batch of locomotives.

D. Russell

D. RUSSELL.
Senior Development Engineer.

TABLE I

REPRESENTATIVE SERVICE READINGS.

Column.		1.	2.	3.	4.
Loco		← D409 →			← I
Engine		← IH6934 →			← I
Condition		In service		Shop Trial	In ser
Date		8.7.70.	8.7.70.	6.7.67.	13.8.70.
Time		16.30.	17.53	12.4	12.47.
Engine speed rpm		860	830	850	869
Main generator	amps	1680	1700	1800	1530
	volts	1040	980	970	1110
	bhp	2500	2400	2500	2400
Total output, bhp		*	*	2700	*
∅ Inlet air °C		23	19	24	25
∅ Air before a/cooler °C		91	86	82	78
∅ Air after a/cooler °C		39°c 52	35°c 51	28°c 54	28°c 50
Water to a/cooler °C		35	34	41	34
Cylinder exhaust temp. °C	mean	490	470	446	494
	max	567	545	471	545
Turbine in temp °C	mean	612	595	552	616
	max	642	613	588	672
Fuel pump rack, mm		11.5 9	12	10½	10½
Boost press		18.5	16	20	19.5
∅ Suction filter depressor		1.5	1.2	-	(1.7)
Blower speed rpm	A bank fly.w.	13000	12200	17500	(16500)
	B bank free	-	-	18000	18200

Notes: * Total output estimated at 2700 -
∅ Measured on A bank flywheel blow

Readings in brackets are interpo
readings at other times during th
test run.

TABLE II

INDIVIDUAL CYLINDER EXHAUST TEMPERATURES IN °C, D413 CORRESPONDING TO COLUMN 5 IN TABLE I

Cylinder No:	1	2	3	4	5	6	7	8
A Bank	485	467	495	x	496	495	454	482
B Bank	532	537	555	518	x	520	532	493

Average 504

Corresponding Turbine Inlet Temperatures.

Pipe :-	1 and 4	2 and 3	5 and 8	6 and 7
A Bank	630	614	599	593
B Bank	687	613	631	643

Individual Cylinder Exhaust Temperature, Loco D.409, Corresponding to Column 1 on Table I.

Cylinder No:	1	2	3	4	5	6	7	8
A Bank	470	480	501	x	544	490	492	440
B Bank	465	582	470	567	x	465	525	470

Average 490

Corresponding Turbine Inlet Temperatures.

Pipe :-	1 and 4	2 and 3	5 and 8	6 and 7
A Bank	634	622	619	556
B Bank	x	590	618	642

Note: (x not read due to inaccesibility.)

TABLE III

REDUCTION OF ENGINE POWER DURING JOURNEY, LOCO D409

	CREWE to GLASGOW				GLASGOW to CREWE					
Time	09.30	10.38	11.08	12.37	16.10	16.18	16.30	16.58	17.50	18.09
Milepost	163	249	265	45	100	93	85	52	290	272
Place	Out of Crewe	Oxenholme	Up Shap	Up Beattock	Out of Glasgow	Fallside	After Wishaw	Up Beattock	After Southwaite	Up Shap
Engine speed rpm	845	805	783	810	860	850	862	822	828	817
Main generator										
amps			1600	1550			1680	1730	1700	1720
volts			950	980			1040	920	980	935
bhp			2200	2200			2500	2300	2400	2300
Boost psi	10	8	7.5	8.5	10	9	9	8.5	8	7.8