OPTIMIZATION OF THE SECONDARY AIR FLOW IN A TWO-STROKE CYCLE METHANOL FUELLED SPARK IGNITION ENGINE WITH EXTRA REED VALVES FITTED ON THE TRANSFER DUCTS

A PROJECT REPORT
submitted in partial fulfilment of the requirements
for the award of the degree of
BACHELOR OF TECHNOLOGY
in
MECHANICAL ENGINEERING

by

TARUN MATHUR
&
SANJAY P. SUBRAMANIAN

Under the guidance of

Prof. K. V. GOPALAKRISHNAN

INTERNAL COMBUSTION ENGINES LABORATORY
DEPARTMENT OF MECHANICAL ENGINEERING
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MADRAS-600 036

MAY 1987

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CERTIFICATE

This is to certify that the project report titled 'OPTIMIZATION OF THE SECONDARY AIR FLOW IN A TWO-STROKE CYCLE METHANOL FUELLED SPARK IGNITION ENGINE WITH EXTRA REED VALVES FITTED ON THE TRANSFER DUCTS' submitted by SANJAY P. SUBRAMANIAN and TARUN MATHUR is a record of bonafide work done by them in the Internal Combustion Engines Laboratory at the Indian Institute of Technology at Madras.

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A C K N O W L E D G E M E N T

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And finally, we each thank the other for contributing towards bringing this project to a successful completion.

*****

CONTENTS

OPTIMIZATION OF THE SECONDARY AIR FLOW IN A TWO-STROKE CYCLE METHANOL FUELLED SPARK IGNITION ENGINE WITH EXTRA REED VALVES FITTED ON THE TRANSFER DUCTS

A B S T R A C T

Two-stroke spark ignition (SI) engines are widely used in the field of light motor cycles, scooters etc. owing to their high power-to-weight ratio, ease and simplicity of manufacture and maintainance. However, two stroke cycle engines have two serious drawbacks in that they have a high specific fuel consumption and high HC and CO e~~m~~missions because of short-circuiting of fresh air-fuel mixture during scavenging. Obviously, any effort made to reduce this short-circuiting of fresh charge during scavenging will result in lower specific fuel comsumption and lower exhaust emissions.

Some work towards this aim has already been done at the I.C. engines Lab at IIT Madras [2] using secondary air induction through reed valves fitted on the transfer duct to improve scavenging. In the present work, the secondary air flow through the reed valves has been optimised for a methanol fuelled two stroke SI engine.

Constant speed tests conducted at various loads and secondary air flows indicate an improvement in brake thermal efficiency, exhaust emission and combustion parameters like combustion duration, peak pressure etc. with reed valves. The improvements are more significant at part throttles.

OPTIMIZATION OF THE SECONDARY AIR FLOW IN A TWO-STROKE CYCLE METHANOL FUELLED SPARK IGNITION ENGINE WITH EXTRA REED VALVES FITTED ON THE TRANSFER DUCTS

2. INTRODUCTION

The two-stroke cycle spark ignition (SI) engine is among the simplest and cheapest prime movers of all to manufacture, service and maintain. In addition, with its high specific output (power to weight ratio), the 2 stroke cycle engine has become very popular for automotive applications especially in the field of light motor cycles, scooters and mopeds et cetera.

All reciprocating engines (2 stroke or 4 stroke) carry out the process of induction, charge transfer, scavenging and exhaust in an unsteady manner. For a two stroke cycle engine, this unsteady gas flow is further complicated during the scavenging and charging, in the engine cycle. The fresh charge is used for scavenging in a two stroke cycle engine. The fresh charge arriving from the crankcase through the transfer ports is used to clear the cylinder of the burned gas and exhaust products which leave through the exhaust port. The result of the unsteady inflow and outflow process is a short circuiting of a part of the fresh air-fuel mixture through the exhaust ports. This lowers the trapping efficiency. Depending on the operating conditions and type of scavenging (cross flow or loop type) , 25 to 40 percent of the incoming charge is lost through the exhaust ports [1 and 3].

This fuel loss leads to

a. High specific fuel consumption
b. High HC (hydrocarbons) and CO (carbon monoxide) emissions.

The exhaust gas dilution in the cylinder necessitates a richening of the mixture and consequently higher CO emissions. It also results in a decreased flame velocity which brings about a decrease in efficiency.

From the above discussion, it is clear that any effort to flush out the exhaust gases properly without loss of any fresh air-fuel mixture will result in an improved overall performance of the two stroke cycle SI engine.

Some work in this direction has already been carried out in the Internal Combustion Engines Lab in IIT Madras[2] and the present work is a continuation of the previous effort with a few changes and modifications. In the present work, efforts have been made to reduce the short circuiting of the fresh charge by optimizing the secondary air induction through reed valves fitted on the transfer ducts of a typical 2 stroke SI engine. A brief description of the reed valves and the principle involved follows.

****

3. REED VALVES-ASSEMBLY AND WORKING PRINCIPLE

The reed valve is a one way valve permitting unidirectional flow of fluids. The flaps open due to pressure differences. Since the flaps are very thin metal strips; they have a very high natural frequency enabling the value to be used effectively at the high speeds that are encountered in two-stroke cycle engines.

The valves currently used in TVS 50 Mopeds (to introduce fuel mixture into the crankcase) were enclosed in specially fabricated stainless steel containers (fig. 1). Since the volume between the engine and the reed valve gets added to the crankcase volume of the unmodified engine, care was taken to minimise the volume in order to avoid problems with scavenging pressure. The assemblies were then screwed on top of the transfer ducts after milling the fins in those areas and drilling and tapping suitable holes (fig. 2).

During the compression stroke, the crankcase and transfer ducts are at subatmospheric pressure. Owing to the pressure difference across them, the reed valves permit atmospheric air to be sucked into the transfer ducts while the fresh air fuel mixture enters the crankcase in the normal way. [fig. 3].

During the downward stroke of the piston, pressure builds up in the crankcase and transfer ducts as soon as the inlet ports close and hence the reed valves close. As the

REED VALVE ASSEMBLY

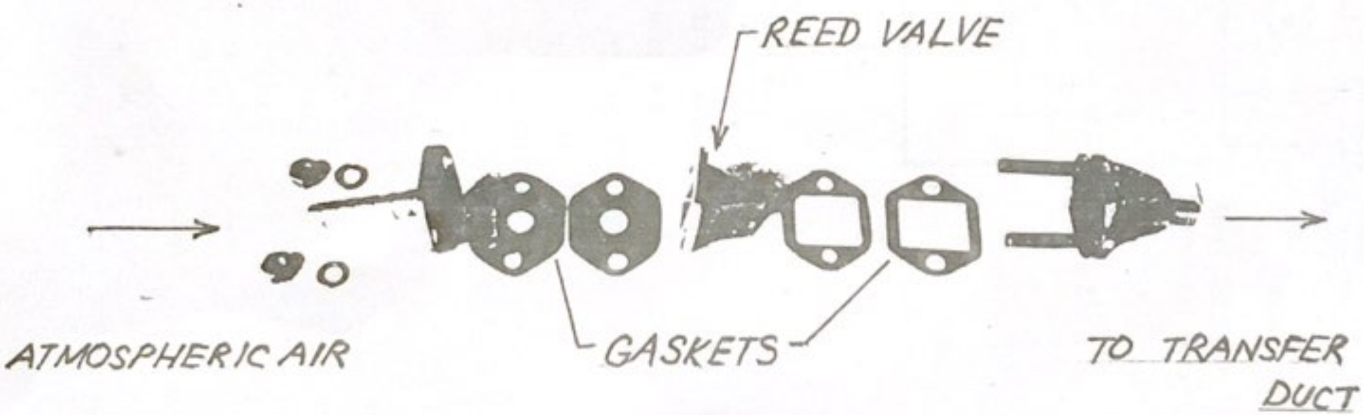


FIG. 1.

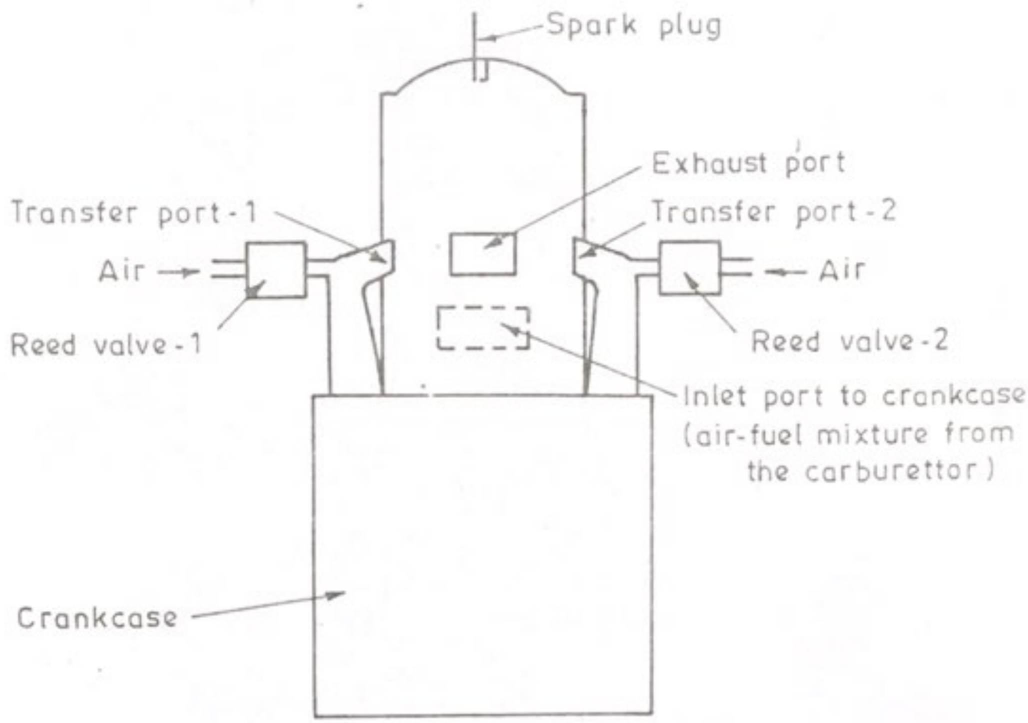


FIG.2.

Two-stroke spark ignition engine fitted with extra reed valves

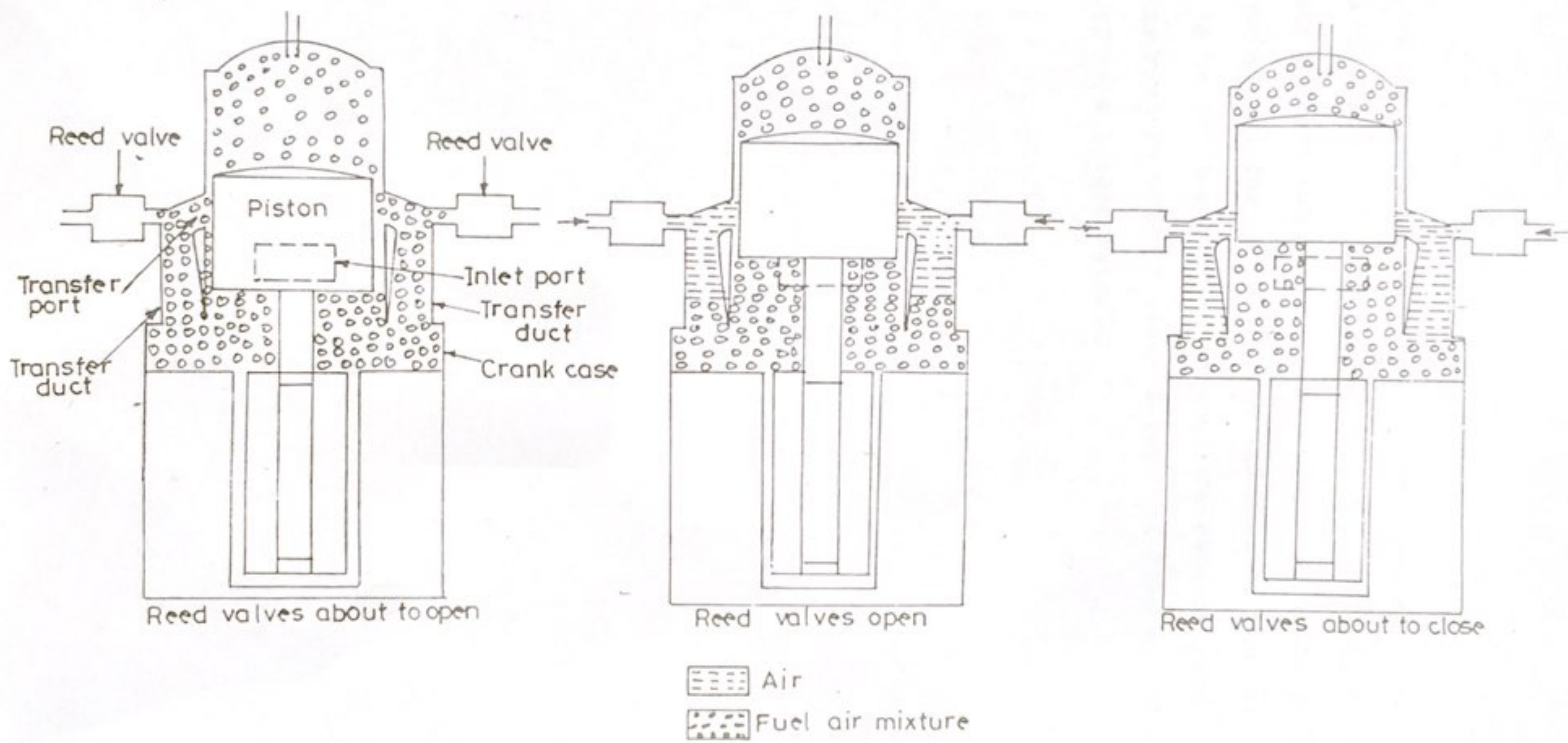


FIG.3. Various stages in the filling up of the transfer duct with air during the upward movement of the piston

piston descends further, the inlet ports open and the air in the transfer ducts enters the cylinder instead of the fuel-air mixture (as in the case of the unmodified engine). This air pushes out the exhaust gases and becomes the main component to be short-circuited through the exhaust port. The fuel-air mixture which follows later is trapped inside the cylinder to a larger extent.

***

4. TEST SET - UP

A schematic diagram of the test set-up used during the tests is shown in fig. 4..

A Bajaj 150 cc Scooter engine, was used for the tests. It was modified to operate on methanol, and connected to an eddy current dynamometer. The dynamometer has a brake control unit (Vibrometer type CEB 104) which regulates the engine speed (or torque) and displays the torque, speed and power on digital read out (DRO).

A calibrated burette and stop watch were used to measure fuel flow. A ceramic filter was introduced in the fuel line to filter the impurities present in the methanol (15 parts of coconut oil + 35 parts of castor oil were mixed with 1000 parts of methanol for lubrication).

A special surge tank was fabricated in the present work. In earlier experiments, there were problems with resonance in the pipes connecting the surge tank, and the engine. The surge tank was mounted directly above the carburettor, and the connecting pipe length was about 2 cm. An air flow meter and air filter were connected to the top of the surge tank.

Polythene tubes and a T-joint were used to interconnect the two reed valves and make a common connection. This was taken to a gas flow meter via a needle valve to regulate the air through the reed valves.

SCHEMATIC DIAGRAM OF TEST SET-UP

1. CARBURETTOR
2. ENGINE
3. DYNAMOMETER
4. BRAKE CONTROL UNIT
5. SURGE TANK
6. AIR FLOW METER
7. AIR FILTER
8. FUEL FILTER
9. EXHAUST TEMP. METER
10. HC & CO ANALYSER
11. EXHAUST LINE
12. TDC PICK UP
13. PRESSURE PICK UP
14. CHARGE AMPLIFIER
15. SIGNAL ANALYSER
16. FLOW CONTROL VALVE
17. GAS FLOW METER
18. FUEL FLOW METER
19. REED VALVES
20. THERMOCOUPLE [EXHAUST]

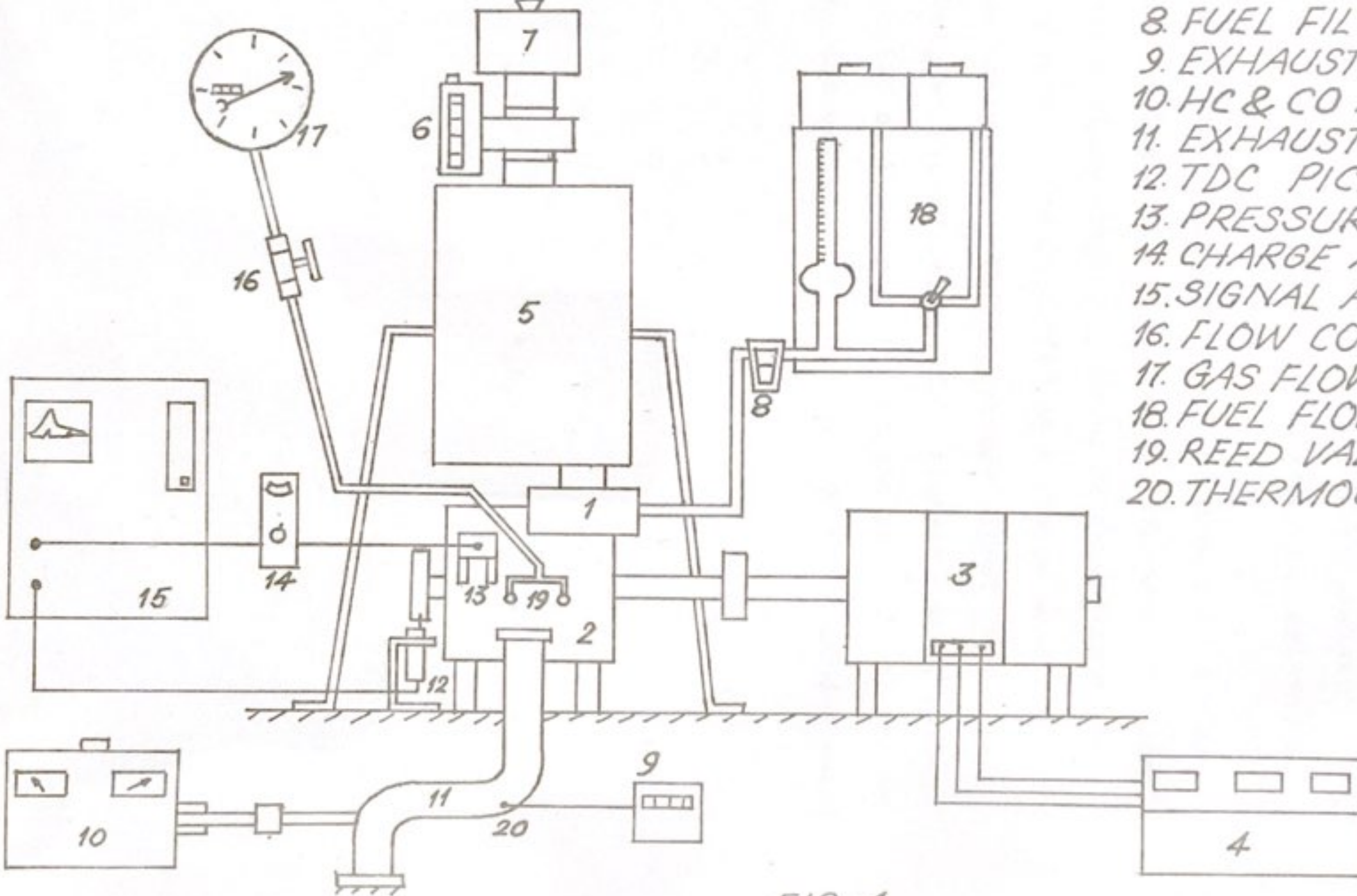


FIG. 4.

A thermocouple fitted in the exhaust pipe led to a meter which displayed the exhaust temperature on a DRO. A tapping from the exhaust line was taken to the HC/CO analyser (MEXA - 324 F-B HORIBA, JAPAN) to measure the emissions.

Pressure-time diagrams (fig. 5) were recorded on floppy discs using a signal analyser. The pressure signal coming from a piezo-electric pick up is converted to an equivalent voltage and amplified by a charge amplifier, and fed to the analyser. This pressure signal was also used to trigger the analyser. TDC signals coming through a pin (mounted on a perspex disc on the crankshaft) and an inductive pick up, were recorded through the second channel.

*****

5. TESTS PERFORMED

5.1. Jet Optimization for Methanol

To run the engine on methanol, the jets had to be enlarged and optimised. Holes of diameters varying from 1.1 mm to 1.6 mm were drilled in standard main jets and from 0.5 mm to 0.7 mm in the standard idling jets. With each combination of main jet and idling jet, the fuel consumption, torque and fluctuations in speed, and torque were noted. Based on the results, main jet of 1.5 mm diameter and idling jet of 0.7 mm diameter were found optimum and all subsequent tests were done with this combination of jets.

5.2 Performance Tests

Constant speed tests at 2000, 3000 and 4000 RPM were conducted with the unmodified engine (i.e. with reed valves closed). At each speed the throttle position was varied and for each such operating condition, various readings were taken (fuel flow, air flow, speed, torque, exhaust emissions, cylinders pressure time history et cetera) and the performance curves were plotted. The file names for these tests in the floppy were 5 digit numbers which were decided as follows:

1st digit	:	fuel (0 for methanol)
2nd digit	:	The thousands figure of speed
3rd digit	:	The hundreds figure of speed
4th digit	:	Throttle position number
5th digit	:	0 for jet combination used (1.5 mm dia. main jet 0.7 mm dia. idling jet)

For example :

```
0 3 0 4 0
│ │ │ │ └── Main jet = 1.5∅, idling jet = 0.7∅
│ │ │ └──── Throttle position 4
│ │ └────── 100 * 0 = 0        ⎫
│ └──────── 1000 * 3 = 3000    ⎭ speed.
└────────── fuel  = methanol.
```

Graphs are plotted with power on the x-axis and brake thermal efficiency, specific fuel consumption, air-fuel ratio, hydrocabon and carbon monoxide emissions, combustion parameters etc on the ordinate.

5.3. Test with Reed Valves :

Constant speed tests with reed valves in operation were carried out at 2000, 3000 and 4000 RPM. At each speed, the throttle position was varied and at each throttle position, the air flow through the reed valve was changed from zero to full flow. At each flow through the reed valve, the previously mentioned parameters were noted in this series of tests and the convention used for naming the floppy files was as follows :

6 digit numbers were used, the first file having the same meaning as 5.2 ; the 6th digit corresponds to the flow position through the reed valves.

<u>For example</u> :

0 3 0 4 0 3

Flow through reed valves: position 3

Main jet = 1.5∅ : idling jet = 0.7∅

Throttle position 4

100 X 0 = 0 } speed

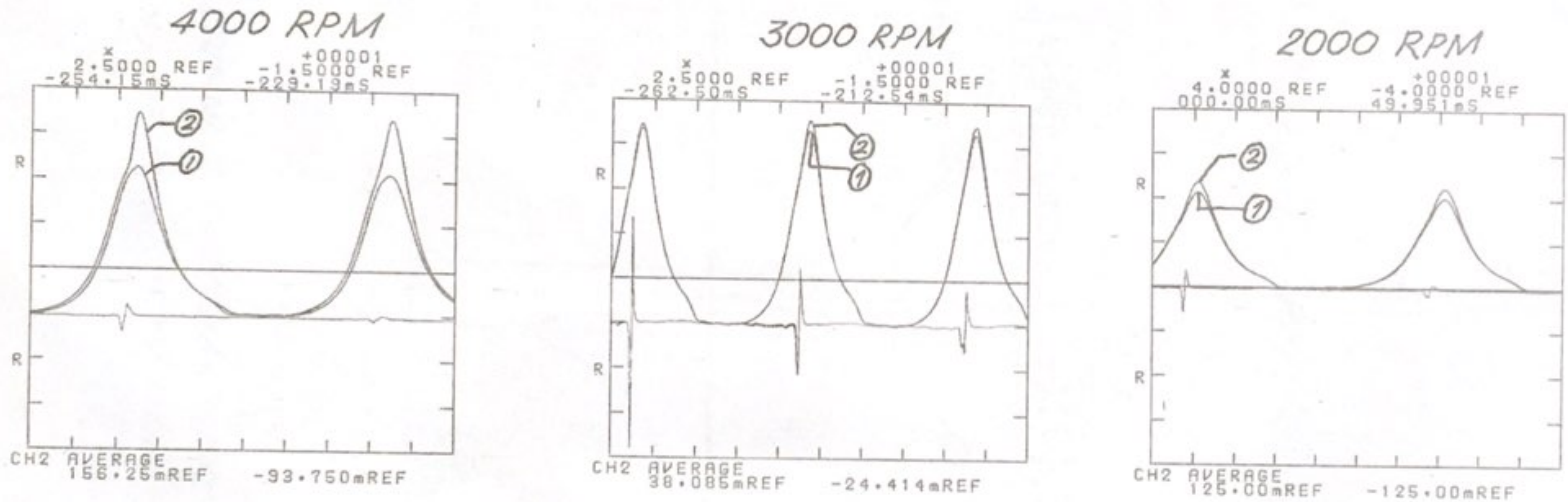
1000 X 3 = 3000 } speed

fuel = methanol.

Graphs are plotted with air ratio (ratio of flow Through reed valves to the main air flow). On the X axis, and the other variables like Brake Thermal efficiency, power specific fuel consumption, exhaust and combustion parameters on the y-axis.

6. ANALYSIS OF PRESSURE-TIME DIAGRAMS:

Pressure-time diagrams are recorded on floppy discs using the signal analyser. The convention followed for naming the files has been discussed above. For the purpose of the analysis.the required pressure and time (TDC) signals are called on to the display. The pressure curve has to be shifted as the charge amplifier signal is unreferenced and has a arbitrary D.C. component. The amplitude at the BDC point is located and a D.C. shift is given to make the amplitude at this point equal to zero (it is assumed that the cylinder pressure is zero gauge at BDC). Once the pressure curve is set right (Fig.5) the peak pressure is located. Now the pressure curve is differentiated and points corresponding to the beginning and end of combustion are located (Fig.6). The maximum rate of pressure change is also found out. The duration of combustion is calculated and the combustion parameters thus obtained are plotted against the air ratio (Fig. 25, 26, and 27).

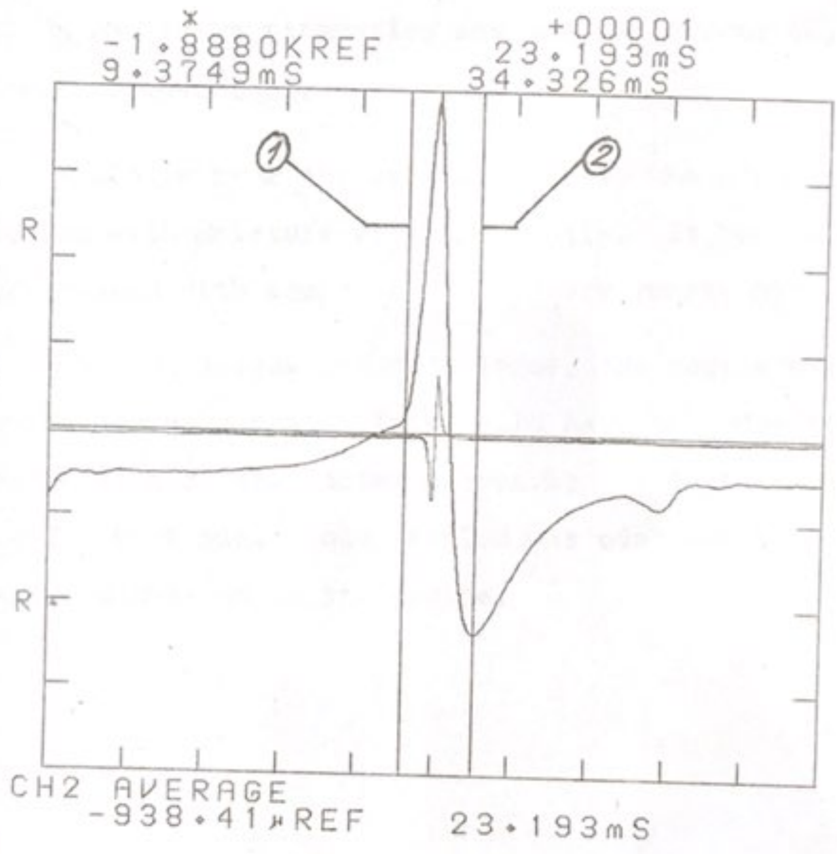


① - WITHOUT REED VALVES
② - WITH REED VALVES

FIG 5. PRESSURE - TIME DIAGRAMS

FIG.6.

A DIFFERENTIATED PRESSURE-TIME DIAGRAM



① - BEGINNING OF COMBUSTION
② - END OF COMBUSTION

7. SOME PROBLEMS FACED DURING THE TESTS

1. The float in the carburettor swells up due to the effect of methanol. This affects the performance of the carburettor unless the float is reduced to its original size by immersion in petrol. Metal floats for the Bajaj engine were not available. Since all the tests were not conducted on the same day, the set up had to be dismantled and the float removed, and soaked in petrol overnight.

2. The pipe from the exhaust line to the HC/CO analyser got blocked with moisture very frequently. It had to be removed and cleaned with compressed air every twenty minutes or so.

3. At high speeds and full loads, the engine used to get overheated very fast. This could have been due to partial obstruction of the engine blower by the perspex disc carrying the TDC mark pin. This problem was overcome by directing a radial blower on to the engine.

8. RESULTS AND DISCUSSION

The results of the constant spedd tests carried out on the unmodified engine are shown in Figures 7 through 12. The Brake Thermal Efficiency (ηth), Brake Specific Fuel Consumption (BSFC), Air Fuel Ratio, HC and CO emissions and exhaust temperature are plotted against the power at each speed for different throttle positions.

The results obtained with the modified engine are shown in Figures 13 through 27. It is seen from these figures that there is considerable improvement in brake thermal efficiency at all speeds with extra air induction through the reed valves. From figure 16 it is seen that at 2000 RPM and low throttle, the Brake Thermal Efficiency increases from about 2% (with reed valves closed) to 8% (with reed valves fully open). There is also a corresponding increase in power output from 0.06 KW to 0.3 KW and a reduction in HC and CO emissions (from 4400 PPm to 3400 PPm and 5% to 0.8% respectively). At the same speed and different throttle position (Refer Figure 15) a similar trend is observed but the optimum operating point corresponds to a lower flow rate through the reed valves. The optimum flow rate through the reed valves depends on the speed and throttle position.

The optimum flow rates at each speed are plotted against the power (Figures 28 through 30) along with the Brake Thermal Efficiencies of the modified and unmodified engine. It is seen that as the throttle opens and the load increases, the optimum air flow required through the reed values decreases.If fitted on to a vehicle some arrangement could be made to reduce secondary air flow with increased throttle opening.It is also seen that at high loads, the improvements in efficiency,power and emissions are not very much.Under these conditions,the resistance to the primary air flow is very low and most of the air takes that path with very little or no air going through the reed valves.

The effect of the reed valves is most pronounced at part throttle and part loads. When the primary air passage is almost blocked and there is a significant secondary air induction through the reed valves resulting in better retention of the air fuel-mixture and lesser exhaust gas dilution leading to better combustion,efficiency and power.This is evident from Figures 16,18,19,23,27.The leaning of the air fuel mixture leads to lowering of HC andCO emissions.At higher throttles,this lowering of emissions is not much as very little air goes into through reed values

Since the cylinder temperature rises owing to a better combustion,the NO_x emissions are likely to go up if reed valves are used.It was not possible to measure NO_x emissions as the exhaust analyser available had provision only for HC and CO measurements.

Figures 25 through 27 show the maximum cylinder pressure combustion duration and maximum rate of pressure rise as a function of the amount of secondary air induction.As can be seen from the above plots,the peak pressure and maximum rate of pressure rise improve with secondary air induction.This is again due to better combustion as a larger amount of air fuel mixture is retained in the cylinder. As seen with efficiency and power, there is a particular air ratio for each speed and throttle position at which the peak pressure is maximum. It is seen from Figures 25 through 27 that the combustion duration decreases and is minimum at the optimum air ratio. Better scavenging results in lesser exhaust gas dilution , the flame velocity increases and the combustion is faster. This brings the combustion closer to the ideal constant volume process resulting in a greater power output. The improvement in combustion parameters are also more pronounced at lower loads than at higher throttles for the reasons discussed above.

9. CONCLUSIONS

* Considerable improvement in efficiency is observed when reed valves are used. This effect is more pronounced at part loads.
* There is a significant decrease in the exhaust emissions especially in carbon-monoxide (CO) content, when reed valves are brought into effect.
* An optimum flow rate through the reed valves can be seen at each operating point and this flow rate depends upon the speed and load.
* Power output also goes up with the reed valves. This could be due to better combustion owing to higher retention of fresh air-fuel mexture. This effect is very pronounced at part load throttle positions.
* In city driving, most vehicles operate under part throttle conditions. Hence fitting of reed valves could be an inexpensive way to bring down fuel consuption and emissions.
* Optimum air flow through the reed valves for different throttle positions and speeds have been found out in the present work and this can be used as an indication of the settings requied for defferent conditions.
* At full throttle conditions; the reed valves do not have much effect on engine performance, since there is very little air flow through them(at full open throttles, the resistance to the main air flow is very low and most of the air enters this way) For future studies, compressed air through the reed valves could be tried and its effedt on performance at full throttle should be investigated.

10. TABLES AND GRAPHS

Symbols and abbreviations used:

▯,X - PWR - Power in Kilowatts.

Δ,# - η_{TH} - Brake Thermal Efficiency in %

□ - SFC - Brake specific fuel consumption in Kg/KWHR

○ - A/F - Air/fuel ratio

0 - HC - Hydrocarbon emissions in ppm

∇ - CO - Carbon Monoxide emissions in volume %

◊ - T_{EXH} - Exhaust Temperature in ^{o}C

+ - AIRRATIO - Ratio of secondary airflow to primary air flow in %

¤ - ΔCOMB - Duration of combustion in degrees of crank angle

◇ - dP_{MAX} - Maximum rate of pressure rise in bar/degree crank angle

+ - P_{MAX} - Peak pressure in bar (gauge).

File Name	Power (K.W)	η_{th}%	S.F.C (g/Kwhr)	A/F Ratio	CO (Vol. %)	H.C (p.p.m)	Texh (°C)	ΔComp (°CA)	P_{max} (bar)	dp_{max} (bar/ CA)
02010	1.91	15.69	1168.21	7.09	3.34	8500	450	48.59	25.95	1.03
02020	1.59	20.30	902.82	7.37	0.13	6000	481	53.76	16.76	0.61
02030	1.23	20.67	912.84	6.16	0.15	3900	479	51.35	13.63	0.29
02040	0.96	16.66	1099.62	4.42	2.94	3600	467	54.85	11.44	0.21
02050	0.64	12.83	1428.78	3.22	4.32	3800	441	46.22	11.99	0.17
02060	0.40	9.07	2020.62	2.73	4.71	5500	413	47.00	7.52	0.13
02070	0.03	0.84	21960	1.17	5.52	6000	352	109.11	7.31	0.15
02080	1.80	17.71	1034.64	7.37	0.92	7500	468	45.65	24.41	0.93

Table 1 : Results of constant speed test carried out on the unmodified engine at 2000 rpm

File Name	Power (KW)	η_{th}%	S.F.C. (g/KWm)	A/F Ratio	CO (volume %)	H.C. (p.p.m.)	Texh. (^oC)	$\Delta\theta_{comb.}$ (^oCA)	P_{max} (bar)	dP_{max} (bar/^{o}CA)
03010	3.09	18.33	999.73	5.91	0.91	6500	503	43.91	25.82	1.12
03020	2.53	21.15	866.34	6.40	0.08	5500	525	47.30	19.84	0.65
03030	2.04	21.50	852.24	6.19	0.15	6500	538	49.56	15.10	0.35
03040	1.48	18.83	973.08	6.75	0.22	6000	540	50.05	11.38	0.16
03050	1.02	14.80	1237.92	5.56	0.25	5100	515	95.94	9.42	0.15
03060(5)	0.55	1011	1813.14	4.81	0.44	3500	450	89.52	8.16	0.15
03070	0.09	2.28	8047.26	3.16	0.45	4000	463	70.85	8.12	0.17
03080	2.96	19.54	937.74	6.27	0.15	4000	513	45.05	23.25	0.87

Table 2 : Results of const. speed tests carried out on the unmodified engine at 3000 rpm

File Name	Power (KW)	η_{th} %	S.F.C ($g/KWhr$)	A/F Ratio	CO (Vol %)	HC (ppm)	T_{exh} (^{o}C)	ΔComb. (^{o}CA)	P_{max} (bar)	dp_{max} ($bar/^{o}CA$)
04010	4.17	19.90	920.64	5.52	0.62	5000	574	39.81	24.84	0.99
04020	3.41	20.94	875.22	6.49	0.15	5000	606	44.43	19.37	0.57
04030	2.78	21.19	864.84	6.27	0.15	4800	627	43.14	15.65	0.36
04040	2.04	19.63	933.36	6.13	0.15	4500	625	31.90	14.67	0.25
04050	1.52	18.25	1004.34	5.38	0.25	4700	610	79.48	8.72	0.14
04060	0.85	12.05	1520.16	3.47	3.24	4400	496	90.02	8.74	0.14
04070	0.47	7.49	2446.08	2.87	3.83	4100	438	91.16	7.94	0.14
04080	0.01	0.16	115974	1.85	4.41	3800	392	-	-	-

Table 3 : Results of constant speed tests carried out on the unmodified engine at 4000 rpm.

File Name	Power (K.W)	η_{th} %	S.F.C (g/KWhr)	A/F Ratio	CO (Volume %)	H.C (p.p.m)	T_{exh} (^oC)	Air Ratio (%)	Δ Comb (^oCA)	P_{max} (bar)	dp_{max} (bar/^oCA)
020101	1.10	18.18	1007.94	7.73	0.15	3400	487	1.66	-	-	-
020102	1.17	19.54	937.56	7.55	0.125	3010	482	0	-	-	-
020201	1.10	19.62	934.02	6.35	0.15	3000	500	11.34	47.09	12.65	0.25
020202	1.12	19.30	949.68	6.48	0.13	3100	490	5.18	47.67	13.21	0.27
020203	1.12	19.28	950.52	6.39	0.13	3000	499	3.25	37.78	13.63	0.29
020204	1.16	19.70	930.18	6.23	0.16	3000	497	2.03	43.57	14.31	0.33
020205	1.14	19.41	943.86	6.18	0.25	3800	500	0	46.51	14.02	0.32
020301	0.94	17.79	1029.92	5.76	0.70	3200	491	14.46	45.31	11.43	0.19
020302	0.91	17.12	1070.04	5.69	1.15	3600	481	15.91	41.84	11.81	0.21
020303	0.89	16.70	1087.76	5.46	1.92	3000	472	8.93	43.61	11.13	0.18
020304	0.87	13.86	1321.86	4.62	2.10	3100	470	5.26	46.73	10.95	0.17
020305	0.80	14.58	1256.82	5.06	2.83	3000	459	0	45.30	10.63	0.17
020401	0.54	10.21	1794.66	4.93	0.53	4200	452	34.25	85.15	8.45	0.14
020402	0.58	10.78	1700.34	4.58	1.12	3300	450	28.48	91.02	8.70	0.14
020403	0.48	11.21	1634.52	5.39	2.23	3800	422	17.17	90.58	8.45	0.14
020404	0.54	11.64	1574.58	4.95	2.84	3600	409	8.53	97.55	8.11	0.14
020405	0.43	9.41	1947.42	4.64	4.13	3400	420	0	94.91	8.13	0.14
020501	0.29	8.01	2282.56	5.27	0.55	3400	412	75.47	91.02	7.66	0.14
020502	0.28	7.88	2325.92	5.11	1.32	3600	413	60.89	90.29	7.88	0.14
020503	0.23	6.46	2837.28	4.48	2.22	3500	381	44.34	86.44	7.83	0.14
020504	0.18	4.73	3869.76	3.88	3.61	3800	359	22.89	103.54	7.73	0.13
020505	0.07	1.72	10665.54	3.05	5.02	4400	319	0	90.15	8.05	0.14

Table 4: Results of constant speed (2000 rpm) tests carried out with reed valves by varying secondary air flow at each throttle position.

File Name	Power (K.W)	η_{th} %	S.F.C. (g/KWhr)	A/F Ratio	CO (Volume %)	H.C (P.P.m)	Texh (^{o}C)	Air Ratio (%)	ΔComb. (^{o}CA)	P_{max} (bar)	dp_{max} (bar/^{o}CA)
030101	2.98	17.51	1046.28	5.85	1.81	8000	522	0	36.00	25.92	1.24
030201	1.83	20.69	885.66	7.21	0.12	5000	574	23.15	40.39	13.41	0.25
030202	1.69	20.10	911.72	6.30	0.13	4500	568	1.95	45.68	12.91	0.23
030203	1.88	20.87	877.98	6.41	0.14	3800	578	0	43.90	13.80	0.27
030301	1.37	18.08	1013.64	5.36	0.25	2500	604	19.89	39.51	10.68	0.15
030302	1.50	19.47	941.22	5.09	0.45	2400	613	14.38	37.77	11.24	0.17
030303	1.47	19.01	963.72	4.86	0.95	2300	602	9.30	42.14	11.23	0.17
030304	1.41	18.17	1008.66	4.64	1.55	2250	590	5.13	41.23	11.39	0.18
030305	1.39	17.58	1041.96	4.38	2.21	2200	577	0	40.41	10.89	0.16
030401	0.92	14.88	1231.38	4.63	0.82	2300	573	48.55	84.32	8.66	0.14
030402	0.86	13.88	1320.12	4.35	1.44	2250	565	36.31	83.43	8.70	0.15
030403	0.80	12.71	1441.68	3.97	2.23	2350	537	23.41	87.82	8.49	0.15
030404	0.69	10.77	1701.36	3.68	3.21	2400	497	12.48	84.30	8.14	0.15
030405	0.54	8.38	2186.04	3.19	4.23	2600	483	0	79.05	7.98	0.15
030501	0.50	10.21	1795.14	4.24	1.21	3500	485	134.38	77.25	7.92	0.14
030502	0.44	8.94	2049.84	4.21	0.45	3150	484	138.01	78.15	8.00	0.15
030503	0.41	8.15	2247.18	3.75	1.32	3200	480	93.18	81.67	7.91	0.15
030504	0.35	6.83	3664.06	3.24	2.43	3300	448	72.00	67.61	7.92	0.15
030505	0.10	3.85	4755.62	3.52	3.2	3500	402	33.68	62.36	7.93	7.93
030506	0.01	0.102	1796-40	1.97	5.2	3700	350	0	74.64	8.04	8.04

Table 5 : Results of constant speed (3000 rpm) tests carried out with reed valves by varying secondary air flow at each throttle position.

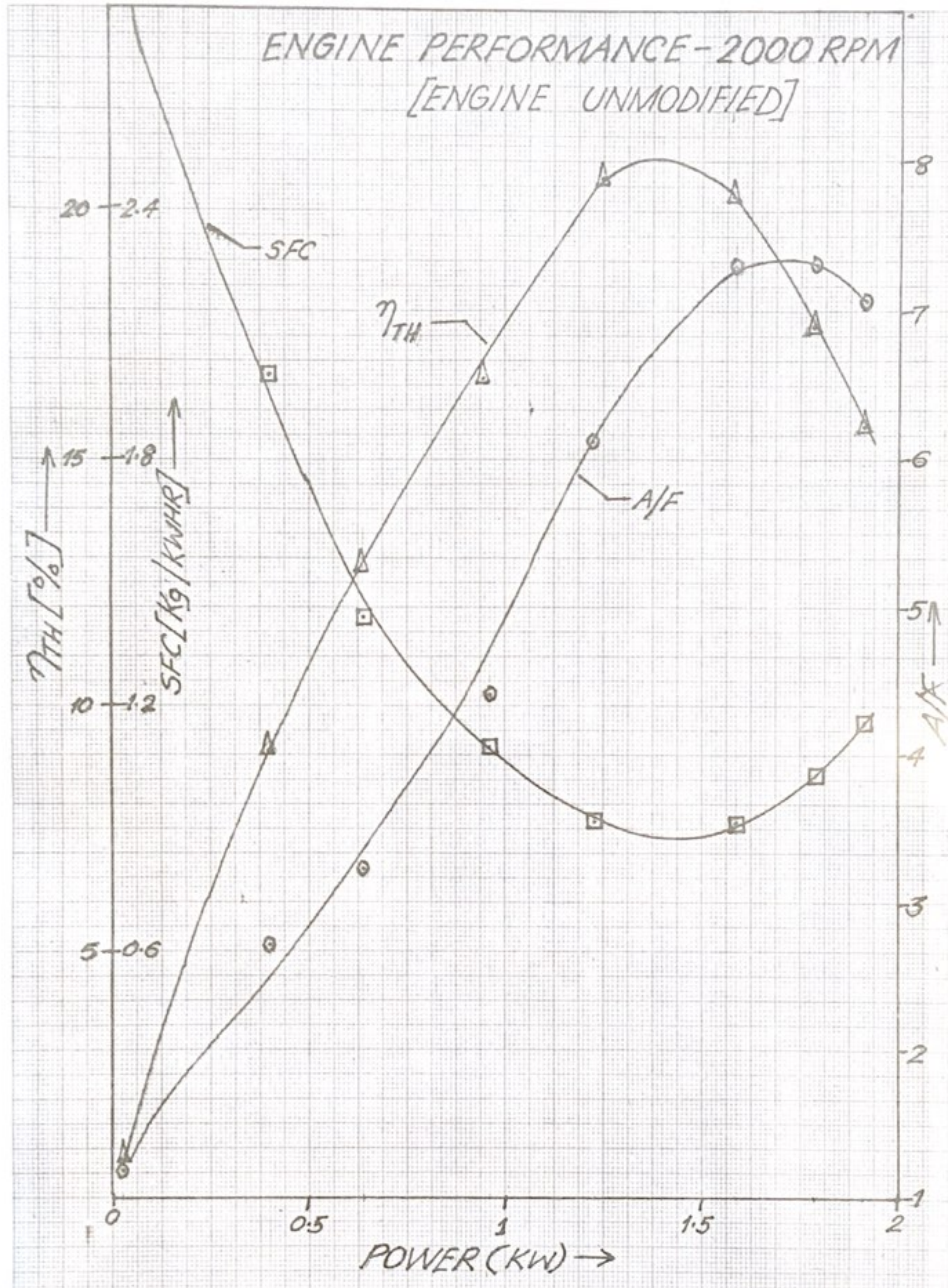
File Name	Power (K.W)	η_{th} %	S.F.C (g/KWhr)	A/F Ratio	CO (Volume %)	H.C (P.P.m)	Texh (^oC)	Air Ratio (%)	ΔComb. (^oCA)	P_{max} (bar)	dp_{max} (bar/^oCA)
040101	3.17	20.856	878.64	6.42	0.12	3200	611	0	43.33	17.67	0.47
040201	2.62	21.24	862.92	6.28	0.15	3800	626	4.57	45.65	14.25	0.27
040202	2.60	21.34	858.72	6.48	0.15	3800	627	4.42	45.65	14.53	0.30
040203	2.54	21.24	862.74	6.43	0.15	3700	625	2.92	45.65	13.97	0.27
040204	2.54	21.86	838.44	6.19	0.15	3600	626	0.82	46.75	13.31	0.23
040205	2.28	20.65	887.12	6.37	0.15	3600	625	0	42.13	12.11	0.18
040301	1.87	19.09	960.06	6.87	0.17	3400	618	11.47	93.67	10.51	0.16
040302	1.72	18.64	1015.62	6.79	0.17	3200	610	10.32	94.88	9.90	0.15
040303	1.84	18.74	977.88	6.56	0.15	3000	615	4.89	91.20	10.77	0.16
040304	1.77	18.40	996.12	6.49	0.15	2900	616	3.02	88.89	10.49	0.16
040305	1.75	18.51	990.06	6.42	0.15	2900	615	0	87.82	10.32	0.15

Table 6 : Results of constant speed (4000 rpm) tests carried out <u>with</u> reed valves by varying secondary air flow at each throttle position.

Contd.....

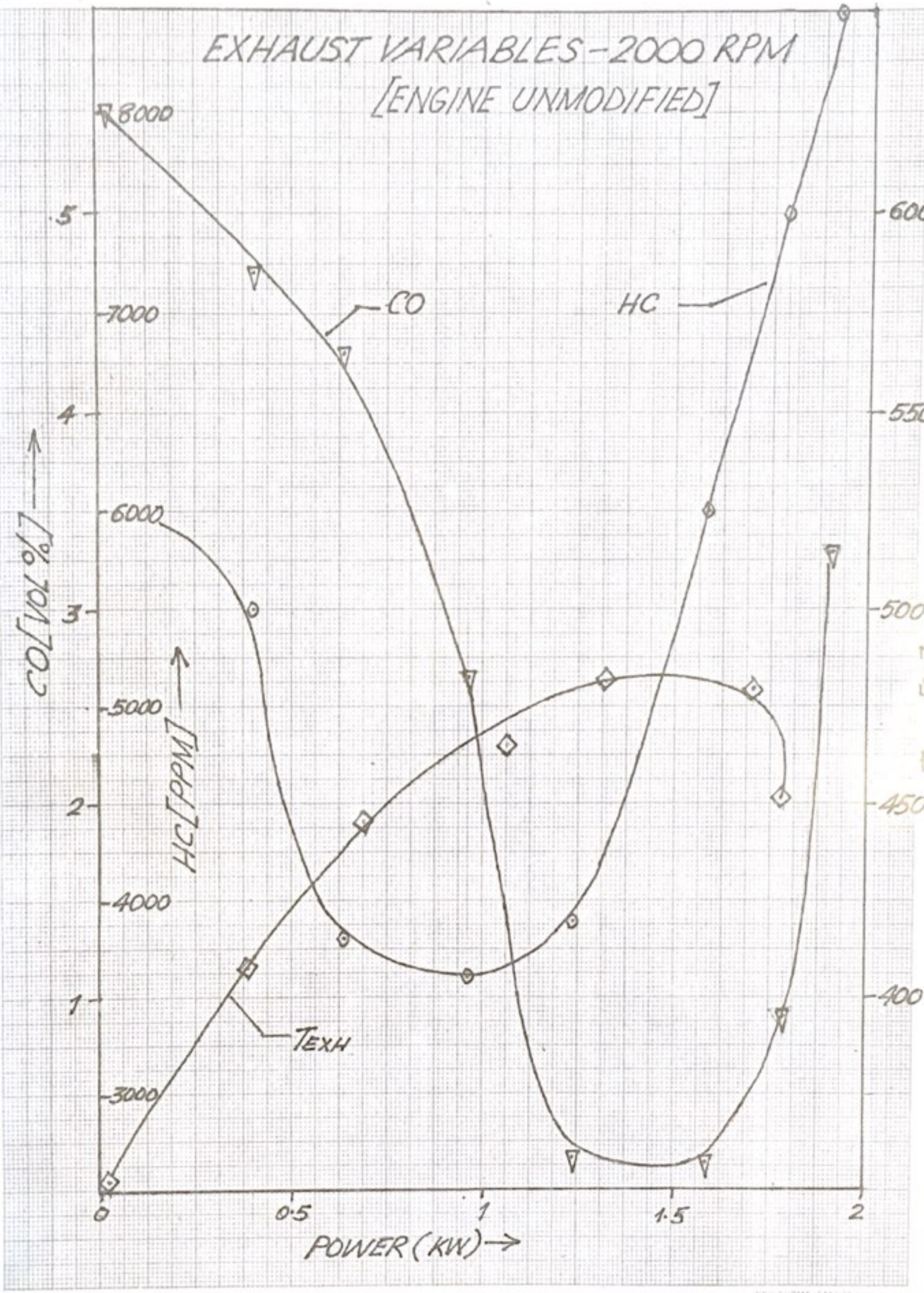
File Name	Power (K.W)	η_{th} %	S.F.C. (g/KWhr)	A/F Ratio	CO (Volume %)	H.C (P.P.m)	Texh (°C)	Air Ratio (%)	ΔComb. (°CA)	P_{max} (bar)	dp_{max} (bar/°CA)
040401	1.11	14.12	1297.32	6.97	0.25	2800	584	22.89	86.62	8.52	0.15
040402	1.21	15.26	1200.92	6.57	0.21	2700	587	15.79	80.79	8.93	0.15
040403	1.25	15.74	1163.88	6.30	0.20	2900	595	11.29	79.62	8.93	0.15
040404	1.45	18.27	1002.84	6.03	0.19	2800	597	5.38	76.11	9.60	0.15
040405	1.56	19.34	947.22	5.42	0.18	2800	600	0	32.78	10.91	0.17
040501	1.27	18.30	1001.22	5.40	0.25	2100	559	54.42	32.81	9.93	0.15
040502	1.35	19.38	945.42	4.75	0.40	2100	556	39.61	36.31	12.01	0.34
040503	1.28	18.23	1005.36	4.33	1.40	1800	528	25.52	40.98	11.11	0.21
040504	1.20	17.19	1065.72	3.89	2.10	1800	512	13.66	35.13	10.93	0.22
040505	0.94	13.35	1372.86	3.27	3.50	1800	491	0	32.81	9.49	0.15
040601	0.98	16.11	1137.66	4.78	0.30	1800	510	95.55	35.10	9.95	0.15
040602	1.12	18.50	990.42	4.25	0.25	1900	497	68.87	37.48	10.57	0.19
040603	1.16	16.65	1100.7	3.70	1.60	1800	507	35.65	35.13	11.05	0.25
040604	1.09	15.72	1165.26	3.25	2.60	1800	484	17.88	37.95	10.27	0.15
040605	0.76	11.08	1653.54	2.98	4.00	1700	463	0	-	-	-
040701	0.99	16.32	1122.54	4.65	0.25	1700	499	107.26	39.81	9.67	0.15
040702	1.14	18.62	984.23	4.16	0.30	1800	494	77.46	31.63	11.18	0.29
040703	1.02	16.46	1113.24	3.46	1.60	1900	473	51.25	35.13	10.47	0.21
040704	0.90	14.57	1257.84	2.91	3.00	2000	449	25.22	32.37	9.94	0.16
040705	0.36	5.82	3150.48	2.22	4.40	1900	420	0	92.65	8.20	0.15

Table 6 : (contd.)



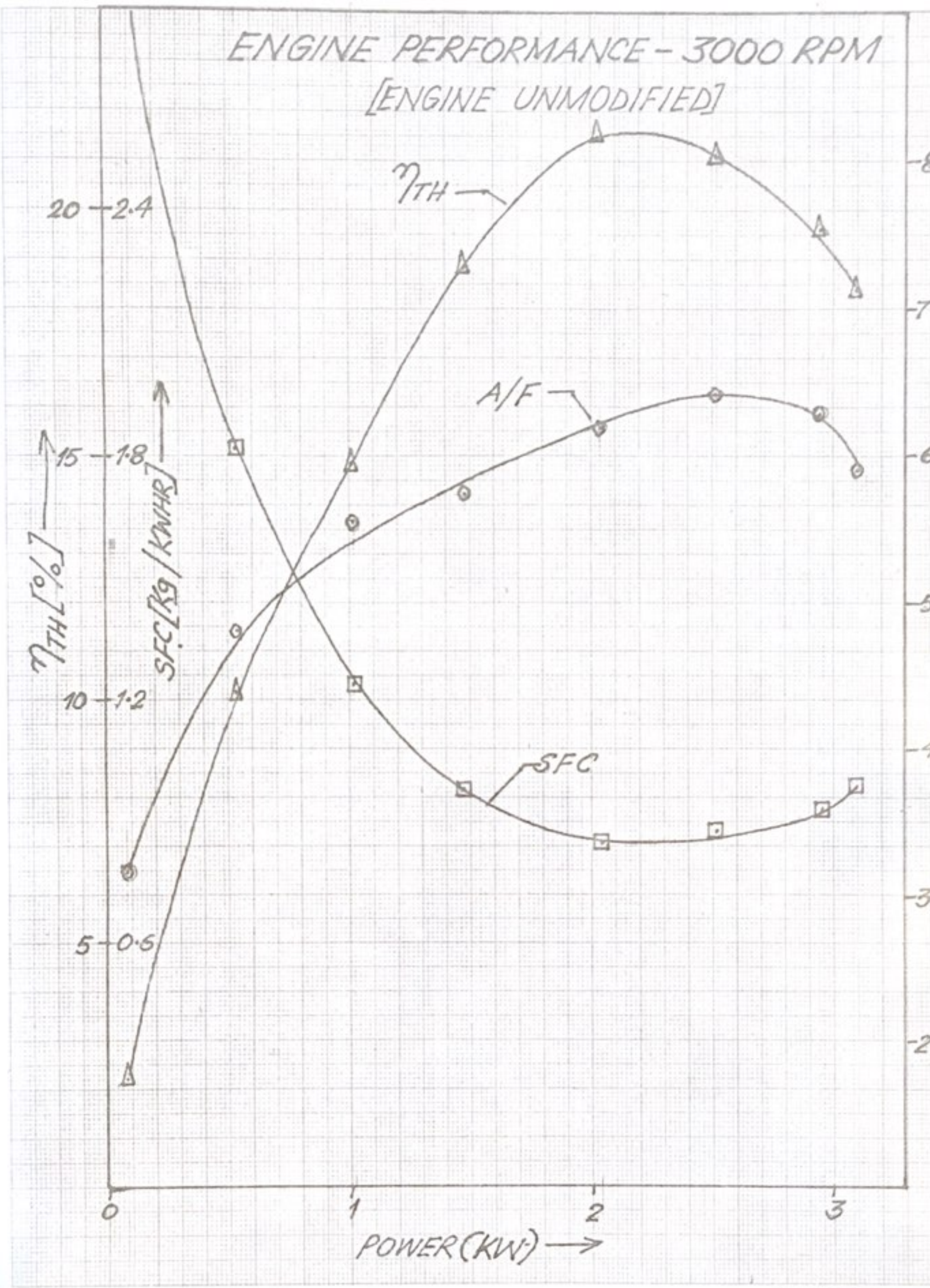
ENGINE PERFORMANCE - 2000 RPM
[ENGINE UNMODIFIED]
SFC
η_{TH}
A/F
η_{TH} [%] →
SFC [Kg/KWHR] →
A/F →
20 - 2.4
15 - 1.8
10 - 1.2
5 - 0.6
0
0.5
1
1.5
2
1
2
3
4
5
6
7
8
POWER (KW) →

FIG. 7.



EXHAUST VARIABLES - 2000 RPM
[ENGINE UNMODIFIED]
CO
HC
TEXH
CO [VOL %]
HC [PPM]
TEXH [°C]
POWER (KW)
8000
7000
6000
5000
4000
3000
5
4
3
2
1
600
550
500
450
400
0
0.5
1
1.5
2

FIG. 8



ENGINE PERFORMANCE - 3000 RPM
[ENGINE UNMODIFIED]
η_{TH}
A/F
SFC
η_{TH} [%]
SFC [Kg/KWHR]
A/F
POWER (KW)
20 2.4
15 1.8
10 1.2
5 0.6
0
1
2
3
8
7
6
5
4
3
2

FIG. 9.

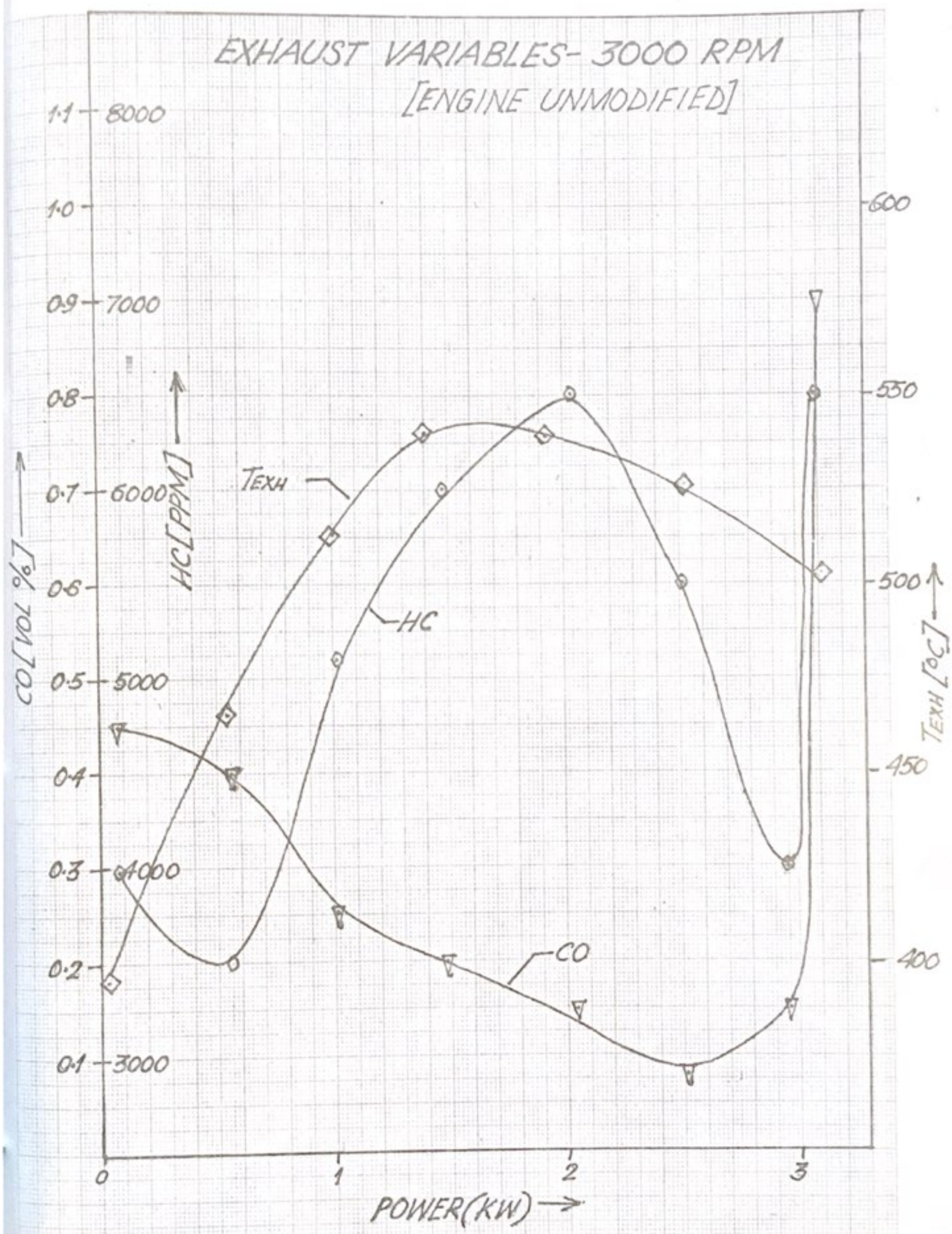

EXHAUST VARIABLES- 3000 RPM
[ENGINE UNMODIFIED]
CO [VOL %]
HC [PPM]
TEXH [°C]
TEXH
HC
CO
POWER(KW)
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
8000
7000
6000
5000
4000
3000
600
550
500
450
400
0
1
2
3

FIG. 10

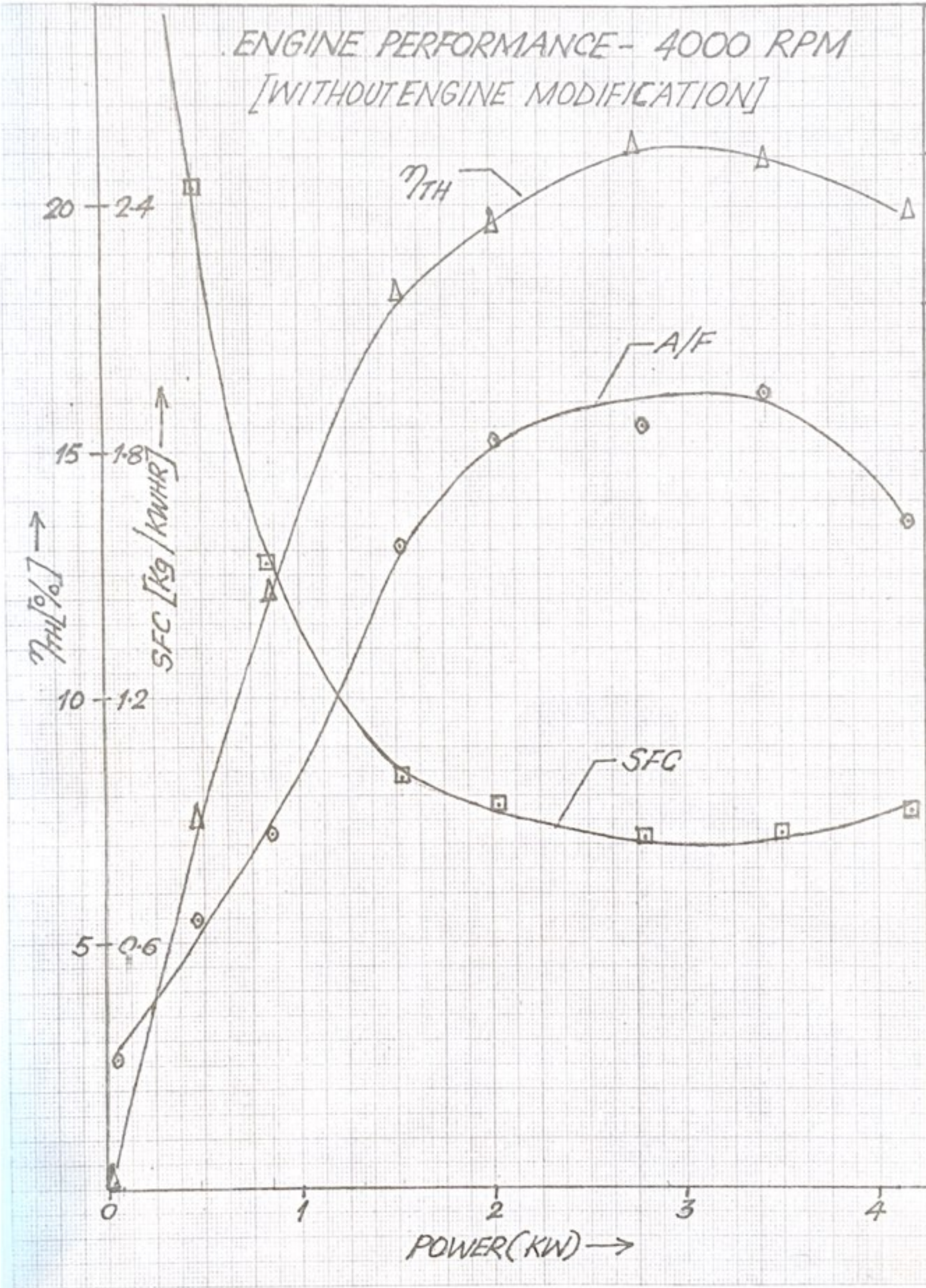
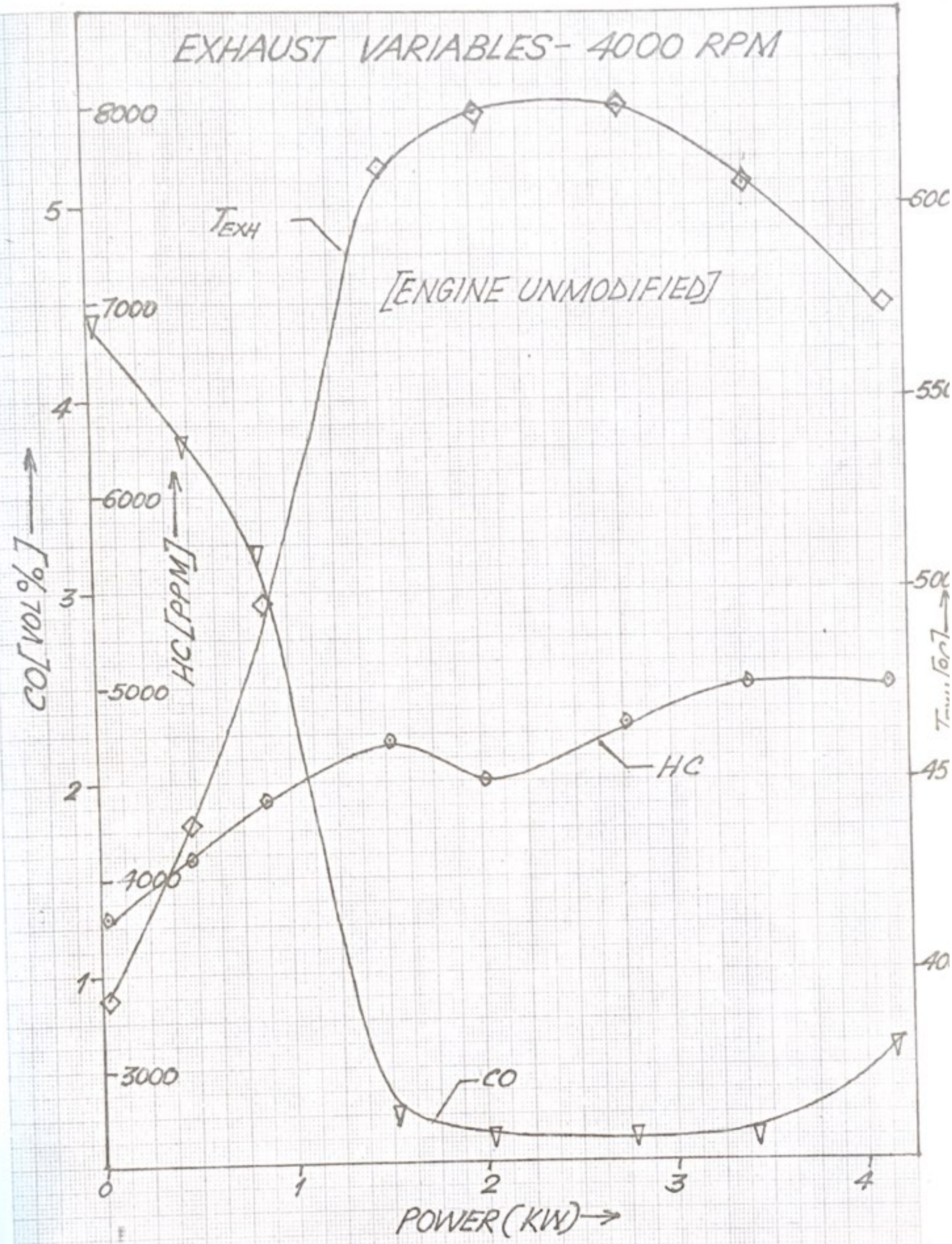

ENGINE PERFORMANCE - 4000 RPM
[WITHOUT ENGINE MODIFICATION]
η_{TH}
A/F
SFC
20
15
10
5
2.4
1.8
1.2
0.6
η_{TH} [%]
SFC [Kg/KWHR]
8
7
6
5
4
3
2
A/F
0
1
2
3
4
POWER(KW)

FIG. 11.



EXHAUST VARIABLES- 4000 RPM
[ENGINE UNMODIFIED]
T_{EXH}
HC
CO
CO[VOL%]→
HC[PPM]→
POWER(KW)→
8000
7000
6000
5000
4000
3000
5
4
3
2
1
0
1
2
3
4
600
550
500
450
400

FIG.12.

2000 RPM- CONSTANT THROTTLE [1·14 KW WITHOUT SECONDARY AIR]

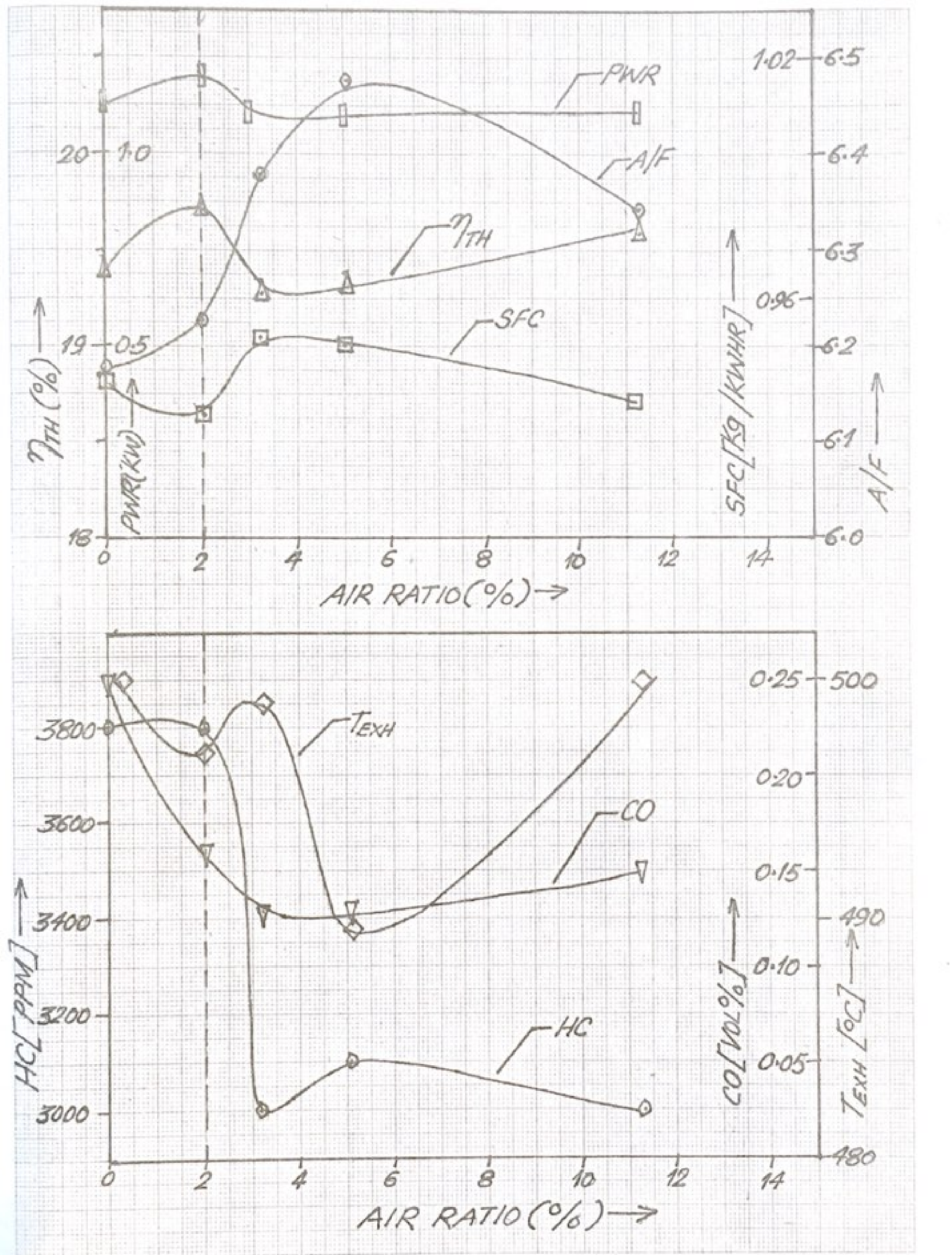


FIG. 13.

020201-020205

000 RPM-CONSTANT THROTTLE[796 W WITHOUT SECONDARY AIR]

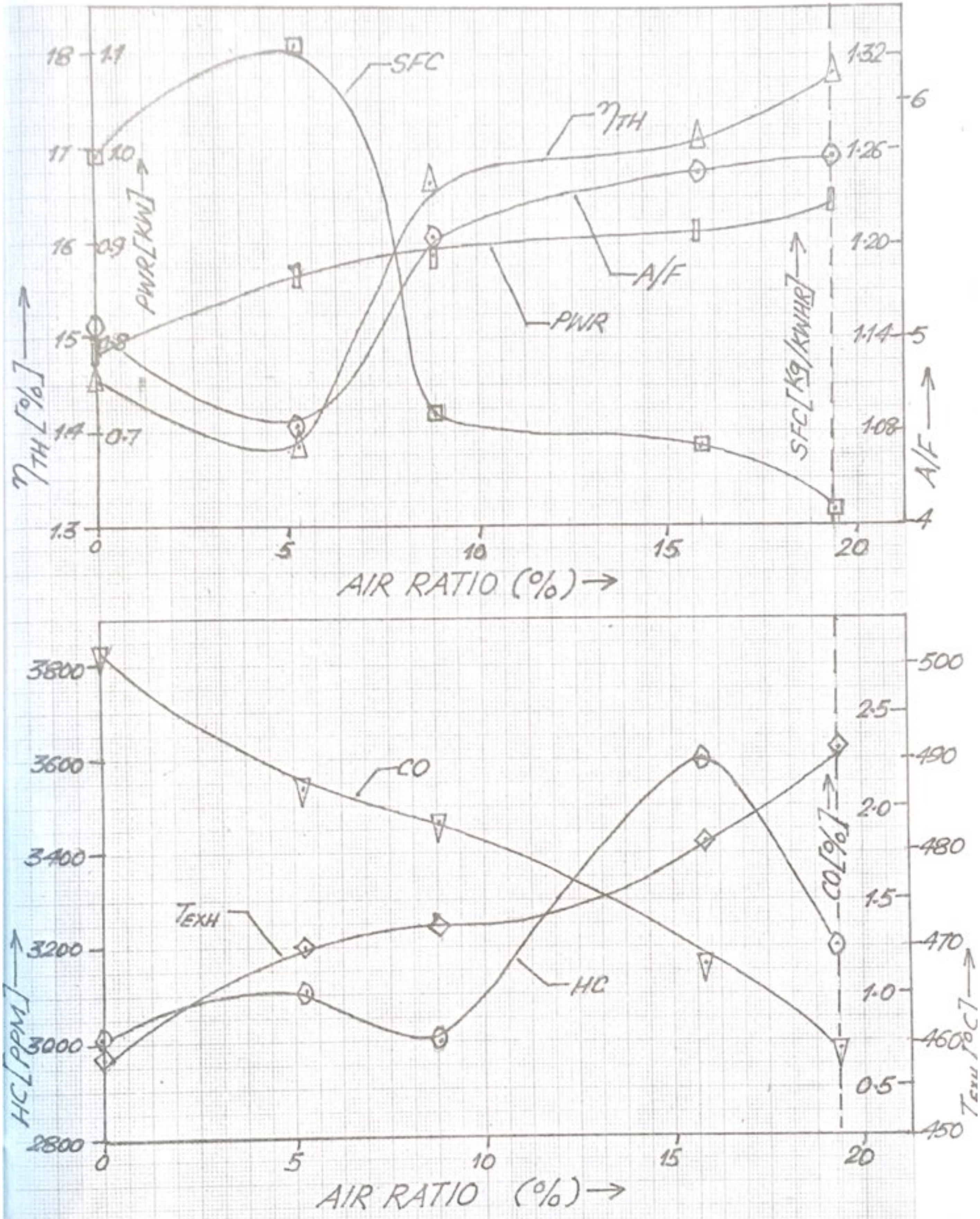
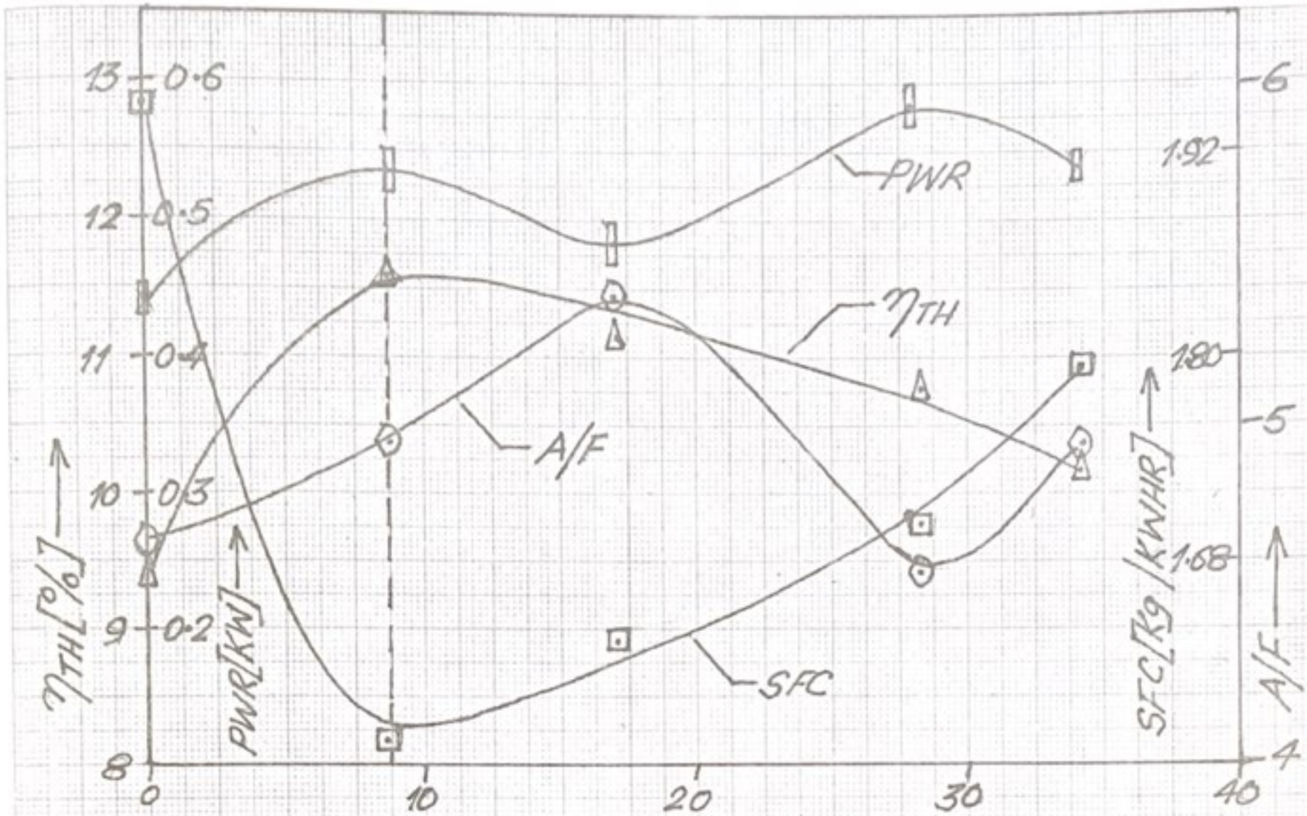


FIG. 14.

020301— 020305

2000 RPM-CONSTANT THROTTLE [435 W WITHOUT SECONDARY AIR]



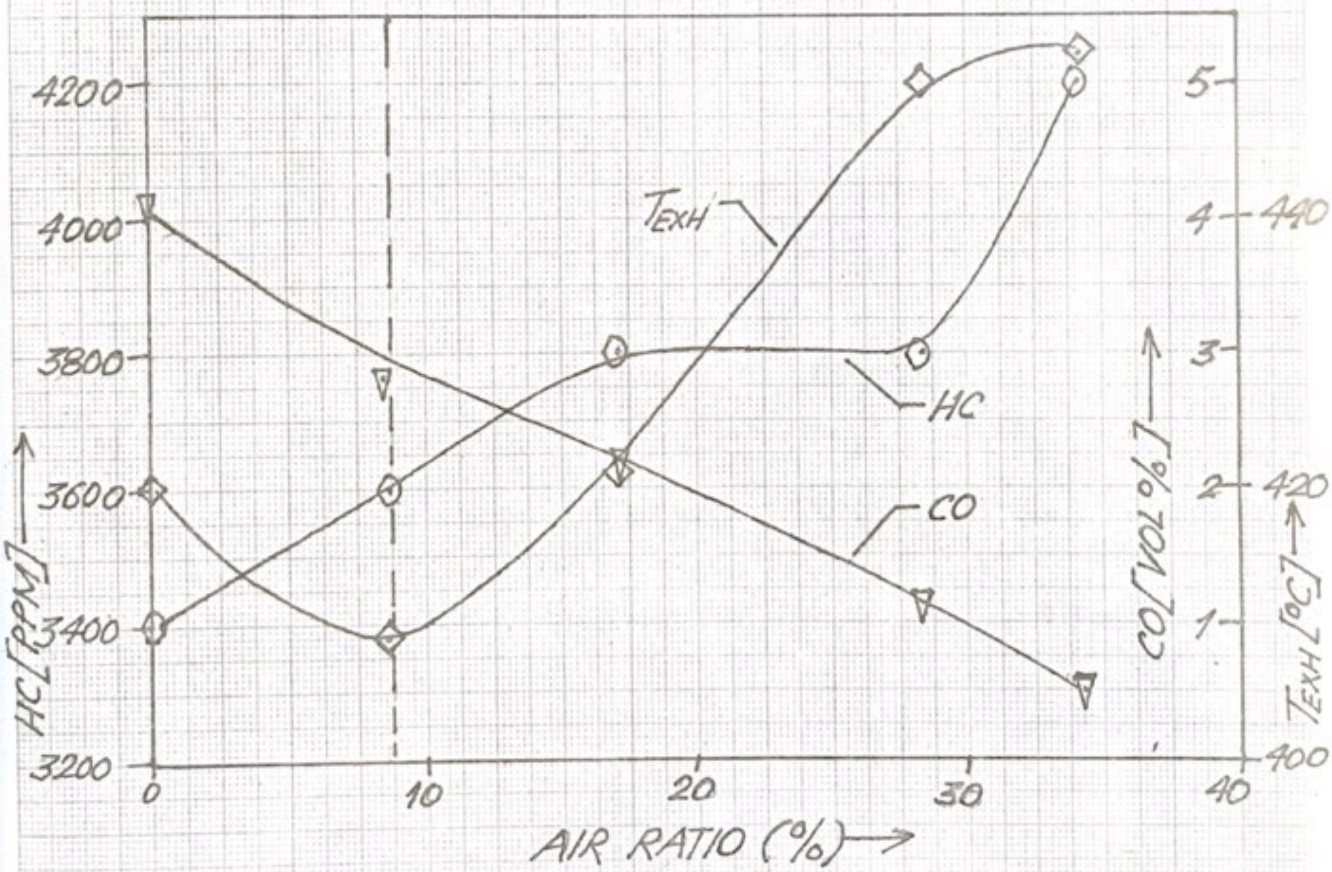


FIG. 15.

2000 RPM-CONSTANT THROTTLE[66 W WITHOUT SECONDARY AIR]

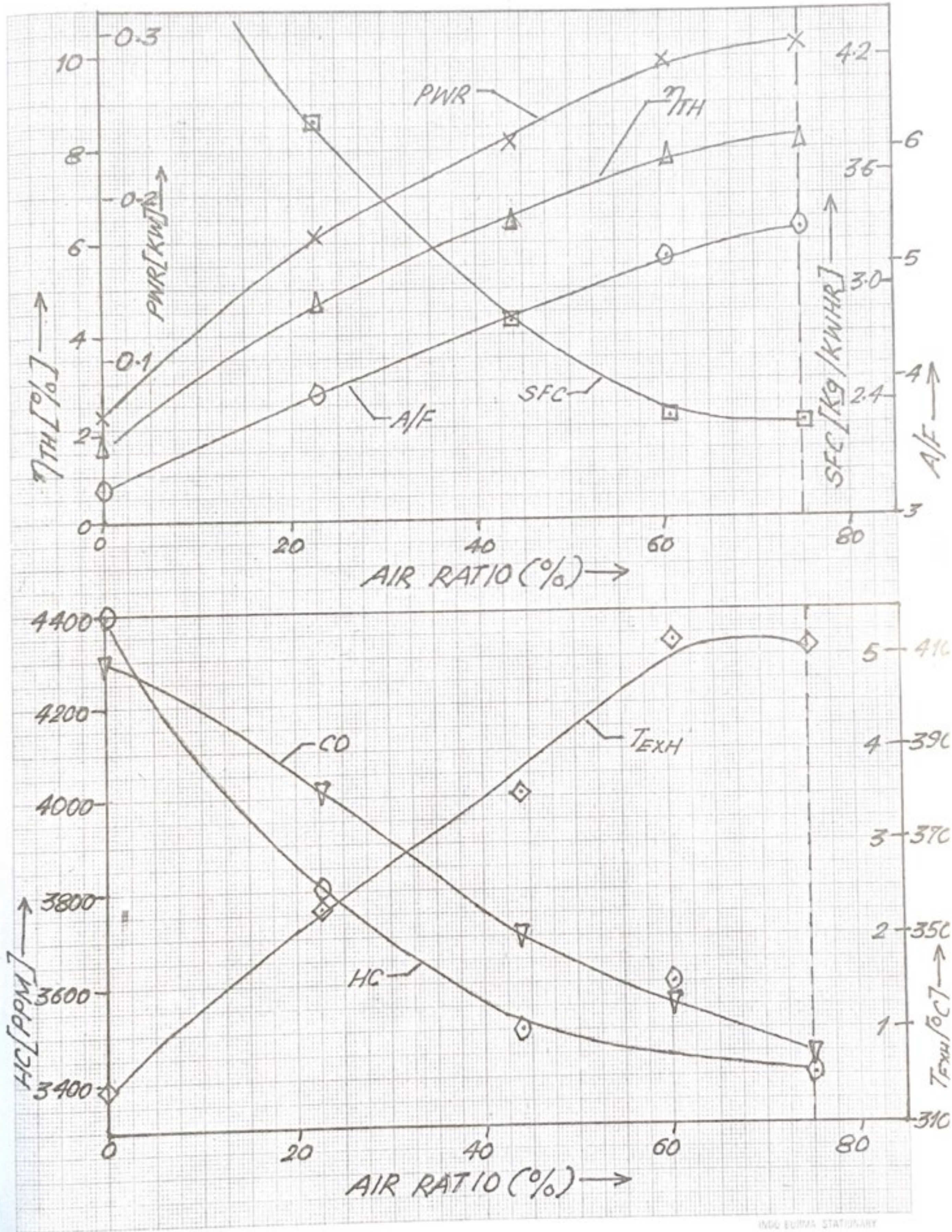


FIG. 16.

020501- 020505

3000 RPM- CONSTANT THROTTLE [1.39 KW WITHOUT SECONDARY AIR]

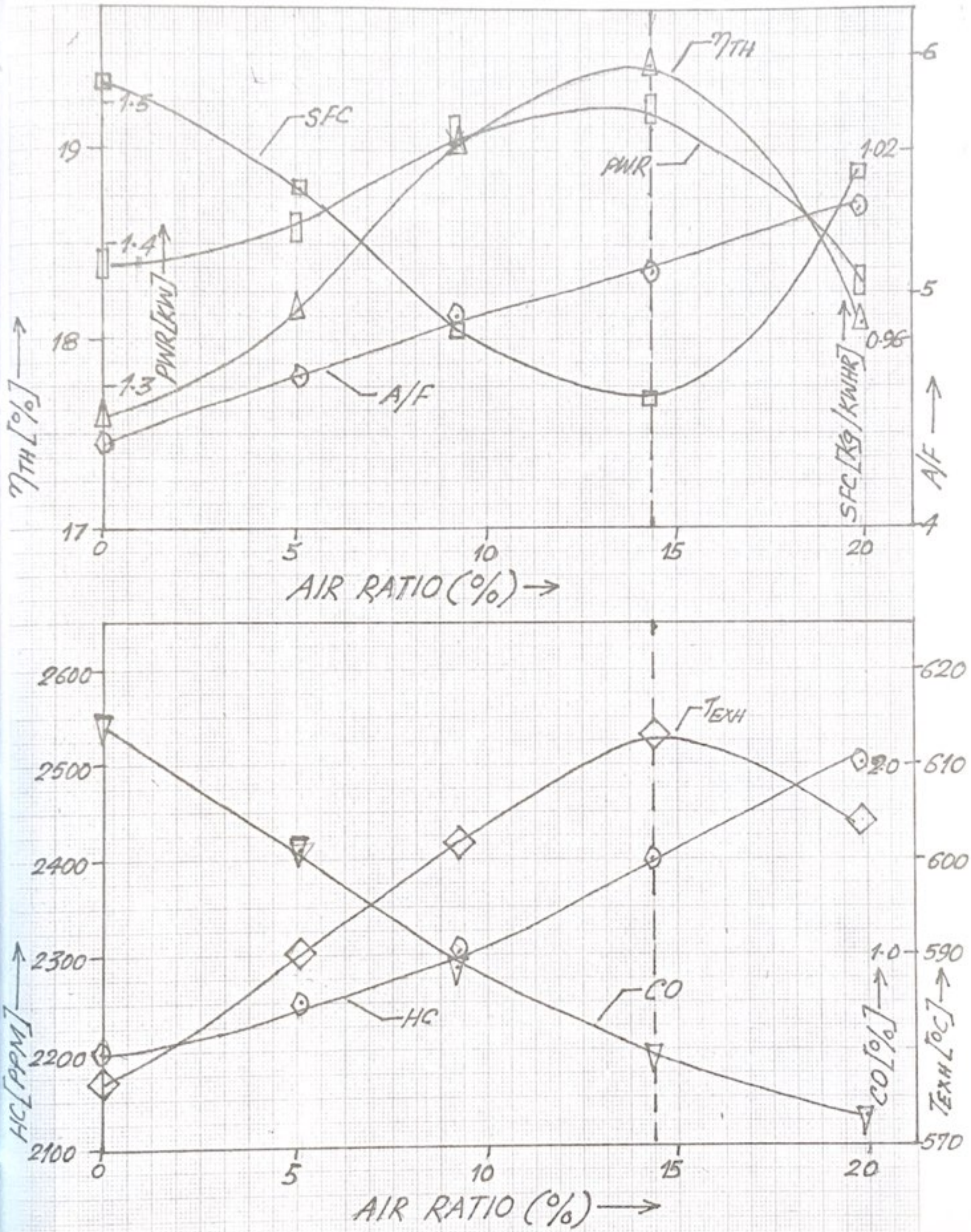
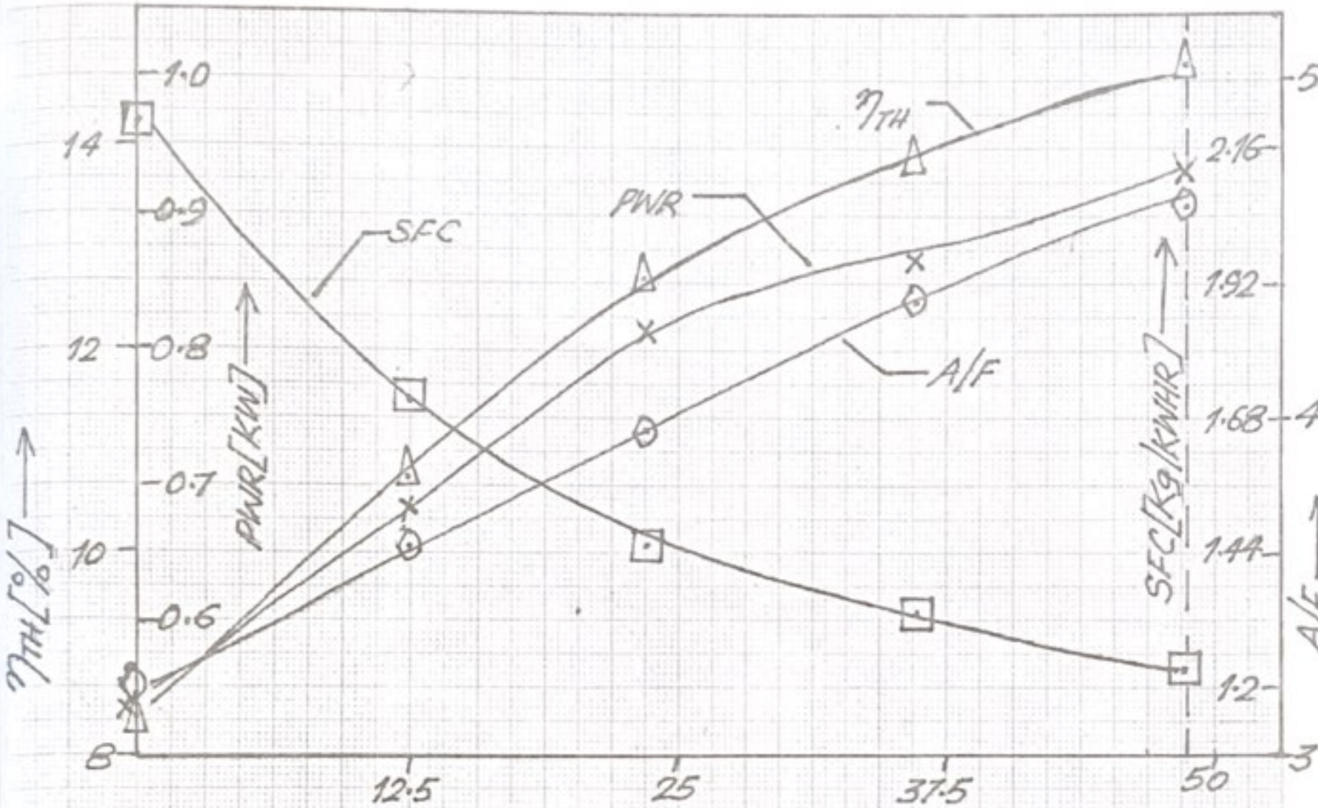


FIG. 17.

030301 - 030305

3000 RPM-CONSTANT THROTTLE [542 W WITHOUT SECONDARY AIR]



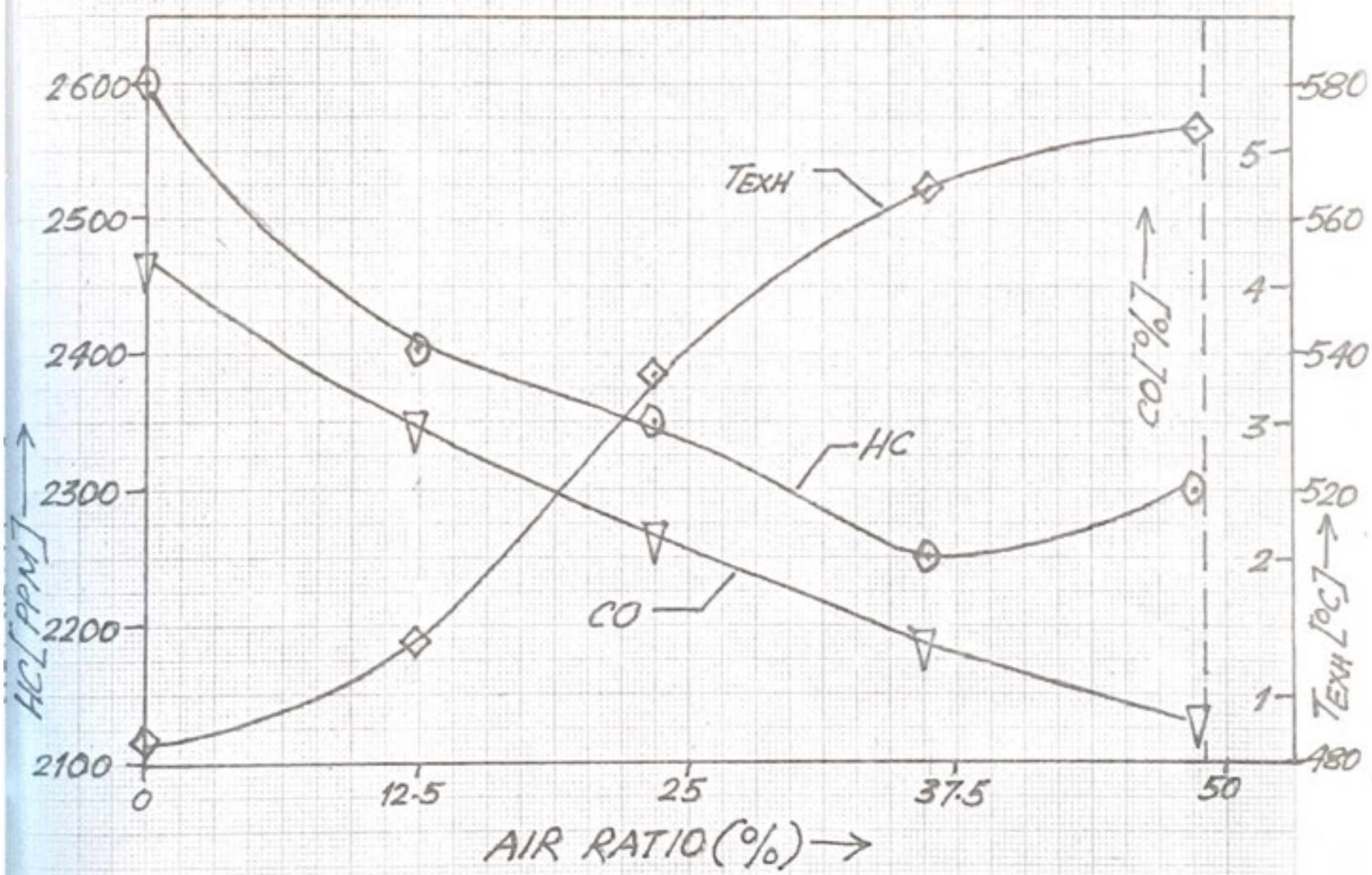


FIG. 18.

030401-030405

3000 RPM-CONSTANT THROTTLE [5W WITHOUT SECONDARY AIR]

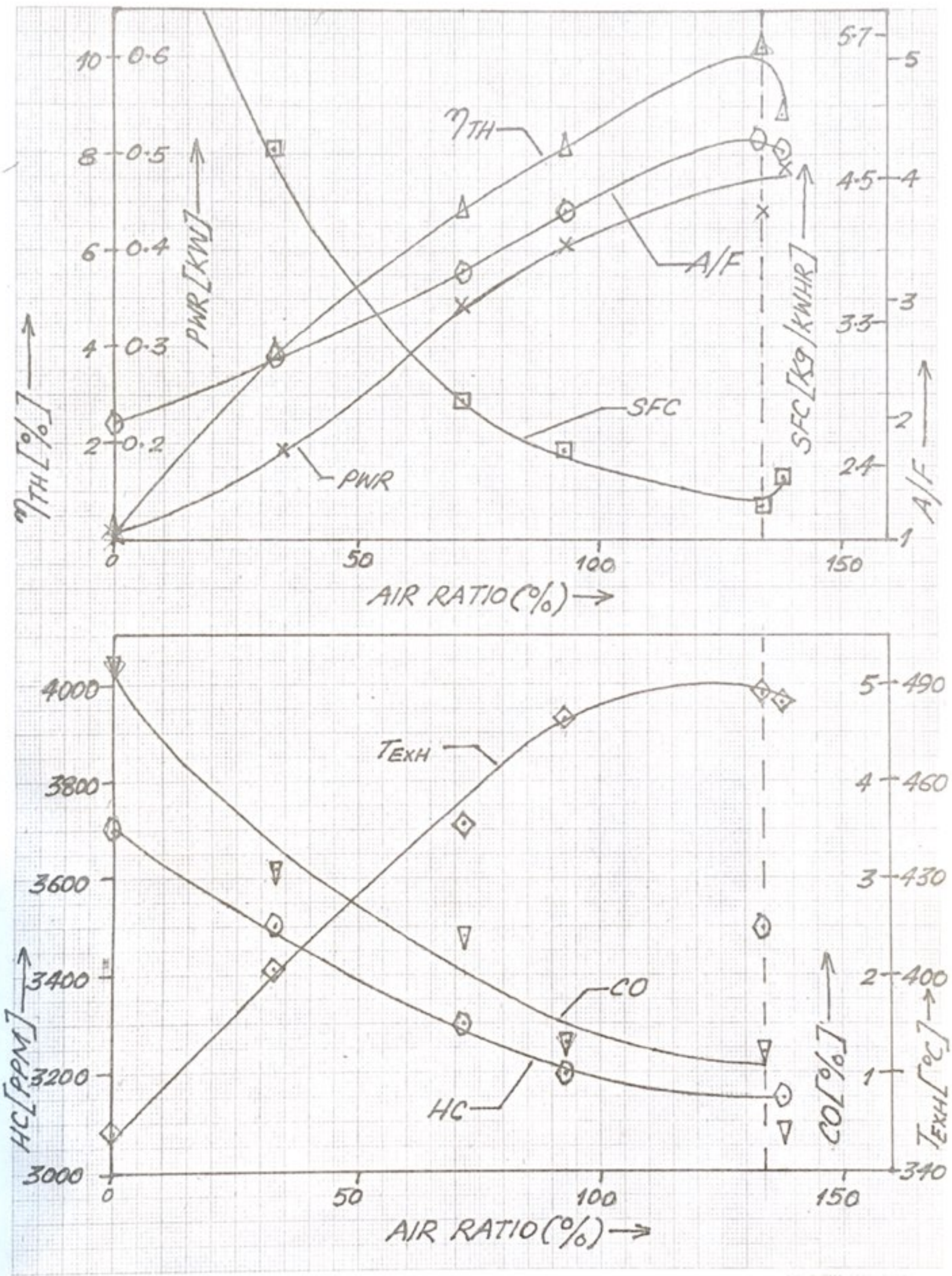


FIG. 19.

030501-030506

4000 RPM – CONSTANT THROTTLE [2.28 KW WITHOUT SECONDARY AIR]

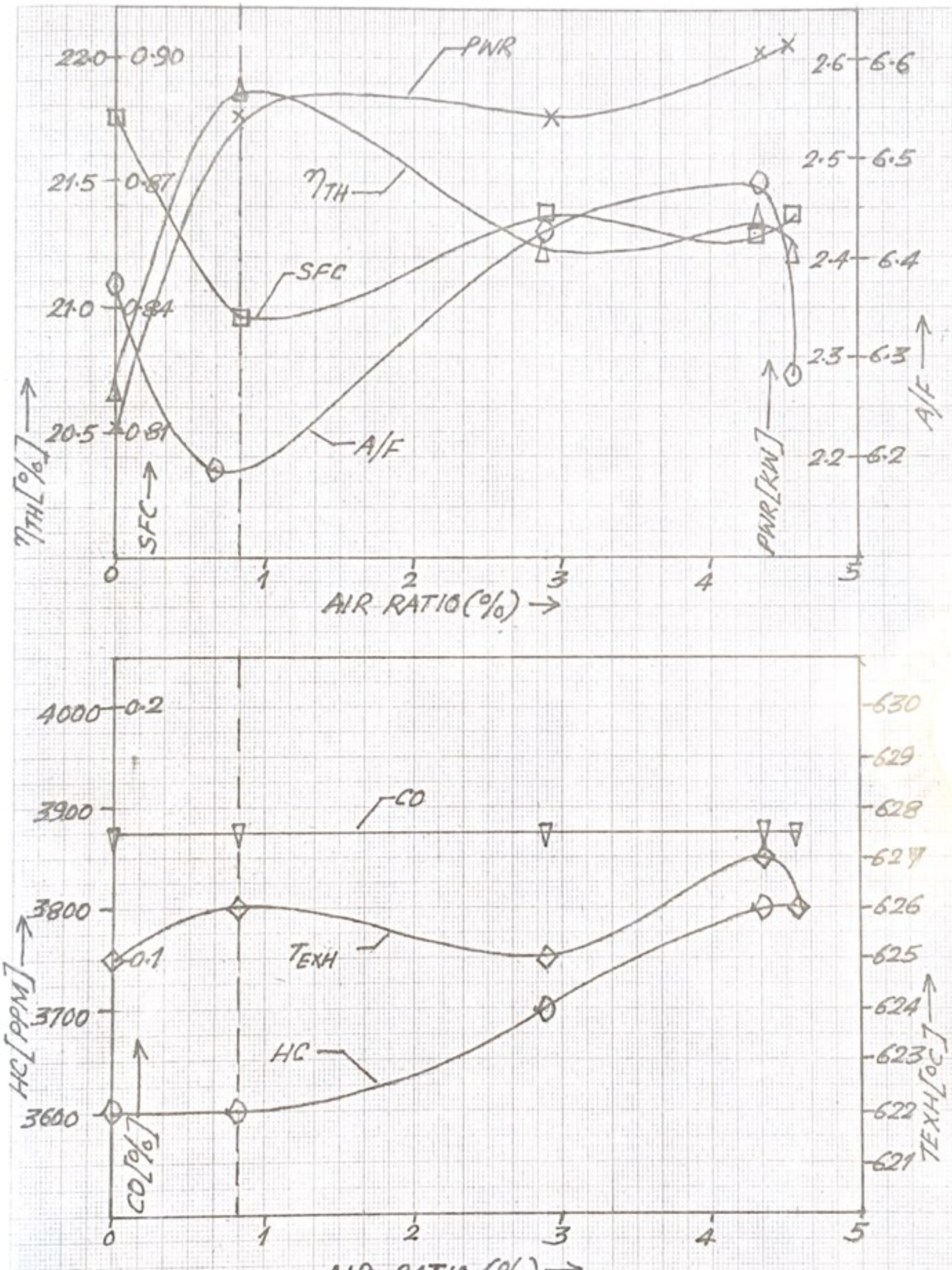


FIG. 20.

4000 RPM- CONSTANT THROTTLE [1·75 KW -WITHOUT SECONDARY AIR]

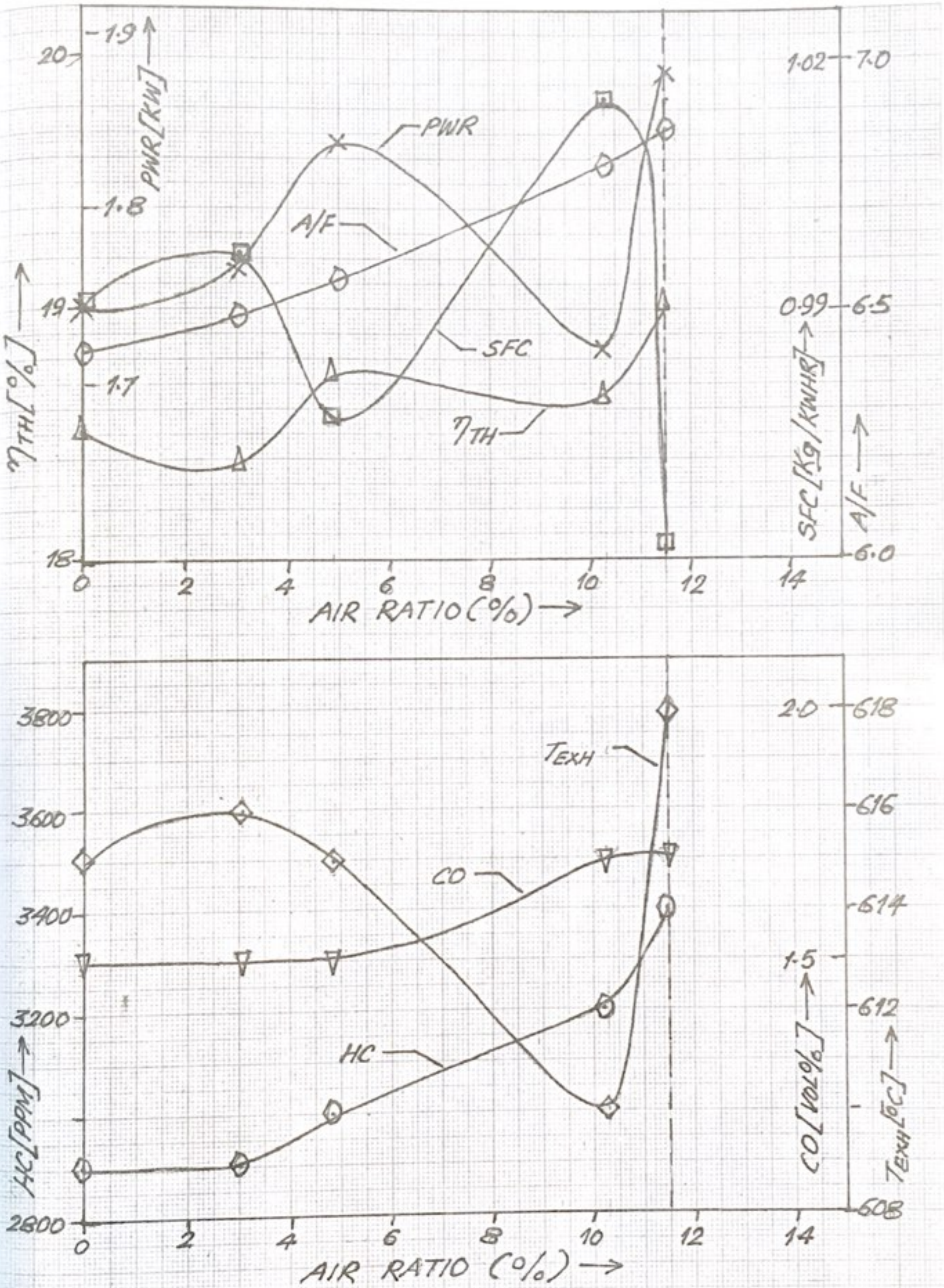


FIG. 21.

4000 RPM- CONSTANT THROTTLE [936 W WITHOUT SECONDARY AIR]

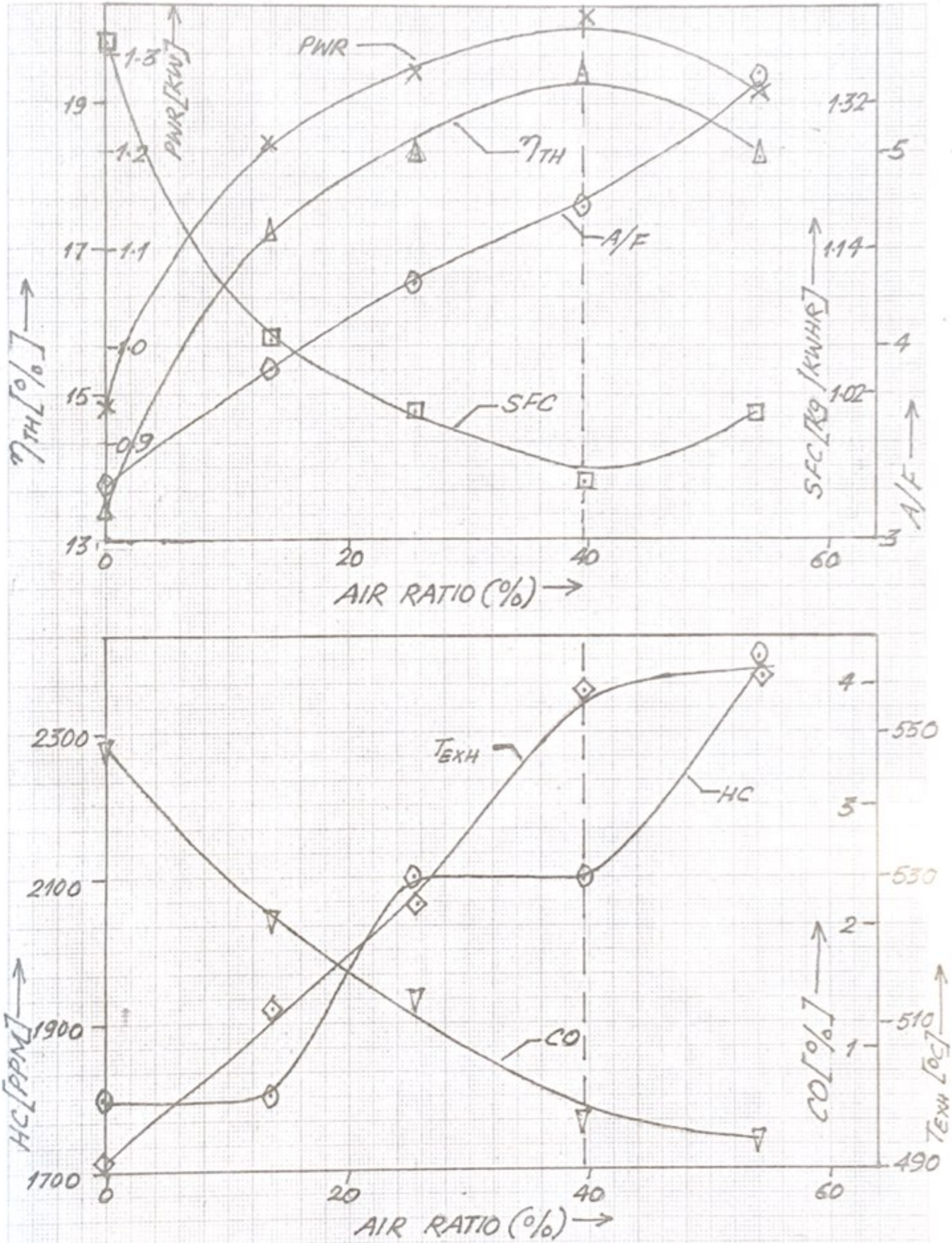


FIG. 22.

4000 RPM-CONSTANT THROTTLE[765 W WITHOUT SECONDARY AIR]

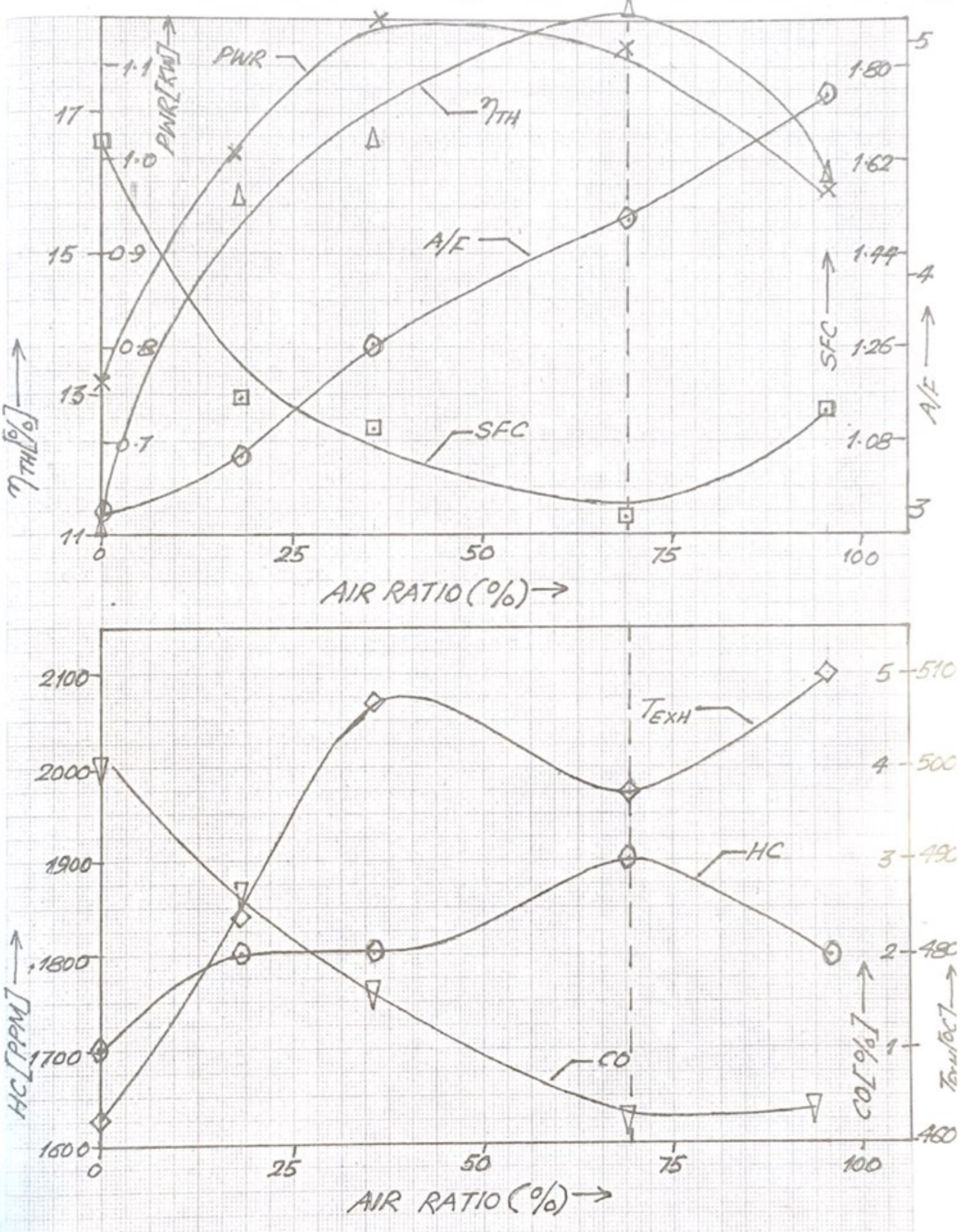


FIG. 23.

040601- 040605

4000 RPM-CONSTANT THROTTLE [357 W WITHOUT SECONDARY AIR]

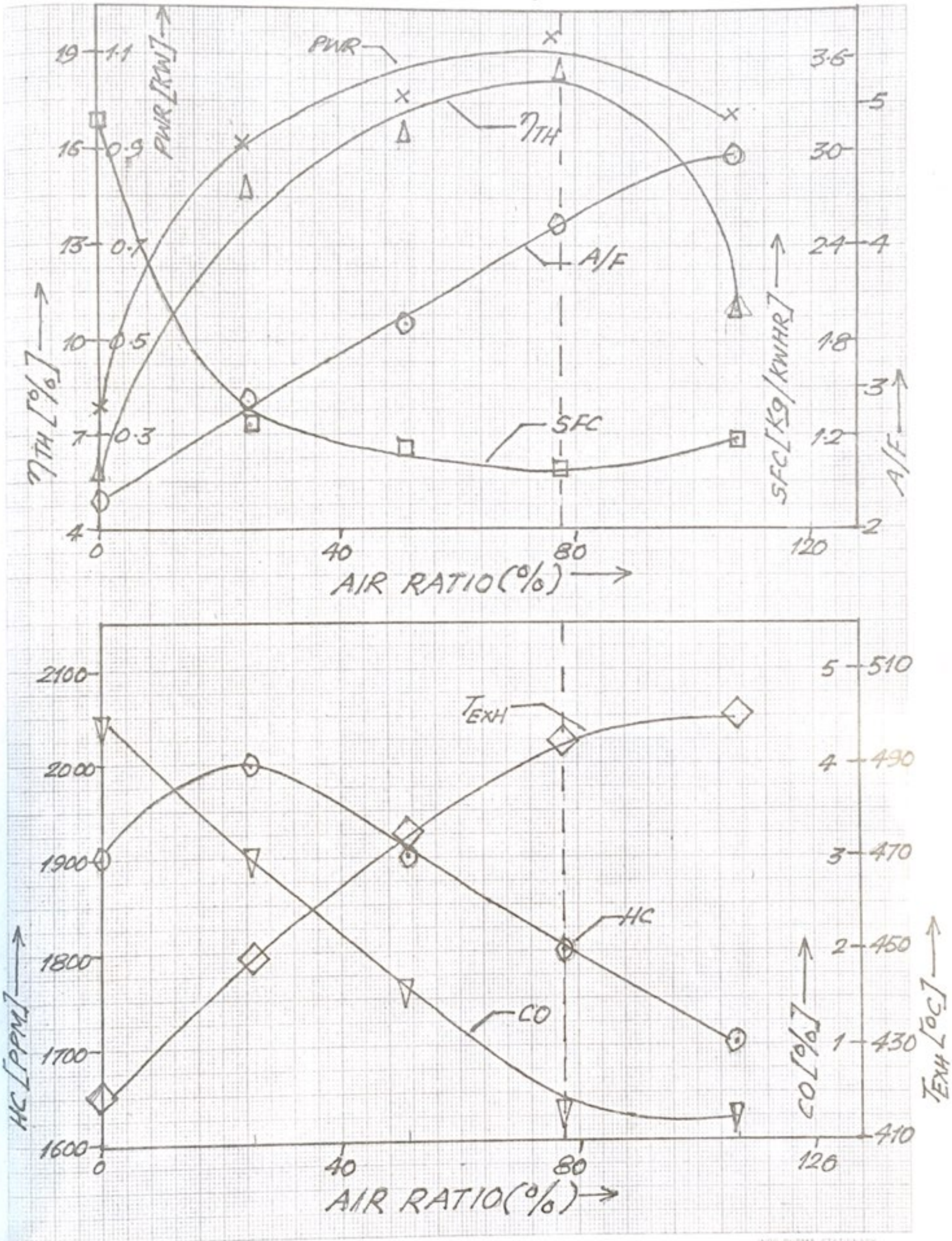


FIG. 24.

040701 - 040705

2000 RPM - CONSTANT THROTTLE [800 W WITHOUT SECONDARY AIR]

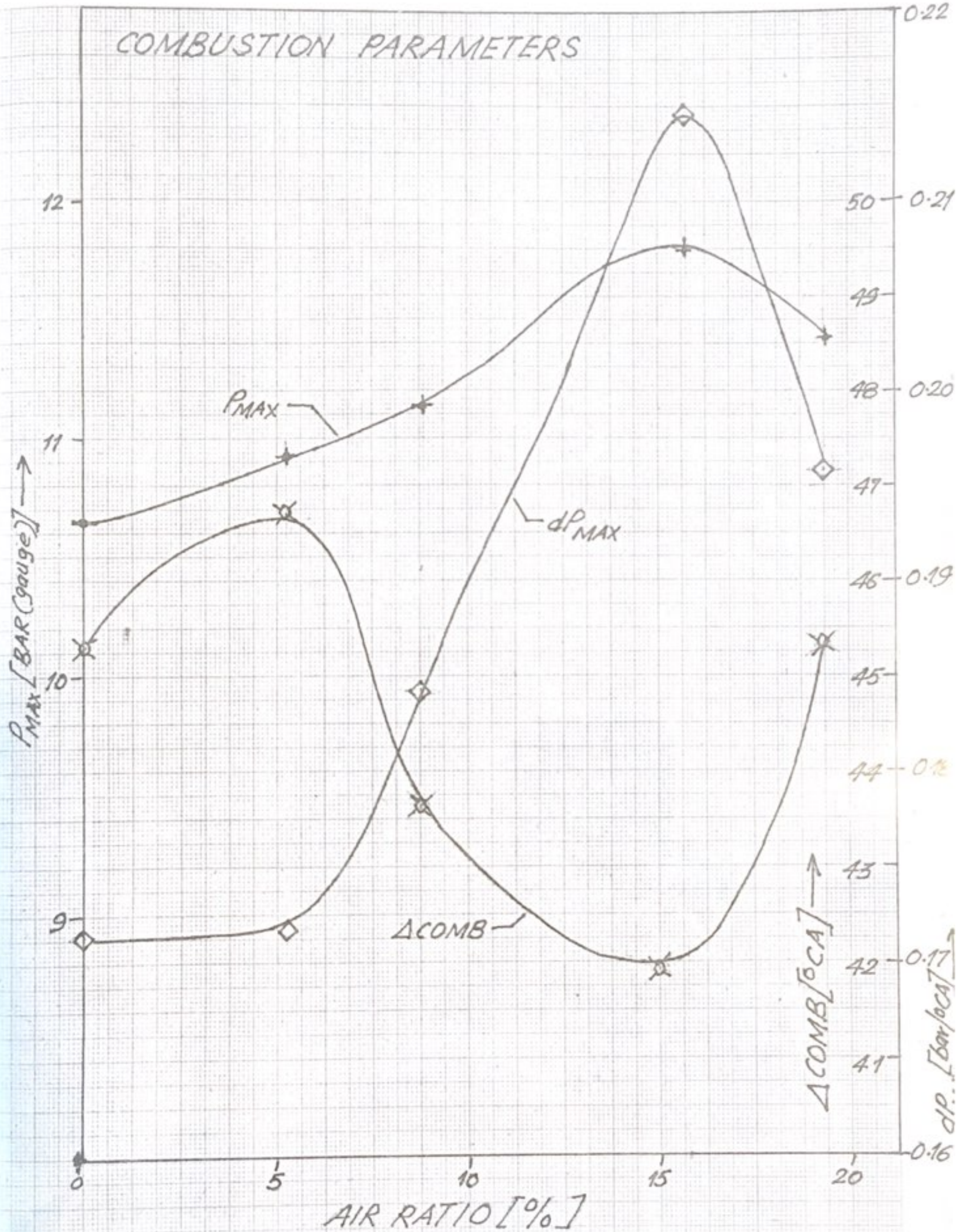


FIG. 25

3000 RPM - CONSTANT THROTTLE [1.39 KW WITHOUT SECONDARY AIR]

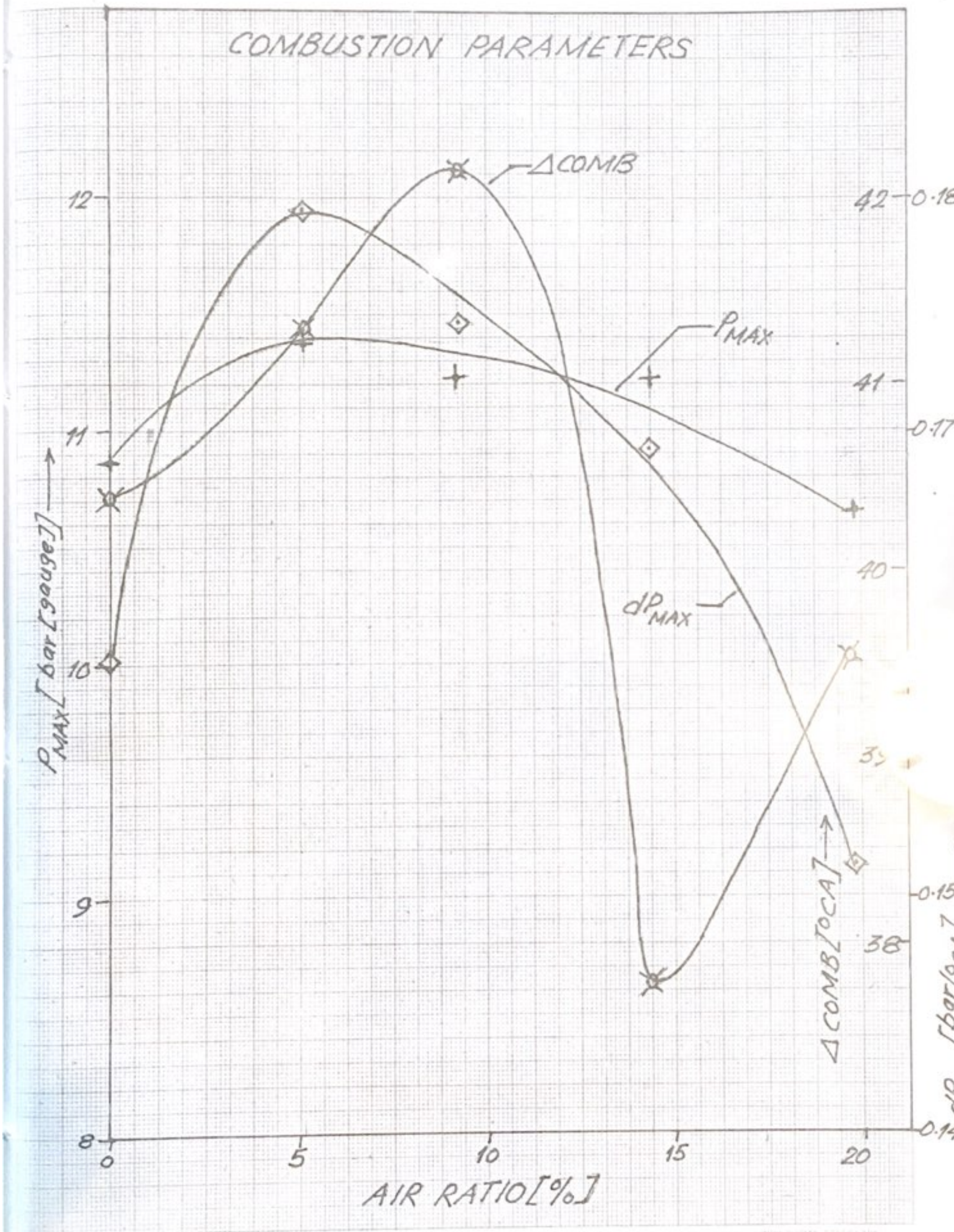


FIG. 26.

030301-030305

4000 RPM - CONSTANT THROTTLE [360W WITHOUT SECONDARY AIR]

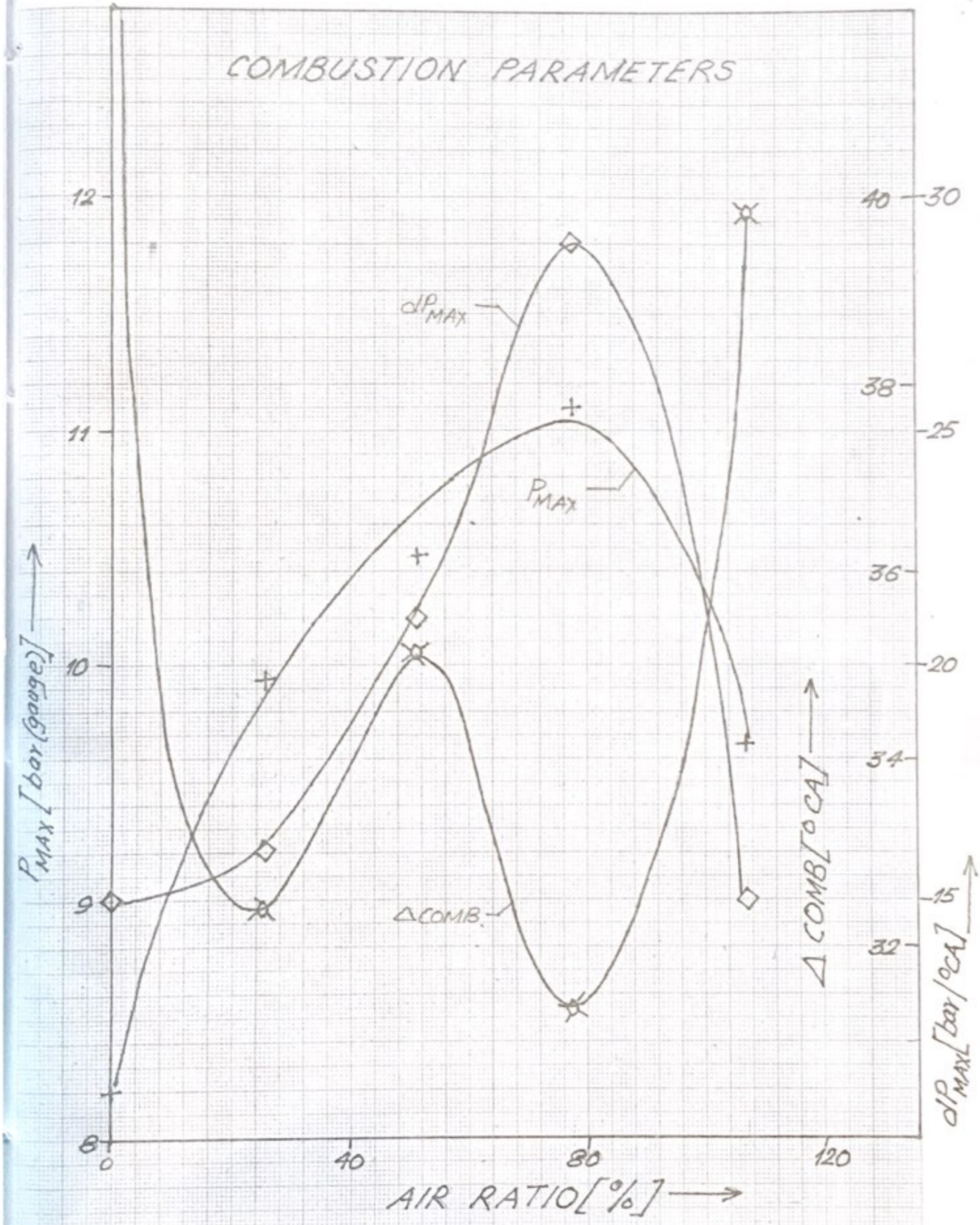


FIG. 27.

2000 RPM - OPTIMUM SECONDARY AIR FLOWS & EFFICIENCIES

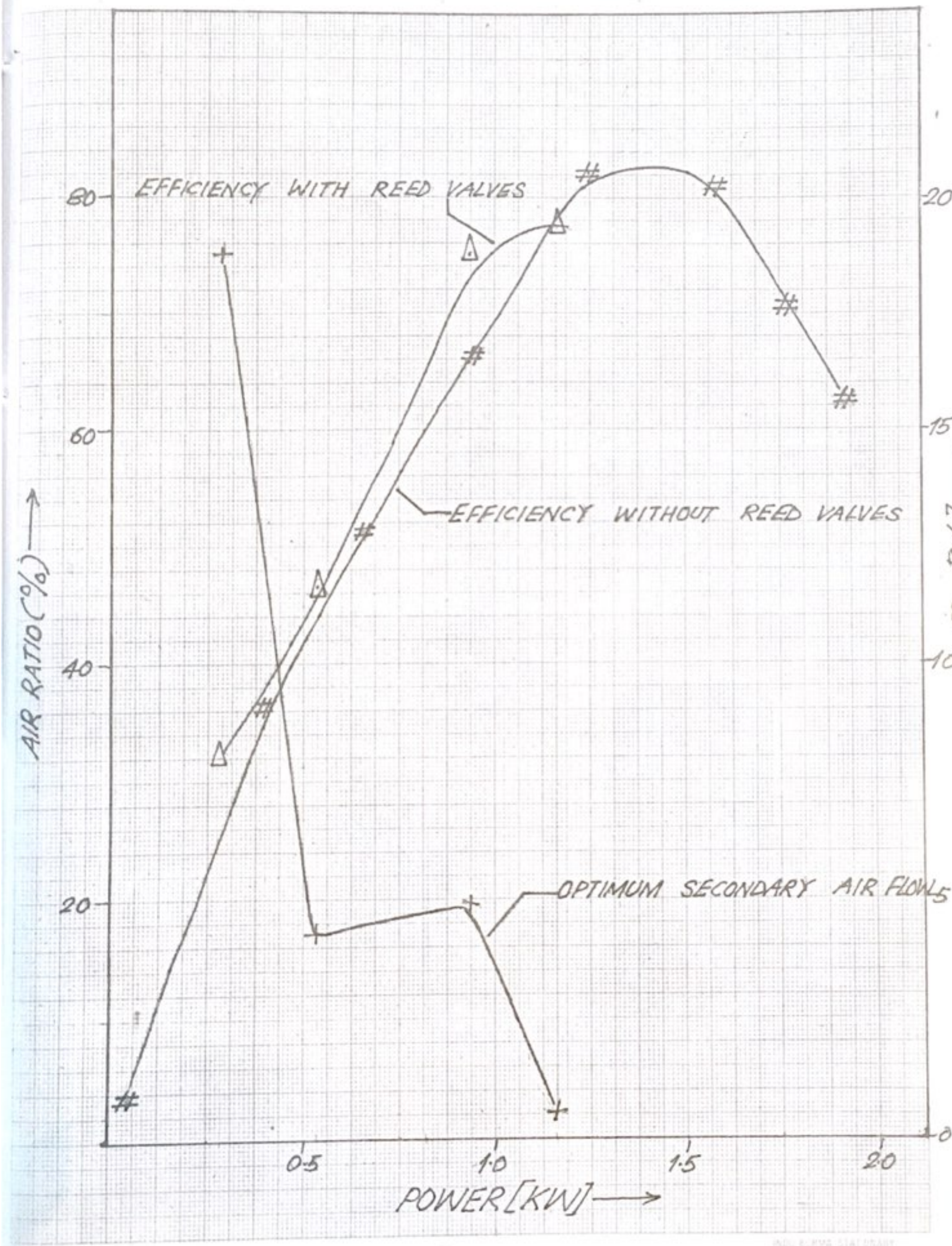


FIG. 28.

3000 RPM - OPTIMUM SECONDARY AIR FLOWS & EFFICIENCIES

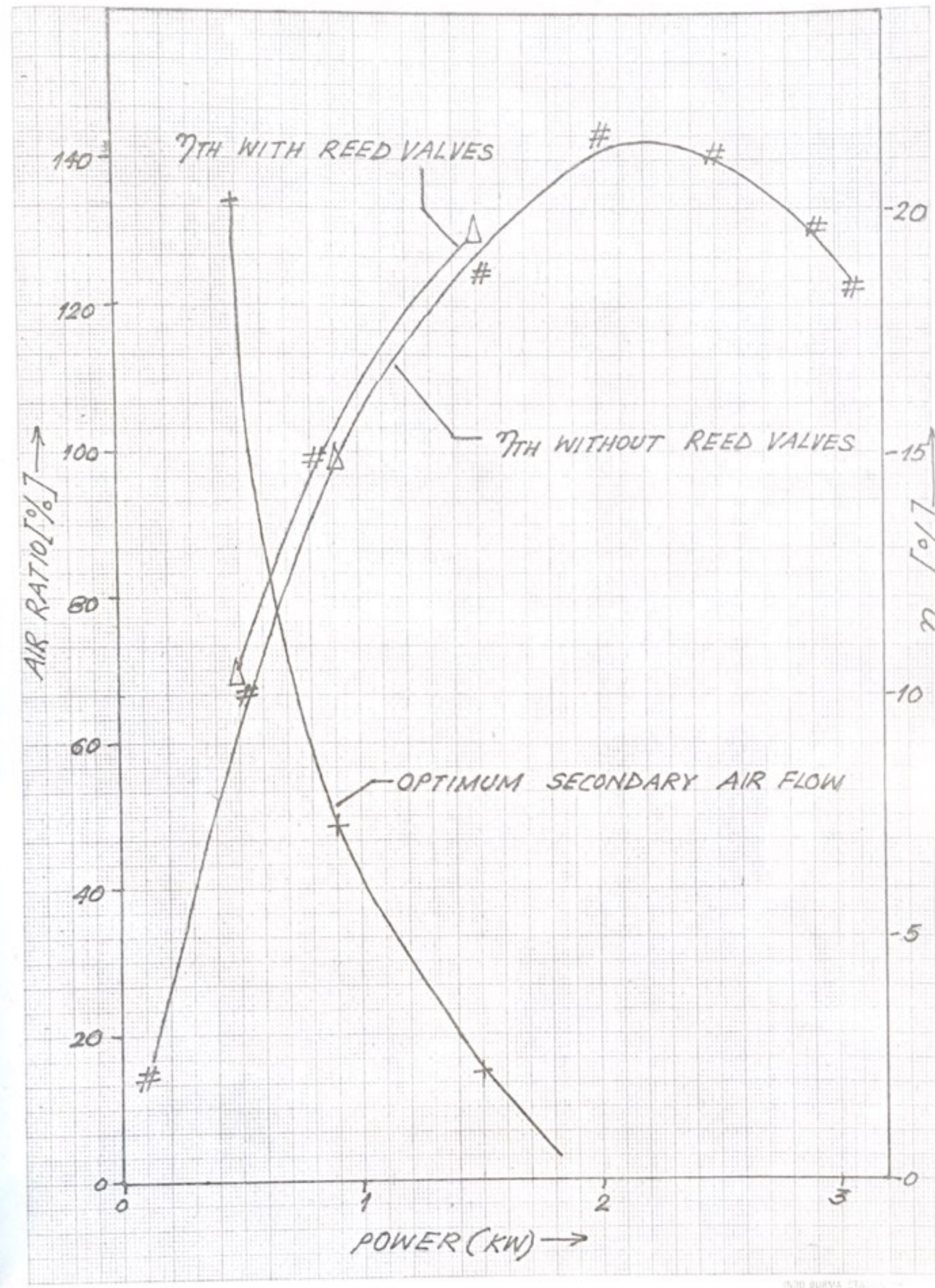


FIG. 29.

4000 RPM - OPTIMUM SECONDARY AIR FLOWS AND EFFICIENCIES

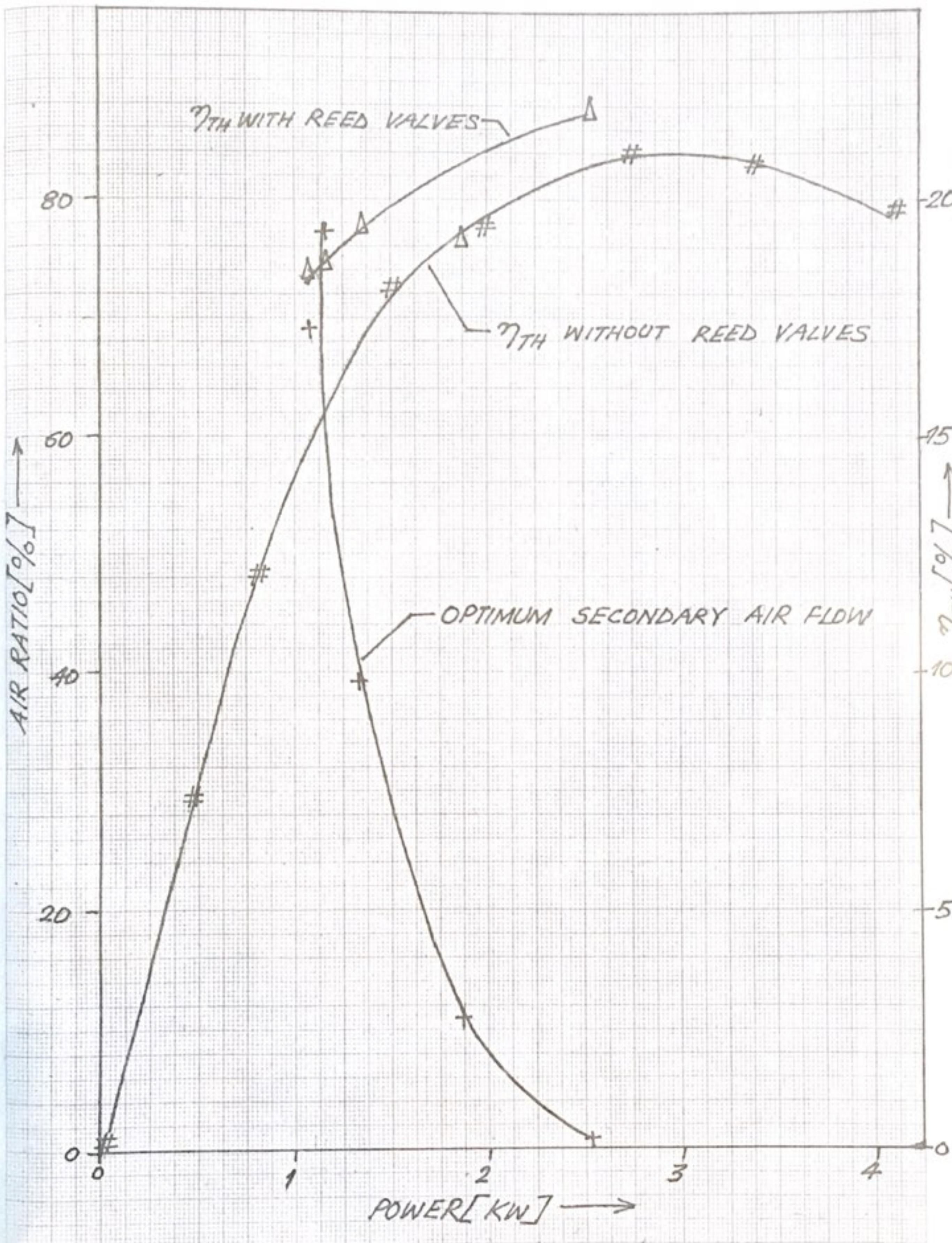
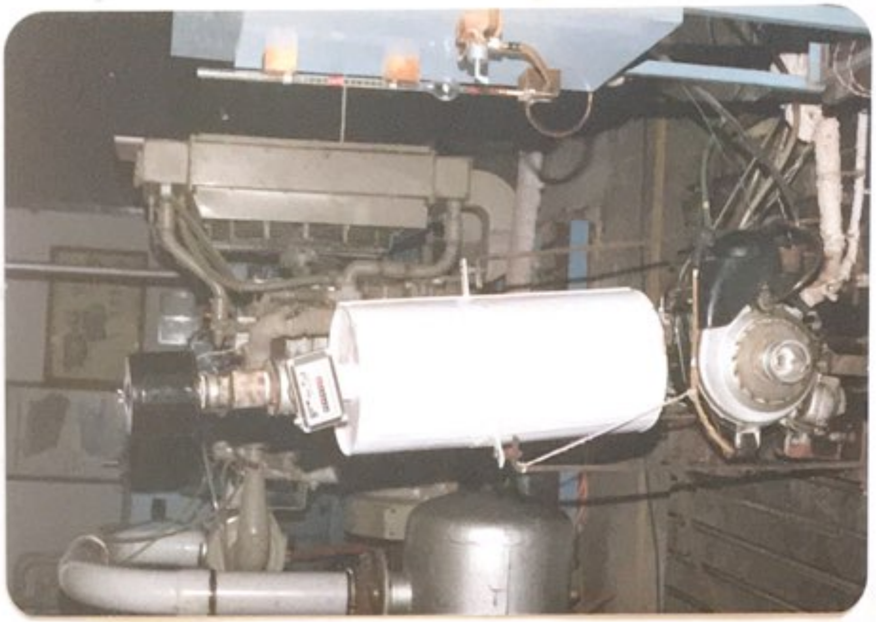
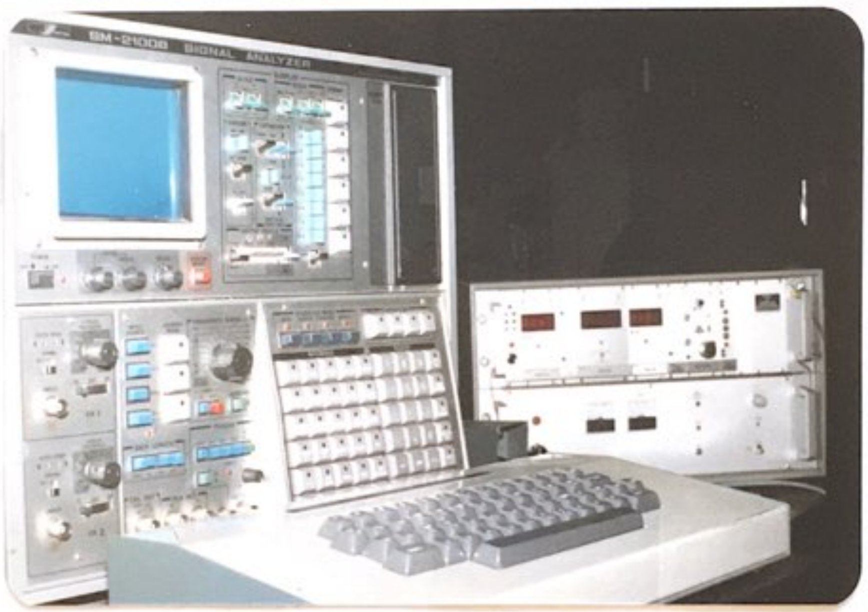


FIG. 30.

11. REFERENCES

1. SAE, 'Technology pertaining to Two Stroke Cycle Spark Ignition Engines'- Progress in Technology series No.26
2. A.Ramesh, 'Improvement in the performance of a two stroke spark ignition engine through extra reed valves fitted near the transfer ports', M.Tech Thesis, Indian Institute of Technology, Madras, Jan. 1985.
3. Giovanni Batoni, 'An Investigation into the future of Two-Stroke Cycle Engine', SAE paper 780710,




SM-2100B SIGNAL ANALYZER