THE EFFECT OF MALADJUSTED VALVE TAPPETS ON THE PERFORMANCE OF AN AUTOMOTIVE ENGINE

BY

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I

INTRODUCTION

The purpose of this investigation is to determine the effect of maladjusted valves on the horsepower out-put and the specific fuel consumption, based on corrected brake horsepower, of an automotive engine.

There is a clearance provided between the valve stem and the cam follower to allow for the valve stem expansion and sinking of the valve seat. An adjustable tappet is used to obtain the desired clearance, and any variation changes the valve timing.

Ideal timing for the sequence of events in the ideal four-stroke cycle would be such that the intake valve would be fully open for 180° rotation of the crank shaft during the suction stroke; intake and exhaust valves closed during the compression and expansion strokes, and the exhaust valve fully opened for 180° rotation of the crank shaft during the exhaust stroke. Such a timing would require that the valves open and close instantaneously, which is impossible. Since as much as 90° rotation of the crank shaft is required to open or close a valve, it has been found that it is best to open it early and close it late. The result is that the events in an actual engine cycle overlap; in other words, the inlet and exhaust valves are open at the same time during some interval of the cycle. Should this overlap be too great, backfiring, or an appreciable amount of air-fuel mixture may pass directly from intake to exhaust port.

In 1942, Martin Stark conducted a thesis entitled, The Effect of Negligence and Misadjustment on the Automotive Engine. The research was conducted in the Internal Combustion Engines Laboratory at the Virginia Polytechnic Institute, and the effect of practically all the adjustments normally included during a "minor" motor tune-up was considered. Mr. Stark, however, did not include any experimentation on the effect of maladjusted valves on engine performance, which phase of automotive adjustment is the subject of this thesis.

A continuation of the work done by Mr. Stark will help to determine to a larger extent the value of a "minor" motor tune-up. This value referred to here is monetary. A realization of this value may or may not be of interest to the average motorist, but it is unquestionably of great interest to the wise fleet operator.

I wish to express my appreciation to the following faculty members for their efforts in connection with this work: to Professor J.B. Jones, for the use of pertinent information with respect to road load performance and for securing the equipment necessary to conduct the tests; and to Mr. S.A. Phillips, for his assistance in "trouble-shooting" and aid during the actual set-up of the apparatus.

The author is also indebted to Miss Kathleen E. Turner of the Soil Conservation Service office in Blacksburg, Virginia, for her help in the actual writing of this report, and to Mr. R.C. Meyers, Mr. Stanley Ragone, and Mr. W.P. Terry, students at V.P.I., for their assistance in conducting the tests.

II

REVIEW OF LITERATURE

There is a vast amount of information to be found with respect to valve timing, and it is appalling to realize the wide variation in the valve timings which are common in the automotive industry today. It is assumed by the author that the automobile manufacturer has chosen the valve timing which gives best results for his product. No information was found that would enable the writer to determine the effect on engine performance of any variation of the tappet clearances specified by the manufacturer.

The following paragraphs summarize the information which was found in popular references:

Lichty[1] states that the exhaust valve is open before dead center in all cases, and the higher the speed the earlier the opening. Early opening reduces the pressure in the cylinder to nearly atmospheric before the exhaust stroke begins, which reduces the work of expansion slightly and that of exhaust appreciably. As a result of a decrease in the tappet clearances on the exhaust valves, the valves would open earlier. We would expect, therefore, an increase in the brake horsepower and some change in the specific fuel consumption. The per cent change in horsepower and fuel consumption for various valve timings is not mentioned.

Heldt[2] points out the fact that there is considerable latitude with

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[1]Lichty, Lester C. Internal Combustion Engines 5th. ed. McGraw-Hill Book Company Inc. 1939 p. 112

[2]Heldt, P.M. High-Speed Combustion Engines 13th. ed. P.M. Heldt, Nyack, N.Y. pgs. 358 and 361

respect to possible valve timings, and has listed the ranges of the different timing points which are representative of the American passenger-car engines of 1938. They are as follows: "Inlet opens from 30° ahead to 6° after top dead center; inlet closes from 28° to 71° after bottom dead center; exhaust opens from 65° to 35° ahead of bottom dead center; exhaust closes from 1° ahead of to 30° past top dead center."[2]

In another article in the same book a possible valve timing for an engine which is intended to "peak" at 3000 - 4000 revolutions per minute is shown. There is no reason given as to why this particular timing was chosen from such a wide field as is revealed in the preceding paragraph. He comments that this choice should prove satisfactory. Assuming that it is possible to get high horsepower and low fuel consumption from such a set-up, would there be any difference in these two characteristics if the valve timing were changed? Again there is no mention of this important phase.

Fraas[3] presents an interesting article on the effect of valve timing. In his discussion there is a basis used for determining valve timing. He says, "Early opening of the exhaust valve results in some loss in indicator card area, but no more of a loss than would be caused by higher back pressures on the piston if it were opened later. The exhaust valve closing is ordinarily timed to leave a minimum amount of burned gas in the cylinder

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[3] Fraas, Author P. Aircraft Power Plants 1st. ed. Mc-Graw-Hill Book Company Inc. New York & London 1943, pgs. 51 and 110

[2] Ibid. p. 361

to be used over in the next cycle. The inlet valve opening and closing are timed to give a maximum amount of fresh charge for each cycle; for the pressures throughout the cycle are proportional to that at the beginning stroke, and the engine power output is proportional to these pressures." In a later chapter Fraas[4] says in regard to the effects of valve overlap and manifold pressure on the performance of aircraft engines, "A considerable amount of valve overlap is necessary for aircraft operation at high speeds. If the manifold pressure is appreciably greater than the exhaust back pressure at low speeds, the large valve overlap will give part of the fresh charge that enters the cylinder the time to pass out through the exhaust port before the exhaust closes. This will cause an increase in the consumption of both fuel and air. The result will be an increase in the specific fuel consumption." This reference by Fraas represents one of the best discussions found on the subject, but there is still a lack of specific data on the subject concerned within this thesis.

Marks[4], in his Mechanical Engineering Handbook, has a discussion which is very similar to those which have been found in other references. He says that intake valves are opened near the beginning of the suction stroke and closed appreciably after the beginning of the compression stroke, thus using the kinetic energy of the incoming mixture to obtain maximum charging at some desirable speed. The higher the desirable speed, the later the intake valve is closed, there being considerable variation with various engines.

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4 Marks, Lionel S. Mechanical Engineers' Handbook 4th. ed. McGraw-Hill Book Company, Inc. New York & London p. 1332

The fact that this variation is considerable has been pointed out previously. The range given by Marks for intake valve closure is astounding and for that reason is given here. For an engine with a rated piston speed of 1000 feet per minute there is a range of from 18° to 42° after top dead center; for an engine with a rated piston speed of 3500 feet per minute the range is 53° to 80° after top dead center. His remarks are in accord with other authorities on the subject in content and the lack of it. If there is any difference in the performance of an engine with its valves timed to any value within the ranges given, it is not mentioned in any way.

In an article by Dyke[5] this relevant material was found: "After the valves have been ground or new valves put in-check up. Don't let your engine overheat or lose power through the fault of the air gap. It will be observed that valve clearance, referred to above as 'air gap', is a very important adjustment."

Since this author has stressed the importance of valve tappet clearance, although many others have not, I am led to the conclusion that maladjusted tappets will affect the performance of the automotive engine.

The references cited here have dealt entirely with valve timing. The reason is that any change in tappet clearance will result in a change in valve timing. This review presents a theoretical background for the investigation.

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[5]Dyke, A.L. Dyke's Automobile Encyclopedia 12th ed. Goodheart-Willcox Company Inc. Chicago 1943 p. 74

III

THE INVESTIGATION

A Object

The object of this experimentation was to determine the effect of maladjusted valve tappets on the performance of the average automotive engine. It is to be remembered that during service it is possible for a poorly adjusted valve condition to develop, and it seemed that such a condition should effect performance. It was felt that these data would form a rational basis for the determination of the importance of maintaining valves adjusted to the manufacturer's recommendation. This investigation chiefly concerns the effect of maladjusted valves on fuel consumption and horsepower output. The exhaust temperatures have been recorded as an interesting side light.

B Apparatus

The apparatus included a six-cylinder BLD-269 International truck engine, with a rating of 85 Net Bhp at 3000 rpm, of which a cut-away view is shown, and a General Electric Dynamometer with which the engine was loaded. Additional equipment necessary included a stop watch, three Fahrenheit thermometers, two fuel burettes, a pyrometer, two mercury manometers, tachometer, and two motor generator sets. Complete identification of the equipment follows:

International Truck Engine
BLD 269
Serial No. 59685

Dynamometer - General Electric No. 1676510

Dynamometer control panel - General Electric No. 2233087

Armature Motor-Generator set:
- Motor - Westinghouse No. 8151223
- Generator - Westinghouse No. 8151221
- Generator - Westinghouse No. 8151219

Field Motor-Generator set:
- Motor - General Electric No. FJ1162
- Generator - General Electric No. 1663442

Revolution counter - Electric Tachometer Corporation No. 1263

Tachometer - Electric Tachometer Company No. 13598

Revolution counter (dynamometer unit) No. 11

Tachometer magneto - No. 80212

Starting Box - Westinghouse Automatic Starting Box
Type A
Style No. 402730

Auxiliary Oil Cooler:
- Pump - no identification
- Motor - Style No. 900912

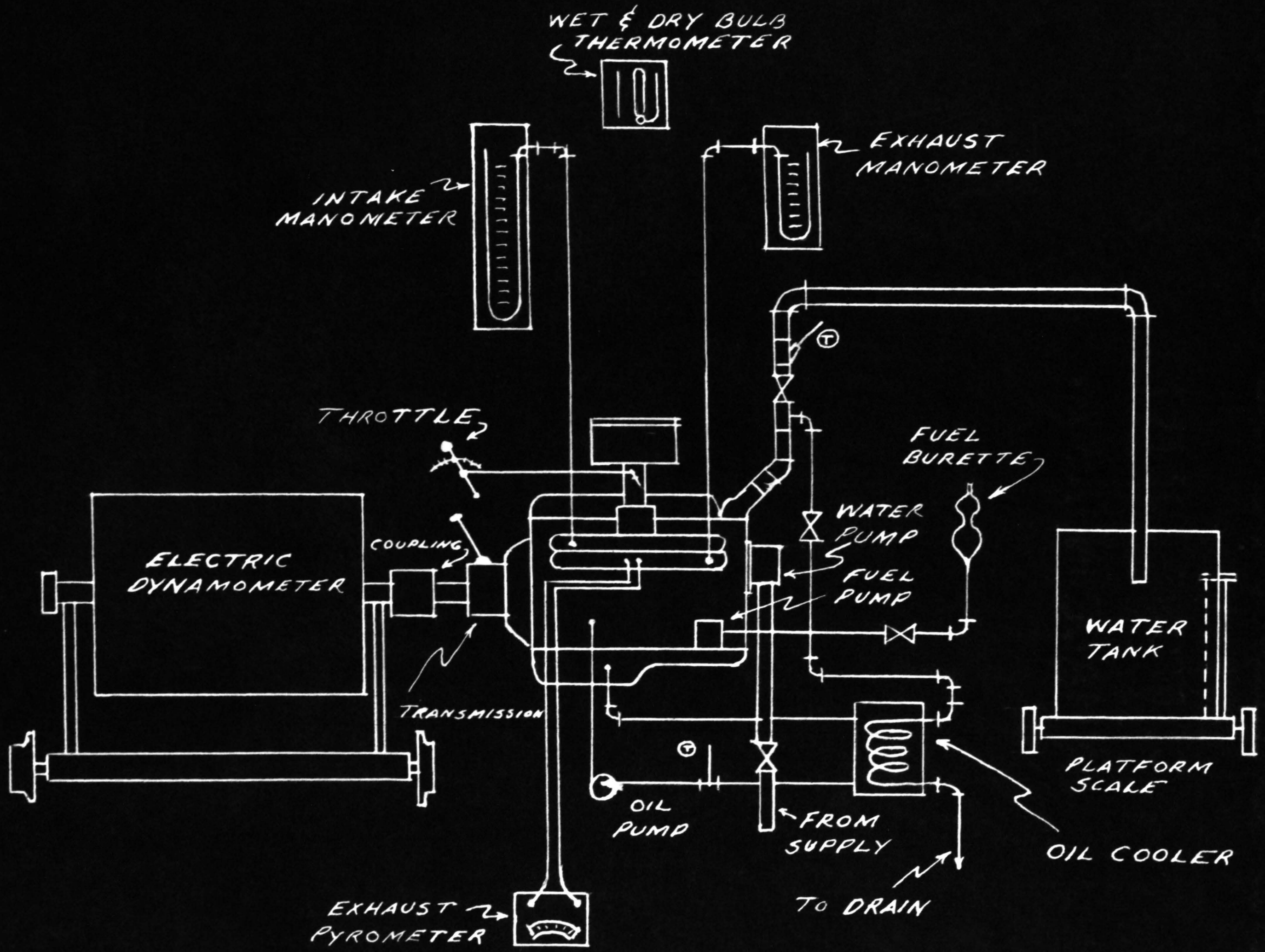
Stop Watch - Meylan

Fuel measuring apparatus - Laboratory constructed

Fuel - Esso Standard

Lubricant - Essolube 20W

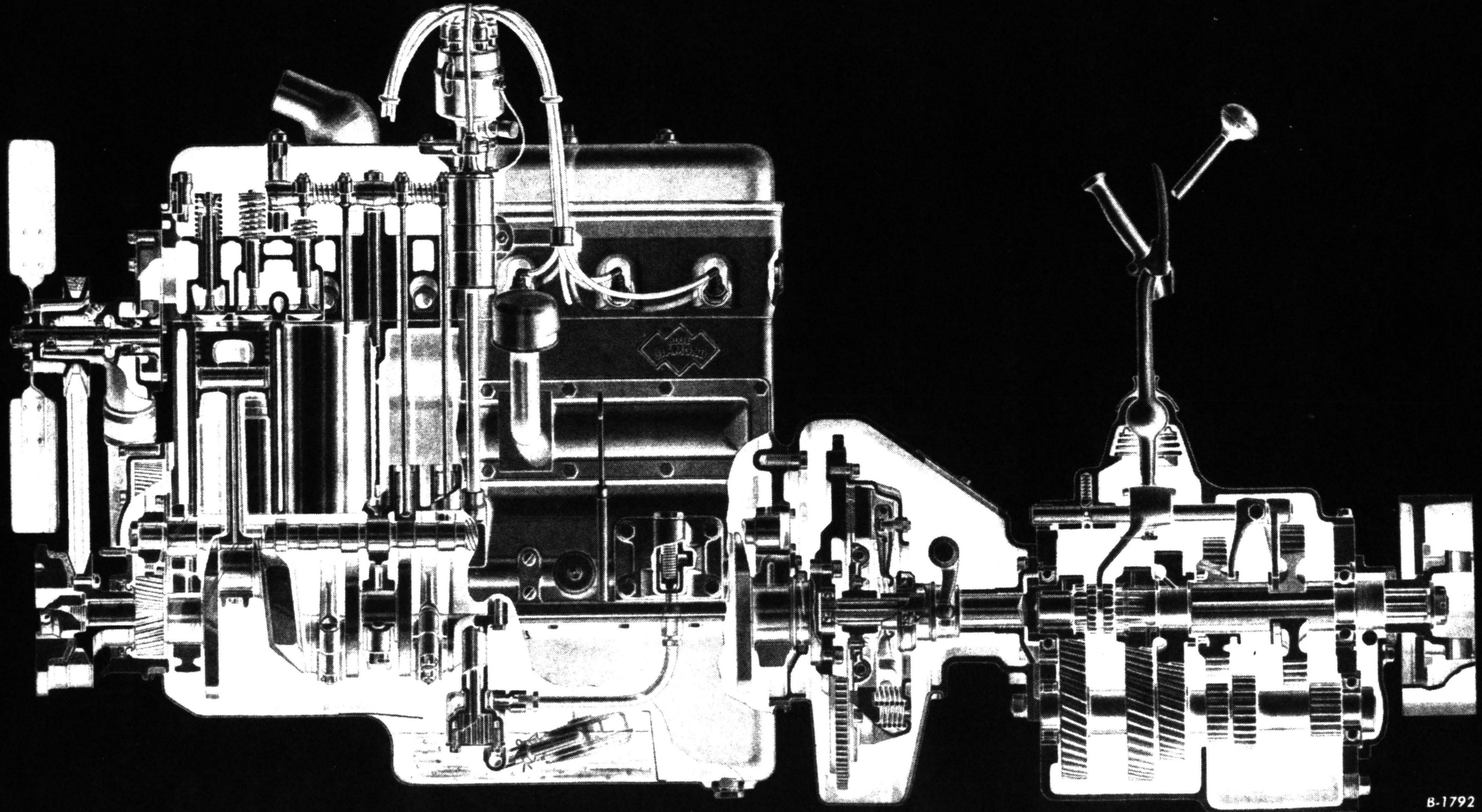
Brown Pyrometer - No. 45091



Ⓣ THERMOMETER

FIGURE I.

SCHEMATIC DIAGRAM OF APPARATUS



Sectional View of the Blue Diamond Engine, Clutch and Transmission

FIGURE 2

The valve mechanism as shown in the cross-sectional view of the engine on the previous page is not very clear. In order that readers who are not familiar with the procedure for adjusting valve tappets to have a better understanding of the work; a discussion of the method of adjustment is necessitated.

The mechanism for operation of the valves is known as the "overhead" type. In this type of arrangement the cam follower is attached to a push rod. The push rod is connected to a rocker arm on top of the engine by means of a ball and socket joint; the socket is an integral part of an adjusting screw threaded to the rocker arm and held in position by a lock nut. The opposite end of the rocker arm comes in contact with the valve stem to affect the opening an closing of the valve. Between the rocker arm and the valve stem there is a small clearance provided to allow for valve stem expansion and sinking of the valve seat. This clearance is the tappet clearance.

The adjustment of this clearance is accomplished in the following manner: the engine is first started and allowed to warm up to operating temperature, then by losening the lock nut and inserting a screw driver in the slot of the adjusting screw it is possible to change the position of the rocker arm on the push rod and thereby vary the tappet clearance. The desired clearance is obtained by means of a "feeler-strip" and the adjusting screw locked in position by tightening the lock nut.

C - Procedure

The procedure for conducting the actual tests was very simple. In order to obtain results which could be compared, a problem commonly encountered in work concerned with Internal Combustion Engines presented itself. In this respect there were two factors over which the investigator had only a limited control; the variability of error in handling the equipment and the changing atmospheric conditions. To combat this situation three runs were made with the engine set to the manufacturer's specifications, and the results of the identical tests indicated that the error caused by the handling of equipment was very slight and negligible. To account for changing atmospheric conditions, the procedure used by the Society of Automotive Engineers was followed. The S.A.E. formulae corrects the results to 29.92 pounds per square inch absolute, 60° Fahrenheit, and to zero vapor pressure. Having corrected the results in this manner it was possible to make comparisons. To reduce the possibility of error even more, the tests were conducted at approximately the same time each day in order to obtain values under reasonably constant atmospheric conditions.

During the tests, progress was often halted by a vapor lock in the fuel system. This condition was caused by the fuel pump's becoming excessively hot during the test runs. The only way found to relieve this situation was to cool the pump by pressing a cold, wet rag against it periodically. Evidently, air passing over the pump when the engine is installed in actual road equipment keeps the pump cool. Although cooling the pump in the manner described did not completely eliminate the problem, it did prove profitable.

The plan used was to run power tests on the engine with everything set to the manufacturer's specifications, and to follow these tests with similar ones at different settings by intentionally maladjusting the engine. This plan proved to be satisfactory only after having adopted the correction procedure mentioned previously. Each of these power tests was divided into two parts, one at full throttle and the other with road load performance.

Data gathered during each test included engine speed, length of time required to burn a given quantity of fuel, brake load, volume of fuel burned, exhaust gas temperature, room temperature, cooling water temperature, oil temperature, intake manifold vacuum, exhaust manifold pressure, and the barometric pressure. The data were collected and recorded over a speed range of from 1000 to 3000 revolutions per minute in increments of 500.

Fixed parameters for full throttle performance were the speed of the engine, the volume of the fuel burned, and the oil and water temperature. All other data were read as they appeared.

The road load tests required that the following parameters be fixed for each run: oil and water temperature, the volume of fuel burned, and the brake load and engine speed. All other data were read as they appeared. The brake load for a particular engine speed was determined as shown in the calculations.

The first tests dealt with full power and road load performance with the engine set to the manufacturer's specifications. These tests were conducted three times, and the results when corrected, were so nearly the same that it was thought unnecessary to compute an average. The investigator used only one of the three as a basis with which to compare the tests which were to follow.

Power tests were made subsequently with the valve tappets intentionally maladjusted to the following conditions:

1 - The intake valve tappets were set to six one thousandths less than that which the manufacturer specified. At this setting the engine began to idle roughly. It is doubted, however, if this condition would be noticed by the untrained ear. The engine appeared to run smoothly at higher speeds.

2 - Before beginning the second series of tests the intake valves were set six one thousandths above the specified clearance, and the exhaust valves checked to ascertain whether or not they had changed appreciably during the first series of tests. Idling was as rough as before.

3 - A third series of tests was conducted with the intake tappets set to the standard clearance, and the exhaust clearance set six one thousandths less than the standard. At this setting it was obvious that fuel consumption had increased, since the exhaust conduit was actually wet with raw gasoline.

4 - The fourth test series was conducted with the intake valve tappets set to standard, and the exhaust tappets set six one thousandths above the manufacturer's recommendation. No apparent change could be detected by eye nor ear.

5 - For this series, both intake and exhaust tappets were set six one thousandths below the standard. The engine at this condition ran very quietly; however, the engine appeared to run roughly and performance was far from normal.

6 - The last series was conducted with both the intake and exhaust tappets adjusted six one thousandths above the manufacturer's specification. Under this condition the engine performed noisily and poorly.

To decide upon a rational value for maladjustment of the valve tappets offered some difficulty. The investigator had first intended to conduct a much more extensive test than was actually run. After having made several tests with the engine maladjusted, it was decided to reduce the number since running with these misadjustments appeared to be harmful to the engine. With this factor in mind and since positive results were desired, only a portion of the originally planned tests were conducted.

D Results

The results of the experimentation have been presented graphically for the purpose of clarity and conciseness. The absolute values obtained with the engine set to standard have been plotted. These values include full-load power, full-load economy, road-load power and road-load economy. The results of subsequent tests have been plotted as a percentage change from normal above and below a zero line which represents the performance of the engine when set to the manufacturer's recommendations. This procedure was followed as the author felt that the changes which occurred with the test engine may not be strictly true with other engines. It is felt, however, that any automotive engine operating with similar maladjustments will perform like the test engine. Three curves are plotted for each power test run under a maladjusted condition, these curves being the changes in full-load power, the change in full-load economy, and the change in road-load economy.

It should be mentioned again that all results have been corrected to the same datum and, therefore, can be compared.

The difficulties encountered with the fuel systems vapor locking should be mentioned again. It is impossible to say definitely whether or not the results were affected by this condition. It seems improbable, in that the engine would not run when it became vapor locked, and all runs during which the engine became vapor locked were, of course, discarded and repeated.

Table No. 1

FULL POWER PERFORMANCE ENGINE SET TO MANUFACTURER'S RECOMMENDATION					
Run Number	1	2	3	4	5
Counter Reading	227	239	248	265	280
Length of Run	2:24.0	1:34.0	1:15.8	1:03.0	0:55.9
Brake Load	108.4	105.4	99.4	86.3	72.7
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1110	1250	1360	1415	1460
Water Temp.	159	162	162	160	159
Oil Temp.	105	110	106	110	118
Room Temp.	81	82	83	83	84
Intake Manifold (a) Pressure (b)	0.44 0.40	0.60 0.70	1.10 1.10	1.50 1.50	1.90 1.90
Exhaust Manifold (a) Pressure (b)	0.75 0.75	1.30 1.30	2.00 2.00	3.00 3.00	3.60 3.60
Actual Test Speed	955	1525	1965	2520	3005
Average Intake Manifold Pressure	0.42	0.60	1.10	1.50	1.90
Average Exhaust Manifold Pressure	0.75	1.30	2.00	3.00	3.60
Average Room Temp.	83	83	83	83	83
Barometric Pressure	28.21	28.21	28.21	28.21	28.21
Vapor Pressure	1.138	1.138	1.138	1.138	1.138
Correction Factor	1.128	1.128	1.128	1.128	1.128
Uncorrected BHP	34.2	53.7	66.4	72.7	72.9
Corrected BHP	38.5	60.5	74.9	82.0	82.9
Specific Fuel Consumption	0.527	0.513	0.519	0.565	0.636

Table No. 2

ROADLOAD PERFORMANCE ENGINE SET TO MANUFACTURER'S RECOMMENDATION					
Run Number	1	2	3	4	5
Counter Reading	488	523	481	450	401
Length of Run	5:20.0	3:05.0	2:24.7	1:48.8	1:20.1
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	660	830	1010	1070	1320
Water Temp.	160	164	164	162	162
Oil Temp.	110	112	107	111	110
Room Temp.	80	82	81	80	83
Intake Manifold (a) Pressure (b)	19.1 19.1	19.3 19.3	18.1 18.1	17.1 17.1	13.25 13.25
Exhaust Manifold (a) Pressure (b)	0.05 0.05	0.10 0.10	0.25 0.25	0.50 0.50	0.95 0.95
Actual Test Speed	918	1740	1990	2485	3000
Average Intake Manifold Pressure	19.1	19.3	18.1	17.1	13.25
Average Exhaust Manifold Pressure	0.05	0.10	0.25	0.50	0.95
Average Room Temp.	81	81	81	81	81
Barometric Pressure	28.21	28.21	28.21	28.21	28.21
Vapor Pressure	1.065	1.065	1.065	1.065	1.065
Correction Factor	1.125	1.125	1.125	1.125	1.125
Uncorrected BHP	2.84	6.50	10.65	16.40	25.40
Corrected BHP	3.20	7.32	12.00	18.45	28.60
Specific Fuel Consumption	1.709	1.290	1.012	0.872	0.766

Table No. 3

RESULTS ENGINE SET TO MANUFACTURER'S RECOMMENDATION					
Speed	1000	1500	2000	2500	3000
Full Load Corrected BHP	40.5	59.5	75.0	82.0	82.9
Full Load Specific Fuel Consumption	0.53	0.51	0.52	0.56	0.636
Road Load Corrected BHP	3.7	7.5	12.1	18.2	28.6
Road LoadSpecific Fuel Consumption	1.65	1.31	1.03	0.84	0.766

Table No. 4

FULL POWER PERFORMANCE INTAKE TAPPETS .006 LESS THAN RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	229	238	244	255	255
Length of Run	3:04.5	1:36.0	1:11.5	1:00.9	0:51.25
Brake Load	106.6	104	97	88	75.5
ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1170	1260	1370	1460	——
Water Temp.	160	160	163	160	160
Oil Temp.	110	118	108	110	110
Room Temp.	74	75	74	74	74
Intake Manifold 1. Pressure 2.	0.7 0.7	0.60 0.60	1.10 1.10	1.50 1.50	1.75 1.75
Exhaust Manifold 1. Pressure 2.	0.70 0.70	0.70 0.70	0.60 0.60	0.80 0.80	1.00 1.00
Actual Test Speed	752	1488	2025	2550	2991
Average Intake Manifold Pressure	0.70	0.60	1.10	1.50	1.75
Average Exhaust Manifold Pressure	0.70	0.70	0.60	0.80	1.00
Average Room Temper.	74	74	74	74	74
Barometric Pressure	28.30	28.30	28.30	28.30	28.30
Vapor Pressure	0.846	0.846	0.846	0.846	0.846
Correction Factor	1.105	1.105	1.105	1.105	1.105
Uncorrected BHP	23.5	51.5	66.2	75.0	75.25
Corrected BHP	26.0	56.9	73.1	82.8	83.2
Specific Fuel Consumption	0.609	0.538	0.558	0.588	0.685

Table No. 5

ROAD LOAD PERFORMANCE INTAKE TAPPETS .006 LESS THAN RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	487	509	485	420	400
Length of Run	5:06.5	3:27.2	2:28.3	1:40.2	1:20.8
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	700	860	1040	1200	1310
Water Temp.	160	160	160	160	160
Oil Temp.	110	115	106	110	110
Room Temp.	74	73	74	74	74
Intake Manifold 1. Pressure 2.	19.0 19.0	19.0 19.0	18.0 18.0	16.2 16.2	13.9 13.9
Exhaust Manifold 1. Pressure 2.	0.1 0.1	0.1 0.1	0.1 0.1	0.1 0.1	0.3 0.3
Actual Test Speed	998	1475	1962	2519	2970
Average Intake Manifold Pressure	19.0	19.0	18.0	16.2	13.9
Average Exhaust Manifold Pressure	0.1	0.1	0.1	0.1	0.3
Average Room Temp.	74	74	74	74	74
Barometric Pressure	28.30	28.30	28.30	28.30	28.30
Vapor Pressure	0.846	0.846	0.846	0.846	0.846
Correction Factor	1.105	1.105	1.105	1.105	1.105
Uncorrected BHP	2.96	5.66	10.08	16.71	25.15
Corrected BHP	3.27	6.27	11.93	18.50	27.80
Specific Fuel Consumption	1.79	1.15	0.984	0.935	0.759

Table No. 6

RESULTS INTAKE TAPPETS .006 LESS THAN RECOMMENDED CLEARANCE Full Power Performance					
Speed	1000	1500	2000	2500	3000
Corrected BHP	37.5	57.2	72.5	82.0	82.9
Change in Full Power	-7.5	-3.87	-3.45	0	0
Specific Fuel Consumption	0.560	0.530	0.560	0.580	0.685
Change in Full Load Economy	+5.78	+4.93	+7.69	+3.57	+7.70
Road Load Performance					
Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.78	1.18	0.90	0.82	0.82
Change in Road	+7.88	-9.93	-12.6	-2.38	+7.05

Table No. 7

FULL POWER PERFORMANCE

INTAKE TAPPETS .006 ABOVE RECOMMENDED CLEARANCE

Run Number	1	2	3	4	5
Counter Reading	228	233	243	254	281
Length of Run	2:14.3	1:33.3	1:11.1	1:02.5	0:56.5
Brake Load	105.1	104.4	97.6	88.0	73.3
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1160	1260	1390	1440	1480
Water Temp.	160	160	160	160	160
Oil Temp.	108	110	115	115	110
Room Temp.	70	70	71	72	72
Intake Manifold (a) Pressure (b)	0.3 0.3	0.6 0.6	1.1 1.1	1.5 1.5	1.8 1.8
Exhaust Manifold (a) Pressure (b)	0.5 0.5	0.7 0.7	0.9 0.9	1.0 1.0	1.24 1.24
Actual Test Speed	1020	1500	2050	2418	2900
Average Intake Manifold Pressure	0.3	0.6	1.1	1.5	1.8
Average Exhaust Manifold Pressure	0.5	0.7	0.9	1.0	1.25
Average Room Temp.	71	71	71	71	71
Barometric Pressure	28.30	28.30	28.30	28.30	28.30
Vapor Pressure	0.765	0.765	0.765	0.765	0.765
Correction Factor	1.10	1.10	1.10	1.10	1.10
Uncorrected BHP	35.8	52.25	66.6	71.4	73.2
Corrected BHP	39.4	57.5	73.25	78.5	80.5
Specific Fuel Consumption	0.5525	0.543	0.561	0.596	0.643

Table No. 8

ROAD LOAD PERFORMANCE INTAKE TAPPETS .006 ABOVE RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	493	505	465	437	390
Length of Run	5:00.25	3:23.6	2:19.2	1:44	1:18.5
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	660	820	1010	1200	1380
Water Temp.	160	160	160	160	160
Oil Temp.	110	110	110	115	106
Room Temp.	71	71	71	71	71
Intake Manifold (a) Pressure (b)	19.0 19.0	19.0 19.0	17.5 17.5	15.7 15.7	13.1 13.1
Exhaust Manifold (a) Pressure (b)	0.05 0.05	0.10 0.10	0.10 0.10	0.15 0.15	0.50 0.50
Actual Test Speed	986	1489	2005	2510	2930
Average Intake Manifold Pressure	19.0	19.0	17.5	15.7	13.1
Average Exhaust Manifold Pressure	.05	.10	.10	.15	.50
Average Room Temp.	71	71	71	71	71
Barometric Pressure	28.30	28,30	28.30	28,30	28.30
Vapor Pressure	0.765	0.765	0.765	0.765	0.765
Correction Factor	1.10	1.10	1.10	1.10	1.10
Uncorrected BHP	3.06	5.71	10.30	16.75	25.30
Corrected BHP	3.37	6.28	11.32	18.40	27.80
Specific Fuel Consumption	1.730	1.375	1.110	0.916	0.805

Table No. 9

RESULTS

INTAKE TAPPETS .006 ABOVE RECOMMENDED CLEARANCE

Full Power Performance

Speed	1000	1500	2000	2500	3000
Corrected BHP	38.5	59.5	77.5	84.5	85.0
Change in Full Power	-3.71	0.0	+3.33	+3.05	+2.54
Specific Fuel Consumption	0.559	0.550	0.560	0.600	0.660
Change in Full Load Economy	+5.48	+7.85	+7.70	+7.15	+3.78

Road Load Performance

Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.73	1.34	1.03	0.86	0.85
Change in Road Load Economy	+4.85	+2.29	0	+2.38	+10.84

Table No. 10

FULL POWER PERFORMANCE EXHAUST TAPPETS .006 BELOW RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	227.7	234.0	231.0	192.0	183.0
Length of Run	2:06.1	1:32.6	1:10.3	0:45.8	0:36.4
Brake Load	108	105.3	98.2	86.5	72.5
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1060	1220	1270	1410	1420
Water Temp.	160	158	162	160	160
Oil Temp.	110	115	110	105	105
RoomTemp.	74	74	76	76	76
Intake Manifold (a) Pressure (b)	0.375 0.375	0.75 0.75	0.50 0.50	0.25 0.25	0.1875 0.1875
Exhaust Manifold (a) Pressure (b)	0.375 0.375	0.50 0.50	0.75 0.75	0.875 0.875	1.0 1.0
Actual Test Speed	1080	1515	1970	2520	3015
Average Intake Manifold Pressure	0.375	0.75	0.50	0.25	0.1875
Average Exhaust Manifold Pressure	0.375	0.50	0.75	0.875	1.0
Average Room Temp.	75	75	75	75	75
Barometric Pressure	28.09	28.09	28.09	28.09	28.09
Vapor Pressure	0.880	0.880	0.880	0.880	0.880
Correction Factor	1.114	1.114	1.114	1.114	1.114
Uncorrected BHP	38.9	53.2	65.1	72.5	72.7
Corrected BHP	43.4	59.4	72.7	80.9	81.2
Specific Fuel Consumption	0.532	0.531	0.572	0.790	0.990

Table No. 11

ROAD LOAD PERFORMANCE EXHAUST TAPPETS .006 BELOW RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	472	502	456	429	388
Length of Run	4:57.5	3:21.5	2:14.0	1:43.8	1:17.5
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	635	815	1010	1090	1230
Water Temp.	160	163	160	162	160
Oil Temp.	110	115	108	105	110
Room Temp.	75	75	75	73	73
Intake Manifold (a) Pressure (b)	19 19	19 19	17 17	16 16	13.25 13.25
Exhaust Manifold (a) Pressure (b)	0.375 0.375	0.375 0.375	0.250 0.250	0.250 0.250	0.375 0.375
Actual Test Speed	968	1505	1955	2480	3000
Average Intake Manifold Pressure	19	19	17	16	13.25
Average Exhaust Manifold Pressure	0.375	0.375	0.250	0.250	0.375
Average Room Temp.	74.2	74.2	74.2	74.2	74.2
Barometric Pressure	28.09	28.09	28.09	28.09	28.09
Vapor Pressure	0.880	0.880	0.880	0.880	0.880
Correction Factor	1.114	1.114	1.114	1.114	1.114
Uncorrected BHP	3.0	5.71	10.02	16.4	25.4
Corrected BHP	3.34	6.36	11.2	18.3	28.3
Specific Fuel Consumption	1.810	1.375	1.172	0.934	0.804

Table No. 12

RESULTS

EXHAUST TAPPETS .006 BELOW RECOMMENDED CLEARANCE

Full Power Performance					
Speed	1000	1500	2000	2500	3000
Corrected BHP	43.4	59.4	73.5	80.0	81.5
Change in Full Power	+7.16	0	+2.00	+1.455	+1.690
Specific Fuel Consumptioh	0.54	0.53	0.575	0.715	0.98
Change in Full Load Economy	+1.88	+3.93	+10.55	+27.6	+54.2
Road Load Performance					
Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.75	1.40	1.10	0.90	0.804
Change in Road Load Economy	+6.06	+6.87	+6.80	+7.15	+5.00

Table No. 13

FULL POWER PERFORMANCE EXHAUST TAPPETS .006 ABOVE RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	228.2	236.0	249.0	265.0	280.0
Length of Run	2:06.1	1:33.2	1:15.1	1:02.4	0:55.2
Brake Load	87.7	83.5	75.2	63.7	52.3
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1040	1140	1360	1360	1410
Water Temp.	162	160	160	160	158
Oil Temp.	105	110	112	110	115
Room Temp.	88	90	99	89	90
Intake Manifold (a) Pressure (b)	0.3 0.3	0.6 0.6	1.0 1.0	1.5 1.5	1.8 1.8
Exhaust Manifold (a) Pressure (b)	0.1 0.1	0.15 0.15	0.15 0.15	0.15 0.15	0.15 0.15
Actual Test Speed	1087	1520	1990	2545	3210
Average Intake Manifold Pressure	0.3	0.6	1.0	1.5	1.8
Average Exhaust Manifold Pressure	0.1	0.15	0.15	0.15	0.15
Average Room Temp.	90	90	90	90	90
Barometric Pressure	28.01	28.01	28.01	28.01	28.01
Vapor Pressure	1.4215	1.4215	1.4215	1.4215	1.4215
Correction Factor	1.160	1.160	1.160	1.160	1.160
Uncorrected BHP	31.75	42.3	49.9	54.2	56.0
Corrected BHP	36.8	49.0	57.8	62.8	65.0
Specific Fuel Consumption	.630	.640	.671	0.746	0.814

Table No. 14

ROAD LOAD PERFORMANCE EXHAUST TAPPETS .006 ABOVE RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	409.0	419.1	405.2	365.0	272.0
Length of Run	4:14.0	2:48.2	2:018	1:28.1	0:55.1
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	550	720	900	1080	1210
Water Temp.	162	164	164	160	160
Oil Temp.	95	100	108	106	110
Room Temp.	91	90	91	90	90
Intake Manifold (a) Pressure (b)	17.4 17.4	17.3 17.3	16.0 16.0	13.5 13.5	8.5 8.5
Exhaust Manifold (a) Pressure (b)	0.05 0.05	0.05 0.05	0.05 0.05	0.10 0.10	0.10 0.10
Actual Test Speed	968	1498	2000	2490	2965
Average Intake Manifold Pressure	17.4	17.3	16.0	13.5	8.5
Average Exhaust Manifold Pressure	0.05	0.05	0.05	0.10	0.10
Average Room Temp.	90	90	90	90	90
Barometric Pressure	28.01	28.01	28.01	28.01	28.01
Vapor Pressure	1.4215	1.4215	1.4215	1.4215	1.4215
Correction Factor	1.16	1.16	1.16	1.16	1.16
Uncorrected BHP	3.00	5.74	10.25	16.50	23.90
Corrected BHP	3.48	6.65	11.90	18.10	27.70
Specific Fuel Consumption	2.00	1.575	1.21	1.11	1.16

Table No. 15

RESULTS

EXHAUST TAPPETS .006 ABOVE RECOMMENDED CLEARANCE

Full Power Performance

Speed	1000	1500	2000	2500	3000
Corrected BHP	34.0	48.5	57.5	63.0	65.0
Change in Full Power	-16.05	-18.50	-22.30	-23.20	-21.50
Specific Fuel Consumption	0.637	0.636	0.670	0.730	0.800
Change in Full Load Economy	+22.5	+24.7	+29.4	+31.5	+25.8

Road Load Performance

Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.86	1.52	1.21	1.12	1.18
Change in Road Load Economy	+12.73	+16.0	+17.5	+32.3	+41.0

Table No. 16

FULL POWER PERFORMANCE INTAKE AND EXHAUST .006 BELOW RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	225.0	228.0	241.2	249.1	279.0
Length of Run	2:04.0	1:00.7	1:10.5	1:00.0	0:55.2
Brake Load	91,0	85.2	76.4	64.3	53.9
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	990	1160	1400	1400	1470
Water Temp.	160	160	160	162	160
Oil Temp.	100	105	105	109	112
Room Temp.	74	72	74	72	74
Intake Manifold (a) Pressure (b)	0.4 0.4	0.6 0.6	1.0 1.0	0.75 0.75	1.9 1.9
Exhaust Manifold (a) Pressure (b)	0.1 0.1	0.1 0.1	0.15 0.15	0.15 0.15	0.15 0.15
Actual Test Speed	1090	----	2050	2491	3030
Average Intake Manifold Pressure	0.4	0.6	1.0	0.75	1.9
Average Exhaust Manifold Pressure	0.1	0.1	0.15	0.15	0.15
Average Room Temp.	73	73	73	73	73
Barometric Pressure	28.01	28.01	28.01	28.01	28.01
Vapor Pressure	0.8183	0.8183	0.8183	0.8183	0.8183
Correction Factor	1.1150	1.1150	1.1150	1.1150	1.1150
Uncorrected BHP	33.0	----	52.2	53.4	54.4
Corrected BHP	36.8	----	58.2	59.5	60.6
Specific Fuel Consumption	0.640	----	0.713	0.818	0.874

Table No. 17

ROAD LOAD PERFORMANCE INTAKE AND EXHAUST .006 BELOW RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	482.2	481.0	445.0	357.0	326.0
Length of Run	4:42.5	3:09.1	2:14.75	1:24.0	1:05.5
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	715	885	1040	1175	1260
Water Temp.	160	160	165	160	164
Oil Temp.	110	105	115	110	110
Room Temp.	73	72	72	72	72
Intake Manifold (a) Pressure (b)	19.0 19.0	18.5 18.5	17.0 17.0	15.0 15.0	11.0 11.0
Exhaust Manifold (a) Pressure (b)	0.2 0.2	0.25 0.25	0.25 0.25	0.35 0.35	0.6 0.6
Actual Test Speed	1025	1530	1985	2550	3170
Average Intake Manifold Pressure	19.0	18.5	17.0	15.0	11.0
Average Exhaust Manifold Pressure	0.20	0.25	0.25	0.35	0.60
Average Room Temp.	72	72	72	72	72
Barometric Pressure	28.26	28.26	28.26	28.26	28.26
Vapor Pressure	0.7912	0.7912	0.7912	0.7912	0.7912
Correction Factor	1.10	1.10	1.10	1.10	1.10
Uncorrected BHP	3.19	5.86	10.15	16.90	26.70
Corrected BHP	3.52	6.45	11.20	18.60	29.40
Specific Fuel Consumption	1.780	1.450	1.170	1.130	0.918

Table No. 18

RESULTS

INTAKE AND EXHAUST .006 BELOW RECOMMENDED CLEARANCE

Full Power Performance

Speed	1000	1500	2000	2500	3000
Corrected BHP	33.5	47.0	57.0	60.5	61.0
Change in Full Power	-17.3	-21.0	-24.0	-26.3	-26.5
Specific Fuel Consumption	0.640	0.670	0.720	0.795	0.870
Change in Full Load Economy	+20.8	+31.4	+38.5	+42.0	+36.8

Road Load Performance

Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.780	1.500	1.180	1.010	0.910
Change in Road Load	+7.87	+14.45	+14.55	+19.00	+18.80

Table No. 19

FULL POWER PERFORMANCE INTAKE AND EXHAUST .006 ABOVE RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	227.0	234.0	251.2	263.0	554.0
Length of Run	2:11.0	1:36.0	1:13.0	1:04.2	0:56.2
Brake Load	83.2	80.6	71.3	63.0	49.5
Ml's of Fuel	500	500	500	500	500
Exhaust Temp.	1000	1180	1320	1420	1480
Water Temp.	160	161	161	164	158
Oil Temp.	102	101	110	110	112
RoomTemp.	88	87	86	86	85
Intake Manifold (a) Pressure (b)	0.3 0.3	0.3 0.3	0.6 0.6	1.4 1.4	1.7 1.7
Exhaust Manifold (a) Pressure (b)	0.05 0.05	0.10 0.10	0.10 0.10	0.10 0.10	0.15 0.15
Actual Test Speed	1040	1462	2065	2470	----
Average Intake Manifold Pressure	0.3	0.3	0.6	1.4	1.7
Average Exhaust Manifold Pressure	0.05	0.10	0.10	0.10	0.15
Average Room Temp.	86	86	86	86	86
Barometric Pressure	28.01	28.01	28.01	28.01	28.01
Vapor Pressure	1.2527	1.2527	1.2527	1.2527	1.2527
Correction Factor	1.146	1.146	1.146	1.146	1.146
Uncorrected BHP	28.8	40.6	49.1	52.0	----
Corrected BHP	33.0	46.5	56.3	59.6	----
Specific Fuel Consumption	0.676	0.655	0.710	0.764	----

Table No. 20

ROAD LOAD PERFORMANCE INTAKE AND EXHAUST .006 ABOVE RECOMMENDED CLEARANCE					
Run Number	1	2	3	4	5
Counter Reading	437.0	433.1	434.0	416.8	360.0
Length of Run	4:33.5	2:57.5	2:10.4	1:45.7	1:11.0
Brake Load	9.3	11.5	15.4	19.9	25.4
Ml's of Fuel	300	300	300	300	300
Exhaust Temp.	640	740	920	1130	1300
Water Temp.	158	160	160	160	162
Oil Temp.	104	108	108	112	115
Room Temp.	83	79	78	77	77
Intake Manifold (a) Pressure (b)	17.3 17.3	17.6 17.6	17.0 17.0	16.0 16.0	11.5 11.5
Exhaust Manifold (a) Pressure (b)	0.05 0.05	0.05 0.05	0.05 0.05	0.05 0.05	0.10 0.10
Actual Test Speed	960	1460	2000	2370	3040
Average Intake Manifold Pressure	17.3	17.6	17.0	16.0	11.5
Average Exhaust Manifold Pressure	0.05	0.05	0.05	0.05	0.10
Average Room Temp.	79	79	79	79	79
Barometric Pressure	28.01	28.01	28.01	28.01	28.01
Vapor Pressure	0.9989	0.9989	0.9989	0.9989	0.9989
Correction Factor	1.126	1.126	1.126	1.126	1.126
Uncorrected BHP	2.97	5.60	10.30	15.70	25.80
Corrected BHP	3.34	6.30	11.60	17.70	29.00
Specific Fuel Consumption	1.93	1.58	1.17	0.95	0.858

Table No. 21

RESULTS INTAKE AND EXHAUST .006 ABOVE RECOMMENDED CLEARANCE Full Power Performance					
Speed	1000	1500	2000	2500	3000
Corrected BHP	31.0	46.7	56.0	59.5	59.6
Change in Full Power	-23.5	-21.5	-25.3	-26.2	-28.1
Specific Fuel Consumptioh	0.685	0.685	0.700	0.765	0.850
Change in Full Load Economy	+29.2	+28.4	+34.6	+36.6	+33.6
Road Load Performance					
Speed	1000	1500	2000	2500	3000
Specific Fuel Consumption	1.88	1.50	1.17	0.94	0.85
Change in Road Load Economy	+14.00	+14.50	+13.60	+11.90	+10.95

ENGINE SET TO MANUFACTURER'S SPECIFICATIONS

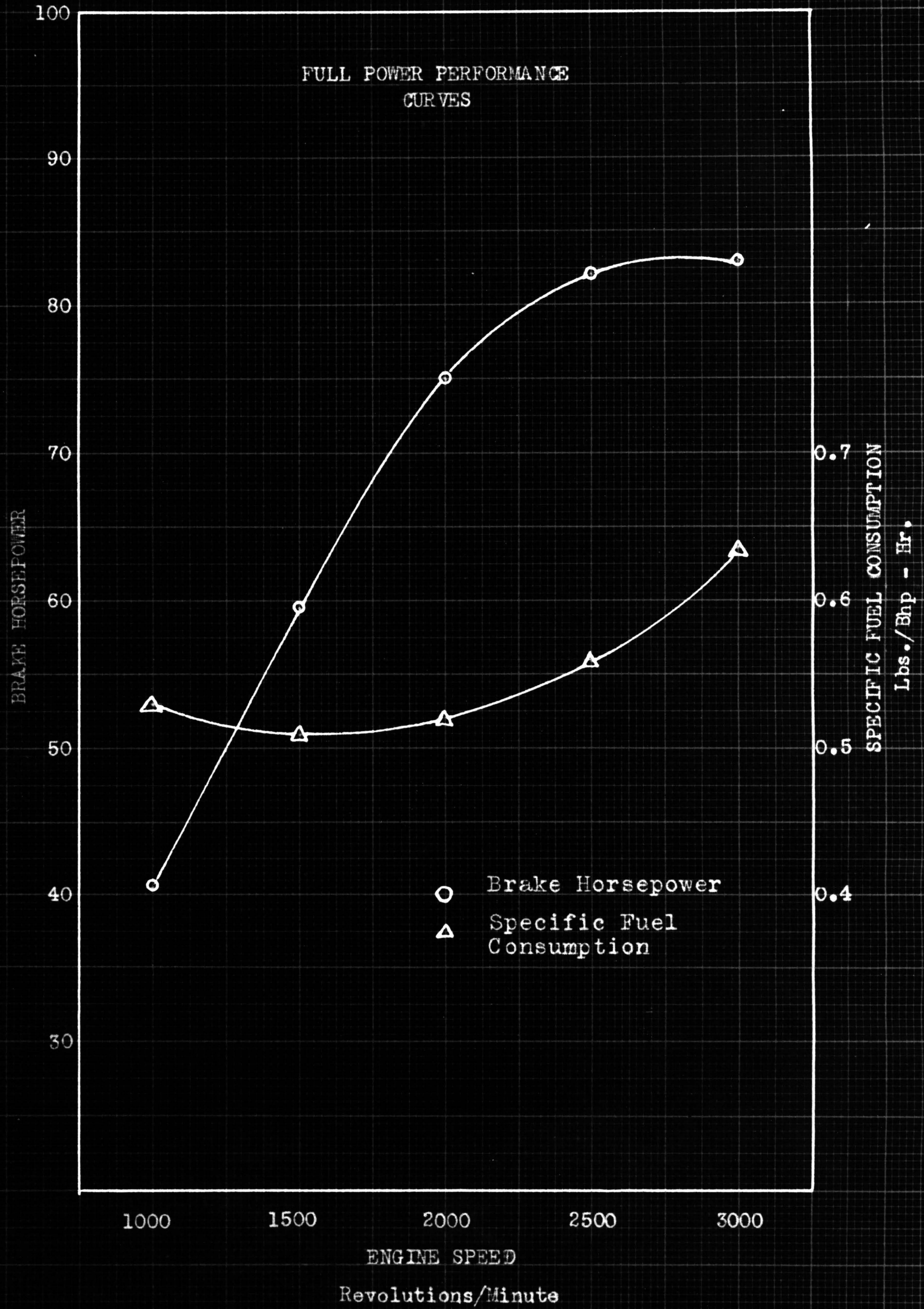


Figure 3

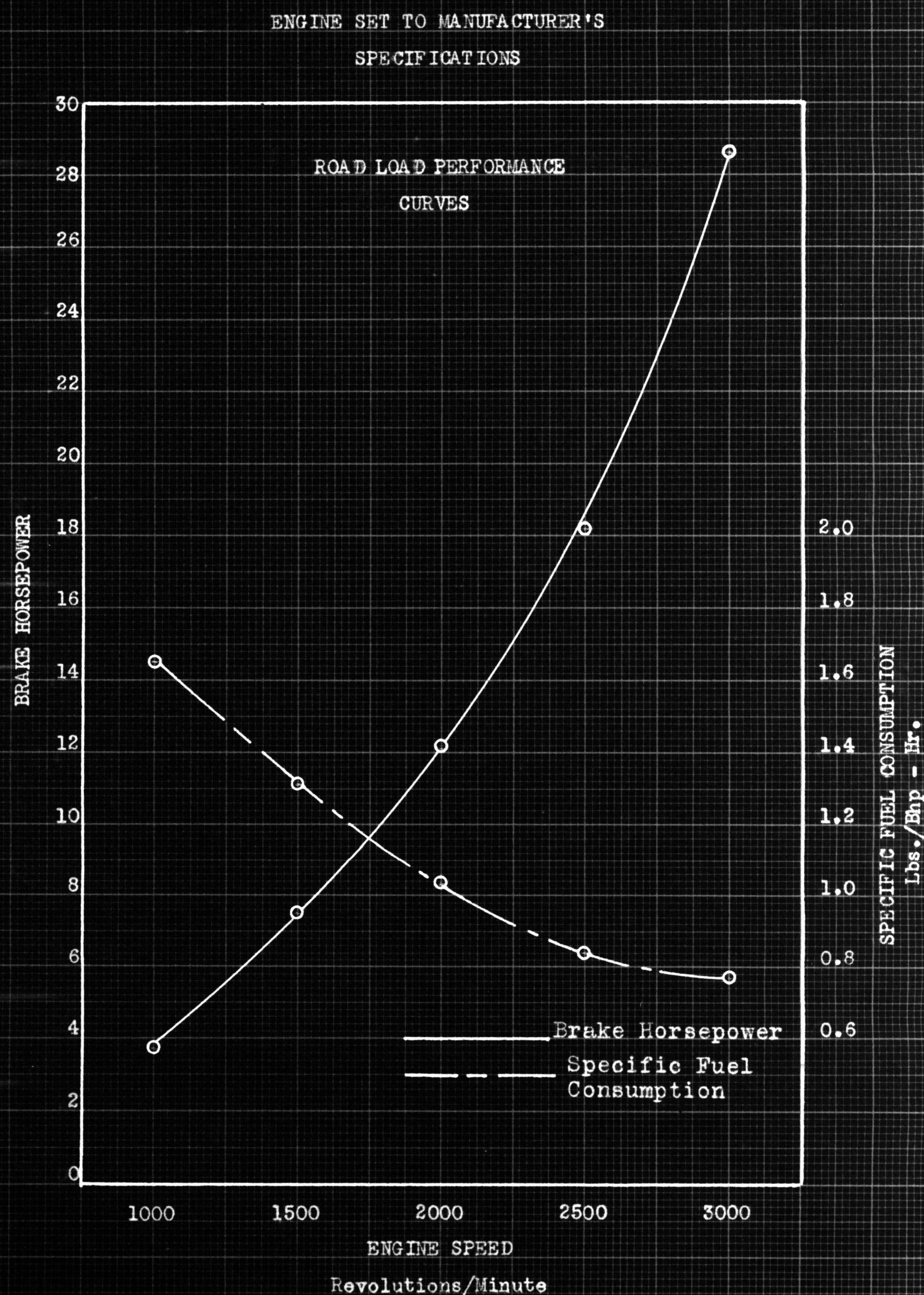

ENGINE SET TO MANUFACTURER'S
SPECIFICATIONS
ROAD LOAD PERFORMANCE
CURVES
BRAKE HORSEPOWER
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
SPECIFIC FUEL CONSUMPTION
Lbs./Bhp - Hr.
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
Brake Horsepower
Specific Fuel
Consumption
1000
1500
2000
2500
3000
ENGINE SPEED
Revolutions/Minute

Figure 4

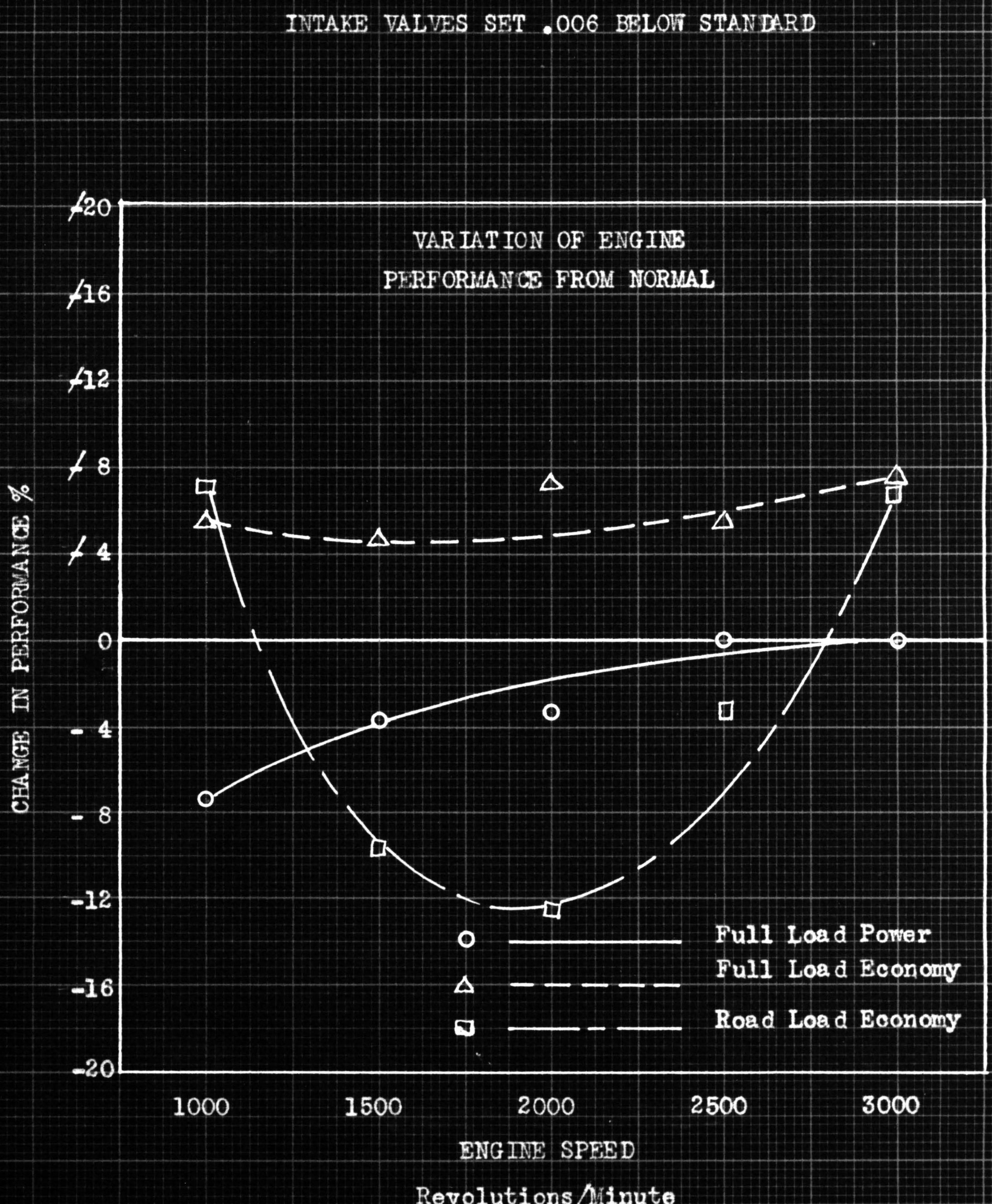

INTAKE VALVES SET .006 BELOW STANDARD
VARIATION OF ENGINE
PERFORMANCE FROM NORMAL
CHANGE IN PERFORMANCE %
+20
+16
+12
+ 8
+ 4
0
- 4
- 8
-12
-16
-20
1000
1500
2000
2500
3000
ENGINE SPEED
Revolutions/Minute
Full Load Power
Full Load Economy
Road Load Economy

Figure 5

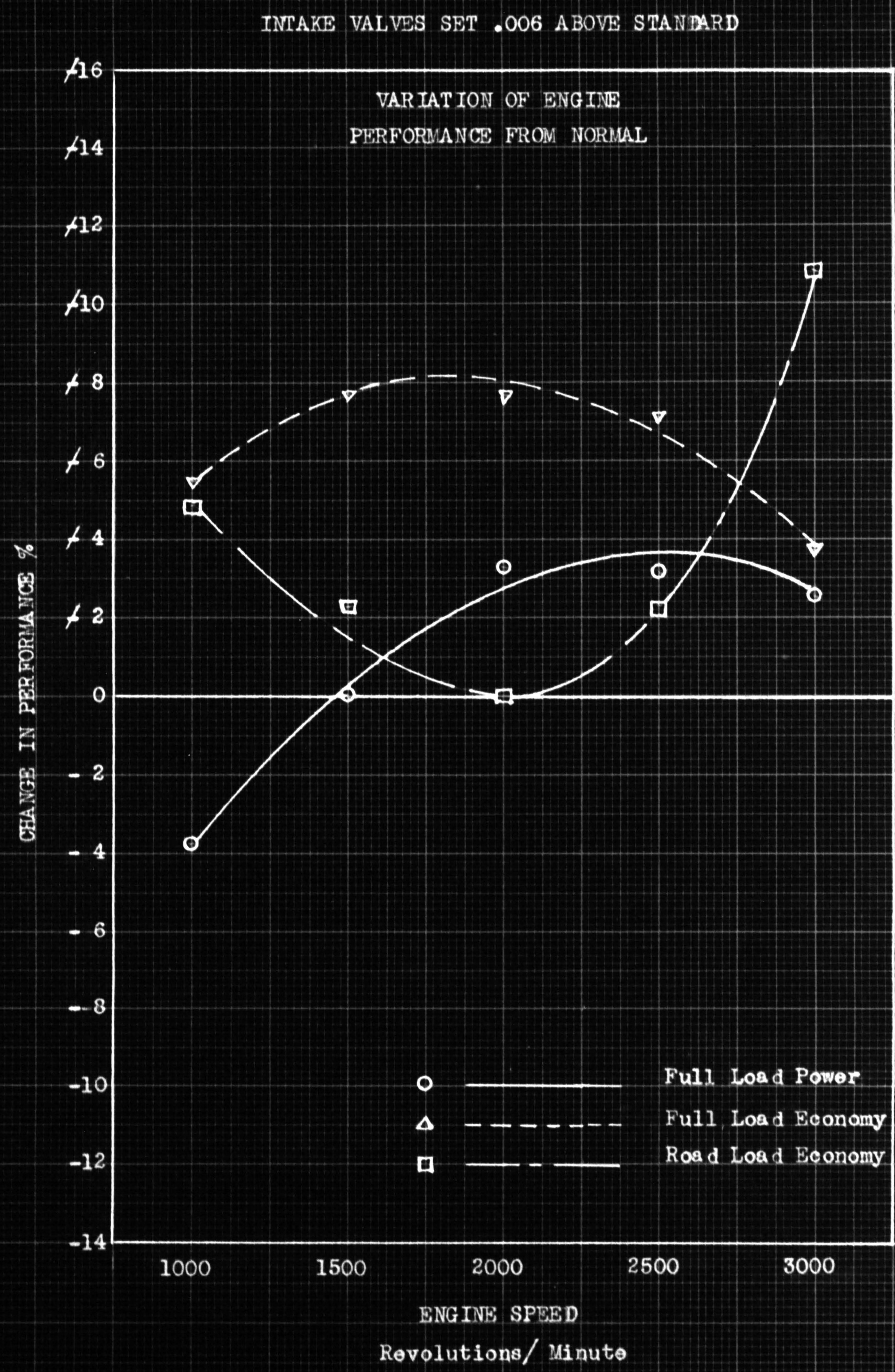

INTAKE VALVES SET .006 ABOVE STANDARD
VARIATION OF ENGINE
PERFORMANCE FROM NORMAL
CHANGE IN PERFORMANCE %
+16
+14
+12
+10
+ 8
+ 6
+ 4
+ 2
0
- 2
- 4
- 6
- 8
-10
-12
-14
1000
1500
2000
2500
3000
ENGINE SPEED
Revolutions/ Minute
Full Load Power
Full Load Economy
Road Load Economy

Figure 6

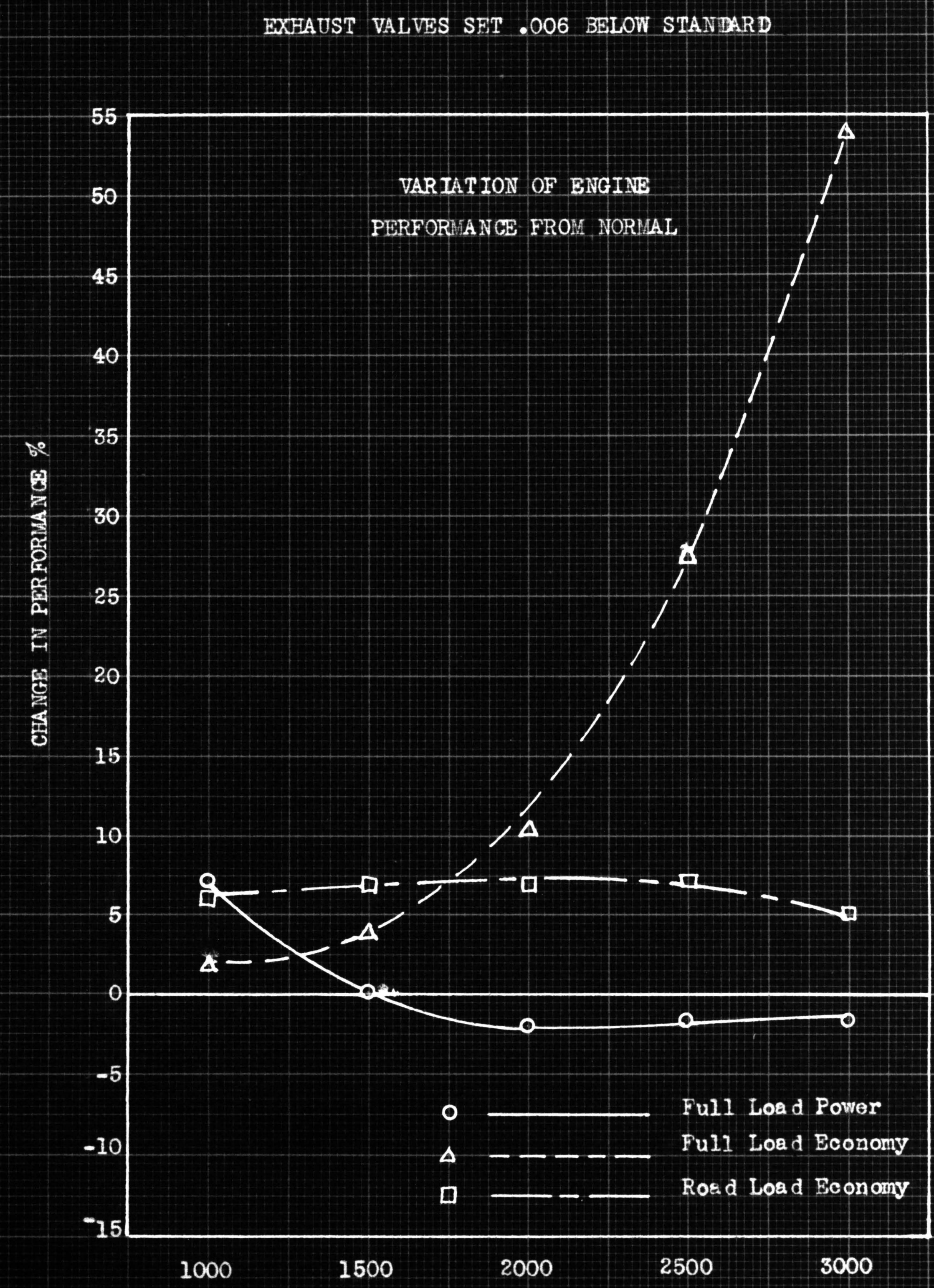

EXHAUST VALVES SET .006 BELOW STANDARD
VARIATION OF ENGINE
PERFORMANCE FROM NORMAL
CHANGE IN PERFORMANCE %
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
1000
1500
2000
2500
3000
Full Load Power
Full Load Economy
Road Load Economy

Figure 7

EXHAUST VALVES SET .006 ABOVE STANDARD

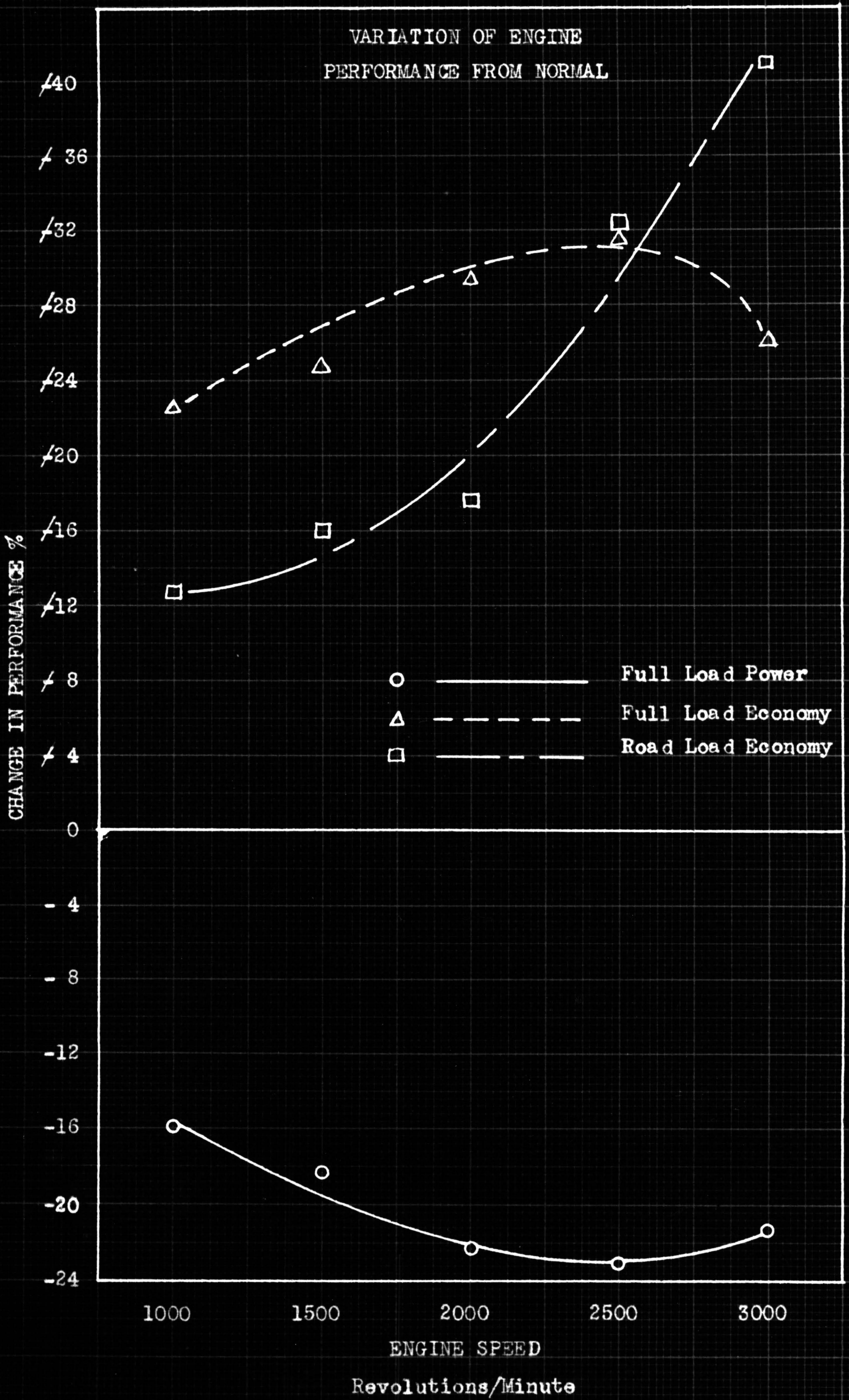


Figure 8

EXHAUST & INLET VALVES SET .006 BELOW STANDARD

VARIATION OF ENGINE PERFORMANCE FROM NORMAL

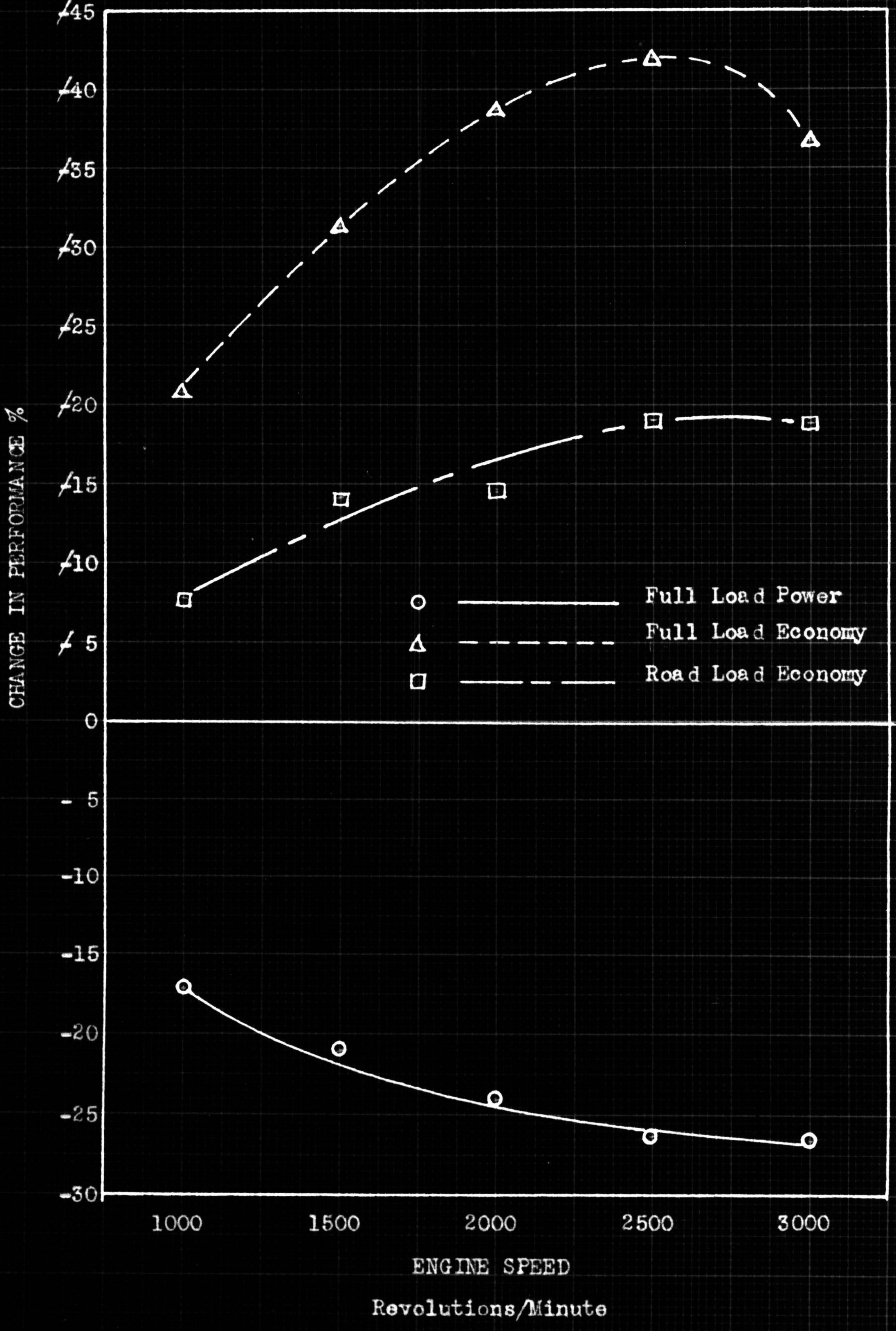


Figure 9

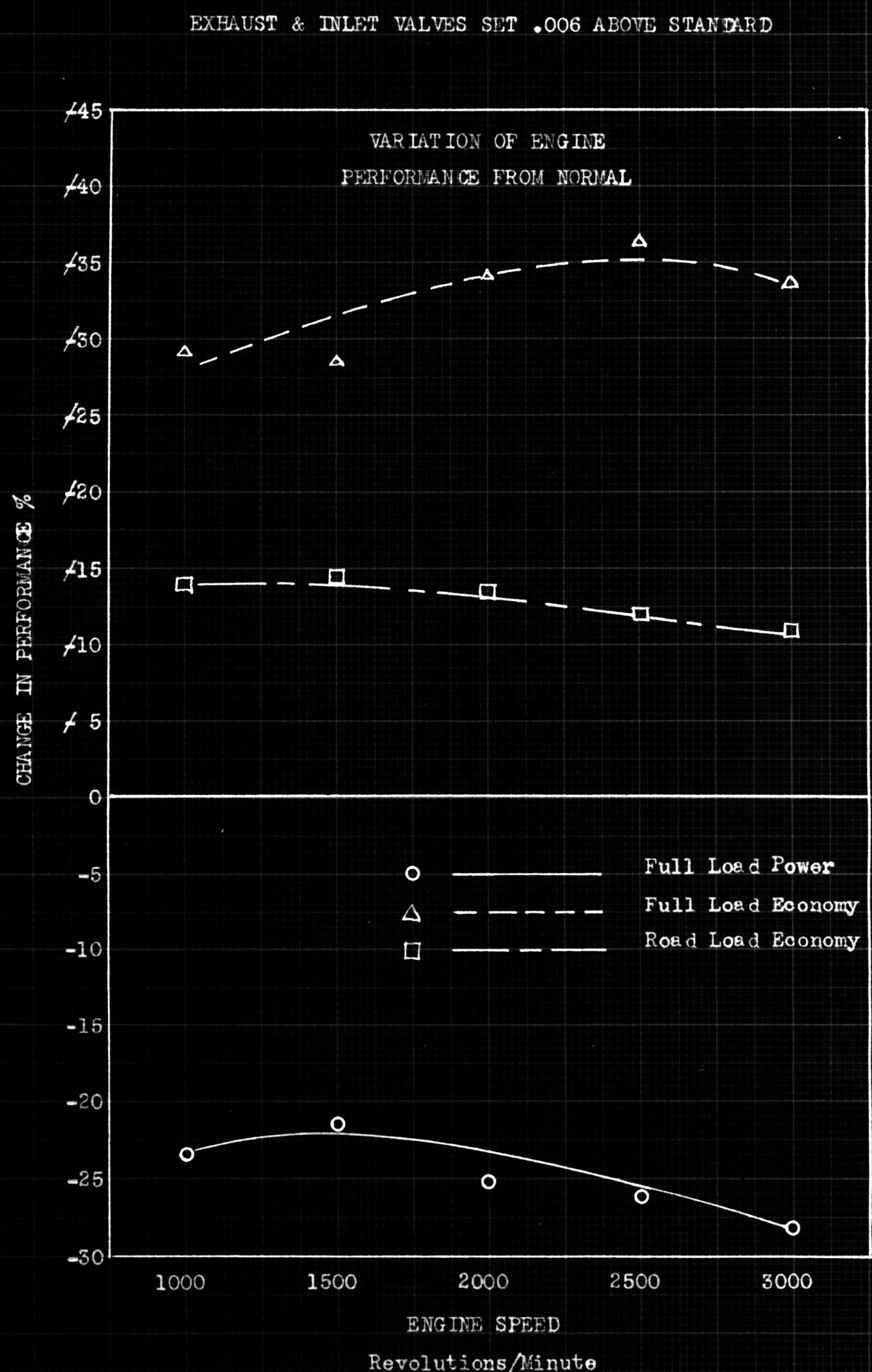

EXHAUST & INLET VALVES SET .006 ABOVE STANDARD
VARIATION OF ENGINE
PERFORMANCE FROM NORMAL
CHANGE IN PERFORMANCE %
+45
+40
+35
+30
+25
+20
+15
+10
+ 5
0
-5
-10
-15
-20
-25
-30
Full Load Power
Full Load Economy
Road Load Economy
1000
1500
2000
2500
3000
ENGINE SPEED
Revolutions/Minute

Figure 10

E Methods of Calculation

1. Calculation of Road Load Horsepower:

Calculations are based on the equation $H.P. = \frac{(KW + K_1AV^2)V}{375}$

where $KW + K_1AV^2 = P$

Values of Constants:

$K = 0.012$

$K_1 = 0.00125$

$A = 28$

$W = 4000$

$K_1A = 0.035$

R.P.M.	Speed M.P.H.	KW	K_1AV^2	P	H.P.
1000	19.3	48	13.0	61.0	3.10
1500	28.9	48	29.3	77.3	5.75
2000	38.5	48	52.0	100.0	10.30
2500	48.2	48	81.3	129.3	16.60
3000	57.8	48	117.0	165.0	25.40

SYMBOLS AND UNITS

K - experimental constant - dimensionless
K_1 - experimental constant - dimensionless
A - projected frontal area of the car - sq. ft.
W - road weight of the car - pounds
V - velocity of the car - miles per hour
P - forward thrust exerted - pounds
H.P. - road load horsepower

The values substituted in the road load equation were taken from a thesis[6] by Martin Stark.

2. Calculation of Brake Horsepower:

$$B.H.P. = \frac{2 \times 3.1416 \times F \times L \times N}{33,000}$$

where:

F = brake load (lbs.)
L = length of dynomometer brake arm (ft.)
N = speed of dynomometer (r.p.m.)

3. Calculation of Corrected Brake Horsepower:

Corrected B.H.P. = (B.H.P.) x (Correction Factor)

where:

$$\text{Correction Factor} = \frac{P_s}{P_o} \times (T_o/T_s)^{\frac{1}{2}}$$

SYMBOLS AND UNITS

P_s = standard atmospheric pressure (inches of mercury)
P_o = observed atmospheric pressure minus the observed vapor pressure
T_s = standard temperature (degrees Rankine)
T_o = observed atmospheric temperature

---

[6]Martin Stark, The Effect of Negligence and Misadjustment on the Automotive Engine, Virginia Polytechnic Institute 1942 p. 31

4. Calculation of Fuel Economy:

See Calculation of Specific Fuel Consumption

5. Calculation of Specific Fuel Consumption:

$$S.F.C. = \frac{Q \times D \times S.G. \times 3600}{T \times 453.6 \times \text{Corrected } B.H.P.}$$

Where:

Q = cubic centimeters of fuel burned (cc)

D = density of water (grams / cubic centimeter)

S.G. = specific gravity of gasoline at the tests temperature (dimensionless)

T = time required to burn a given volume of fuel (sec.)

IV

DISCUSSION

Before discussing any of the results, it should be made clear that it was not the purpose of this experimentation to establish exact values to be expected as a result of valve misadjustment. It is felt, however, that a similar maladjustment in other engines would bring about a like change in performance.

It should also be pointed out that the road load performance is based on the test engine being installed in a 1941 Pontiac sedan. This situation presents itself in that the constants of the road load equation were available for the Pontiac. This set-up was presupposed to be satisfactory since relative values of performance were all that was desired. Further, in connection with the road load performance, the horsepower equation gives the horsepower at a particular engine speed, without regard to the atmospheric conditions. A comparison, however necessitates that all results be relative to the same data. With this situation in mind and the fact that it was very difficult and considered impractical to obtain exactly the same horsepower for each series of runs under road load conditions, readings were taken as in the full-throttle tests and the results corrected to standard conditions.

The results of the first series of tests during which the engine was set to specifications are very much as expected. The full-throttle output horsepower increases with engine speed and "peaks" at 2900 revolutions per minute. At this speed the value of the brake horsepower was 83. The engine, according to the manufacturer, should develop 85 horsepower at 3000 revolutions per minute. The variation in the test data may be explained by the fact that a battery was used to supply the primary voltage of the ignition coil instead of a generator. The full throttle specific fuel consumption curve indicates that maximum economy occurs at an engine speed of 1500 revolutions per minute of the engine. This engine, installed in a 1941 Pontiac chassis, would give a maximum economy at a speed of 28.9 miles per hour; in the truck for which the engine is designed, maximum economy would occur in the neighborhood of 35 miles per hour. The road load specific fuel consumption decreases with speed up to 3000 r.p.m. of the engine. More gasoline is burned of course at the higher speeds, but a greater horsepower is developed at the same time.

The changes in performance resulting from the maladjustments in some cases are very difficult to explain. Varying the tappet clearances changes the valve timing. A change in valve timing effects the volumetric efficiency, intake manifold vacuum, and exhaust temperature. A change in exhaust temperature indicates a change in the temperature inside of the cylinder. The temperature in the cylinder affects the air-fuel ratio and burning characteristics of the fuel. To separate and evaluate each of the factors mentioned above is far beyond the scope of this thesis. For this reason, any explanation of the results will be, what seems to the author, as of paramount significance.

With the intake valve tappets set six one thousandths of an inch less than the clearance recommended by the manufacturer, valve timing has been altered so that the valves open earlier and close later than they would normally. This condition brought about a decrease in full load power at low speeds and has no effect at 3000 r.p.m.. It is not improbable that higher speeds might have resulted in an increase in power, as it is possible to utilize the kinetic energy of the incoming gases to obtain a greater volumetric efficiency. At the lower speeds the fresh charge may have been diluted by the exhaust gases, thus causing a loss of power. This loss of power explains the increase in specific fuel consumption. The change in road load economy is amazing in that at low and high speed the specific fuel consumption increases but decreases through the intermediate speeds. This change may be a net effect caused by the previously mentioned factors.

It seems as though the most erratic performance occurs as a result of an intake valve tappet maladjustment. Reference to Figure 6 indicates an increase in the full load power at the higher speeds and also an increase in specific fuel consumption, although it is not constant over the entire speed range for both full load and road load performance. This increase may also be a result of the extraneous variables introduced by changing the tappet clearances.

The results of the remaining tests were somewhat as expected. Fuel economy increased rapidly over the full load performance range when the exhaust tappets were set to six one-thousandths of an inch less than the specified clearance. This setting would mean that the exhaust valves open earlier and close later than usual; fuel, under this condition, would pass through the exhaust port unburned. The effect would be a decrease in power during full load and an increase in fuel economy under any load condition.

When the exhaust valves open late there is a small increase in the work of expansion, which, when the exhaust tappets were set to six one-thousandths of an inch above the standard, seemed to be overcome by the increased work of exhaust. Under this condition fuel consumption was increased over the entire speed range, whereas the full load power was decreased by a considerable amount.

The combined effect of the intake and exhaust valve tappets being set above or below that clearance which was recommended was very nearly the same. The results indicate an increase in fuel economy during road load and full load performance, and a decrease in full load power for both maladjustments over the entire speed range.

V

CONCLUSIONS

1. The tappet clearances recommended by the manufacturer are the result of careful consideration and are, in general, the best setting from a power and economy standpoint.

2. All variations from the clearances recommended by the manufacturer for which tests were run brought an increase in specific fuel consumption.

3. A decrease in the exhaust valve tappet clearance recommended by the manufacturer will seriously increase the specific fuel consumption under road load and full load conditions.

4. An increase in the exhaust valve tappet clearance recommended by the manufacturer will seriously increase specific fuel consumption under road load or full load operation and reduce full load power.

5. A condition such that both the exhaust and intake valve tappets are set either above or below that clearance which is recommended by the manufacturer will have a similar effect on road load economy, full load economy and full power, as does a decrease in the exhaust valve tappet clearances.

VI

RECOMMEMDATIONS

It is believed by the author that a possible explanation of some of the more erratic results of this experimentation may be explained through the motion of the valve. There is a possibility that the valve may "float" while operating under a maladjustment. This situation may be accentuated when the tappet clearance is large, as the valve has less time to open and close and inertia forces may cause the valve mechanism to leave the cam follower. If this condition could be ascertained through some experimentation, it may be that the results obtained during this investigation could be explained to a larger extent.

Another interesting project would be to determine the effect of various tappet clearances on the valve itself. It is well known that valves which are set too "tight" often burn or warp; however, the exhaust temperature did not deviate a great deal, during the tests of this thesis, from those observed during the tests with the engine set to standard. To determine the cause of valve burning would be a worthy investigation.

VII

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