1-1-1976

Analysis of laboratory performance data for a low cost commercial gasoline engine test assembly.

Lac-Minh-Chau.

ANALYSIS OF LABORATORY PERFORMANCE DATA FOR

A LOW COST COMMERCIAL GASOLINE ENGINE TEST ASSEMBLY

by

Lac-Minh-Chau

A Thesis

Present to the Graduate Committee

of Lehigh University

in Candidacy for the Degree of

Master of Science in Mechanical Engineering

Lehigh University

1976

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science.

May 6 , 1976

(date)

Professor Thomas Edgar Jackson
Thesis Adviser

Prfessor Ferdinand Pierre Beer
Chairman of the Department

ACKNOWLEDGMENT

I wish to thank Professors JACKSON and EPPES for their guidance and assistance in the preparation of this thesis. I also would like to thank the Faculty of MECHANICAL ENGINEERING & MECHANICS DEPARTMENT for their help in improving my technical knowledge.

I am grateful to Dr.BEER, the Mechanical Engineering Department and LEHIGH - UNIVERSITY for providing employment as a research assistant during the past year, which was necessary to provide the needed financial help to complete my study at Lehigh.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A commercially available gasoline engine test assembly, complete with dynamometer and measuring instruments, was tested to determine deficiencies in engine performance and to evaluate the need for additional instrumentation to give laboratory data that could be more closely related to internal combustion theory as taught in a college level course. The engine volumetric efficiency was found to be low, 67% compared to 85% or more on other engines. The engine performance chart, which presents complete performance analysis with all measured performance parameters included, compares qualitatively with data obtained on a Ford V-8 engine. Installation of equipment for changing and measuring spark advance during operation was recommended to widen the choice of control variables in testing. The use of this engine for detailed analysis of internal combustion engine theory is greatly curtailed without the availability of equipment to measure the indicated work, both on the power and the pumping cycles.

1. Introduction

Due to space limitation and financial restrictions many engineering colleges are purchasing low cost commercial small-siz internal combustion engine assemblies for laboratory testing. These units represent the various engine types, such as the four-stroke cycle gasoline, the Wankel gasoline and the diesel engine. These test assemblies are designed primarily to provide somparative engine performance data, but can be used to some extent to illustrate the effect on performance of some of the engine operational design factors that are treated in a college level course on the theory of internal combustion engines.

It is the purpose of this thesis to analyze the performance data for a low cost commercial gasoline four-stroke cycle gasoline engine test assembly:

A. To find deficiencies in the performance of the engine as received from the manufacturer without modification.

B. To relate as far as possible the engine performance data to engine operational theory that is taught in a college level course on internal combustion engines, and

C. To suggest the installation of additional instrumentation and control devices to increase the number of engine performance parameters that can be studied through laboratory testing.

2. Engine Test Assembly

Fig. 1 shows the engine test assembly as built by the Go Power Corporation. The Briggs and Stratton gasoline engine is coupled directly to the water brake dynamometer. Air flow to the engine is calculated by means of a calibrated nozzle at the plenum drum entry, with the pressure drop for the nozzle being read on the water manometer. The gasoline fuel flow to the engine is measured by means of a calibrated rotometer located between the fuel tank and the carburetor. The instruments shown on the dynamometer housing give readings for the engine RPM and the dynamometer arm force, to be used for calculating the BHP and the brake torque. Load on the engine is controlled by valves which regulate the supply of water.

Detailed specifications and operational descriptions of the Model 80302 Briggs and Stratton 4 stroke cycle gasoline engine are given in Table 1. The engine has a compression ratio of 7.5 and a piston displacement volume of 7.73 cu. in. (127 cc). The spark advance can not be varied during operation. Also there is no manometer for measuring the inlet manifold pressure, after the throttle valve. The carburetor is of simple design, with needle valve adjustment for both the main jet and the idling jet. A mechanical fly-ball governor is provided to set the maximum speeds of the engine both at full and at part throttle.

3. Data Measurement and Analysis

The calibration data for the fuel rotometer are given in Table 2, the results being plotted in Fig.2. to reduce data scatter and to provide a representative curve of fuel flow versus rotometer reading. This curve was used for determing all fuel flow rate values.

Fig. 3 shows the calibration of the 0.50 inch throat diameter precision ASME long radious flow nozzle used for air measurement. This curve was used for calculating all air flow values.

Tables 3A, 3B, 3C, 3D, 3E and 3F present the operating data as measured during the tests, namely - engine RPM, dynamometer arem force, air nozzle manometer reading, fuel rotometer deading, exhaust gas temperature and head bolt temperature. Table 3A applies to the full throttle run, when the flyball governor was set for 5600 RPM with the dynamometer unloaded. The throttle remained fully open for all speeds below 5500 RPM. Tables 3B, 3C and 3D apply to the three part throttle runs which were made for governed maximum speed settings of 4850, 4600 and 4500 RPM, dynamometer unloaded. The exhaust gas temperatures and head bolt temperatures are given in Tables 3E and 3F respectively. These temperatures were read only for the full throttle run.

Figs.4A, 4B, 4C and 4D for the full throttle and the three part throttle runs present measured data for fuel flow rate, kg/hr, versus engine RPM, with representative curves being drawn through the data points to minimize data error. The fuel flow rates used in the "adjusted" calculations, Tables 4, 5, 6 and 7, were taken from the representative surves.

Similarly Figs. 5A, 5B, 5C and 5D for the full throtte and the three part throttle runs present the measured data for air flow rate, kg/hr, versus engine RPM. Again the representative curves are drawn through the data points to minimize data error. The air flow rates used for the calculated engine performance data, Figs. 4, 5, 6 and 7, were taken from the representative curves.

The uncorrected BHP data as calculated from the measured data for the four runs are plotted in Figs. 6A, 6B, 6C and 6D, with representative curves being drawn to minimize the effects of data scatter. The BHP used for calculated engine performance data, Tables 4, 5, 6 and 7, were taken from the representative curves.

4. Presentation and Discussion of Engine Performance

The calculated engine performance data for the full throttle and the three part throttle runs are presented in Tables 4, 5, 6 and 7. The procedure of using representative curves for smoothing out the measured data on fuel flow rate, air flow rate and BHP greatly improved the consistency of the calculated performance data, as shown in the following performance curves.

Fig. 6E shows on one graph the representative BHP versus RPM curves developed in the individual plots of Figs. 6A, 6B, 6C and 6D. The full throttle curve gives a maximum BHP of approximately 2.8 at 4100 RPM. The engine warrantee power value is between 2.55 and 3.0 BHP at a speed of approximately 3600 RPM. The decrease in BHP at the higher engine speeds is caused by the higher engine pumping losses and by increased mechanical friction.

The volumetric efficiency versus engine RPM for the full throttle run only is shown in Fig. 7. The maximum volumetric efficiency of 74% is somewhat lower than what might be expected. Rogowski (Ref. 1) shows volumetric efficiency values in the order of 85%. It is not possible to locate the cause of this lower volumetric efficiency, but it does indicate some restriction in air flow through the engine, such as small air passages, poor valve design and perhaps valve timing. Improvements would require a major design change. It is possible that the manufacturer purposely provided a restriction in air flow to prevent overloading or overheating of the engine.

Fig. 8 shows the adjusted BMEP versus engine RPM curves for the full and par t throttle runs. These curves show the expected variations with increase in engine speed. The BMEP values would be higher if it were possible to increase air through-put at full throttle by an increase in volumetric efficiency.

The adjusted values of BSFC, kg/BHP-hr, are plotted against engine speed in Fig. 9. The representative curves smooth out deviations in the data and provide more consistent BSFC values that are used in the Engine Performance Chart, Fig. 10.

An Engine Performance Chart is presented in Fig. 10. This chart maps the complete performance of the engine. For example, it is possible to select particular values of BHP and RPM and read from the performance chart the values of remaining parameters, such as BMEP, Brake Torque and BSFC. Or, best BSFC for a given condition can be selected by the proper choice of BMEP and RPM at a given BHP.

The BSFC data show remsrkably consistency, as can be seen from the "fit" of the calculated BSFC values for each BSFC curve. This plot shows the same qualitative variations in BSFC with engine speed as reported by

Rogowsky (Ref. 1) for a Ford V-8 engine. The occurance of a region of minimum BSFC at low engine speed at values of BMEP below the maximum for the speed is caused in part by changes in the fuel-air ratio as supplied by the carburetor. The variations in the fuel air ratio are shown in Fig. 12 (Fig. 11 for air-fuel ratio, which is commonly used). At low loads (part throttle) there is a high fuel-air ratio. With increase in load at constant speed fuel-air ratio decreases to maintain best economy, but at maximum power demand the fuel-air ratio must be increased to a higher value to get the additional power. The higher values of BSFC at higher engine speeds are due to increased engine Pumping losses and to increased mechanical friction.

The exhaust gas temperature measurement for full throttle is shown in Fig. 13. This measured temperature increases with increased speed, and is caused by increasing engine power at the lower speeds and by lower thermal efficiencies (higher BSFC values) at higher speeds. Too much reliance should not be placed on the accuracy of the readings since heat transfer from the exhaust gases to the cylinder head modifies the gas temperature.

The head bolt temperature variation with engine RPM shown in Fig. 14 indicates a decrease with increased engine speed. This is attributed to the increase in cooling air flow from the fan as the engine speed increases.

5. Conclusions and Recommendations

A. The volumetric efficiency of the engine is lower than values attained by other engines of similar type, 74% as compared to 85% reported. A major change in design would probably be need to improve volumetric efficiency to give higher air through-put and higher BHP output.

B. The usefulness of this engine as an educational vehicle would be greatly increased if it were possible to obtain inducator cards to show what is happending during the combustion process. These cards would show changes in the pumping losses with variations in engine load and speed. It is recommended that further study be made to determine the feasibility of providing indicator cards.

C. The absence of any means of varying the spark advance during operation prevents the adjustment of the spark advance to best power position for variations in fuel air ratio, engine load and engine apeed. It is recommended that the engine be modified to permit change in spark advance under operation, with a neon light installation to indicate the spark advance value.

D. A manometer should be provided to give the inlet manifold pressure since this is a commonly recorded value in engine testing and may be used as a control variable.

TABLE 1: ENGINE TEST ASSEMBLY SPECIFICATION AND

OPERATION DESCRIPTION.

A. Engine test assembly sales distributor

GO-POWER CORP.,155 MONTGOMERY STREET
SAN-FRANCISCO,CALIFORNIA.

B. Engine specification and design description.

BRIGGS & STRATTON model 80300 engine
Rated 3BHP at 3600 RPM.Assembly line engine BHP warrenteed at least 85% of rated BHP value.

2.375 in.by 1.75 in.,bore and stroke.
7.75cu.in. piston displacement. 7.5 comp. ratio.
Air cooled cylinder.
FLO-JET carburator with idle and power mixture adjustments.
Governor - mechanical fly - ball type,spring load control adjustable for maximum or for set speed control.
Ignition-magneto type voltage build up in primary circuit,with conventional condenser and breaker point for spark emission.Fixed spark advance.No automatic variation for speed or manifold pressure changes.No manual adjustment during operation.
Tachometer for continuos measurement of RPM.

C. Dynamometer

Provided by GO-POWER CORP. Model DY -7D.

Hydraulic type, with water flow regulation for torque control.

Load cell, calibrated in pounds force for measurement of dynamometer arm force.

Torque arm length .525 foot.

D. Dynamometer assembly base block by GO-POWER CORP.

Table 2. Fuel flow - Rotameter calibration data.

ROTAMETER	.50	1.25	1.95	2.90	4.00	4.90	6.00
VOLUME OF GASOLINE(CC)	.25	8.00	10.00	25.00	25.00	25.00	25.00
TIME (SECOND)	1023	431.2	143.4	108.8	55.7	40.5	31.0
FUEL FLOW (KGS/HR)	.0006	.049	.185	.612	1.195	1.644	2.148

ROTAMETER	6.50	7.00	7.95	8.40	8.95	9.45	9.90
VOLUME OF GASOLINE(CC)	25.00	25.00	50.00	50.00	50.00	50.00	50.00
TIME (SECOND)	28.5	25.6	44.6	41.8	38.0	36.4	32.2
FUEL FLOW (KGS/HR)	2.336	2.600	2.986	3.186	3.505	3.660	4.136

TABLE 3A :MEASURED DATA - BRIGGS & STRATTON ENGINE MODEL 803C2

FULL THROTTLE (MAX. 5600 RPM UNLOADED)

ENGINE RPM	2000	2500	2850	3250	3700	4250	4950	5500
FUEL ROTAMETER READING	2.55	2.80	3.00	3.20	3.30	3.35	3.80	4.20
AIR FLOW MANOMETER, IN. H_2O	.12	.16	.20	.24	.29	.34	.40	.39
DYNAMOMETER ARM FORCE (LBF)	4.62	7.30	7.26	7.20	7.05	6.30	4.89	3.52

TABLE 3B : MEASURED DATA - BRIGGS & STRATTON ENGINE MODEL 80302

PART THROTTLE (MAX.4850 RPM UNLOADED)

ENGINE RPM	2000	2400	2650	2950	3400	3900	4350	4750
FUEL ROTAMETER READING	2.40	2.50	2.60	2.65	2.70	2.80	2.90	3.10
AIR FLOW MANOMETER, IN. H_2O	.15	.16	.17	.19	.21	.23	.24	.25
DYNAMOMETER ARM FORCE (LBF)	6.65	6.70	6.67	6.60	6.17	5.07	3.74	2.54

TABLE 3C : MEASURED DATA - BRIGGS & STRATTON ENGINE MODEL 80302

PART THROTTLE (MAX. 4600 RPM UNLOADED)

ENGINE RPM	2000	2300	2700	3000	3450	3700	4150	4500
FUEL ROTAMOMETER READING	2.20	2.35	2.40	2.60	2.65	2.70	2.85	3.10
AIR FLOW MANOMETER, IN. H_2O	.15	.16	.19	.21	.24	.26	.28	.30
DYNAMOMETER ARM FORCE (LBF)	6.60	6.56	6.43	6.30	6.00	5.28	4.00	2.31

TABLE 3D : MEASURED DATA- BRIGGS & STRATTON ENGINE MODEL 80302

PART THROTTLE (MAX. 4500 RPM UNLOADED)

ENGINE RPM	2000	2400	2700	3000	3400	3750	4100	4400
FUEL FLOW ROTAMETER READING	2.20	2.30	2.40	2.40	2.45	2.50	2.60	2.80
AIR FLOW MANOMETER , IN. H_2O	.08	.11	.13	.14	.15	.16	.17	.18
DYNAMOMETER ARM FORCE (LBF)	5.84	5.94	5.40	5.00	4.41	3.70	2.25	1.41

Table 3E : Measured data - BRIGGS & STRATTON engine model 80302

Head bolt temperature (full throttle)

ENGINE RPM	2000	2200	2500	2850	3100	3300	3500
HEAD BOLT TEMPERATURE (^{o}F)	358	359	360	361	364	360	358
HEAD BOLT TEMPERATURE (^{o}C)	181	182	182	183	184	182	181

ENGINE RPM	3850	4200	4500	4800	5100	5300	5500
HEAD BOLT TEMPERATURE (^{o}F)	347	332	315	298	278	264	252
HEAD BOLT TEMPERATURE (^{o}C)	175	167	157	148	137	129	122

Table 3F.: Measured data - BRIGGS & STRATTON engine model 80302

Exhaust temperature (full throttle)

ENGINE RPM	2000	2200	2400	2600	2800	3100	3400
EXHAUST TEMPERATURE (^oF)	725	750	775	804	830	875	916
EXHAUST TEMPERATURE (^oC)	385	399	413	429	443	468	491

ENGINE RPM	3700	4100	4450	4650	5000	5200	5500
EXHAUST TEMPERATURE (^oF)	950	1000	1047	1074	1124	1130	1099
EXHAUST TEMPERATURE (^oC)	510	538	564	579	607	610	593

TABLE 4 : CALCULATED ENGINE PERFORMANCE-BRIGGS & STRATTON ENGINE

MODEL 80302

FULL THROTTLE (MAX. 5600 RPM UNLOADED)

ENGINE RPM	2000	2500	2850	3250	3700	4250	4950	5500
UNCORRECTED FUEL FLOW (KGS/HR)	.450	.570	.670	.785	.840	.860	1.090	1.200
ADJUSTED FUEL FLOW (KGS/HR)	.450	.570	.670	.750	.840	.880	1.070	1.200
UNCORRECTED BRAKE HORSEPOWER	1.38	1.85	2.10	2.37	2.63	2.72	2.46	2.00
ADJUSTED BRAKE HORSEPOWER	1.38	1.82	2.12	2.40	2.63	2.72	2.47	2.00
ADJUSTED BMEP (NEWTON/CM^2)	47.97	50.61	51.71	51.33	49.41	44.49	34.69	25.28
UNCORRECTED AIR FLOW (KGS/HR)	4.54	6.50	8.00	9.50	11.40	13.00	14.50	14.45
ADJUSTED AIR FLOW (KGS/HR)	4.54	6.60	8.00	9.60	11.35	13.05	14.50	14.45
ADJUSTED AIR/FUEL RATIO	10.09	11.58	12.12	12.89	13.19	13.59	12.50	11.11
ADJUSTED BSFC. (KGS/HR-HP)	.326	.313	.311	.312	.320	.330	.433	.650
ADJUSTED VOLUMETRIC EFF. (%)	.497	.378	.614	.647	.672	.672	.642	.575

TABLE 5 : CACULATED ENGINE PERFORMANCE-BRIGGS & STRATTON ENGINE

MODEL 80302

PART THROTTLE (MAX. 4850 RPM UNLOADED)

ENGINE RPM	2000	2400	2650	2950	3400	3900	4350	4750
UNCORRECTED FUEL FLOW (KGS/HR)	.380	.425	.475	.500	.556	.570	.620	.730
ADJUSTED FUEL FLOW (KGS/HR)	.380	.430	.475	.500	.556	.580	.640	.730
UNCORRECTED BRAKE HORSEPOWER	1.35	1.63	1.80	1.97	2.12	2.00	1.65	1.09
ADJUSTED BRAKE HORSEPOWER	1.35	1.63	1.82	1.97	2.12	2.00	1.66	1.09
ADJUSTED BMEP (NEWTON/CM^2)	46.93	47.22	47.24	46.50	42.32	35.65	26.53	15.95
UNCORRECTED AIR FLOW (KGS/HR)	4.54	5.90	6.81	7.50	8.80	9.08	9.75	10.00
ADJUSTED AIR FLOW (KGS/HR)	4.54	5.95	6.81	7.50	8.80	9.09	9.75	10.20
ADJUSTED BSFC. (KGS/HR-HP)	.281	.263	.260	.253	.261	.320	.415	.670
ADJUSTED VOLUMETRIC EFF. (%)	.497	.538	.562	.556	.569	.533	.528	.470
ADJUSTED AIR/FUEL RATIO	11.95	13.72	14.33	15.00	15.80	15.65	15.23	13.97

TABLE 6: CALCULATED ENGINE PERFORMANCE BRIGGS &STRATTON ENGINE

MODEL 80302

PART THROTTLE (MAX. 4600 RPM UNLOADED)

ENGINE RPM	2000	2300	2700	3000	3450	3700	4150	4500
UNCORRECTED FUEL FLOW (KGS/HR)	.280	.330	.380	.425	.500	.556	.600	.690
ADJUSTED FUEL FLOW (KGS/HR)	.280	.330	.385	.425	.500	.556	.610	.690
UNCORRECTED BRAKE HORSEPOWER	1.34	1.59	1.84	1.92	2.10	2.00	1.70	1.08
ADJUSTED BRAKE HORSEPOWER	1.34	1.56	1.80	1.97	2.02	1.98	1.72	1.08
ADJUSTED BMEP (NEWTON/CM^2)	46.58	47.15	46.35	44.49	40.70	37.20	28.81	16.68
UNCORRECTED AIR FLOW (KGS/HR)	5.35	6.36	7.71	8.63	9.53	10.44	11.12	11.70
ADJUSTED AIR FLOW (KGS/HR)	5.35	6.36	7.44	8.40	9.75	10.74	11.10	11.80
ADJUSTED AIR/FUEL RATIO	19.10	19.27	19.60	19.76	19.50	19.33	18.19	16.90
ADJUSTED BSFC. (KGS/HR-HP)	.209	.207	.209	.216	.250	.280	.354	.633
ADJUSTED VOLUMETRIC EFF.(%)	.586	.606	.604	.611	.618	.617	.596	.574

TABLE 7 : CACULATED ENGINE PERFORMANCE-BRIGGS & STRATTON ENGINE

MODEL 80302

PART THROTTLE (MAX. 4500 RPM UNLOADED)

ENGINE RPM	2000	2400	2700	3000	3400	3750	4100	4400
UNCORRECTED FUEL FLOW (KGS/HR)	.280	.320	.380	.380	.400	.425	.475	.570
ADJUSTED FUEL FLOW (KGS/HR)	.280	.320	.360	.385	.4100	.440	.460	.570
UNCORRECTED BRAKE HORSEPOWER	1.18	1.45	1.48	1.52	1.52	1.40	.93	.63
ADJUSTED BRAKE HORSEPOWER	1.18	1.38	1.45	1.53	1.53	1.40	1.14	.63
ADJUSTED BMEP (NEWTON/CM^2)	41.01	39.97	38.11	35.45	31.28	25.95	19.33	9.35
UNCORRECTED AIR FLOW (KGS/HR)	2.91	4.30	5.00	5.45	5.90	6.36	6.81	7.26
ADJUSTED AIR FLOW (KGS/HR)	2.91	4.20	5.00	5.45	6.00	6.50	6.81	7.26
ADJUSTED AIR/FUEL RATIO	10.39	12.81	13.88	14.15	14.63	14.77	14.57	12.73
ADJUSTED BSFC (KGS/HR-HP)	.237	.231	.236	.251	.270	.314	.394	.876
ADJUSTED VOLUMETRIC EFF. (%)	.319	.373	.405	.398	.386	.380	.366	.361

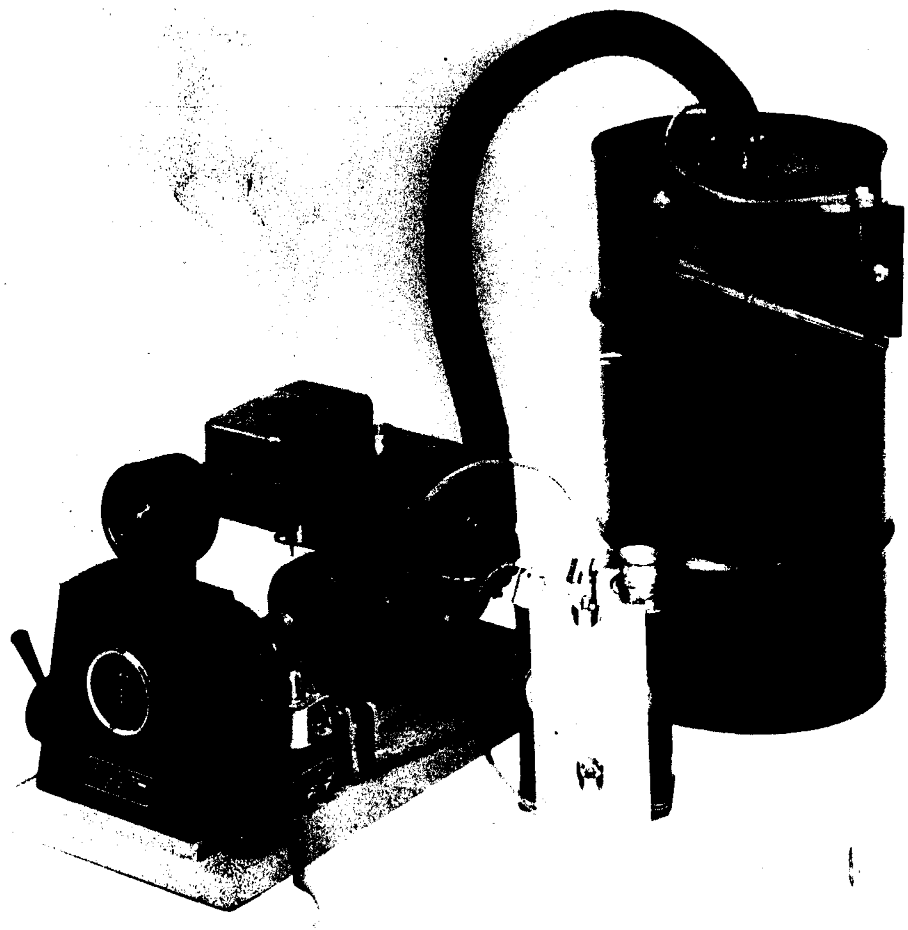

Figure 1 : Engine Test Set Up

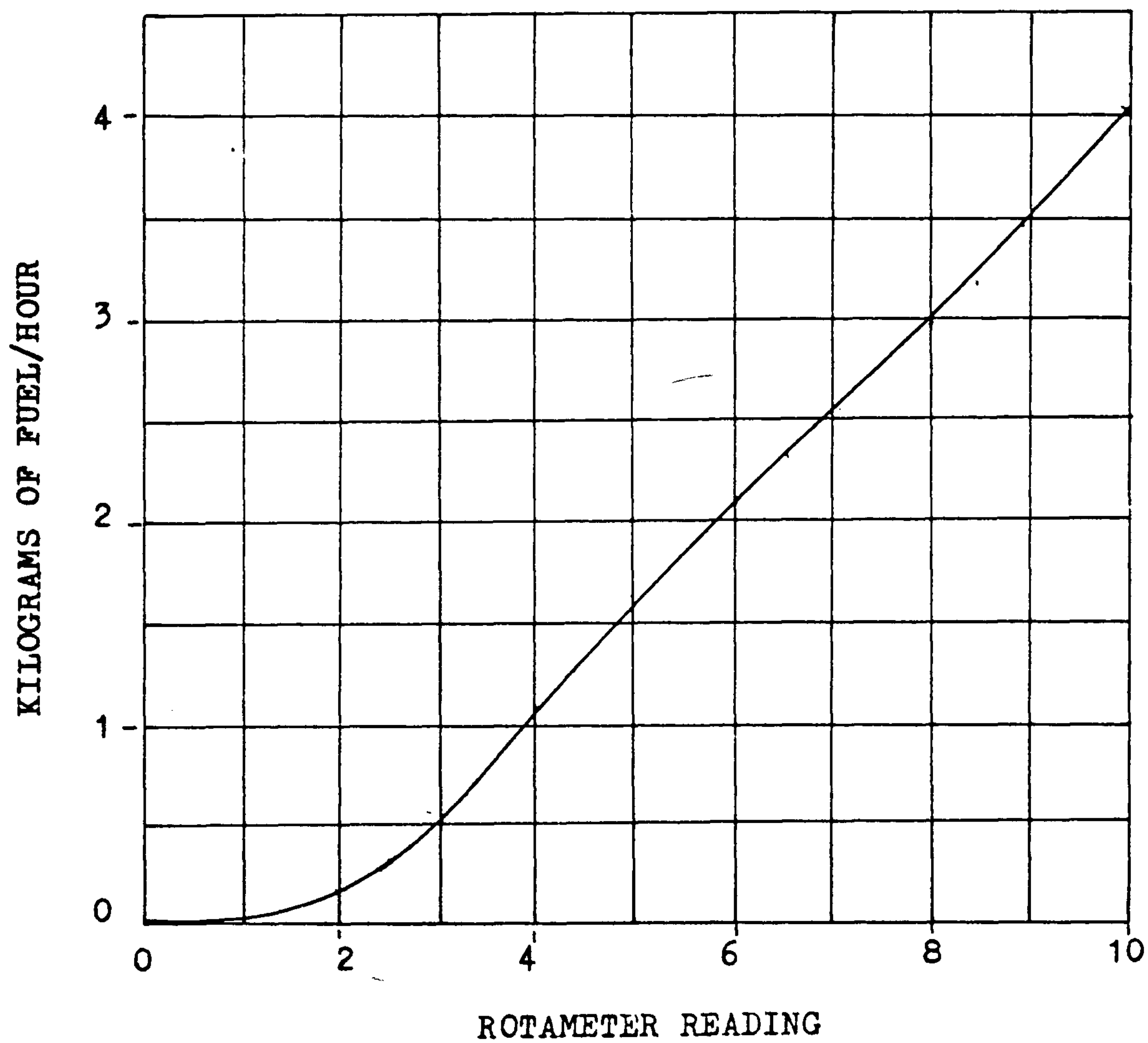

Figure 2 : Rotameter calibration

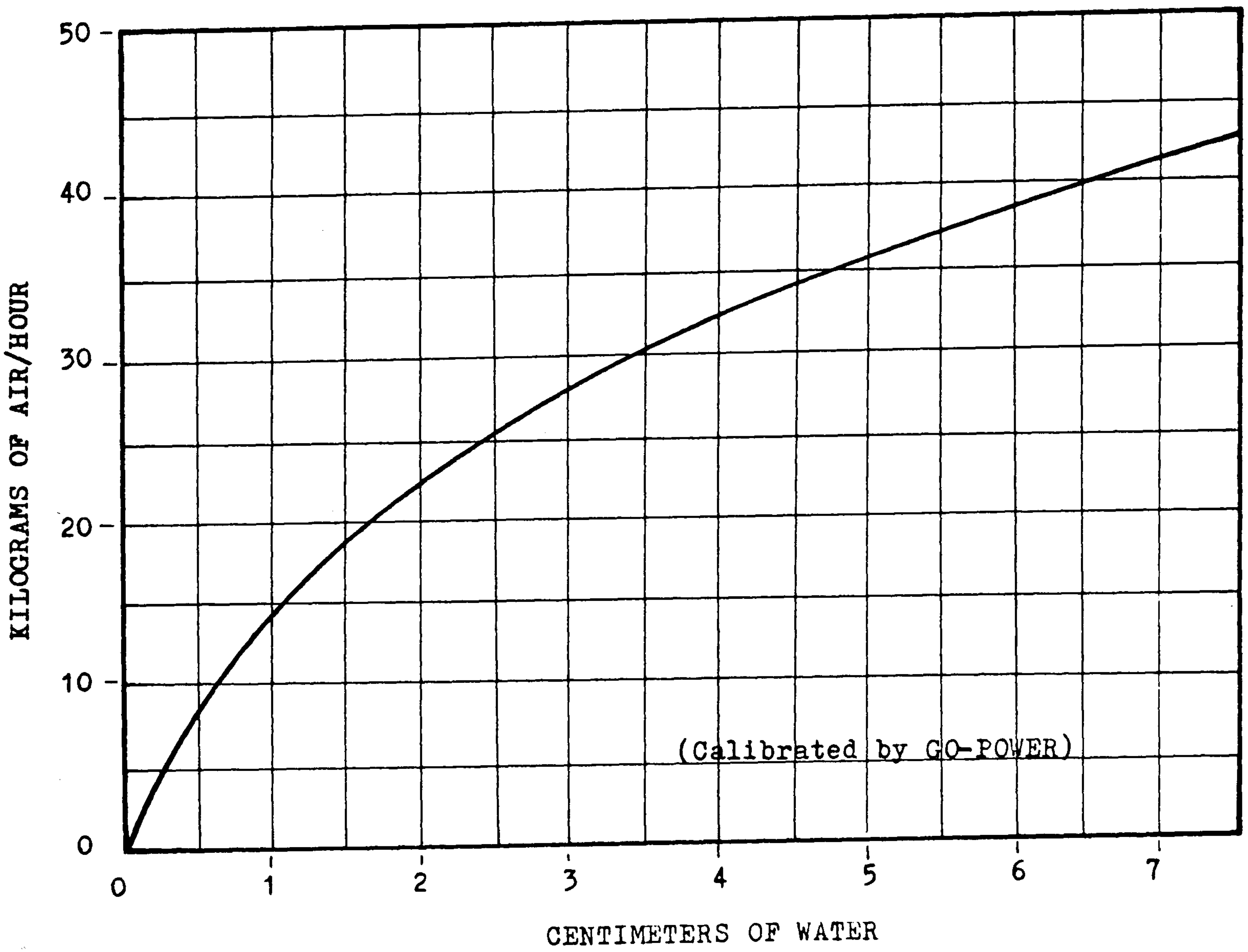

Figure 3 : Air flow orific calibration

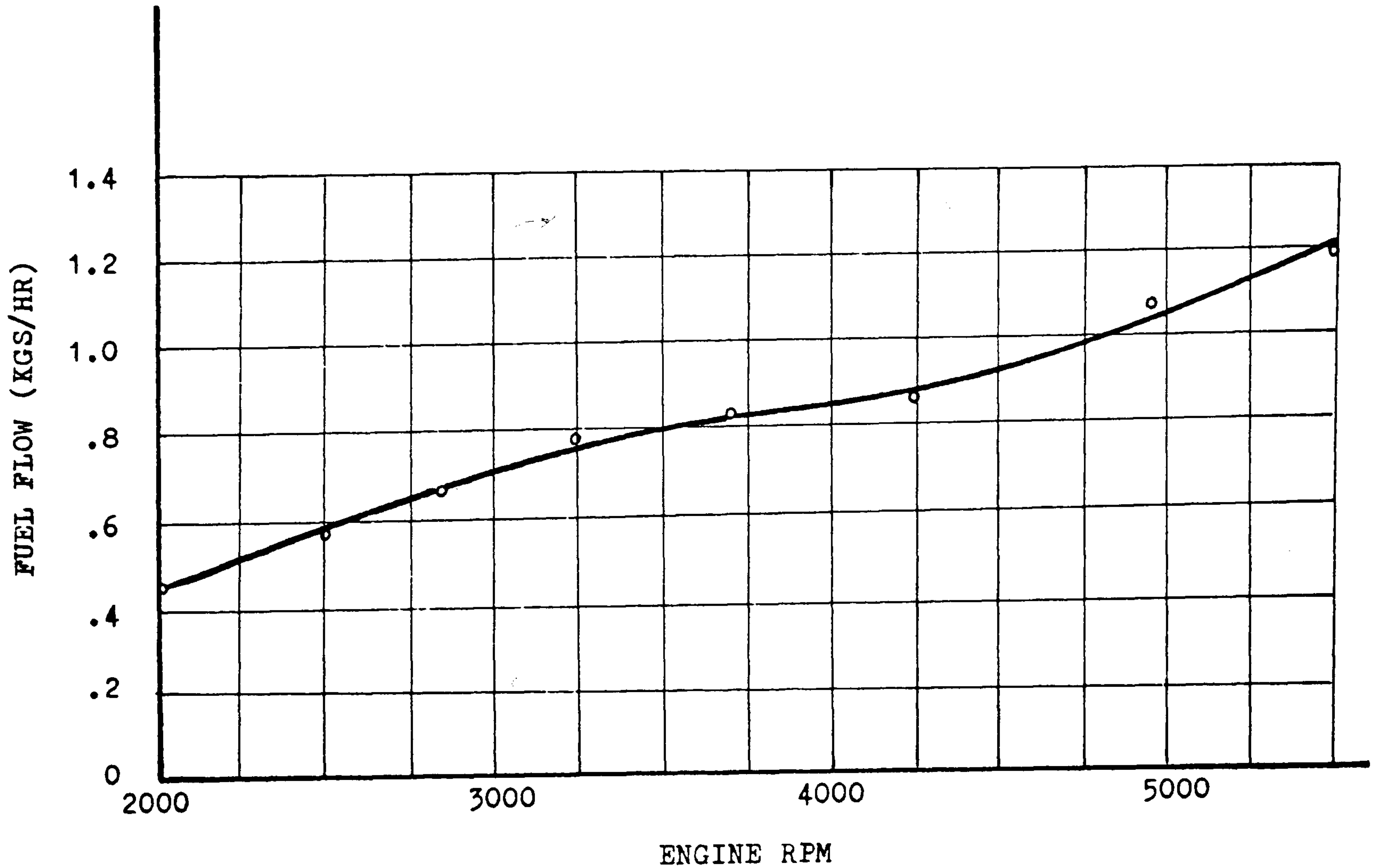

Figure 4A : Uncorrected fuel flow rate vs engine speed(max.5600 RPM unloaded)

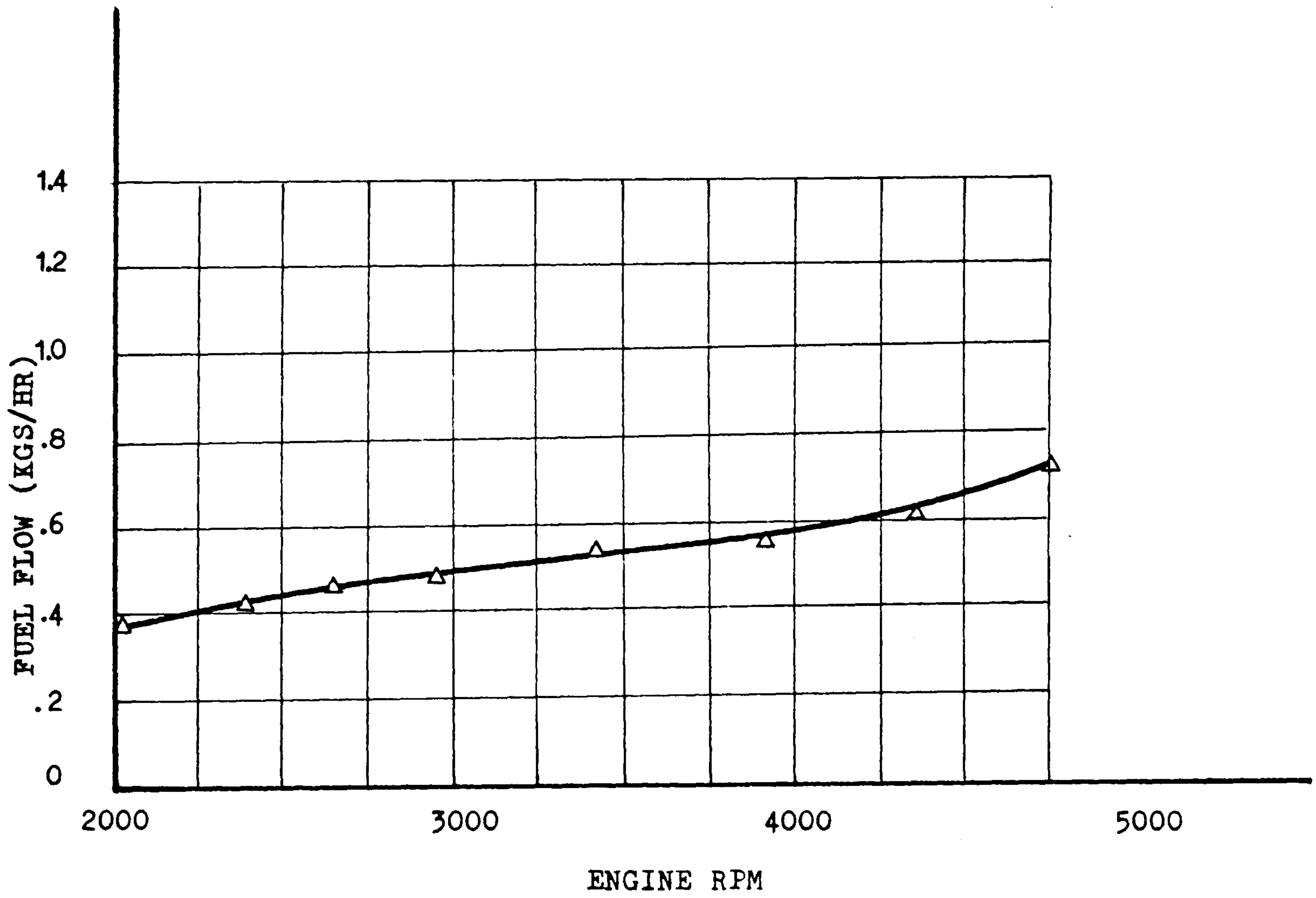

FIGURE 4B : Uncorrected fuel flow vs engine speed (max.4850 RPM unloaded)

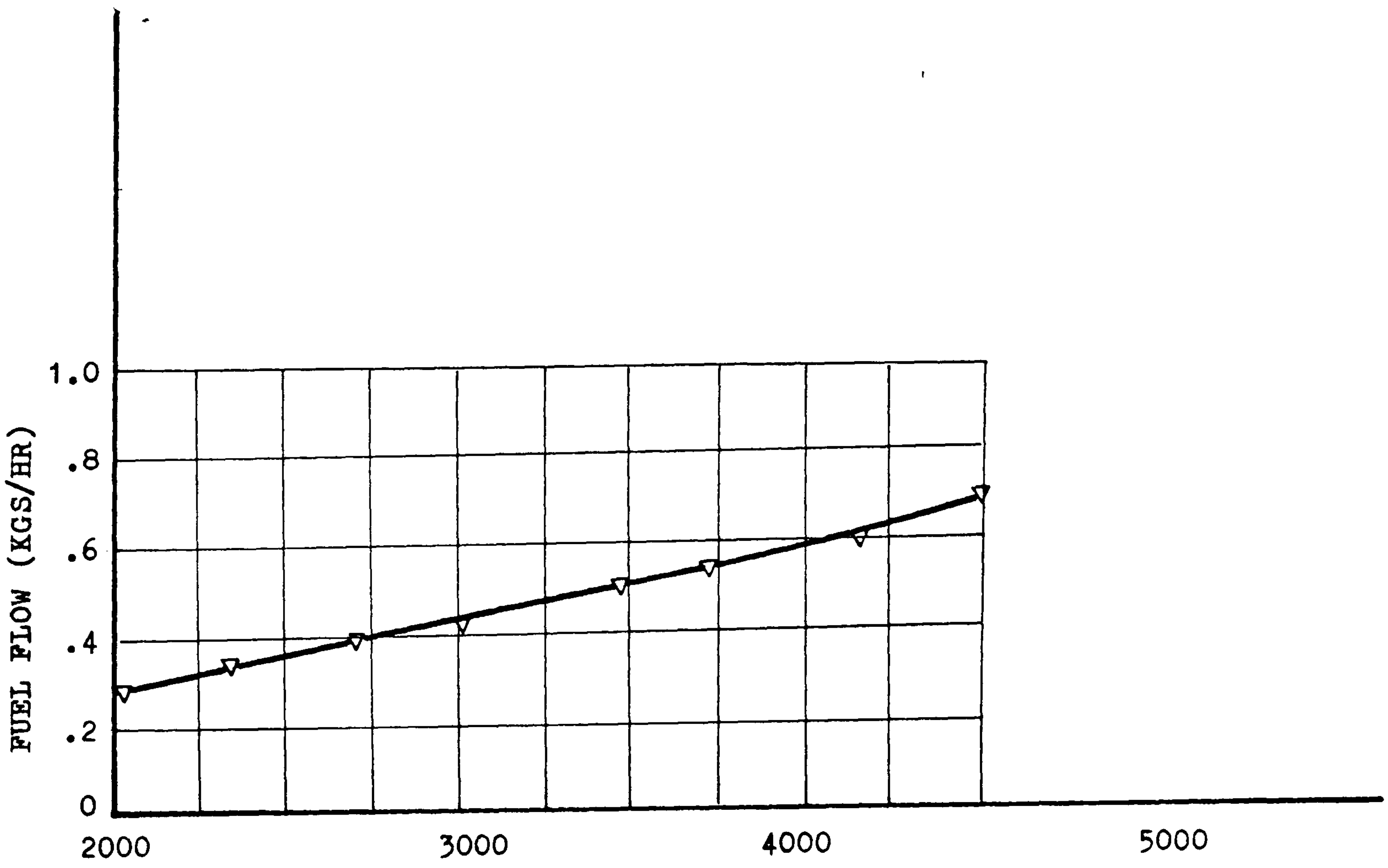

FIGURE 4C : Uncorrected fuel flow vs engine speed (max.4600 RPM unloaded)

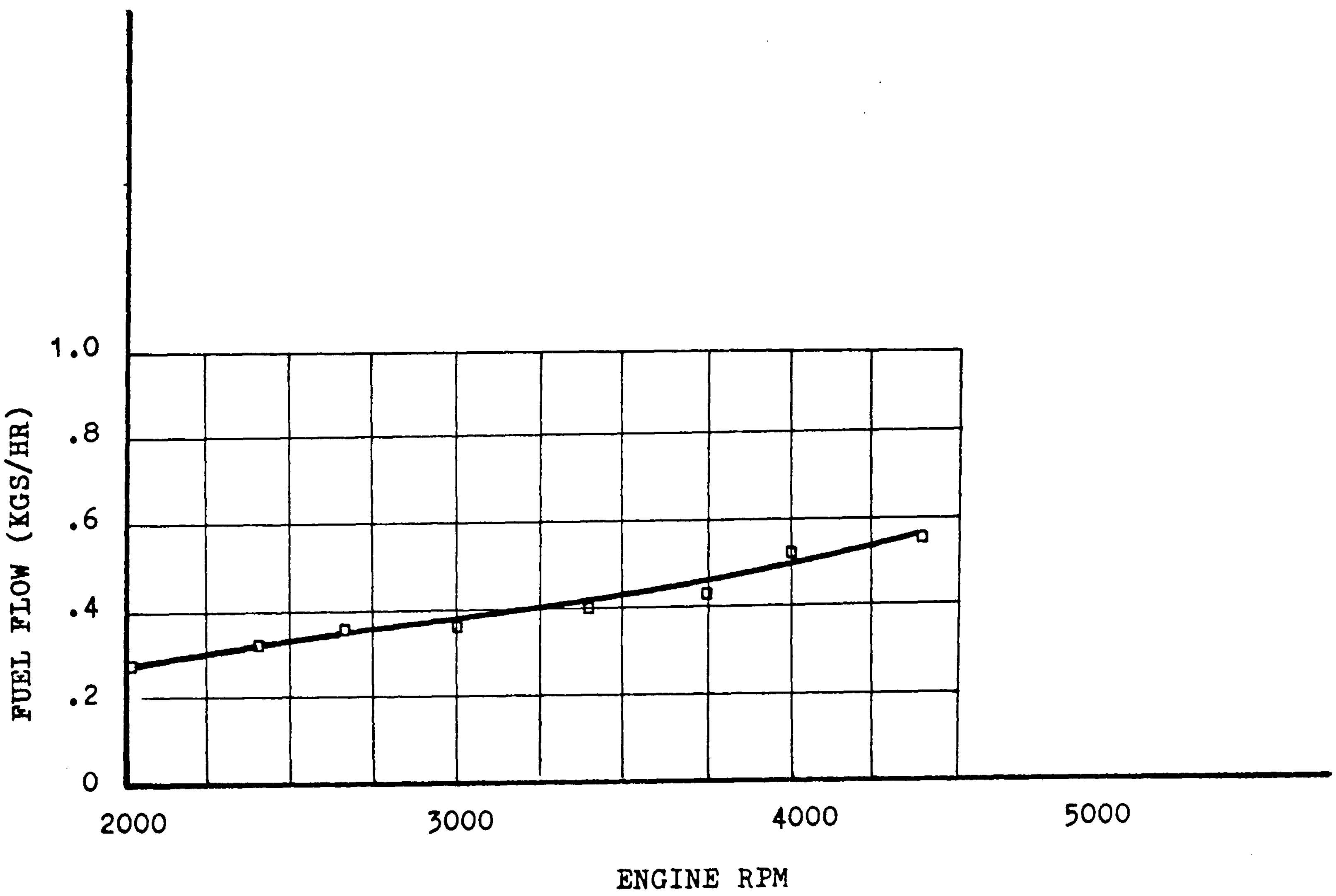

FIGURE 4D : Uncorrected fuel flow vs engine speed (max.4500 RPM unloaded)

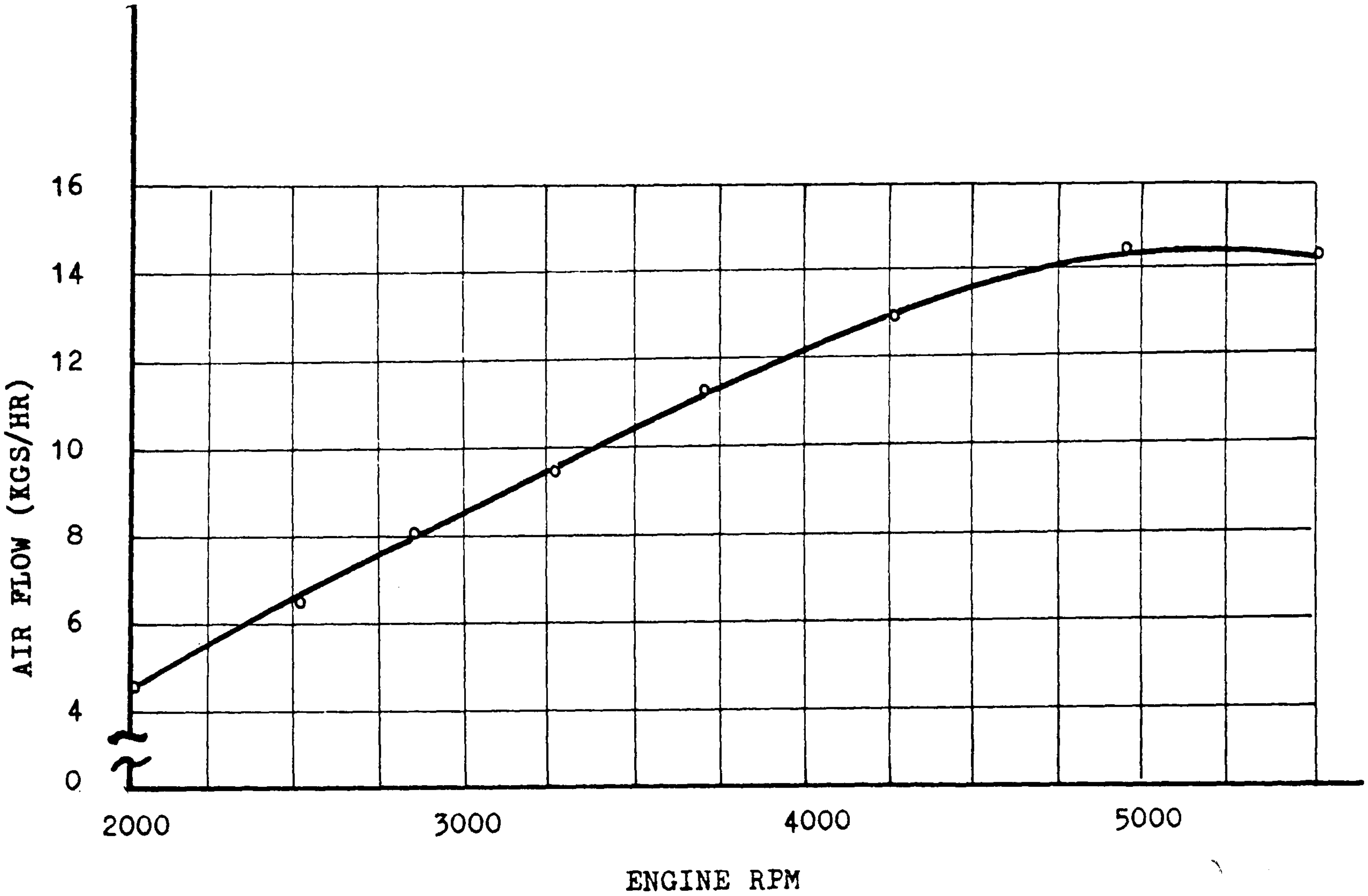

FIGURE 5A :Uncorrected air flow vs engine speed (max.5600 RPM unloaded)

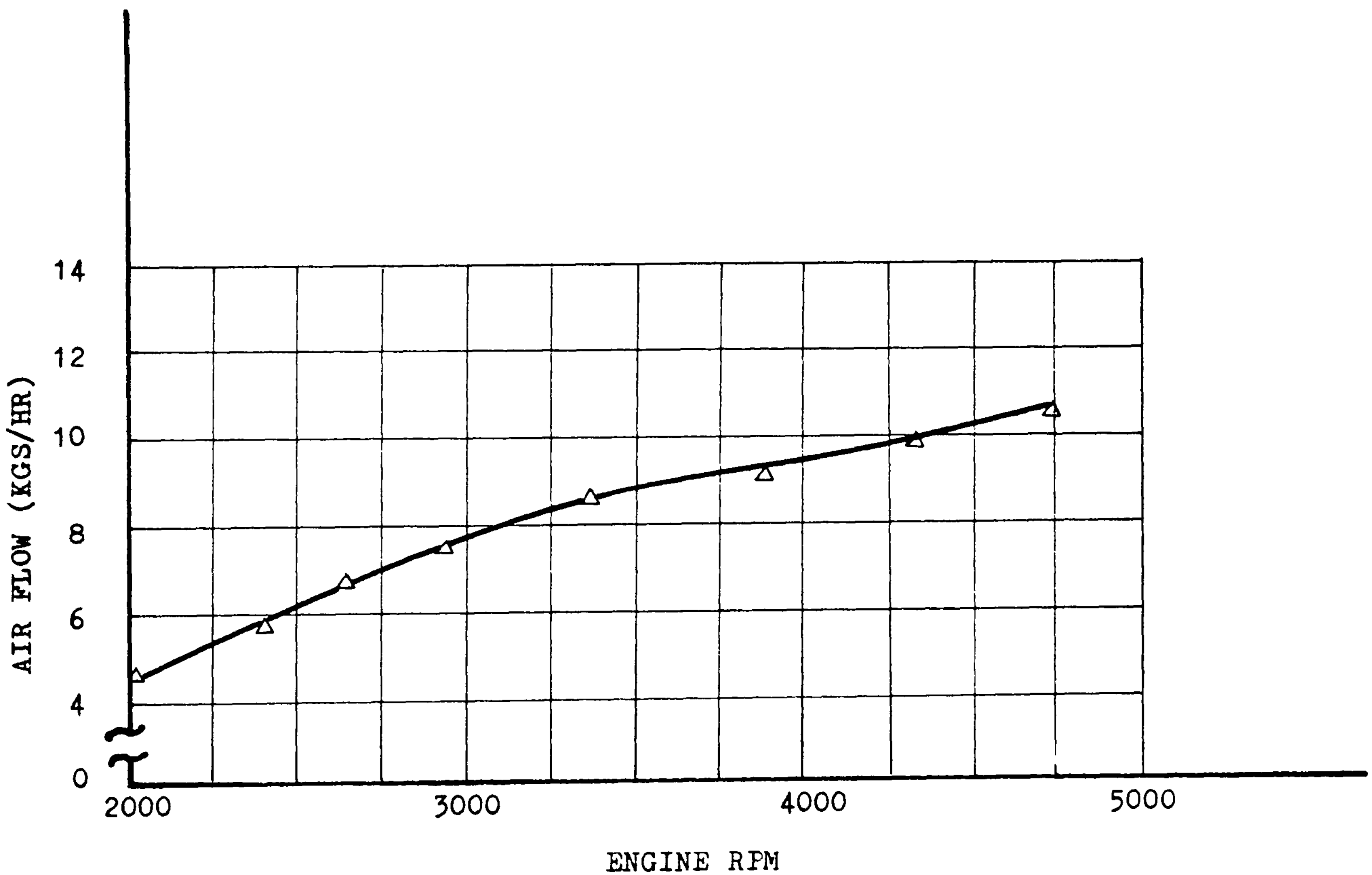

FIGURE5B : Uncorrected air flow vs engine speed (max.4850 RPM unloaded)

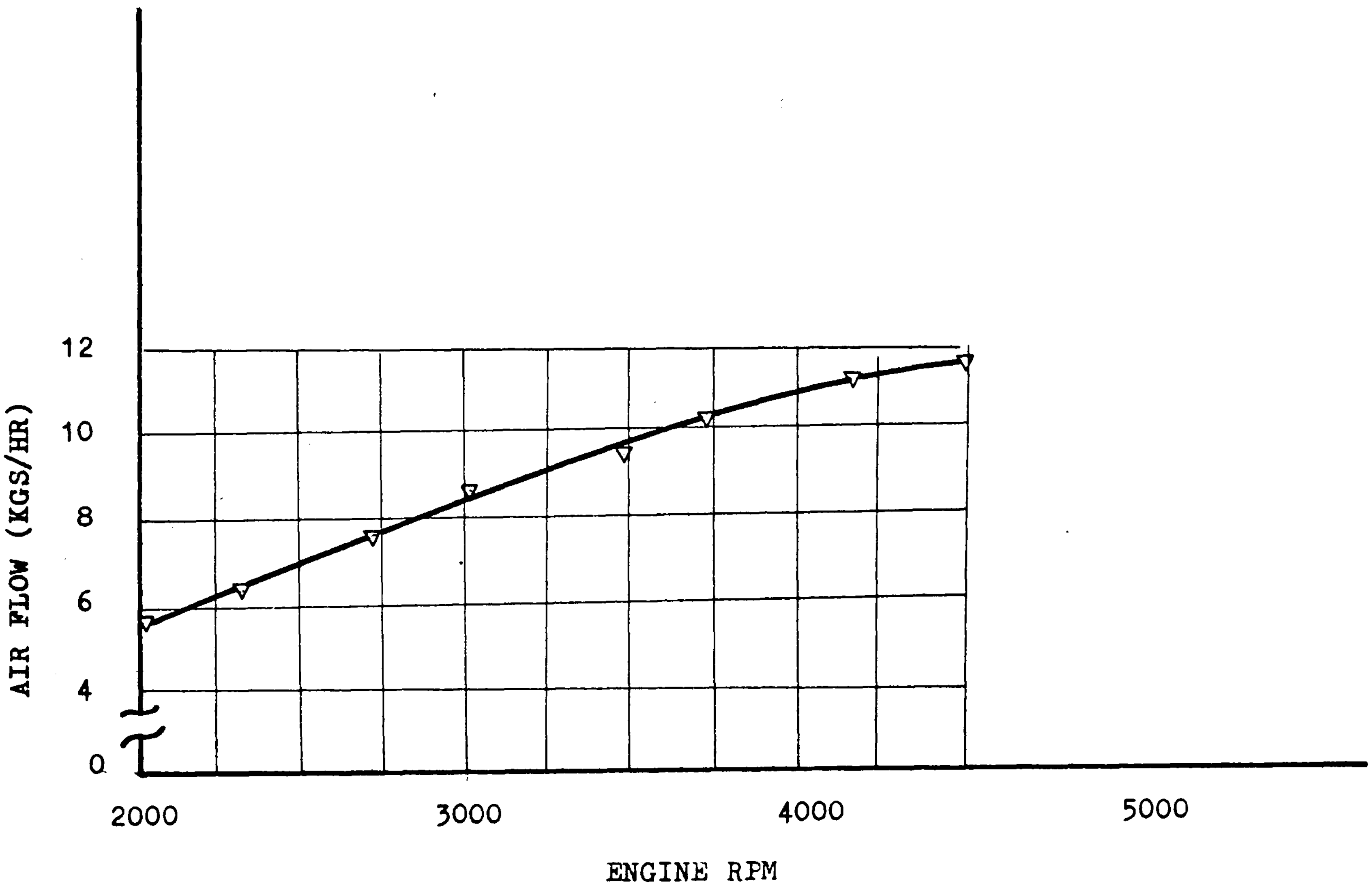

FIGURE 5C : Uncorrected air flow vs engine speed* (max.4600 RPM unloaded)

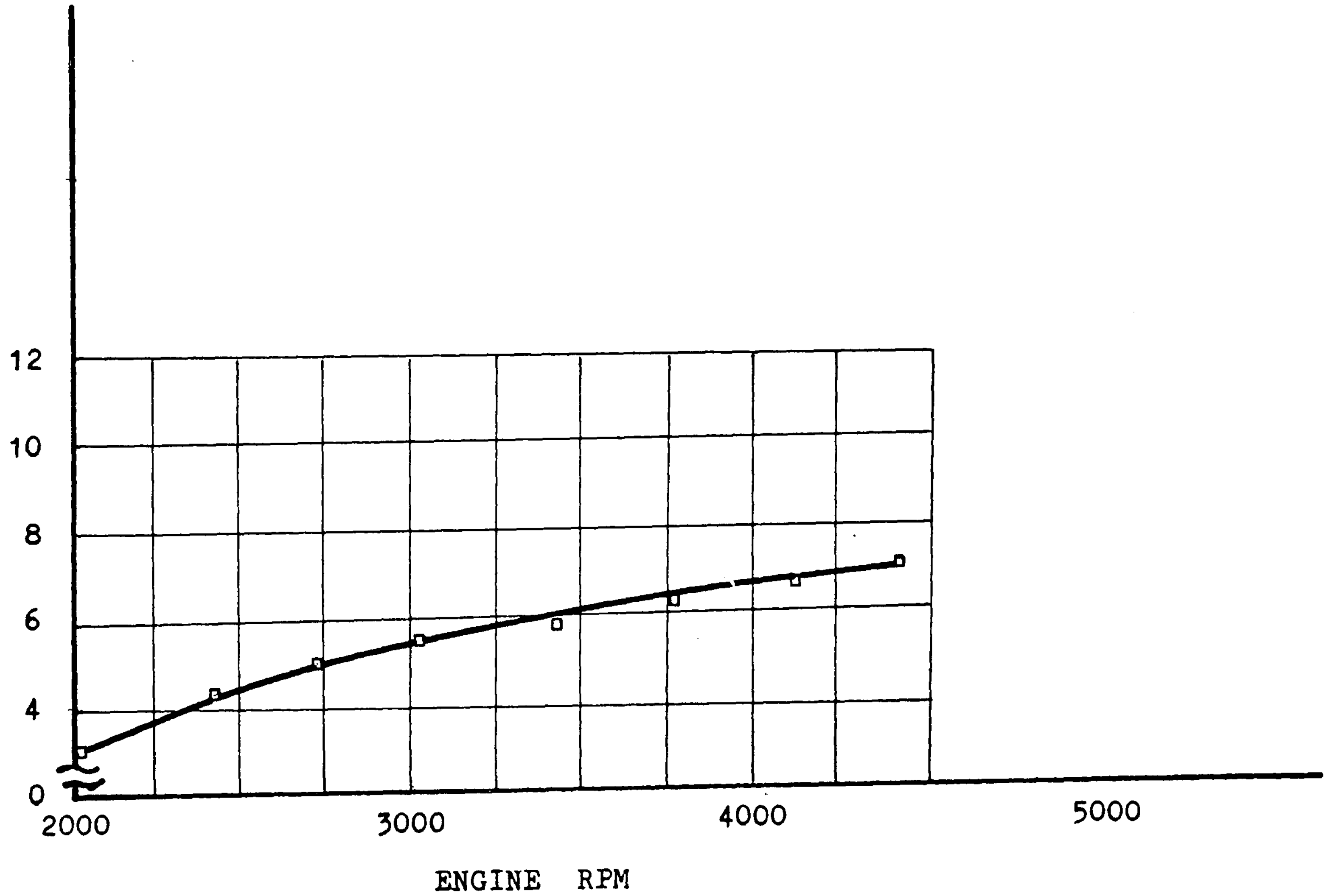

FIGURE 5D : Uncorrected air flow vs engine speed (max.4500 RPM unloaded)

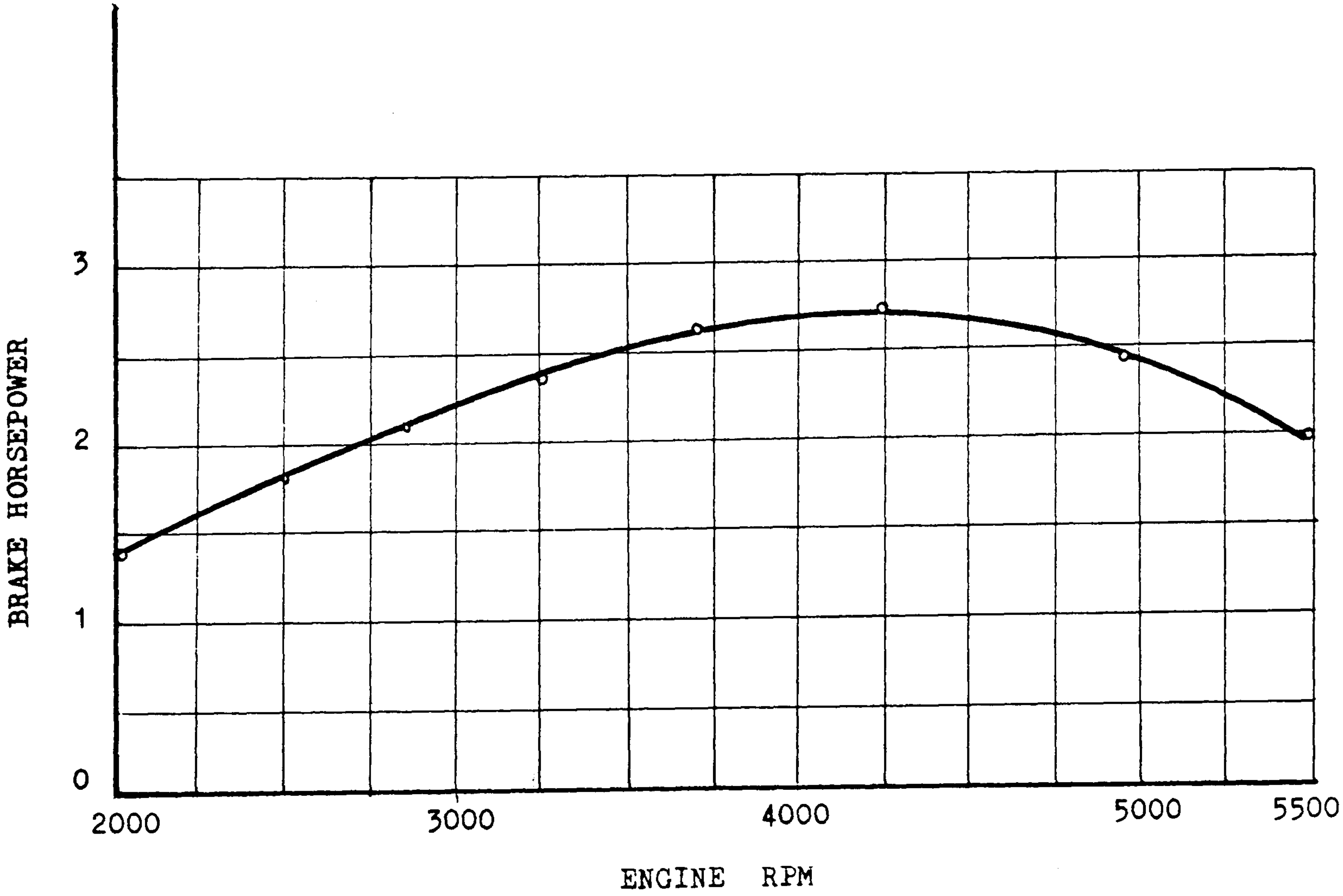

Figure 6A : Uncorrected brake horsepower vs enginespeed(max. 5600 RPM unloaded)

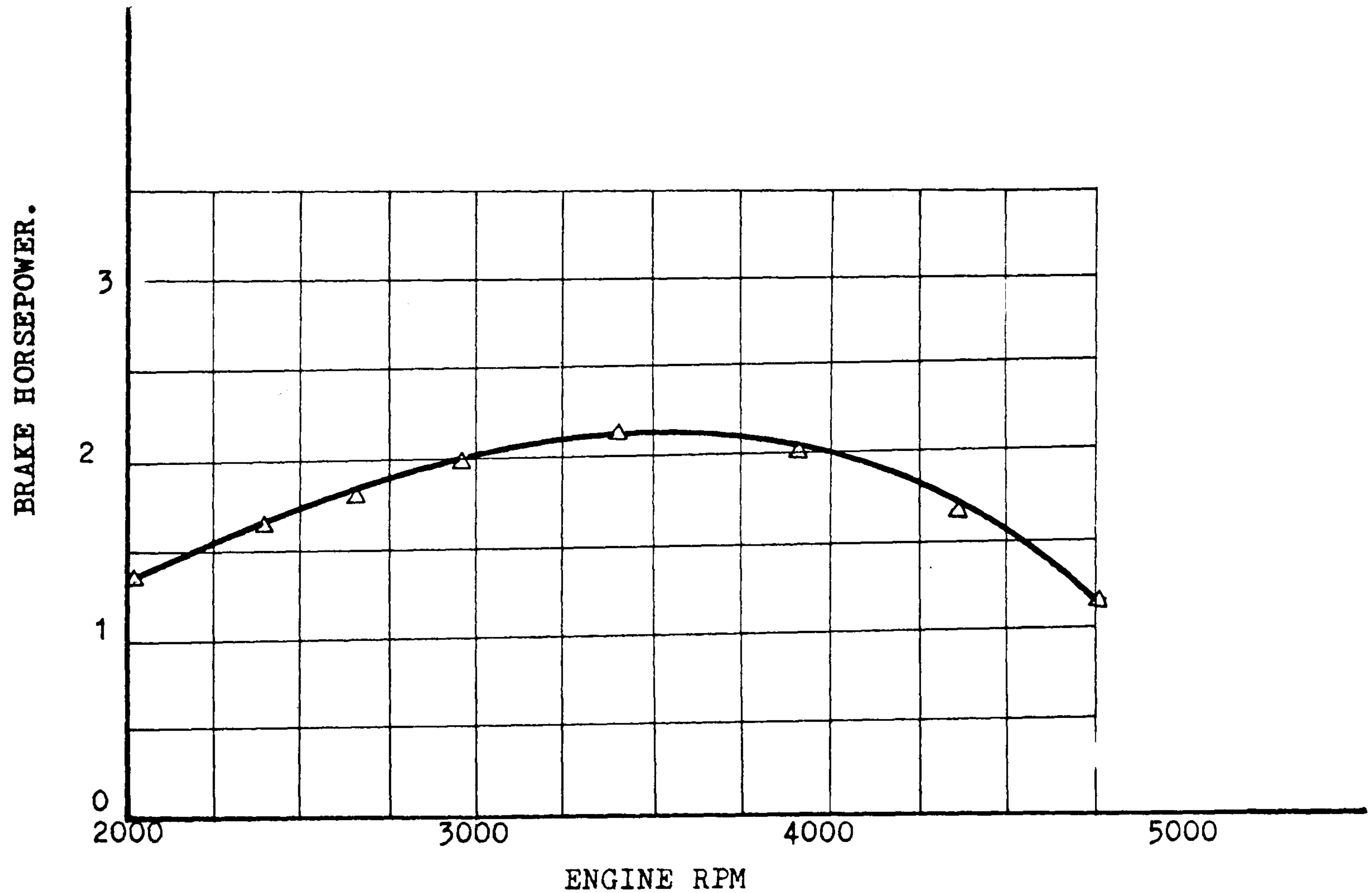

FIGURE 6B : Uncorrected brake horsepower vs engine speed(max.4850 RPM unloaded)

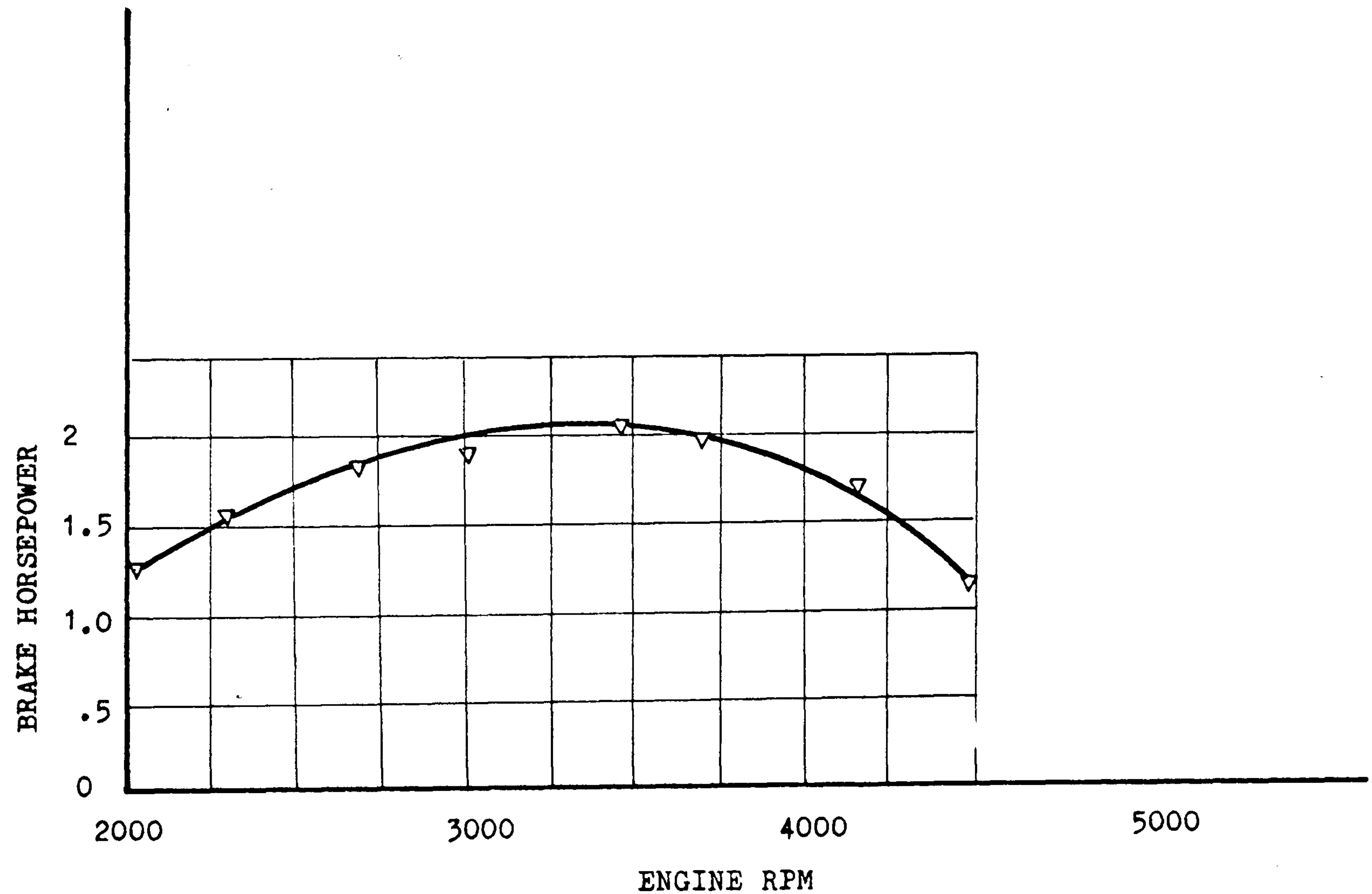

FIGURE 6C : Uncorrected brake horsepower vs engine speed(max.4600 RPM unloaded)

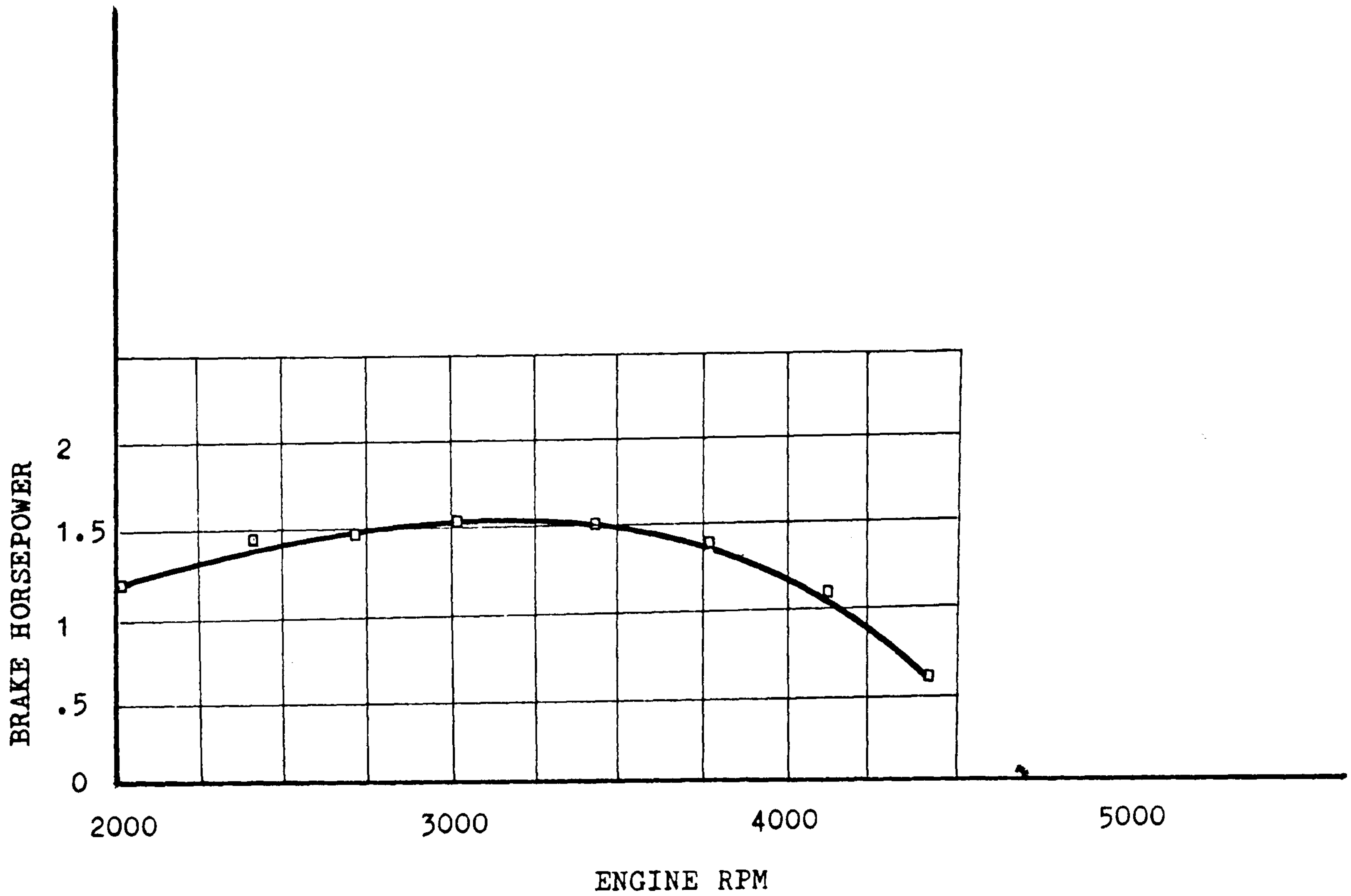

FIGURE 6D : Uncorrected brake horsepower vs engine speed(max.4500 RPM unloaded)

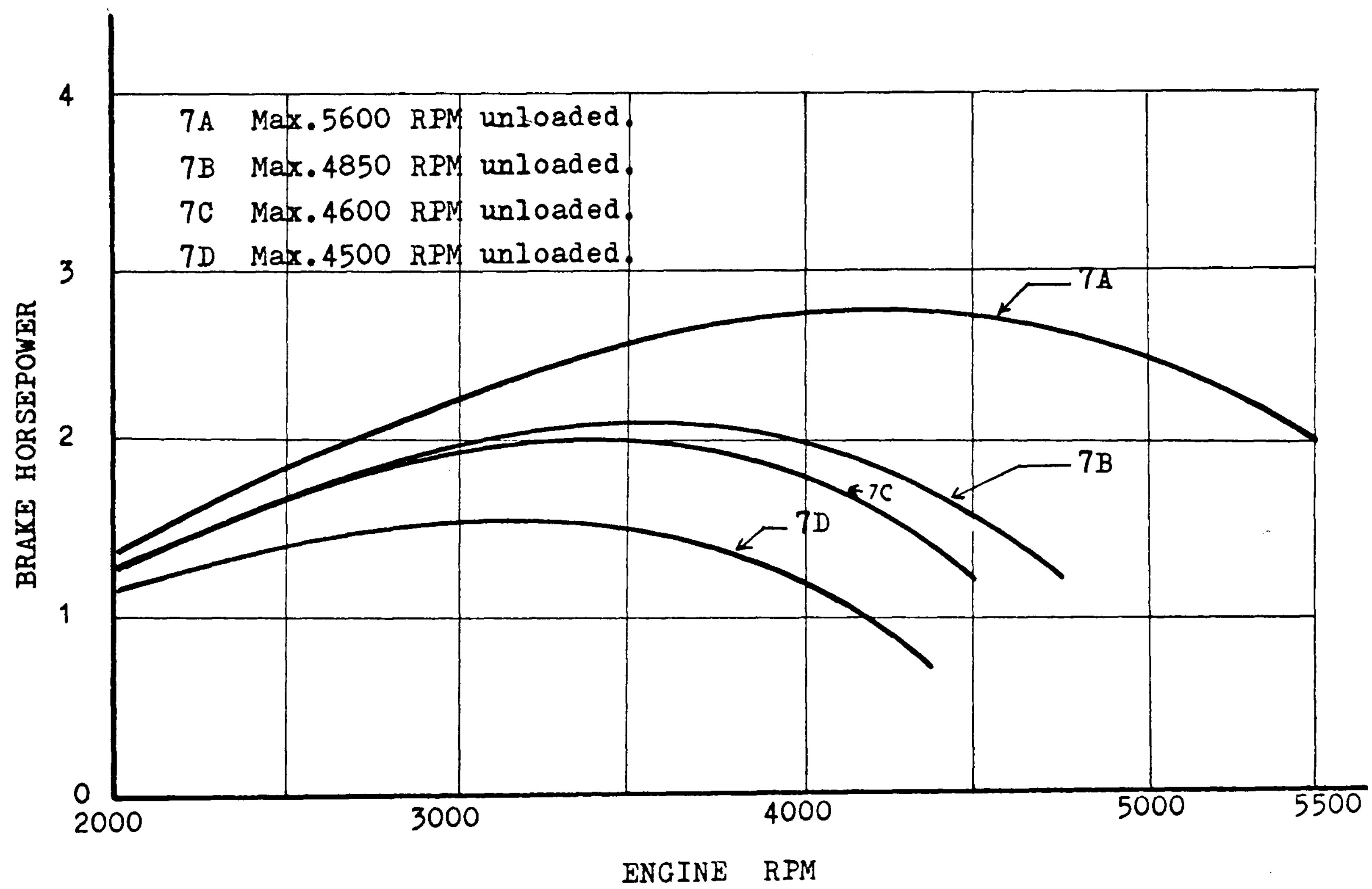

Figure 6E : ADJUSTED BRAKE HORSEPOWER **vs** SPEED ENGINE.

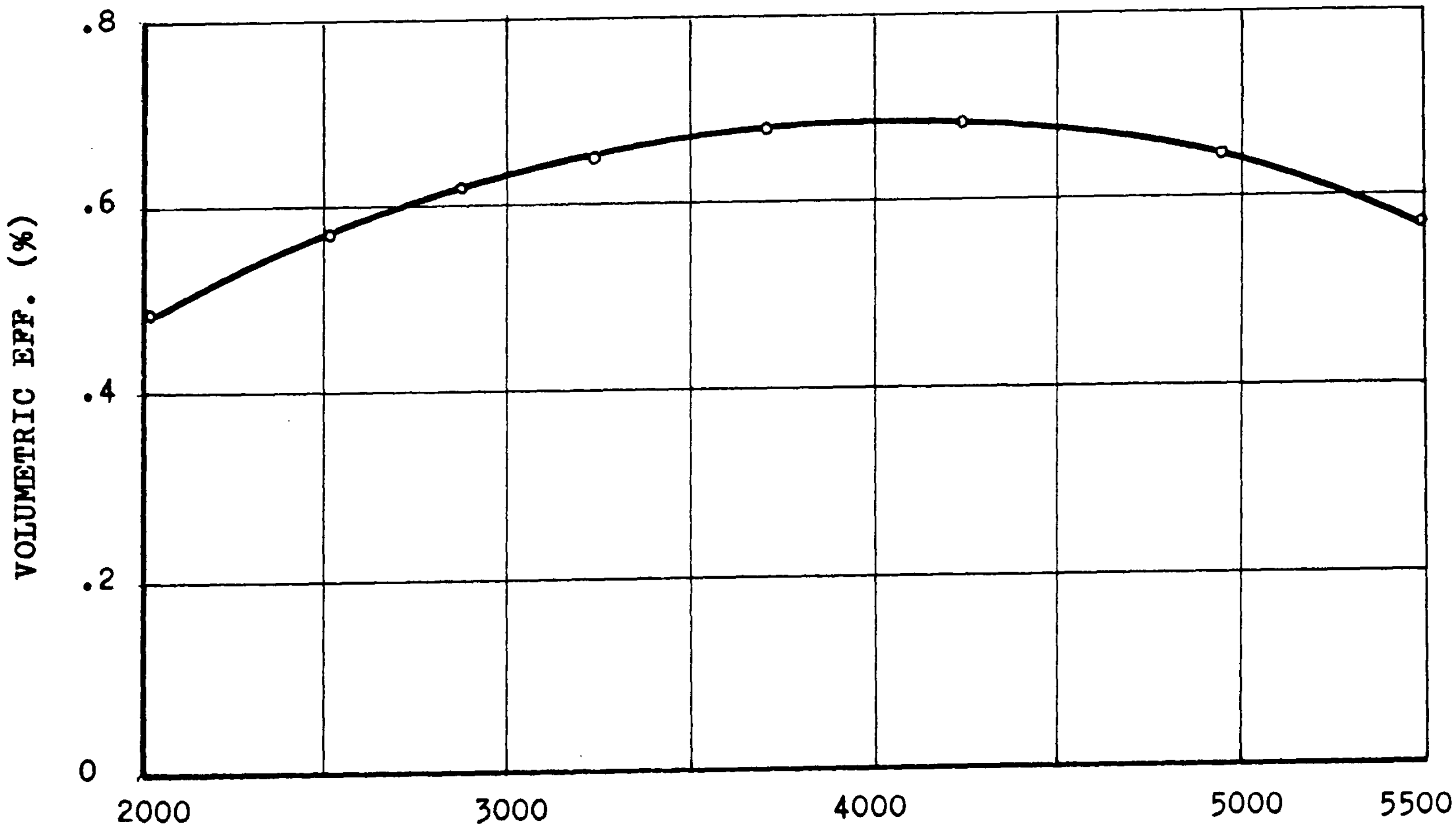

Figure 7 : Volumetric efficiency vs engine speed (full throttle)

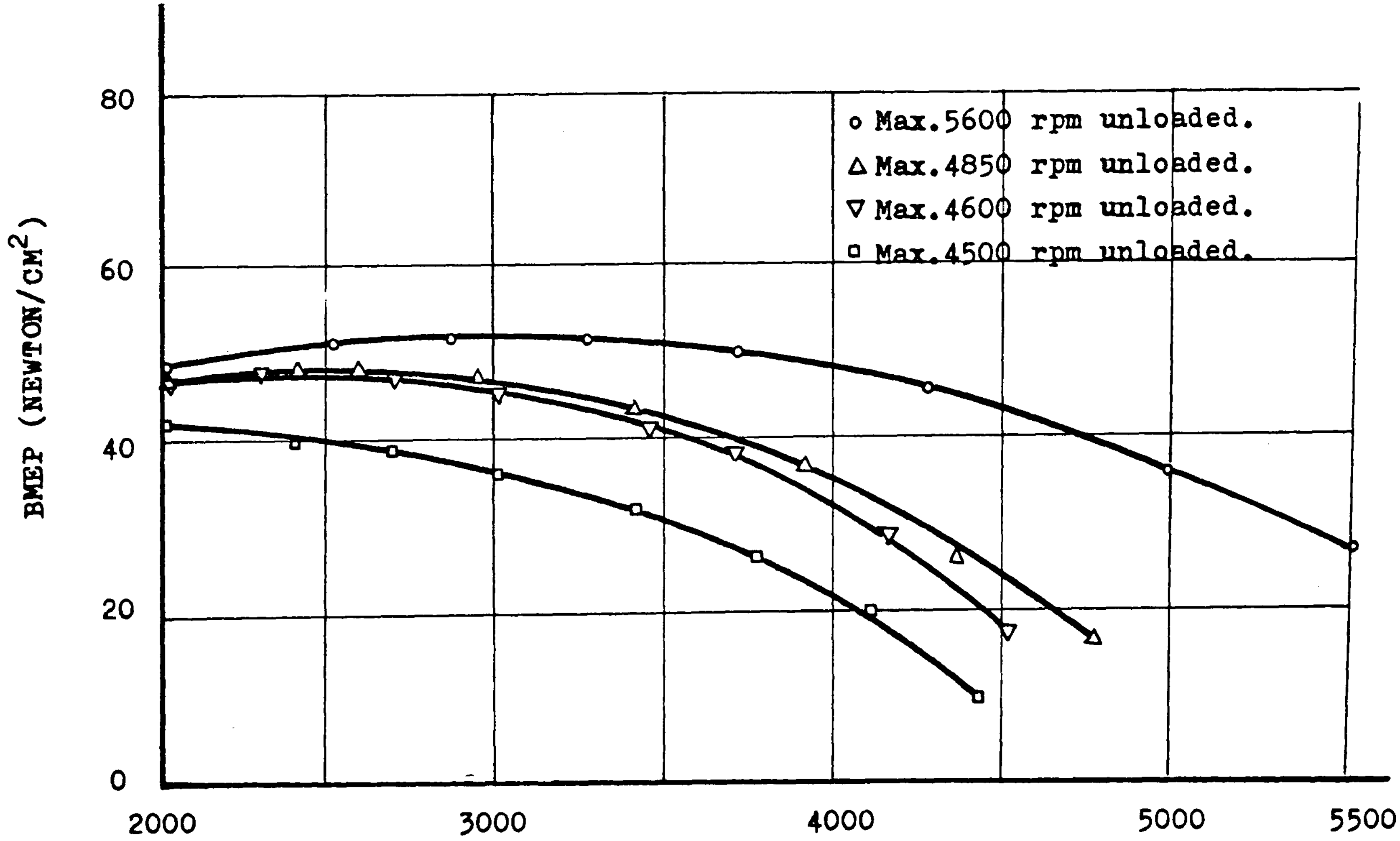

Figure 8 : Adjusted BMEP vs engine speed.

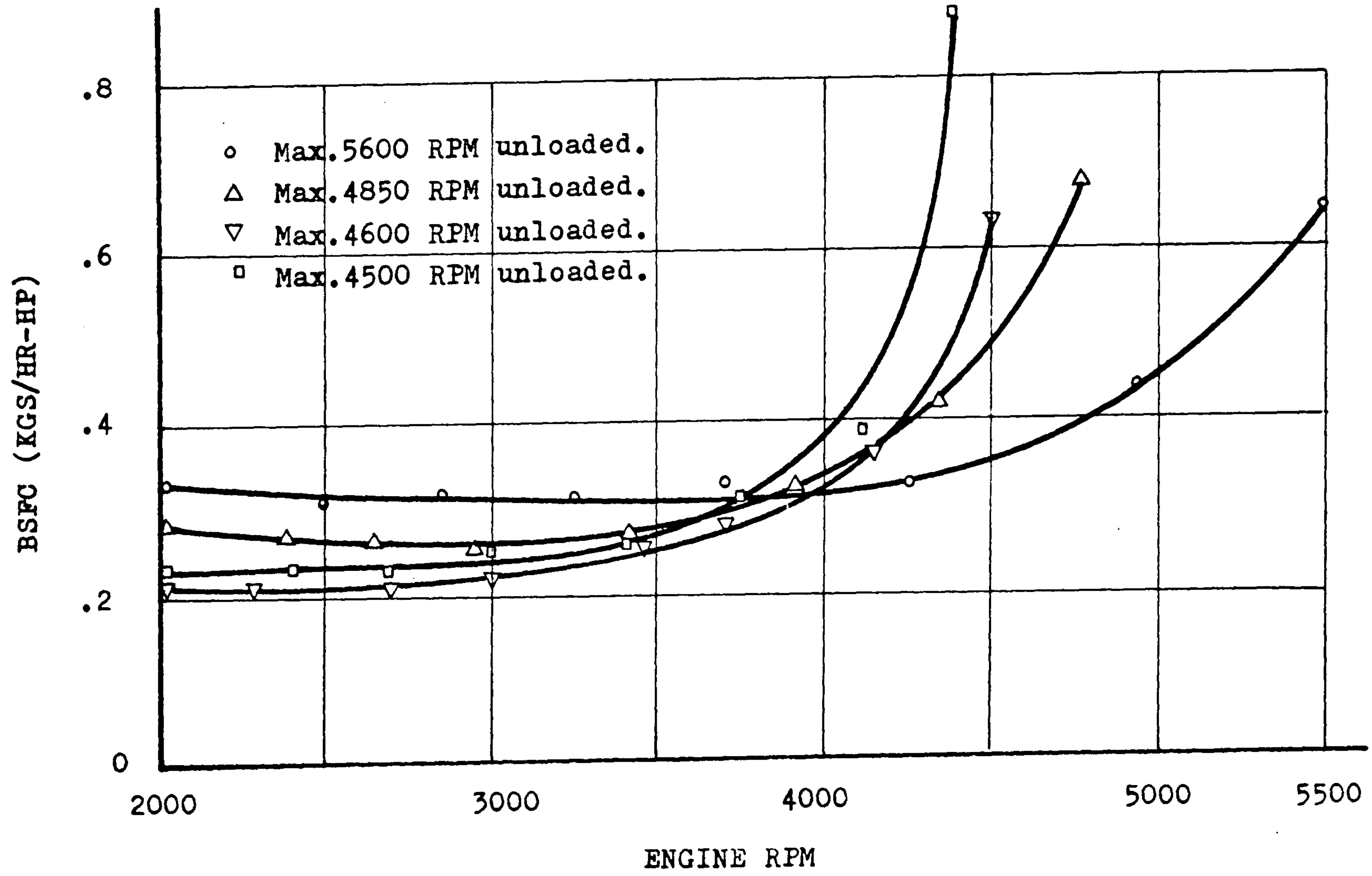

Figure 9 : Adjusted BSFC vs engine speed.

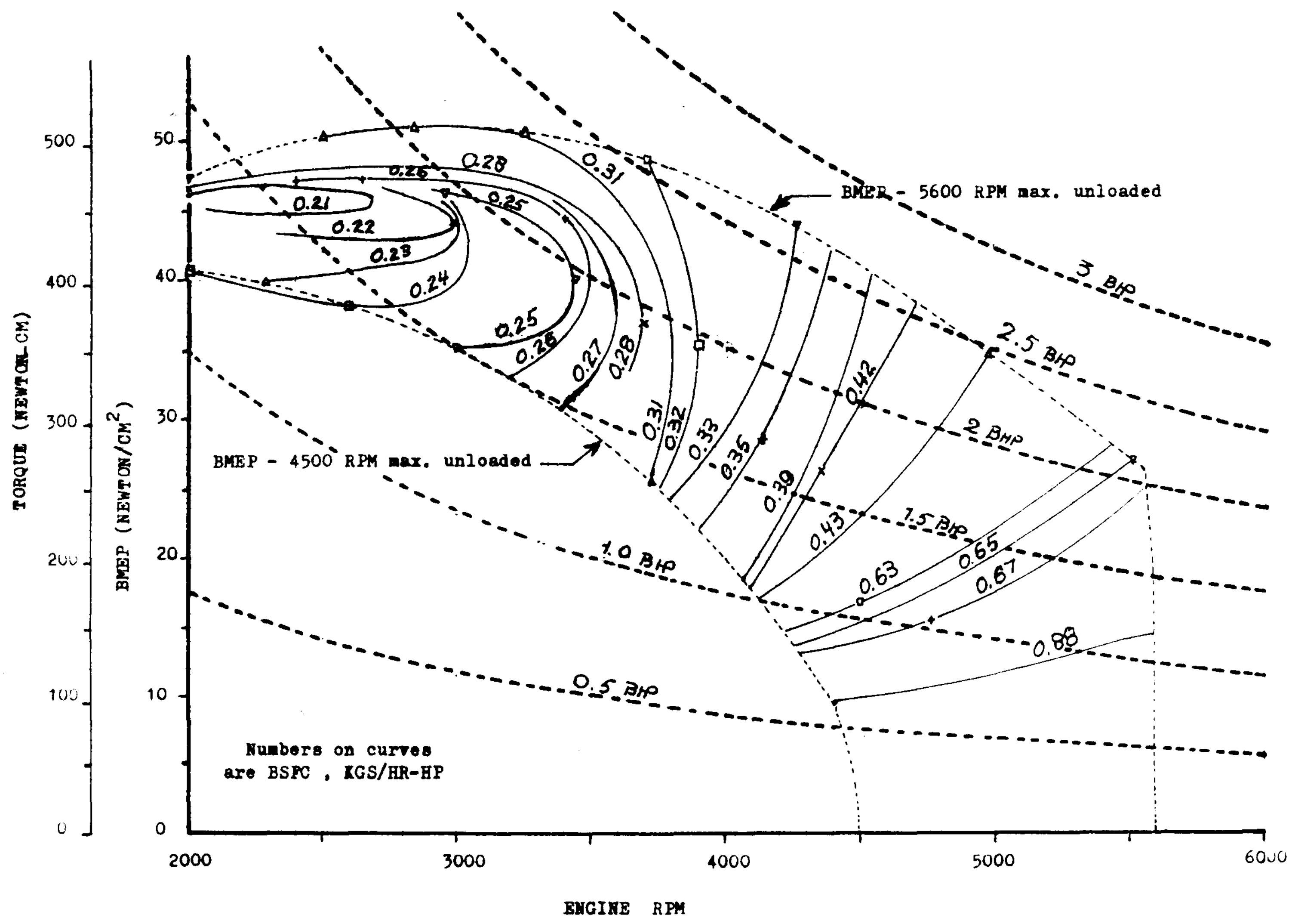

Figure 10 : Engine performance chart.

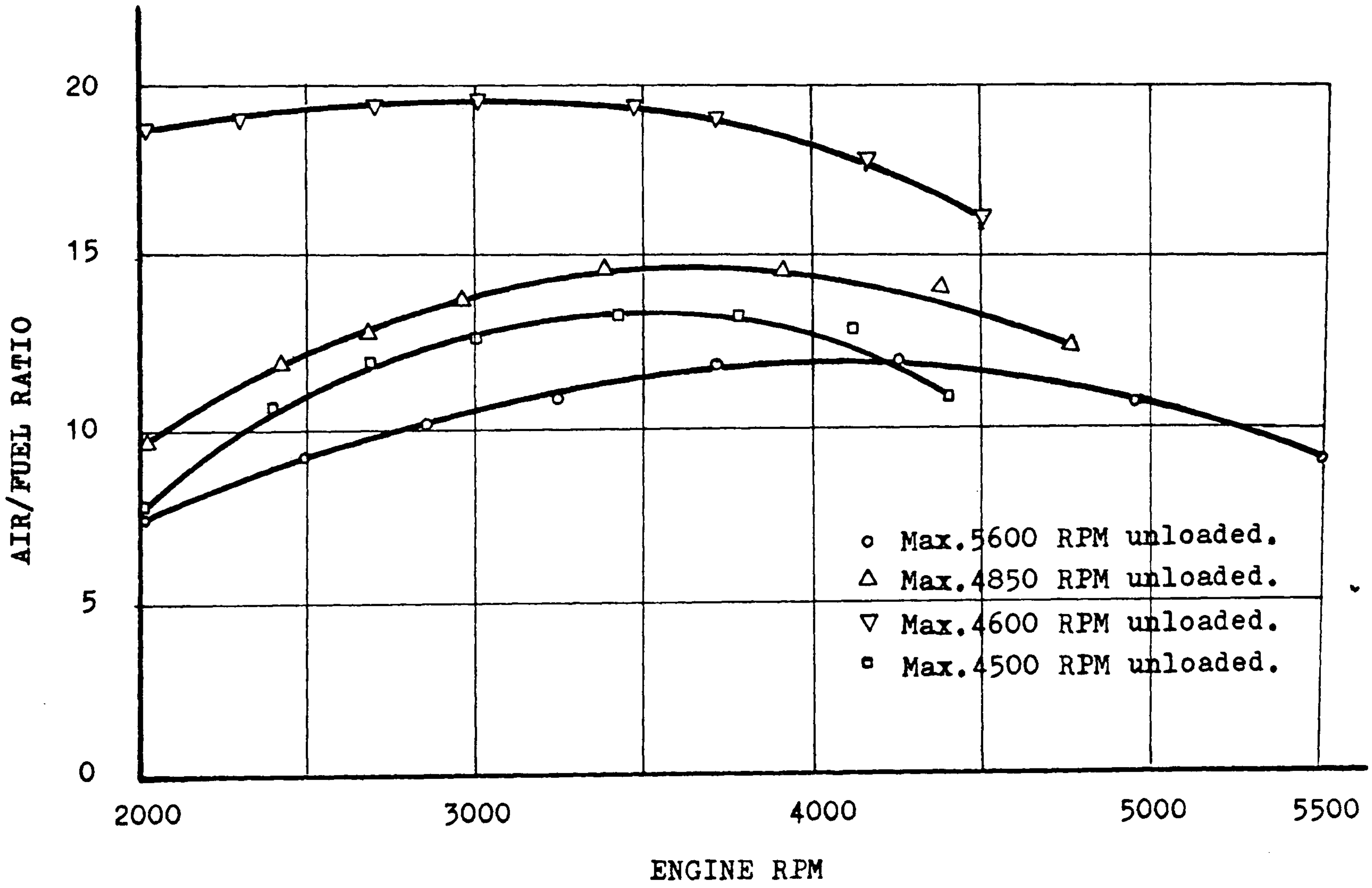

Figure 11 : Air to fuel ratio.

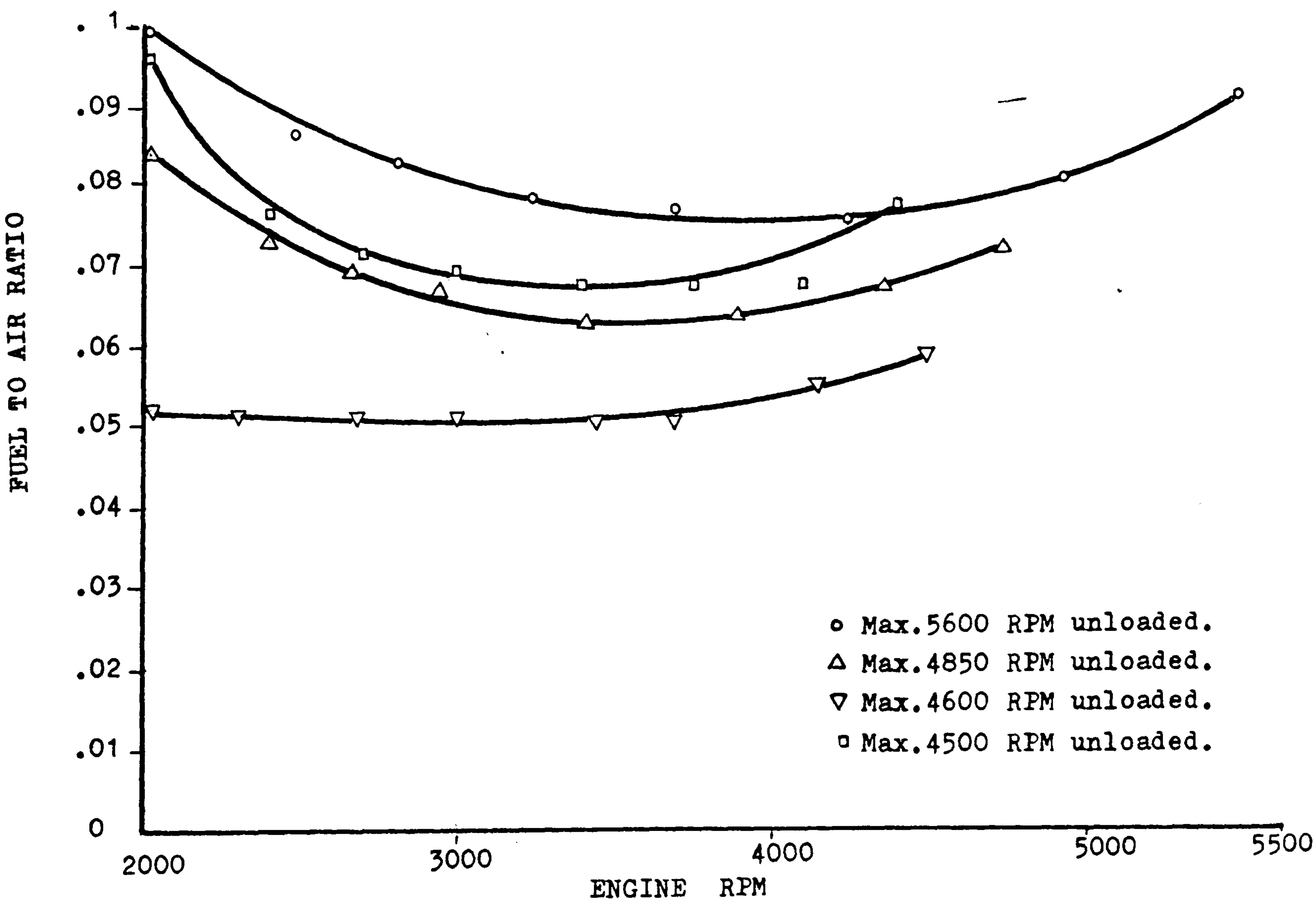

Figure 12: Adjusted Fuel to air ratio.

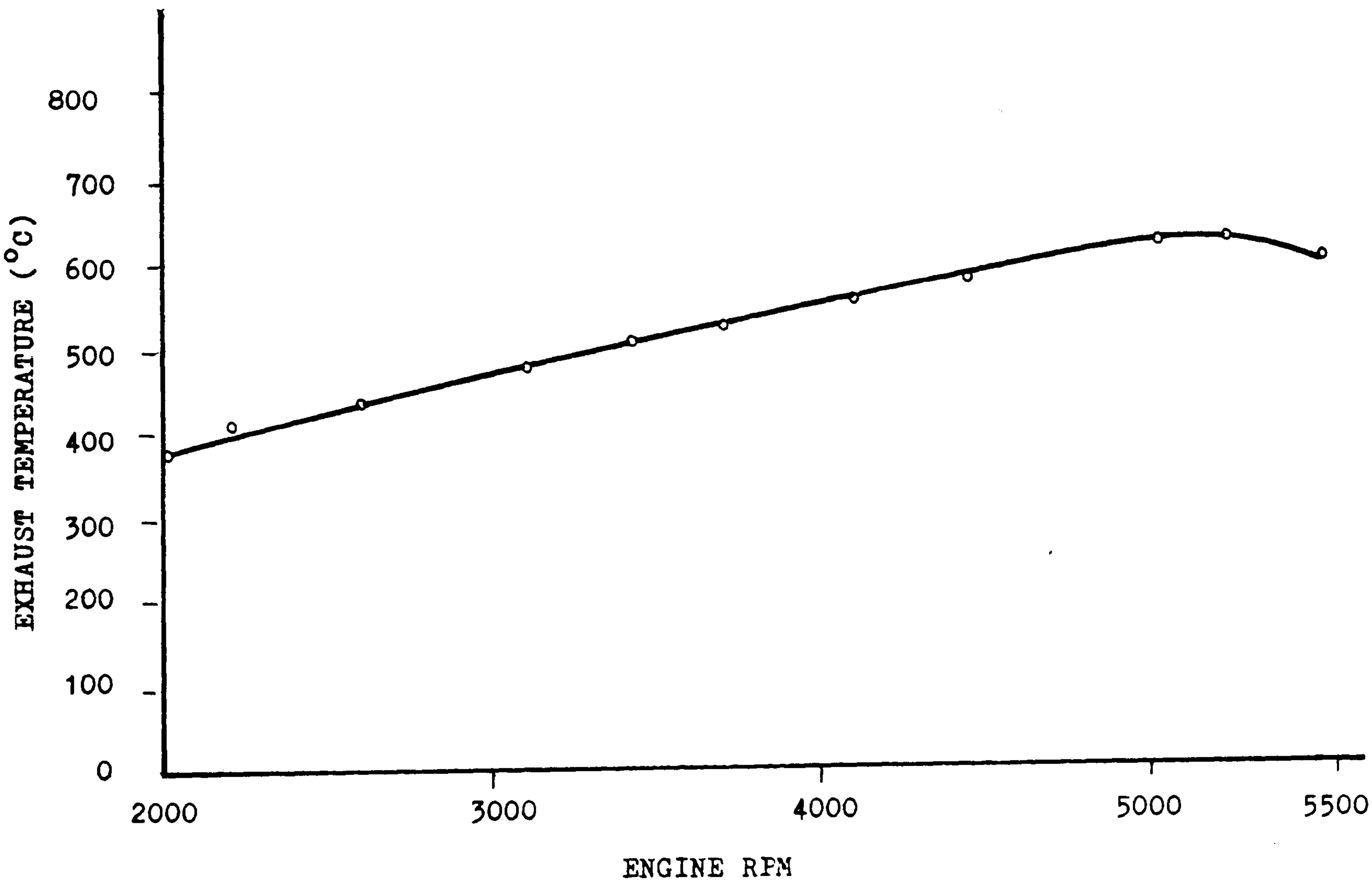

Figure 13 : Exhaust gas temperature vs engine speed (full throttle)

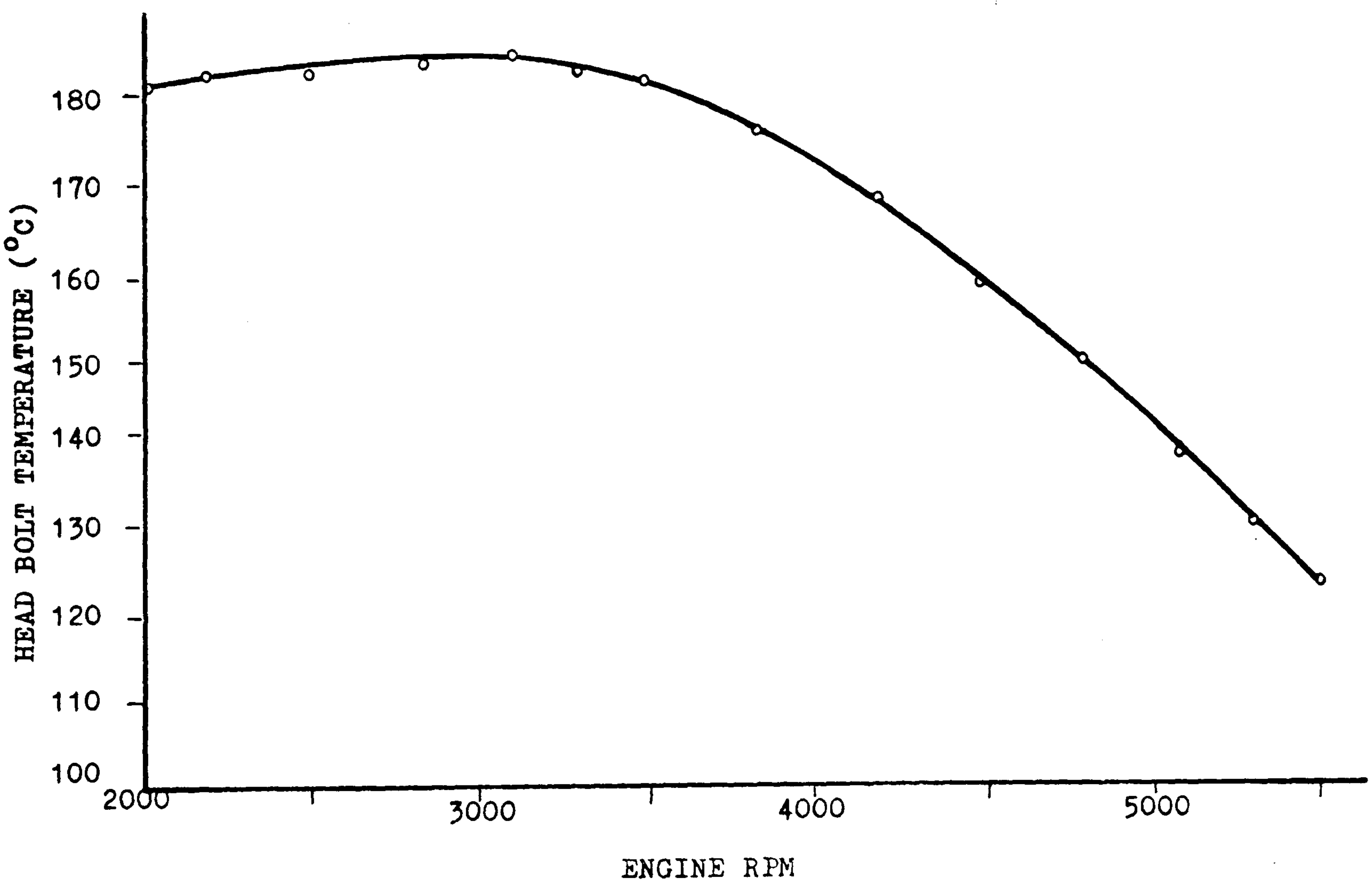

Figure 14 : Head bolt temperature vs engine speed (full throttle)

REFERENCES

Books

1. Rogowski, A. R. "Elements of Internal Combustion Engines. McGraw Hill, New York, 1953.

2. Taylor, C. F. and E. S. Taylor. "The Internal Combustion Engine". International Textbook, Scranton, Pa., 1948.

3. Lichty, L. C. "Internal Combustion Engines" 6th Ed., McGraw Hill, New York, 1951

VITA

Lac-Minh-Chau was born on May 15, 1944 in Kien-Hoa VIET NAM.He is the son of Mr & Mrs Lac-Van-Bay.

After finishing high school,he attended the VIETNAMESE NATIONAL MILITARY ACADEMY where he received a Bachelor degree.He came to Lehigh in the Fall of 1973 to study for the degree of MS in Mechanical Engineering.

He received a scholarship from Agency International Development from the Fall of 1973 to August 1975.From September 1975 to December 1975 he was employed as a teaching assistant in the Department of Mechanical Engineering.From January 1976 he has been employed as a research assistant in the Department.