UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

15368

Distr.
LIMITED

UNIDO/IO.625
3 January 1986

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

BLENDING OF ALCOHOLS WITH DIESEL FUELS *

US/GLO/83/039

prepared by

E.J. Lom and R.R. Reeves**

* This document has been reproduced without formal editing.

** APACE Research Ltd., Richmond, Australia

V.85-50036

PREFACE

This report presents the work undertaken by APACE RESEARCH LTD., to evaluate the performance of a Diesel Engine when fuelled with Surfactant Stabilized Hydrated Ethanol/Distillate Emulsions containing Ignition Improving Additives. The work was funded by UNIDO under project US/GLO/83/039 - Blending of Alcohol with Diesel Fuels.

APACE RESEARCH LTD. has developed an effective distillate/alcohol emulsifier technology for the blending of hydrated alcohols with distillate and the use of "diesohols" in unmodified Diesel Engines. Up to 30% substitution of Diesel for Ethanol can be achieved with minimum engine modification.

The report describes a test programme undertaken to evaluate the thermodynamic performance of a commercially available, unmodified engine with ethanol/distillate emulsions containing varying proportions of different ignition improvers. Experimental equipment, procedures and results are described. The significance of the results are discussed and recommendations for further activities involving vehicle trials and fleet tests in Developing Countries are presented.

Explanatory Notes

Besides the common abbreviations, symbols and terms, the following have been used in this report:

ARL	Apace Research Ltd.
BTDC	Before Top Dead Centre
deg	Degrees
ION	Iso Octyl Nitrate
kPa	Kilo Pascals
lbf	Pounds Force
NM	Newton-Meters
rpm	Revolutions per minute
SFC	Specific Fuel Consumption
TEGDN	Triethyleneglycoldinitrate

Mention of the names of firms and commercial products does not imply endorsement by the United Nations Industrial Development Organization.

CONTENTS

TABLES

EXECUTIVE SUMMARY.

ALCOHOLS AS FUELS FOR UNMODIFIED DIESEL ENGINES

* The use of alcohols as extenders of gasoline fuels has led to significant implementation of "gasohol" in several countries (e.g. Brazil).

* The ratio of distillate to gasoline usage in developing countries is such that an extender for distillate is far more necessary than an extender for gasoline.

* Distillate is an income producing fuel having a vital role to play in the agricultural, goods and product transportation and industrial sectors thus further strengthening the need for a suitable extender.

* A number of countries have surplus ethanol or the capacity to produce ethanol and could significantly achieve foreign exchange savings from substituting domestically produced ethanol for imported crude oil or refined distillate.

* Ethanol production for fuel is labour rather than capital intensive and provides real opportunity for effective decentralisation in developed nations and a strong base for third world countries.

* While the technology for mixing hydrated ethanol with gasoline is relatively straightforward, in the past it has not been possible to produce an economical stable blend of hydrated ethanol and distillate, i.e. "diesohol".

* Apace Research Ltd. has developed an effective distillate/alcohol emulsifier technology that, for the first time, enables the practical and economical blending of hydrated alcohols (both ethanol and methanol) with distillate and the use of these diesohhols in existing, unmodified diesel engines.

* The level of ethanol substitution that can be readily achieved is:

15% ethanol	- No engine modifications or ignition improver required.
25% ethanol	- No engine modification required, fuel and/or timing re-adjustment may be desirable. Ignition improver required.
30% ethanol	- No engine modification needed in majority of cases, however some fuel injection equipment may require modification. In some cases new fuel injection equipment will be required leading to possible engine changes.

Etnanol substitution in excess of 30% is not recommended for unmodified existing diesel engines.

At the 15% substitution level rapid and flexible implementation of a diesohol technology is possible and can be followed by the gradual introduction of higher substitution levels.

* Patents have been granted for the technology in five countries, including the United States and Australia, and futher patent applications are pending in 30 other countries.

* Agreements have been made with two major international companies - Albright & Wilson Limited and Shell Internationale Research Maatschappij B.V. (Shell).

  Albright & Wilson has been granted a world-wide non-exclusive licence to produce and market the Apace emulsifier and diesohols.

  Shell has been granted a world-wide licence to undertake a research and development programme covering optimisation of diesohols.

  Shell has also been granted the right of first refusal to the second world-wide non-exclusive licence to commercially produce and market the Apace emulsifier and diesohols.

ABSTRACT

The thermodynamic performance of a FORD 3000 diesel engine was evaluated on an engine test bed using stable ethanol/distillate emulsions containing varying proportions of different ignition improvers. Additionally a limited road test using a Toyota Landcruiser was also performed.

It has been previously shown that increasing the alcohol content of an alcohol/distillate blend (including emulsion) decreases both the ignition quality (cetane number) and the calorific value of such a blend. In a diesel engine the effect of the former leads to knock or quench but can increase the thermal efficiency, while the latter results in a power drop.

Previous tests and subsequent discussions with major engine manufacturers have indicated that an ethanol/distillate emulsion containing 20% by volume ethanol without ignition improving additives is extremely marginal as far as ignition delay and knock are concerned. In fact engine manufacturers would not approve the use of an emulsion containing in excess of 15% v/v ethanol without ignition improving additives.

The purpose of this project was to evaluate ignition improving additives of two types, one which enhances the ignition quality of the continuous distillate phase, the other affecting only the dispersed alcohol phase. Also investigated was the effect of variations in injection timing and establishment of the optimum timing for an ethanol emulsion.

The results obtained have shown that the alcohol compatible ignition improver Triethyleneglycoldinitrate (TEGDN) is extremely effective in reducing ignition delay and knock throughout the engine speed and load range. The cold starting characteristics of the Toyota Landcruiser were also substantially enhanced. The quantity required was only 75% of that recommended by the supplier for use with ethanol as the sole fuel in diesel engines and it may be beneficial to reduce this quantity even further in order to achieve improved thermal efficiency.

The timing changes showed that as far as engine performance was concerned there was minimal difference betweeen the distillate and emulsion containing TEGDN in terms of power, thermal efficiency, ignition delay and combustion pressure characteristics. Retarding the timing improved the performance of the engine on both fuels. There was however a dramatic increase in observed smoke on distillate with retarded timing which was not evident on the ethanol/ distillate emulsion.

It should be noted that most engine manufacturers set the timing slightly advanced and sacrifice some performance for smoke free exhaust. The timing using the emulsion could therefore be set to the optimum and some of the loss of performance due to the lower calorific value regained.

ETHANOL/DISTILLATE EMULSIFIED BLENDS IN DIESEL ENGINES.

An Evaluation of Diesel Engine Performance when Fuelled by Surfactant Stabilised Hydrated Ethanol/Distillate Emulsions containing Ignition Improving Additives.

1. INTRODUCTION

Apace Research Ltd. (A.R.L.) is a non profit company concerned with the research and development of renewable energy technologies mainly in the biomass sector. It is especially involved in the production and application of alcohols with emphasis on fuels for diesel engines.
The company competes for research funds from governments and the private sector and in addition has a capacity for internally funded research in these and other areas.

A large proportion of the R.& D. as well as marketing effort of A.R.L. to date has been directed towards developing energy efficient means of production and utilisation of the alcohols, ethanol and methanol. The reasons for encouraging the implementation of fuel alcohol industries/utilisation include :

* Concern over guarantee of supply of distillate and it's cost.

* Alcohol production is strongly linked to the agricultural base. Because of economic limitations imposed by the transport of large quantities of biomass feedstock, alcohol for fuel production is effectively a labour intensive industry and provides real opportunity for effective decentralisation in developed nations and a strong base for third world countries.

* Compared to coal and oil shale conversion to synthetic hydrocarbon fractions, alcohol production is not capital intensive. Furthermore, in the case of methanol produced from non-renewable resources, i.e. natural gas or coal, it's cost is already competitive with petroleum based fuels. Methanol is also available as a by-product from coal or natural gas to synthetic gasoline processes, for example Sasol and Mobil processes respectively, and hence could readily be utilised as both a gasoline and distillate extender.

* When produced from biomass, fuel alcohol does not result in cumulative increase of atmospheric carbon dioxide.

* In order to avoid competition for land for food production, more effective land utilisation and the development of integrated, multi-purpose agriculture and horticulture will be encouraged.

* In a broad view, alcohol is a valuable feedstock for the chemical industry generally.

In the applied sense, the research effort of A.R.L. has been directed towards resolving three major criticisms of the fuel alcohol industry. These are :

* The absence of a cost and performance effective method of using alcohols in diesel engines.

* In relation to ethanol for fuel, the high processing energy requirement of conventional technology, in particular that of distillation, often results in an overall negative energy balance for the fuel.

* The lack of a low cost and effective waste treatment process for fermented biomass.

While patent applications have resulted from work in all three areas the main marketing effort to date has concerned the A.R.L. technology for extension of distillate with alcohols. That technology also constitutes the subject of the UNIDO funded project reported here.

2. EXTENSION OF DIESEL FUELS WITH ALCOHOLS

2.1 Background.

Since even hydrated methanol or ethanol are easily made miscible with gasoline, such blends received world-wide attention and in several countries significant "gasohol" programmes are under way.

However, because of a number of hitherto technical difficulties, the widespread use of alcohols in diesel engines has not been realised. This has created impediments to future fuel alcohol industries in a number of ways :

Studies on the economic feasibility of alcohol fuels have been limited to considering the use of alcohols in the gasoline market only.

Because of increasing demand for distillate world-wide, and because of the relatively inflexible ratio of gasoline to distillate in the refining operation, cracking to satisfy distillate demand results in gasoline surplus or lower quality distillate. If alcohol substitution occurs only in the gasoline market the refinery balance is further aggravated.

Since the great bulk of fuel consumed by income producing activity is distillate, alcohols have, by default given added importance to other alternatives exclusively for distillate, such as esterified vegetable/ animal oils/fats.

However it should be recognised and stressed that for the gasoline and distillate markets a common extender for either market as the situation demands is highly desirable.

A.R.L. has developed a technology which enables the practical and economic blending of hydrated alcohols and distillate and the use of such blends in unmodified existing diesel engines.

The commercial value and importance of this inherently simple concept and technology lies in its potential benefits for a broad spectrum of interests :

> At a national level, the direct substitution of domestically produced alcohols, from whatever source, for imported petroleum products, benefits through savings in foreign exchange. In this context it is also important to note that falling or low world crude oil prices can result in increasing domestic consumption, which can aggravate balance of payments, particularly for those countries heavily dependent on the importation of refined or crude petroleum products.
>
> By allowing for a market to be created for methanol as a liquid transport fuel, the A.R.L. technology can give added incentives and markets for major coal and/or gas resource development projects which may be suffering a downturn in their more traditional markets.
>
> Considering petroleum refining operations, even in the short term, indications are that critical problems of refinery balance and efficiency of operation will be encountered due to a rapidly increasing market demand for distillates and lead free gasolines,and the falling quality of crude cracking stock for their production. The ability to offset this trend by the substitution of alcohols for distillates is thus of considerable significance and value to refinery practice. Further the ability to extend the automotive distillate market sector with alcohol may allow the refineries to produce more aviation turbine fuel without greatly upsetting the gasoline-distillate balance at the refinery. Alternately, should the local demand and refinery practice be such that the shortage is in the gasoline rather than the distillate sector then "gasohol" can be easily produced.

2.2 Technology Description and Research and Development Rationale.

Opportunities to use methanol or ethanol directly as distillate extenders, as opposed to their indirect use in esterified vegetable oils, continue to arise on both local and national levels as a reflection of changing socio-economic circumstances, and out of foreign exchange savings considerations.

At the present stage of implementation of alternative fuels however, such opportunities , and the optimum level of alcohol substitution are often the subject of particular sets of circumstances which in themselves are subject to change.

Thus, maximum flexibility in the level of alcohol substitution is an important consideration when assessing the known methods of achieving alcohol substitution in existing diesel engines in particular.

In general terms, the current methods of achieving alcohol substitution in diesel engines involve modification of the fuel to suit the engine, modification of the engine to suit the fuel, or a combination of both. The methods are conveniently summarised in Table 1. (Page 9)

Alcohol cannot be used as the fuel in compression ignition (diesel) engines because the high self ignition temperature and high latent heat of vaporisation result in unacceptable ignition delay leading at best to severe knock and at worst quench (no ignition at all) without the use of ignition improvers. Changes are almost certainly required to the fuel injection system and lubricants need to be added to the alcohol.

However, when considering the introduction of alcohol extended transport fuels into the established infrastructure, blends to about 15% by volume of alcohol are usually of prime interest. As to the available choices of achieving at least this level of substitution, there is a choice of two approaches. These are -dual fuel systems or blended fuels.

In the dual fuel system, alcohol and distillate are kept in separate tanks and metered to the engine via separate arrangements. A control system is employed to limit the amount of alcohol admitted to the combustion chamber under those conditions where extended ignition delay would otherwise occur. Such systems have been shown to work, but the costs to retrofit existing engines are considerable, and there is the added complication of fuelling with two different fuels. Additionally the resale value of such vehicles can be substantially reduced if on resale it is moved to an area where no alcohol is available as an extender.

The blended fuel approach incorporates modifying the fuel so that little or no modifications are required to the engine or fuel injection equipment. From the user point of view this is by far the best approach.

Further, in relation to strategy and programme for the introduction of fuel alcohols into the established transport infrastructure it should also be noted that an advantage of the blended fuel aproach is that the successful use in engines of blends containing in excess of 15% by volume alcohol requires the incremental addition to such blends of a suitable ignition improver with possible progressive fuel injection equipment and engine adjustments or modifications.

Thus in this way, with existing diesel engine population, the blended fuel approach allows for progressively higher levels of alcohol substitution coincident with alcohol availability, while still retaining a high degree of flexibility in relation to engine fuelling.

The obvious starting point for the blended fuel approach is to mix hydrated alcohol and distillate together in one tank and then assess engine performance when running on the mix.

Unfortunately, although strictly anhydrous ethanol and distillate are miscible at high temperatures, the presence of even 0.05%(v%) water in the mixture causes phase separation. Since even so called "anhydrous alcohol" often contains at least 0.5% (v%) water it is virtually impossible to obtain a homogeneous mixture of ethanol and distillate. Further even strictly anhydrous methanol is immiscible with distillate.

One method of overcoming this problem is to form an emulsion of the ternary system alcohol/distillate/water by use of chemical emulsifiers.

To this end A.R.L. has developed a new surfactant for producing emulsions of such ternary systems which in addition to producing long term stable emulsions is also economical in use and environmentally acceptable. It also exhibits compatibility with distillate only operation and high tolerance to water ingress.

The precise composition of the surfactant is still proprietary but it essentially consists of a mixture of a poly (ethyleneglycol-styrene) copolymer and a poly(butadiene -styrene) copolymer. Thus only the elements carbon,hydrogen and oxygen are present.

In terms of physical chemistry of the emulsions, there are two types:

> Alcohol/water as the dispersed phase in a continuous phase of distillate, termed EW/D,
>
> Distillate as the dispersed phase in a continuous phase of of alcohol/water, termed D/EW.

The preferred type for a number of reasons is the EW/D type.

The structure of the emulsions also allows other additives, such as ignition or combustion improvers, which are compatible with either the distillate or the alcohol phases to be incorporated into the emulsions. This broadens considerably the range of additives available.

General criteria used in the development of A.R.L. "diesohols" are on two fronts , commercial and physical, as follows.

Table 1. COMPARISON OF CURRENTLY AVAILABLE METHODS FOR ACHIEVING SUBSTITUTION IN EXISTING DIESEL ENGINES

% ALCOHOL SUBSTITUTION

0 10 20 30 40 50 60 70 80 90 100

Approach	Method	Characteristics
BLENDED FUEL APPROACH (Modification of alcohol fuel to suit the existing diesel engines)	DALCO CHEMICAL EMULSION	Low cost, Unmodified engines. Compatible with diesel only engine operation. Water tolerant
	DALCO CHEMICAL EMULSION PLUS IGNITION/CETANE IMPROVER	Increasing engine modification required Decreasing compatibility with diesel only operation Increasing engine development costs Water tolerant over whole range
DUAL FUEL AND MECHANICAL MODIFICATION APPROACH (Modification of existing diesel engines to suit alcohol fuel)	MECHANICAL EMULSION	Installation needs comprehensive mods to fuel system. High installation costs.
	MECHANICAL EMULSION PLUS IGNITION/CETANE IMPROVER	As for chemical emulsion plus ignition/cetane improver Complication of fuelling with two different fuels
	ASPIRATION	Complicated engine and fuel injection equipment modifications required. Can be compatible with diesel only operation. High engine development costs. Complications of fuelling with two different fuels.
	DUAL INJECTION	As for aspiration, at greater cost but gives superior performance. Alcohol fuel may require lubricant additive.
	SPARK IGNITION SYSTEMS →	Not compatible with diesel only engine operation. Fuel may require lubricant additive. High engine development costs.

2.3 Commercial suitability criteria:

- To enable the use of lower cost hydrated alcohols containing to at least 10% by volume water.

- The contribution to the cost of diesohols due to surfactant and its incorporation to be relatively insignificant. The A.R.L. method of preparation of diesohols is as follows:

  A surfactant concentrate is prepared and then metered in the correct proportion with likewise metered quantities of distillate and hydrated alcohol and passed through an in-line, high shear mixer or low pressure ultrasonic homogeniser to achieve a dispersion of hydrated alcohol in distillate.

- Total surfactant concentration to be less than 1% (w/v) (i.e. less than 10 grams per litre of blend).

- The raw materials for the manufacture of the compounds comprising the surfactant to be common, widely available and low cost.

2.4 Physical suitability criteria:

- On storage, which ensures minimum loss of ethanol by evaporation, stability towards phase separation to be in excess of 12 months.

- To be suitable for use in existing diesel engines and require no or minimal modifications to be made to the engine or fuel injection system. Also the EW/D type "diesohols" to be miscible with distillate in any proportion.

- An absolute viscosity not largely different from that of automotive distillate (2.5-3.5 centipoise @ 38 deg C).

- To be physically stable at high pressure and temperature. This is particularly relevant to the high volume of return line fuel which characterises particular types of fuel injection systems. Portion of such fuel has been subjected to the maximum operating pressure and temperature of the fuel prior to return to the fuel tank.

- Hydrated alcohols have poor lubricating qualities. An EW/D emulsion reduces the risk of increased corrosion/erosion of mechanical parts by hydrated alcohol.

- The surfactant not to adversely affect any mechanical components, lubricating oil, etc.

- The surfactant not to release unacceptable pollutants upon combustion.

3. PROJECT DESCRIPTION.

3.1 Project objectives.

This UNIDO funded project furthers the work already carried out by Apace Research Ltd. to establish the feasibility of extending distillate fuel supplies by the addition of ethanol, especially in developing countries.

Prior work by Apace was aimed at establishing the ethanol substitution level possible without the use of ignition improvers. It was concluded that, on the engines then tested, 20% substitution was the limit. Since then, however, further testing with different engines reduced this level to approx. 15%. This lower figure is more acceptable to engine manufacturers.

The objective of this project was to establish the maximum level of ethanol substitution possible, by the addition of suitable ignition improvers to emulsions to reduce the degree of knock and quench resulting from the use of ethanol in excess of 15% , without incurring high fuel or engine modification costs.

3.2 Project Work Program

* Establish the effect of different types of ignition improvers on the thermodynamic performance of a suitably instrumented diesel engine (specifically a FORD 3000) mounted on a test bed and connected to a dynamometer.

* Establish the optimum injection timing for the emulsion fuels.

* Establish the maximum economic level of alcohol substitution possible for existing unmodified diesel engines.

* Perform chassis dynamometer testing and road trials in a suitable vehicle.

3.3 Main Findings and Main Conclusions

Two commercially available ignition improvers were tested, one (Isooctyl nitrate (ION)) is already widely used to improve the ignition quality of distillate, and the other (Triethyleneglycoldinitrate (TEGDN)) is specifically formulated for use in diesel engines modified for 100% ethanol.

It was found that ION did not reduce ignition delay and knock to any great extent when used in the recommended quantities (0.2 -0.4% of the emulsion) but projections show that somewhere around 0.8- 1.0% could give acceptable results in a 20% emulsion.

The product containing TEGDN supplied for evaluation,"Alcoolita", also contained dibutylphalate and diphenylamine as stabilisers (present to ensure product safety), castor oil,other lubricants and an anti-corrosive agent.
The quantity of TEGDN alone required for acceptable engine performance is 3.1% of the alcohol content of the emulsion. Therefore the percentage needed for, say, a 25% emulsion would constitute 0.78% of the total emulsion volume.

3.4 Diesel engine thermodynamic performance.

The assesment of engine thermodynamic performance was based mainly on the following criteria:

* Maximum cylinder pressure
* Maximum rate of change of cylinder pressure
* Ignition delay i.e. the number of degrees of crankshaft rotation occurring between start of injection and start of combustion.

Torque, Power, Specific fuel consumption and Thermal efficiency are considered of secondary importance in this instance, however they were not ignored.

Maximum cylinder pressure.

The maximum pressure reached in a cylinder during combustion is mainly determined by the applied load and injection timing with the emulsion alcohol content having only minor effects. Table 2. shows this quite clearly where for example at 20 deg static timing the difference in cylinder pressure between the two extreme fuels (these being emulsion + 0.62% TEGDN and 20% ethanol emulsion) is only 1.2 bar at full load whereas a change in timing of six degrees causes a change in pressure obtained with distillate in excess of 6 bar. The effect of the different fuel type on engine cylinder pressure is more significant at lower applied loads but of course the pressures are also much lower. An example of "tailoring" the maximum cylinder pressures of an alcohol emulsion is also shown where almost identical cylinder pressures are achieved throughout the load range for distillate at 20 degrees and 25% ethanol emulsion containing 0.78% of TEGDN at 18 degrees static timing.

Maximum rate of change of cylinder pressure.

At any given engine speed this is dependent on

* Ignition quality of the fuel
* Dynamic injection timing
* Applied load

and is probably the most important of the thermodynamic criteria. Too high a rate can result in a destructive knock condition whereas too low a rate will lead to an inefficient thermodynamic cycle.

Table 3 shows the relationship between the various factors. The inter-relationship is quite complex. In the example selected a 12 degree change in timing changes the rate from 19.1 to 11 bar/deg under full load conditions on distillate which is equivalent to a reduction of 42.6%. A load change from full load to 1/3 load at 20 deg using the same fuel reduces the rate by 47%. The highest rates of pressure rise are obtained using the E20 emulsion with no ignition improvers. The addition of TEGDN to the 20% emulsion has the effect of modifying the ignition quality, as far as rate of pressure rise is concerned, to being almost equivalent to that of distillate. The E25/TEGDN at 18 deg BTDC exhibits a lower rate of pressure rise at full load, however part load match with distillate at 20 deg is very close.

TABLE 2. Maximum cylinder pressure (bar)

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	89.8	88.6	96.2	97.1	95.9	103	102	96.9
2/3	66.8	69.6	75.4	78.8	76.7	85	85	75
1/3	56.6	51.6	61.4	65.3	60.5	67	66	61

Notes: Static timing is expressed in degrees BTDC.
DIST = 100% automotive distillate
E20 = Emulsion containing 20% v/v hydrated ethanol and no ignition improvers.
TEGDN= Emulsion containing 20% v/v hydrated ethanol where the alcohol contains 3.1% TEGDN.
E25/TEGDN= Emulsion containing 25% v/v hydrated ethanol where the alcohol contains 3.1% TEGDN.
LOAD = These are nominal loads only and FULL,2/3 and 1/3 are for identification only, however part loads are identical for all fuels. Thus 2/3 load is the same for any speed,fuel or timing test condition.

Results apply to an engine speed of 1400 rpm.

TABLE 3. Maximum rate of cylinder pressure rise (bar/deg)

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	11	10.8	15.7	22.2	15	19.1	20.2	14.2
2/3	8.2	8.3	10.7	13.7	9.9	14.1	14.5	11
1/3	6.8	4.5	8.3	10.2	6.9	9.6	8.9	7.2

Notes: As per Table 2.

Ignition delay.

There is a tendency by most other researchers into thermodynamic behaviour to express the ignition delay in terms of time only, this being taken from the point of commencement of injection (as determined by needle lift diagrams) and commencement of combustion (determined by the inflection of the cylinder pressure curve). Although the Apace equipment has the ability to determine these times, we believe that the sensitivity of the delay expressed in terms of degrees is greater than in terms of time alone. Thus the results on which decisions can be made have been based on the degree mode.
As Table 4 shows the ignition delay is mainly affected by injection timing (over the 12 degree range). The load has very little effect at more retarded timings, but has a significant effect at the more advanced timings. The ignition quality of the fuel also has a major bearing on the ignition delay.

TABLE 4. Ignition delay (Crank angle degrees).

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	8	7.8	10.1	11.6	9.7	12.4	12.0	8.8
2/3	8	8	8.9	10.4	8.8	10.9	10.4	8.5
1/3	8.4	8.8	9.2	9.8	8.1	10.8	9.2	8.3

Notes: As per Table 2.

On the basis of the results presented in Tables 2,3 and 4 it can be seen why 18 deg timing was chosen for the E25/TEGDN emulsion to achieve similar power output to the 20 deg distillate timing. Table 5 shows the torque (and hence the power) attained under the various conditions. Although the calorific value of the E25/TEGDN emulsion is reduced to 37.66MJ/kg from 42.75MJ/kg for distillate (an 11.9% drop) the torque is actually decreased by only 3.2% (This is fairly typical throughout the speed range). Similar results can be applied to the TEGDN emulsion(20% v/v ethanol where the alcohol contains 3.1% of TEGDN) and 14 deg timing where the reduction is even less.

It should be noted that because of smoke emissions the engine could not be operated normally at 14 deg static timing on distillate and therefore comparison must be made to the 20 deg timing. The emulsions are reasonably smoke free at the retarded conditions and could be operated at the 14 deg setting.

TABLE 5. Observed engine torque (NM)

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	166	159	160	148	152	142	142	153

Notes: As per Table 2.

Thermal efficiency.

The thermal efficiency is dependent in the main on the start of combustion, rate of pressure rise and the completeness of combustion. The most efficient heat cycle is the constant volume cycle and the closer the approch to this ideal the higher the thermal efficiency. That an emulsion containing no ignition improvers (such as the listed E20) should exhibit higher thermal efficiency can be readily explained by the first two factors i.e. later start of combustion and higher rate of pressure rise. The same cannot be stated for the E20 emulsion containing TEGDN and thus any efficiency improvement must be attributed to improved combustion.

Table 6. sets out the efficiencies obtained under the various conditions and it can be discerned that again injection timing plays a significant role as does the fuel type. The typical characteristic indicating that the highest efficiency is obtained somewhere between 55 and 80% of full load is also very much in evidence under all conditions.

TABLE 6. Thermal efficiency (%)

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	27.4	29.2	26.5	27.6	27.5	23.4	25.8	28.5
2/3	30	30.5	29.7	29.3	29.4	27.9	28.3	29.6
1/3	20.4	20.2	21.5	20.6	20.1	19.2	20.4	20.4

Notes: As per Table 2.

Specific fuel consumption.

The thermal efficiency of the engine heat cycle and calorific value of the fuel determine the specific fuel consumption.
Table 7. lists the values of the specific fuel consumptions obtained and the interaction of efficiency and calorific values observed. Thus it can be seen that 100% distillate because of its high calorific value tends to exhibit the lowest specific

fuel consumption even when its efficiency is low compared to the emulsions. Where the efficiencies between the fuels are similar (as at part loads) then specific fuel consumption must increase in direct relationship to the calorific value of the fuel. This is further adversely compounded by the density of the fuel as most operators use volumetric instead of gravimetric fuel consumption criteria.

TABLE 7. Brake specific fuel consumption. (BSFC gms/KW/hr)

STATIC TIMING	14 deg		20 deg			26 deg		18 deg
LOAD	DIST	TEGDN	DIST	E20	TEGDN	DIST	TEGDN	E25/TEGDN
Full	307	319	289	336	338	360	361	335
2/3	281	306	281	317	317	301	329	323
1/3	412	462	410	450	464	439	456	470

Notes: As per Table 2.

Toyota Landcruiser experience.

The Toyota vehicle fitted with a 6 cylinder H series indirect injection engine was down on power when operated on a 20% ethanol emulsion containing .62% v/v TEGDN. The power could be readily restored by fuel rack adjustment only, rather than carrying out timing alterations. This would, obviously, increase the fuel consumption to compensate for the reduced calorific value of the fuel.

Observations made of the cold starting ability indicated that cold starting was much easier using the emulsion fuel with ignition improver than with distillate. Apart from the fact that the glow plugs needed to be used for a shorter period there was an almost total lack of cold start "crackle" (knock) and black smoke from the start-up excess fuel.

Driving the vehicle normally on the road did not reveal any necessity for re-establishing the power output, the engine operated smoothly throughout the load and speed range. At no time was any black smoke emitted.

3.5 Conclusions on the results obtained

It would be inappropriate to make any firm recommendations based on the results obtained. However it can be stated with reasonable confidence that 20%, probably 25% in the vast majority of cases and in certain applications (such as large stationary or railway engines) even 30% ethanol substitution can be achieved.

The scenarios envisaged are :

* 15% ethanol substitution- No engine modifications and no ignition improver required.
* 20% ethanol substitution- No engine modifications required, but some fuel delivery or timing changes may be required. Ignition improver required.
* 25% ethanol substitution- No engine modifications required in majority of cases, but fuel delivery and/or timing changes will be required. Ignition improver required.
* 30% ethanol substitution- No engine modifications required in majority of cases however some fuel injection equipment may need to be modified. In extreme cases new fuel injection equipment will be required leading to possible engine changes. Ignition improver required.
* Ethanol substitution in excess of 30% would not be recommended as fuel injection equipment modifications would be required in virtually all cases. The ethanol/distillate emulsion may also require lubricant in addition to ignition improver and emulsifier.

4. POTENTIAL FOR INDUSTRIAL/COMMERCIAL APPLICATION.

The apparent stability and oversupply of crude oil existing at present would seem to indicate that the emulsion technology would have limited application. However the quality of the available crude is dropping rapidly and the need for additional cracking and refining for the lead-free gasoline market as well as the demand for high grade (and highly profitable) aviation kerosene is eroding that part of the barrel generally sourcing the automotive type distillate. There is already evidence of quite serious down-grading in terms of the ignition quality of automotive distillate which is being boosted by the addition of ignition improvers. To this state of affairs must be added the plight of the alcohol (either ethanol or methanol), sugar and starch producers which is causing a serious glut of alcohol in the market place. This situation will not be improved when the Middle East mega-litre methanol plants come on stream in the near future.

Distillate can be considered as an income producing product having a vital role to play in the agricultural, industrial and goods/product transportation sectors. This is especially true in developing countries where the ratio of distillate to gasoline consumption is high. The cost of distillate to these countries is very high (at the time of writing the strength of the American dollar was having a significant effect on these costs) and thus the introduction of emulsions incorporating indigenously produced alcohol could alleviate balance of payment problems.

It is the opinion of the authors that there are a number of countries at present where socio-economic conditions are such that great benefits would accrue rapidly from the introduction of the emulsion technology.

Apace Research Ltd. has filed complete patent specifications relating to the emulsion technology in the following countries.

Australia	U.S.A.	Europe
Argentina	Colombia	designating
Mexico	Chile	Austria
Norway	India	Belgium
South Africa	Mauritius	France
Israel	New Zealand	Federal Republic of Germany
Japan	Republic of China(Taiwan)	Italy
Philippines	Sri Lanka	Liechtenstein
Indonesia	Nigeria	Luxembourg
Canada	Pakistan	Netherlands
Brazil	Republic of Korea	Sweden
Venezuela	Thailand	Switzerland
Turkey		United Kingdom

with confirmation applications to be filed in:

Kenya
Malaysia
Singapore
Fiji

Negotiations in relation to licensing the technology have culminated in the granting of a world-wide non-exclusive licence to Albright and Wilson Ltd.(UK), a major international chemical company, to manufacture, use and sell the emulsifier and the emulsions.
The right of first refusal for the second such licence has been granted to Shell (Netherlands).

Governments and/or organisations interested in implementing the technology should contact either or both of these organisations.

5. ENGINE PERFORMANCE TESTS.

5.1 TEST ENGINES.

All preliminary test work to establish the effect of the selected ignition improvers was conducted on a Ford 3000 engine located in the Engineering Department at Hawkesbury Agricultural College.

This engine was considered to be suitable for this type of work for a number of reasons, the main ones being:

a. It was used on previous methanol projects and has proved itself tolerant to a considerable degree of abuse (i.e. knock).

b. A complete engine is available as a spare, including Fuel Injection Pumps and Injectors. Spare parts are available locally at reasonable cost.

c. The combustion chamber is not state of the art design and thus should be relatively sensitive to fuel quality. A bore to stroke ratio of 1:1 is used and cylinder volume is around the 1 litre capacity. Max governed speed is 2200 r.p.m. although 2000 r.p.m. was considered more suitable for the tests. A full specification for this engine is listed in Table 8.

Table 8.

Specification for Ford 3000 Test Engine.

Make	Ford
Model	3000
Type	4 stroke,direct injection, naturally aspirated.
No. of cyl.	3
Bore	106.7 mm (4.2")
Stroke	106.7 mm (4.2")
Displacement	2860 cc (174.5 cis)
Comp. Ratio	16.5:1
Firing Order	123
Max. No Load Speed	2175-2225 r.p.m.
Idle Speed	600-700 r.p.m.
Compression pressure @ 1000 r.p.m.	38 bar (550 p.s.i.)
Injection Timing	The injection timing was arbitrarily set to 20 deg B.T.D.C.
Injection Pump	D.P.A. 3233F161
Injector Nozzle	BDLL150S6443
Opening Pressure	185 atm

5.2 ENGINE TEST EQUIPMENT AND MEASURING METHODS.

The equipment used for this project comprised a combination of conventional test equipment used by many other research establishments for this type of work and equipment designed by Apace Research Ltd. to enhance the measuring techniques.

Typical equipment and methods for the measurement of engine parameters consist of :

(1) Manual reading and recording of fairly stable test parameters such as :
   a. Dynamometer load
   b. Engine speed
   c. Fuel consumption
   d. Various engine and dynamometer temperatures

(2) Recording of cylinder pressures and needle lift by means of an oscilloscope and Polaroid photography. In a number of more advanced engine test facilities ignition delay is measured by means of an ignition delay meter, although this requires a degree of skill on the part of the engine tester.

It should be noted however that more advanced systems are being installed utilising such items as digital storage oscilloscopes, F.F.T. analysers and computer aquisition systems.

The investigation of the effects of different fuels having widely differing ignition characteristics is hampered by the existing manual methods leading to considerable inaccuracies and slow analysis and interpretation.

The equipment and methods used by Apace Research Ltd. for the aquisition of all engine parameters are completely computer based and are believed to offer a degree of accuracy of results not possible with conventional or indeed other methods under development.

The following is a brief description of the equipment and methods used :

(1) HEENAN and FROUDE Type G Hydraulic Dynamometer modified for electrical readout of applied load. The dynamometer is still however manually operated.

(2) Fuel consumption measurement is mass based and comprises a Mettler PE3600 electronic balance equipped with a 2400 baud serial interface. Fuel flow to the weighed fuel container is controlled by a solenoid valve under instruction from the computer. An electric pump delivers the fuel to the engine.

(3) A Kistler Type 6123 Piezo-electric pressure transducer coupled with Type 5041 charge amplifier is used to convert the cylinder pressure into an appropriate electrical signal. Great care had been taken with the installation of this transducer in the cylinder head, mounted vertically with the diaphragm flush with the cylinder head face and well within the piston bowl periphery. It is mounted within a separate tube and a degree of installation compliance has been built in. This is to reduce cylinder head transmitted vibration to the pressure transducer.

(4) The Injector needle lift is measured by means of a C.A.V. Type 1368 FM system consisting of :

a. Inductive measuring coil which detects the movement of the aluminium extension attached to the injector push rod.

b. Oscillator

c. Demodulator/amplifier/filter.

The measuring system produces a voltage proportional to the needle lift.

(5) Heated air is supplied to the engine from an airbox fitted with a thermostatically controlled heater and recirculating fan. The airbox has a volume of approximately 2 cubic metres and air is drawn out of it at a rate dependant on engine demand.

(6) Thermocouples are used to measure temperatures of:

a. Engine cooling water inlet
b. Engine cooling water outlet
c. Sump oil
d. Fuel oil inlet
e. Air inlet 150mm prior to the inlet manifold
f. Air box
g. Exhaust gas approximately .5m downstream of the manifold.
h. Cooling tower water in
i. Cooling tower water out.

(7) The data aquisition and instrument system is under the control of a Hewlett-Packard 86B computer complete with disc drives, HP-IB, RS232 and GP-IO interfaces. Additionally the memory has been expanded to 256k and I/O and Advanced Programming enhancement ROMs have been installed. Although it was not considered an ideal machine for the application it proved adequate in the majority of respects. It's main drawback is the slow Basic operating system. With the time limitations imposed on us by the delays to complete the project it was not considered worthwhile to re-write the programme in machine language.

(8) Equipment described above is conventional in nature, however in order to make the best use of it, it was necessary to design and build a special interface. The interface is based on the S100 bus and briefly consists of :

a. 16 bit address bus
b. 16 bit data bus
c. 4 1/2 digit A-D converter is used for the measurement of all slow changing signals such as thermocouples with a maximum conversion speed of 330mS. A demultiplexer allows differential signals to be steered to the converter via a differential instrumentation amplifier. The BCD coded output of the converter is hardware translated to binary code.

d. A 12 bit A-D converter is employed to convert the voltage produced by the Cylinder pressure charge amplifier to offset binary code. This is then placed into a memory location determined by crankshaft position and specified measurement parameters. A sample-hold amplifier at the input of the A-D converter ensures accuracy of the signal. The conversion rate is in the region of 25 micro-seconds.

e. An 8 bit A-D converte. 'sed to convert the signals from the Ne. lift amplifier to unipolar binary code and this is also stored in a specified memory location. Again a sample -hold amplifier is placed at the input to the A-D converter to ensure data integrity. As the output is unipolar, an offset voltage is applied at the input so that only positive voltage is seen. The conversion rate is approximately 4 micro-seconds.
It should be noted that a second 8 bit A-D converter together with sample hold and high gain instrumentation amplifier is installed for use with a fuel line pressure transducer.

f. Five pre-settable down counters. Each counter has associated with it a data latch which can be directly addressed and loaded with data by the computer. The function of the five counters are :

i. Number of measurement samples to be taken
ii. Measurement delay expressed as number of grads after bottom dead centre.
iii. Actual number of consecutive grads when cylinder pressure and needle lift are to be measured and stored in their respective memories.
iv. Cycles between consecutive measurements. It allows the selection of complete engine cycles (two revolutions) when no cylinder or needle lift are recorded.
v. Revolution counter which generates an interrupt signal to the computer that the specified number of revolutions has been completed.

g. An up counter which measures actual engine revolutions and is under computer control. It is used to determine engine speed and fuel consumption.

All the counters are preset to their initial value (data in the latches for the down counters, zero for the up counter) by a trigger signal from the computer.

h. Memories and memory management.
Each high speed A-D converter has it's own 4k of memory, 8 bit wide in the case of the needle lift and 12 bit wide in the case of the cylinder pressure. The memory address is accomplished by means of up-counters which are either addressed by engine crankshaft position sensors during the write cycle or by the computer during the read cycle. Again the counters are preset to their initial value (zero) by the trigger signal from the computer.

i. Electronic switching is used for the RS232 signals so that single serial interface of the computer can be used for reading the fuel measurement system data or writing to a printer. Additional switching is also provided for the GP-IO interface to cater for a plotter drive.

(9) In order to synchronise the aquisition of the high speed data i.e. cylinder pressure and needle lift with the combustion cycle, the crankshaft position must be monitored. This is achieved by means of a disc having 400 slots machined in its periphery, each slot corresponding to one grad. One of the slots is longer and corresponds to Nol crank being at bottom dead centre. Two infra red sensitive photo transistor/ diode sensors coupled with Schmitt triggers sense the slots and output a square edged pulse each time a slot passes the detector. Thus one detector produces 400 pulses per crankshaft revolution while the other produces only one pulse at bottom dead centre per crankshaft revolution. A proximity type switch is installed near the camshaft gear which is fitted with a steel flag indicating whether the compression/expansion part or the exhaust/ induction part of the combustion cycle is in progress.

The combination of the three sensors together with some counters can therefore determine the crankshaft position within a combustion cycle to within one grad. (0.9 deg = 1 grad)

The measurement methods are fairly simple and operate in a number of different modes. These are :

(1) Idle mode.
In this mode the only measurements that are taken are the slow response ones i.e. temperatures, torque and engine speed. A complete measurement cycle takes approximately 10 seconds. This is useful for monitoring engine parameters for stabilisation and setting up for a more complete measurement mode. The computer always starts up in this mode and always reverts to it at the completion of any other mode. Exit from this mode to any other mode or function is accomplished by use of the special function keys. While in this mode it is also possible to alter all the measurement parameters such as grads delay,number of samples, number of revolutions for the fuel consumption measurement and number of grads to be read.

(2) Beginning of injection mode.
The purpose of this mode is to aquire needle lift data during the latter part of the compression stroke and early part of the expansion stroke and calculate by the use of a suitable algorithm the dynamic starting point of injection. This allows for re-adjustment of the pump timing to obtain the required dynamic commencement of injection.

The programmed default parameters are :

a. One sample only
b. Grads delay set to 150 grads
c. Grads measured set to 100 grads. These can, of course, be altered by entering the required data into the computer. This allows the study of either short term or long term changes in engine parameters by varying the sampling period.

(3) Ignition Delay.
This mode is identical to the Beginning of injection mode in all aspects but also includes the cylinder pressure data, number of revolutions and time taken to complete that number of revolutions. Once the data has been collected and commencement of injection calculated then another algorithm is used to determine the start of combustion from the cylinder pressure data. It is then a simple matter to establish the ignition delay from the time and number of revolutions both in terms of time and crank angle.

The additional default parameter is the number of revolutions and is set to 100. Again if higher accuracy or greater number of samples are required then this parameter can be easily re-specified.

When either the beginning of injection or this mode is specified an internal computer flag is set which enables, at the completion of the measuring cycle, for needle lift and cylinder pressure data to be graphically displayed on the computer monitor. Additionally the commencement of injection and combustion are marked together with grad marks and top dead centre.

(4) Full run.
This mode is selected when the engine has reached correct specified operating conditions such as

a. Water temperature
b. Oil temperature
c. Air inlet temperature
d. e.t.c

and the engine speed and load have been set and stabilised.

The following sequence takes place when this mode is entered :

i. A quick check is made of the engine speed over 100 revolutions and stored.

ii. A calculation is made how many readings of engine load and all temperatures (i.e. how many idle loop equivalents) can be made within 1000 revolutions at the speed obtained in (i.). This determines how many readings of these parameters will be taken during the full run. This figure is however deliberately limited to five and if neccessary the computer will enter into a wait state to achieve equally spaced readings.

iii. The fuel feed to the fuel measurement system is switched off and a wait period of five seconds initiated.

iv. The counter latches are set up with test conditions, the default ones being:
a. Samples = 5
b. Delay ,grads = 10
c. Number of grads measured = 780
d. Number of cycles between samples = 89
e. Number of revolutions = 1000
Note that the number of cycles between samples (89) + 1 sample = 90 so that a sample is taken every 90 engine cycles or 180 engine revolutions.

v. The memory address counters are set to zero.

vi. The RS232 port connected to the balance is selected and the buffer registers in the serial interface cleared. Two consecutive readings from the balance are read by the computer and the first one rejected, the timer is started and all counters loaded with data from their respective latches and enabled by common trigger signal. The interrupt from the down counter is also enabled.
At this point the Apace interface commences to collect data from the cylinder pressure, needle lift and (when available) fuel line pressure at every specified grad and storing the data in the relevant memory locations.

vii. While the interface is collecting and storing the rapidly changing data the computer performs basically a number of idle loops as established in para. ii.

viii. After the specified number of revolutions have been completed an interrupt is generated by the interface and the computer responds to this by checking that the balance RS232 port is still connected, clearing the serial interface buffer registers of accumulated data,again accepting two readings from the balance and rejecting the first one. At this point it stops the revolutions up counter and reads the elapsed time from the start of the measurement cycle.

ix. The computer now restarts the fuel flow to the fuel consumption measuring system and commences the data transfer from the Apace interface memory into it's own memory. On completion of the data transfer internal flags are set to signify that the data is now ready to be stored on disc, displayed graphically on the monitor, selected data output to a printer or to a plotter .
The last two features were not utilised during this series of tests as vast quantities of data were collected and it was preferable to process the data in a less hostile environment.

x. The computer now re-initialises all setup parameters back to the idle loop conditions and restarts that loop.

The statistics of this type of data aquisition are quite surprising. Typically a single full run mode would produce in 1000 engine revolutions the following amount of information :

* 3900 data points for needle lift
* 3900 data points for cylinder pressure
* 3900 data points for fuel line pressure(when available)
* 5 applied load readings
* 50 temperature readings (5 of each measured temperature)
* 2 fuel mass readings (one at the commencement, the other at the end of the test run)
* Elapsed time between the two fuel mass measurements
* Number of engine revolutions occuring during the elapsed time.
* Barometric pressure

Additional information that must be recorded includes such items as Test ID, Fuel ID, Fuel density, Fuel calorific value, Date, Record ID, Number of samples, Number of cycles between measurements, Grads delay, Number of grads measured, Engine specification, Dyno parameters and any comments.

In spite of virtually all information being stored in condensed form this still amounts to 16500 bytes per full run mode. The method selected for fuel evaluation requires 16 runs (3 different loads at 5 speeds and one idle condition) and thus 264,000 bytes of information have to be stored per single fuel.

Eight fuels have been evaluated during this project resulting in the collection of 3,696,000 bytes of information to be digested. It is rather fortunate that a large proportion of this information is not directly required, thus reducing the information to be processsed to a much more manageable 500,000 bytes (approx).

5.3 TEST FUELS.

All the emulsions were prepared by Apace Research Ltd. from a common batch of Mobil distillate and C.S.R. Industrial Methylated Spirit.

The ignition improvers used were carefully selected from the literature, previous experience and private communications from other research organisations. Two ignition improvers were chosen for investigation, iso octyl nitrate (ION) for improving the ignition quality of the distillate phase and Triethyleneglycol-dinitrate (TEGDN) for improving the ignition quality of the ethanol phase of the emulsion.

Samples of ION were supplied by The Associated Octel Co. Ltd. (UK). It is also available from other organisations such as Ethyl Corporation who market ION under the trade name DII3. It is available worldwide at competitive prices.

The TEGDN used in the tests was obtained by Perkins Engines Ltd. on behalf of Apace Research Ltd. from Explo-Industrias Quimicas e Explosivos S.A. Brazil. The product containing TEGDN is marketed under the trade name of "Alcoolita". Alcoolita contains 60% ethyl alcohol, 32% TEGDN and the remaining 8% contains dibutylphalate, diphenylamine, castor oil, Maxlube, an anti- corrosive agent and other minor ingredients.

A blend of 13 parts of Alcoolita to 87 parts hydrated (96%) alcohol produces a fuel for use in specially adapted diesel engines. Thus the TEGDN content amounts to 32% of 13% which is equal to 4.16% of the total volume.

It is believed that the present production of TEGDN is in the order of 300 tonnes/month and can be readily expanded.

Initially five emulsions were prepared containing different amounts of ignition improver and their engine performance was compared with that of 100% distillate.
Based on the results obtained another two emulsions were prepared.
Table 9. shows the properties of the various fuels.

Table 9.
Fuel Properties.

Fuel Id.No	Dist. %	Eth. %	ION %	Density gm/cc	L.C.V. MJ/Kg
DIST 100	100			.849	42.75
E20	80	20		.845	38.83
E20/.2ION	79.8	20	.2	.845	38.83
E20/.4ION	79.6	20	.4	.845	38.83
			TEGDN		
E20/2.6TEGDN	80	19.48	0.416	.848	38.69
E20/5.2TEGDN	80	18.96	0.832	.850	38.55
E20/3.9TEGDN	80	19.22	0.624	.849	38.62
E25/3.9TEGDN	75	24.03	0.78	.848	37.66

NOTES.
1. Distillate was supplied by Mobil
2. "Ethanol" was Industrial Methylated Spirit supplied by CSR Ltd. and contains nominally 5% v/v of water. Its L.C.V. has been taken as 23.96 MJ/Kg.
3. The L.C.V. of TEGDN has been quoted as 13.2 MJ/Kg and the density taken as 1.338 gm/cc.
4. Densities shown in the table are those at 15 deg.C.
5. The surfactant is assumed to be part of the distillate.
6. Fuel identification.
   For emulsions with ION the identification is simply expressed as the alcohol volume and ION volume in the emulsion. Thus E20/.2ION = 20% hydrated ethanol+
   0.2% ION +
   79.8% distillate.(% by volume)
   For emulsions with TEGDN the identification is expressed as non-distillate volume and percentage of non-alcohol constituents of the non-distillate volume. Thus
   E25/3.9TEGDN= 25% non distillate components +
   75% distillate
   where the 25% non distillate component comprises
   21.1% hydrated ethanol +
   3.9% non alcohol components
   and the 3.9% non alcohol components comprise
   3.12% TEGDN +
   0.78% stabilisers, lubricants and anti-corrosive agents.

5.4 ENGINE MATRIX TESTS.

A test matrix of 16 load and speed conditions covering the entire engine range was carried out using each emulsion in addition to a distillate datum.

The matrix test conditions were :

3 loads......Full load
2/3 load (nominal)
1/3 load (nominal)

5 speeds.....2000 rpm (nominal)
1700 rpm (nominal)
1400 rpm (nominal)
1100 rpm (nominal)
800 rpm (nominal)

An idle condition at 800rpm and minimum load.

At each matrix condition the following parameters were measured and recorded.

* Engine speed
* Dynamometer load (5 readings)
* Nett fuel consumption (1 reading over 1000 + engine revolutions)
* Air inlet temperature (5readings)
* Air box temperature (5 readings)
* Exhaust temperature (5 readings)
* Engine oil temperature (5 readings)
* Cooling water in temperature (5 readings)
* Cooling water out temperature (5 readings)
* Fuel temperature at fuel pump inlet (5 readings)
* Cooling tower water in temperature (5 readings)
* Cooling tower water out temperature (5 readings)
* Ambient/cold junction temperature (5 readings)
* Needle lift and cylinder pressure readings at one grad intervals commencing at 190 grads BTDC on compression stroke and continuing for 780 grads.Five of the above cycles were repeated at intervals of 180 complete engine revolutions.

The method adopted for the aquisition of of all data for the various test fuels was as follows:

The engine was run at 1700 rpm and approximately 75% load until engine cooling water temperature was stabilised at about 80 deg C. outlet, 50 deg C inlet, sump oil temperature in excess of 80 deg C. and air inlet temperature of 30 deg C. When these parameters were reached a check of the dynamic performance was made by invoking the timing/delay measurement mode. If this was considered satisfactory then the full test matrix was carried out in the following order:

1. Full load -2000 rpm
   -1700 rpm
   -1400 rpm
   -1100 rpm
   - 800 rpm
2. 2/3 load -2000 rpm
   -1700 rpm
   -1400 rpm
   -1100 rpm
   - 800 rpm
3. 1/3 load -2000 rpm
   -1700 rpm
   -1400 rpm
   -1100 rpm
   - 800 rpm
4. Idle - 800 rpm

A check of all major parameters was made prior to executing full run mode at any matrix condition.

The engine remained unaltered for all tests with the exception of timing changes

The methodology adopted was to compare 20% ethanol emulsion containing first guess quantities of ignition improvers to a 20% emulsion with no ignition improver, and 100% distillate. First guess quantities were 0.2% and 0.4% ION in the emulsion then 2.1% and 4.2% TEGDN in the alcohol phase of the emulsion. All of these fuels were tested at the static timing of 20 deg BTDC to establish the effect of the ignition improvers. From the results obtained the preferred ignition improver was selected together with its optimum required quantity for best thermodynamic engine performance.
The emulsion containing the required quantity of the preferred ignition improver was then compared to 100% distillate at various injection timing swings ranging from 6 deg (engine) retarded to 6 deg (engine) advanced in order to establish the optimum timing. Once the ignition improver, its quantity and the optimum timing were thus established an emulsion containing 25% ethanol plus ignition improver was prepared and compared to 100% distillate.

5.5 ENGINE MATRIX TEST RESULTS.

All engine test results are presented separately in:
Appendix 1.,"Engine Results Curves", FIG AP1 to AP125
Appendix 2.,"Engine Results Tables", Page 1 to 56

The results for torque, and its derivatives, shown in Appendix 1., have been corrected for atmospheric pressure only since the air inlet temperature was maintained relatively constant.

The engine results for torque (and power) shown in Appendix 2.have been corrected to standard conditions for atmospheric pressure and temperature as per Australian Standard "Method for Rating and Testing Internal Combustion Engines" AS 1501-1976 (100 kPa and 27 deg.C).

The most important criteria when assessing alternative fuels for diesel engines, especially fuels containing large percentages of single boiling point, high latent heat of vapourization, self ignition temperature liquids are ignition delay and rate of pressure rise.

The emphasis in this report (and indeed of the specialised instrumentation) is therefore directed to these aspects rather than the more conventional ones of torque, power, specific fuel consumption and thermal efficiency. These have not been ignored in the analysis, but the weighting given to them is less than would normally be the case.

Definitions of some of the terms used :

Three different loads have been used in the engine performance and these have been arbitrarily called Full load, 2/3 load and 1/3 load. The actual loads used are:

Full load- The maximum load that can be applied to the engine at any particular engine speed. This is dictated by the fuel delivery, fuel calorific value and thermal efficiency.

2/3 load-This is a load of 11.22 N (2.5 lbf) or torque of 89 NM. applied at any speed.

1/3 load-This is a load of 4.49 N (1.0 lbf) or torque of 35.6 NM applied at any speed.

Engine speeds quoted for comparison purposes are nominal engine speeds. There can be a variation of upto 50 rpm between the nominal and actual speeds. Actual speeds are used in all calculations and graphs.

(a) Commencement of Injection and Combustion, Max. Cylinder Pressure and Max. Rate of Pressure.

FIG AP1 to AP24 show the needle lift and cylinder pressure diagrams obtained on the initial fuels tested. These were:

* Distillate FIG AP1 -AP4
* E20 FIG AP5 -AP8
* E20/2.6TEGDN FIG AP9 -AP12
* E20/5.2TEGDN FIG AP13 -AP16
* E20/.2ION FIG AP17 -AP20
* E20/.4ION FIG AP21 -AP24

These diagrams show the repeatability of the needle lift and cylinder pressure taken every 360 engine revolutions (Note that while five actual readings were taken every 130 engine revolutions, only the first, third and fifth readings are plotted). The table of results at the right hand side of each of the diagrams gives the average of the FIVE readings.
Typically the needle lift is repeatable at higher speeds and variable at the low speed, low delivery (i.e. idle) conditions. Please note that only the commencement of needle lift is taken into consideration and not vertical separation (which is to some extent influenced by the self tuning characteristics of the transducer system used). Considerable changes in needle lift, for example FIG AP8, indicate fuel delivery variations resulting in significant changes in combustion characteristics. This would be expected for the CAV DPA pump which exhibits a variable commencement of injection with load. This coupled with metering being accomplished by throttling leads to substantial changes in the amount of fuel injected and dynamic timing. The effect is particularly evident on three cylinder engines.

TEGDN emulsion fuels.
FIG AP25 -AP27 compare max. cylinder pressure, max. rate of cylinder pressure, start of injection and start of combustion of emulsions containing TEGDN with 100% distillate and E20 at different speeds and loads.
At full load there is virtually no difference in max. pressure with any of the fuels. At part loads the percentage difference is greater but the actual pressures are reasonably close between the fuels.
The start of injection at full and 2/3 loads within the 800 to 2000 rpm speed range is almost completely independent of the emulsion used. 100% distillate shows a departure from the other fuels only at 800 rpm exhibiting 2 deg of retard.

At 1/3 load there is a considerable change in the dynamic timing at 1400 rpm for the two fuels containing TEGDN ignition improver. Apart from this point the behaviour of 100% distillate and the emulsions follow the same pattern as at full and 2/3 load conditions.
At this stage there is no reasonable explanation for this phenomena. It certainly is not due to incorrect data aquisition as the max. pressure and max. pressure rate follow suit.
The change in the start of injection at 800 rpm can most probably be attributed to the advance device fitted to this pump which is load, viscosity and fuel bulk modulus sensitive. Its highest sensitivity would lie at the lower speeds where the transfer pressure is also most fuel viscosity sensitive.

The start of combustion at full and 2/3 load,again within the 1100 to 2000 rpm range, is fairly consistent with the 100% distillate and the two emulsions containing TEGDN. The E20 emulsion shows a considerable change in the start of combustion being much later than the other three fuels. Although the 1/3 load appears to be somewhat haphazard, careful study shows that similar conclusions can be drawn, although they are not as obvious when compared to the other conditions.

The max. rate of pressure is most certainly affected by fuel type. The worst (i.e. one exhibiting the highest rate) being the E20 emulsion and the best being the E20/5.2 TEGDN emulsion. The difference is most obvious under full load conditions at the higher speeds. At 2/3 and 1/3 load the difference between 100% distillate and the two emulsions containing TEGDN is much reduced.

FIG AP31 to AP33 show the effect of load at various speeds when using emulsions containing TEGDN compared with E20 emulsion and 100% distillate.

FIG AP37 to AP39 show how the max. pressure, max. rate of pressure, start of injection and combustion vary with emulsions containing TEGDN compared with E20 emulsion and 100% distillate at various speeds and loads.

ION emulsion fuels.
The max. cylinder pressure, max. rate of pressure, start of injection and combustion for the emulsions containing ION are compared to E20 emulsion and 100% distillate in FIG AP28 to AP30, AP34 to AP36 and AP40 to AP42.

The results show a trend similar to that obtained with the emulsions containing TEGDN but not to the same extent.
Thus max. cylinder pressures are almost identical at the full load conditions at all speeds for all four fuels with some di ergence at the 2/3 and 1/3 loads.
Max. rate of pressure does decrease with the inclusion of ION to a small but significant degree. Again the main effect is seen at the higher speeds under full load conditions. Start of injection for the full and 2/3 loads is almost identical throughout the speed range for all the emulsions, some deviation occuring when using 100% distillate at 800 rpm. A similar phenomenom takes place at the 1400 rpm, 1/3 load condition to that obtained with the emu sions containing TEGDN i.e the start of injection is similar for the 100% distillate and E20 emulsion while the ignition improved emulsions are similar to each other but are somewhat retarded with respect to the 100% distillate and E20.

(b) Fuel delivery, Torque and Specific fuel consumption (S.F.C.)

FIG AP43 and AP44 show the effect of the six initial fuels on the maximum fuel injection pump delivery and maximum torque. The deliveries are very similar for all the fuels tested and thus it can be stated that the fuel pump delivery is relatively insensitive to these particular fuels. It should be noted that the method of obtaining the fuel delivery is indirect. The actual fuel used is measured gravimetrically, then its volume is calculated from its known density at 15 deg C and the fuel pump inlet temperature. The volume so calculated is then divided by the number of injection strokes during the measuring period.
The maximum torque is again very similar for each of the fuels the maximum difference occurs at 2000 rpm amounting to 5%, while the difference for the rest of the speed range is reduced to 2.5%. The S.F.C. for the emulsions containing TEGDN (FIG AP43) shows an apparent high variation, however the effect of the figure scaling must be noted and in fact, the greatest difference shown between the E20 emulsion and the E20/5.2 TEGDN emulsion at

1400 rpm amounts to only 2.5%. The emulsions containing ION (FIG AP 44) show even lower divergence in S.F.C. between the various fuels.

(c) Fuel delivery, Efficiency and Specific fuel consumption. (S.F.C)

TEGDN emulsion fuels.
FIG AP45 to AP48 show the effect of applied load (torque) on the above three parameters at three different speeds with the emulsion containing TEGDN.

Typically it can be deduced that 100% distillate is required in the least amount by comparison to all the emulsions to attain any given torque under the majority of conditions. The worst fuel in this respect is the E20/2.6 TEGDN emulsion. Efficiency varies with the torque and the fuel used e.g. at full and 2/3 loads, (all speeds), maximum efficiency is attained with the E20 emulsion while the 100% distillate shows minimum efficiency at full loads only.
Specific fuel consumption is dependant on the efficiency and fuel calorific value and therefore 100% distillate appears to be superior to the other fuels throughout the load and speed range. The two emulsions containing TEGDN give higher specific fuel consumptions, with the E20 emulsions showing a slight improvement over them.
The disparity in the fuel consumptions is more evident at part loads than at full load.
FIG AP51 compares the fuel delivery, efficiency and S.F.C. under full load conditions directly for the four fuels, 100% distillate, E20, E20/2.6 TEGDN and E20/5.2 TEGDN, and the three speeds.

ION emulsion fuels.
FIG AP48 to AP50 depict the variations in fuel delivery, efficiency and S.F.C. against applied load (torque) at various speeds with the emulsions containing ION.
Once again 100% distillate is required in the least amount compared to all the emulsions to attain any given load although under full load conditions the difference between any of the fuels is negligible. The three emulsions E20, E20/.2ION and E20/.4ION have almost identical performance throughout the load range at the three speeds selected, the exception being 2/3 load at 800 rpm. where greater delivery of E20/.4ION is required to attain the desired load.

The three emulsions (E20, E20/.2ION and E20/.4ION) exhibit higher efficiency under most loads and speeds, the only exception being the 2/3 load, 800 rpm condition using E20/.4ION.
Again the specific fuel consumption of all the emulsions is higher than that of 100% distillate at all loads other than full load. At the full load condition all the fuels give extremely close results.
FIG AP52 compares the fuel delivery,efficiency and S.F.C. under full load conditions directly for the four fuels, 100% distillate, E20, E20/.2ION, and E20/.4ION, and the three speeds.

Based on the results obtained it was projected that the optimum ignition improver would be TEGDN in the ratio of 3.12% TEGDN in the hydrated ethanol. This conclusion was drawn based mainly on matching the ignition delay and the rate of change of cylinder pressure to that of 100% distillate. Although it appeared that ION could be made to match at full load there was some doubt as to whether part load conditions could be matched as well. The amount that would be required was estimated at 0.8 to 1.0% of the total emulsion. Note that these amounts would be greater than those required for emulsions containing TEGDN.

The next stage of evaluation was to establish the effect of changes to static injection timing when using the "optimised E20/3.9TEGDN" emulsion. The E20/3.9TEGDN emulsion was compared to a 100% distillate datum and a full performance matrix test was carried out at 14 deg, 20 deg and 26 deg BTDC static injection timings for both fuels.
Opportunity was taken to evaluate the repeatability of results over long term for the 100% distillate used as reference.

The results for this series of tests were as follows:

(a) Commencement of Injection and Combustion, Max. Cylinder Pressure and Max. Rate of Pressure.

FIG AP53 to AP76 show the needle lift and cylinder pressure diagrams for the two fuels and the various static timings.

* 100% Distillate	20 deg BTDC	FIG AP53 - AP56
* "	14 deg BTDC	FIG AP57 - AP60
* "	26 deg BTDC	FIG AP61 - AP64
* E20/3.9TEGDN	20 deg BTDC	FIG AP65 - AP68
* "	14 deg BTDC	FIG AP69 - AP72
* "	26 deg BTDC	FIG AP73 - AP76

Again both the needle lift and cylinder pressure show good repeatability at the higher speeds and loads and poor repeatability at the low load, low speed or idle condition.

100% Distillate fuel.
FIG AP77 to AP79 are included to observe the repeatability with time using 100% distillate on these parameters. Some difference is observed in the max. pressure at full load this amounting to 5.5% at 2000 rpm where minor timing change occurred and 8% where considerable retardation (3.7 deg.) of commencement of injection occurred. The repeatability (especially at part loads) is considered very good and if timing would have been re-adjusted for each condition to ensure constant dynamic timing then excellent repeatability would have been attained.

FIG AP80-AP82 show the effect of static timing on the max. pressure, max rate of pressure and the ignition delay. As can be seen the max. pressure at full load increases considerably for a timing change from 14 deg to 20 deg BTDC but the increase in this pressure for the timing change from 20 deg to 26 deg BTDC is small. At part loads the max. pressure tends to be more proportional to the static timing at the higher speeds but follows the characteristics of the full load condition at the lower speeds.
Apart from the 800 rpm condition both the max. rate of pressure and ignition delay tend to be proportional to the static timing and they increase as the timing is advanced.
FIG AP86-AP88 are presented to show the variation in max. pressure, max. rate of pressure and ignition delay with load at the three different timings and three different speeds. It can be seen that both the max. pressure and max. rate of pressure are significantly load sensitive.
The ignition delay shows very little sensitivity to load (in fact it is marginally extended at the lower loads as would be expected from a cooler combustion chamber), it is however affected by the timing.
FIG AP92-AP94 show directly the effect of timing on the four parameters ,Max.Pressure, Max. Rate of Pressure , Commencement of Injection and Commencement of Combustion.

E20/3.9 TEGDN emulsion fuel.
Results for the E20/3.9 TEGDN emulsion (FIG AP83 -AP85, AP89-AP91, AP96-AP98) are virtually identical for those obtained on 100% distillate with the exception that the timing change from 26 deg to 20 deg has a greater effect on max. cylinder pressure under full load conditions.

(b) Fuel Delivery, Torque and Specific Fuel Consumption.(S.F.C.)

100% Distillate.

The delivery at 2000 rpm varies by a max of 4% between that at the 20 deg timing compared to the other two. This could be due to slight governor interference however the magnitude need not be considered of great importance.
Torque increases considerably as the timing is retarded and from the results obtained it could be deduced that further retard could be possible. This does not however take into account that smoke is the limiting factor at approx. 18 deg BTDC.
The specific fuel consumption also decreases with retarding the timing as would be expected from the increased torque without a corresponding increase in delivery. See FIG AP98.
FIG AP100-AP102 show the delivery required to attain a given part load condition at different engine speeds. It can be noted that the major effect of timing on all the parameters (delivery, efficiency, specific fuel consumption) occurs at full load conditions. This is shown more clearly in FIG AP106 where the delivery, efficiency and S.F.C. are plotted directly against the static timing for the various speeds.

E20/3.9 TEGDN emulsion.
(FIG AP100) Delivery is practically identical to that obtained on 100% distillate however the torque does not increase at the same rate with change in the timing. At 26 deg BTDC the torque for both the 100% distillate and E20/3.9 TEGDN emulsion are very similar but at 14 deg BTDC the torque at 1100 rpm is 5.7% lower on the emulsion than on the distillate. Specific fuel consumption follows suit being 5.7% higher on the emulsion at 1100 rpm at the retarded timing.
FIG AP103-105. Typically the thermal efficiency of the E20/3.9 TEGDN emulsion is higher than that for 100% distillate at all speeds and loads in excess of approx. 50%, at comparable timing settings. Below the 50% load the thermal efficiencies for both the distillate and emulsion are identical. Although the thermal efficiency using the emulsion

is at no time lower than that for distillate under identical conditions, the emulsion specific fuel consumption is higher than that for distillate under almost all conditions with the exception of full load at 2000 rpm and 26 deg BTDC timing (FIG AP107).

The results obtained from this test matrix indicate that a retarded timing for both the 100% distillate and E20/3.9TEGDN emulsion is highly desirable to obtain best torque, efficiency and S.F.C. Excessive smoke limits the static timing to 18 deg BTDC when using 100% distillate.

After carefully assessing all the results obtained to this point, it was considered appropriate to prepare an E25/3.9 TEGDN emulsion and set the static timing to 18 deg BTDC. Results obtained were as follows:

(a) Commencement of Injection and Combustion, Max. Cylinder Pressure and Max. Rate of Pressure.

The needle lift and cylinder pressure diagrams are shown in FIG AP108-AP111 for 100% distillate and FIG AP112-AP115 for the E25/3.9TEGDN emulsion. Once again good repeatability is obtained at the higher speeds and loads. The low idle condition, no load and 800 rpm, is worst for repeatability both in terms of timing and start of combustion.

The commencement of injection and combustion for both 100% distillate and emulsion throughout the the speed and load range are virtually identical. The only exceptions to this statement occur at the 800 rpm speed where the emulsion dynamic timing tends to be approximately 1 deg advanced and at 1400 rpm, 1/3 load where this increases to almost 2 deg.

Max. pressures for the two fuels are again almost identical throughout the speed and load range.

Maximum rate of pressure is generally higher for E25/3.9 TEGDN emulsion than for 100% distillate under full load conditions at 18 deg BTDC static timing. Typically the rate increase is approx. 2 bar/ deg which is equivalent to 14% (FIG AP116-AP118).

FIG AP119-AP121 show the variation in ignition delay, max. rate of pressure and max. pressure with torque at different speeds. The ignition delay is identical for 100% distillate and E25/3.9 TEGDN emulsion and the max. cylinder pressures are very similar. The maximum difference between the two fuels occurs in the max. rate of pressure, however, as already pointed out in the previous paragraph this increase with the emulsion amounts to a maximum of only 14%.

(b) Fuel delivery, Torque and Specific Fuel Consumption (S.F.C.). FIG AP122

The fuel delivery using E25/3.9 TEGDN emulsion is marginally higher than with 100% distillate throughout the speed range under full load conditions with the exception of 1700 rpm where it is marginally lower. It could however be considered that the fuel delivery is insensitive to the type of fuel being used.
The maximum reduction in torque occurs at 1700 rpm using the E25/3.9 TEGDN emulsion and amounts to 6.9%. From consideration of calorific value and actual fuel deliveries, the reduction in torque should have been in the order of 13.75%.
S.F.C. does increase with the emulsion, typical increase being in the order of 5.4%.

FIG AP123-AP125 show the effect of torque on the fuel delivery, efficiency and S.F.C. It can be seen quite clearly that increased fuel delivery of the E25/3.9TEGDN emulsion is required to attain the same torque as that obtained with 100% distillate.
The efficiency at loads exceeding 50% is almost always higher with the emulsion the only exception being the 2/3 load condition at 800 rpm. Below the 50% load the efficiencies of the two fuels are very similar.

5.6 DISCUSSION OF ENGINE TEST RESULTS.

From the results obtained it can be readily deduced that a stable emulsion containing distillate, hydrated ethanol and ignition improver can be readily prepared using the Apace Research Ltd. emulsifier. It is also apparent that this emulsion can be formulated to obtain the ignition characteristics of a high quality automotive distillate and that the alcohol content is not limited by thermodynamic considerations. The fact that TEGDN is used as an ignition improver for 100% hydrated ethanol engines should make this obvious.
The maximum amount of ethanol substitution will therefore be governed by other factors, either physical or economic.

The FORD 3000 engine used in these tests exhibited, on 100% distillate, a rather poor thermal efficiency with correspondingly low torque and high specific fuel consumption. The improvement in performance on emulsion was relatively high, in fact much higher than could be reasonably expected. It is suspected that with more developed engines, the extent of performance improvement will be reduced over that obtained with the FORD 3000 engine.

It is to be expected that performance in terms of torque (power) will be reduced in some proportion to the calorific value of the fuel and hence, in the case of emulsions, to the amount of alcohol present. In the majority of cases the power drop will not be directly proportional to the calorific value of the fuel, the increased thermal efficiency and re-adjustment of the injection timing offsetting some of the calculated theoretical change. For example the calculated power drop for an E25/3.9 TEGDN emulsion compared to distillate on calorific value only should be 11.9%. The actual power drop obtained on the FORD 3000 engine amounted to an average of 2.2% when comparing the distillate results at 20 deg BTDC and E25/3.9 TEGDN emulsion at 18 deg BTDC static timing.
It would be unwise to predict this sort of performance for other engines and a more realistic figure would be in the order of 7% power drop when changing from 100% distillate to the E25/3.9 TEGDN emulsion with the static timing optimised.
Should the application demand that full power be restored then the fuel delivery would have to be increased by a corresponding amount.
Generally there are two ways to increase the fuel delivery from a fuel injection pump. One way is to lengthen the injection period while the other is to increase the injection rate.
It would seem that increasing the injection period is the simplest way of increasing the fuel delivery and in the vast majority of instances this will be the case. It must however be borne in mind that a combination of retarded timing and extended injection period could cause late cycle burn to occur in some engines. This would result in loss of thermal efficiency and high exhaust gas temperatures.
Engines fitted with in-line fuel injection pumps having constant beginning of injection control helix would simply require maximum fuel and injection timing re-setting which is a simple operation. Generally an in-line pump has excess fuel capacity of at least 40%. There may however be rare applications where the additional fuel is injected over a sensitive cam radius with resultant high cam stresses.
Increasing the injection period on a DPA distributor type pump results in a change of injection timing and

this timing change would have to be taken into account in addition to any other timing change required. This pump does not possess excess fuel capability and in some instances may already be operated close to its maximum rated fuel delivery. Additionally in some applications the roller- camring contact occurs coincidentally with (or it may even precede) the delivery port opening. Increasing the delivery period under these circumstances would lead to high cam stresses and cam failure. A change of cam to delivery port phasing can be achieved by a change of either the camring or advance piston but this would affect the torque curve shape of the engine.
Increasing the fuel pump delivery by increasing the fuel injection rate would necessitate larger diameter pumping elements (irrespective of the type of pump). New injector nozzles, hopefully only having larger diameter spray holes, would also have to be fitted. Again there will be instances where a pump is already close to its design limit and a completely new pump would be required. This method, even in its simplest implementation could be considered as economically unsuitable.

5.7 CONCLUSIONS ON ENGINE PERFORMANCE.

* The performance of the engine was considerd excellent when operating on ethanol emulsions containing TEGDN ignition improver.
* The amount of TEGDN required is determined by the ethanol content of the emulsion. The optimum amount of TEGDN is considered to be 3.12% of the hydrated (95% v/v) ethanol. Please note that for a 15% ethanol emulsion there is no requirement for an ignition improver.
* The maximum ethanol substitution should be considered as 25% of the emulsion resulting in changes limited to minor adjustments only.
* Although not commented upon elsewhere, noise levels using the emulsion containing TEGDN were comparable to those using 100% distillate.

6. TOYOTA LANDCRUISER.

A Toyota Landcruiser Model HJ 45RV-KCQ fitted with an H series engine (indirect injection) has been used by Apace Research Ltd. for the evaluation of a number of emulsions over a period of years. Most of the evaluation period (3 years and 50000kms) was spent operating on 15% ethanol emulsion containing no ignition improvers. No problems have been experienced during this period and average road operating fuel consumption was virtually identical for both 100% distillate and 15% ethanol emulsion (12.5 km/litre). Cold starting, although always satisfactory

when used with glow plugs, resulted in a period of knock during the engine warm-up period with both the 100% distillate and 15% ethanol emulsion. The warm up period tended to be longer (20 seconds instead of 10 seconds) with the emulsion.
Once the optimum ignition improver had been established on the engine test bed, a road performance test was carried out.
The fuel selected for this test was E20/3.9 TEGDN where the 20% ethanol content of the emulsion contained 3.12% TEGDN. It was considered that this would probably be the most widely used fuel where little or no engine/ fuel injection equipment changes would be required and yet have similar thermodynamic properties to that of distillate.
A long, straight and level stretch of road was selected for the vehicle road testing. A number of full acceleration tests were carried out at 30 to 60 km/hr in third gear , 60 to 80 and 60 to 90 km/hr in top (fourth) gear. The times obtained during these acceleration tests were averaged and are shown in Table 10. It should be noted that run to run variations in the measured times exceeded the average difference between the fuels. For example the time for the 60 to 80 km/hr test using distillate varies from 10.96 to 12.26 seconds giving an average of 11.65 seconds while for the E20/3.9TEGDN emulsion the time varies from 11.59 to 13.02 seconds with an average of 12.175 seconds.
The reduction in power when using the E20/3.9 TEGDN emulsion (although it appears to be considerable when times are taken into account) is not reflected in the driveability of the vehicle. The fuel pump delivery was temporarily reset, by allowing an extra 0.25 mm control rack travel, and it can be seen that power could be quite easily regained if absolutely essential.

TABLE 10. Acceleration Times for Toyota Landcruiser.

Speed Range km/hr	30-60	60-80	80-90	60-90
DIST 100	3.22	11.65	6.39	18.04
E20/3.9TEGDN	3.56	12.175	7.445	19.62
E20/3.9TEGDN (0.25 mm rack adjustment)	8.23	11.4	6.9	18.3

The engine performed smoothly on the E20/3.9TEGDN emulsion and virtually no smoke was emitted even when operating on excess fuel on start up. Cold starting was found to be superior to that on 100% distillate in as much that glow plugs needed to be used for shorter periods (approx 50%) at any given ambient temperature and there was an almost total absence of the cold start knock.

7. RECOMMENDATIONS.

* From the results obtained from these tests there would appear to be no thermodynamic barriers to prevent the introduction of ethanol emulsions containing ignition improvers into existing diesel engined equipment. As has been shown, the emulsions can be tailored to give a performance equal to that of distillate without the need for any engine changes, with the exception of possible minor adjustments to fuel injection equipment.
Consequently engine manufacturers and fuel injection equipment manufacturers should be approached and test programmes established in conjunction with the traditional fuel distributors and potential fuel (alcohol) producers/ suppliers within developing countries.

* Large scale trials should be undertaken in developing countries to:
  - Make potential users aware of the availability of emulsion technology.
  - Demonstrate the compatibility of the emulsion with distillate and existing diesel engines.
  - Demonstrate that emulsion fuels can be used with no impairment to the performance of diesel engined equipment.

Such trials should have the following features:
- Undertaken in a country with an indigenous ethanol supply (e.g. Malawi, Thailand, Brazil).
- Comprise a mixed fleet of automotive, agricultural and earth moving equipment totalling 30 to 50 units. These units should be based within a limited area of 20 km radius and have an operating range of 50 km. A further 5 to 10 mixed units should be tested concurrently on 100% distillate to serve as controls.
- Adequate field workshop facilities should be available for on site unit maintanance. Any part failures should be evaluated by both the original manufacturer and an independant assessor.
- Adequate emulsion blending facilities and storage should be centrally located in the test area.
- Supervision and monitoring of the trial should include:
  a. Regular measurement of engine power.
  b. Constant measurement of fuel consumption.
  c. Regular sampling of engine oil.
  d. Keeping of a maintanance log.
  e. Good record keeping of all aspects of the trial.
- The trial should extend for a minimum period of one year.
- Visits by senior government officials of other developing countries to observe the trials should be encouraged.

Such trials would put to rest the fears and doubts concerning this "new fuel" that will inevitably exist.

* Further research should be carried out in the area of ignition improvers with special emphasis on :
  - Increasing the effectiveness of TEGDN.
  - Establishing the effect of TEGDN in emulsions containing low ignition quality distillates.
  - Determining the effect of emulsions containing ignition improvers on exhaust emissions.

8. APPENDICES

8.1. Engine Results Curves

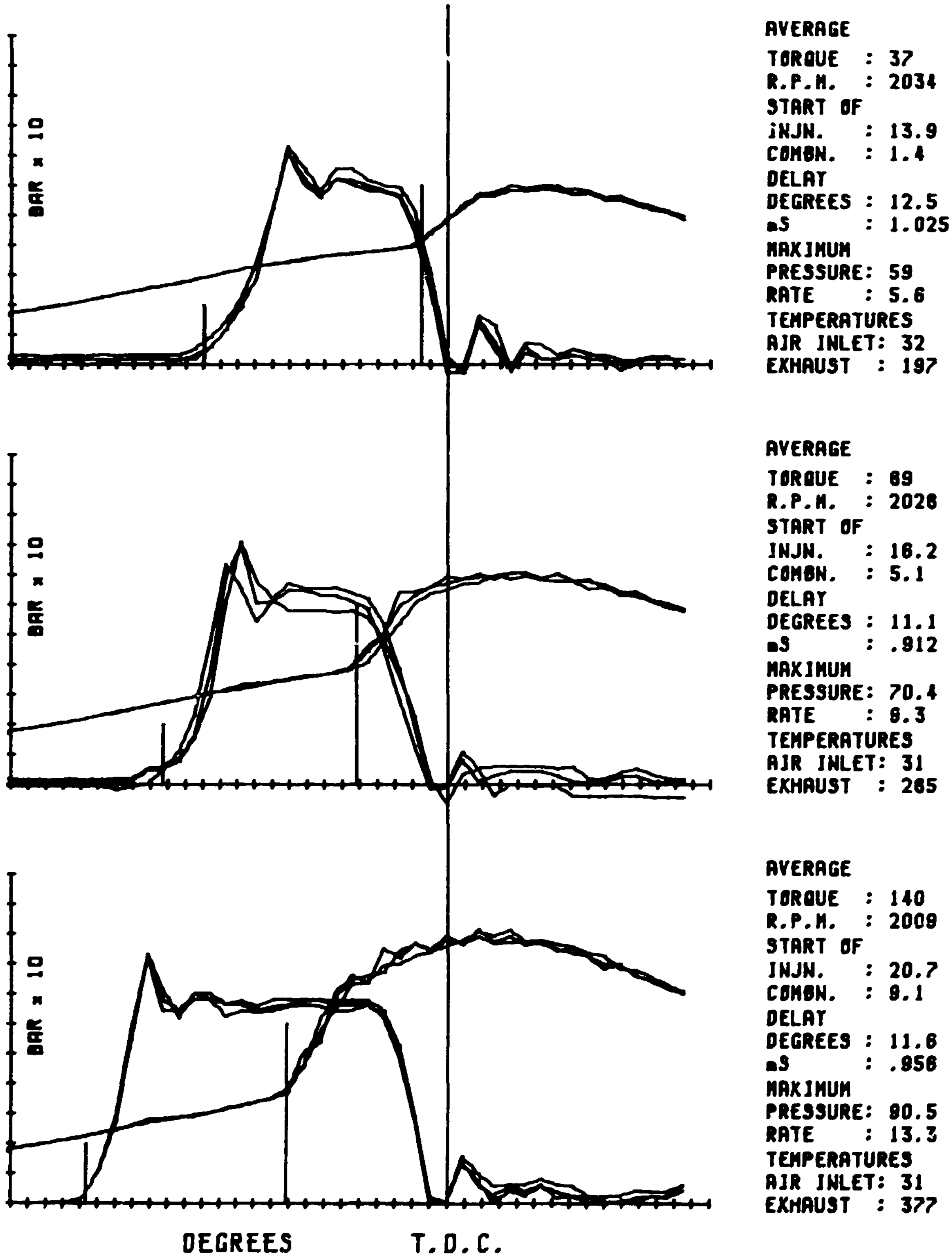
FIG	Title		
AP1	Repeatability of Needle Lift and Cyl. Pressure	DIST 100	2000 rpm
AP2	"	"	1400 "
AP3	"	"	800 "
AP4	"	"	IDLE
AP5	"	E20	2000 rpm
AP6	"	"	1400 "
AP7	"	"	800 "
AP8	"	"	IDLE
AP9	"	E20/2.6TEGDN	2000 rpm
AP10	"	"	1400 "
AP11	"	"	800 "
AP12	"	"	IDLE
AP13	"	E20/5.2TEGDN	2000 rpm
AP14	"	"	1400 "
AP15	"	"	800 "
AP16	"	"	IDLE
AP17	"	E20/0.2ION	2000 rpm
AP18	"	"	1400 "
AP19	"	"	800 "
AP20	"	"	IDLE
AP21	"	E20/0.4ION	2000 rpm
AP22	"	"	1400 "
AP23	"	"	800 "
AP24	"	"	IDLE
	Effect of TEGDN on Start of Injection, Combustion, Max. Pressure and Pressure Rate v rpm		
AP25	DIST 100, E20, E20/2.6TEGDN, E20/5.2TEGDN	Full load	
AP26	"	2/3 load	
AP27	"	1/3 load	
	Effect of ION on Start of Injection, Combustion, Max. Pressure and Pressure Rate v rpm		
AP28	DIST 100, E20, E20/0.2ION, E20/0.4ION	Full load	
AP29	"	2/3 load	
AP30	"	1/3 load	
	Effect of TEGDN on Start of Injection, Combustion, Max. Pressure and Pressure Rate v Torque		
AP31	DIST 100, E20, E20/2.6TEGDN, E20/5.2TEGDN	Full load	
AP32	"	2/3 load	
AP33	"	1/3 load	

FIG	Title		
	Effect of Static Timing on Ignition Delay, Max. Pressure and Pressure Rate v Torque		
AP86	14 deg, 20 deg, 26 deg BTDC	DIST 100	2000 rpm
AP87	"	"	1400 "
AP88	"	"	800 "
AP89	"	E20/3.9TEGDN	2000 rpm
AP90	"	"	1400 "
AP91	"	"	800 "
	Effect of Static Timing on Start of: Injection, Combustion, Max. Pressure and Pressure Rate		
AP92	Full load, 2/3 load, 1/3 load	DIST 100	2000 rpm
AP93	"	"	1400 "
AP94	"	"	800 "
AP95	"	E20/3.9TEGDN	2000 rpm
AP96	"	"	1400 "
AP97	"	"	800 "
	Effect of Static Timing on Injection Pump Delivery, Torque and S.F.C. v rpm		
AP98	14 deg, 20 deg, 26 deg BTDC	DIST 100	Full load
AP99	"	E20/3.9TEGDN	Full load
	Effect of Static Timing on Injection Pump Delivery, Efficiency and S.F.C. v Torque		
AP100	14 deg, 20 deg, 26 deg BTDC	DIST 100	2000 rpm
AP101	"	"	1400 "
AP102	"	"	800 "
AP103	"	E20/3.9TEGDN	2000 rpm
AP104	"	"	1400 "
AP105	"	"	800 "
	Effect of Static Timing on Injection Pump Delivery, Efficiency and S.F.C.		
AP106	2000 rpm, 1400 rpm, 800 rpm	DIST 100	Full load
AP107	"	E20/3.9TEGDN	Full load

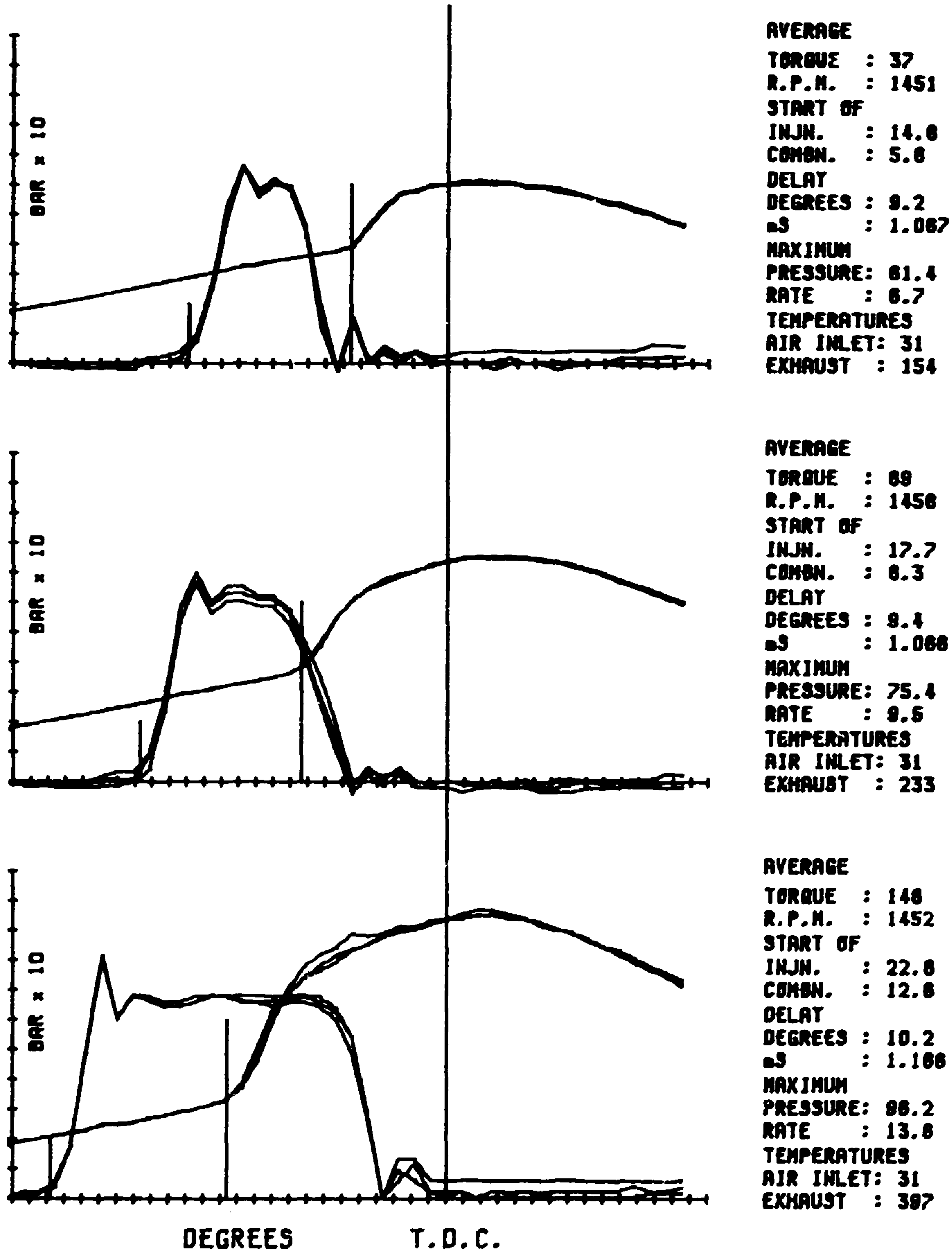
FIG	Title		
	Repeatability of Needle Lift and Cyl. Pressure		
AP108	18 deg BTDC	DIST 100	2000 rpm
AP109	"	"	1400 "
AP110	"	"	800 "
AP111	"	"	IDLE
AP112	"	E25/3.9TEGDN	2000 rpm
AP113	"	"	1400 "
AP114	"	"	800 "
AP115	"	"	IDLE
	Effect of TEGDN on Start of Injection, Combustion, Max. Pressure and Pressure Rate v rpm		
AP116	DIST 100, E25/3.9TEGDN	18 deg	Full load
AP117	"	"	2/3 load
AP118	"	"	1/3 load
	Effect of TEGDN on Ignition Delay, Max. Pressure and Pressure Rate v Torque		
AP119	DIST 100, E25/3.9TEGDN	"	2000 rpm
AP120	"	"	1400 "
AP121	"	"	800 "
	Effect of E25/3.9TEGDN Emulsion on Injection Pump Delivery, Torque and S.F.C.		
AP122	DIST 100, E25/3.9TEGDN	"	Full load
	Effect of E25/3.9TEGDN Emulsion on Injection Pump Delivery, Efficiency and S.F.C. v Torque		
AP123	DIST 100, E25/3.9TEGDN	"	2000 rpm
AP124	"	"	1400 "
AP125	"	"	800 "

8. APPENDICES

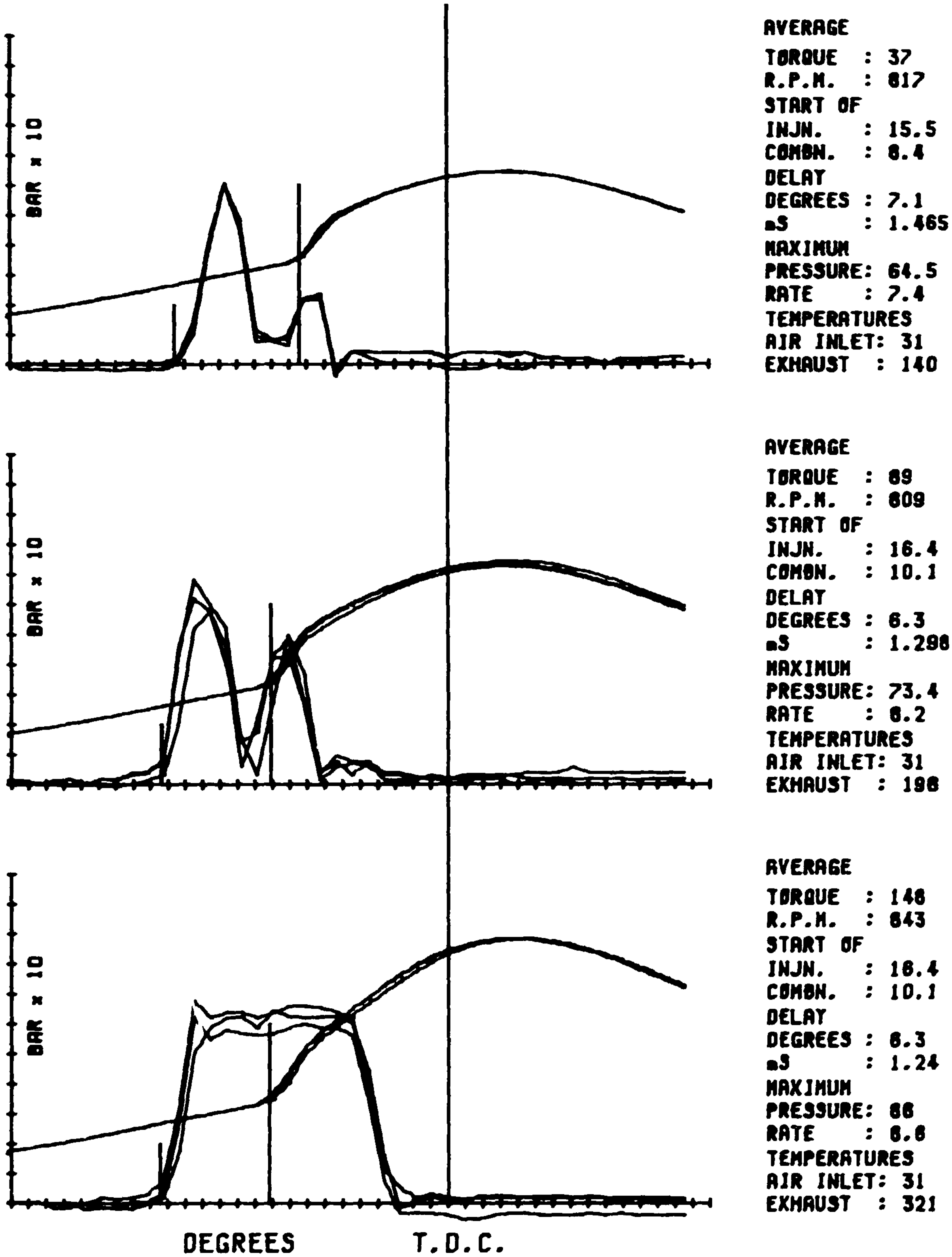
8.1. Engine Results Curves



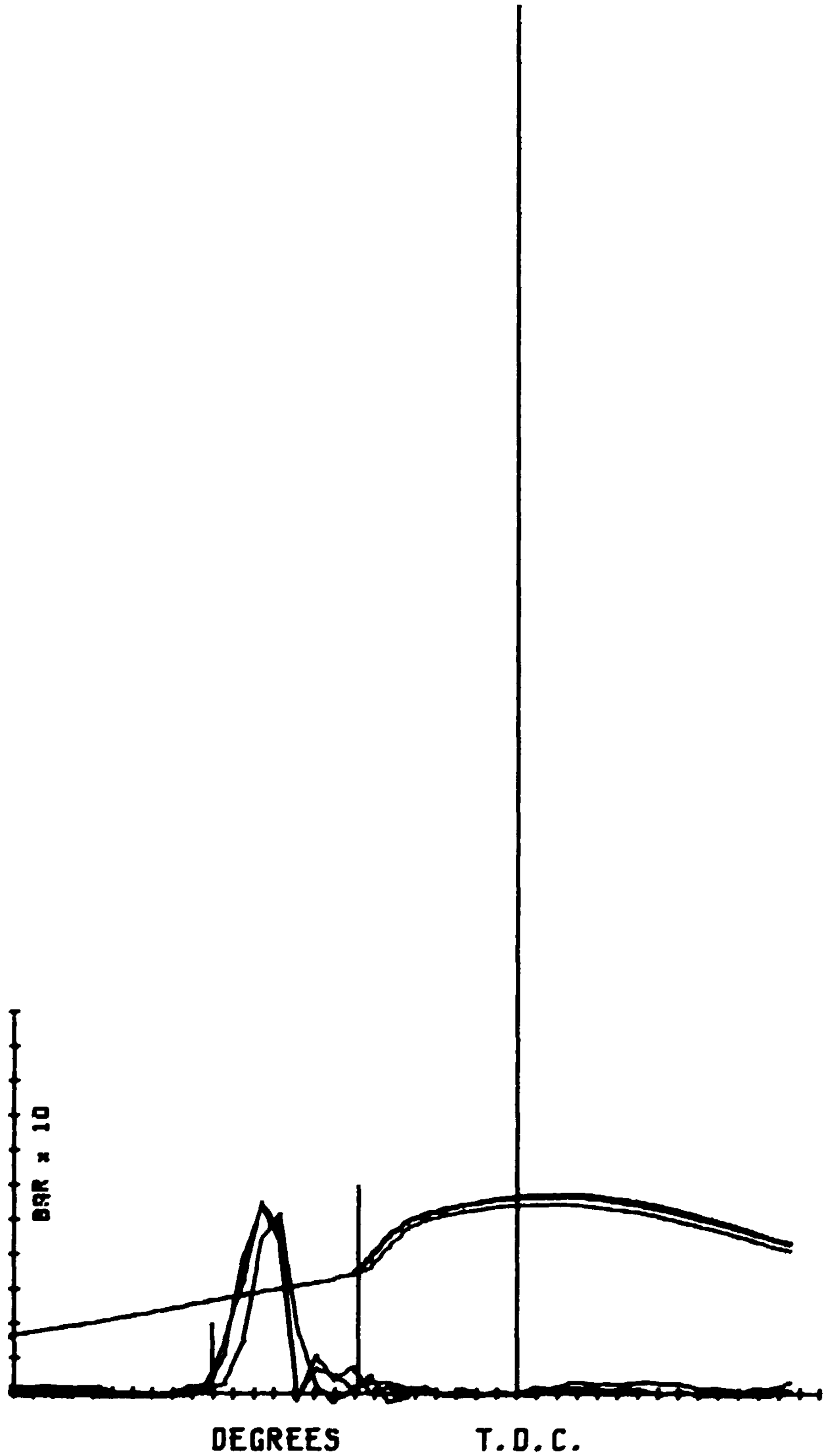
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNIDO-0	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP1



ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNIDO-0	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP2

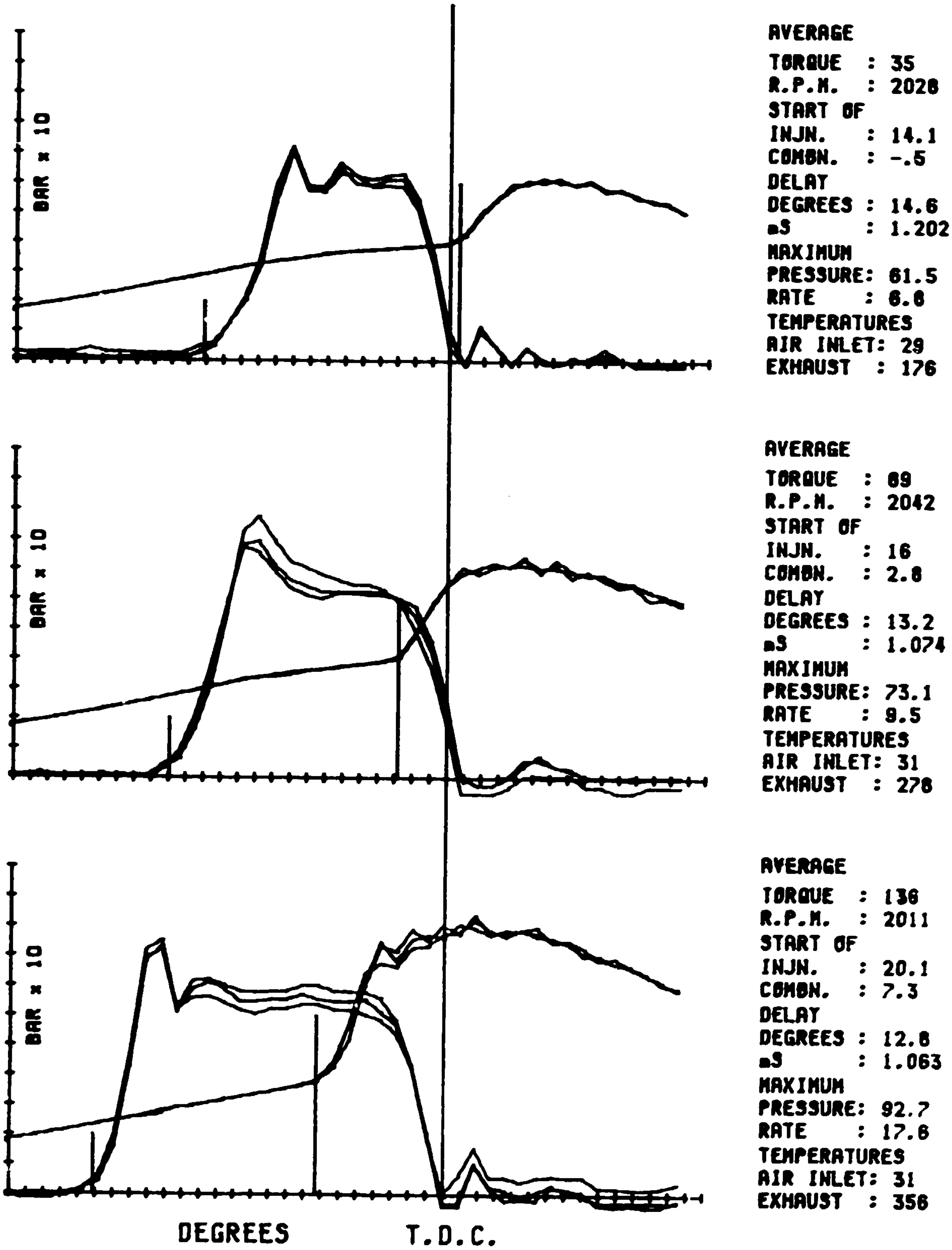


ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNIDO-0	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP3

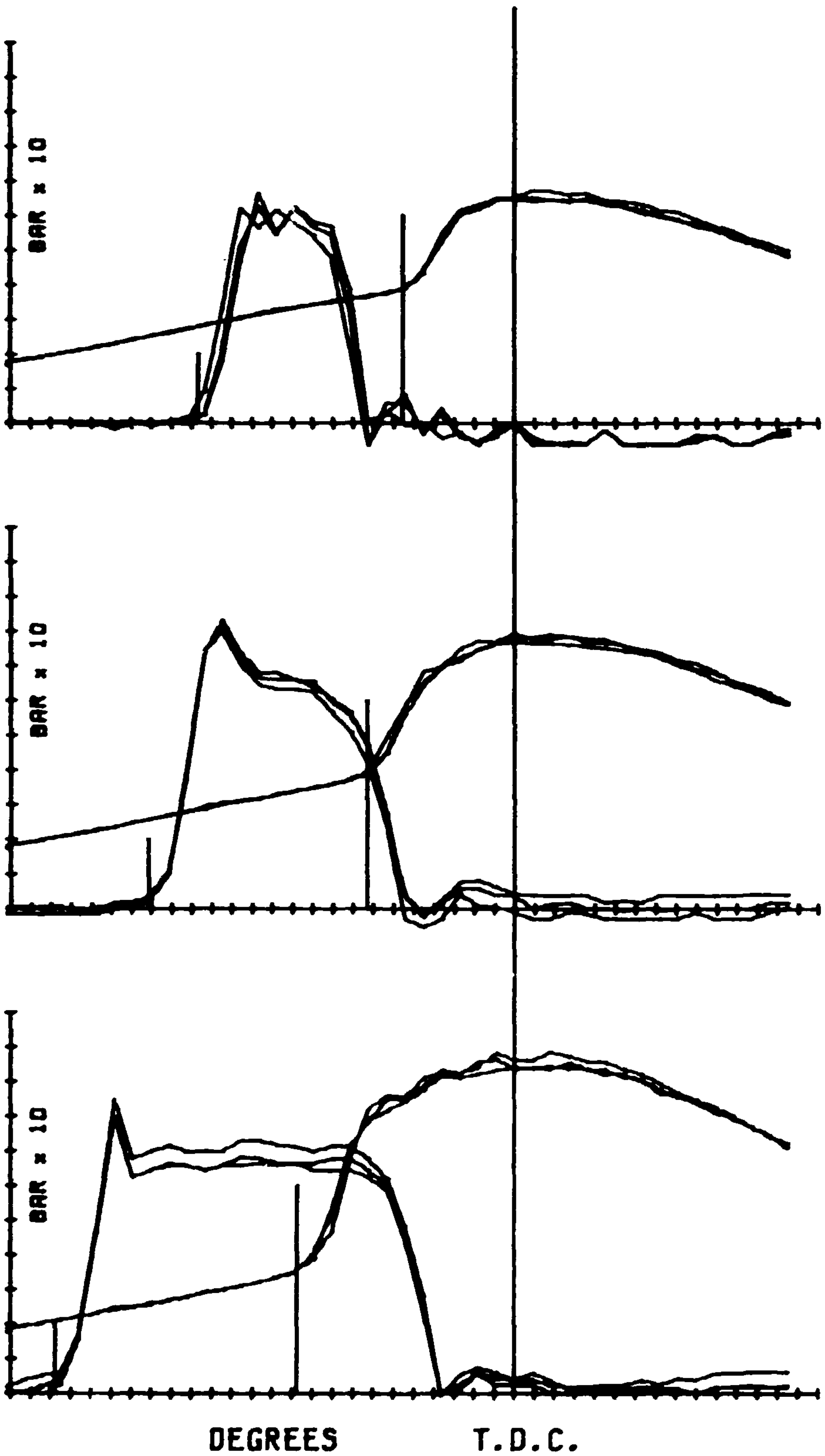


AVERAGE
TORQUE : 3
R.P.M. : 820
START OF
INJN. : 15.1
COMBN. : 7.8
DELAY
DEGREES : 7.3
mS : 1.471
MAXIMUM
PRESSURE: 55.8
RATE : 8.3
TEMPERATURES
AIR INLET: 28
EXHAUST : 84

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNIDO-0	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP4



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20 C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-1	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP5

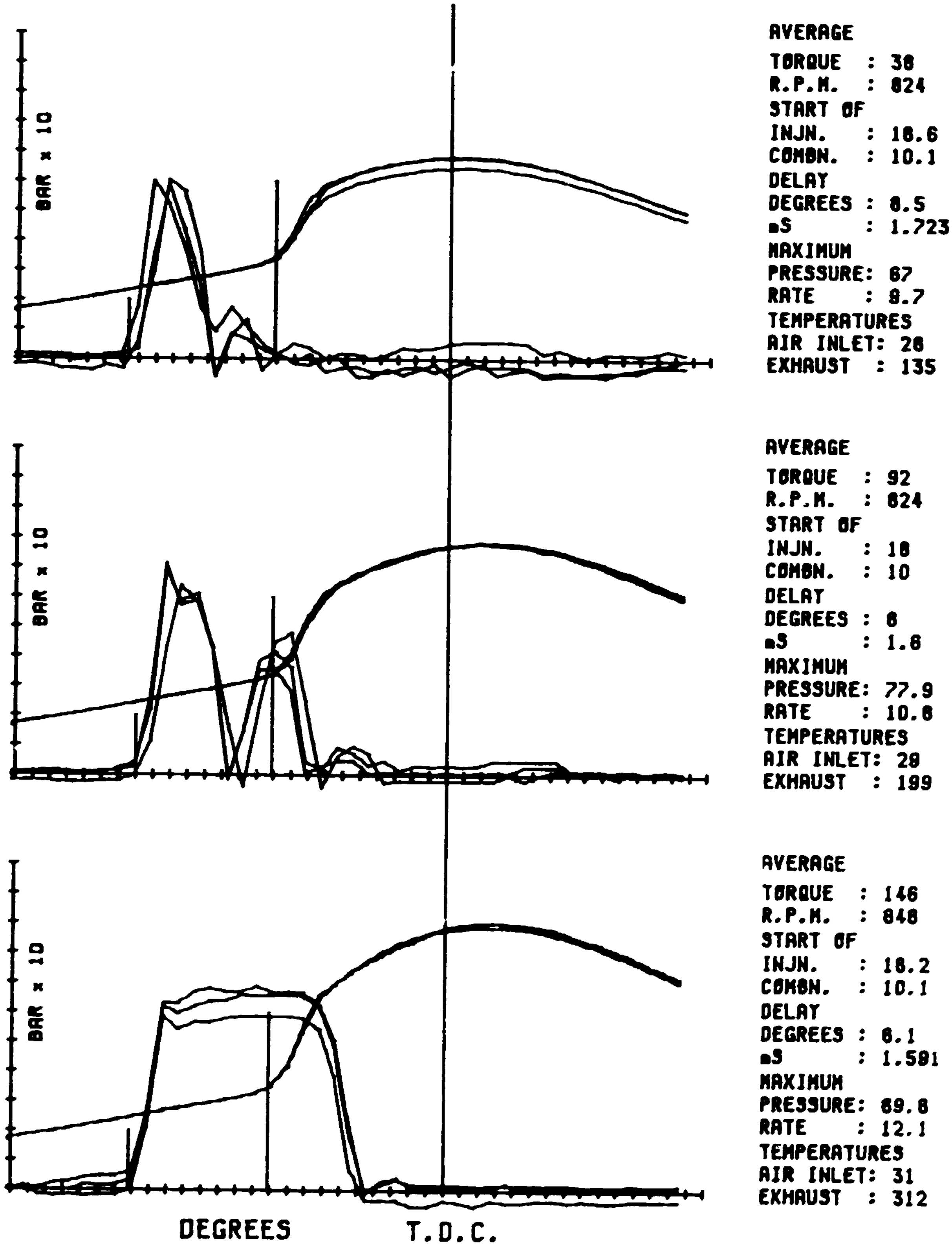


AVERAGE
TORQUE : 39
R.P.M. : 1436
START OF
INJN. : 15.6
COMBN. : 5.5
DELAY
DEGREES : 10.1
mS : 1.178
MAXIMUM
PRESSURE: 65.3
RATE : 9.1
TEMPERATURES
AIR INLET: 29
EXHAUST : 155

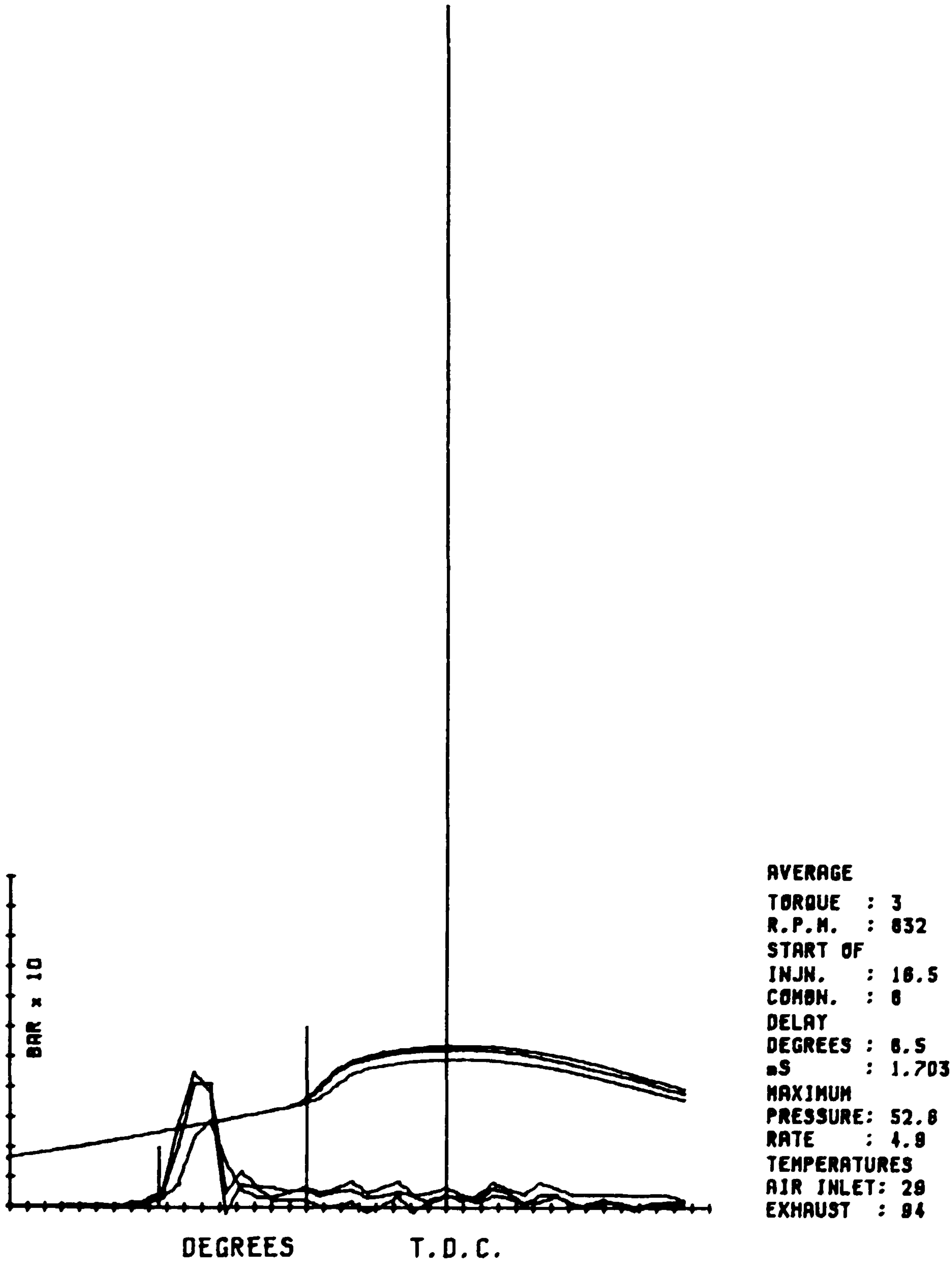
AVERAGE
TORQUE : 89
R.P.M. : 1444
START OF
INJN. : 18.1
COMBN. : 7.3
DELAY
DEGREES : 10.8
mS : 1.25
MAXIMUM
PRESSURE: 78.8
RATE : 12.4
TEMPERATURES
AIR INLET: 32
EXHAUST : 230

AVERAGE
TORQUE : 146
R.P.M. : 1450
START OF
INJN. : 22.8
COMBN. : 10.7
DELAY
DEGREES : 12.1
mS : 1.383
MAXIMUM
PRESSURE: 97.1
RATE : 20
TEMPERATURES
AIR INLET: 30
EXHAUST : 371

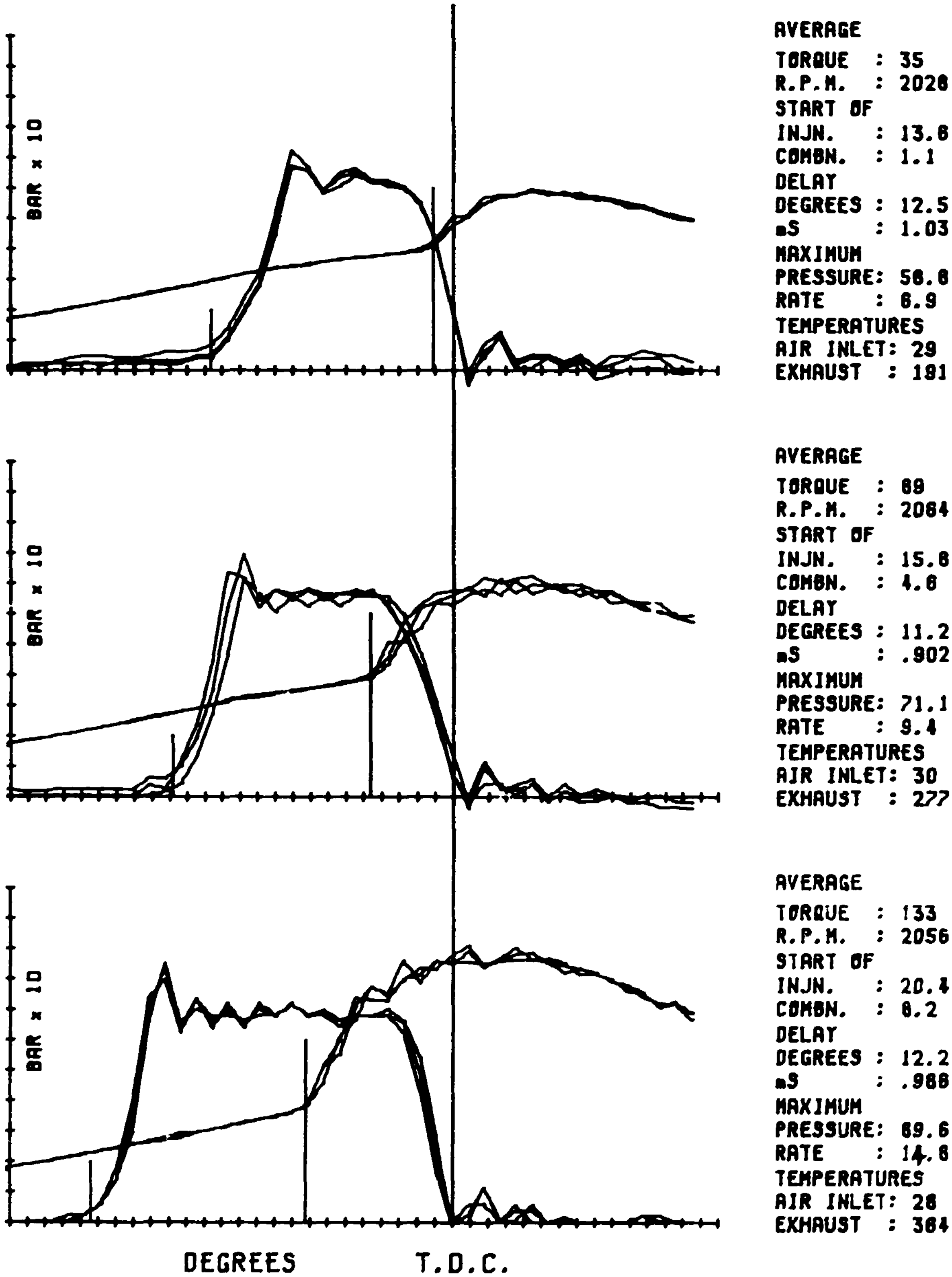
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20 C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-1	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP6



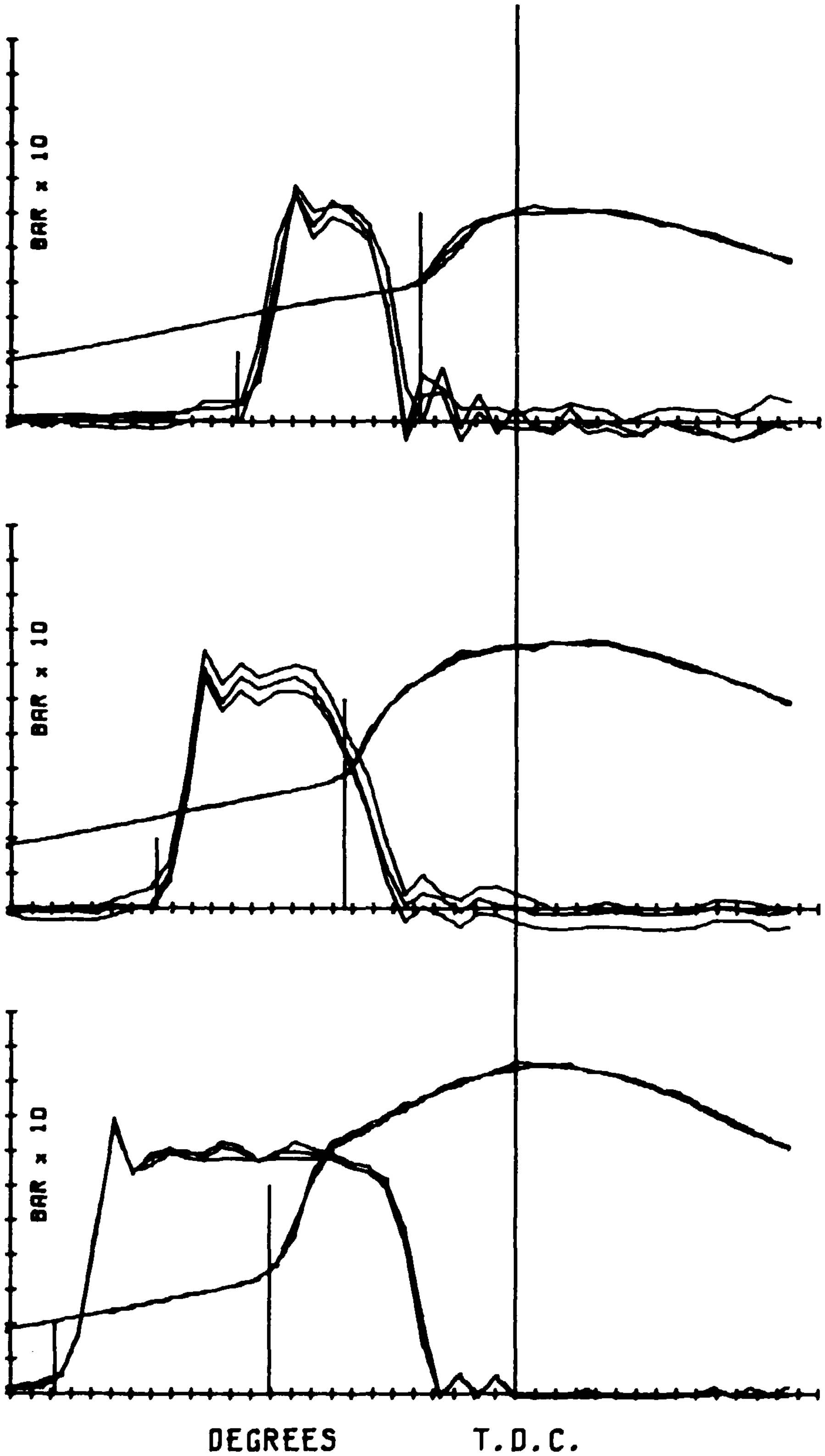
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20 C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-1	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP7



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20 C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-1	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP8



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/2.6TEGDN C.V. : 38.42 DENSITY : .847
TEST ID. : UNIDO-2	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP9

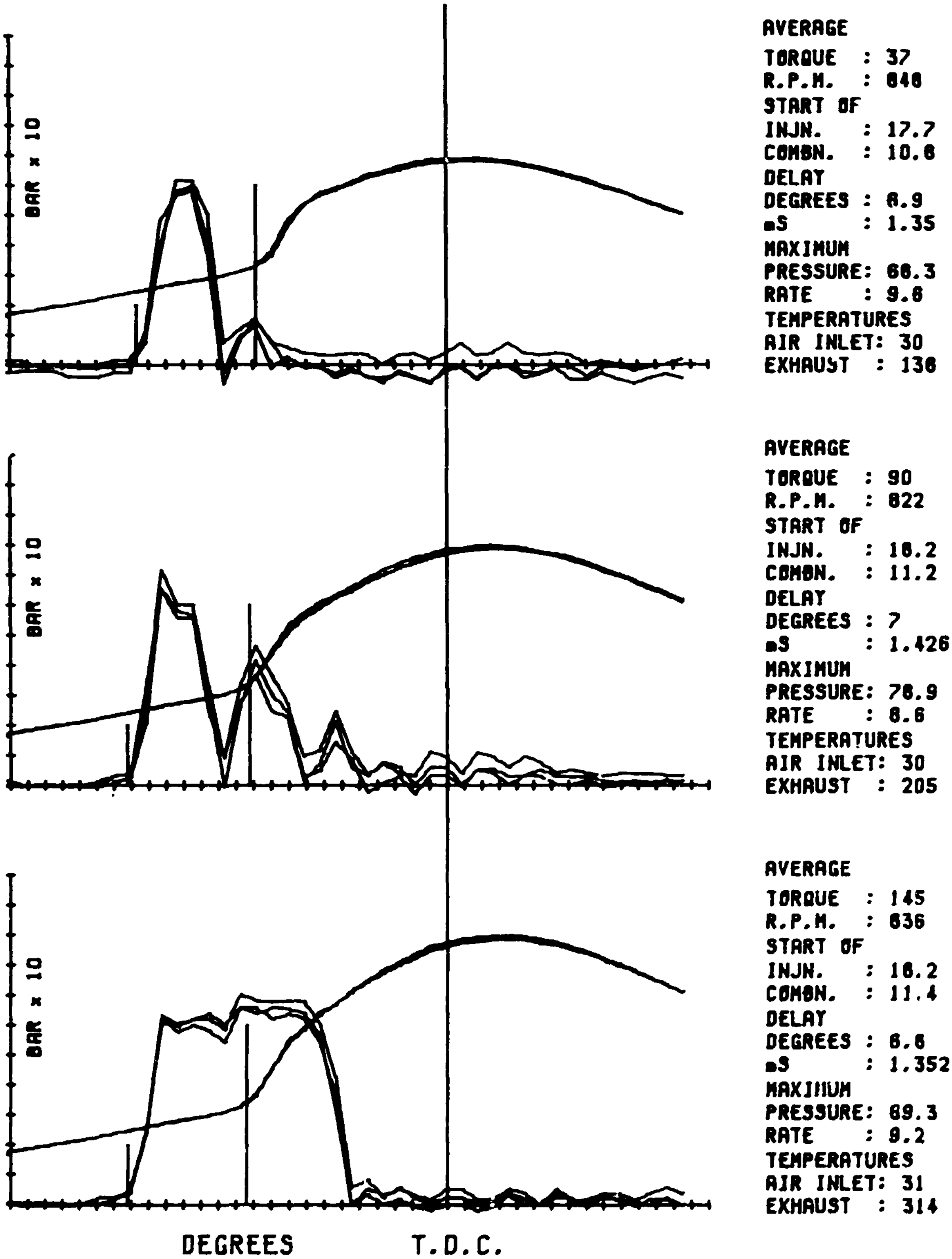


AVERAGE
TORQUE : 35
R.P.M. : 1436
START OF
INJN. : 13.7
COMBN. : 4.7
DELAY
DEGREES : 9
mS : 1.049
MAXIMUM
PRESSURE: 61.1
RATE : 6.6
TEMPERATURES
AIR INLET: 26
EXHAUST : 153

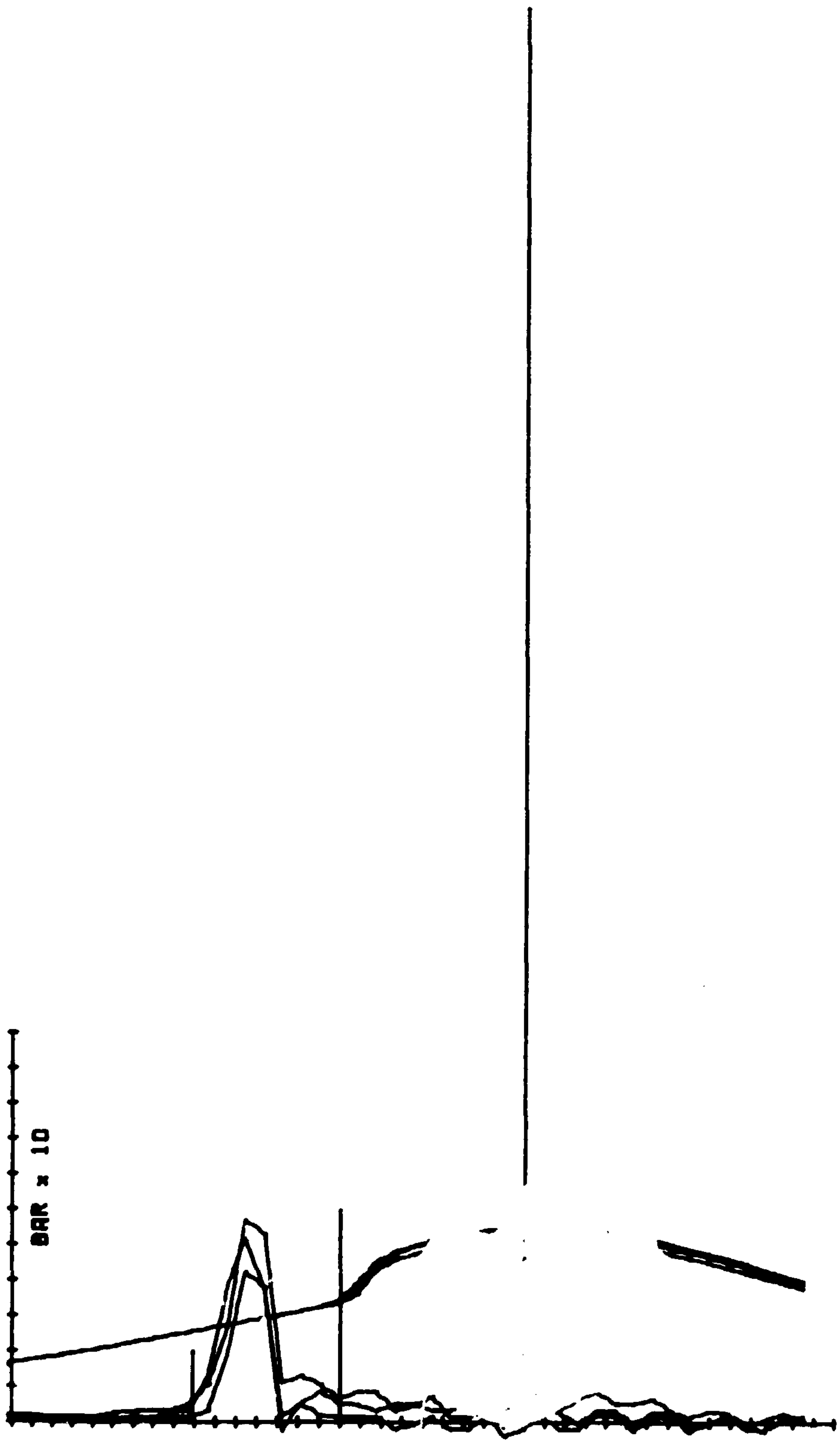
AVERAGE
TORQUE : 66
R.P.M. : 1443
START OF
INJN. : 17.8
COMBN. : 8.4
DELAY
DEGREES : 9.4
mS : 1.084
MAXIMUM
PRESSURE: 77.2
RATE : 10.6
TEMPERATURES
AIR INLET: 30
EXHAUST : 226

AVERAGE
TORQUE : 144
R.P.M. : 1444
START OF
INJN. : 22.8
COMBN. : 12.1
DELAY
DEGREES : 10.7
mS : 1.241
MAXIMUM
PRESSURE: 95.5
RATE : 16
TEMPERATURES
AIR INLET: 29
EXHAUST : 375

ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : E20/2.6TEGDN C.V. : 38.42 DENSITY : .847
TEST ID. : UNIDO-2	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP10

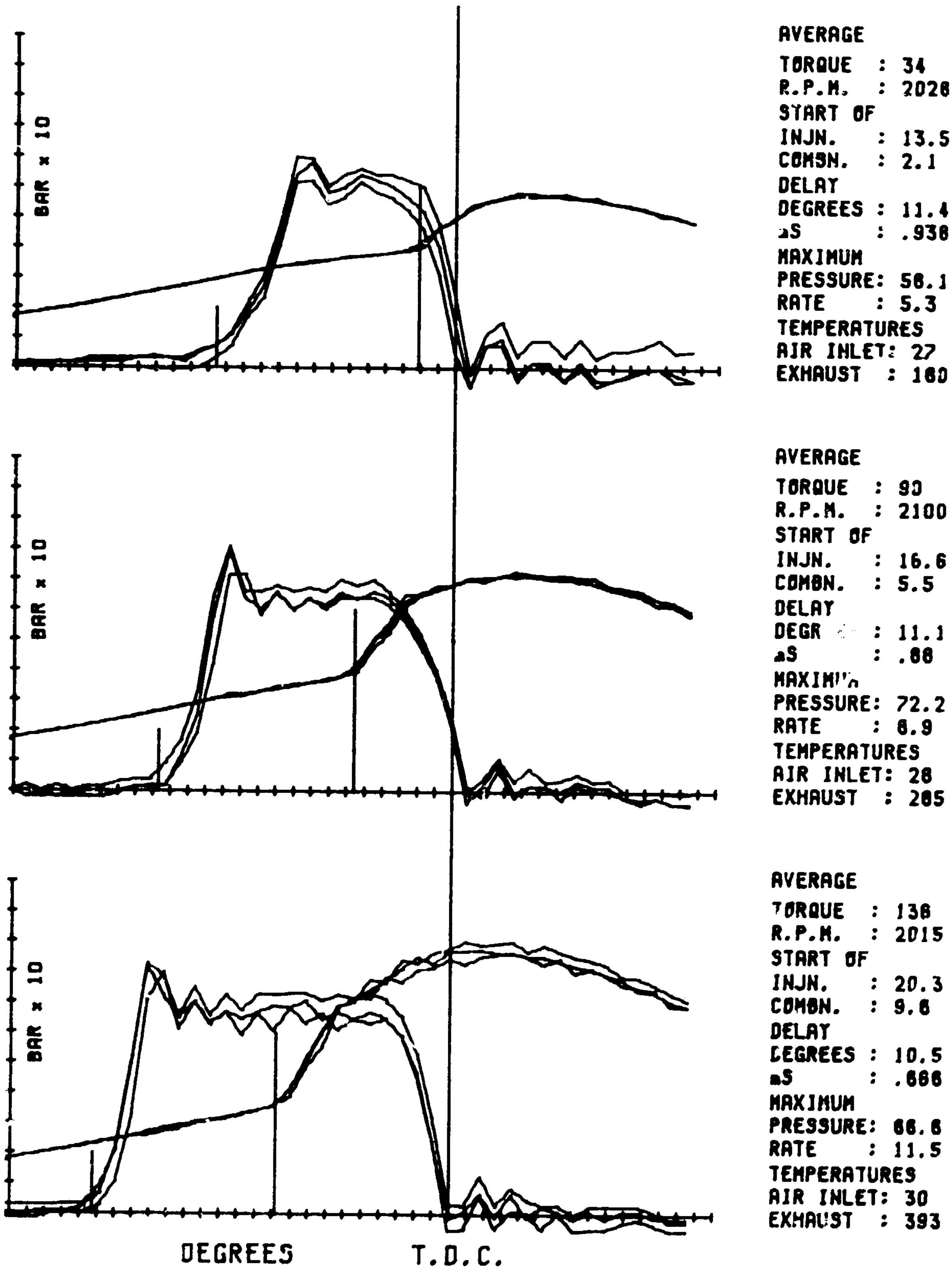


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/2.6TEGDN C.V. : 38.42 DENSITY : .847
TEST ID. : UNIDO-2	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP11

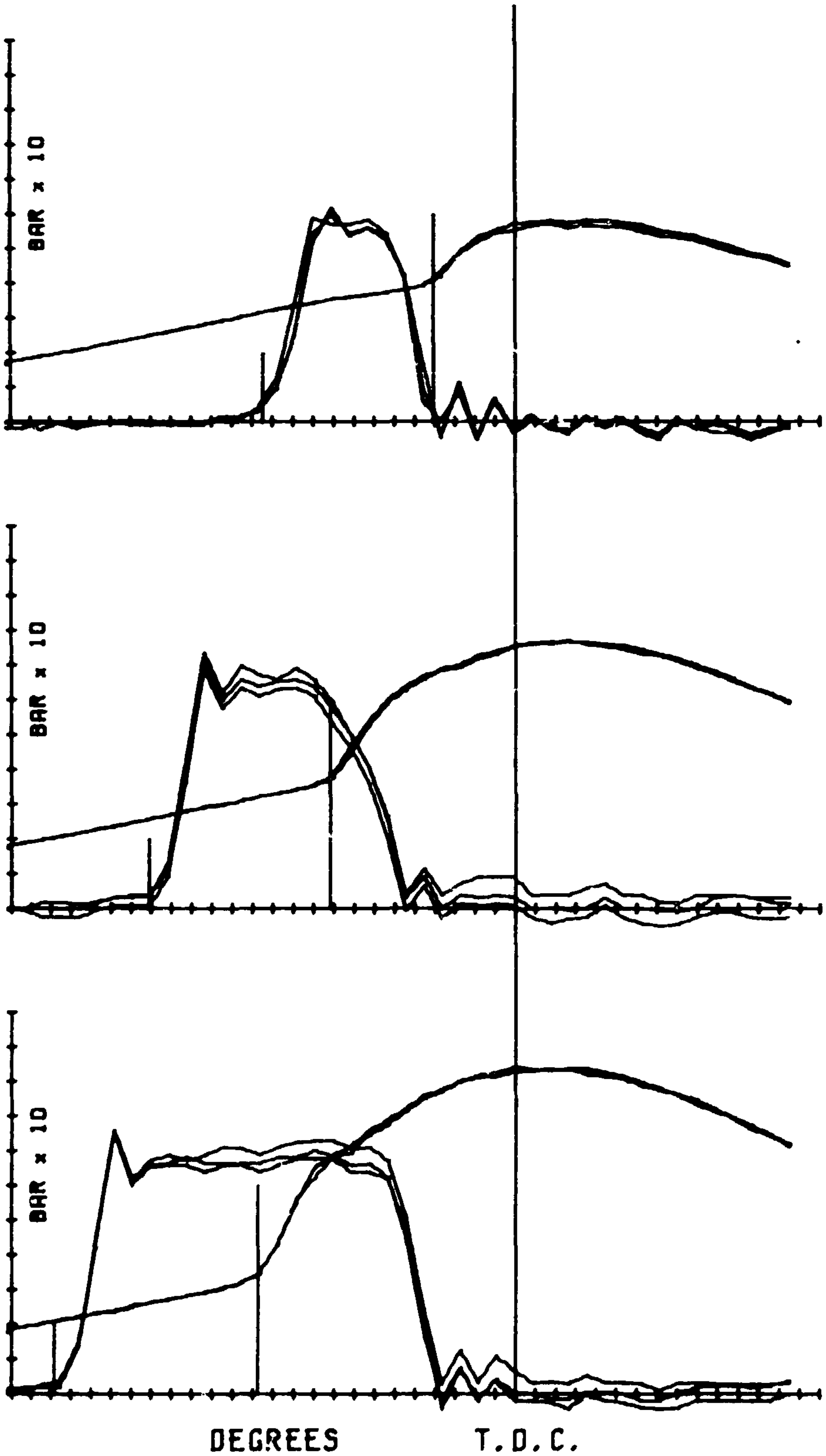


AVERAGE
TORQUE : 3
R.P.M. : 829
START OF
INJN. : 16.1
COMBN. : 9
DELAY
DEGREES : 7.1
mS : 1.424
MAXIMUM
PRESSURE: 54.4
RATE : 6.1
TEMPERATURES
AIR INLET: 28
EXHAUST : 100

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/2.6TEGDN C.V. : 38.42 DENSITY : .847
TEST ID. : UNIDO-2	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP12



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/5.2TEGDN C.V. : 38.29 DENSITY : .849
TEST ID. : UNIDO-4	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP13

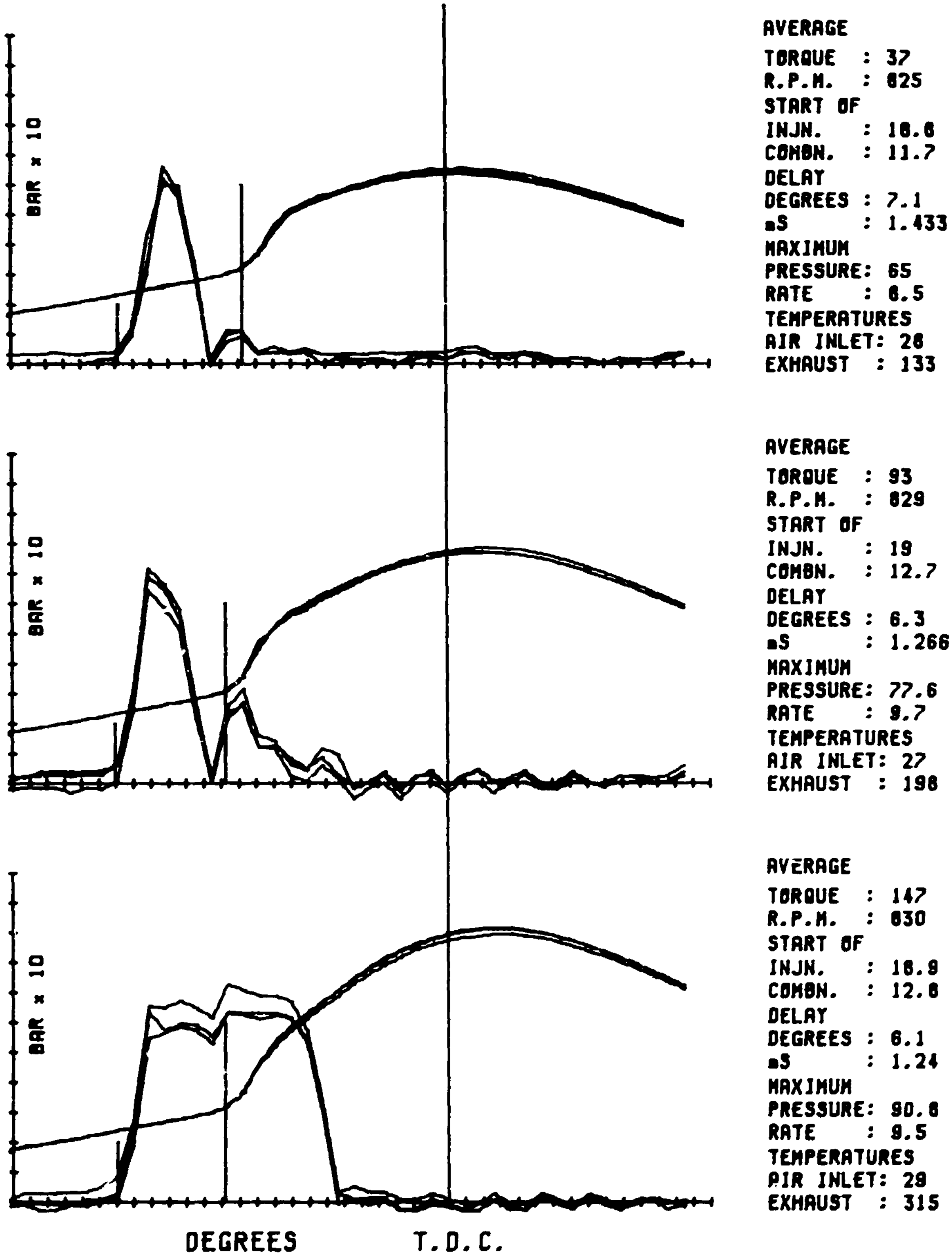


AVERAGE
TORQUE : 35
R.P.M. : 1438
START OF
INJN. : 12.4
COMBN. : 4
DELAY
DEGREES : 8.4
mS : .97
MAXIMUM
PRESSURE: 58.1
RATE : 5.7
TEMPERATURES
AIR INLET: 29
EXHAUST : 152

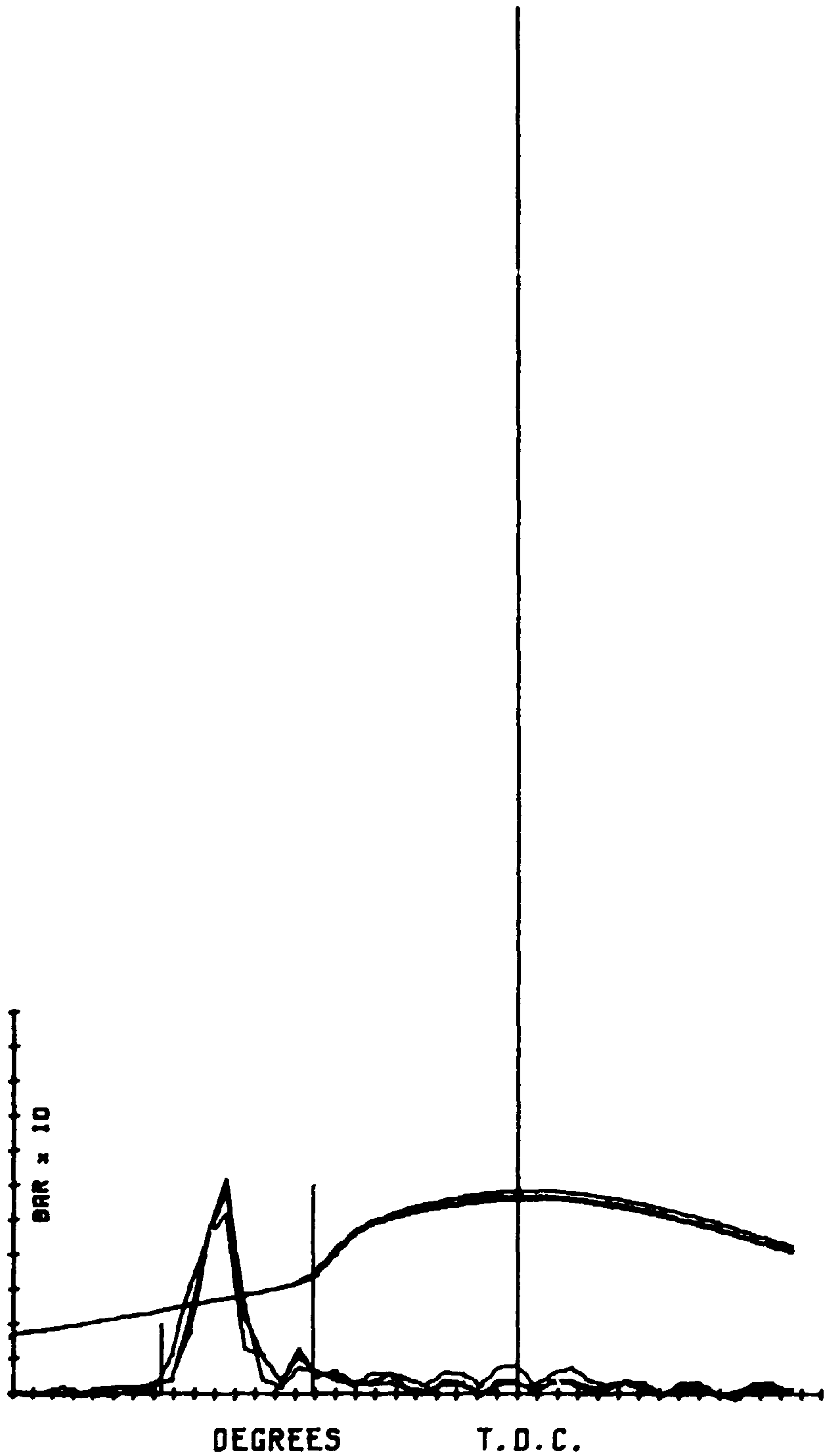
AVERAGE
TORQUE : 89
R.P.M. : 1443
START OF
INJN. : 18.1
COMBN. : 9.2
DELAY
DEGREES : 8.9
mS : 1.032
MAXIMUM
PRESSURE: 77.3
RATE : 8.8
TEMPERATURES
AIR INLET: 29
EXHAUST : 231

AVERAGE
TORQUE : 146
R.P.M. : 1437
START OF
INJN. : 22.8
COMBN. : 12.7
DELAY
DEGREES : 10.1
mS : 1.169
MAXIMUM
PRESSURE: 94.4
RATE : 12.3
TEMPERATURES
AIR INLET: 31
EXHAUST : 377

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/5.2TEGDN C.V. : 38.29 DENSITY : .849
TEST ID. : UNIDO-4	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP14

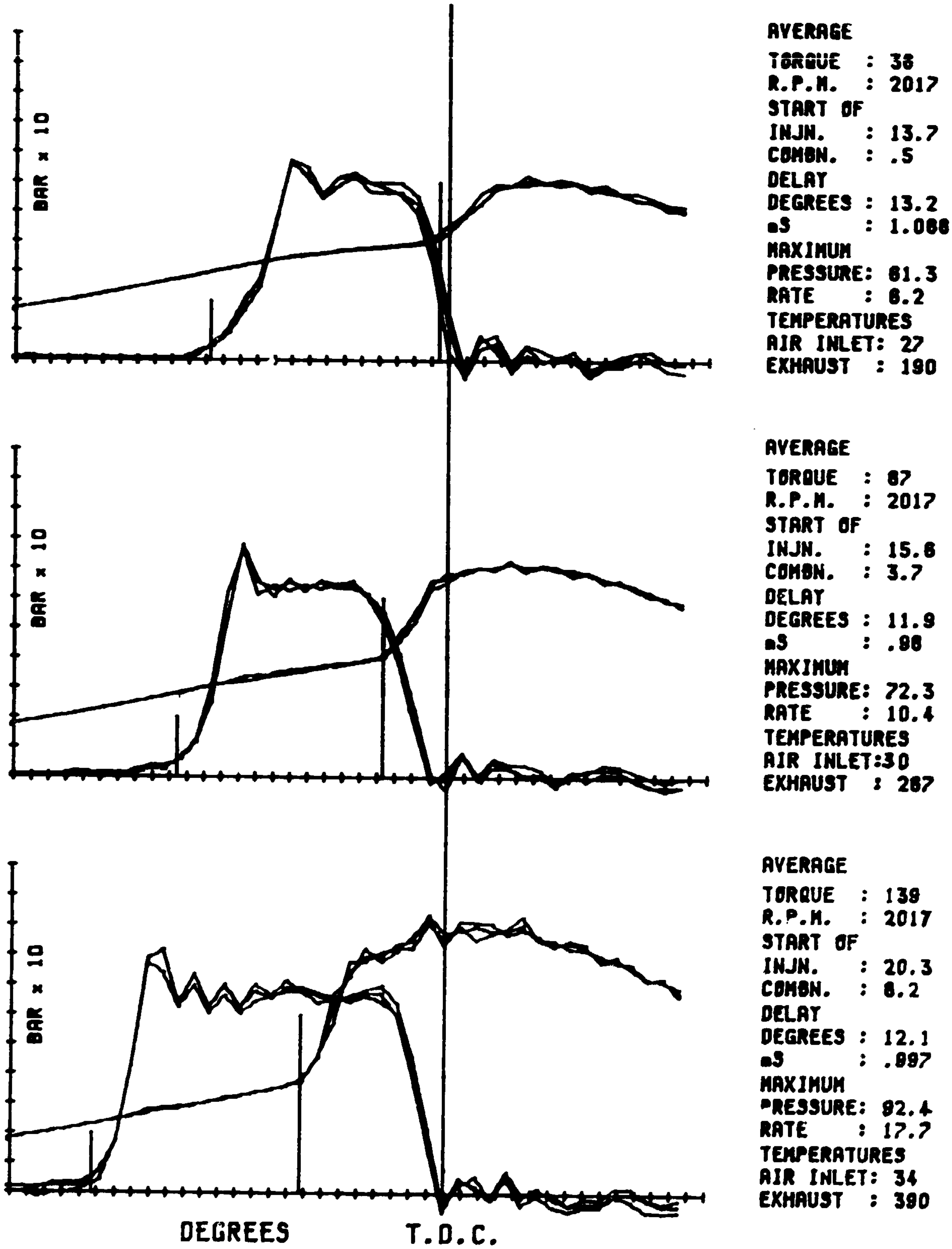


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/5.2TEGDN C.V. : 38.29 DENSITY : .849
TEST ID. : UNIDO-4	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP15

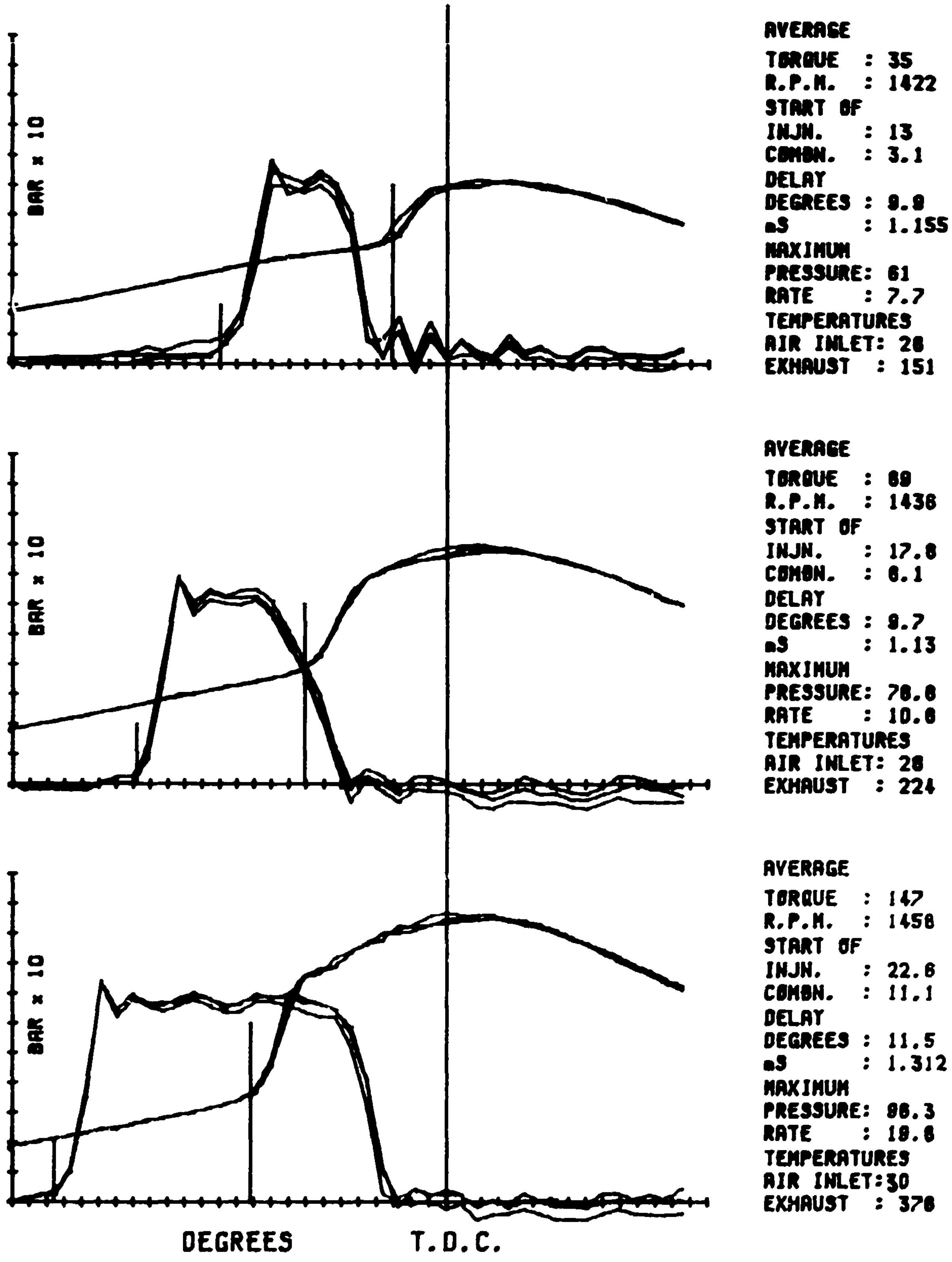


AVERAGE
TORQUE : 3
R.P.M. : 627
START OF
INJN. : 17.7
COMBN. : 10.1
DELAY
DEGREES : 7.6
mS : 1.52
MAXIMUM
PRESSURE: 56.5
RATE : 5.7
TEMPERATURES
AIR INLET: 26
EXHAUST : 97

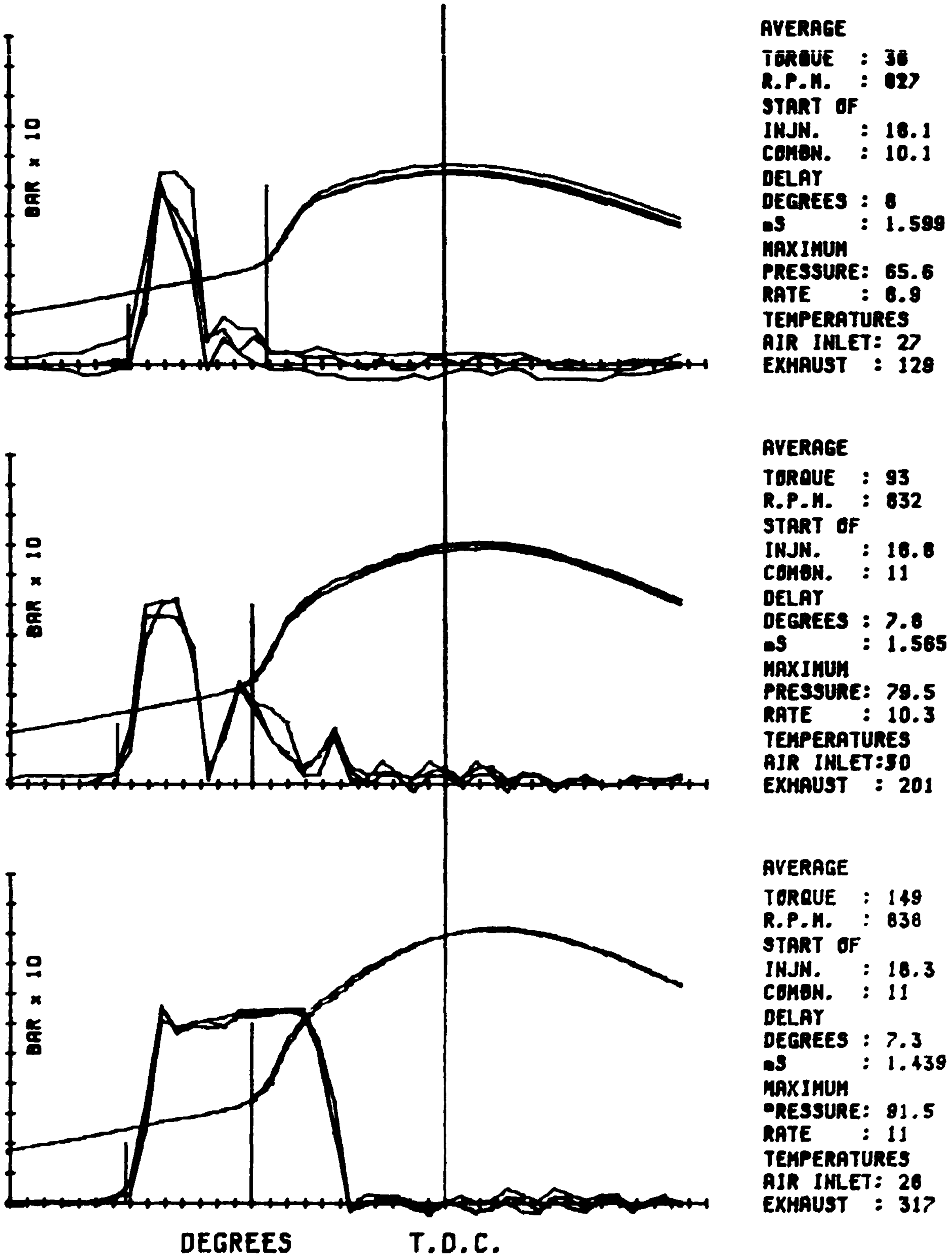
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/5.2TEGDN C.V. : 38.29 DENSITY : .848
TEST ID. : UNIDO-4	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP16



ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : E20/.210N C.V. : 36 DENSITY : .846
TEST ID. : UNIDO-5	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP17



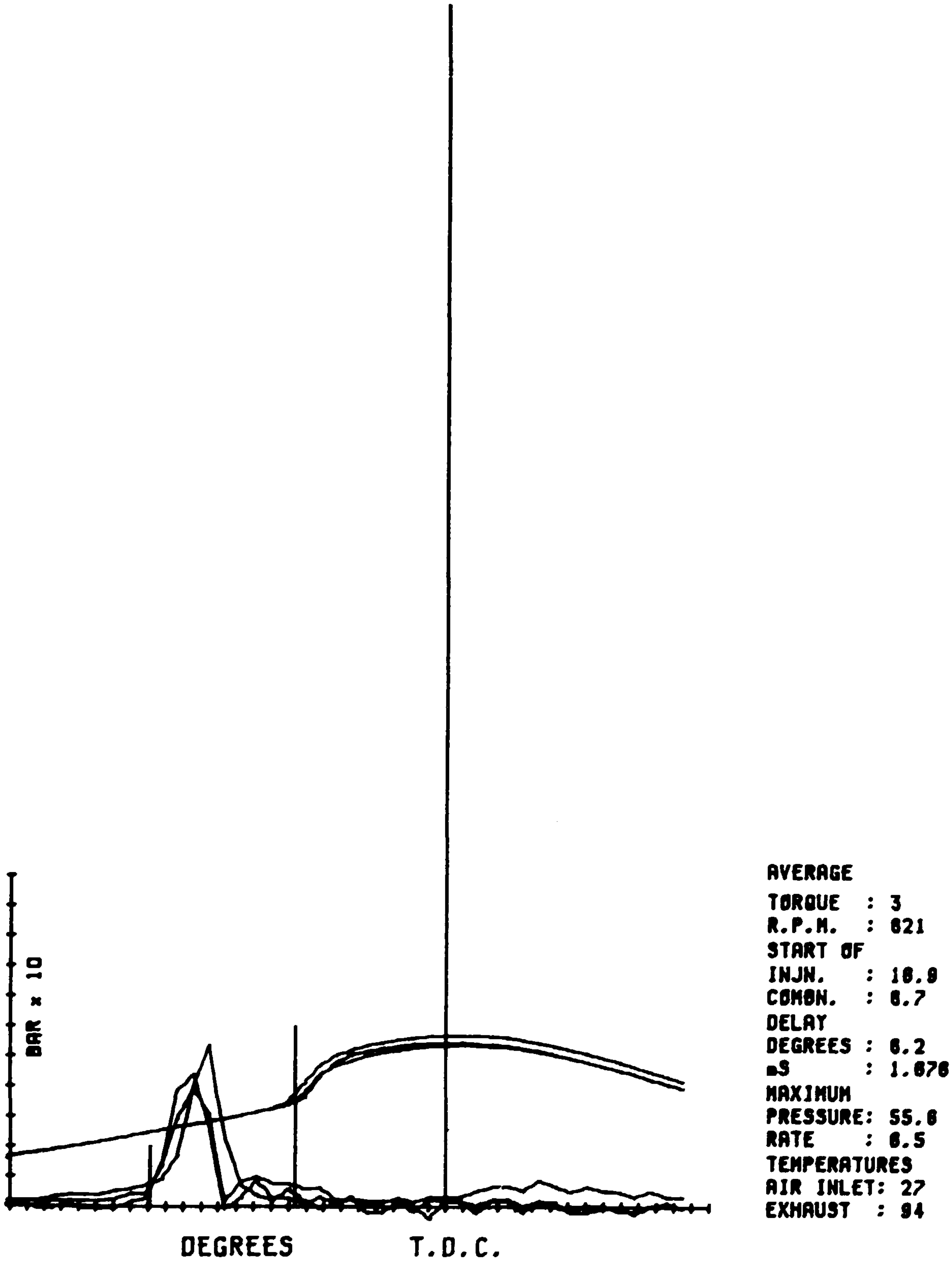
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : E20/.2ION C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-5	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP18



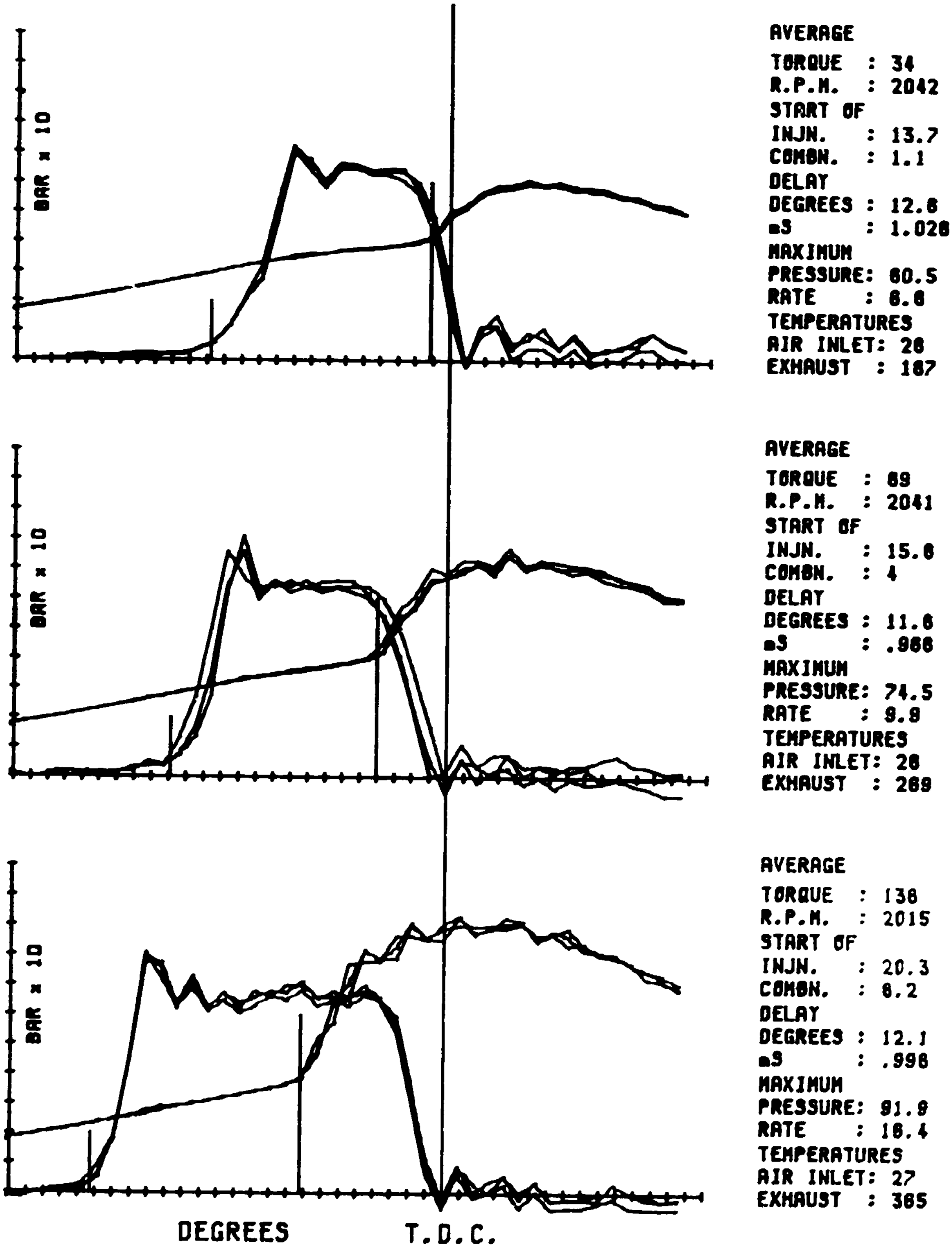
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : E20/.2ION C.V. : 38 DENSITY : .846
TEST ID. : UNIDA-5	

REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE

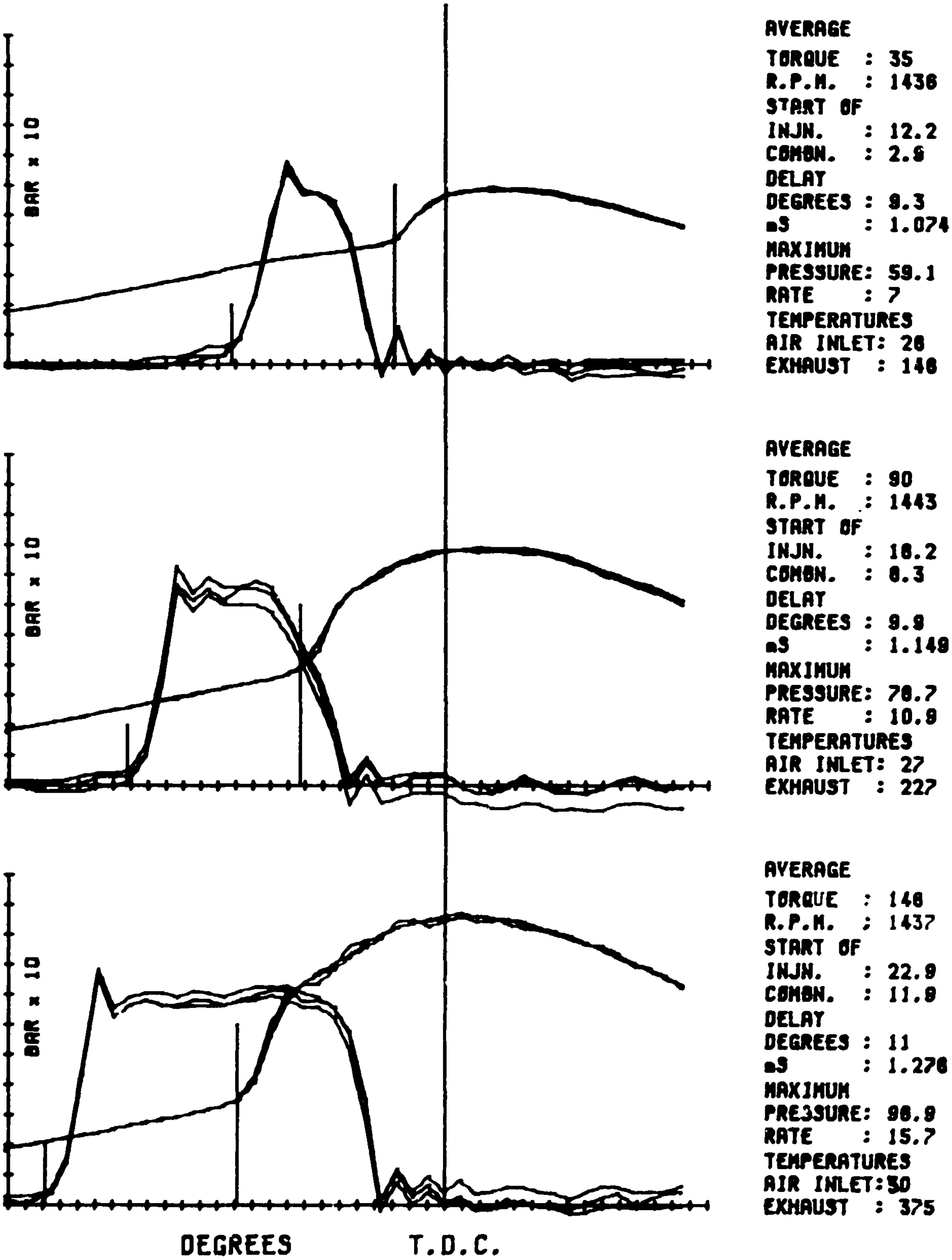
FIG AP19



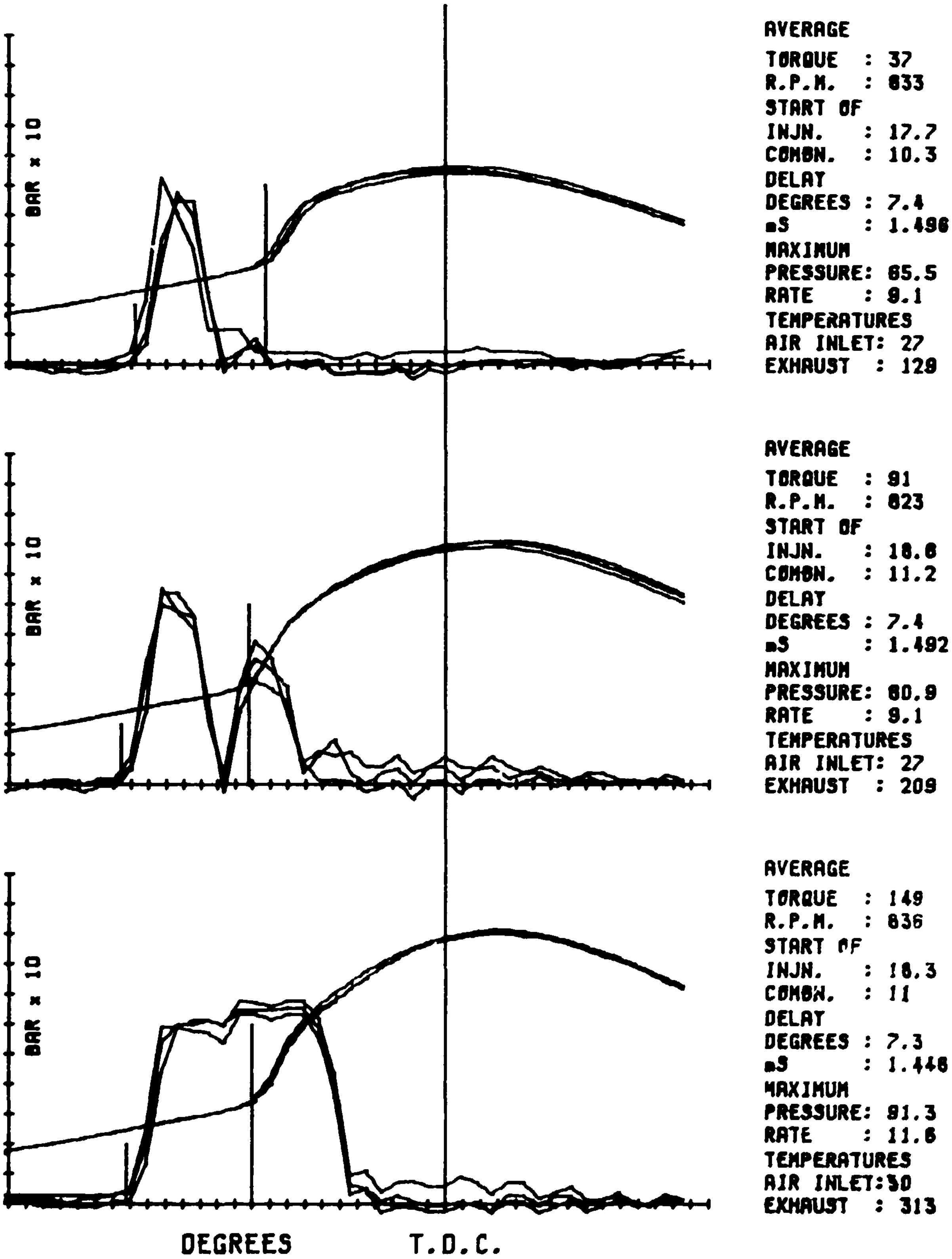
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/.210N C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-5	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP20



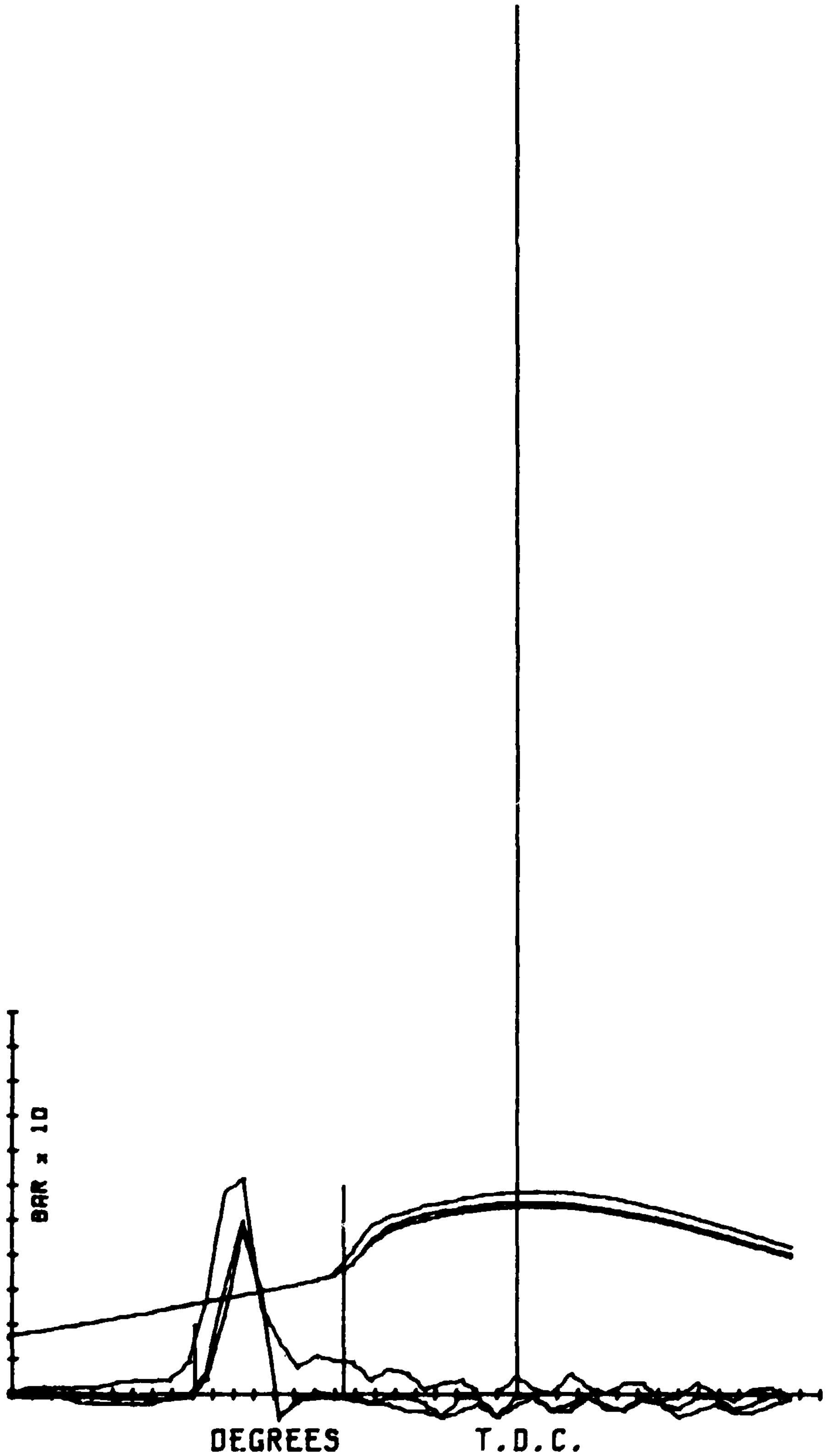
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/.4ION C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-6	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP21



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/.4ION C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-6	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP22

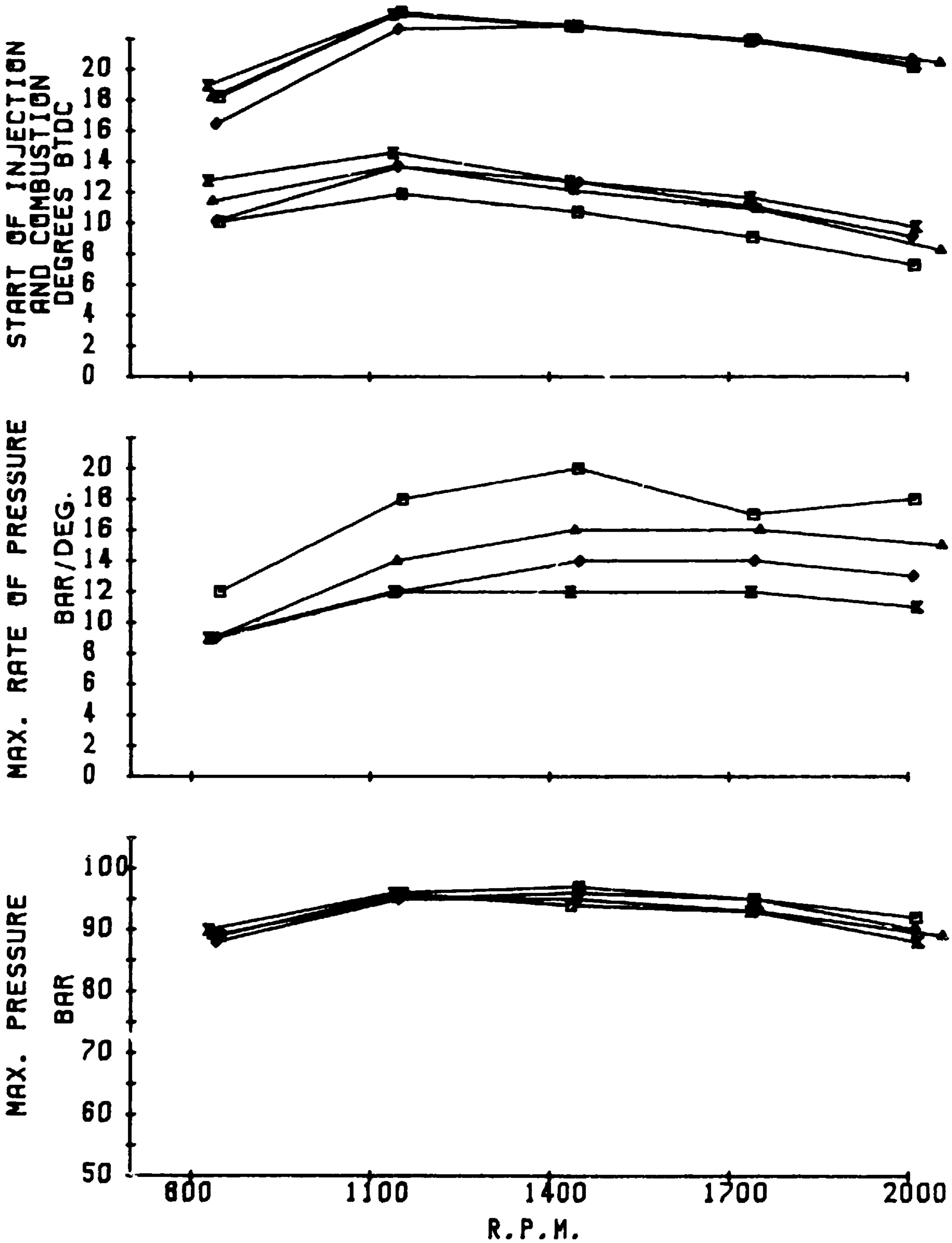


ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : E20/.4ION C.V. : 36 DENSITY : .646
TEST ID. : UNIDO-6	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP23

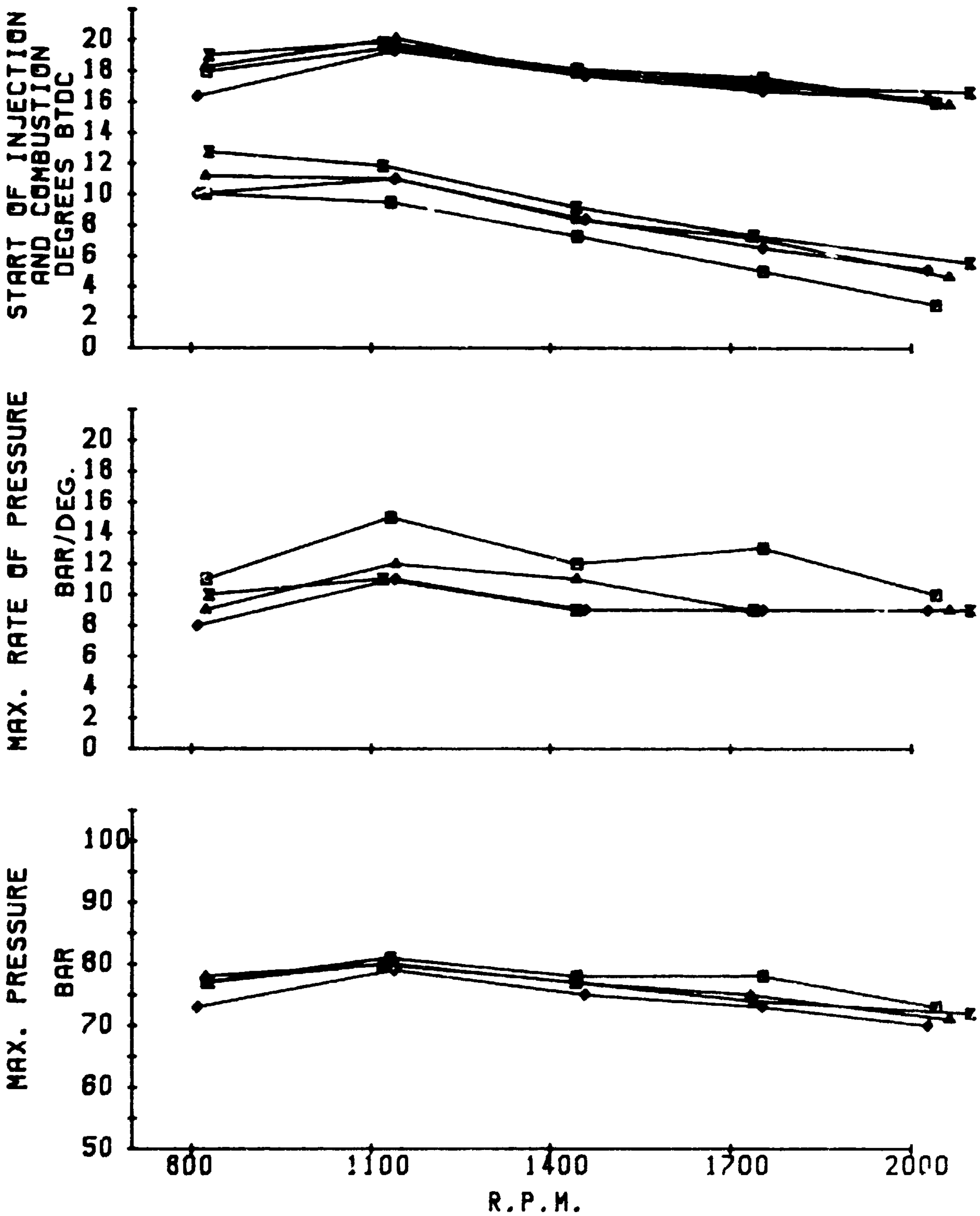


AVERAGE
TORQUE : 3
R.P.M. : 822
START OF
INJN. : 15.8
COMBN. : 8.5
DELAY
DEGREES : 7.4
mS : 1.495
MAXIMUM
PRESSURE: 55.2
RATE : 8.2
TEMPERATURES
AIR INLET: 28
EXHAUST : 82

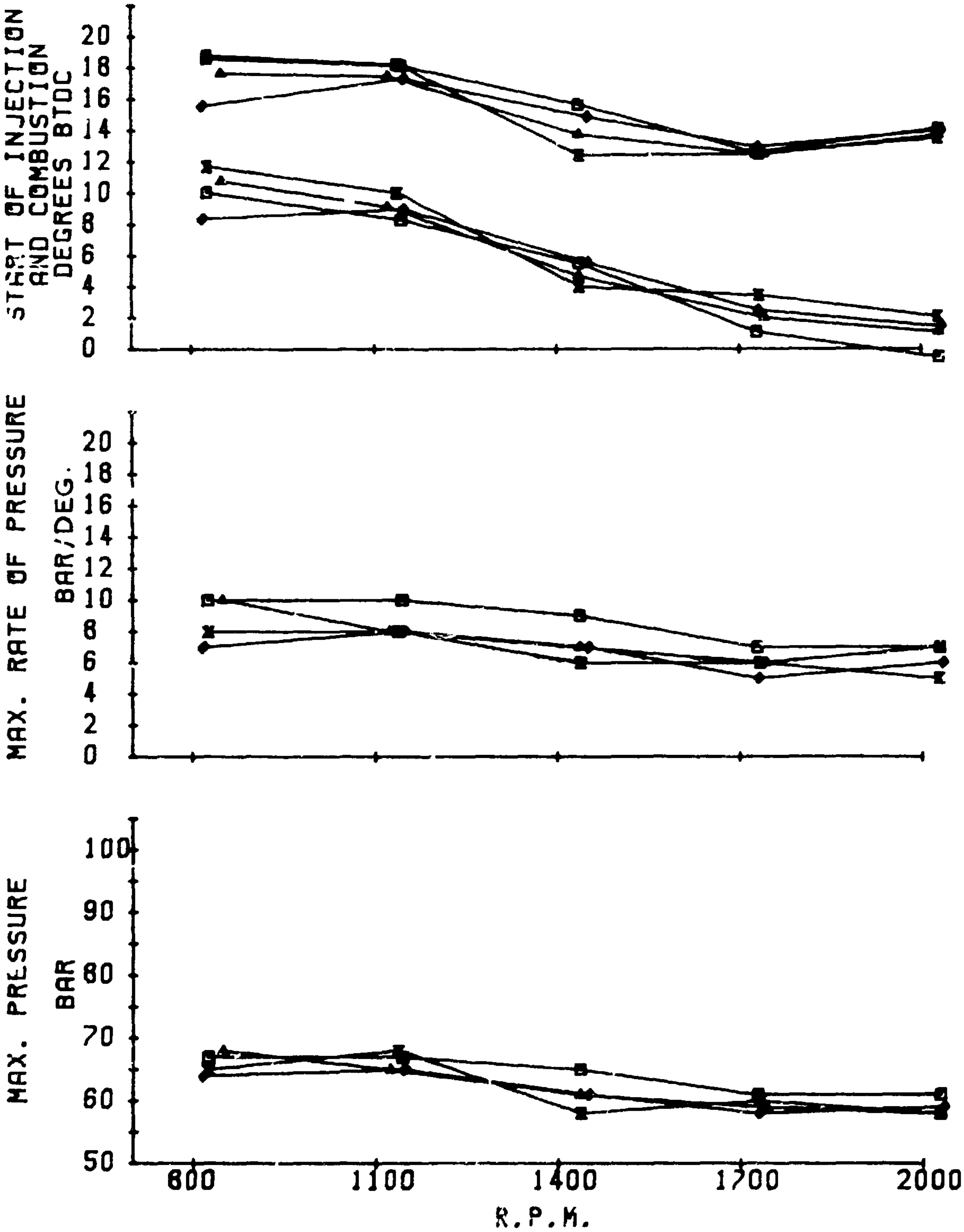
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E20/.4ION C.V. : 38 DENSITY : .846
TEST ID. : UNIDO-6	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AF24



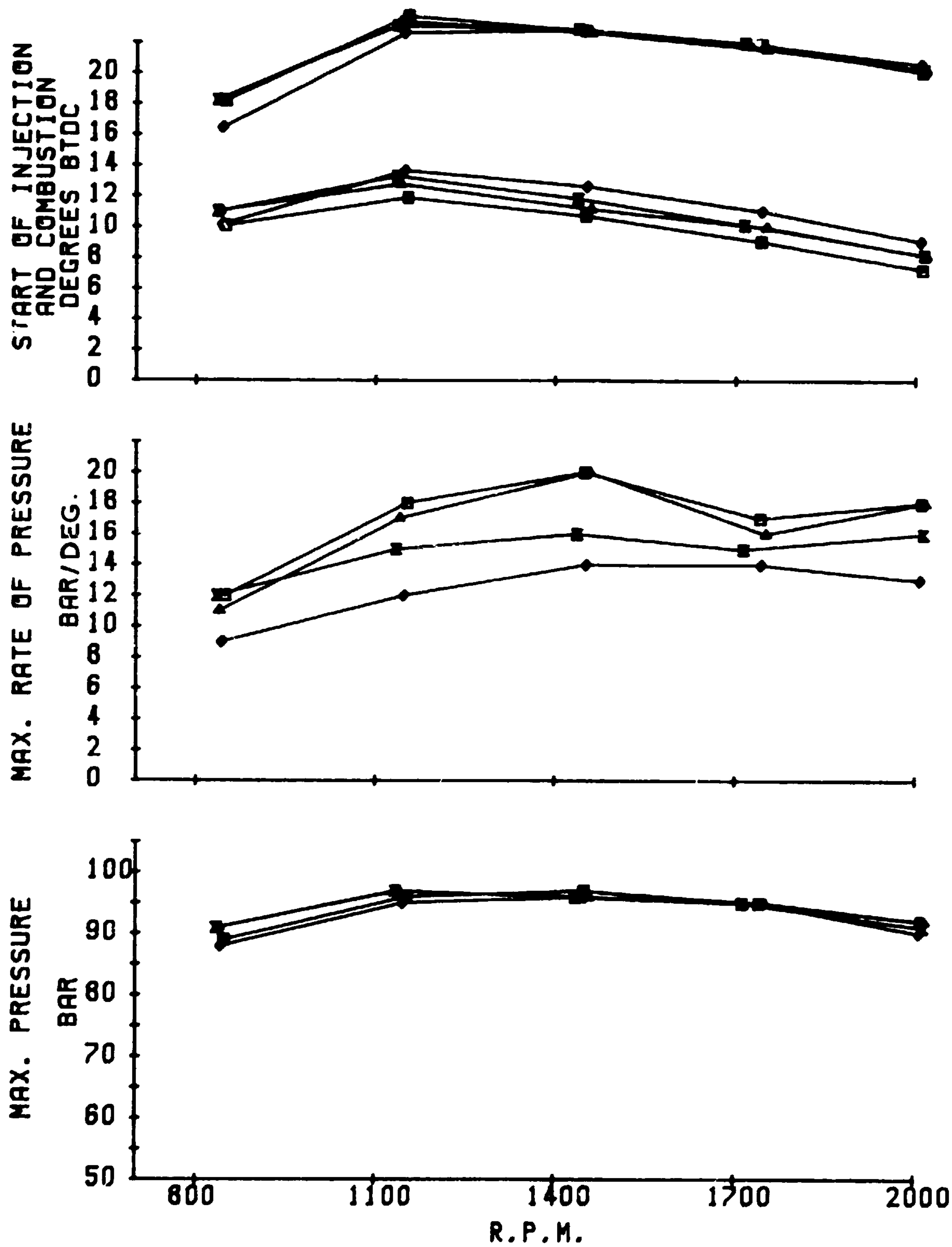
ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/2.6TEGDN ⧗ E20/5.2TEGDN FULL LOAD
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP25



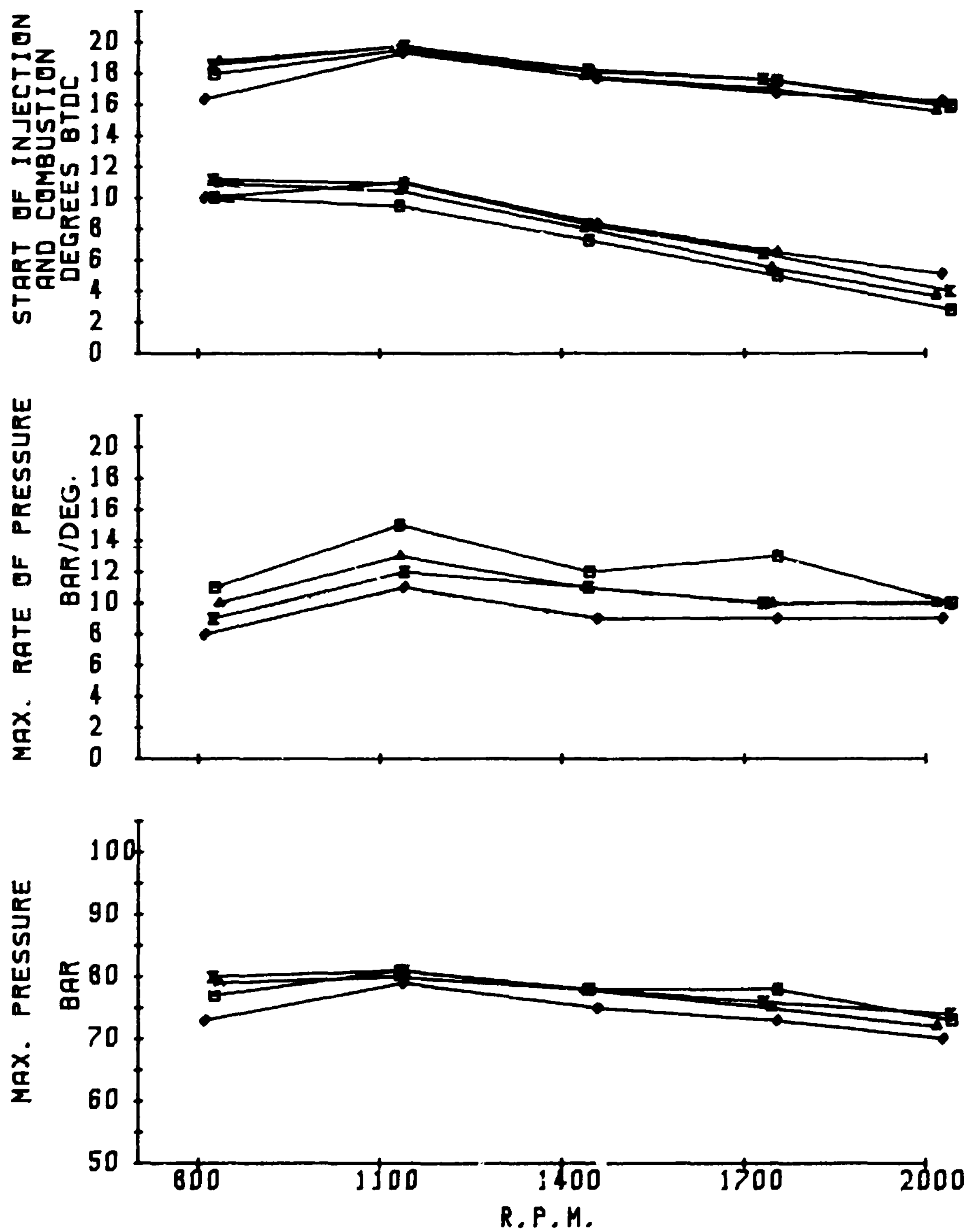
ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/2.6TEGDN ⧗ E20/5.2TEGDN 2/3 LOAD
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP26



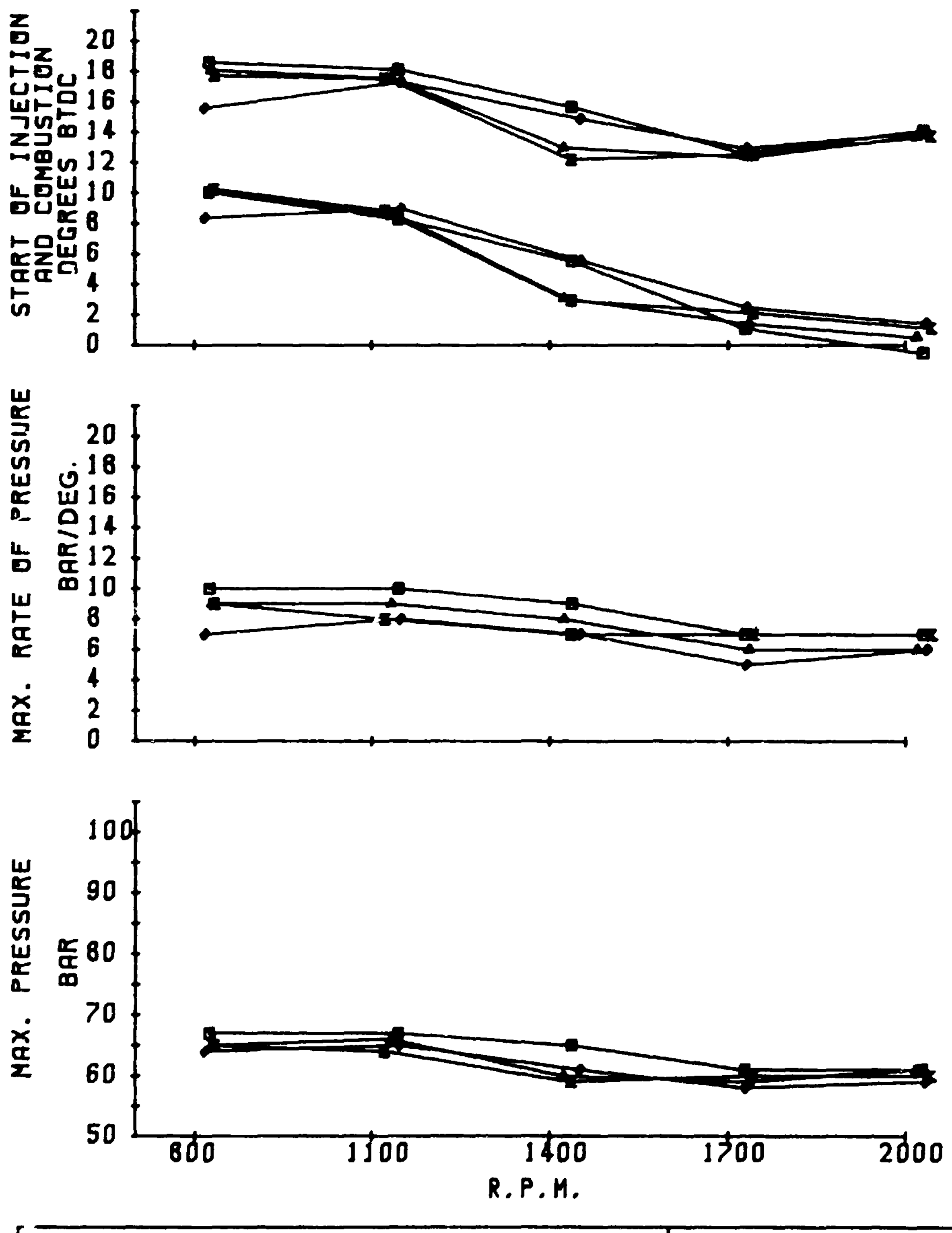
ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ▫ E20 ▲ E20/2.6TEGDN ⵅ E20/5.2TEGDN 1/3 LOAD
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP27



EN' : FORD 3000 CAP..CITY: 2860	◆ DIST 100 ■ E20 ▲ E20/.2ION ⧗ E20/.4ION FULL LOAD
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP28



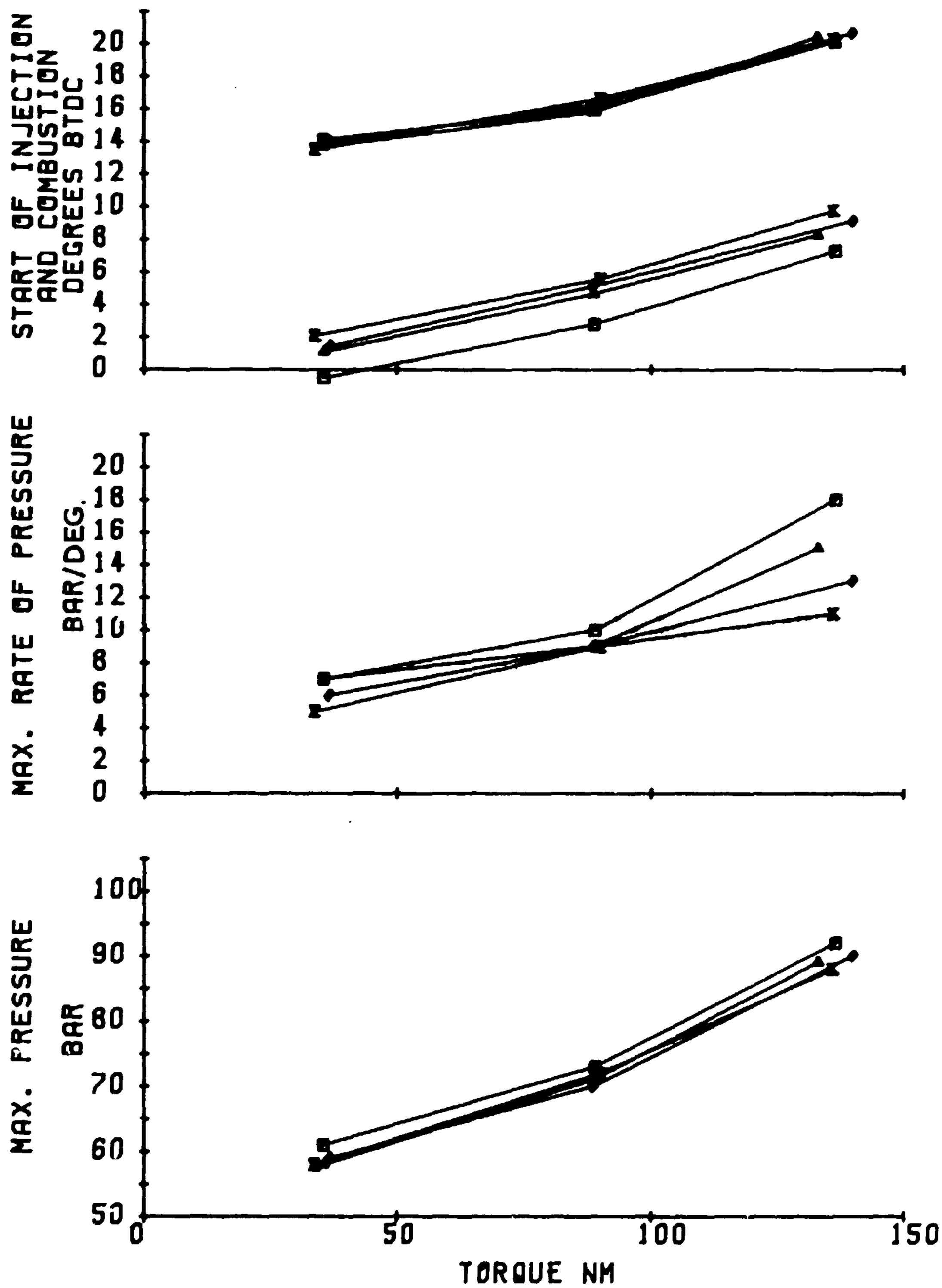
ENGINE : FORD 3000 CAPACITY: 2860	♦ DIST 100 ▪ E20 ▲ E20/.2ION ✕ E20/.4ION 2/3 LOAD
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP29



ENGINE : FORD 3000
CAPACITY: 2860

EFFECT OF ION ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

FIG AP30

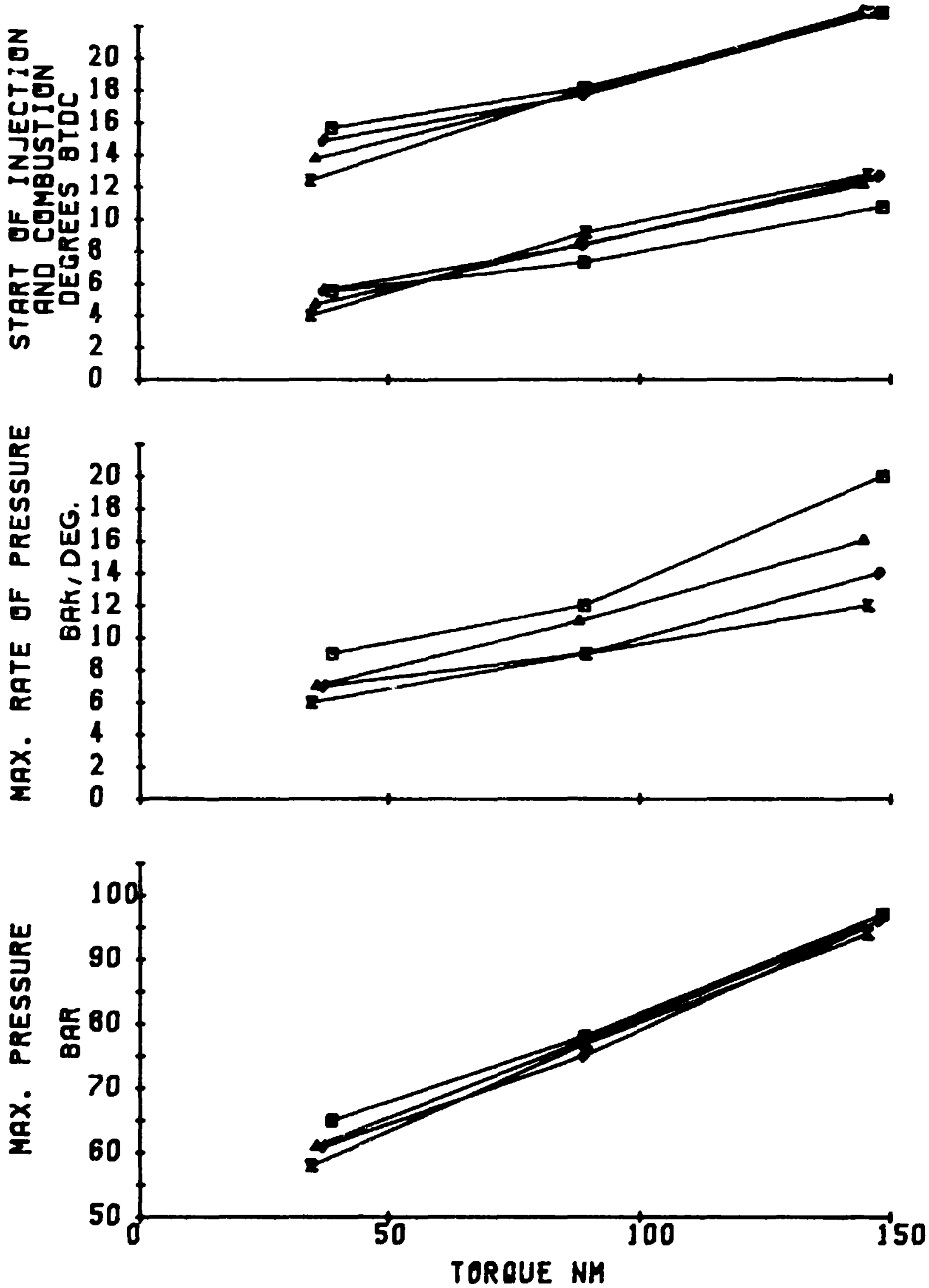


ENGINE : FORD 3000
CAPACITY: 2860

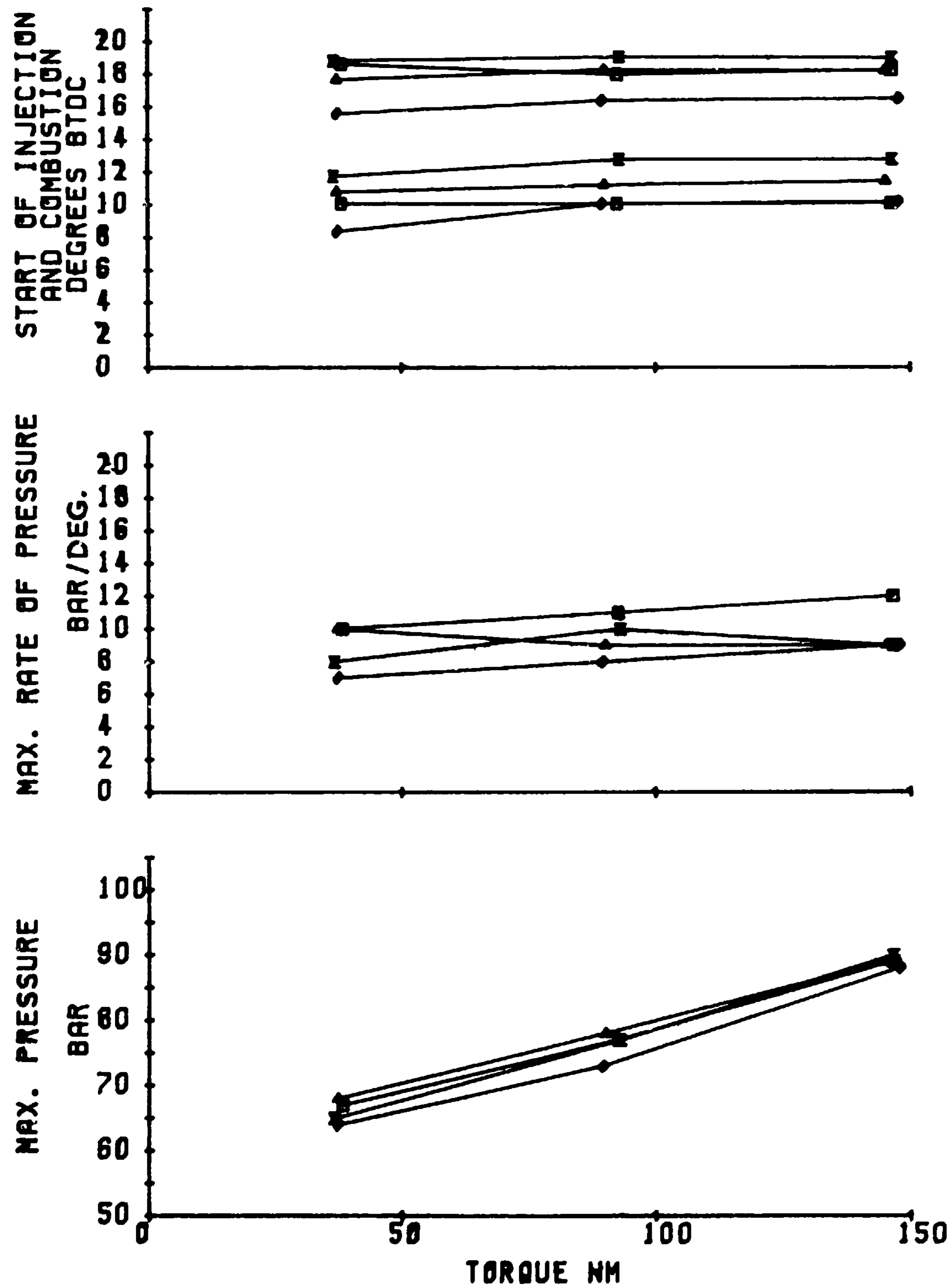
EFFECT OF TEGON ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

♦ DIST 100
■ E20
▲ E20/2.6TEGON
⧗ E20/5.2TEGON
2000 R.P.M.

FIG AP31



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/2.6TEGON ⧗ E20/5.2TEGON 1400 R.P.M.
EFFECT OF TEGON ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP32

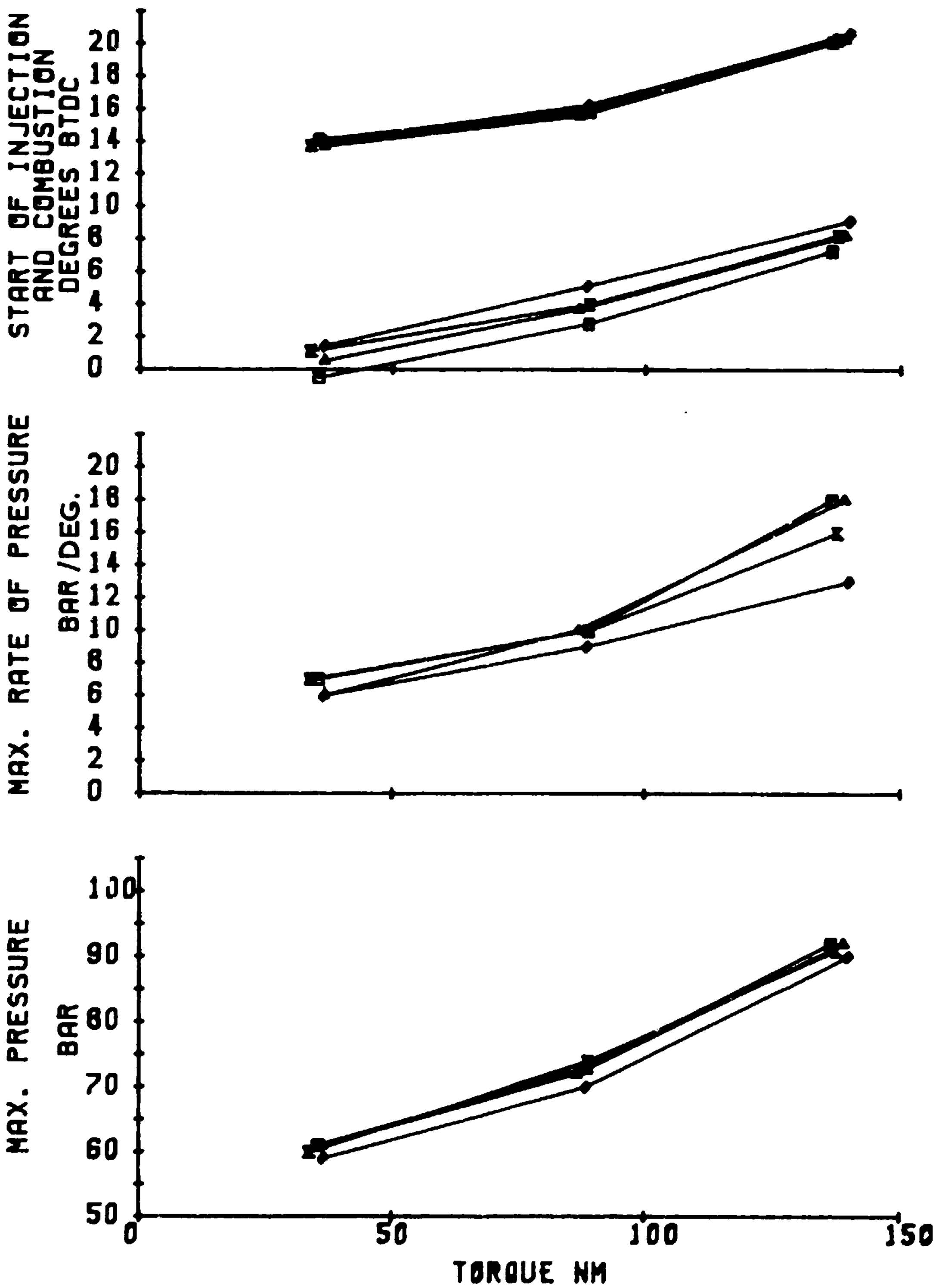


ENGINE : FORD 3000
CAPACITY: 2860

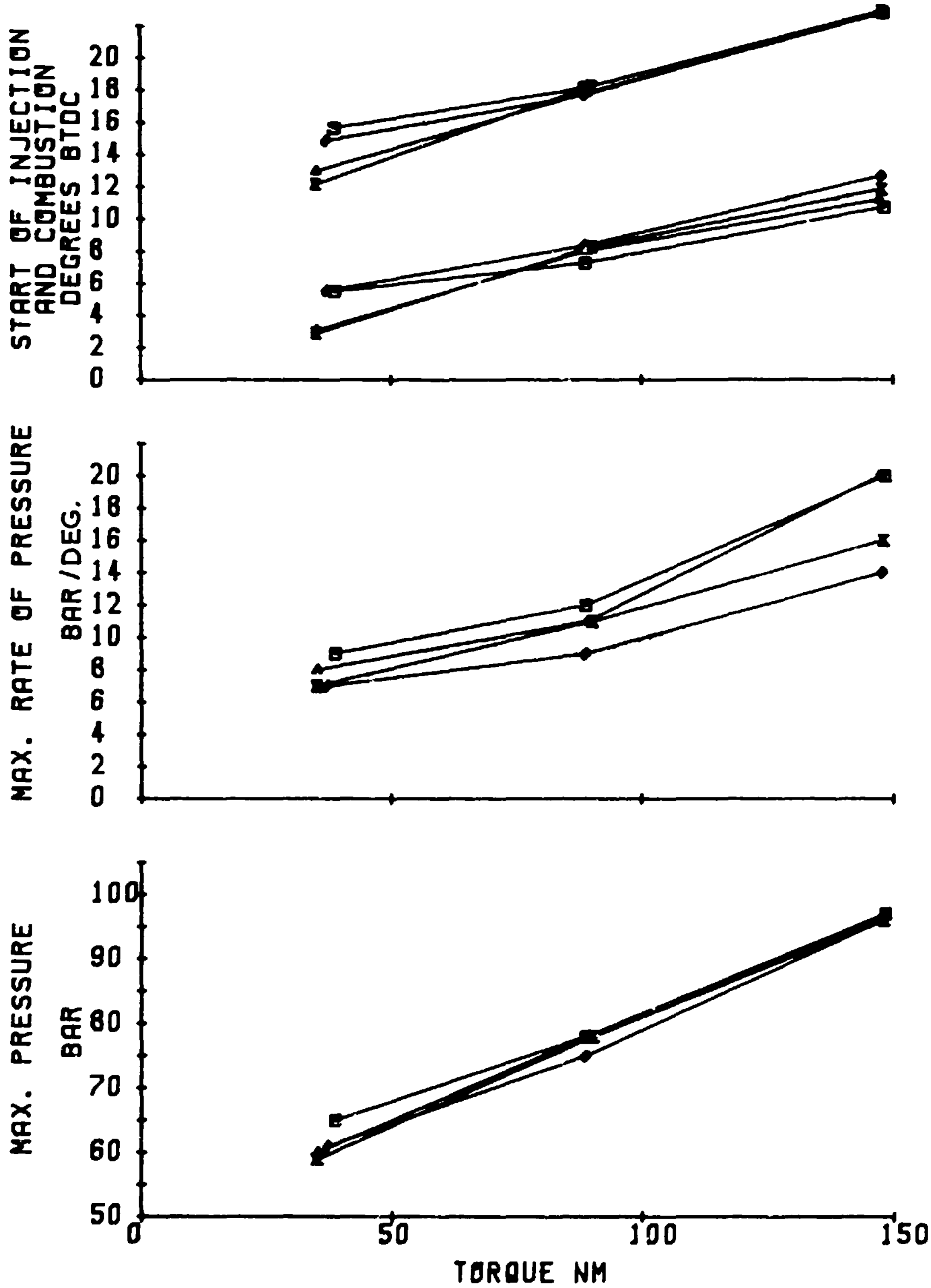
EFFECT OF TEGON ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

◆ DIST 100
■ E20
▲ E20/2.6TEGON
⧗ E20/5.2TEGON
800 R.P.M.

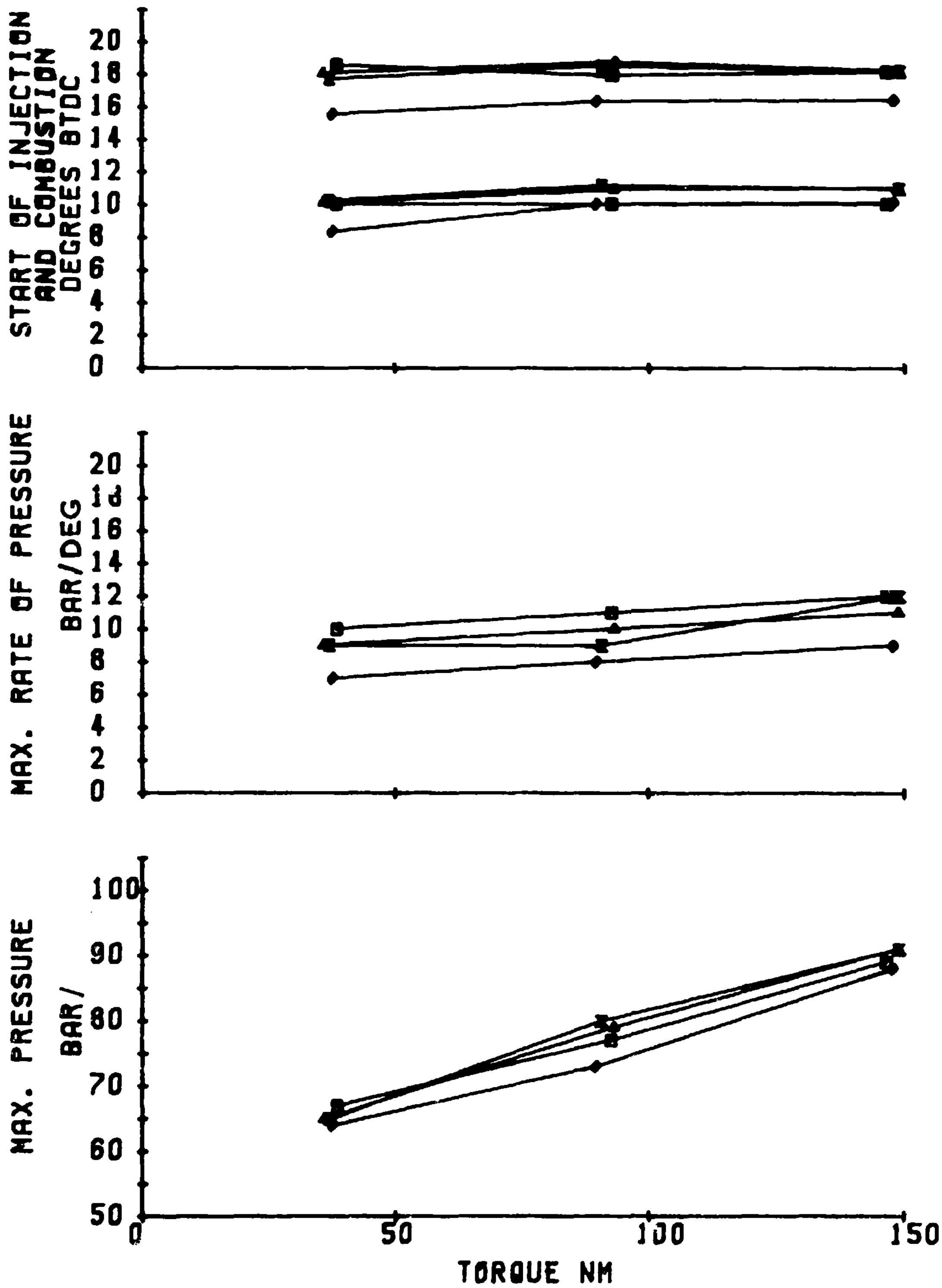
FIG AP33



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/.2ION ⧗ E20/.4ION 2000 R.P.M.
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP34



ENGINE : FORD 3000 CAPACITY: 2660	◆ DIST 100 ■ E20 ▲ E20/.2ION ⧗ E20/.4ION 1400 R.P.M.
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP35

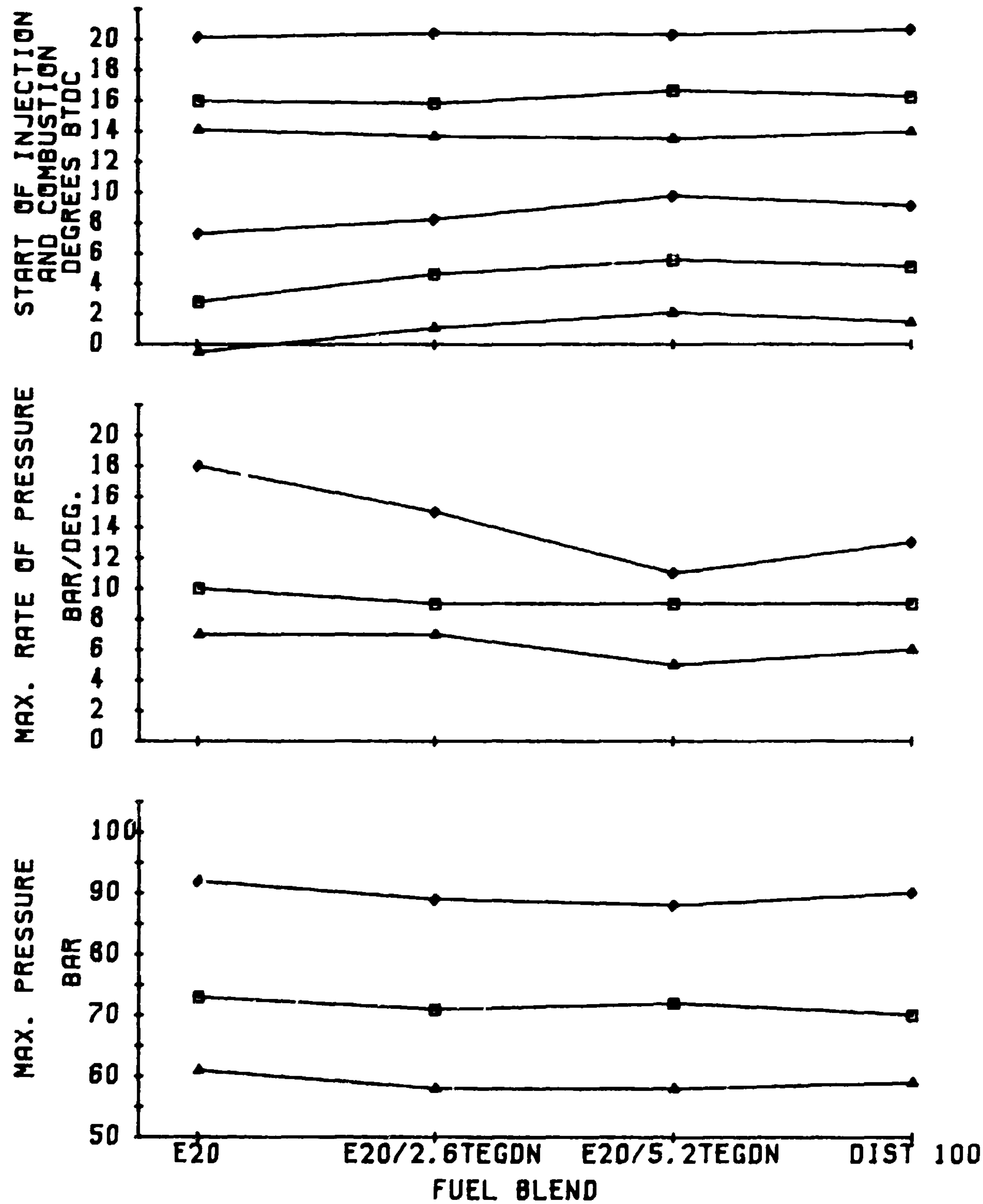


ENGINE : FORD 300C
CAPACITY: 2660

EFFECT OF ION ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

♦ DIST 100
■ E20
▲ E20/.2ION
⧗ E20/.4ION
600 R.P.M.

FIG AP36



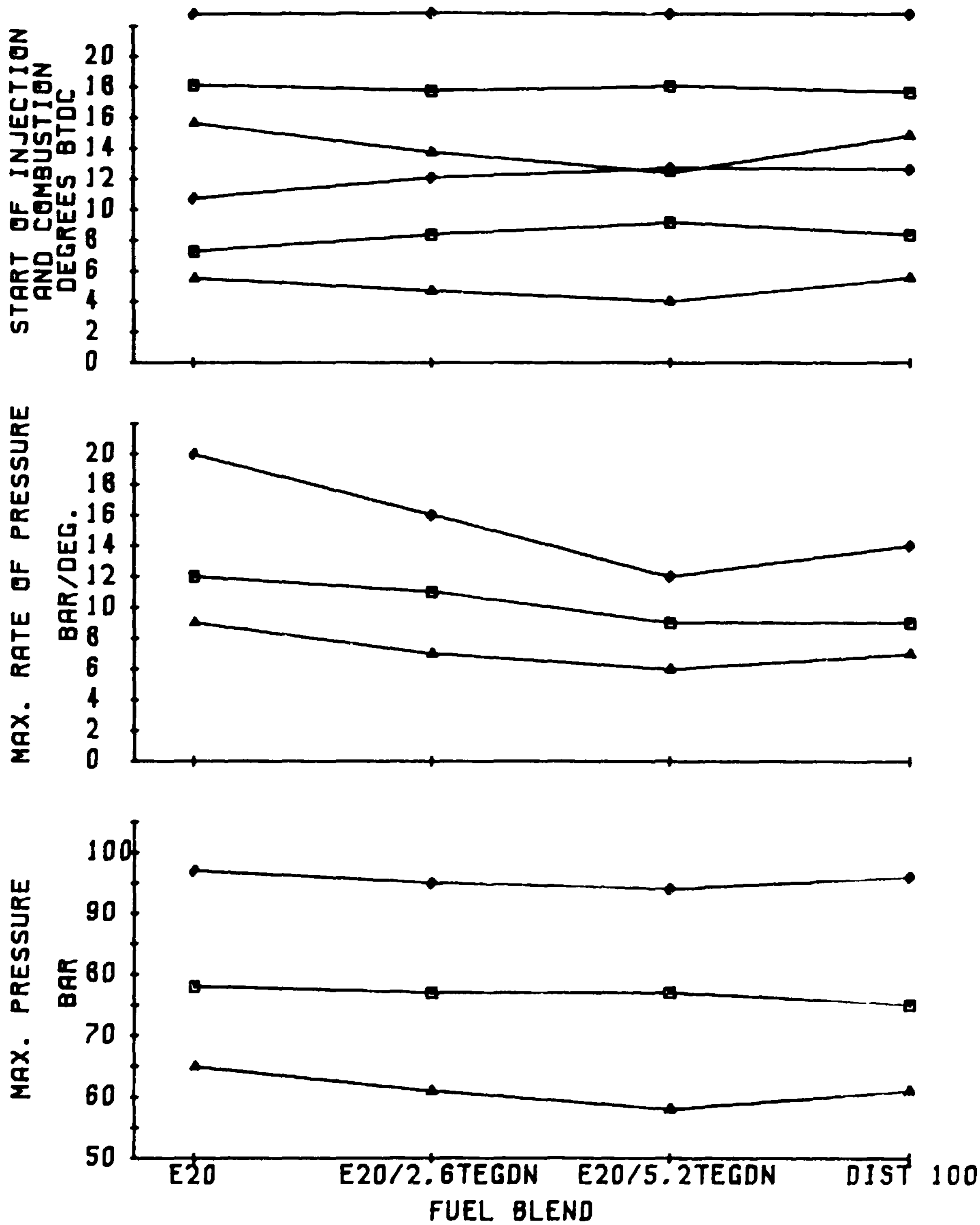
ENGINE : FORD 3000
CAPACITY: 2860

◆ FULL LOAD
■ 2/3 LOAD
▲ 1/3 LOAD

EFFECT OF TEGDN ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

2000 R.P.M.

FIG AP37



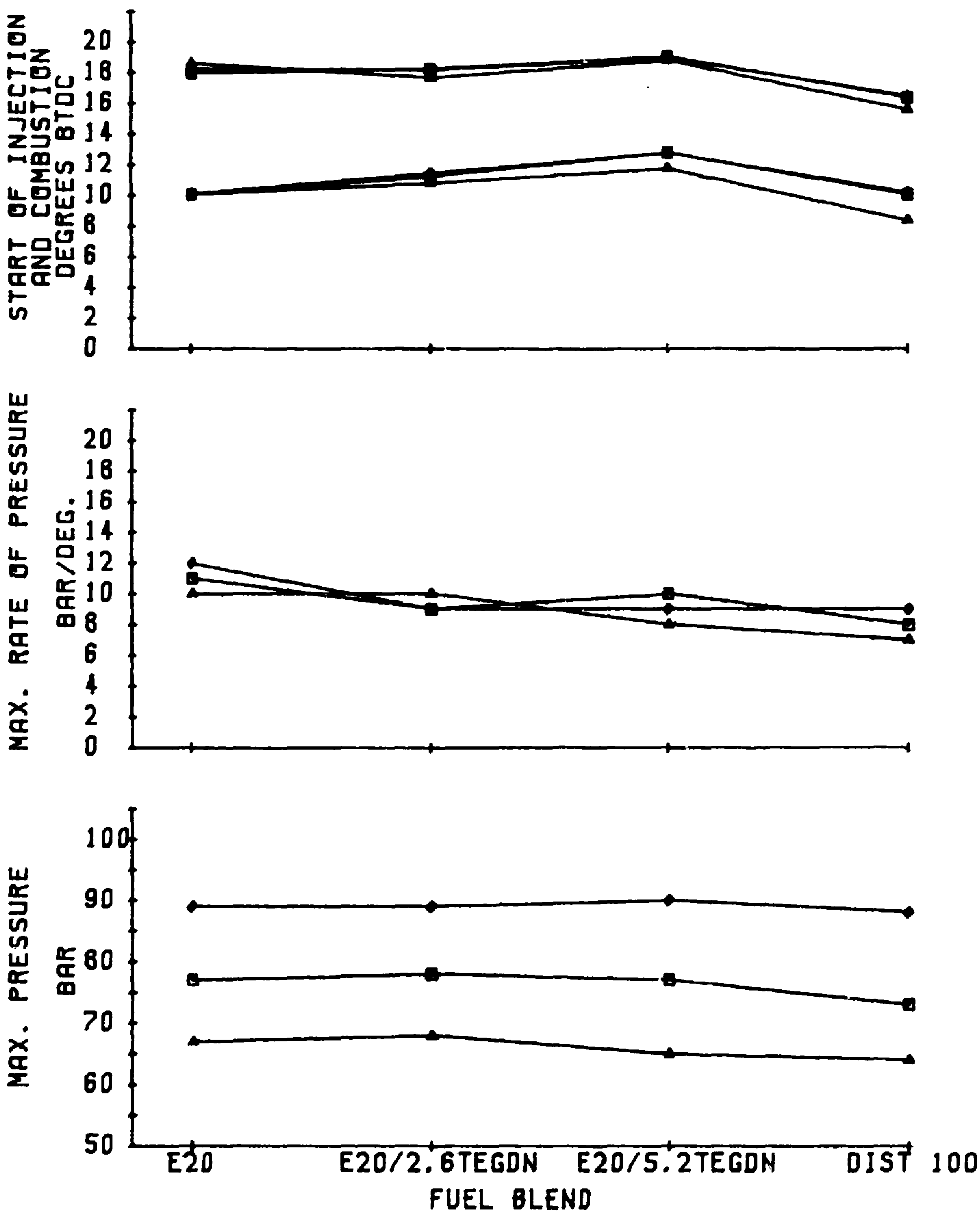
ENGINE : FORD 3000
CAPACITY: 2860

EFFECT OF TEGDN ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

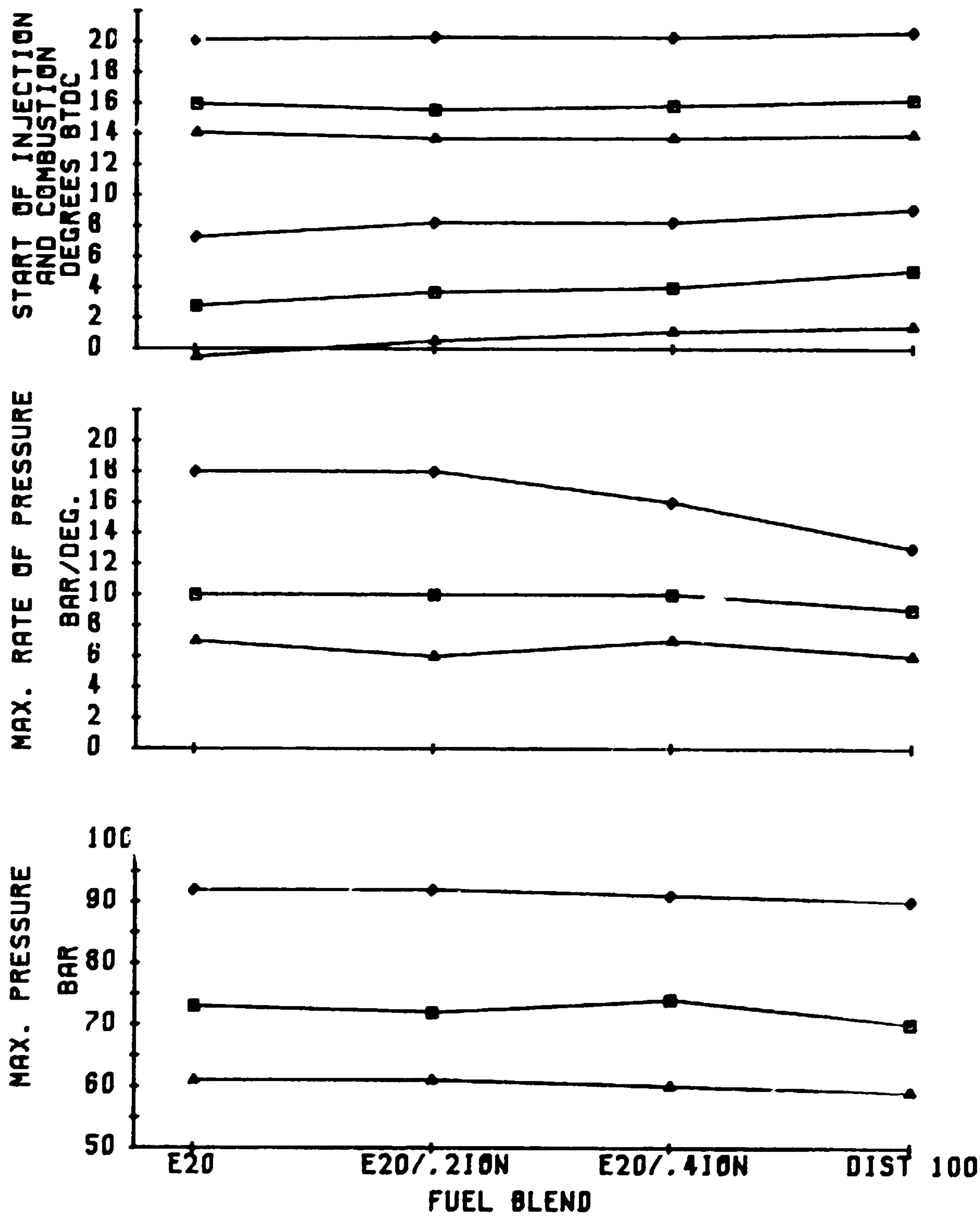
◆ FULL LOAD
■ 2/3 LOAD
▲ 1/3 LOAD

1400 R.P.M.

FIG AP38



ENGINE : FORD 3000 CAPACITY: 2860	◆ FULL LOAD ▪ 2/3 LOAD ▲ 1/3 LOAD
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	800 R.P.M. FIG AP39



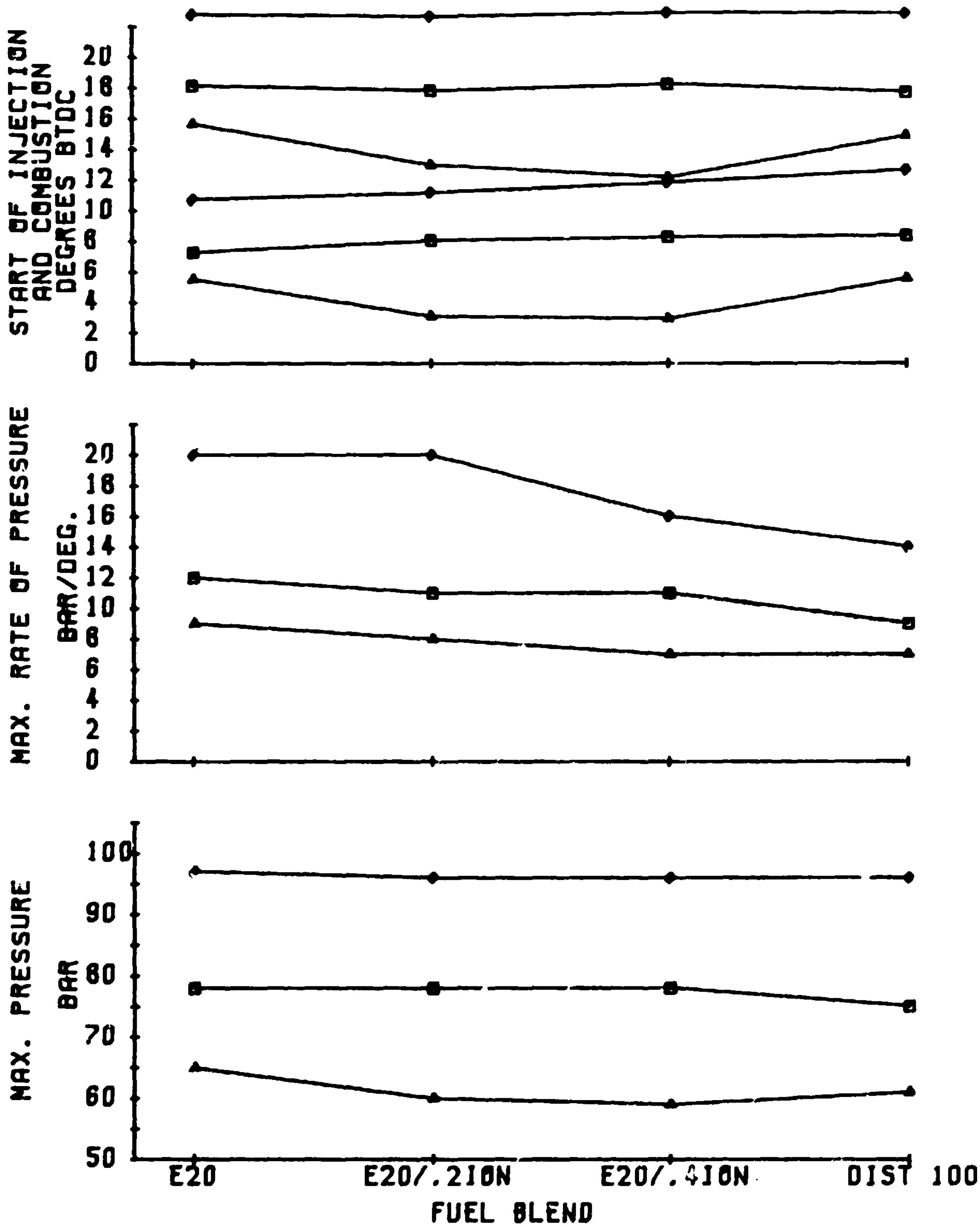
ENGINE : FORD 3000
CAPACITY: 2860

◆ FULL LOAD
■ 2/3 LOAD
▲ 1/3 LOAD

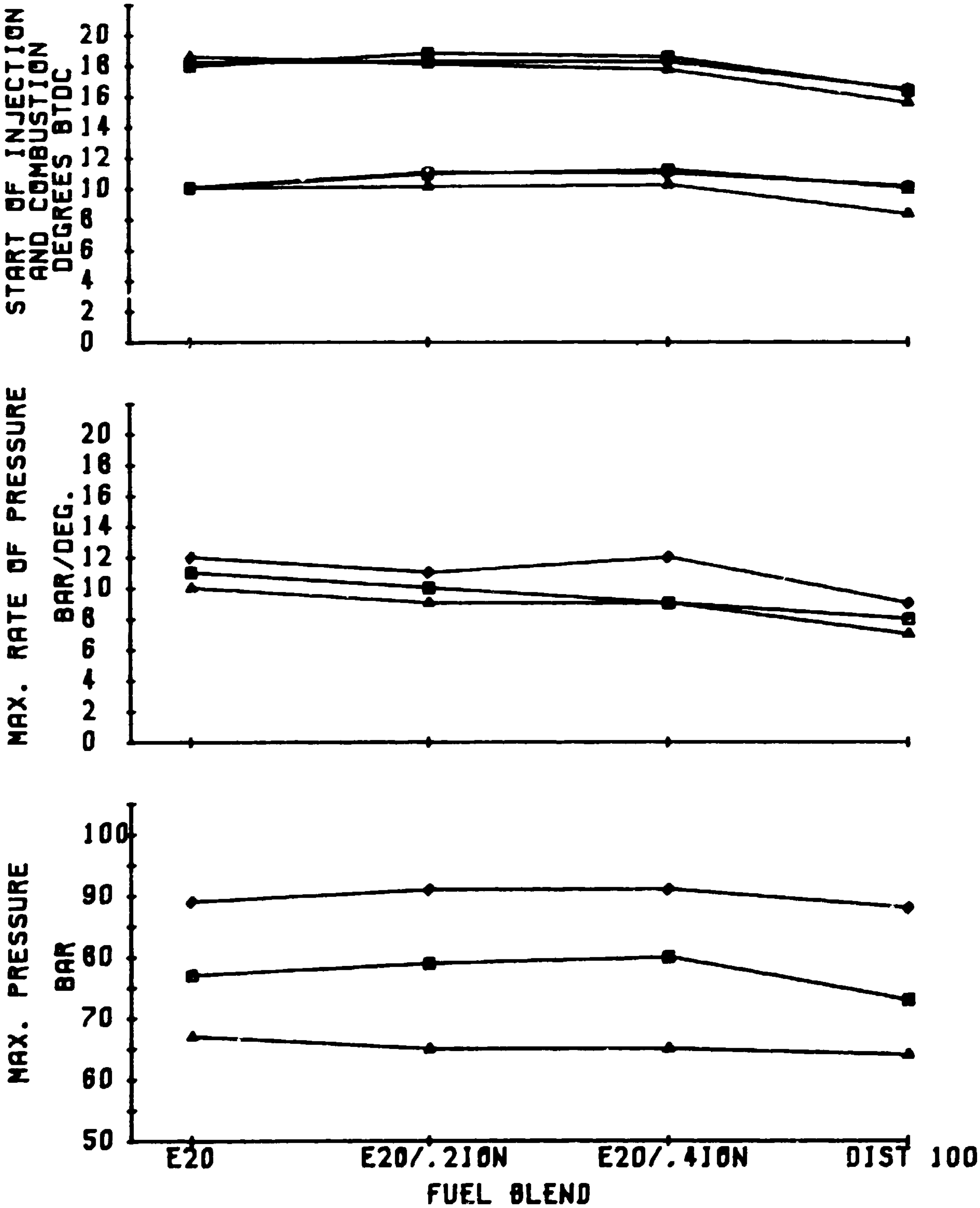
EFFECT OF ION ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

2000 R.P.M.

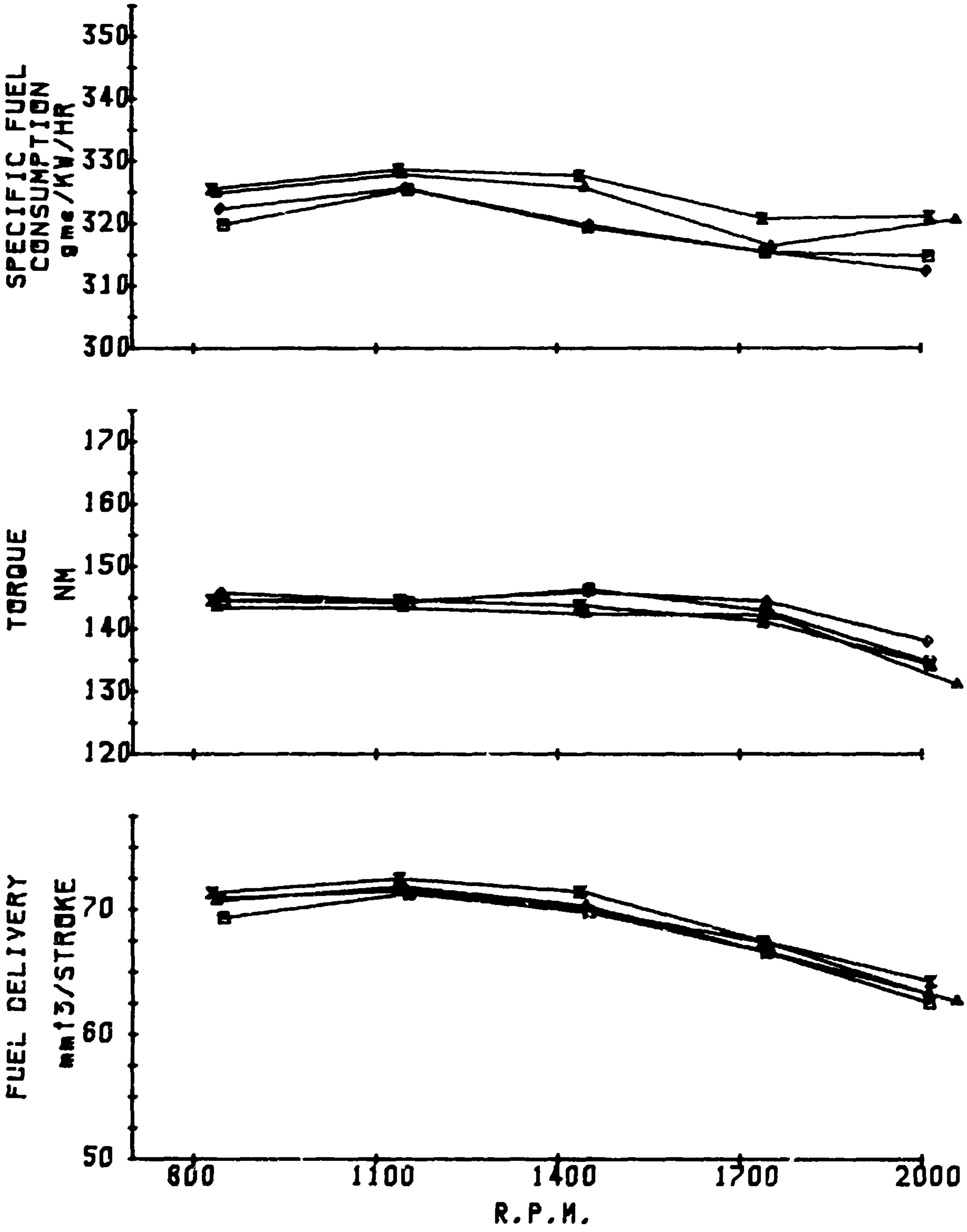
FIG AP40



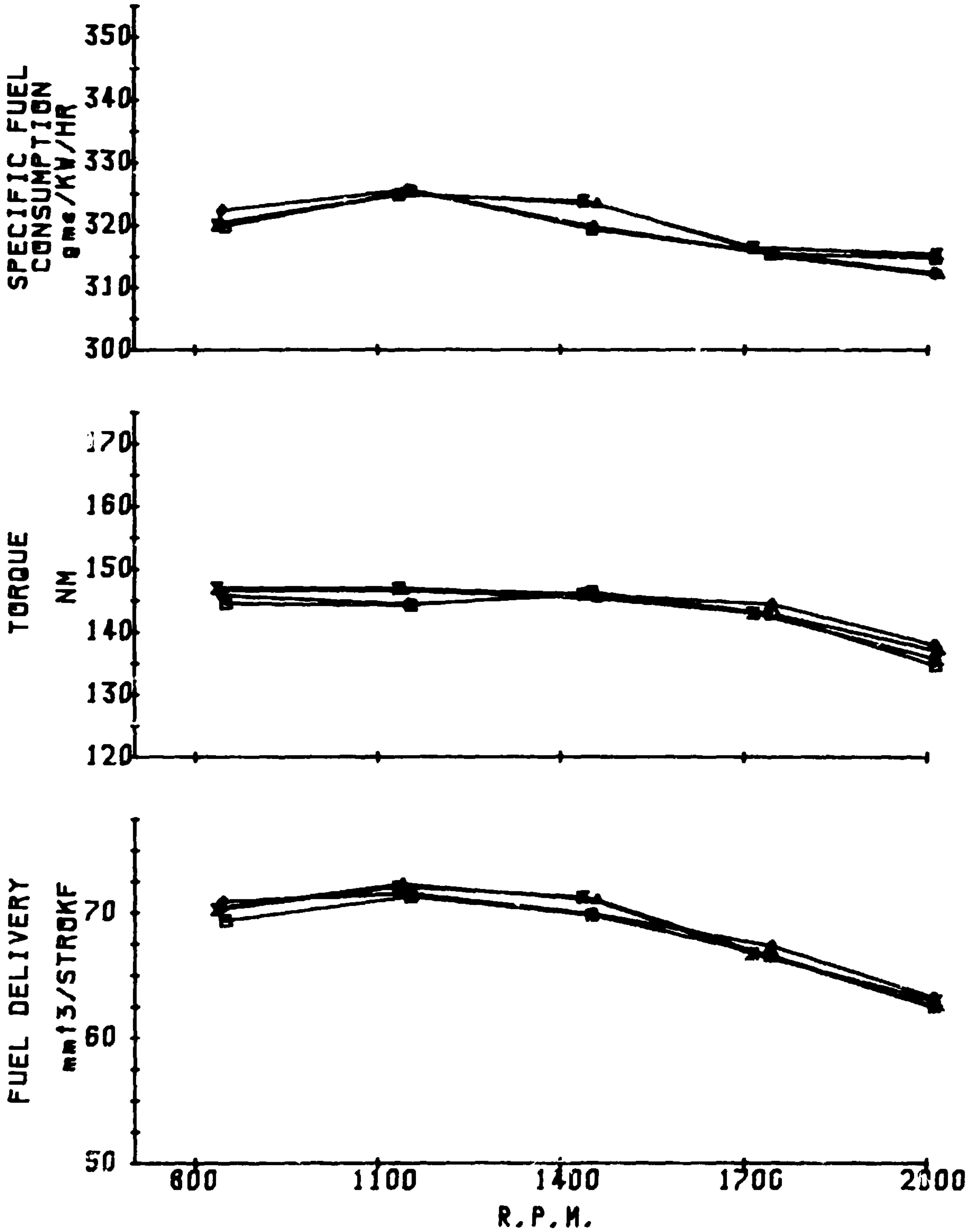
ENGINE : FORD 3000 CAPACITY: 2660	◆ FULL LOAD ■ 2/3 LOAD ▲ 1/3 LOAD
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	1400 R.P.M. FIG AP41



ENGINE : FORD 3000 CAPACITY: 2860	◆ FULL LOAD ■ 2/3 LOAD ▲ 1/3 LOAD
EFFECT OF ION ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	800 R.P.M.
	FIG AP42



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ▫ E20 ▲ E20/2.6TEGDN ✕ E20/5.2TEGDN FULL LOAD
EFFECT OF TEGDN ON INJECTION PUMP DELIVERY, TORQUE & S.F.C.	FIG AP43

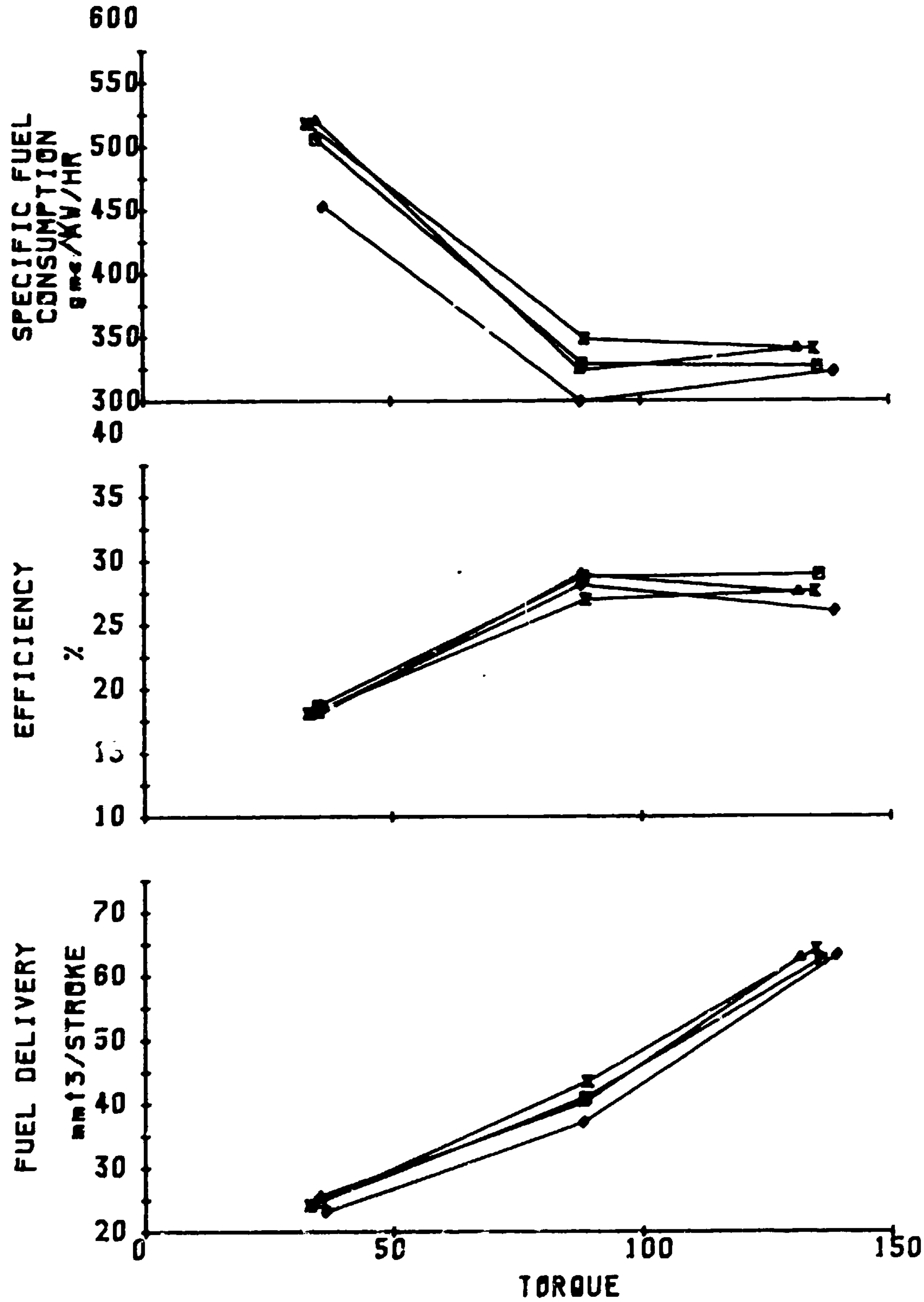


ENGINE : FORD 3000
CAPACITY: 2360

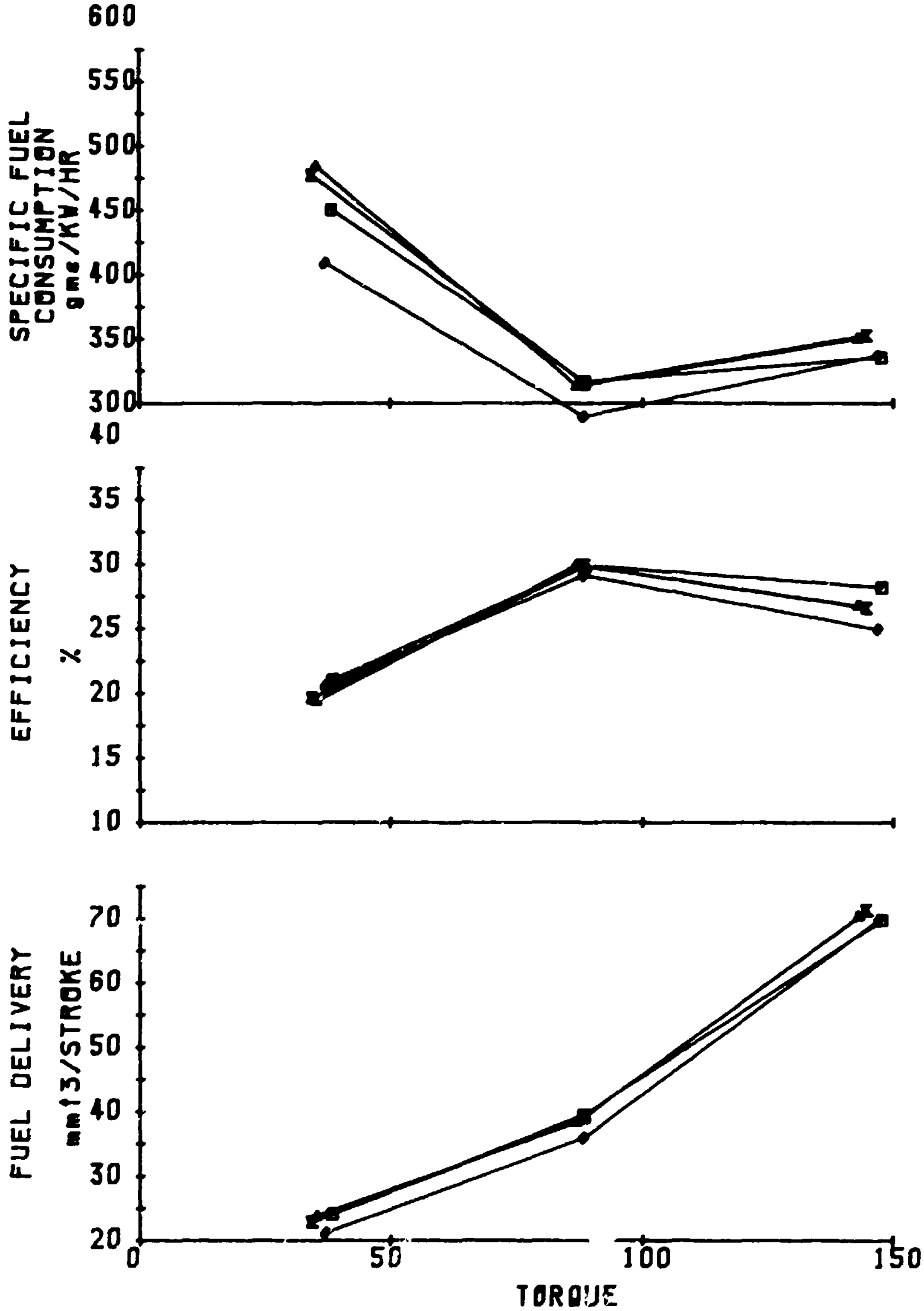
EFFECT OF ION ON
INJECTION PUMP DELIVERY,
TORQUE & S.F.C.

◆ DIST 100
■ E20
▲ E20/.2ION
x E20/.4ION
FULL LOAD

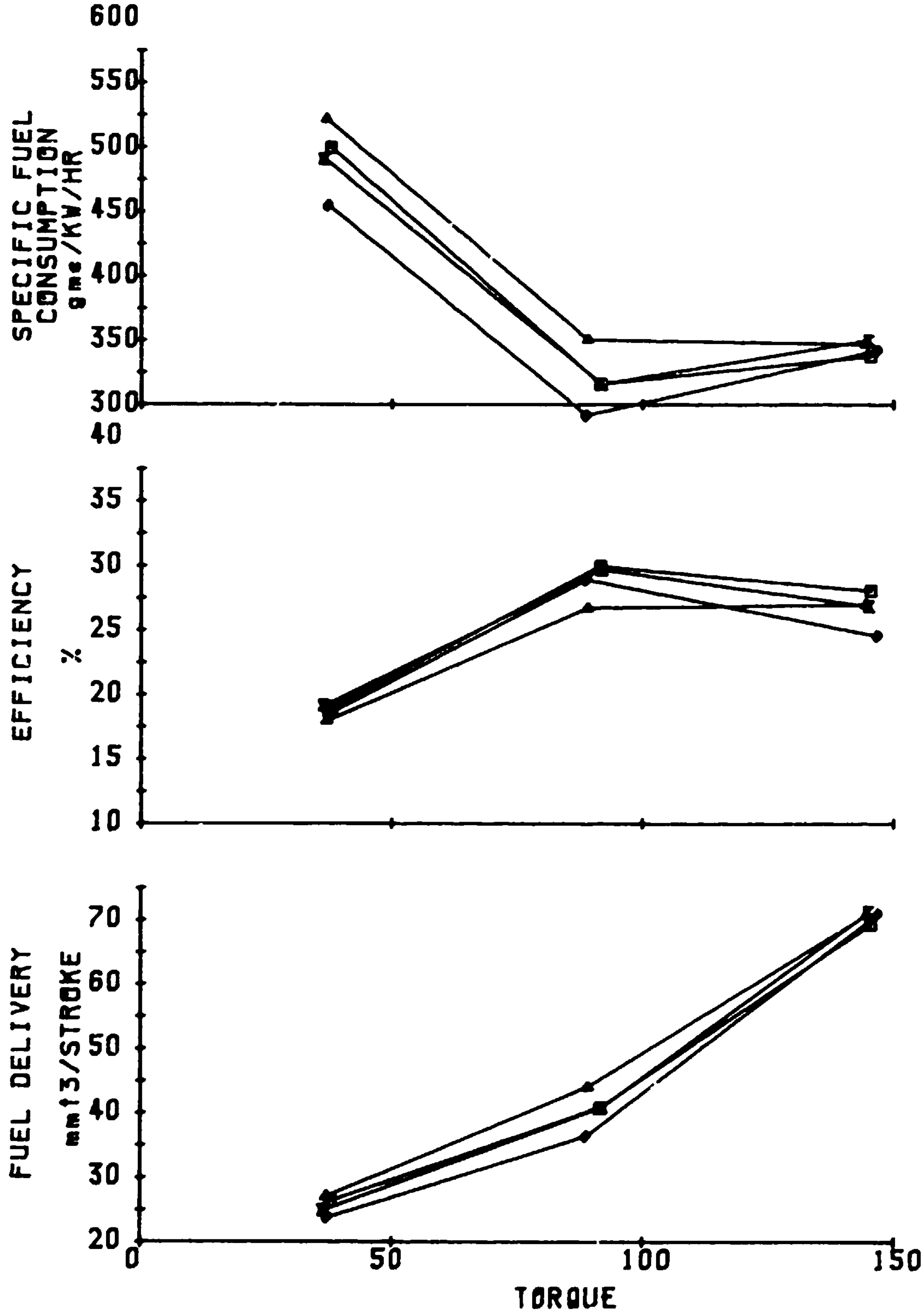
FIG AP44



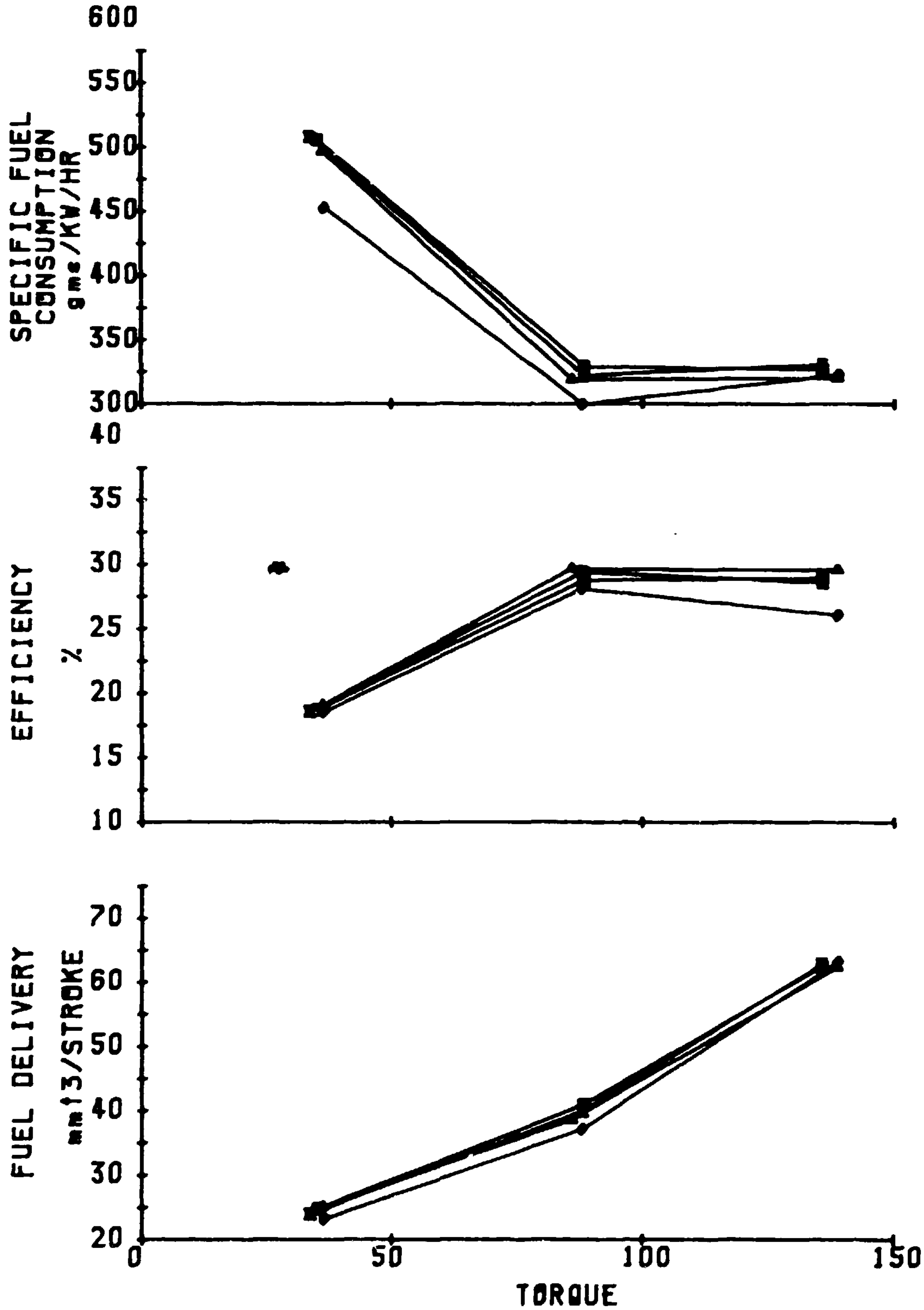
ENGINE : FORD 3000 CAPACITY: 2860	♦ DIST 100 ▪ E20 ▲ E20/2.6TEGDN x E20/5.2TEGDN 2000 R.P.M.
EFFECT OF TEGDN ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP45



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/2.6TEGON ⧗ E2J/5.2TEGON 1400 R.P.M.
EFFECT OF TEGON ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP46



ENGINE : FORD 3000 CAPACITY: 2860	♦ DIST 100 □ E20 ▲ E20/2.6TEGDN x E20/5.2TEGDN 800 R.P.M.
EFFECT OF TEGDN ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP47

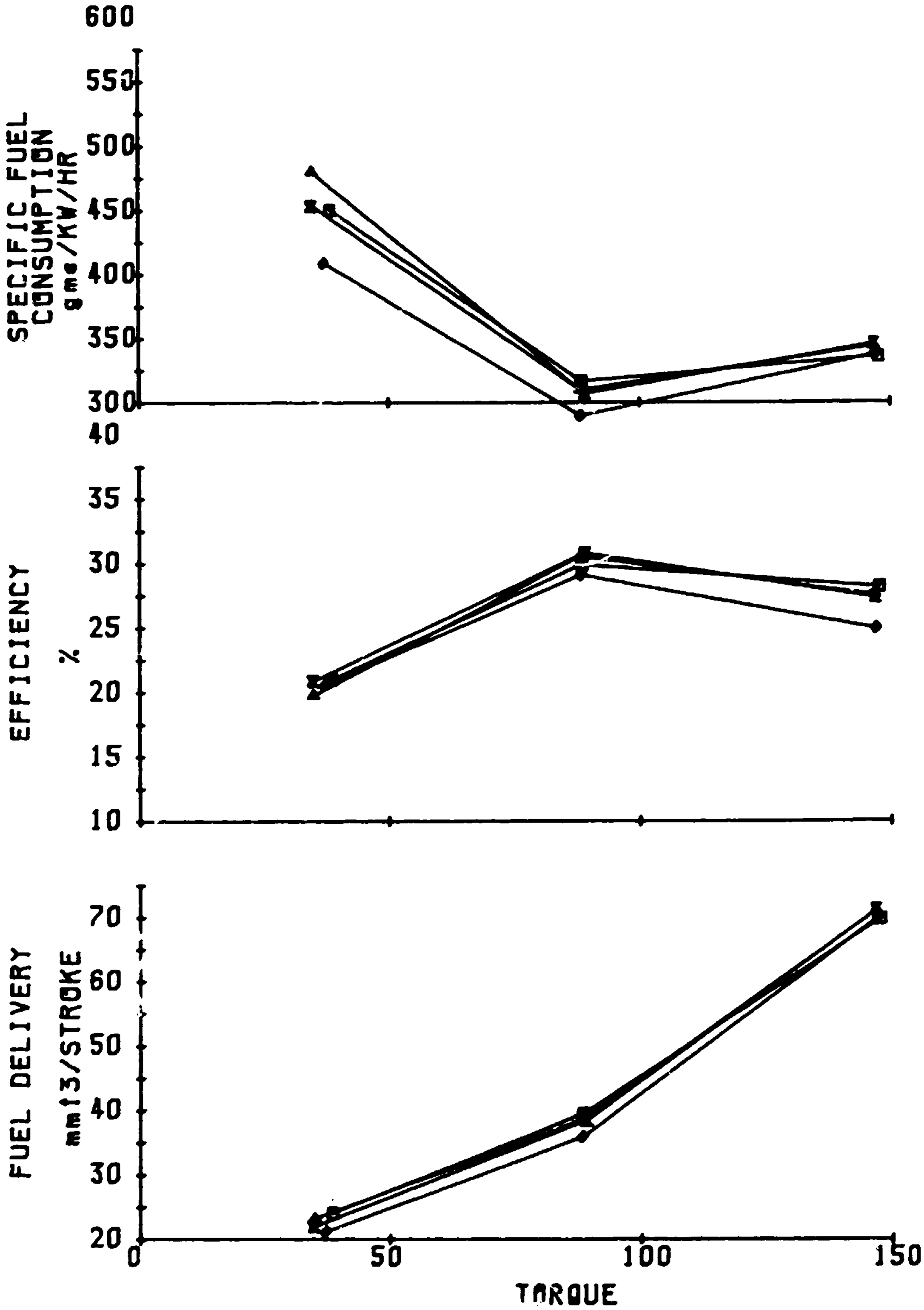


ENGINE : FORD 3000
CAPACITY: 2860

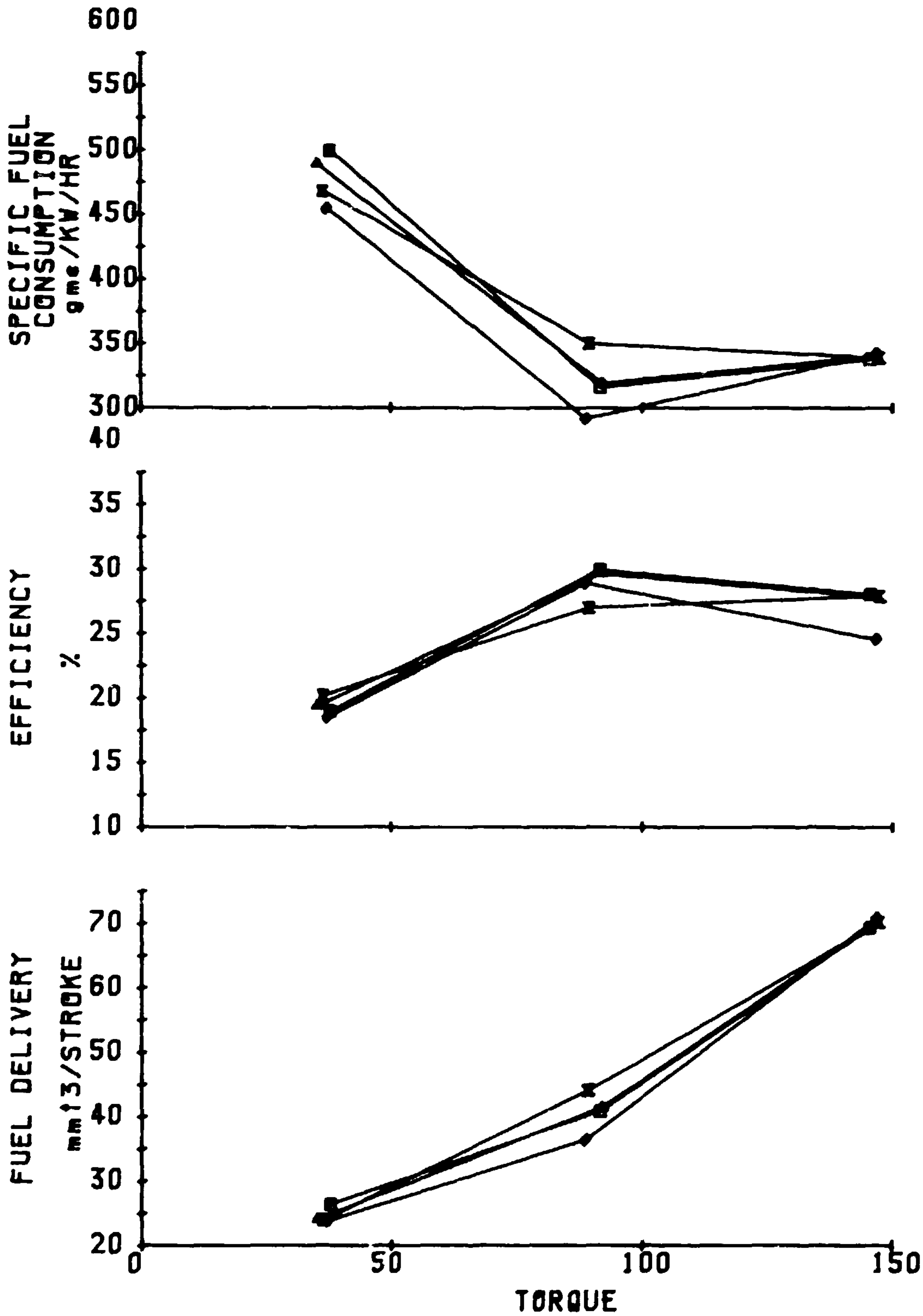
EFFECT OF ION ON
INJECTION PUMP DELIVERY,
EFFICIENCY & S.F.C.

• DIST 100
■ E20
▲ E20/.2ION
⁎ E20/.4ION
2000 R.P.M.

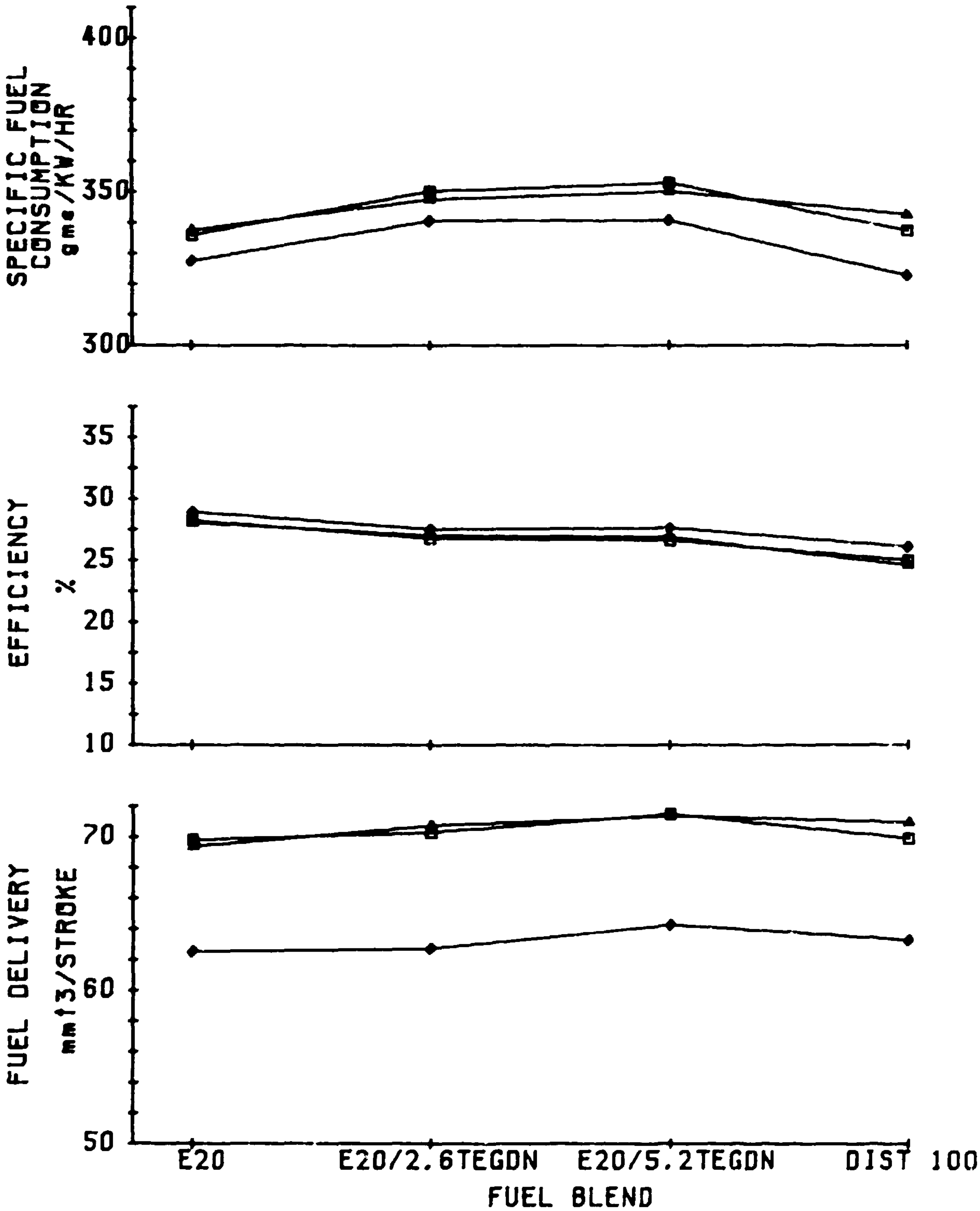
FIG AP4B



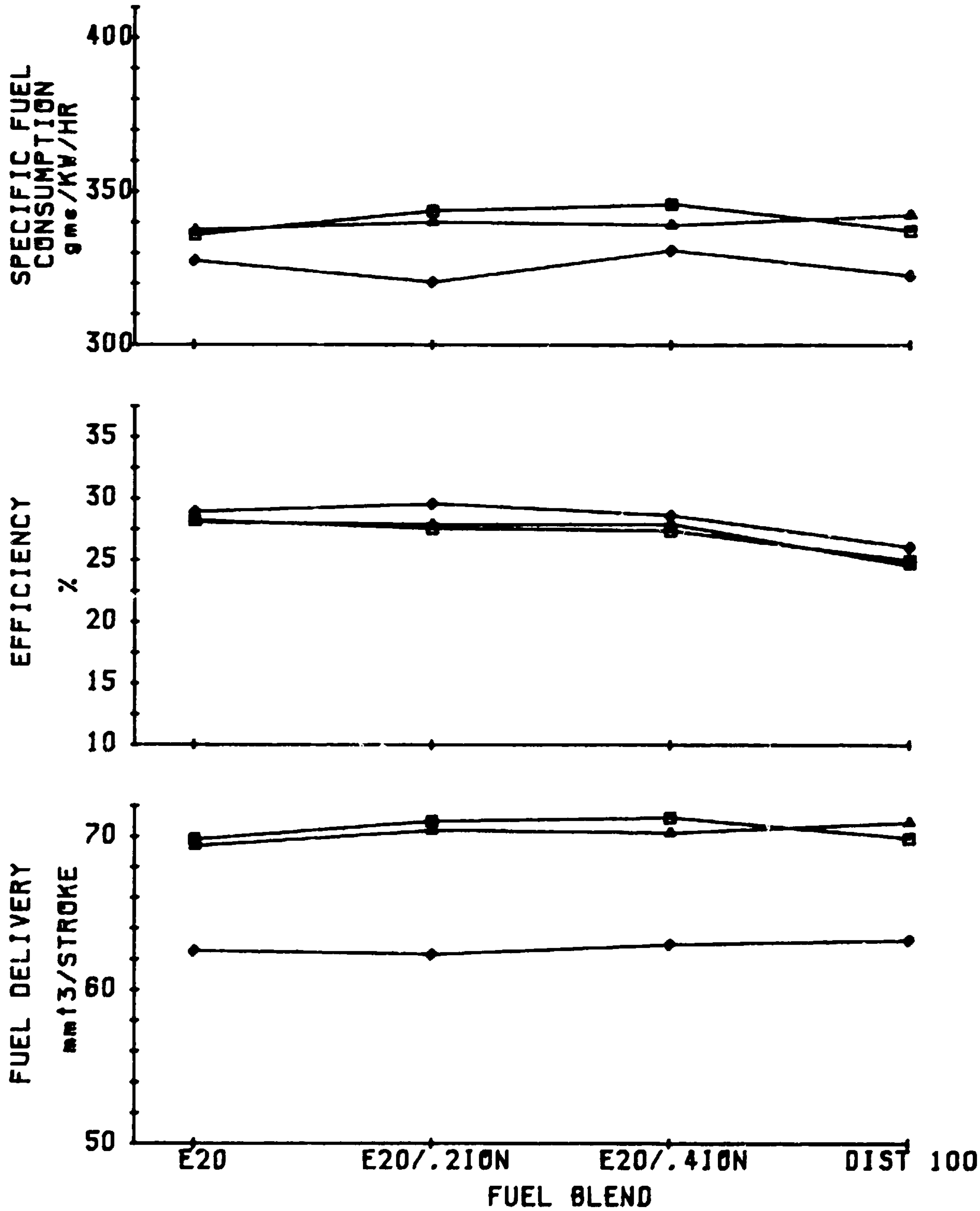
ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/.2ION ⧗ E20/.4ION 1400 R.P.M.
EFFECT OF ION ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP49



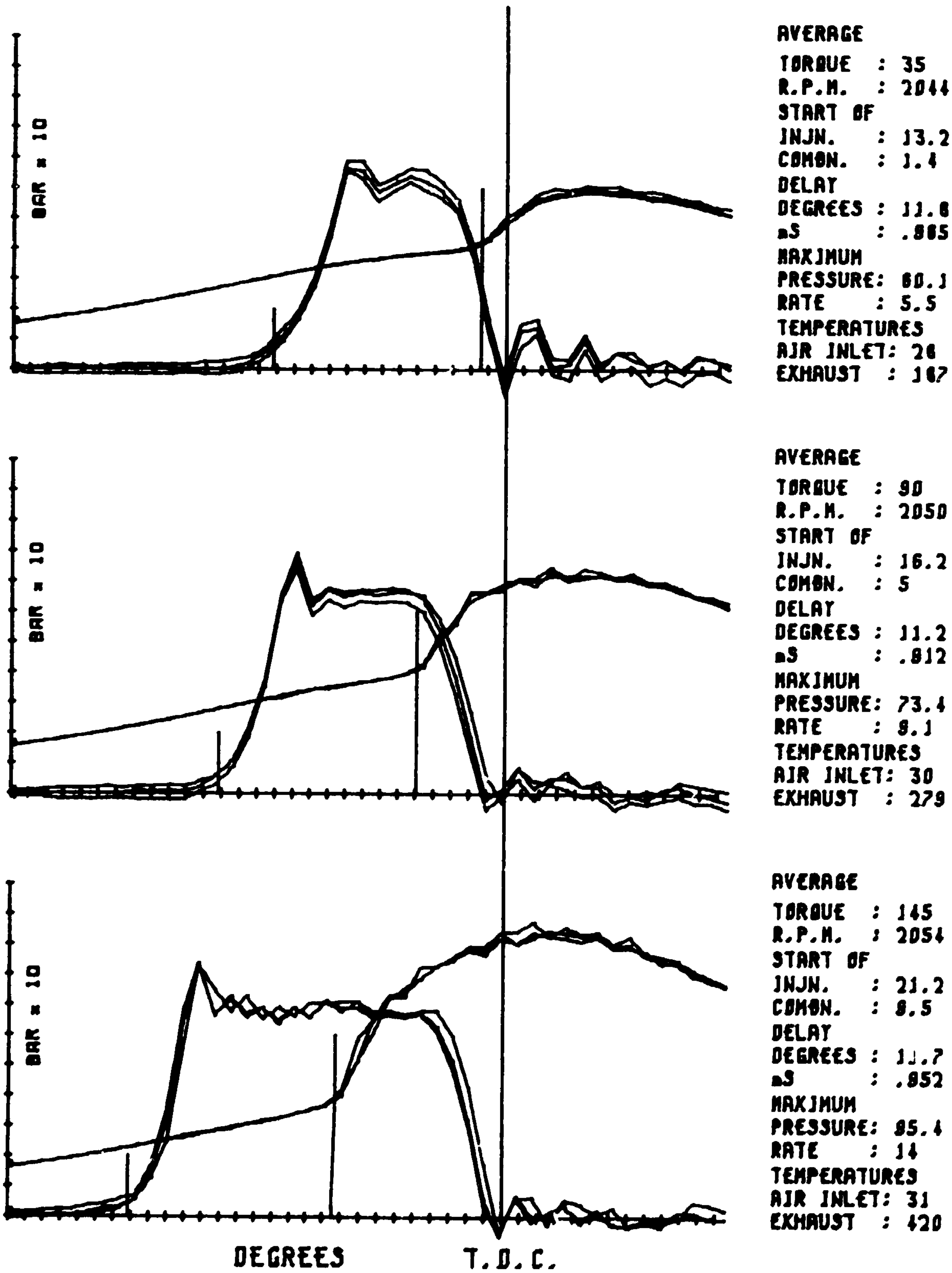
ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E20 ▲ E20/.2ION ⧗ E20/.4ION 600 R.P.M.
EFFECT OF ION ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP50



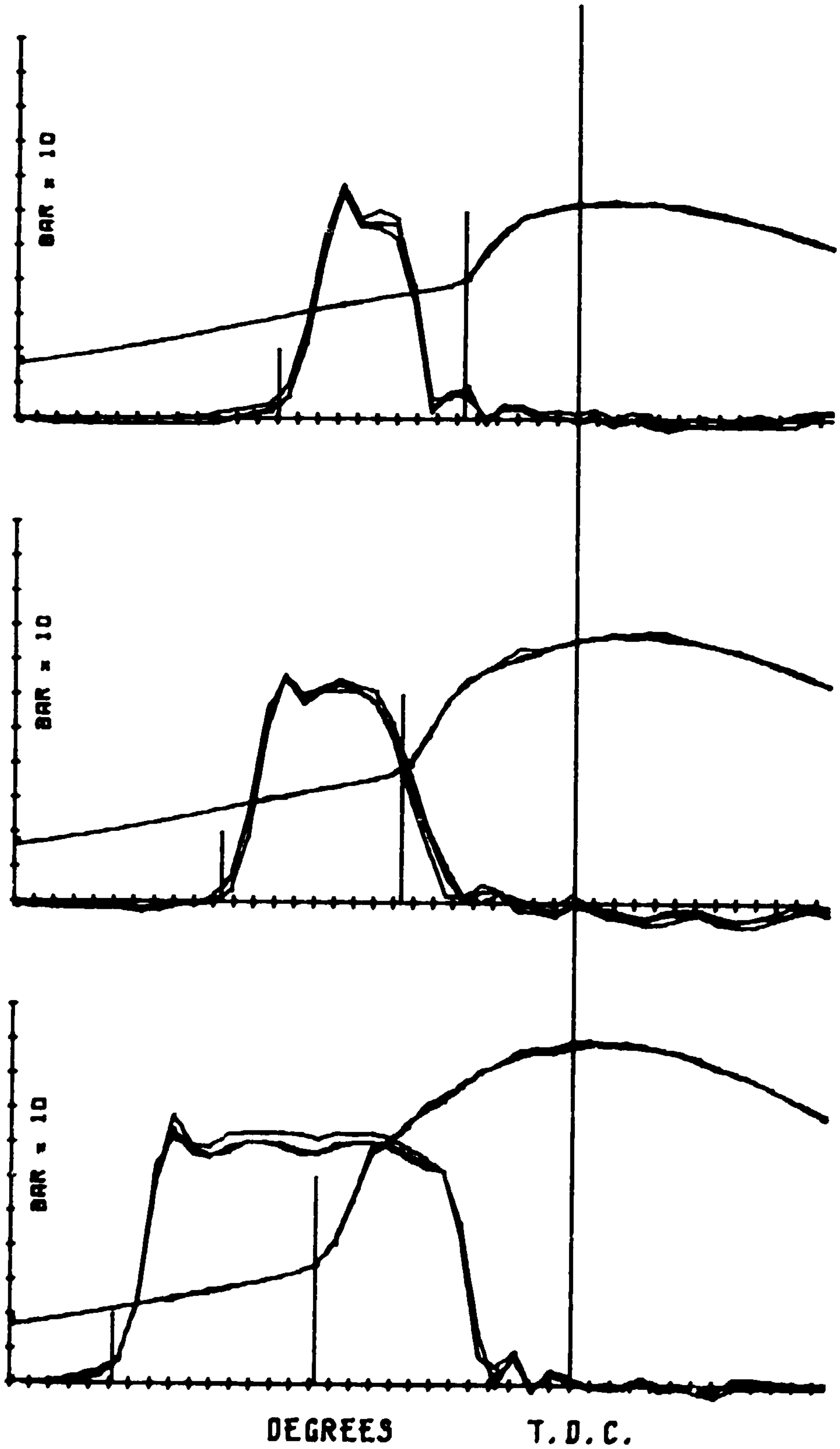
ENGINE : FORD 3000 CAPACITY: 2860	• 2000 R.P.M. ▫ 1400 R.P.M. ▴ 800 R.P.M.
EFFECT OF TEGDN ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FULL LOAD FIG AP51



ENGINE : FORD 3000 CAPACITY: 2860	• 2000 R.P.M. ■ 1400 R.P.M. ▲ 600 R.P.M.
EFFECT OF ION ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FULL LOAD
	FIG AP52



ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID010	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP53

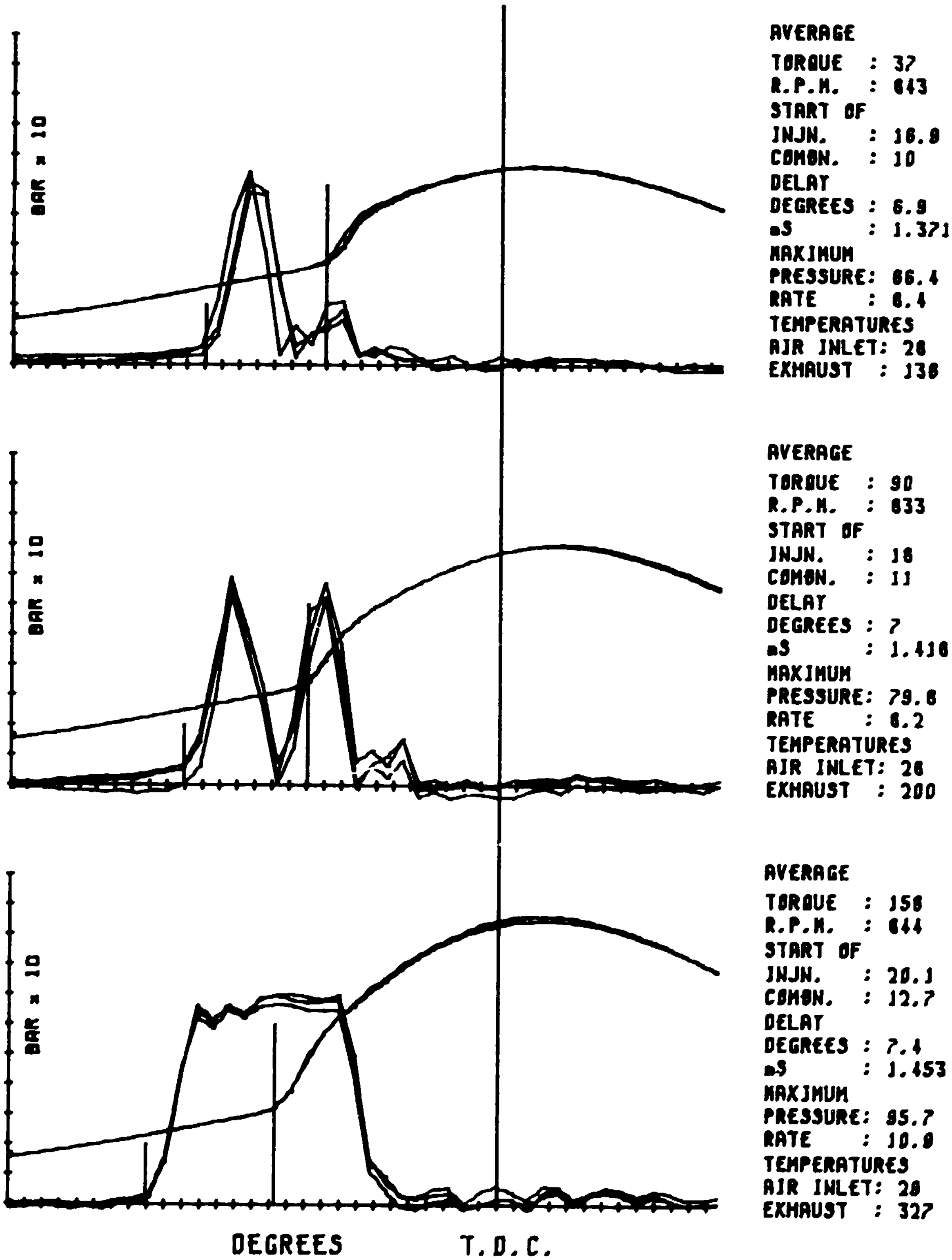


AVERAGE
TORQUE : 38
R.P.M. : 1438
START OF
INJN. : 14.8
COMBN. : 5.8
DELAY
DEGREES : 8.3
mS : 1.081
MAXIMUM
PRESSURE: 63.2
RATE : 7.5
TEMPERATURES
AIR INLET: 26
EXHAUST : 151

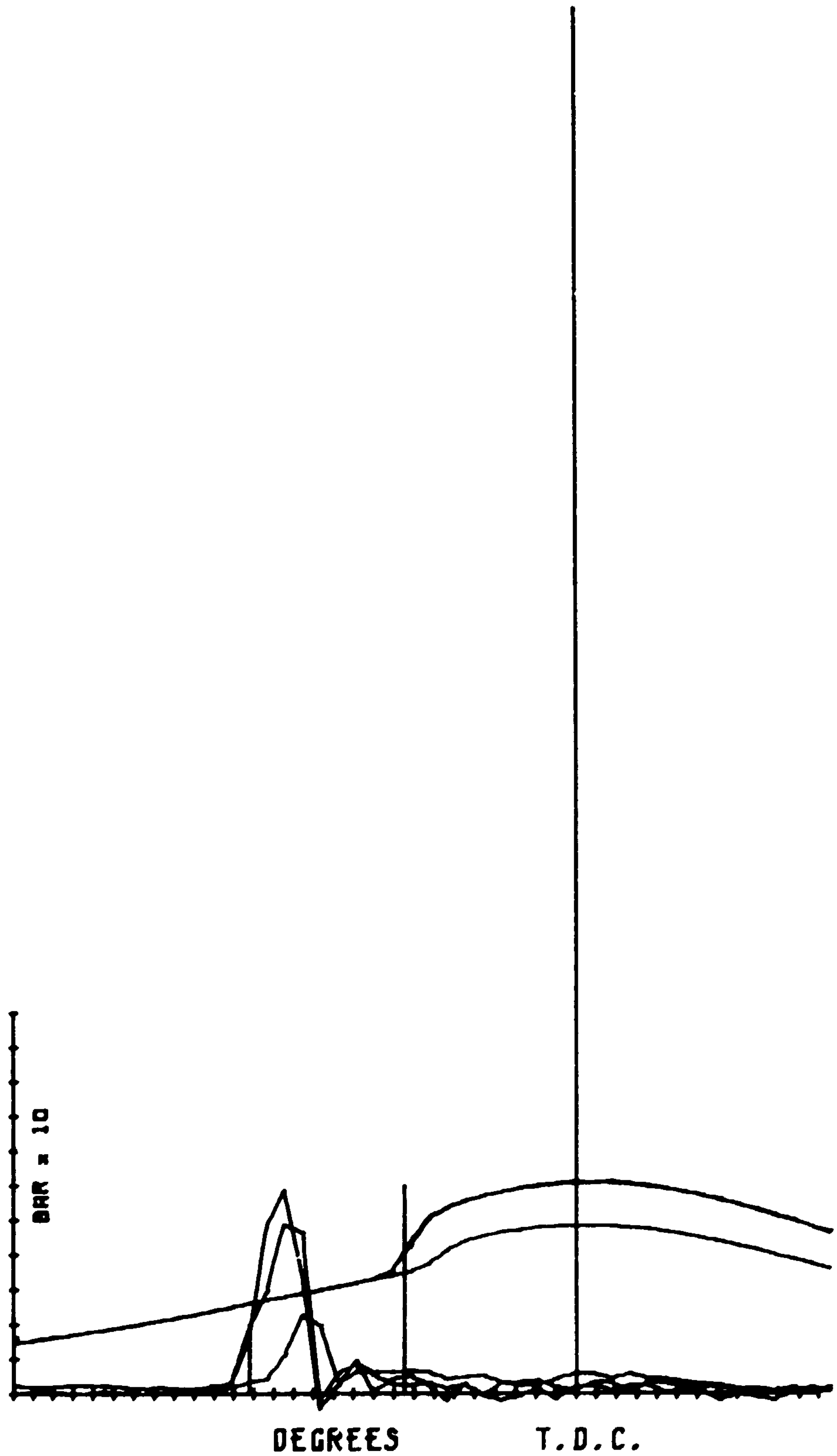
AVERAGE
TORQUE : 68
R.P.M. : 1447
START OF
INJN. : 17.6
COMBN. : 6.6
DELAY
DEGREES : 8
mS : 1.036
MAXIMUM
PRESSURE: 76
RATE : 8.6
TEMPERATURES
AIR INLET: 28
EXHAUST : 225

AVERAGE
TORQUE : 154
R.P.M. : 1432
START OF
INJN. : 22.6
COMBN. : 12.6
DELAY
DEGREES : 10
mS : 1.173
MAXIMUM
PRESSURE: 88.5
RATE : 14.1
TEMPERATURES
AIR INLET: 30
EXHAUST : 405

ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID010	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP54

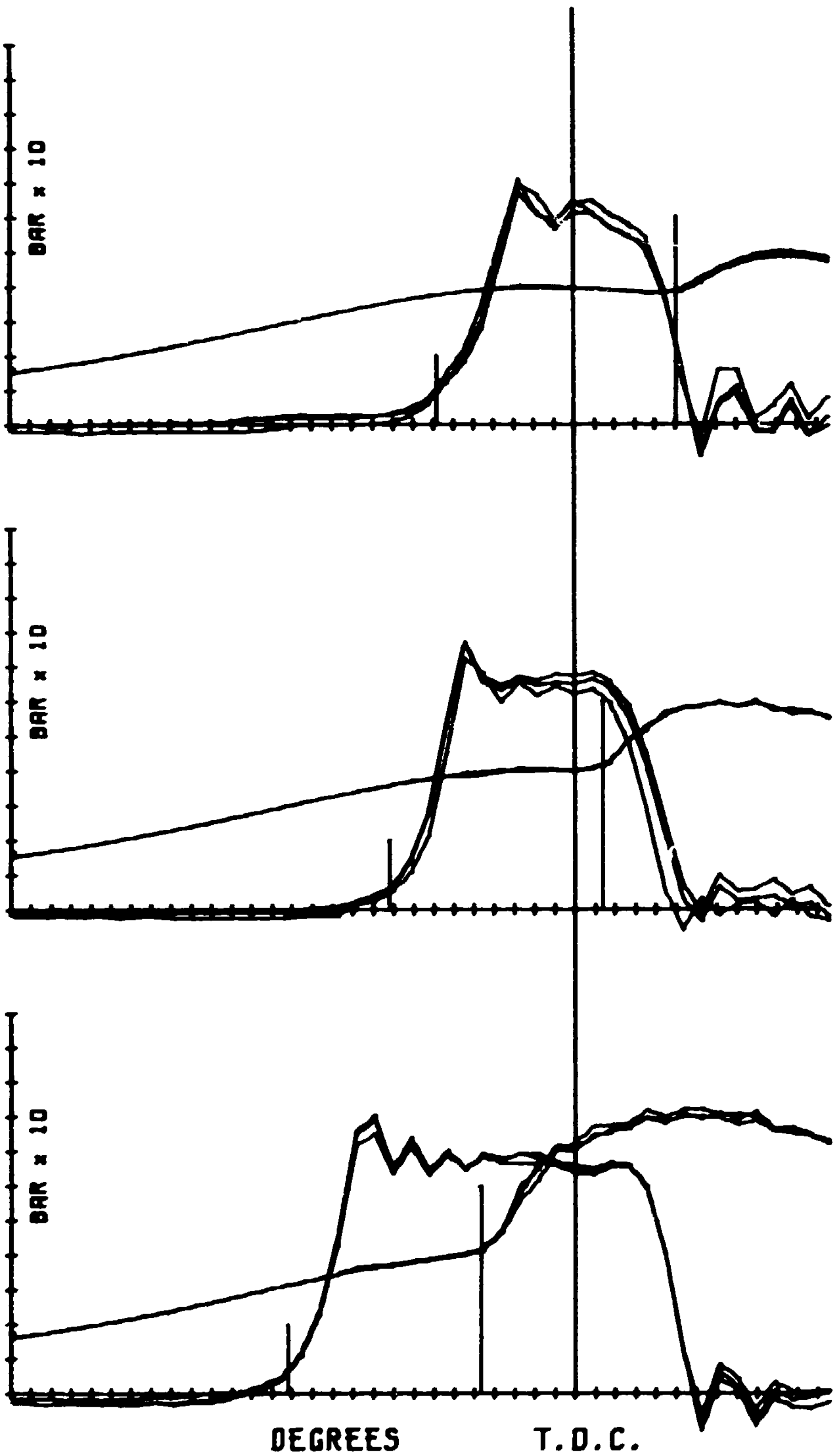


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID010	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP55



AVERAGE
TORQUE : 3
R.P.M. : 616
START OF
INJN. : 16.2
COMBN. : 6.5
DELAT
DEGREES : 7.7
mS : 1.574
MAXIMUM
PRESSURE: 56.9
RATE : 6.9
TEMPERATURES
AIR INLET: 26
EXHAUST : 97

ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID010	
REPEATABILITY OF NEEDLE LIFT AND CTLINDER PRESSURE	FIG AP56



AVERAGE
TØRQUE : 37
R.P.M. : 2030
START ØF
INJN. : 6.8
CØMBN. : -5.1
DELAY
DEGREES : 11.9
mS : .977
MAXIMUM
PRESSURE: 49.3
RATE : 3
TEMPERATURES
AIR INLET: 26
EXHAUST : 200

AVERAGE
TØRQUE : 69
R.P.M. : 2050
START ØF
INJN. : 9.2
CØMBN. : -1.4
DELAY
DEGREES : 10.6
mS : .865
MAXIMUM
PRESSURE: 60.3
RATE : 6.4
TEMPERATURES
AIR INLET: 30
EXHAUST : 276

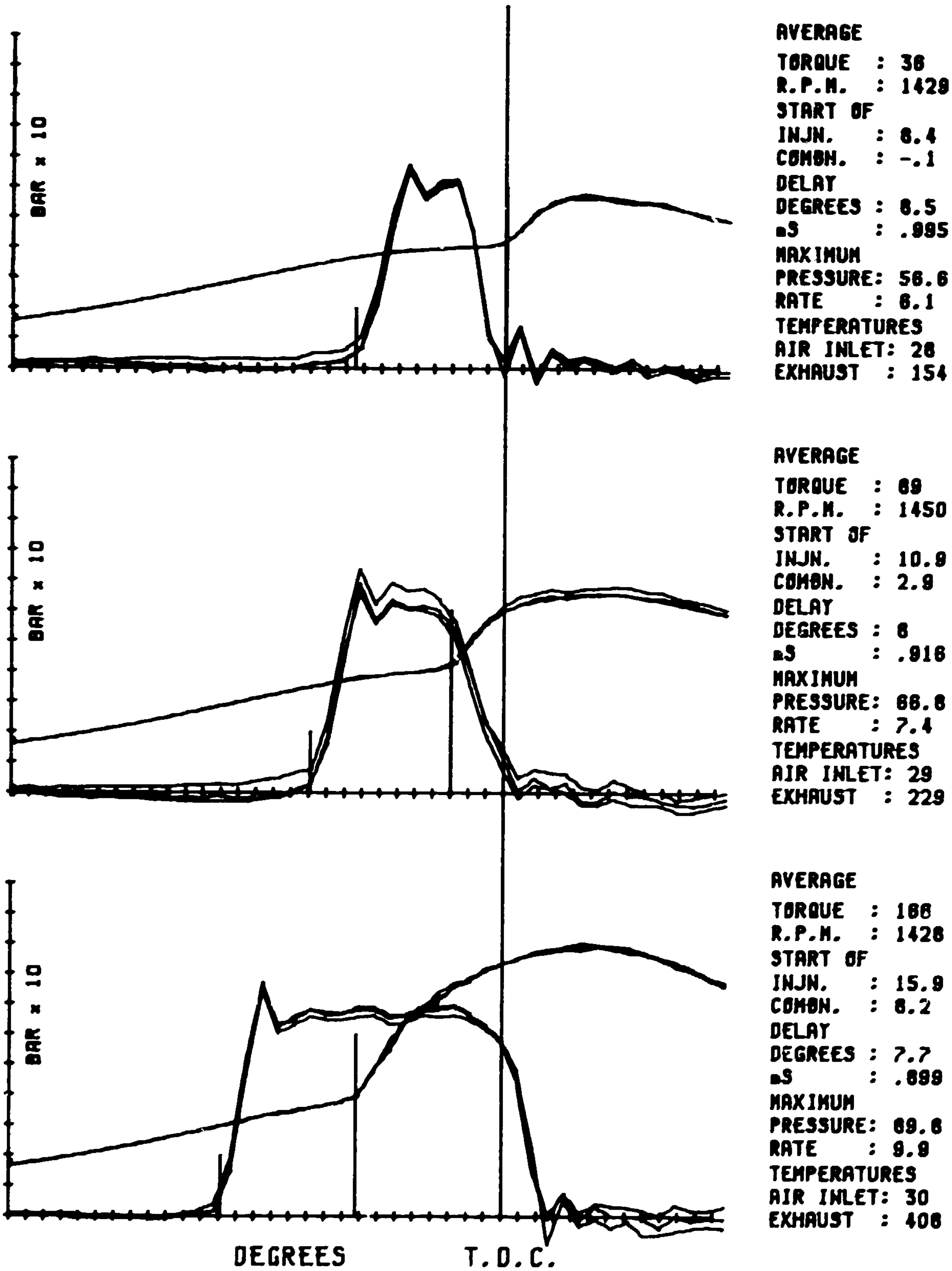
AVERAGE
TØRQUE : 153
R.P.M. : 2052
START ØF
INJN. : 14.2
CØMBN. : 4.6
DELAY
DEGREES : 9.6
mS : .777
MAXIMUM
PRESSURE: 61.5
RATE : 10.1
TEMPERATURES
AIR INLET: 29
EXHAUST : 424

ENGINE : FØRD 3000
CAPACITY : 2860
TEST ID. : UNID012

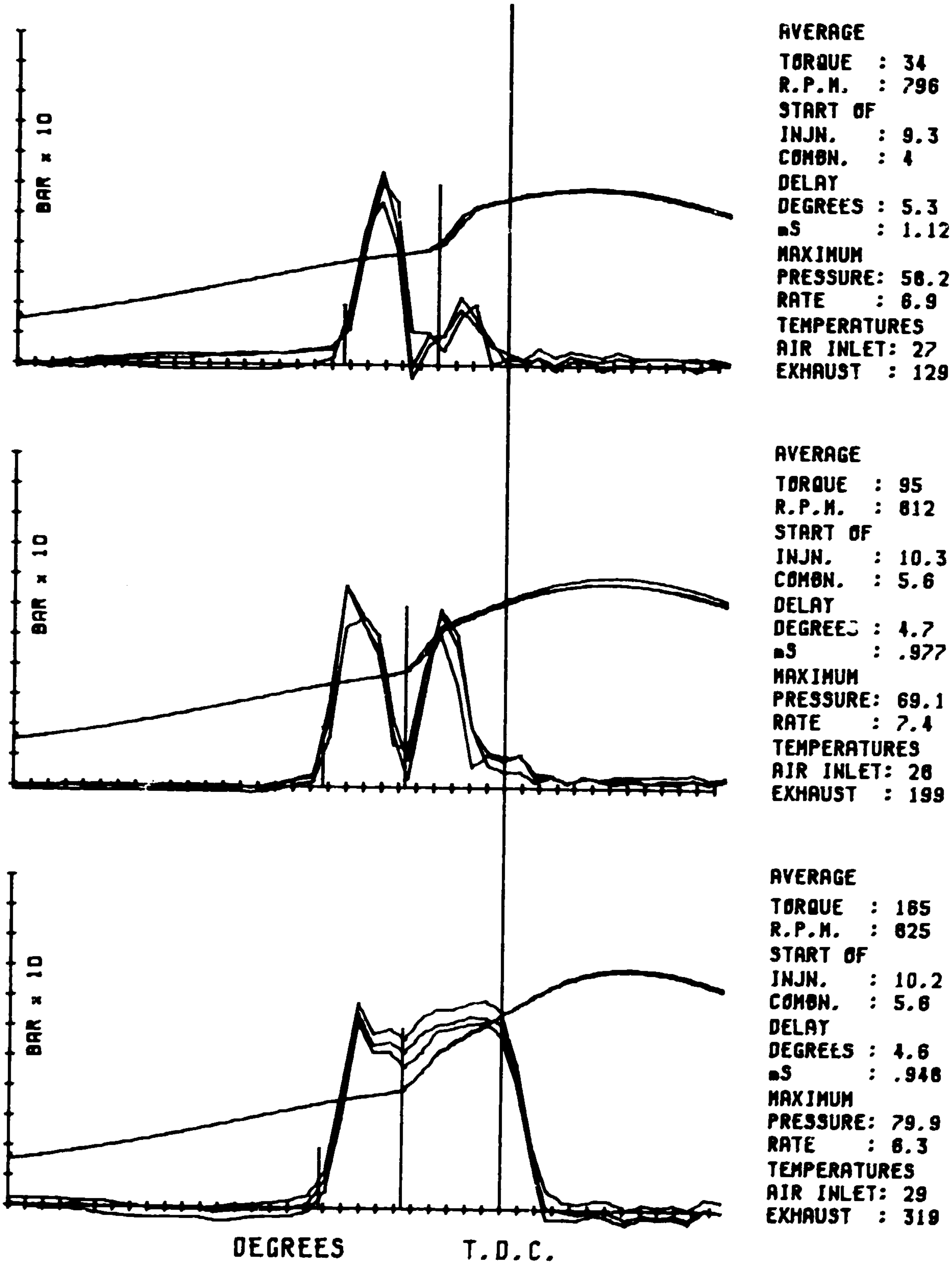
FUEL ID : DIST 100
C.V. : 42.75
DENSITY : .849

REPEATABILITY ØF NEEDLE LIFT AND CYLINDER PRESSURE

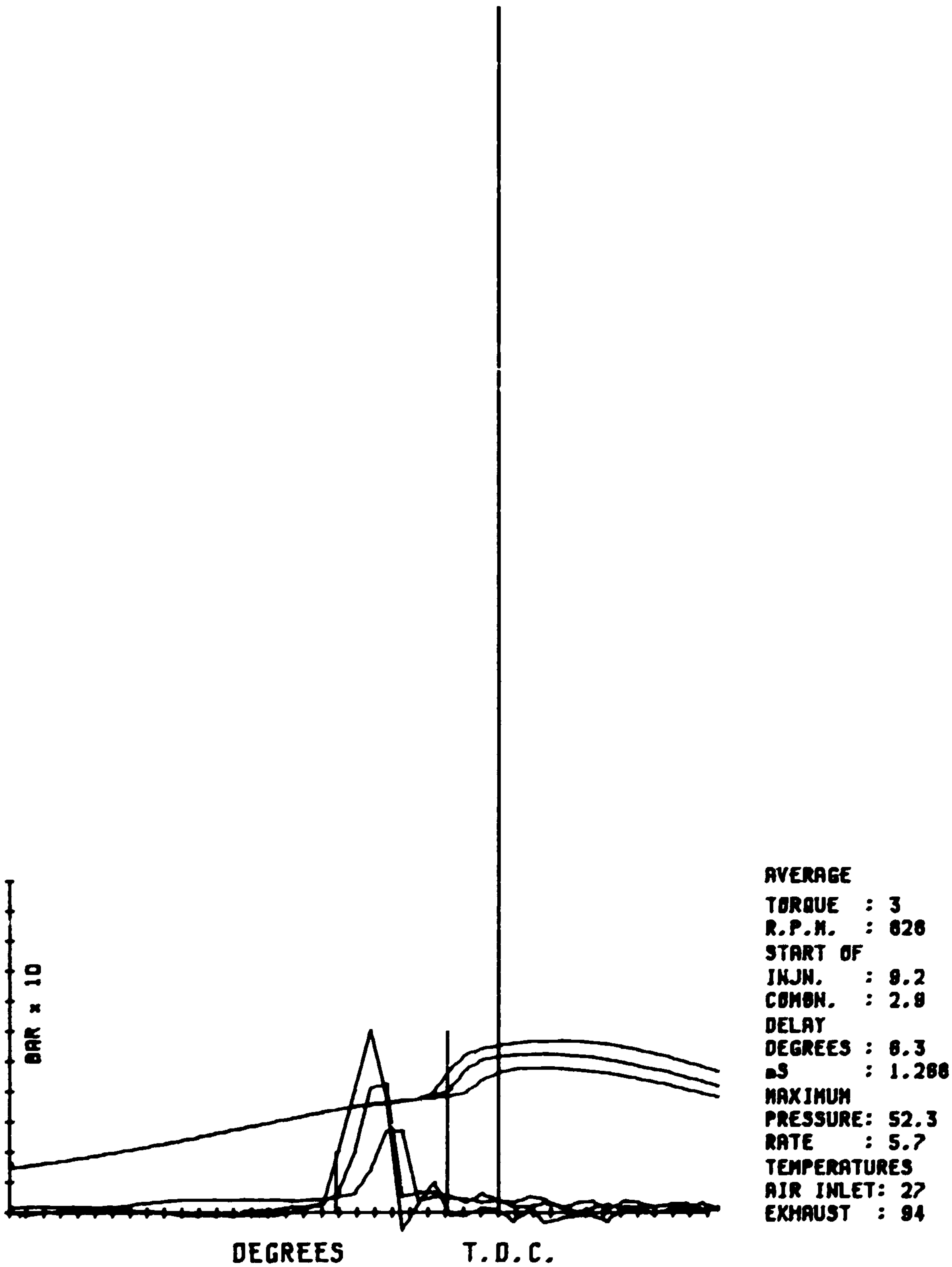
FIG AP57



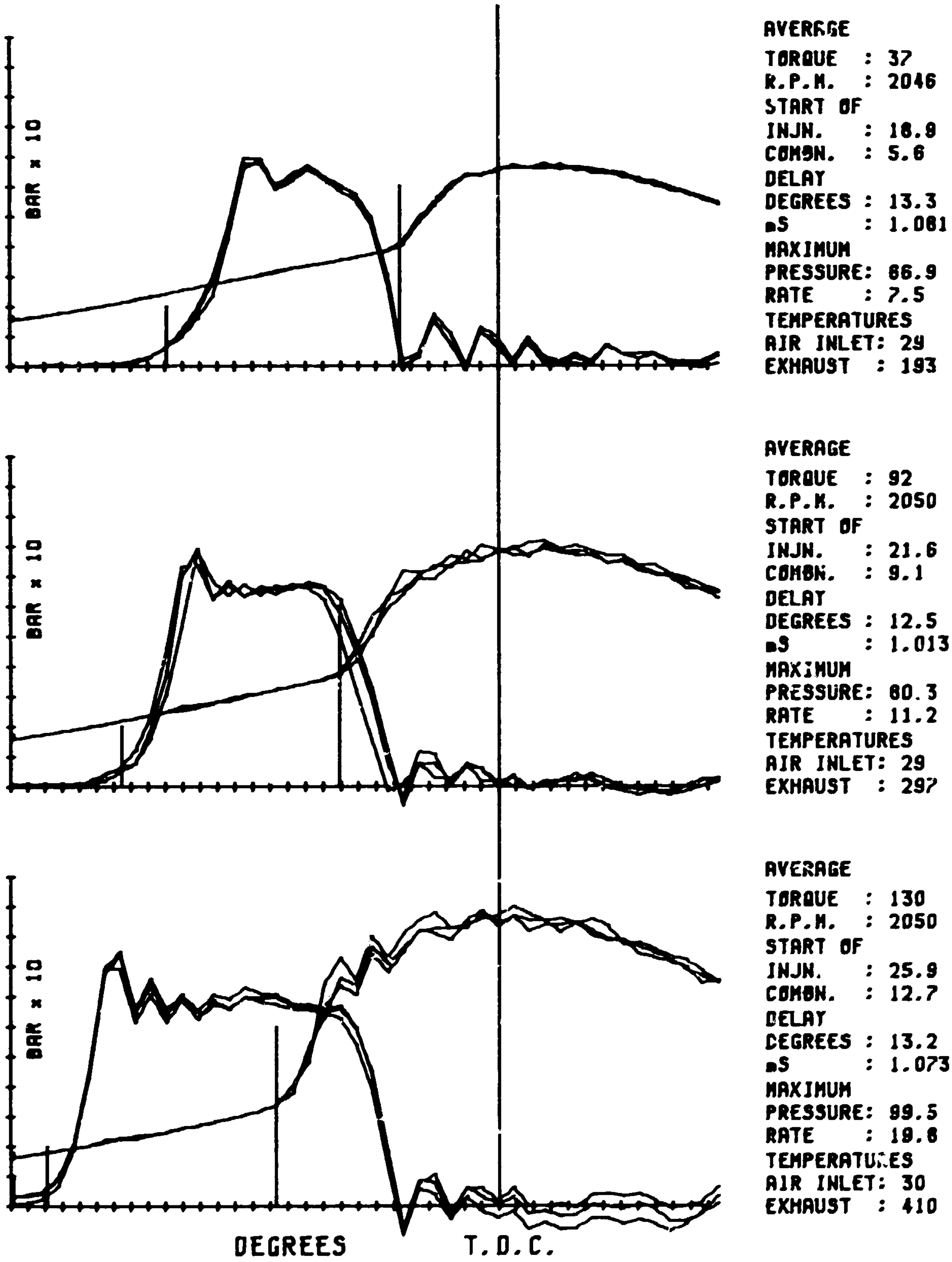
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNI0012	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP58



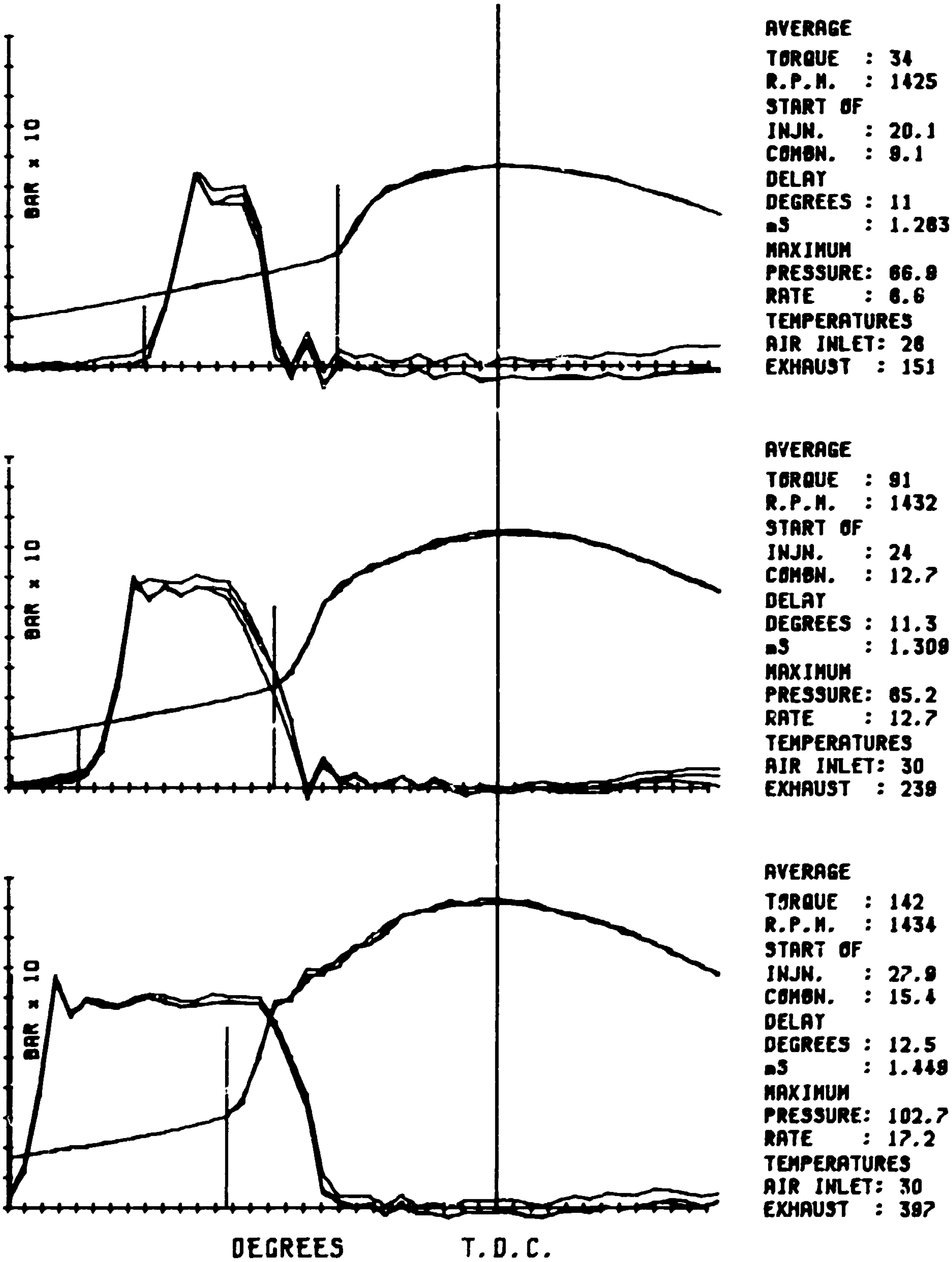
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID012	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP59



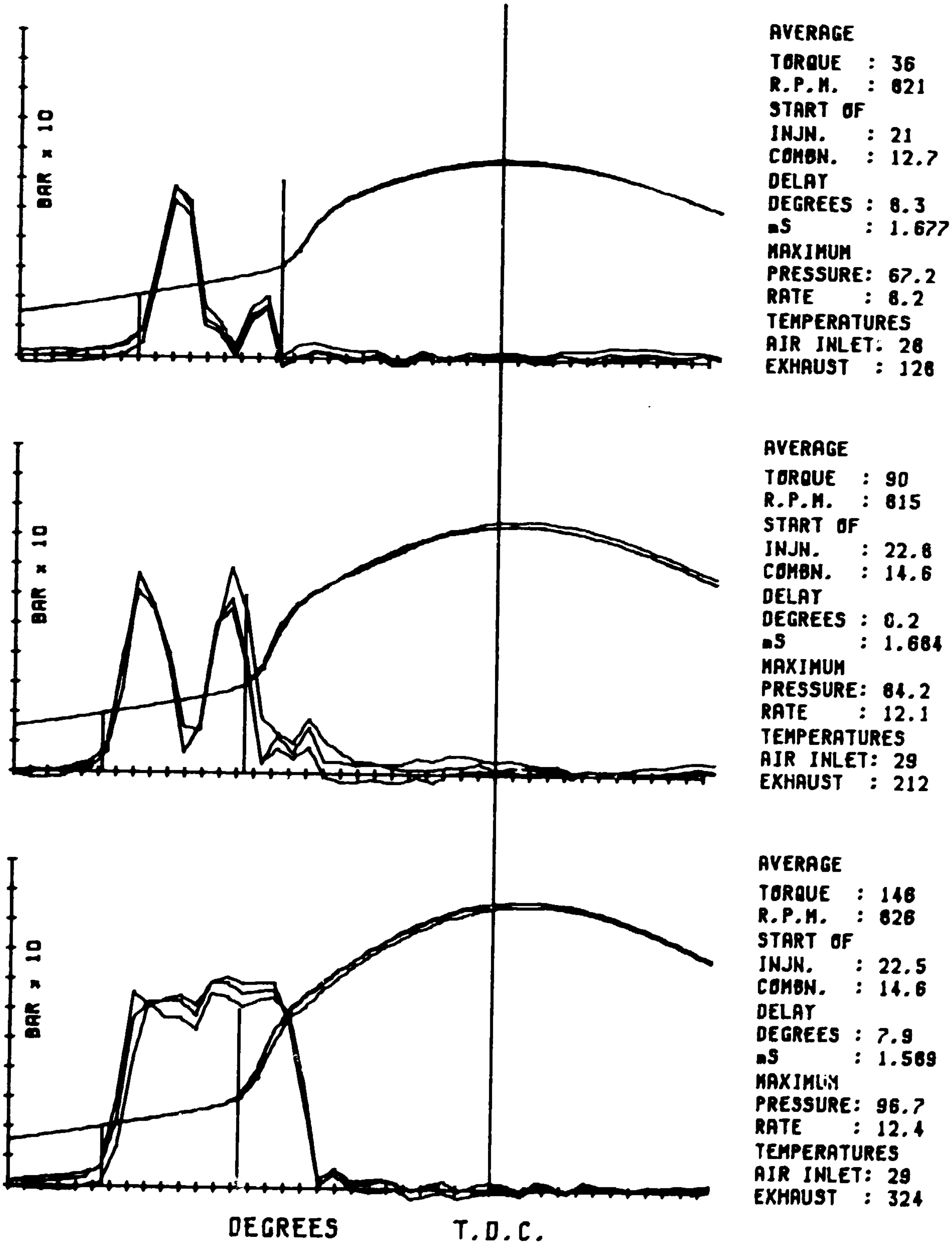
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID012	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP60



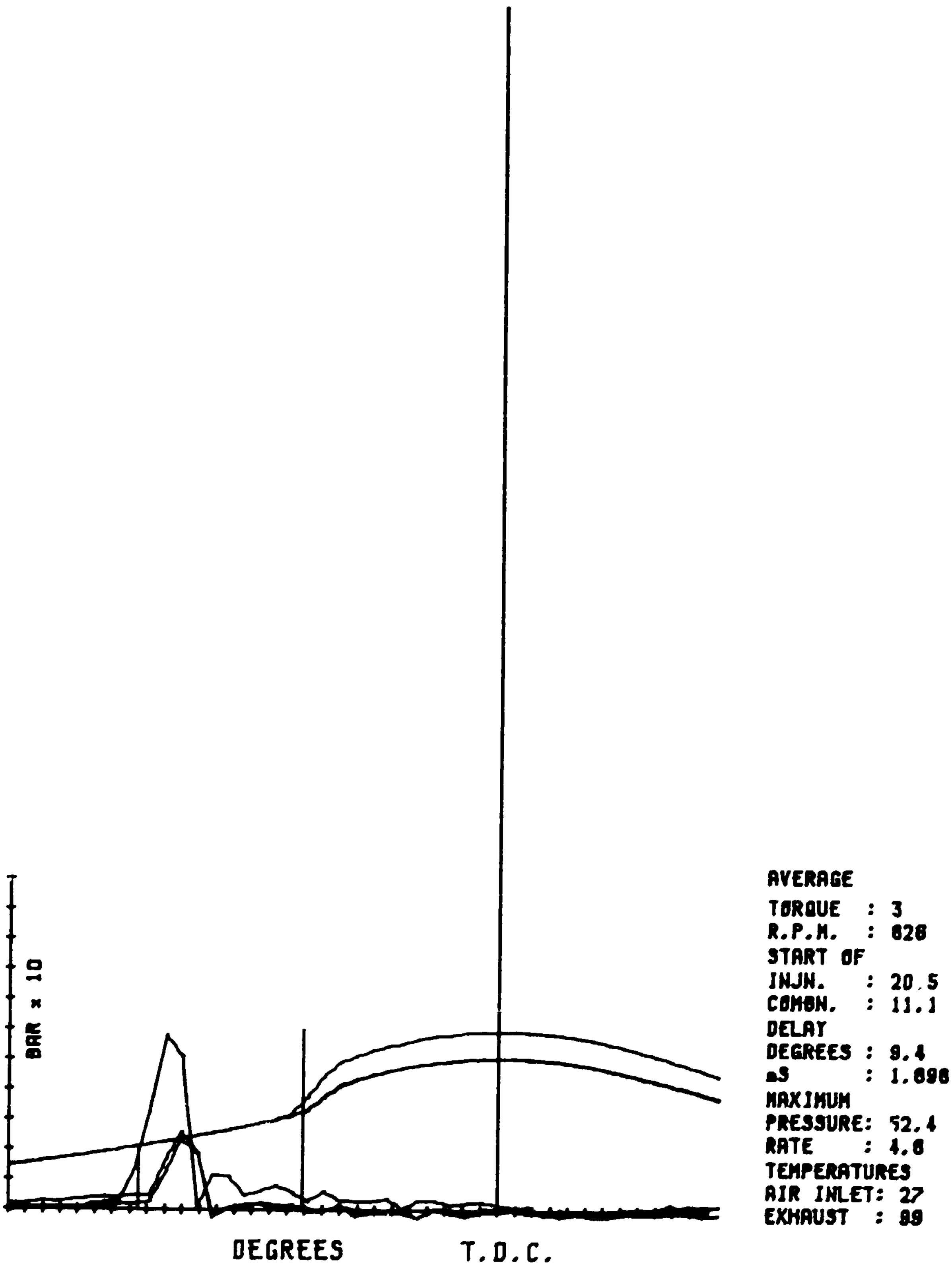
ENGINE : FØRD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNI0011	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP61



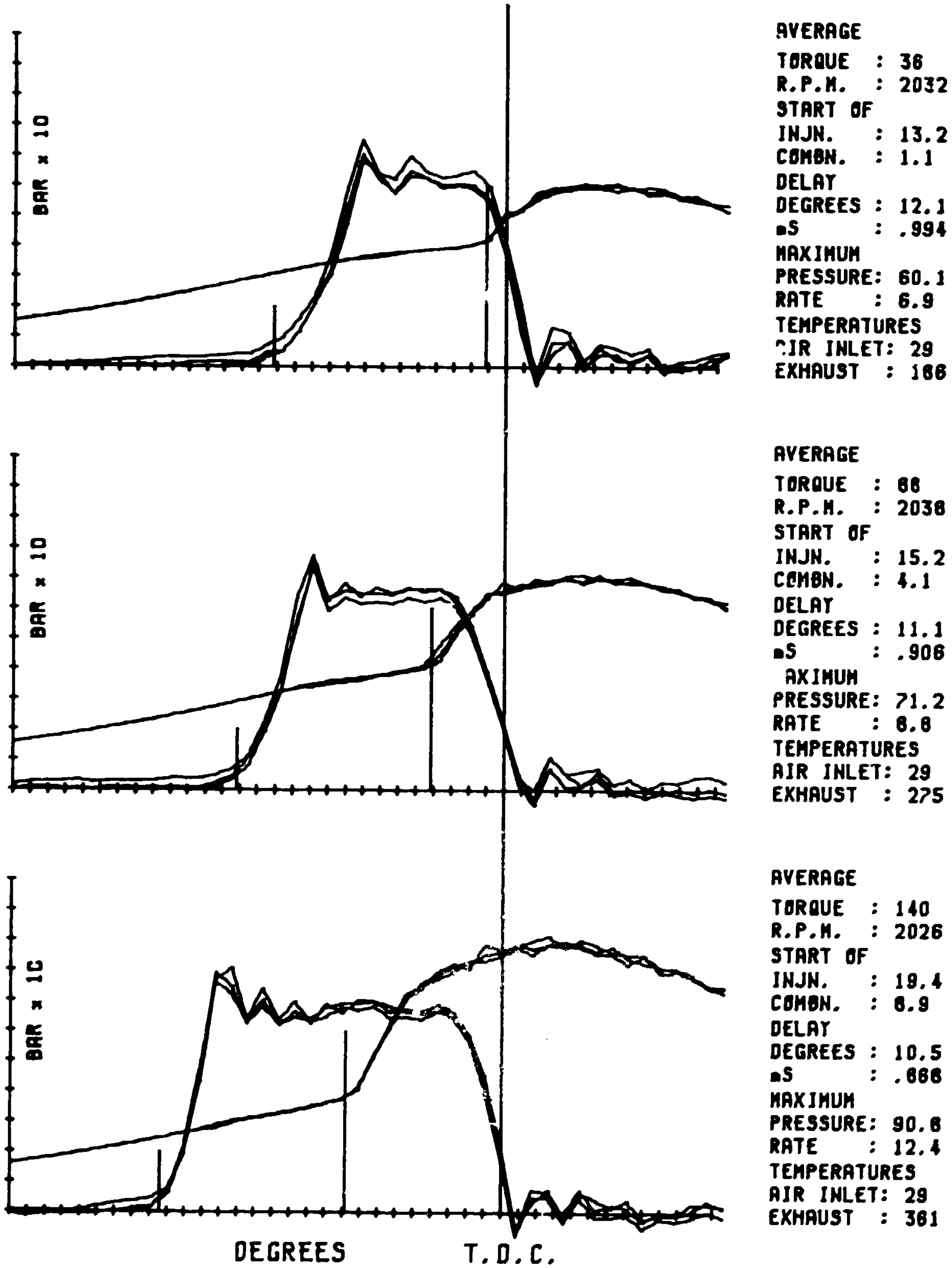
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID011	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP62



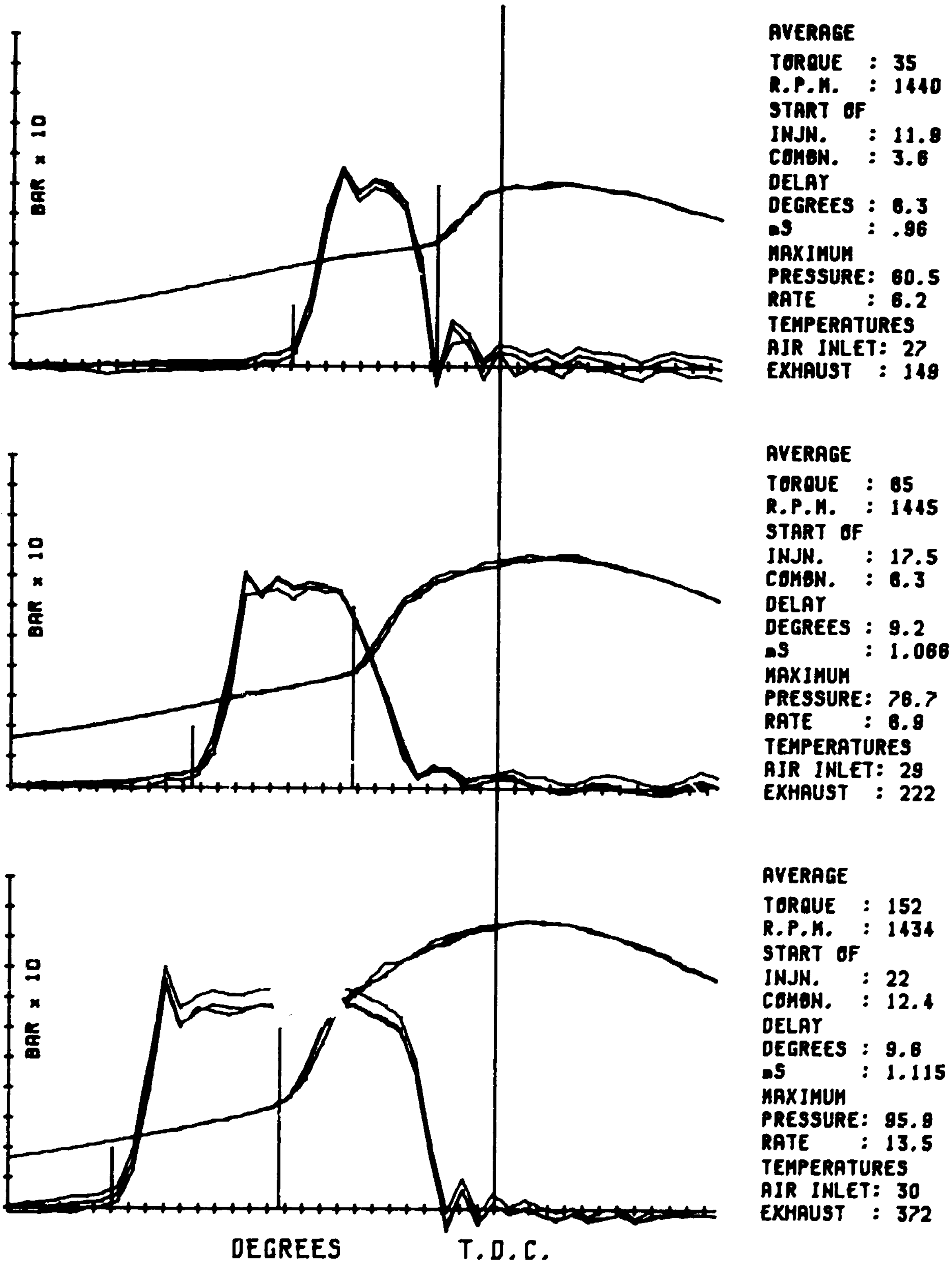
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID011	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP63



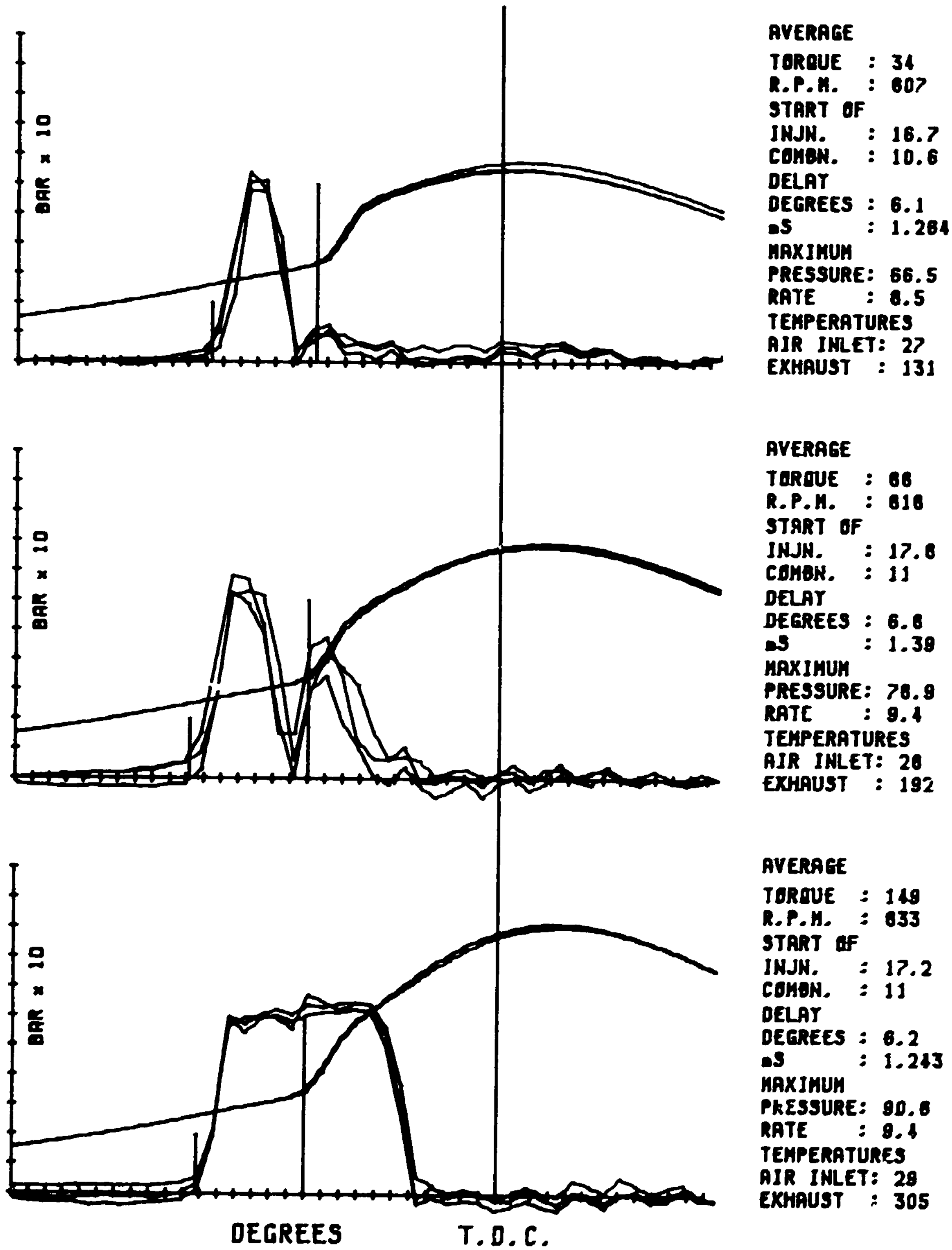
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID011	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP64



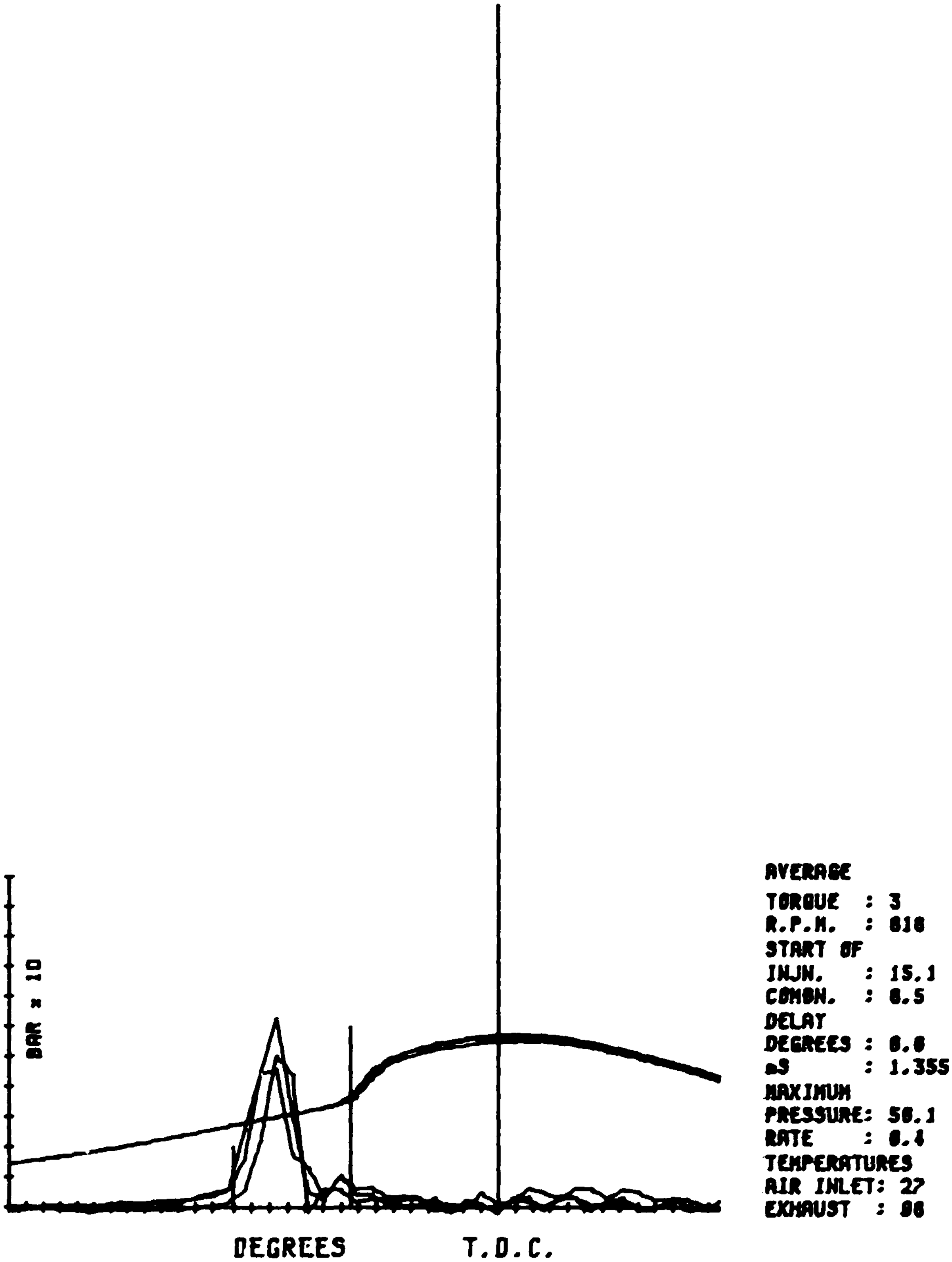
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .846
TEST ID. : UNID014	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP65



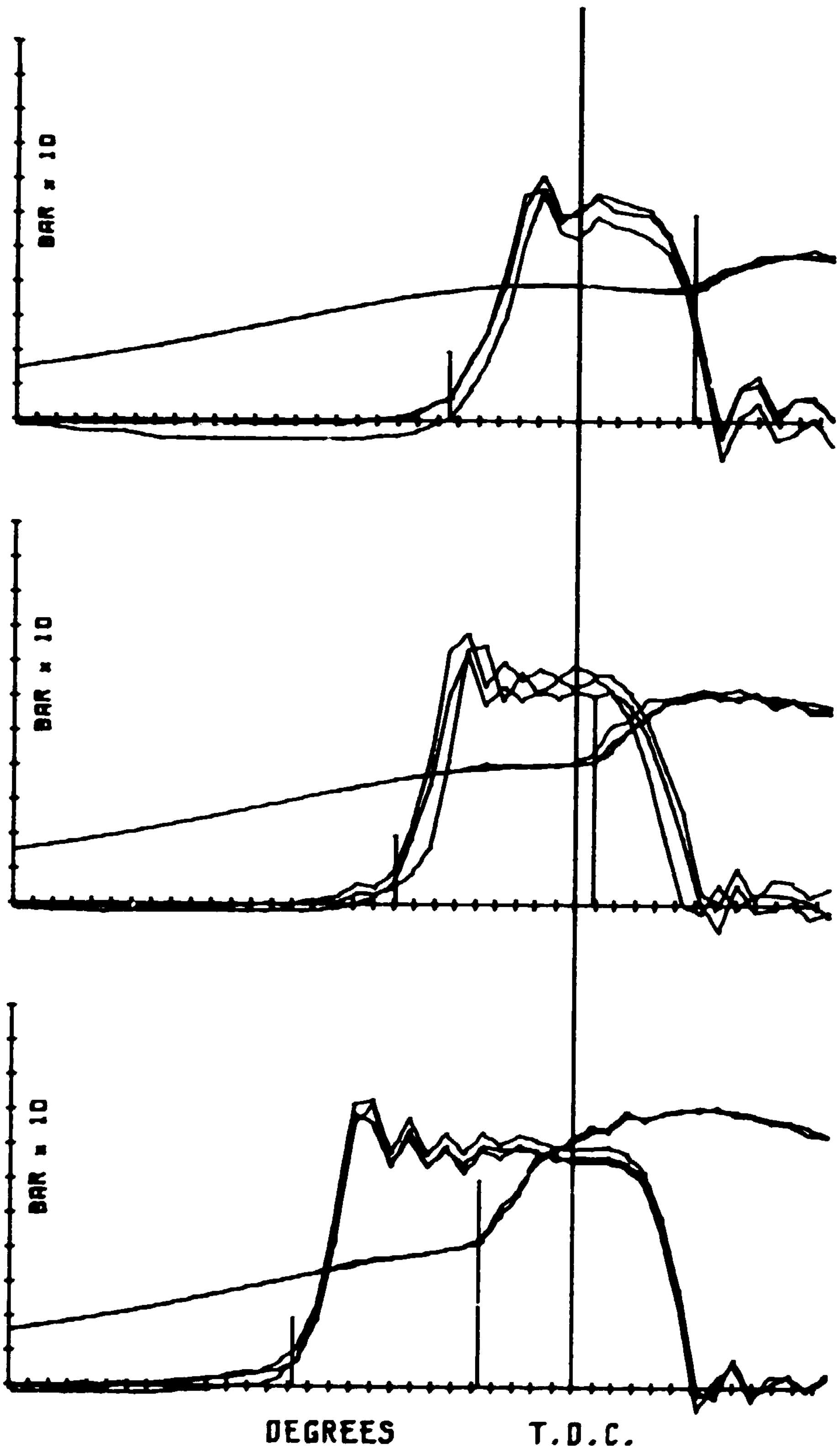
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .846
TEST ID. : UNID014	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP66



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID014	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP67



ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID014	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP68

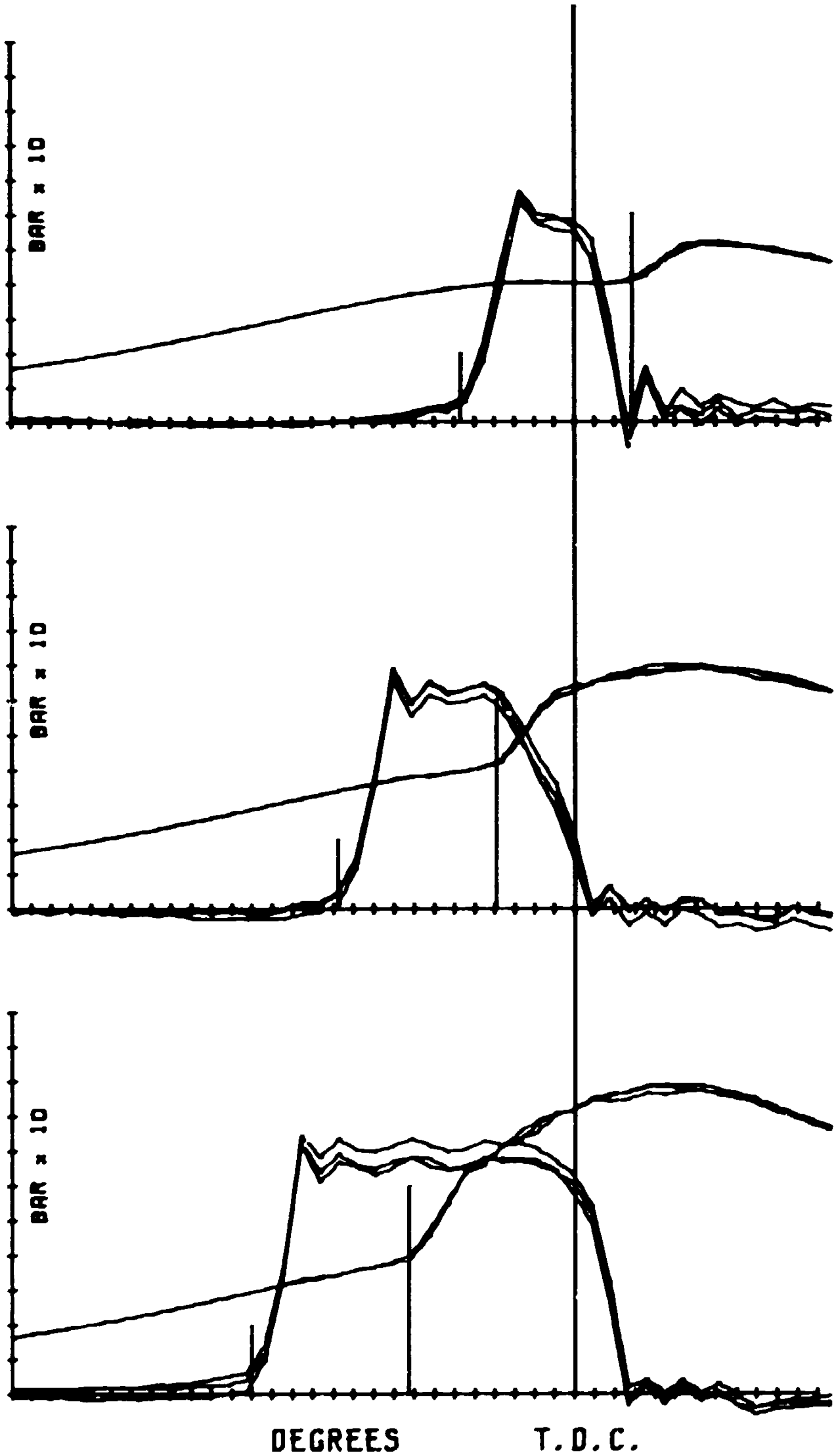


AVERAGE
TORQUE : 33
R.P.M. : 2044
START OF
INJN. : 6.4
COMBN. : -5.8
DELAY
DEGREES : 12.2
mS : .995
MAXIMUM
PRESSURE: 48.7
RATE : 3.3
TEMPERATURES
AIR INLET: 28
EXHAUST : 180

AVERAGE
TORQUE : 87
R.P.M. : 2042
START OF
INJN. : 9
COMBN. : -.9
DELAY
DEGREES : 9.9
mS : .803
MAXIMUM
PRESSURE: 81.3
RATE : 5.9
TEMPERATURES
AIR INLET: 28
EXHAUST : 277

AVERAGE
TORQUE : 149
R.P.M. : 2030
START OF
INJN. : 13.8
COMBN. : 4.7
DELAY
DEGREES : 9.1
mS : .75
MAXIMUM
PRESSURE: 81.5
RATE : 8.4
TEMPERATURES
AIR INLET: 29
EXHAUST : 378

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID013	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP69

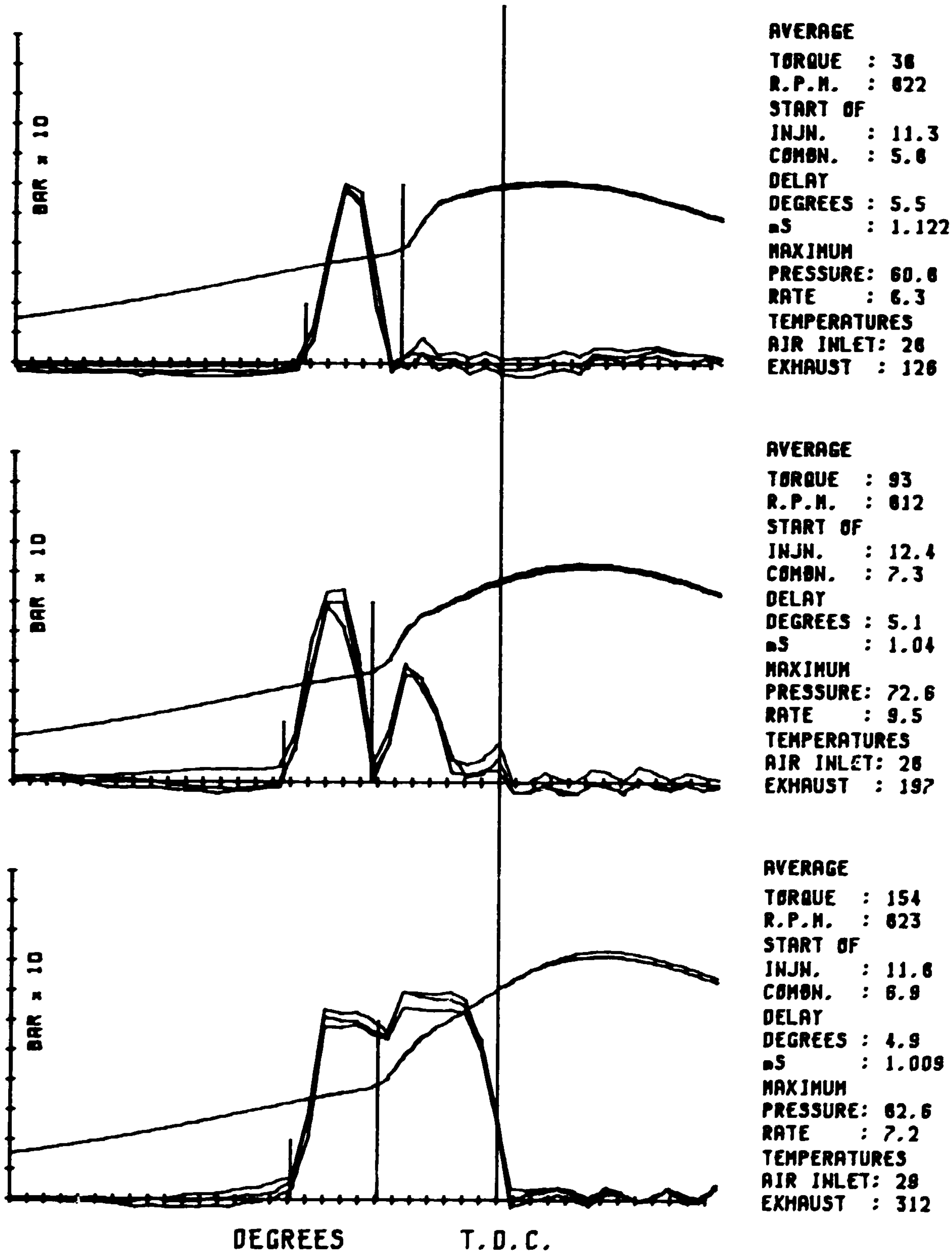


AVERAGE
TØRQUE : 34
R.P.M. : 1432
START ØF
INJN. : 5.0
CØMBN. : -2.0
DELAY
DEGREES : 6.5
mS : .001
MAXIMUM
PRESSURE: 51.0
RATE : 4.1
TEMPERATURES
AIR INLET: 27
EXHAUST : 150

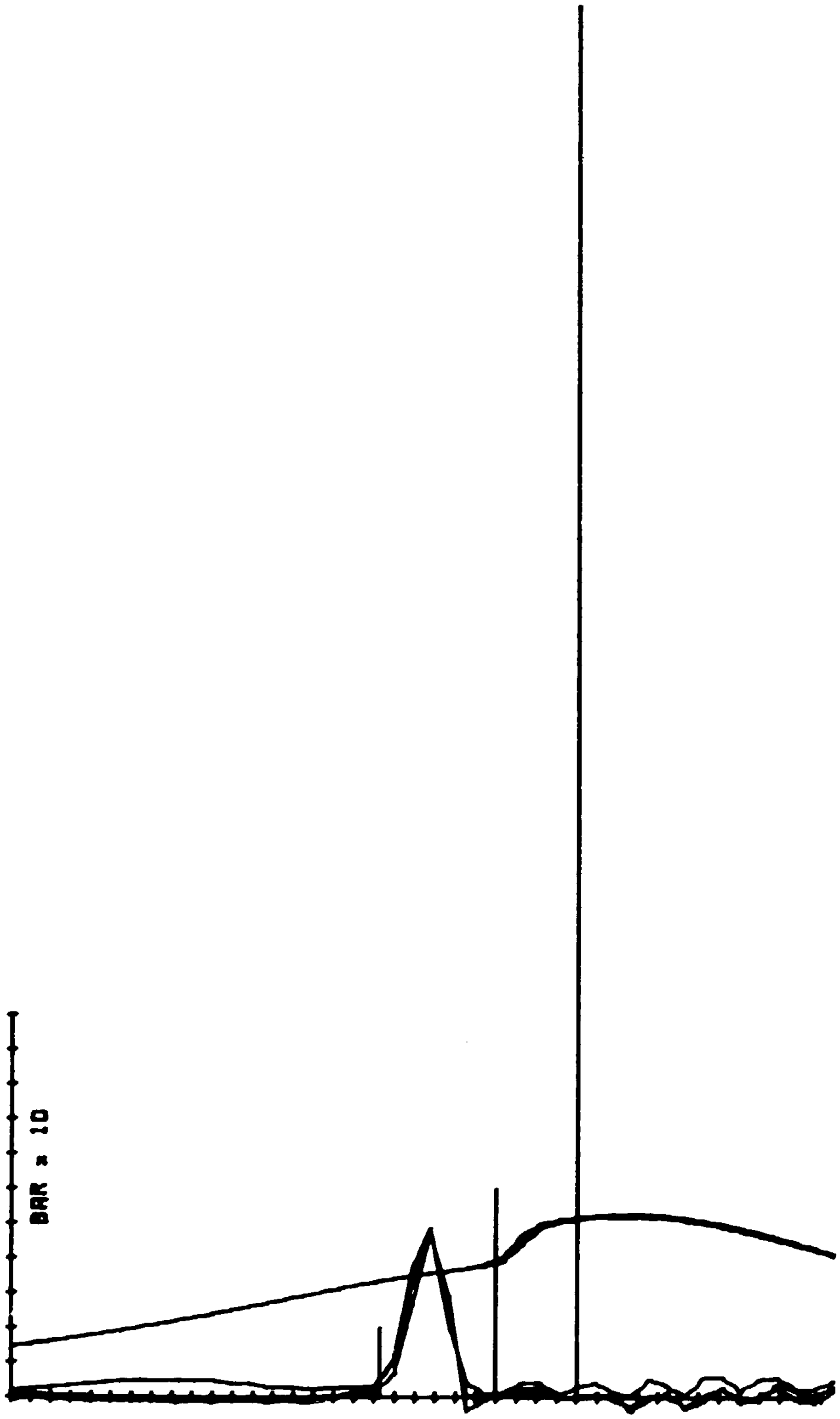
AVERAGE
TØRQUE : 92
R.P.M. : 1440
START ØF
INJN. : 11.0
CØMBN. : 3.9
DELAY
DEGREES : 7.9
mS : .915
MAXIMUM
PRESSURE: 69.0
RATE : 7.5
TEMPERATURES
AIR INLET: 28
EXHAUST : 229

AVERAGE
TØRQUE : 159
R.P.M. : 1446
START ØF
INJN. : 10
CØMBN. : 6.2
DELAY
DEGREES : 7.6
mS : .695
MAXIMUM
PRESSURE: 66.6
RATE : 8.7
TEMPERATURES
AIR INLET: 30
EXHAUST : 376

ENGINE : FØRD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID013	
REPEATABILITY ØF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP70

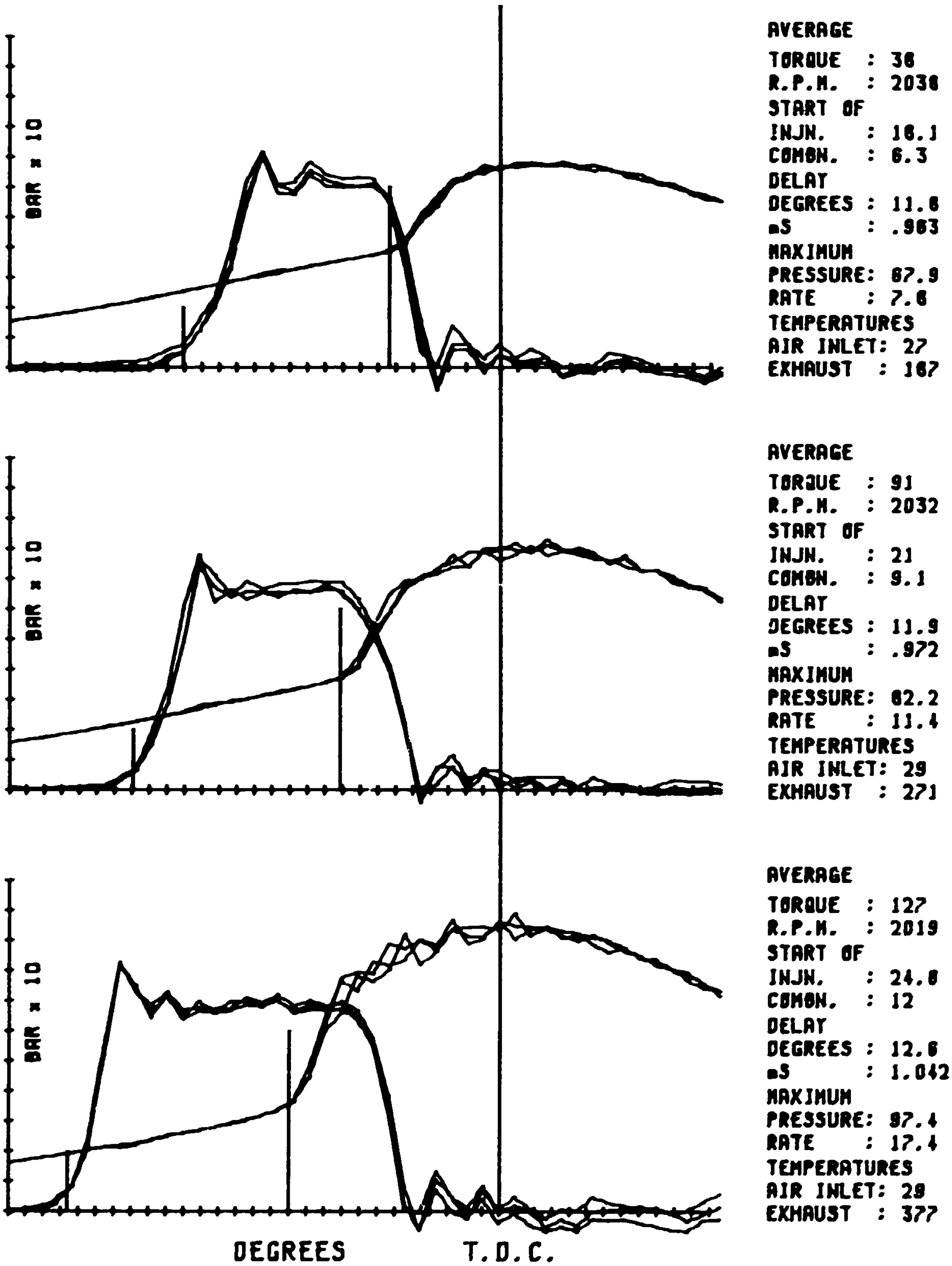


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID013	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP71

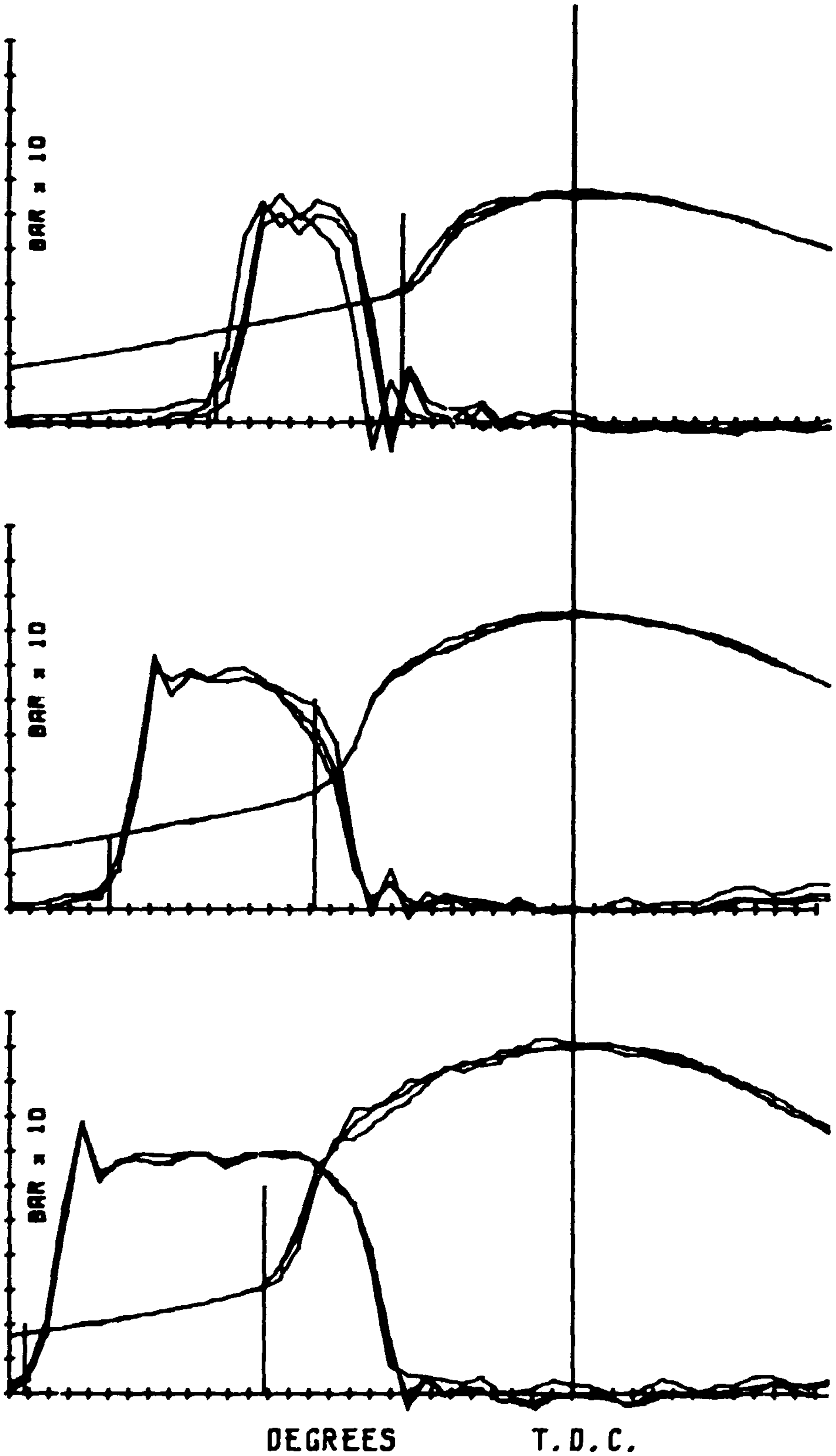


AVERAGE
TORQUE : 3
R.P.M. : 823
START OF
INJN. : 9.7
COMBN. : 4
DELAY
DEGREES : 5.7
mS : 1.152
MAXIMUM
PRESSURE: 52.1
RATE : 5.2
TEMPERATURES
AIR INLET: 27
EXHAUST : 87

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID013	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP72



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGON3.9 C.V. : 38.35 DENSITY : .846
TEST ID. : UNID015	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP73

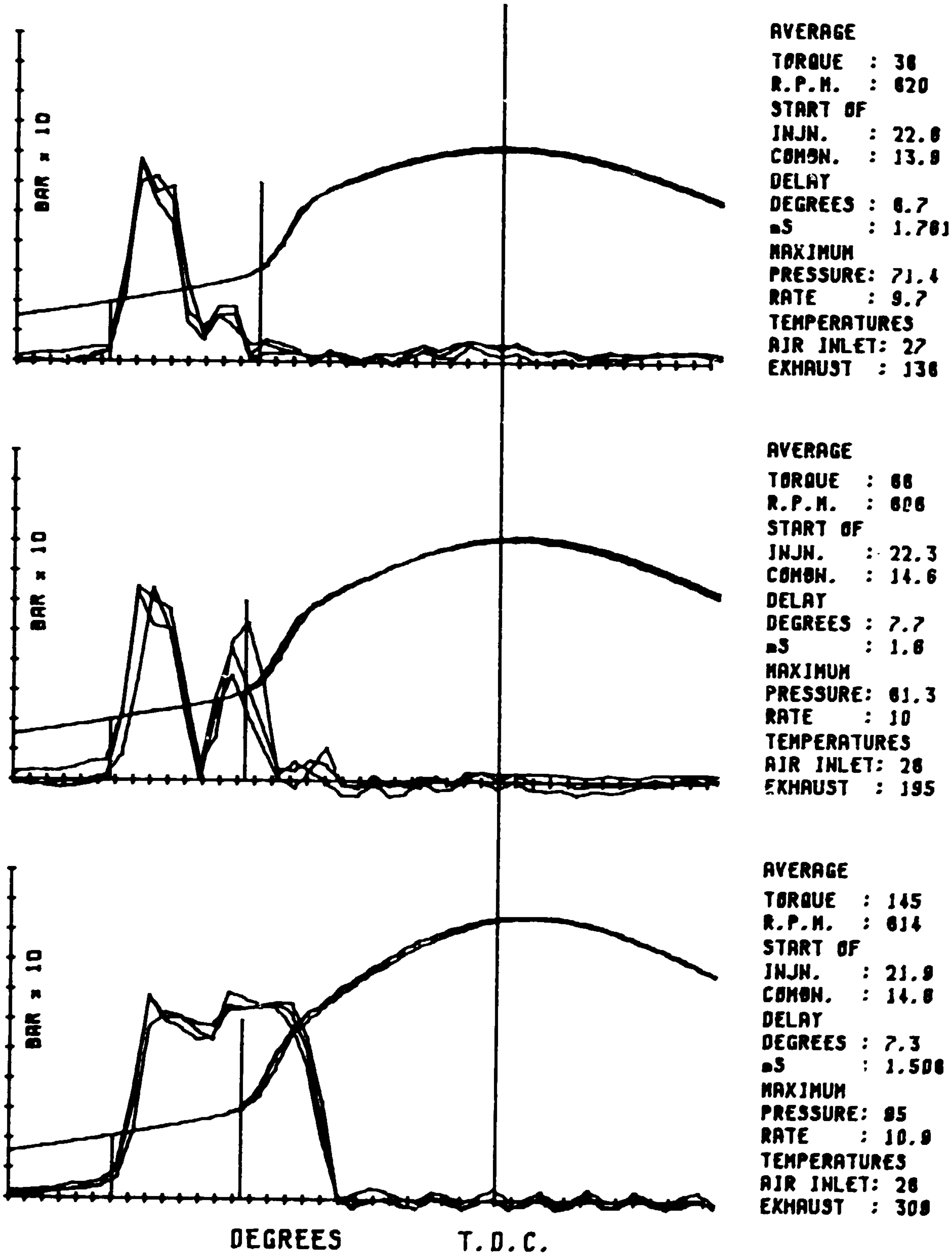


AVERAGE
TORQUE : 37
R.P.M. : 1441
START OF
INJN. : 17.6
COMBN. : 8.4
DELAY
DEGREES : 9.2
mS : 1.084
MAXIMUM
PRESSURE: 85.6
RATE : 6
TEMPERATURES
AIR INLET: 27
EXHAUST : 150

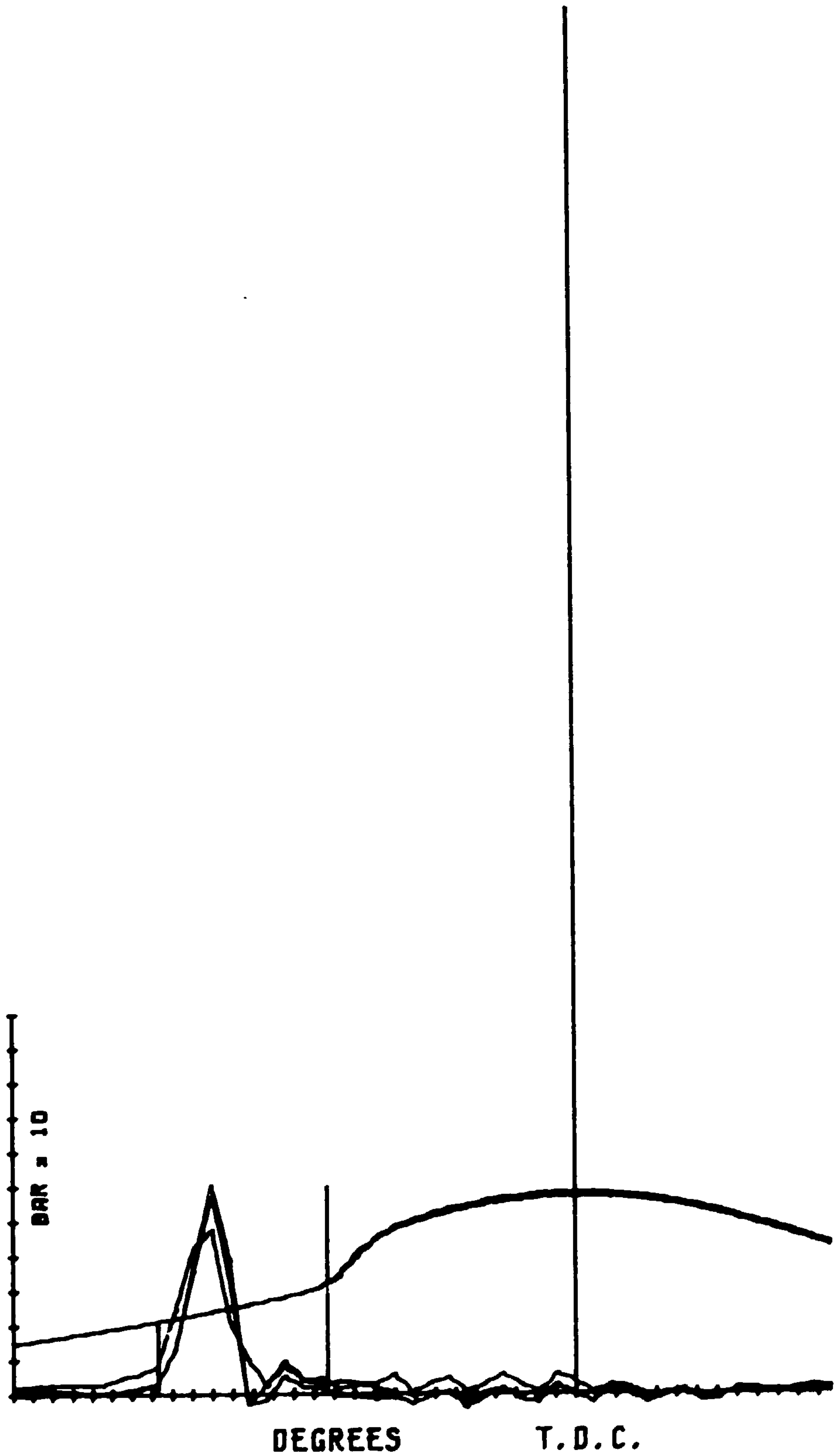
AVERAGE
TORQUE : 91
R.P.M. : 1428
START OF
INJN. : 23
COMBN. : 12.7
DELAY
DEGREES : 10.3
mS : 1.202
MAXIMUM
PRESSURE: 85.4
RATE : 13
TEMPERATURES
AIR INLET: 28
EXHAUST : 232

AVERAGE
TORQUE : 142
R.P.M. : 1447
START OF
INJN. : 27.2
COMBN. : 15.2
DELAY
DEGREES : 12
mS : 1.378
MAXIMUM
PRESSURE: 101.7
RATE : 16.2
TEMPERATURES
AIR INLET: 29
EXHAUST : 308

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID015	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP74

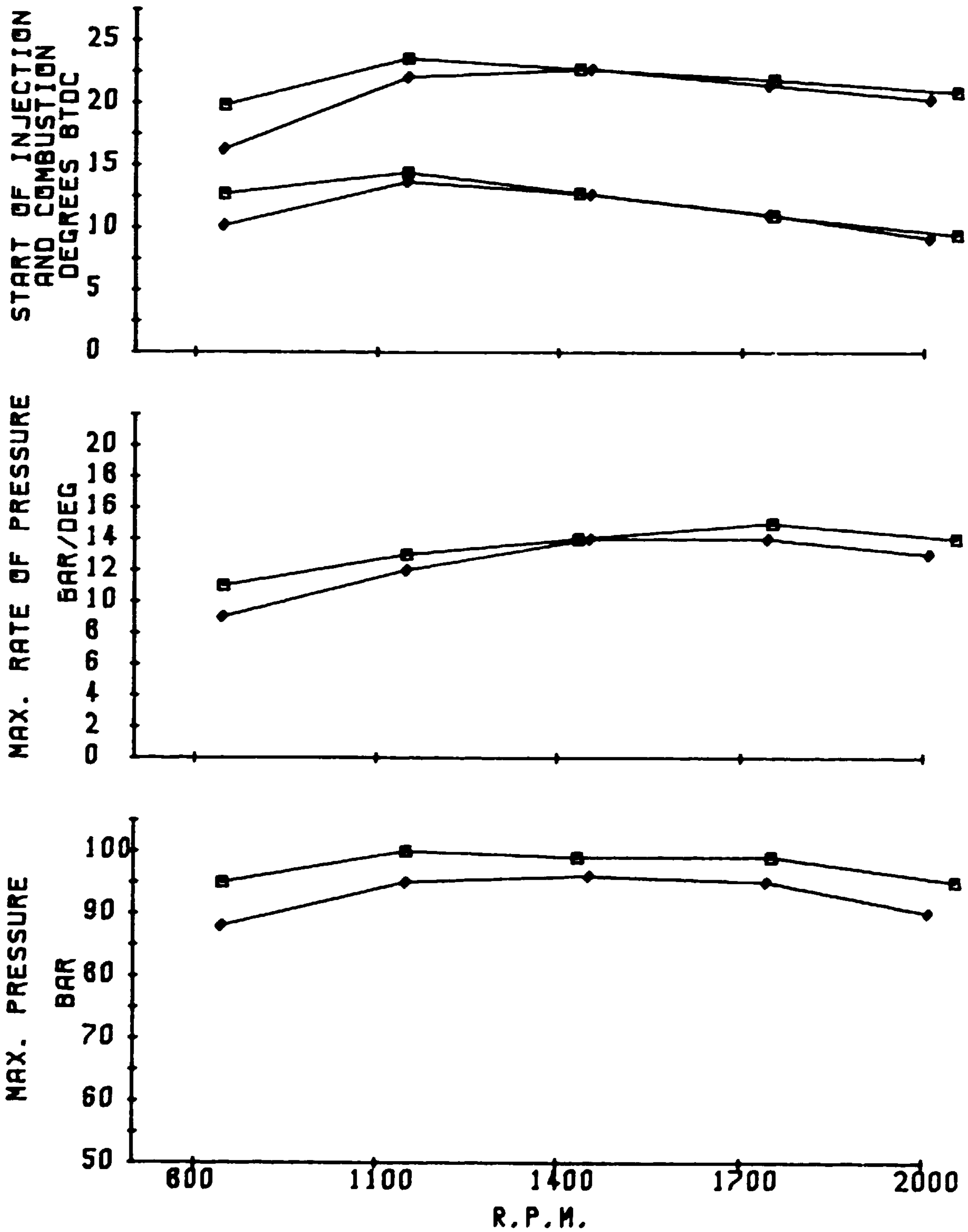


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : TEGON3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID015	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP75

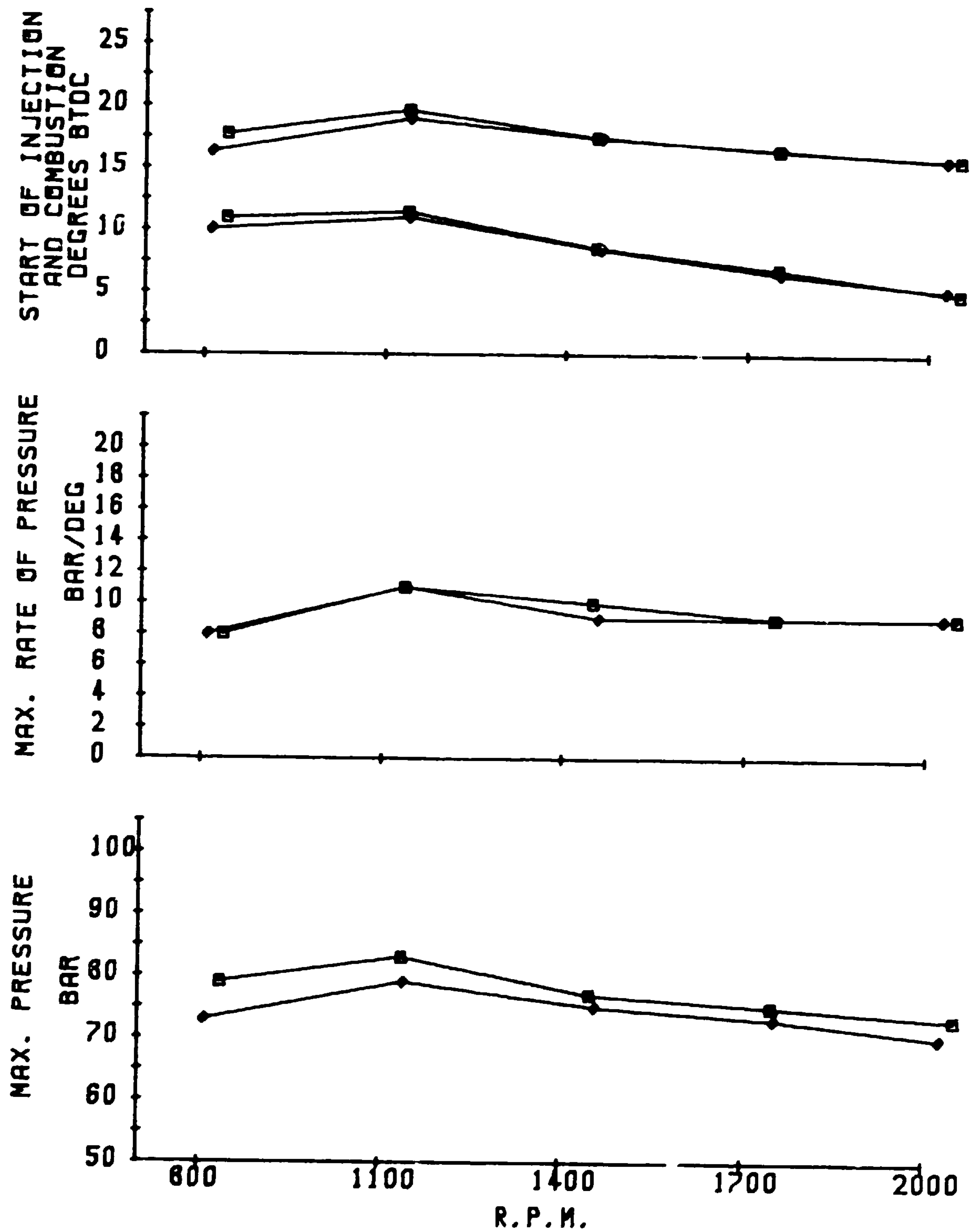


AVERAGE
TØRQUE : 3
R.P.M. : 828
START ØF
INJN. : 20.7
CØMBN. : 12.3
DELAY
DEGREES : 6.4
mS : 1.68
MAXIMUM
PRESSURE: 57.2
RATE : 5.6
TEMPERATURES
AIR INLET: 28
EXHAUST : 69

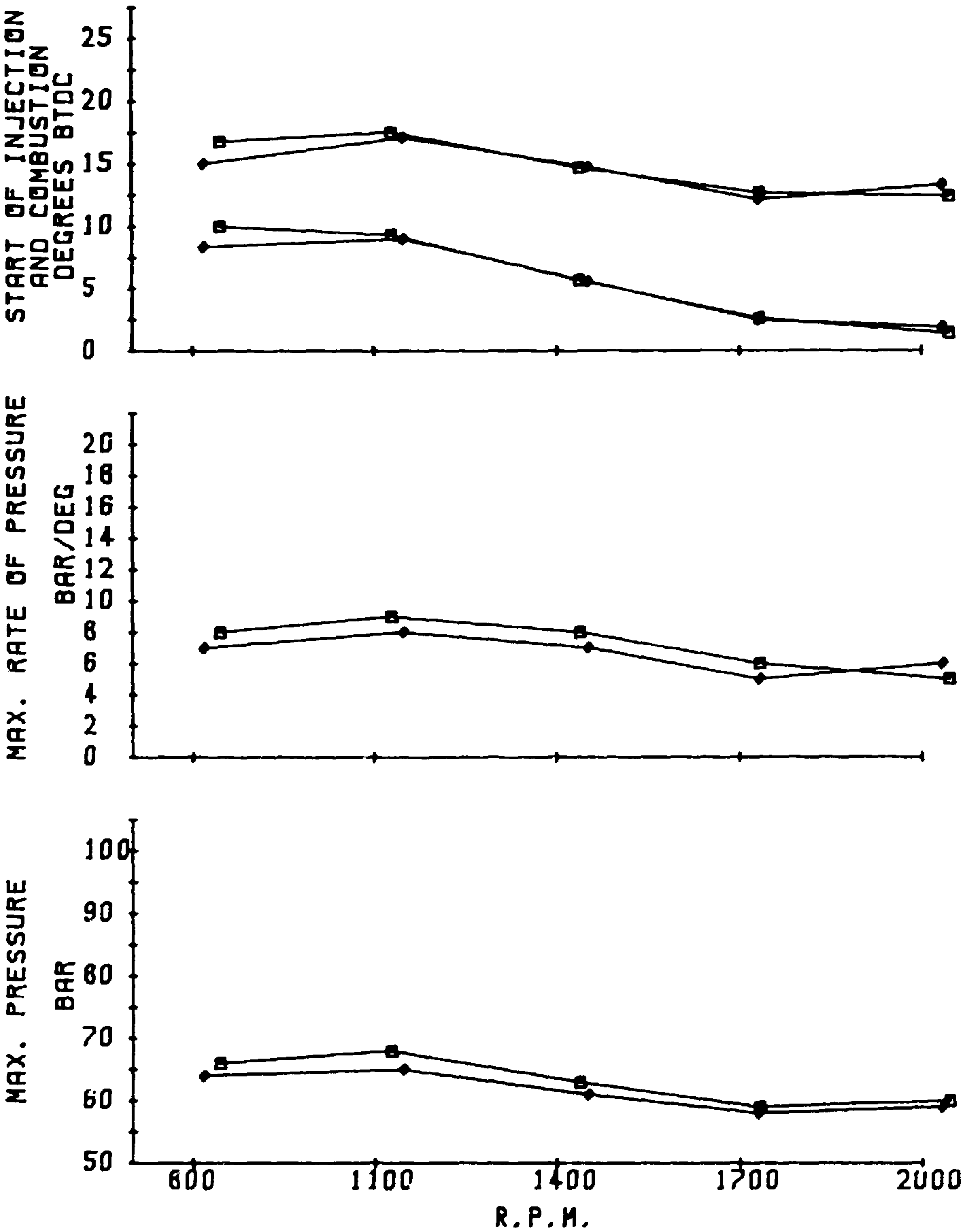
ENGINE : FØRD 3000 CAPACITY : 2660	FUEL ID : TEGDN3.9 C.V. : 38.35 DENSITY : .848
TEST ID. : UNID015	
REPEATABILITY ØF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP76



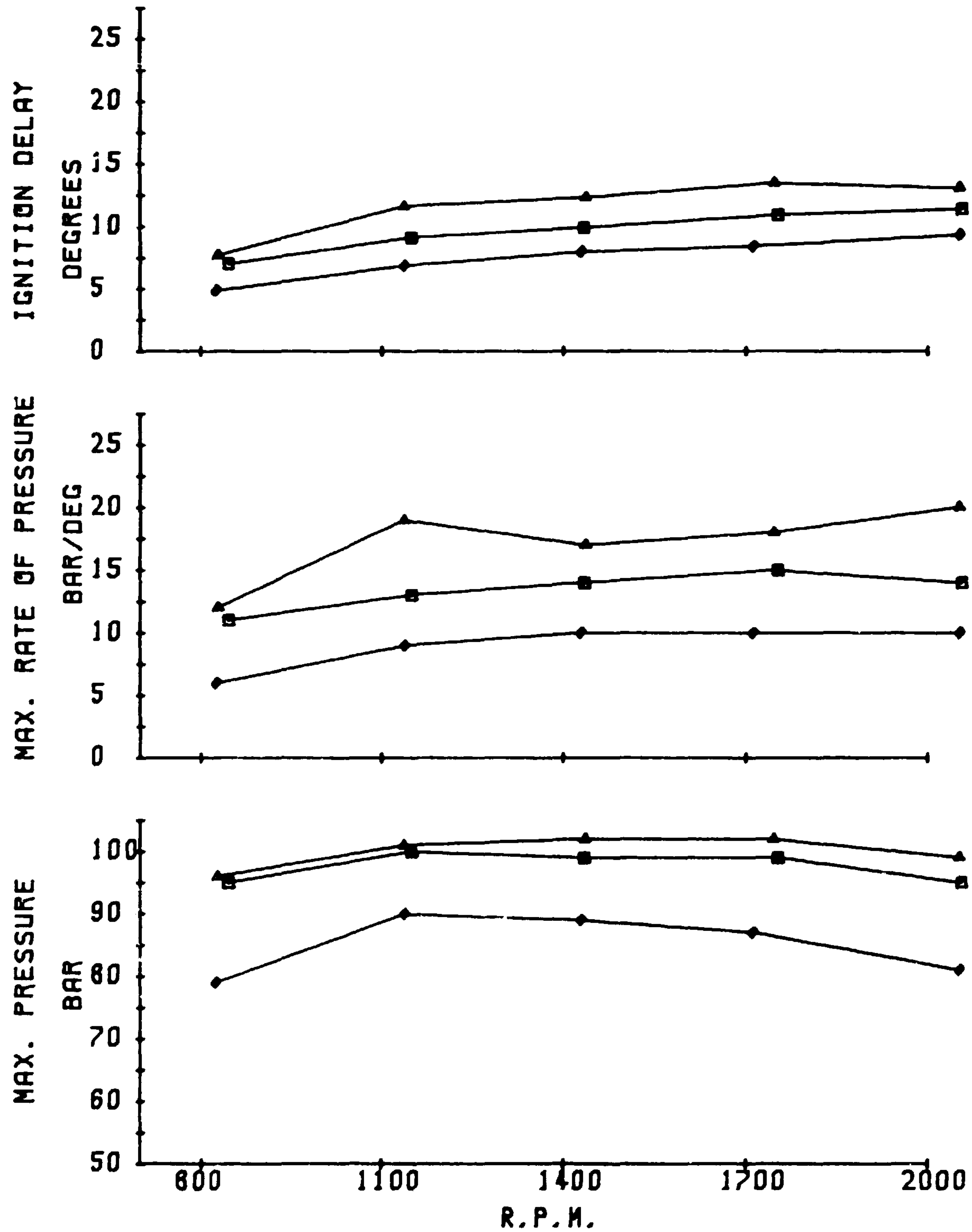
ENGINE : FORD 3000 CAPACITY: 2860	◆ 22/5/85 ▣ 10/5/85
LONG TERM DIST 100 REPEATABILITY OF START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FULL LOAD FIG AP77



ENGINE : FORD 3000 CAPACITY: 2860	◆ 22/5/85 ▪ 10/5/85
LONG TERM DIST 100 REPEATABILITY OF START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	2/3 LOAD
	FIG AP78



ENGINE : FORD 3000 CAPACITY: 2860	◆ 22/5/85 ▣ 10/5/85
LONG TERM DIST 100 REPEATABILITY OF START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	1/3 LOAD F1 AP79

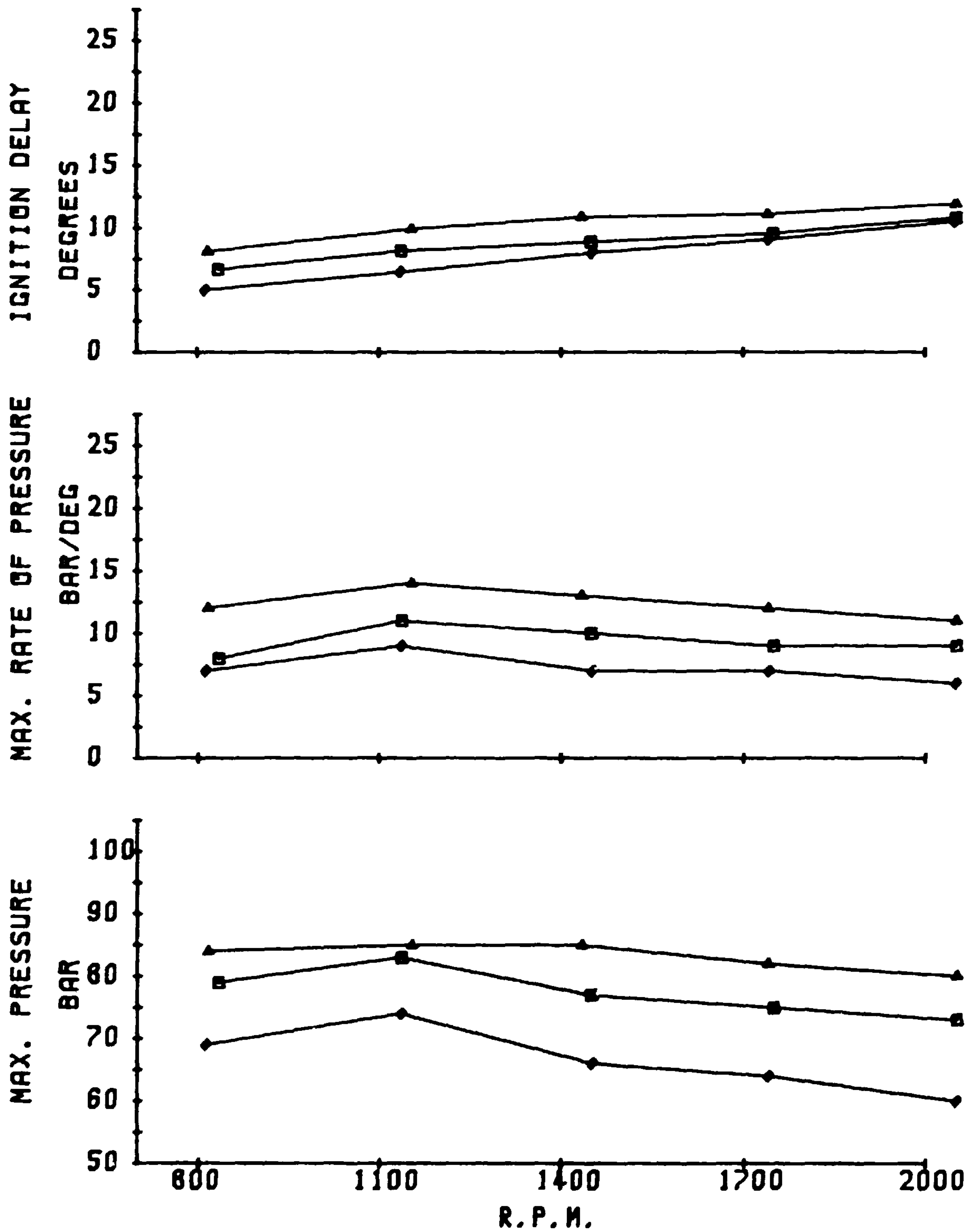


ENGINE : FORD 3000
CAPACITY: 2860

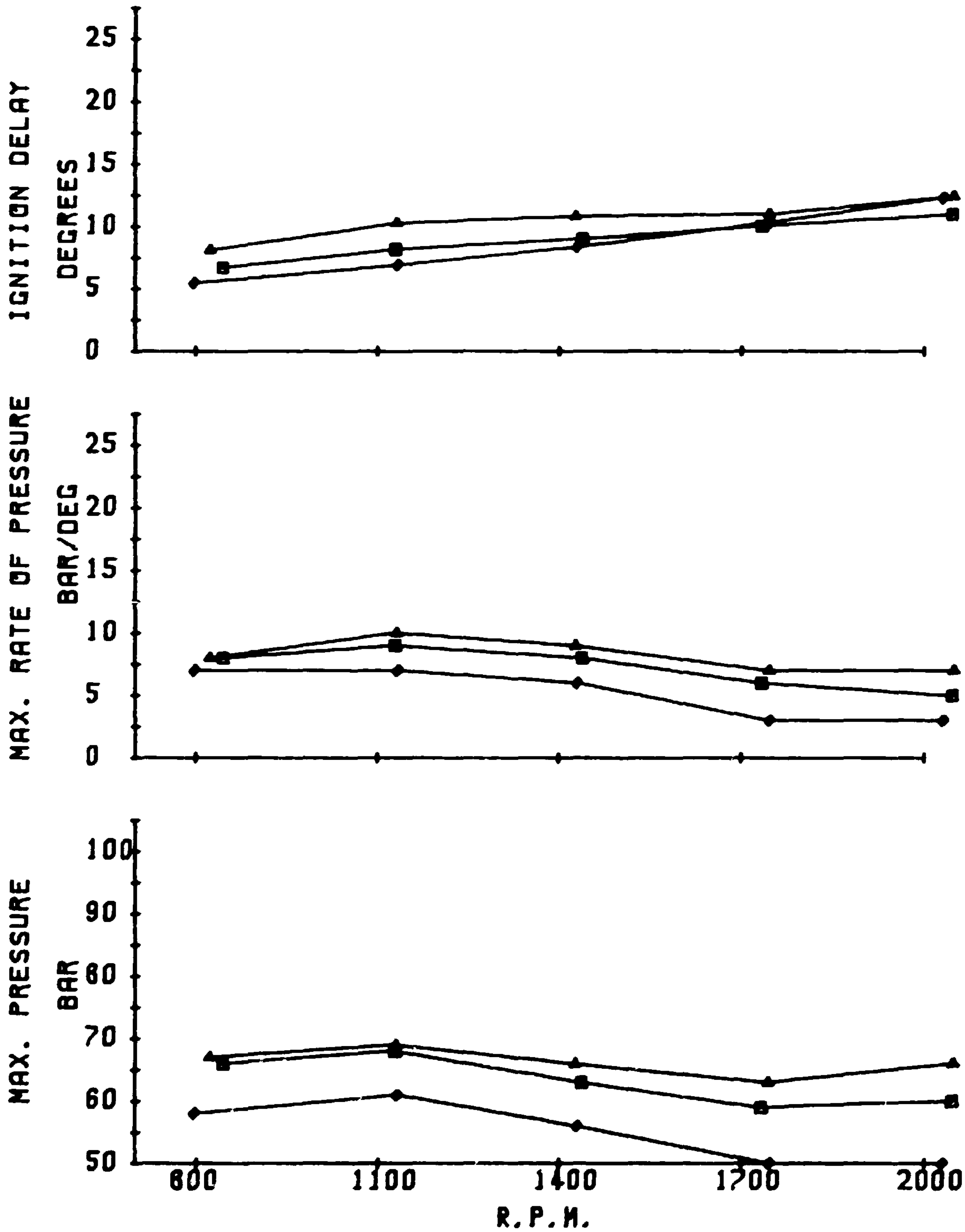
EFFECT OF STATIC TIMING ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
100 DIST
FULL LOAD

FIG AP80



ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ▣ 20 deg BTDC ▲ 26 deg BTDC 100 DIST 2/3 LOAD
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP61

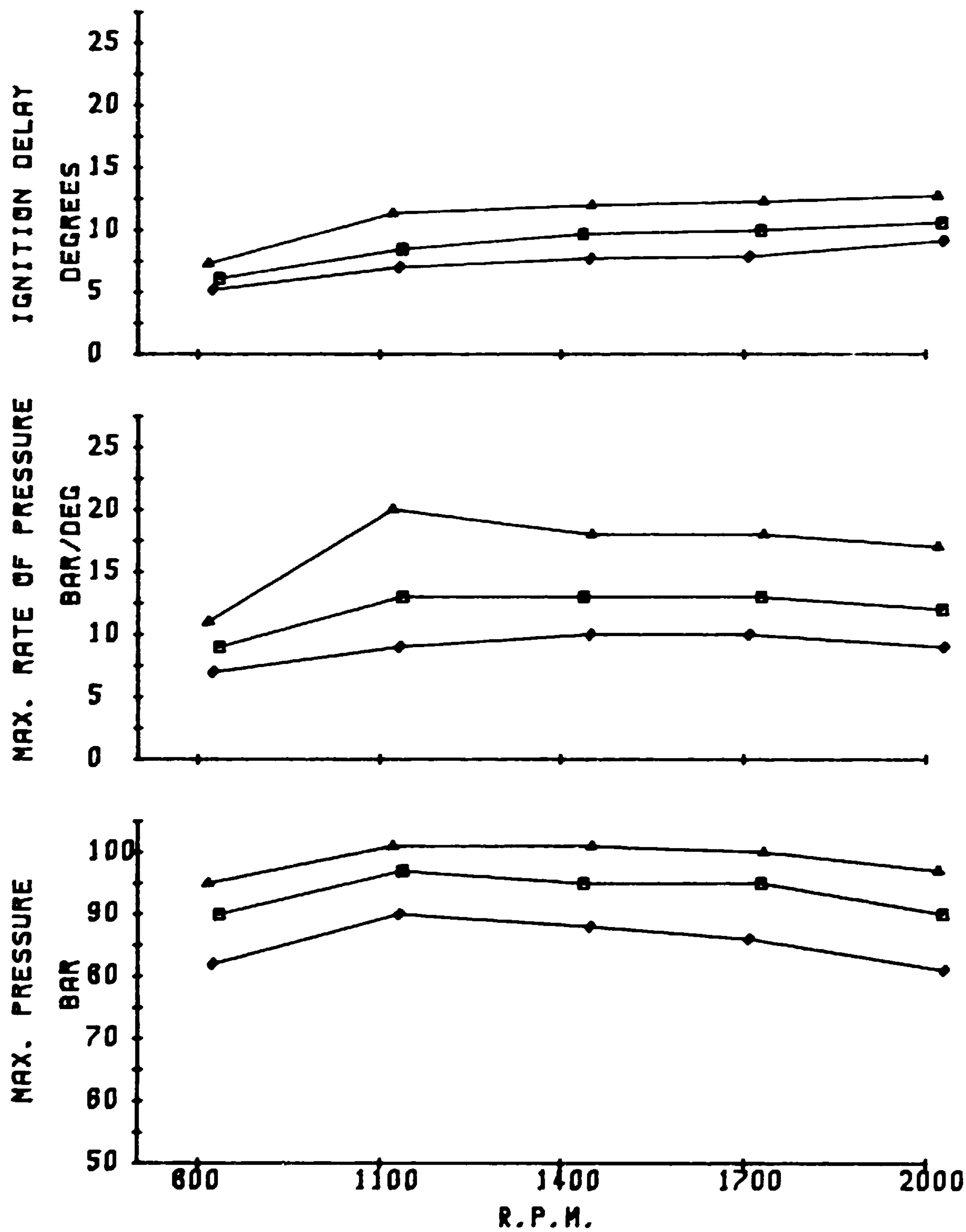


ENGINE : FORD 3000
CAPACITY: 2860

EFFECT OF STATIC TIMING ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
100 DIST
1/3 LOAD

FIG AP82

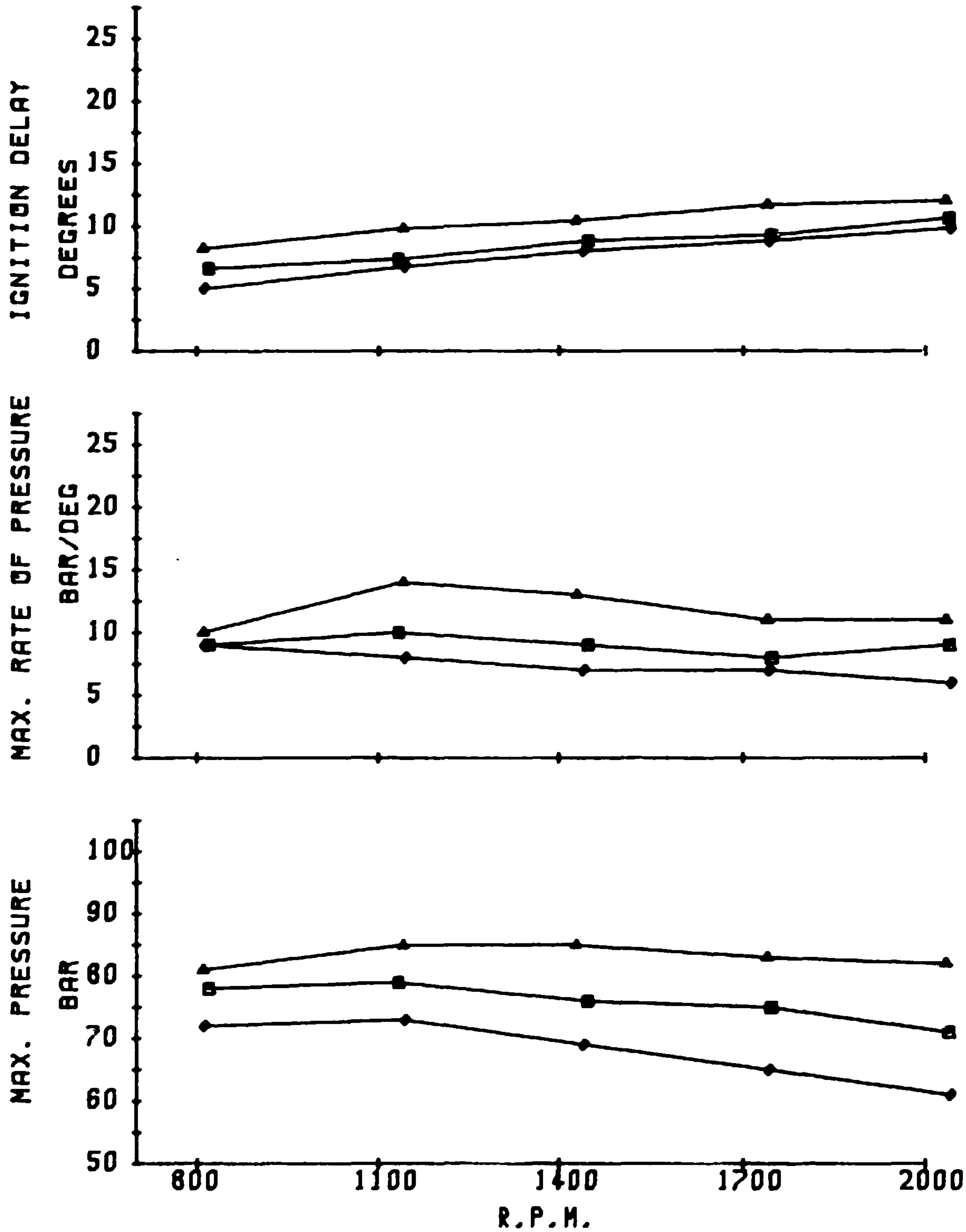


ENGINE : FORD 3000
CAPACITY: 2860

EFFECT OF STATIC TIMING ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
FULL LOAD

FIG AP83

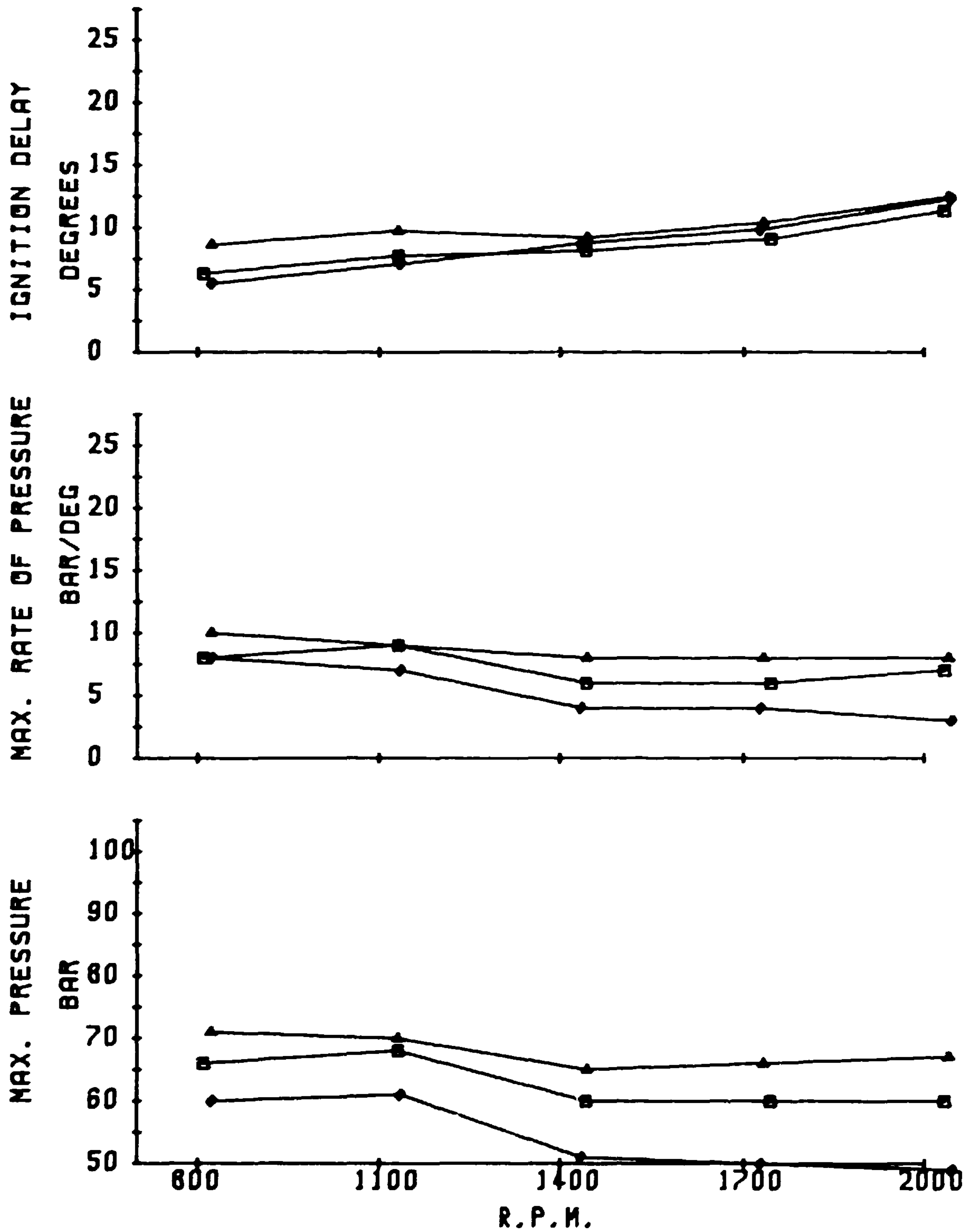


ENGINE : FORD 3000
CAPACITY: 2860

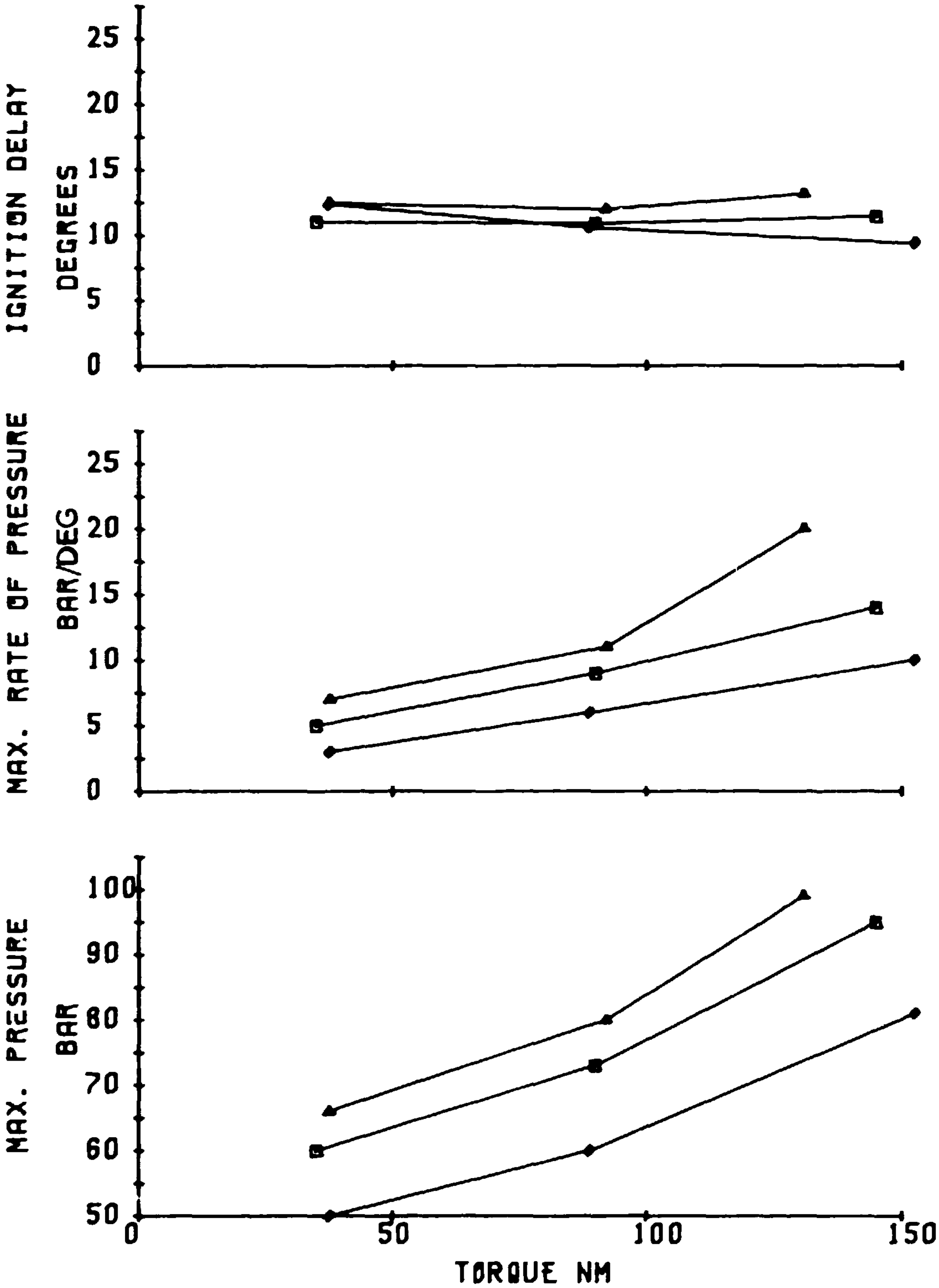
EFFECT OF STATIC TIMING ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
2/3 LOAD

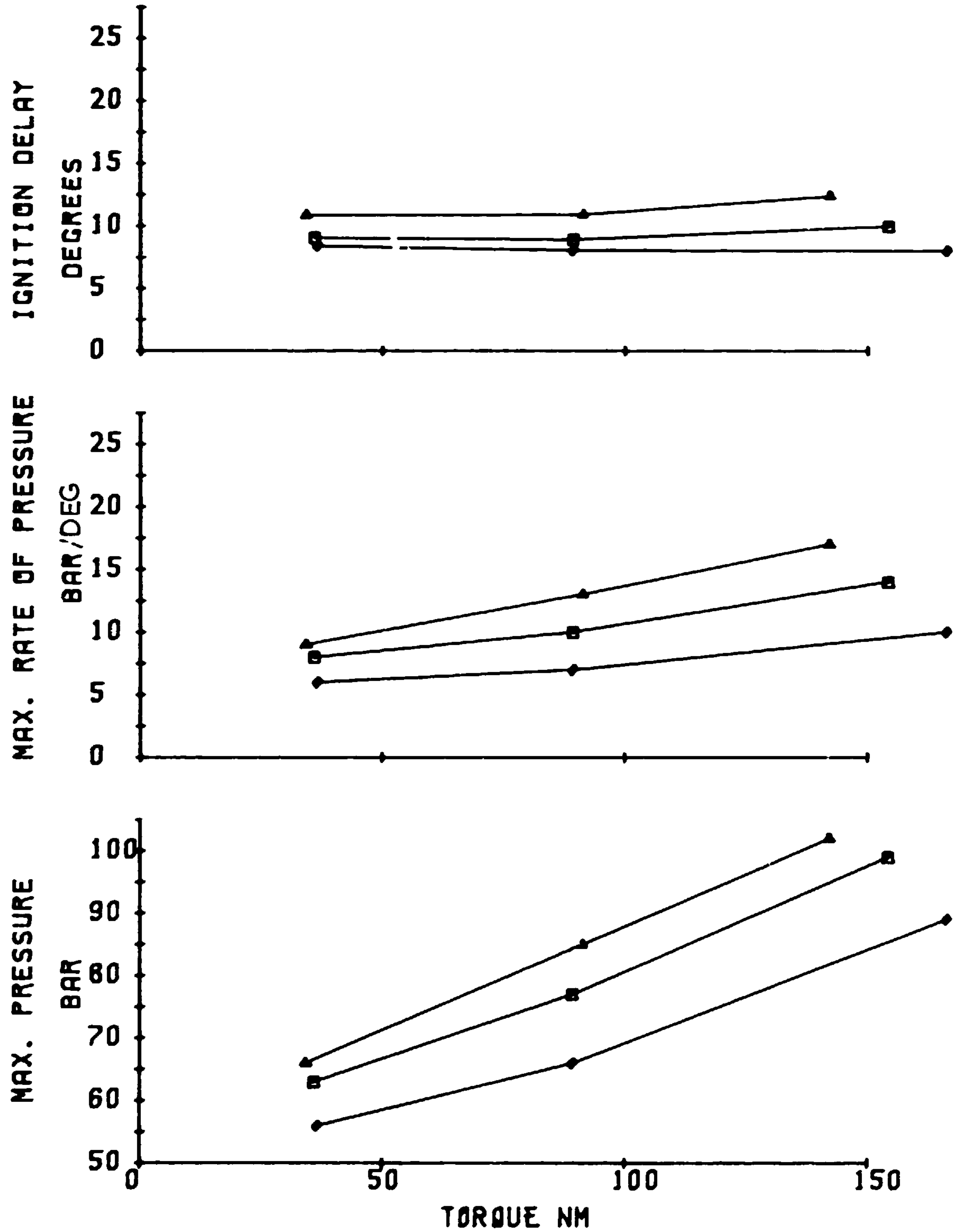
FIG AP84



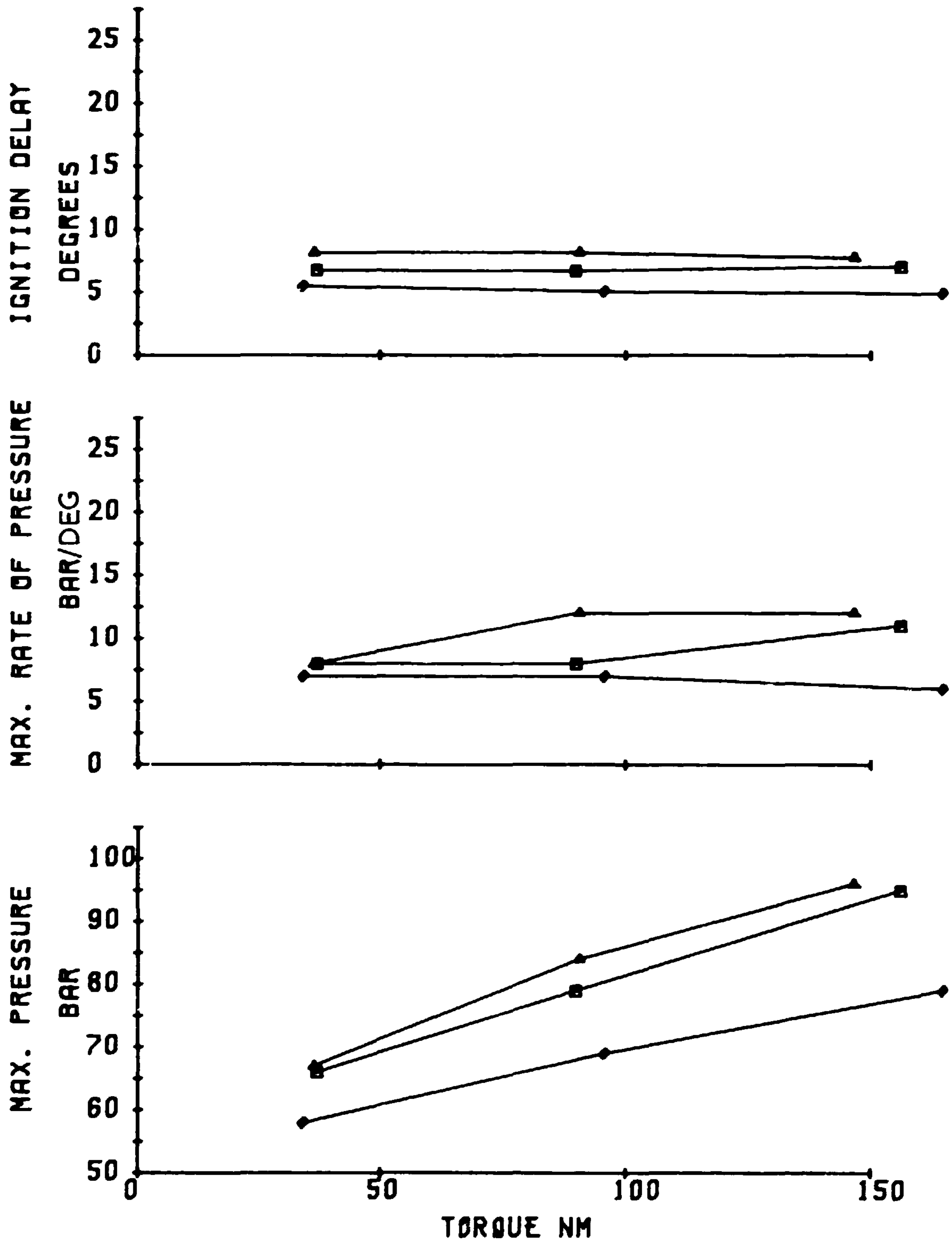
ENGINE : FORD 3000 CAPACITY: 2860	• 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC TEGDN3.9 1/3 LOAD
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP85



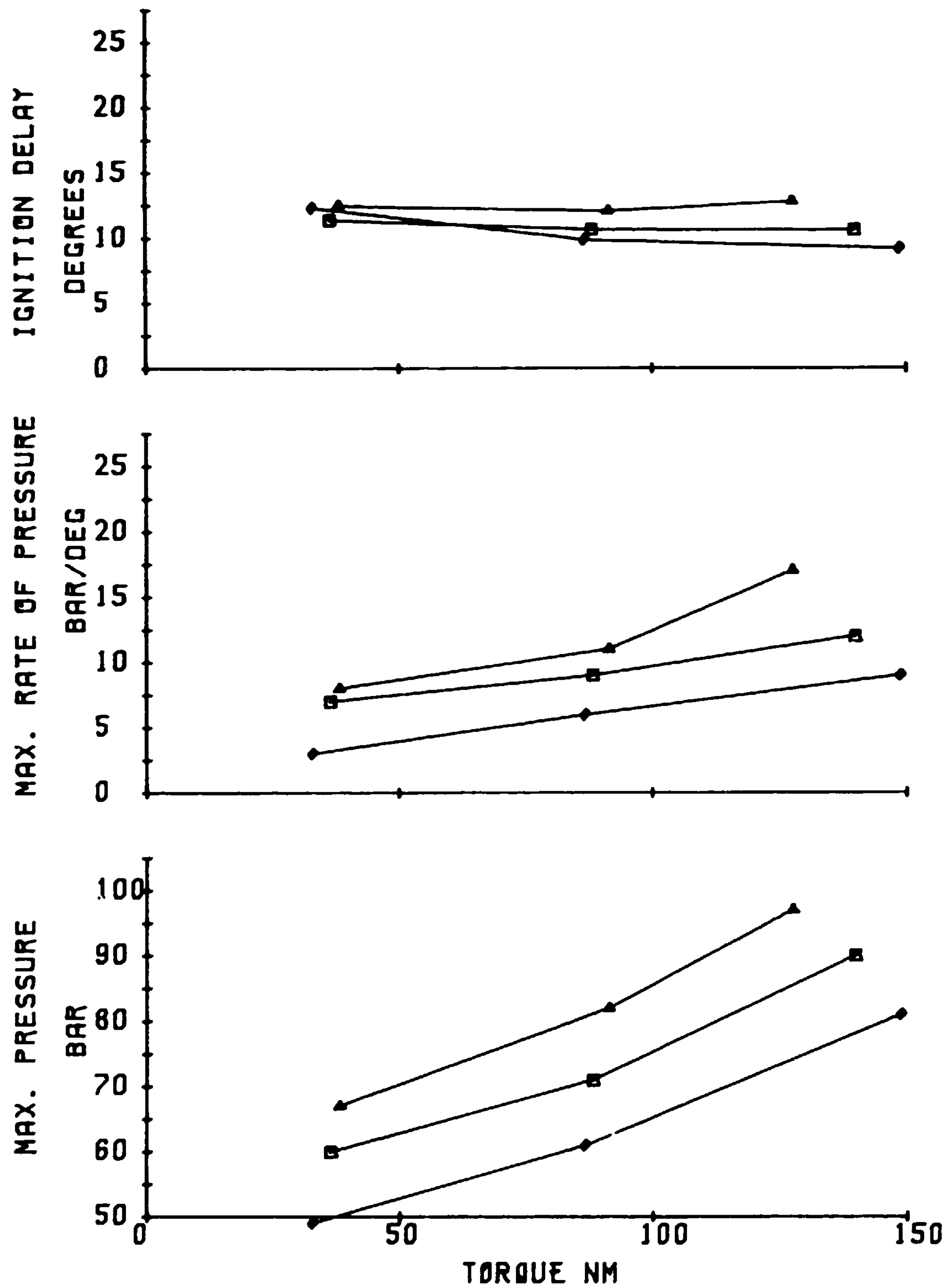
ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC DIST 100 2000 R.P.M.
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP86



ENGINE : FORD 3000 CAPACITY: 2860	♦ 14 deg BTDC ▪ 20 deg BTDC ▲ 26 deg BTDC DIST 100 1400 R.P.M.
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP87



ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC DIST 100 800 R.P.M.
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP88

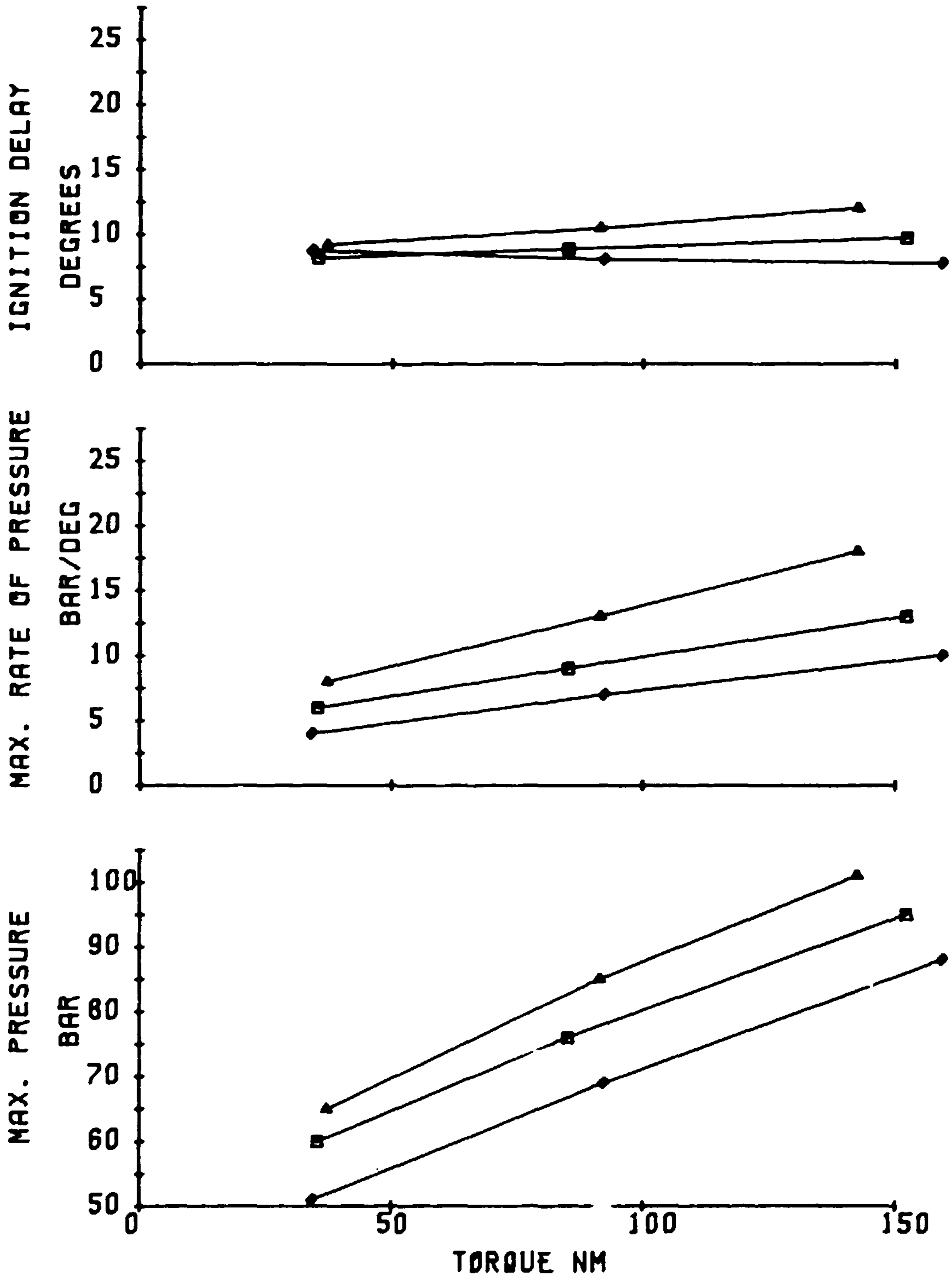


ENGINE : FORD 3000
CAPACITY: 2860

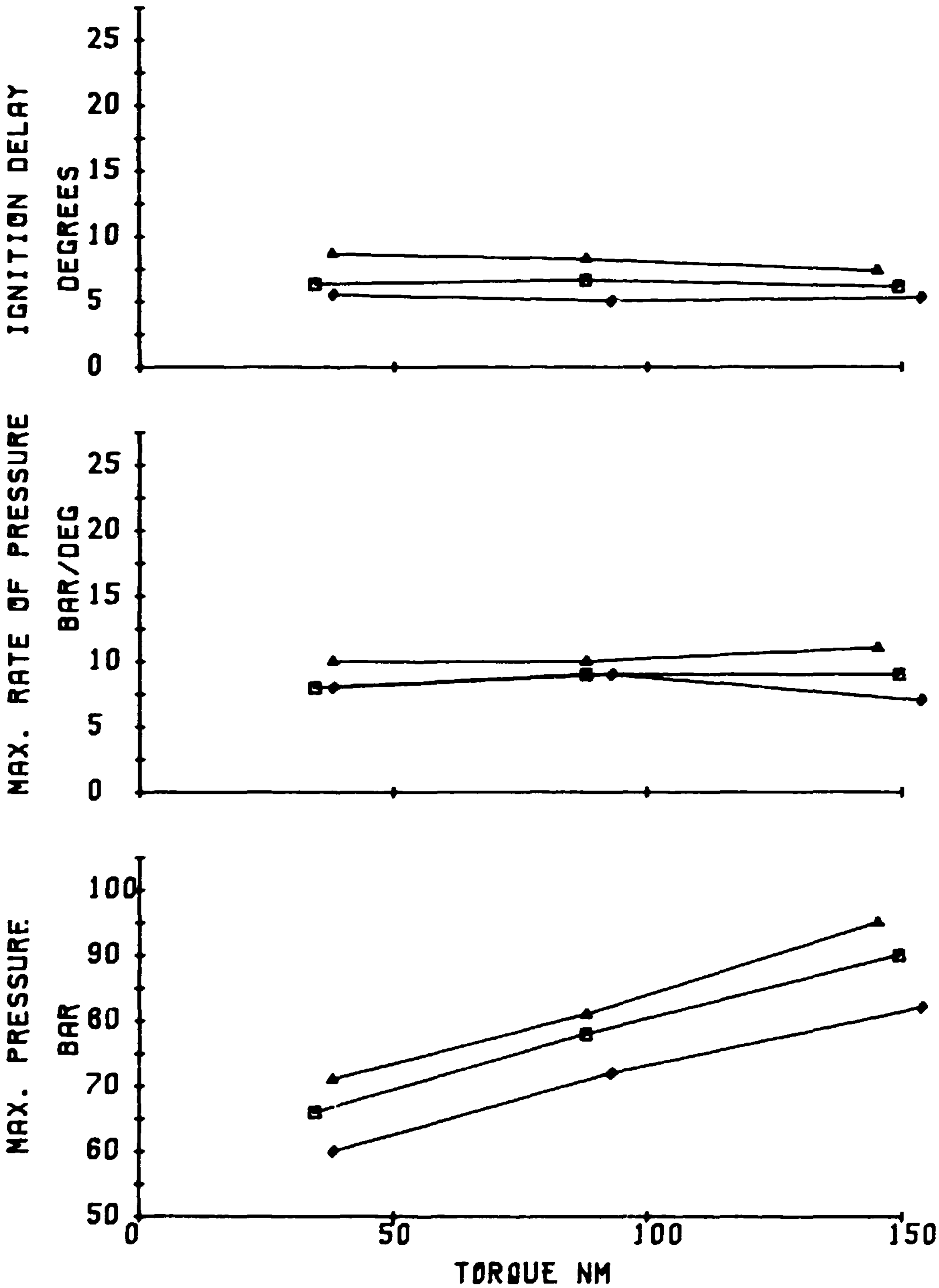
EFFECT OF STATIC TIMING ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

◆ 14 deg BTDC
▣ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
2000 R.P.M.

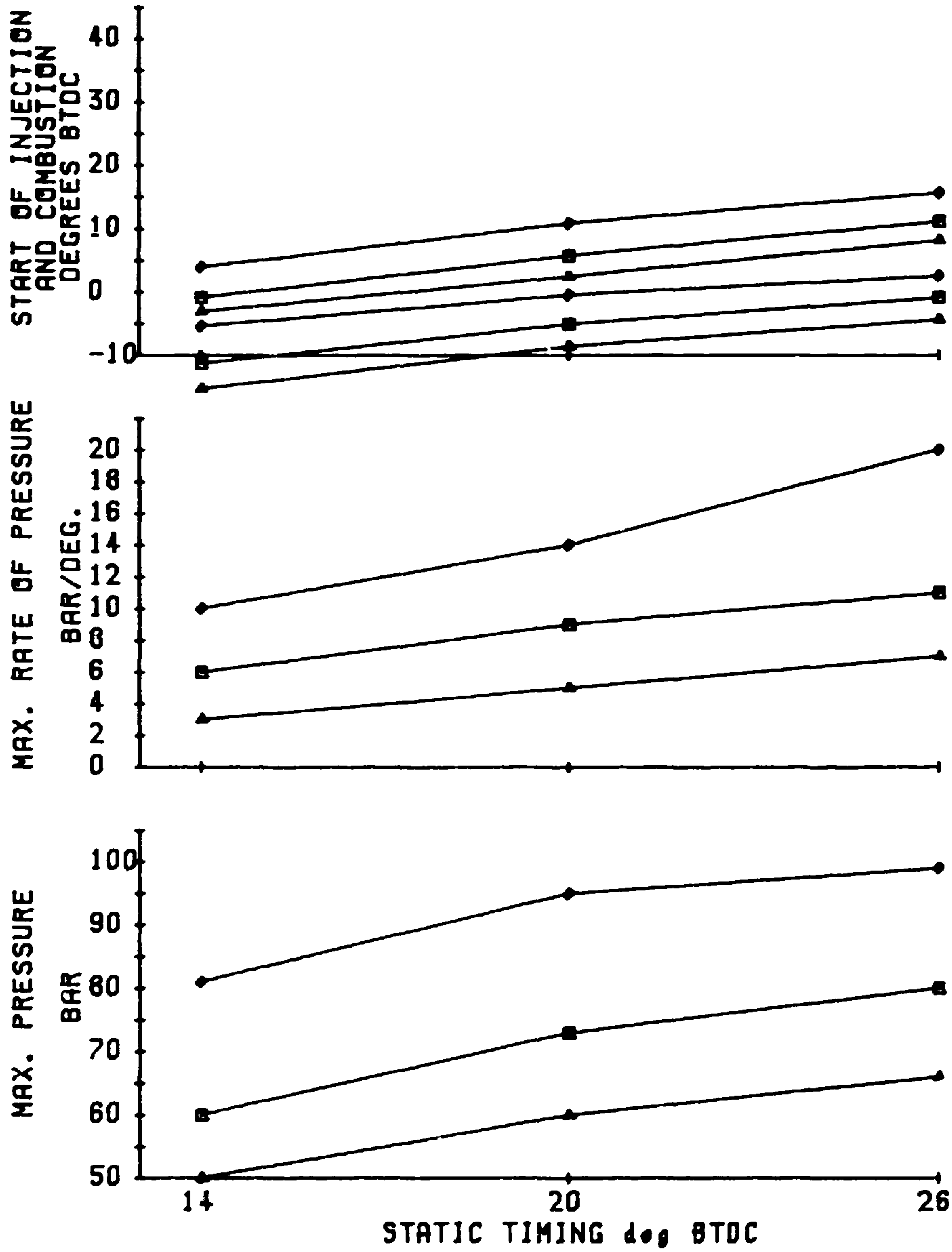
FIG AP89



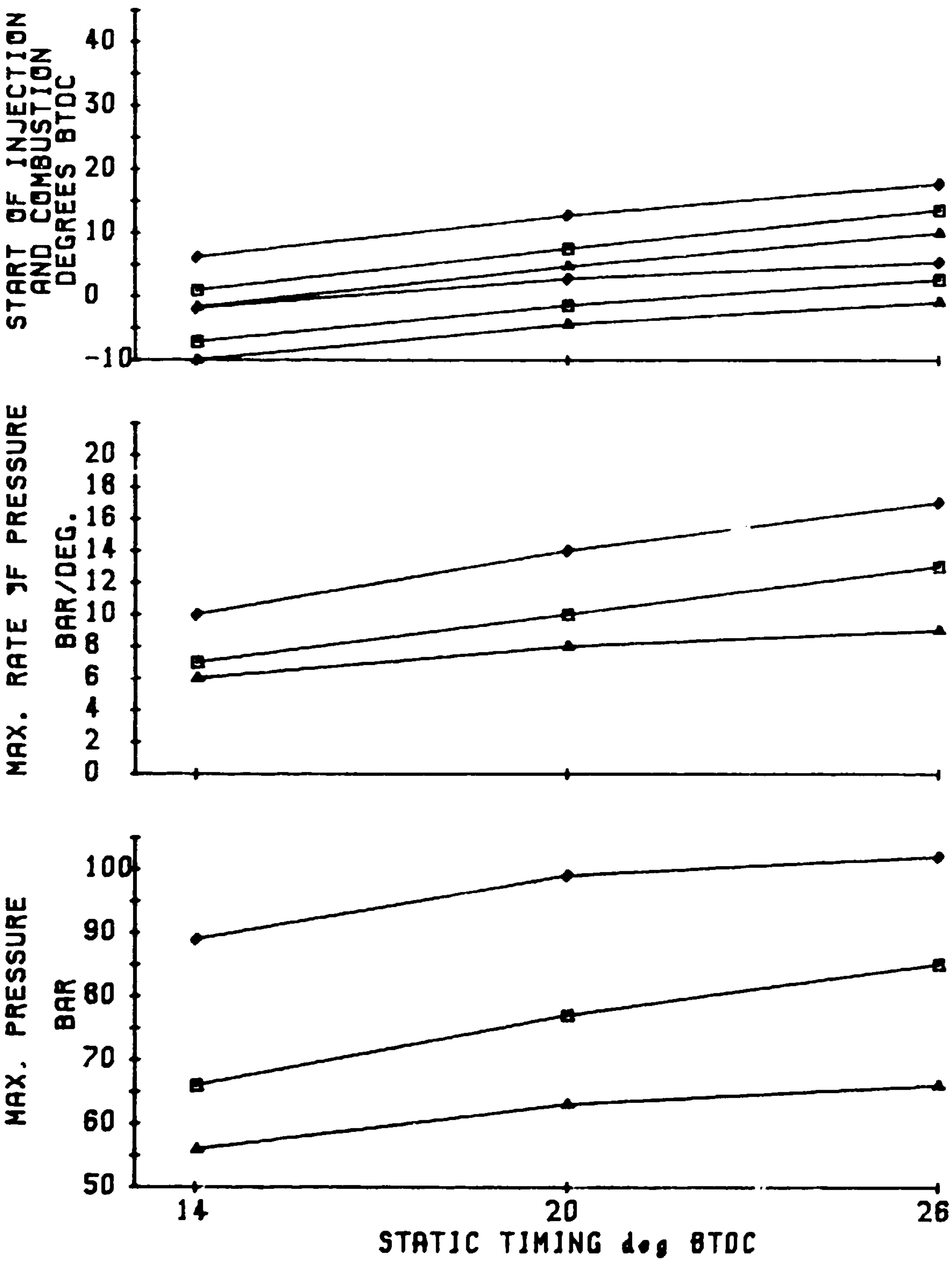
ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ▪ 20 deg BTDC ▲ 26 deg BTDC TEGDN3.9 1400 R.P.M.
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP90



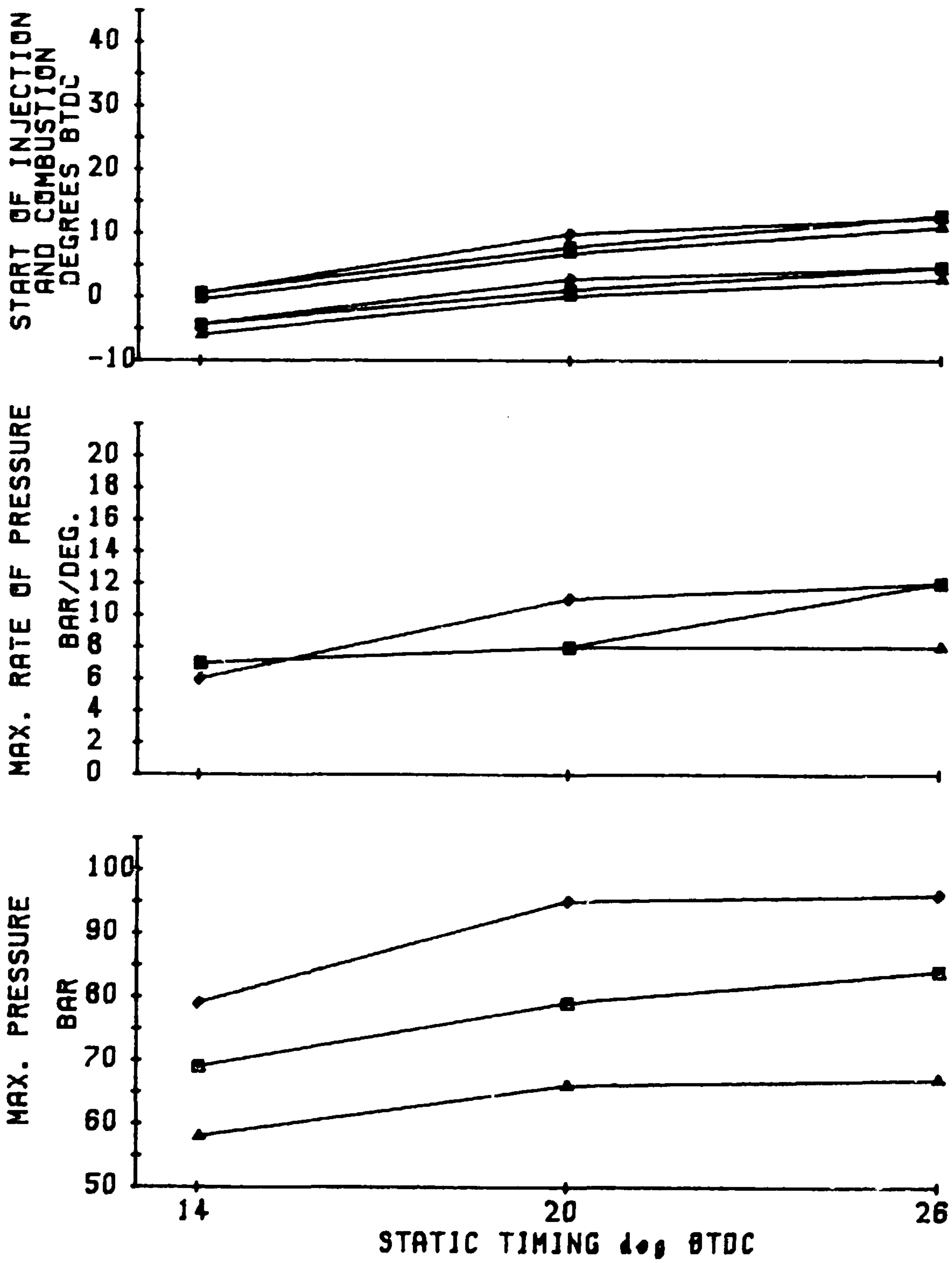
ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ▣ 20 deg BTDC ▲ 26 deg BTDC TEGDN3.9 800 R.P.M.
EFFECT OF STATIC TIMING ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	FIG AP91



ENGI. FORD 3000 CAPACI... 2860	◆ FULL LOAD ■ 2/3 LOAD ▲ 1/3 LOAD DIST 100 2000 R.P.M.
EFFECT OF STATIC TIMING ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP92



ENGINE : FORD 3000 CAPACITY: 2860	◆ FULL LOAD ▣ 2/3 LOAD ▲ 1/3 LOAD DIST 100 1400 R.P.M.
EFFECT OF STATIC TIMING ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP93

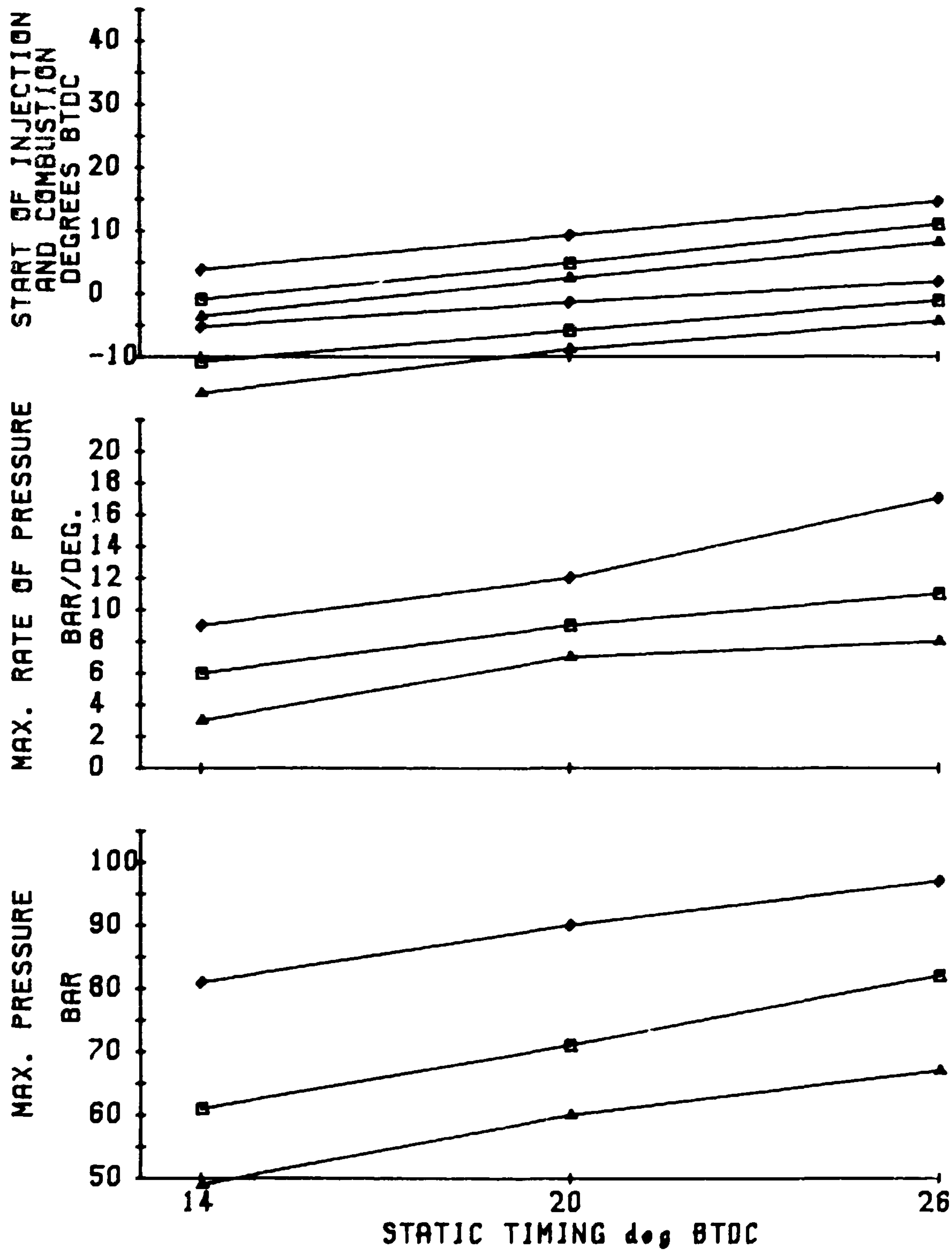


ENGINE : FORD 3000
CAPACITY: 2860

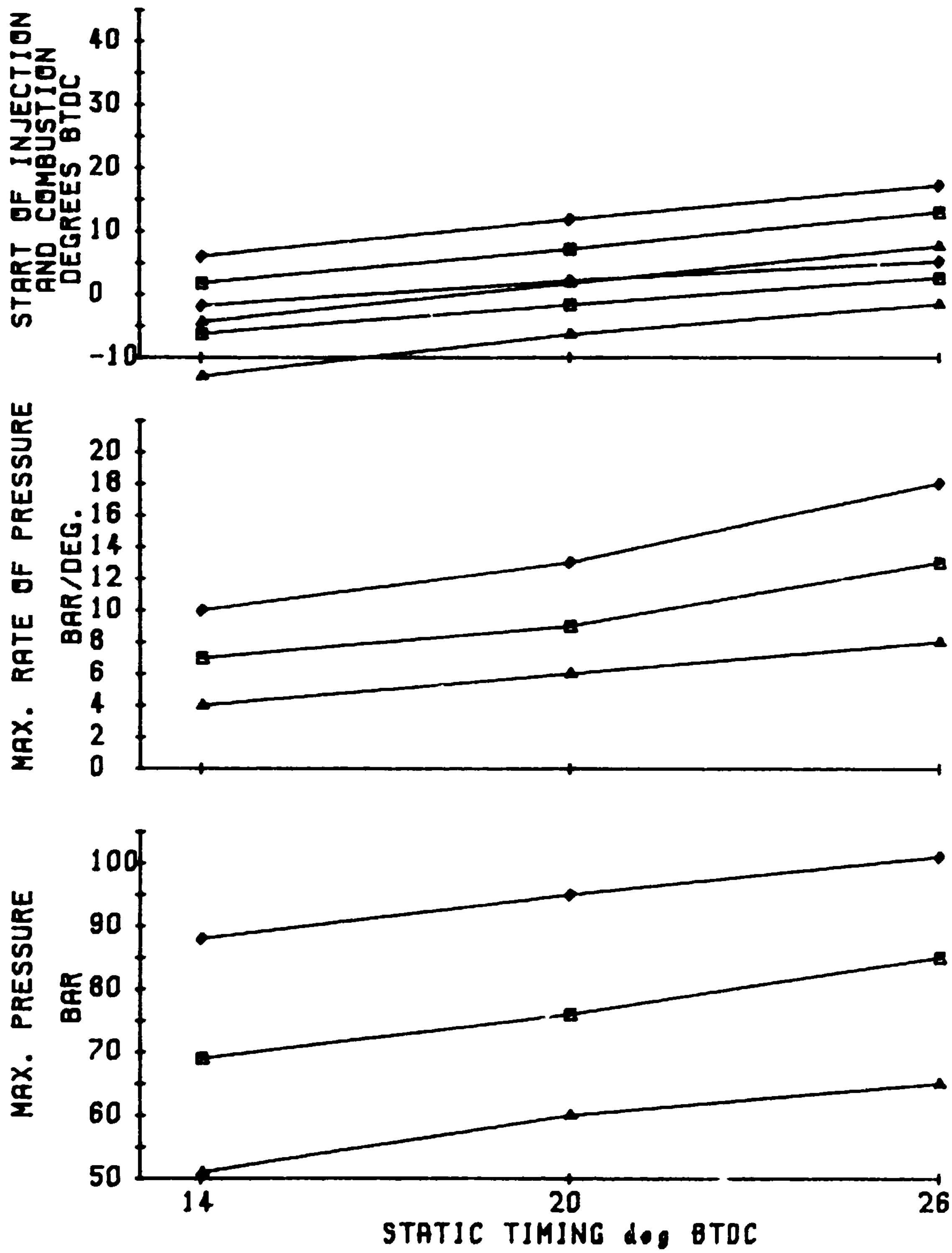
EFFECT OF STATIC TIMING ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

◆ FULL LOAD
■ 2/3 LOAD
▲ 1/3 LOAD
DIST 100
800 R.P.M.

FIG AP94



ENGINE : FORD 3000 CAPACITY: 2860	◆ FULL LOAD ▫ 2/3 LOAD ▲ 1/3 LOAD TEGDN3.9 2000 R.P.M.
EFFECT OF STATIC TIMING ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP95

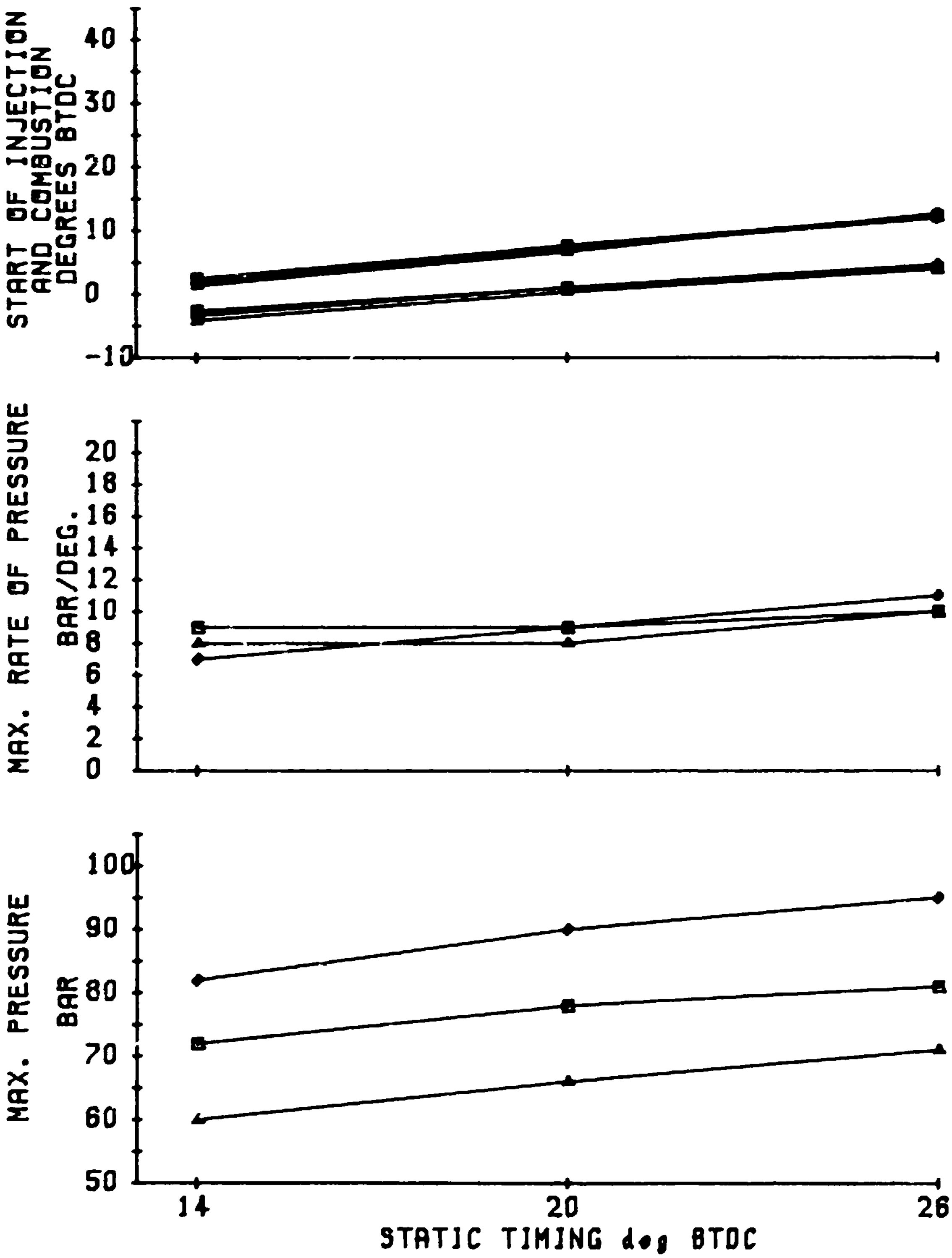


ENGINE : FORD 3000
CAPACITY: 2860

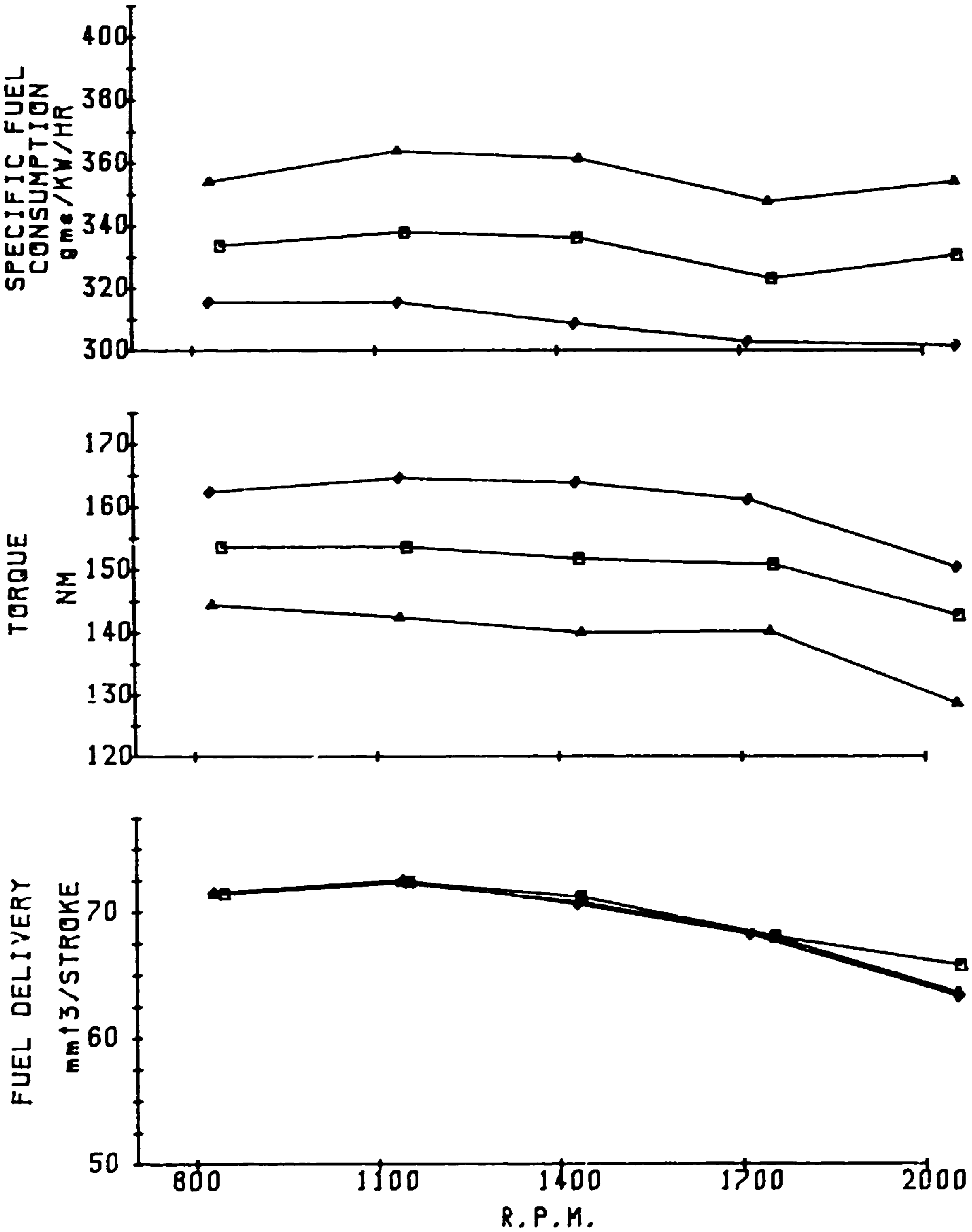
EFFECT OF STATIC TIMING ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

◆ FULL LOAD
■ 2/3 LOAD
▲ 1/3 LOAD
TEGDN3.9
1400 R.P.M.

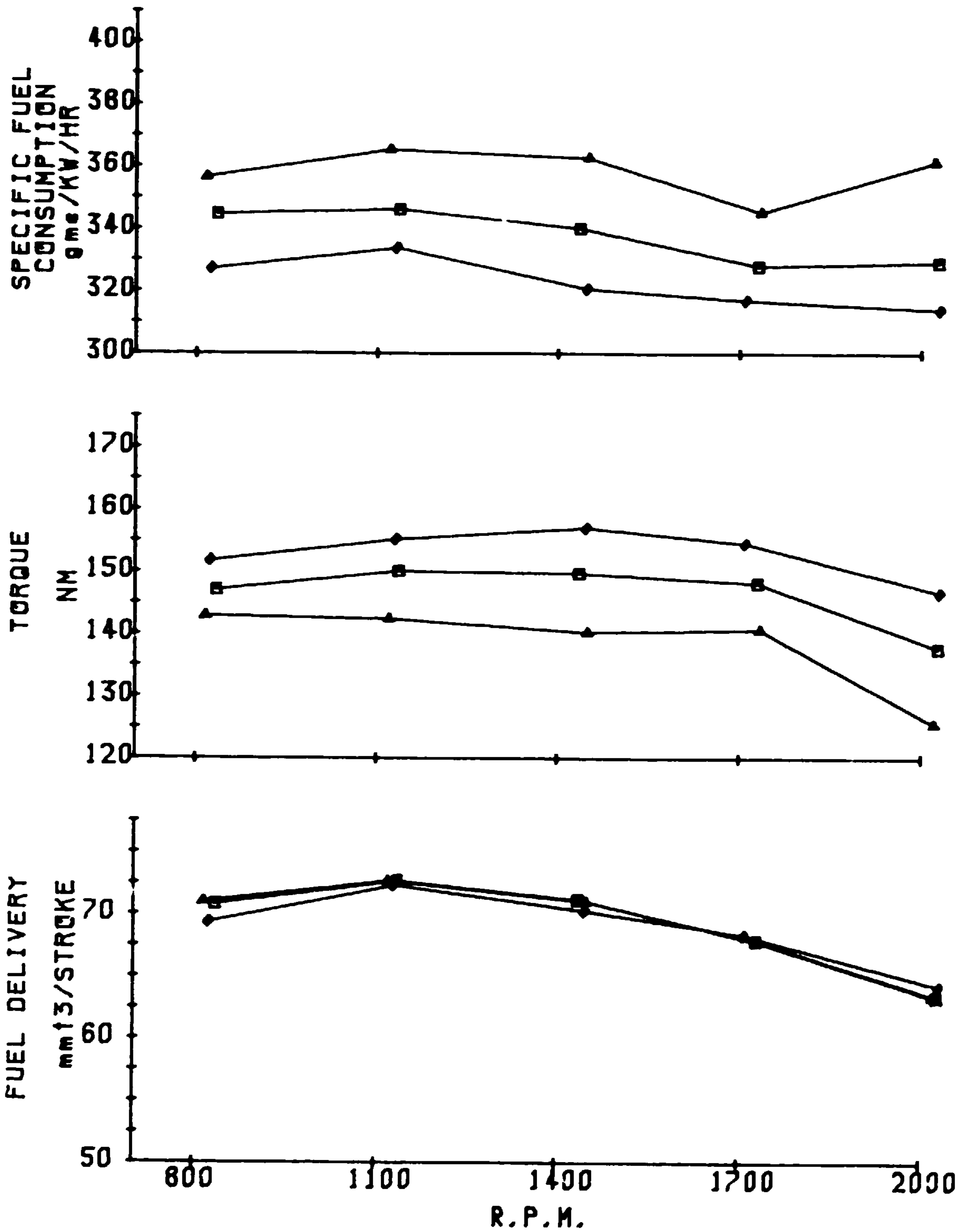
FIG AP96



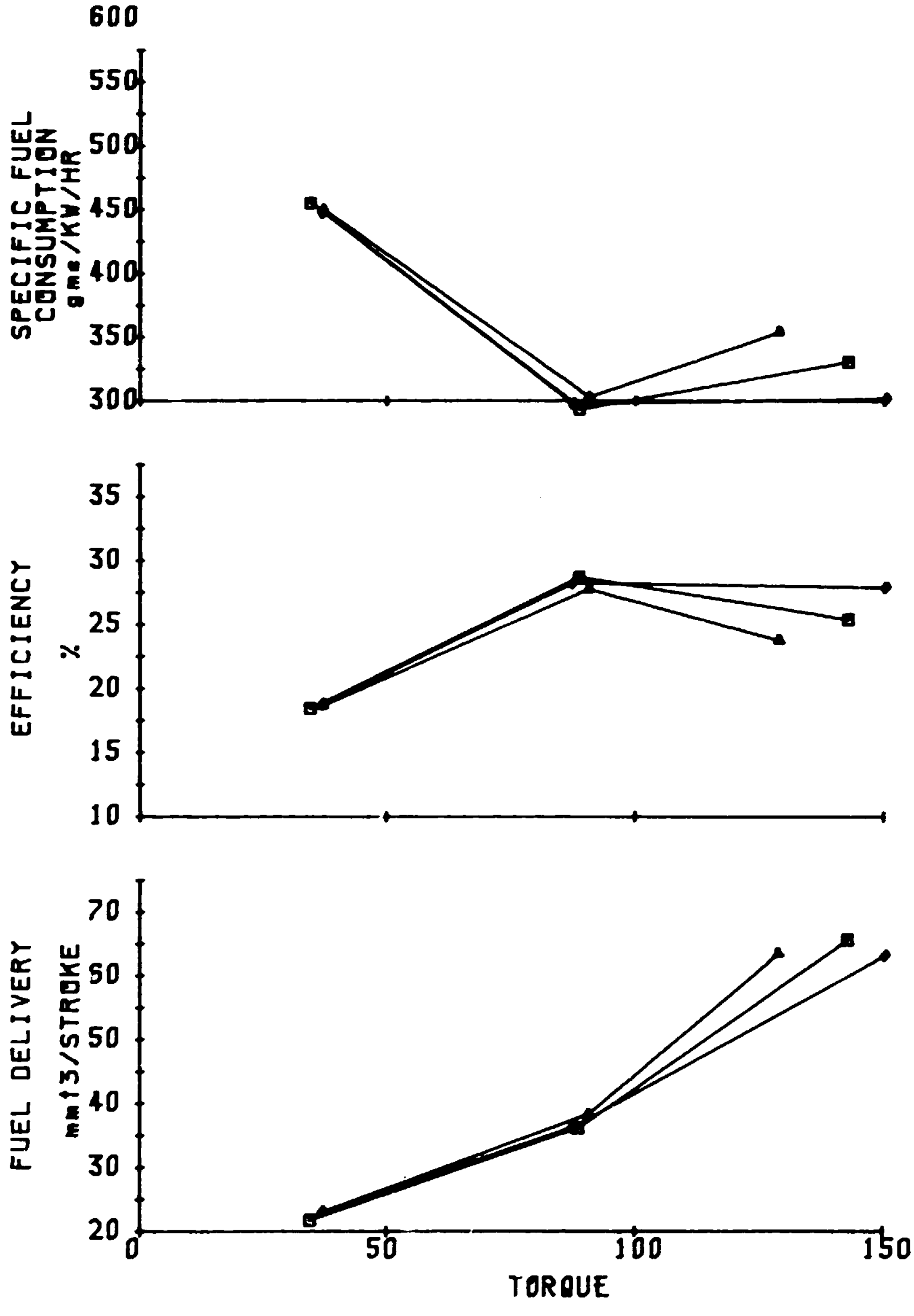
ENGINE : FORD 3000 CAPACITY: 2860	◆ FULL LOAD ■ 2/3 LOAD ▲ 1/3 LOAD TEGDN3.9 800 R.P.M.
EFFECT OF STATIC TIMING ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	FIG AP97



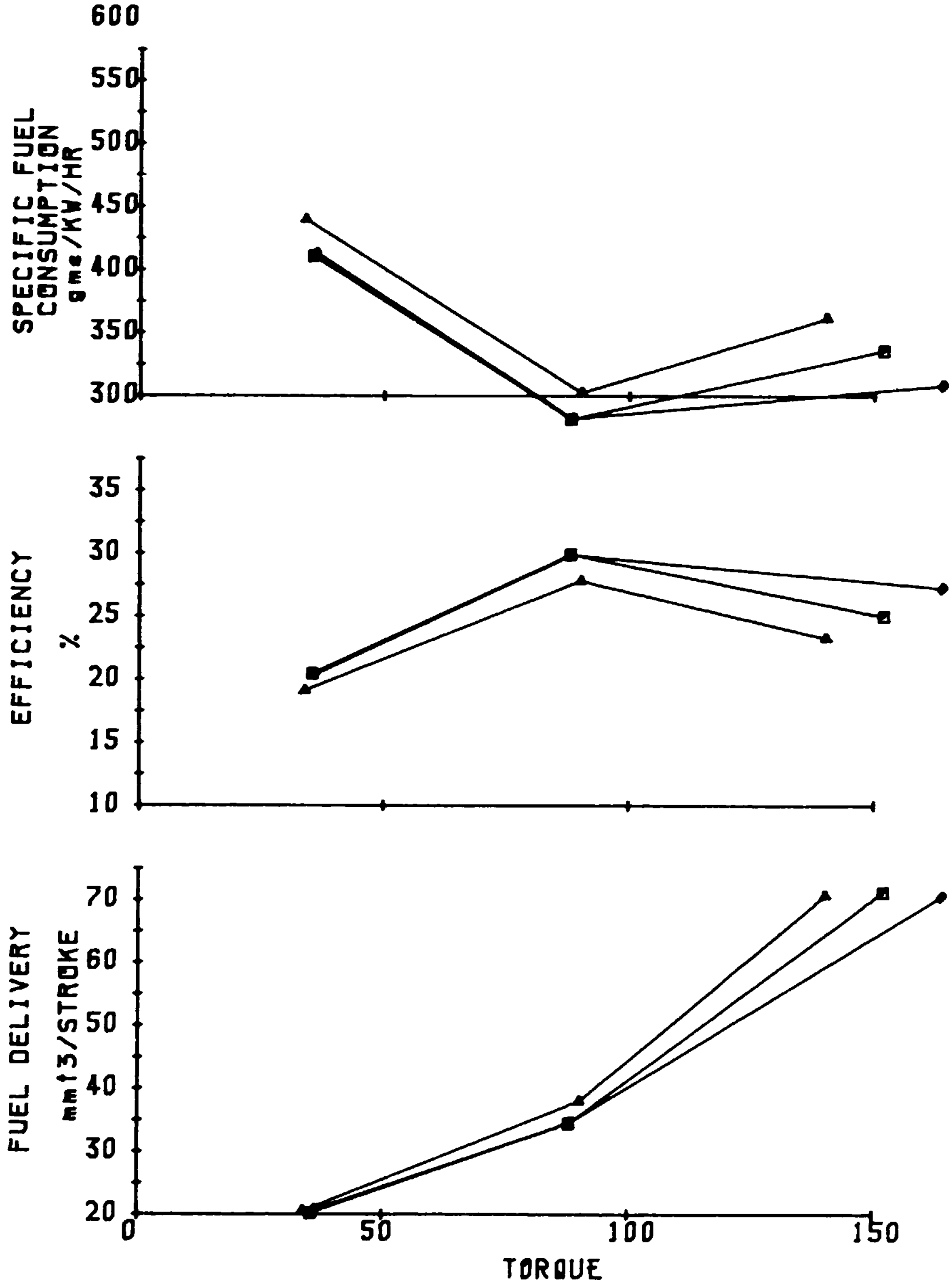
ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ▫ 20 deg BTDC ▲ 26 deg BTDC DIST 100 FULL LOAD
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, TORQUE & S.F.C.	FIG AP98



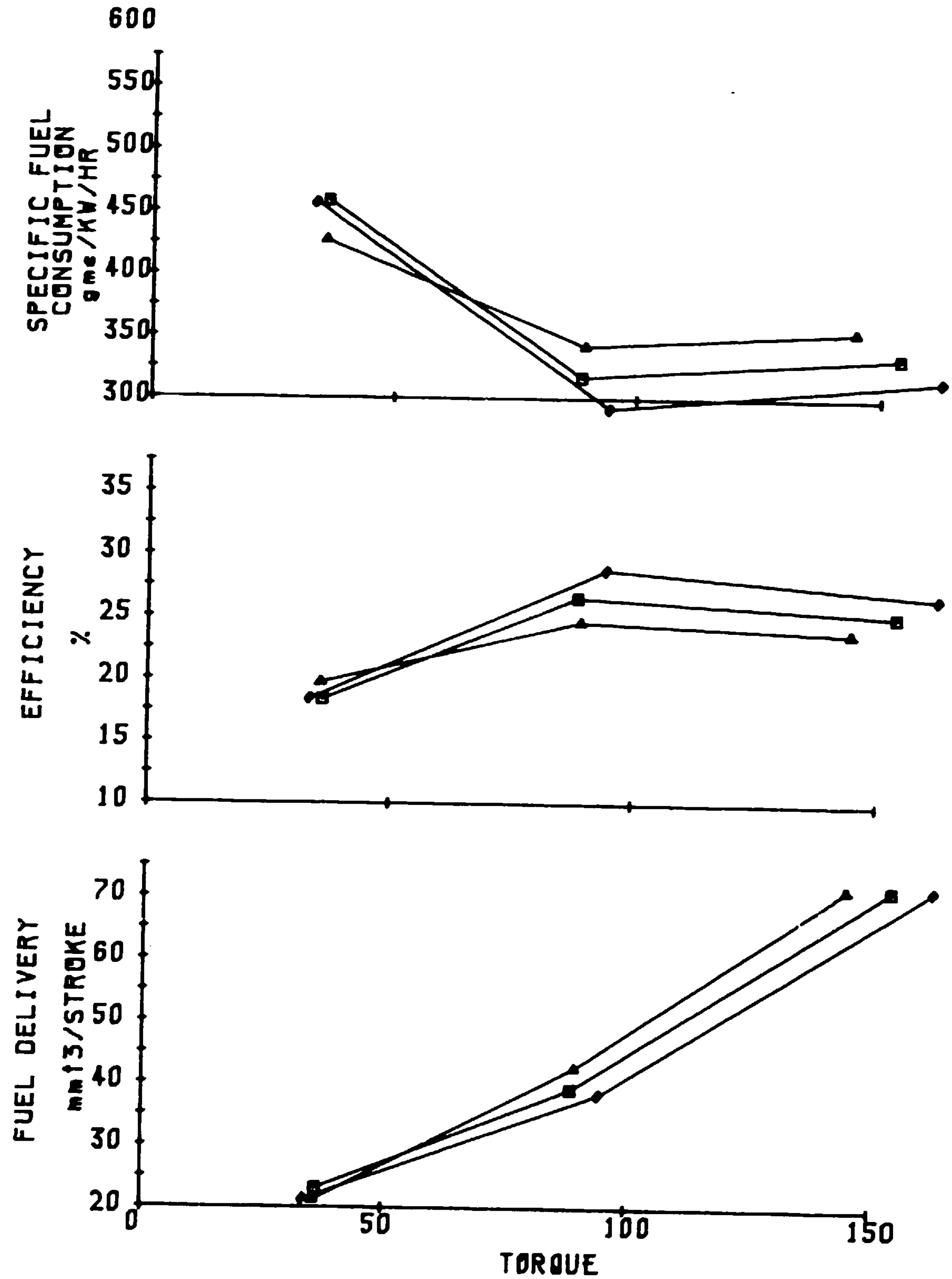
ENGINE : FORD 3000 CAPACITY: 2860	◆ 14 deg BTDC ▣ 20 deg BTDC ▲ 26 deg BTDC TEGDN3.9 FULL LOAD
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, TORQUE & S.F.C.	FIG AP99



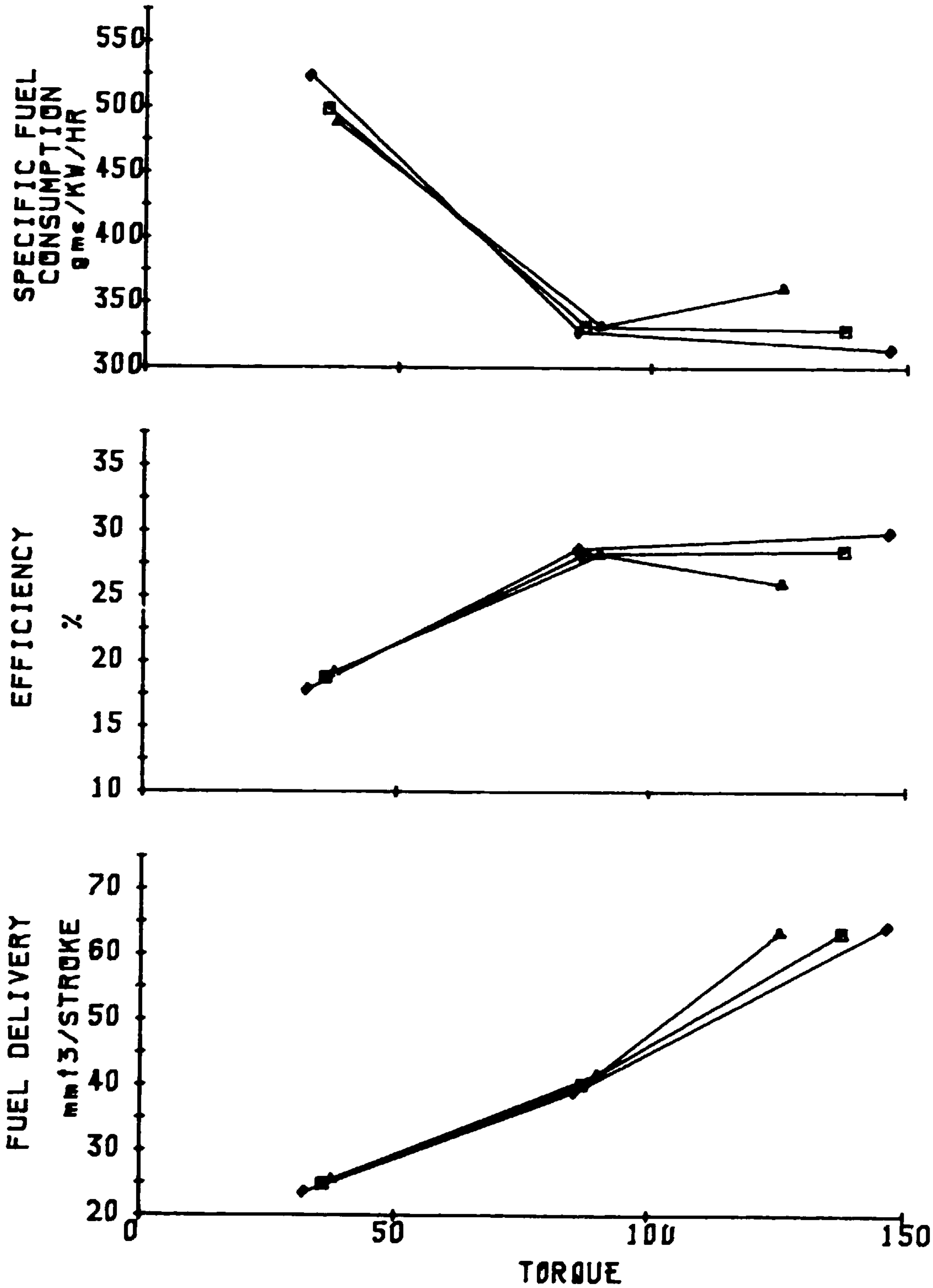
ENGINE : FORD 3000 CAPACITY: 2660	◆ 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC DIST 100 2000 R.P.M.
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP100



ENGINE : FORD 3000 CAPACITY: 2660	◆ 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC DIST 100 1400 R.P.M.
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP101



ENGINE : FORD 3000 CAPACITY: 2860	♦ 14 deg BTDC ■ 20 deg BTDC ▲ 26 deg BTDC DIST 100 800 R.P.M.
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP102

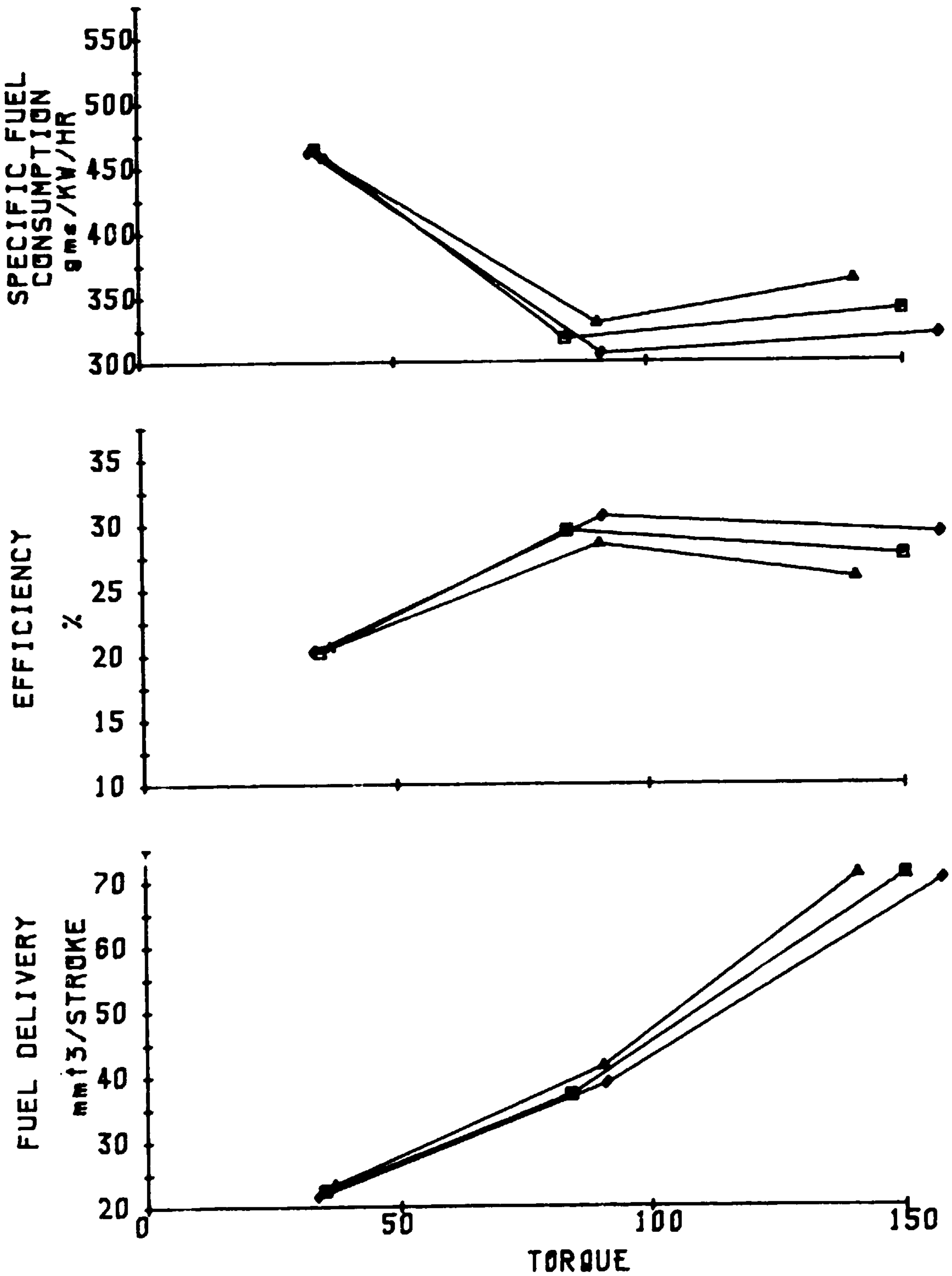


ENGINE : FORD 3000
CAPACITY: 2860

EFFECT OF STATIC TIMING ON
INJECTION PUMP DELIVERY,
EFFICIENCY & S.F.C.

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
2000 R.P.M.

FIG AP103

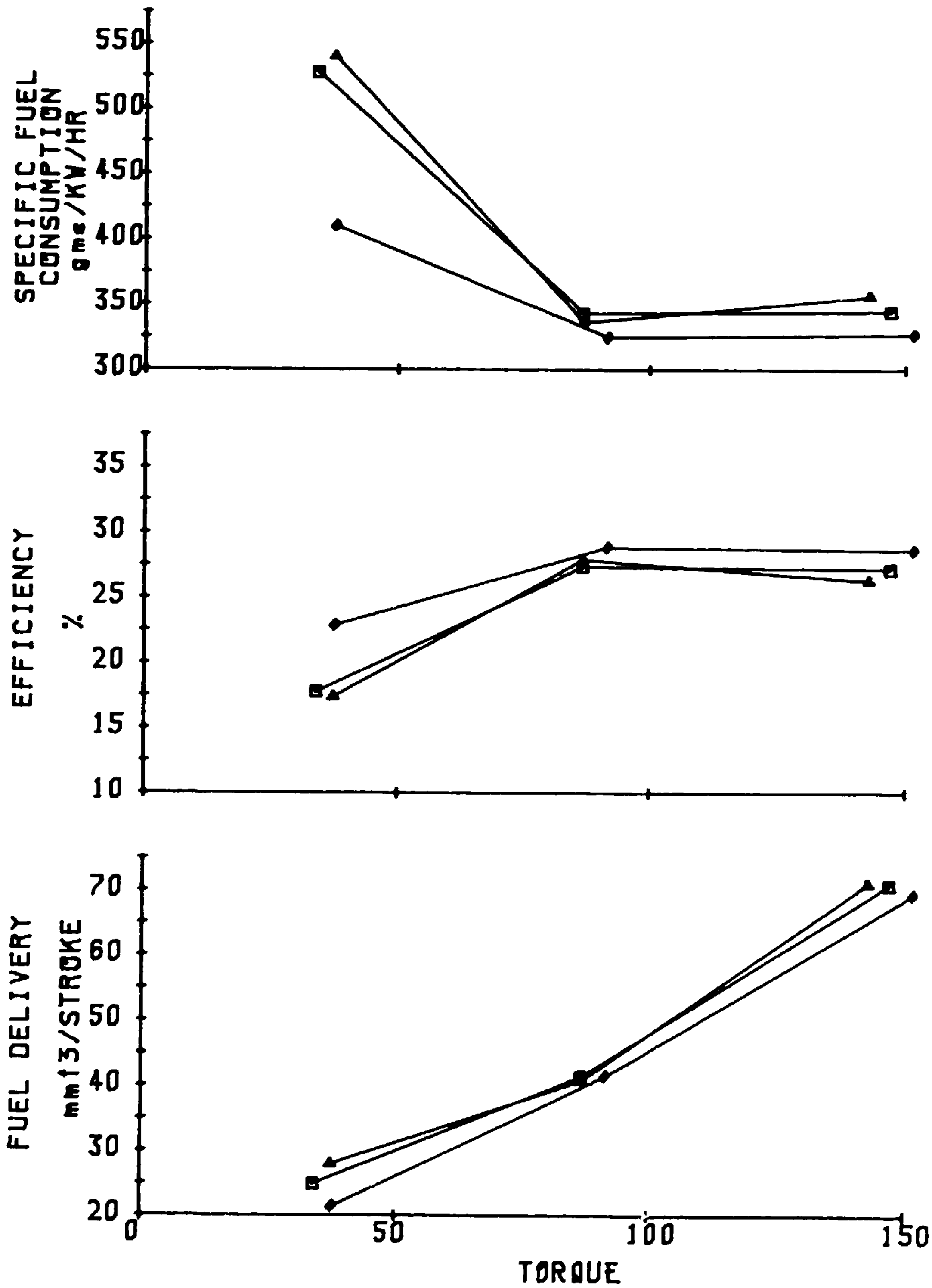


ENGINE : FORD 3000
CAPACITY: 2660

EFFECT OF STATIC TIMING ON
INJECTION PUMP DELIVERY,
EFFICIENCY & S.F.C.

◆ 14 deg BTDC
■ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
1400 R.P.M.

FIG AP104

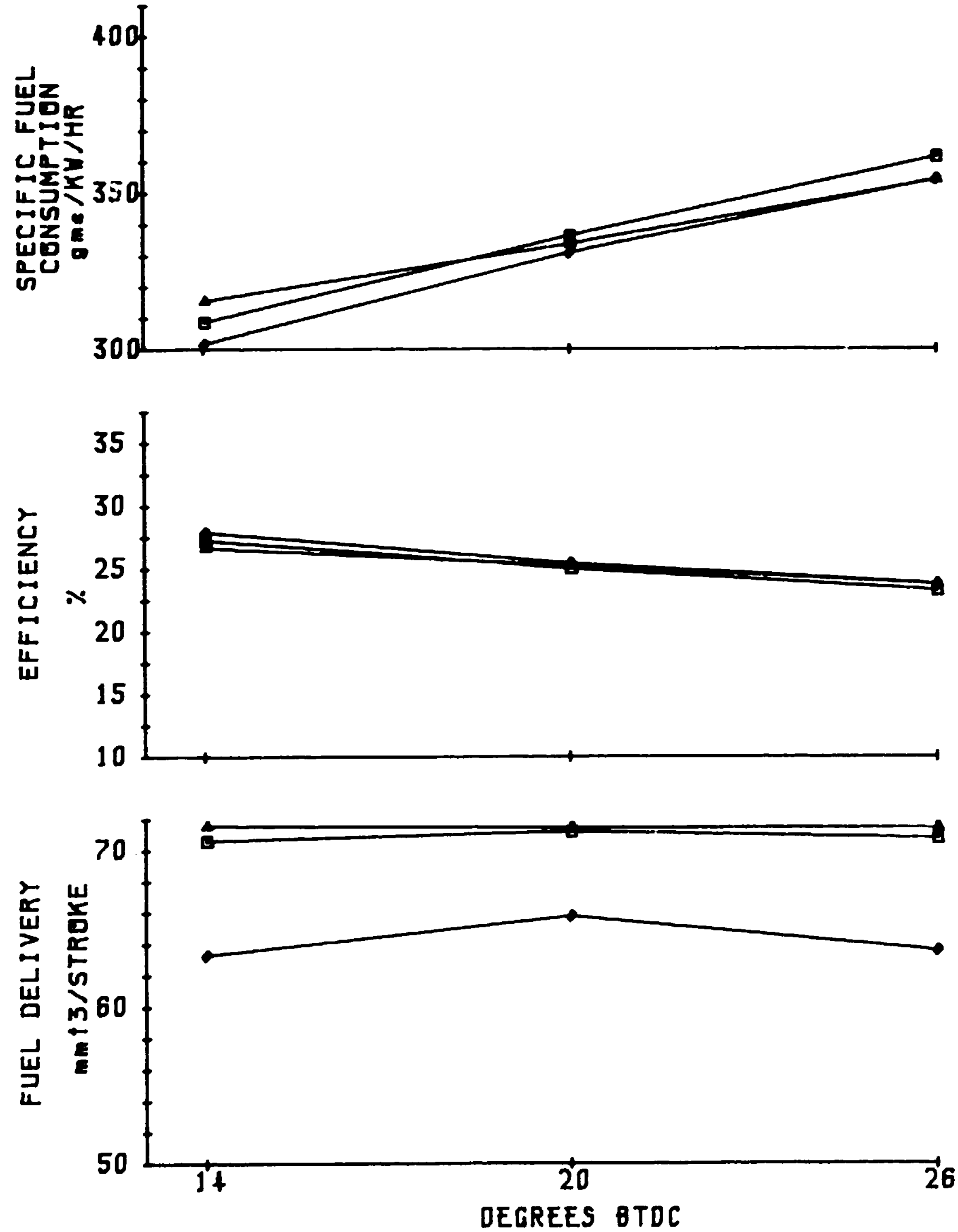


ENGINE : FORD 3000
CAPACITY: 2860

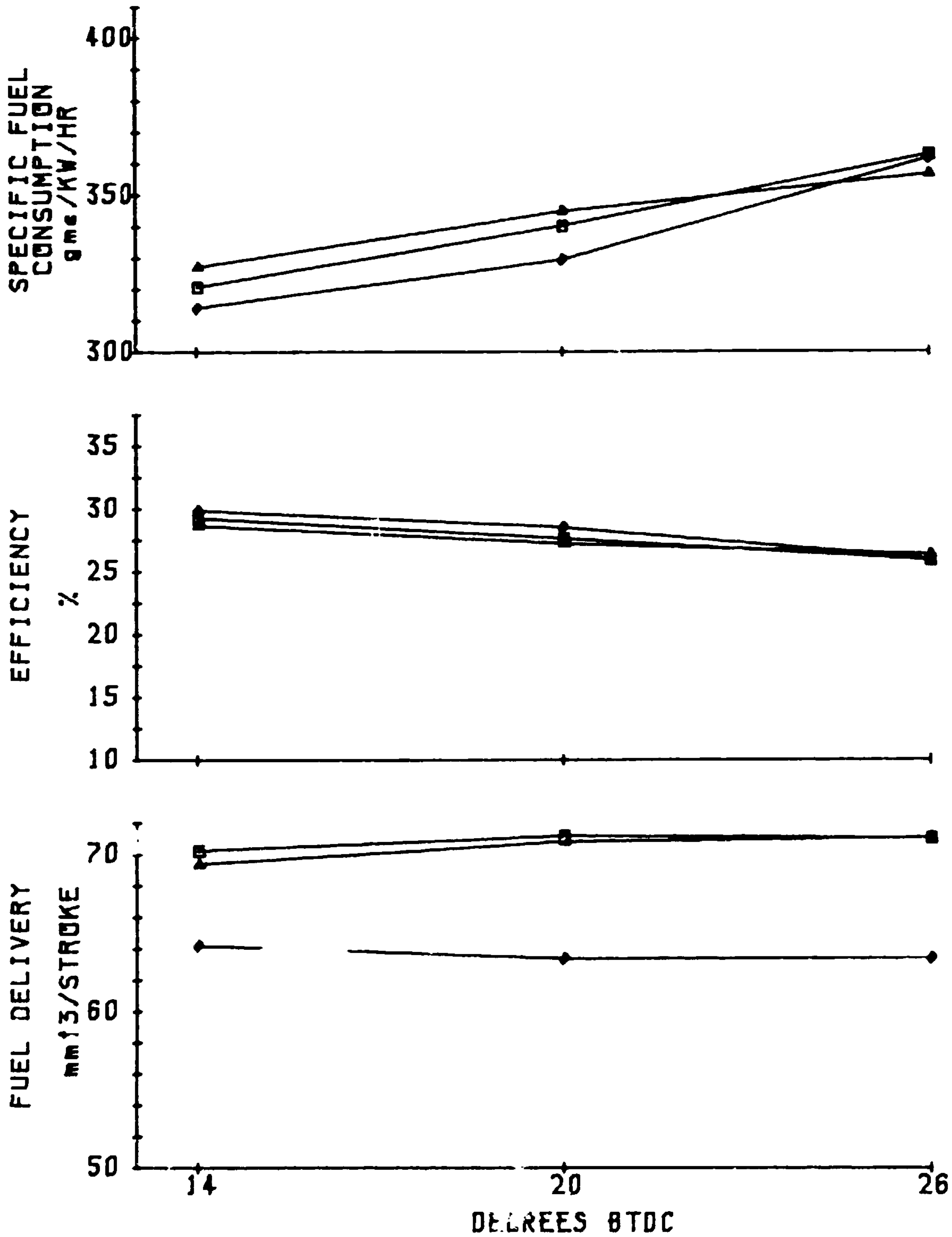
EFFECT OF STATIC TIMING ON
INJECTION PUMP DELIVERY,
EFFICIENCY & S.F.C.

◆ 14 deg BTDC
▣ 20 deg BTDC
▲ 26 deg BTDC
TEGDN3.9
800 R.P.M.

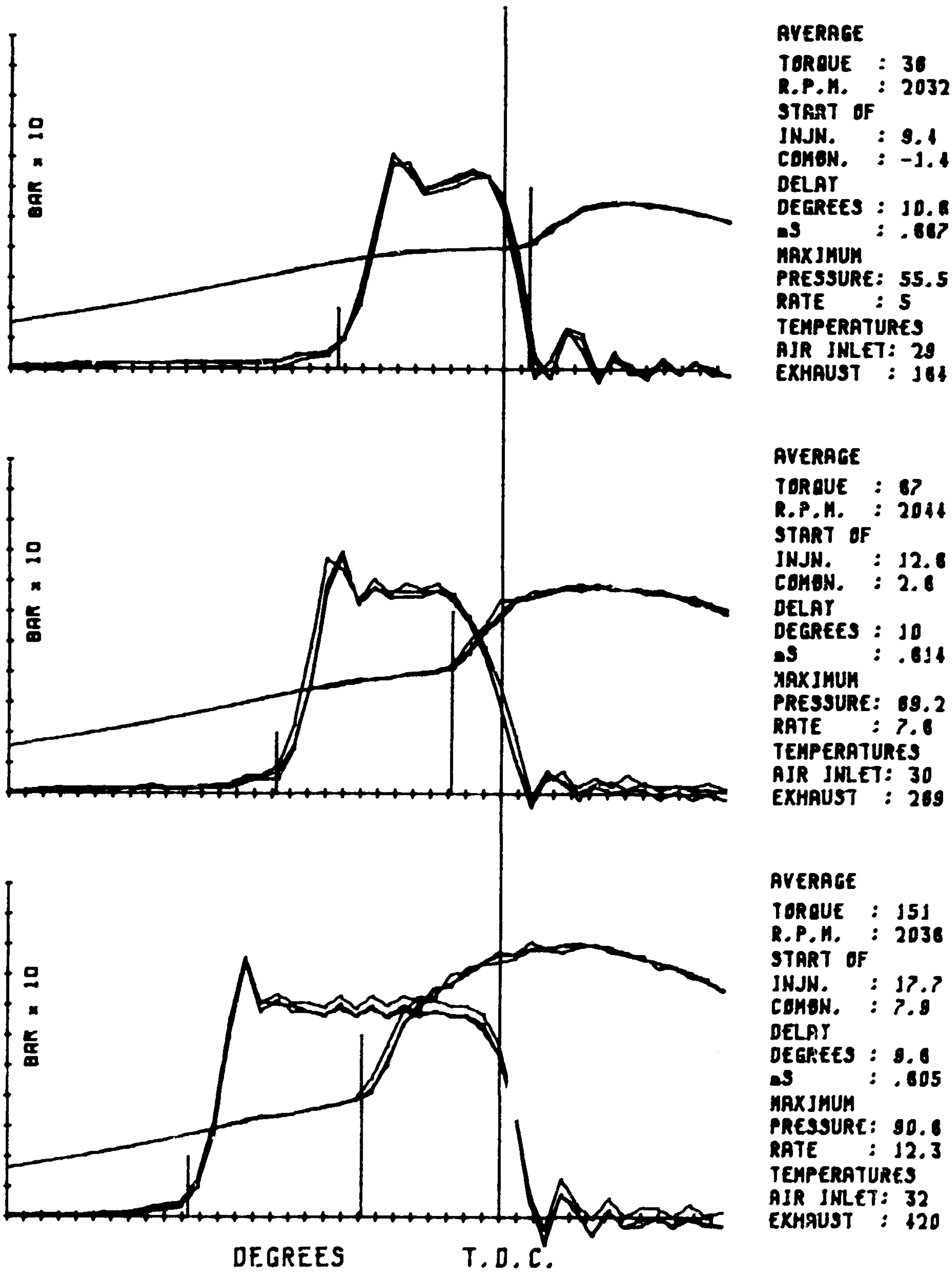
FIG AP105



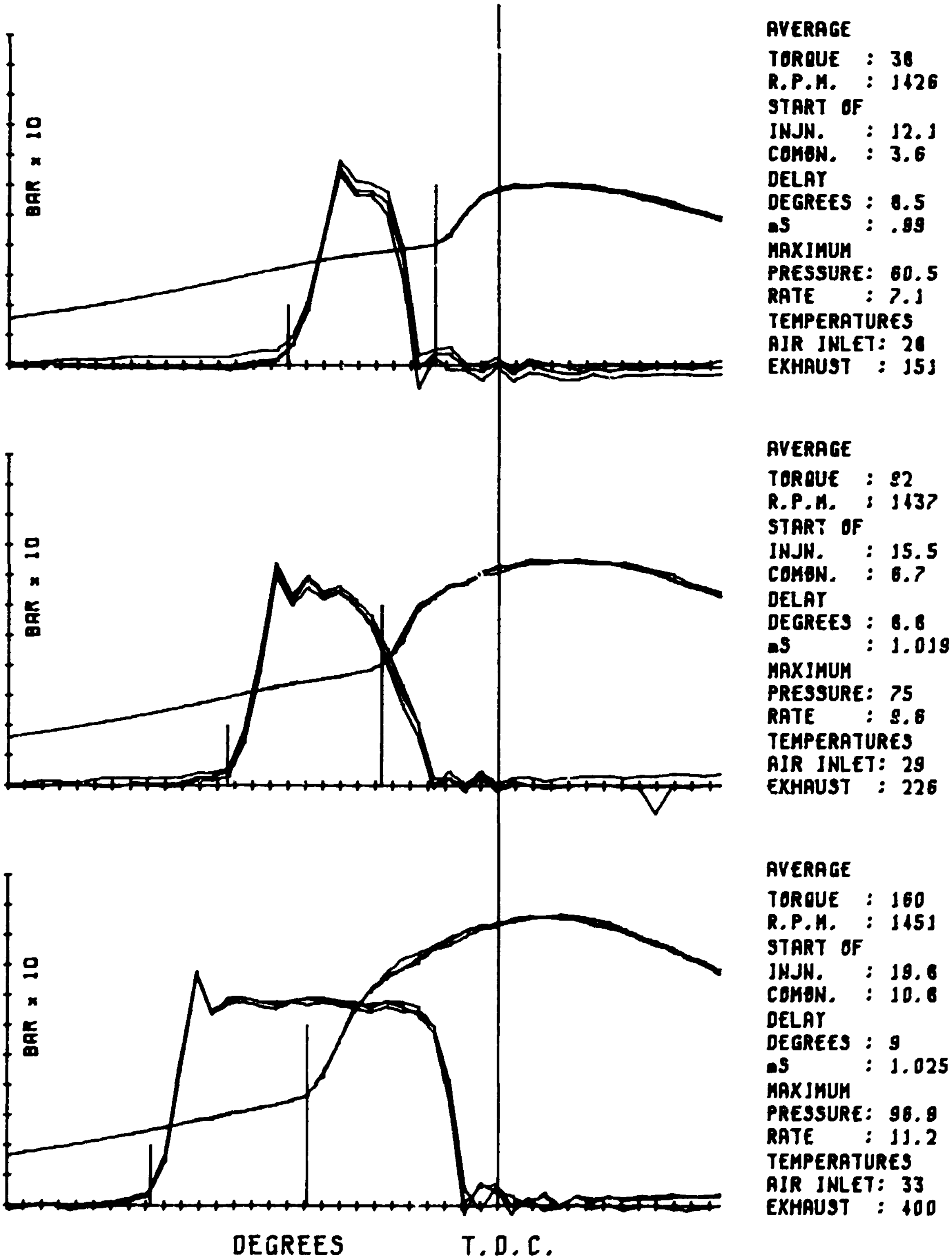
ENGINE : FORD 3000 CAPACITY: 2860	◆ 2000 R.P.M. ▣ 1400 R.P.M. ▲ 800 R.P.M. DIST 100 FULL LOAD
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP106



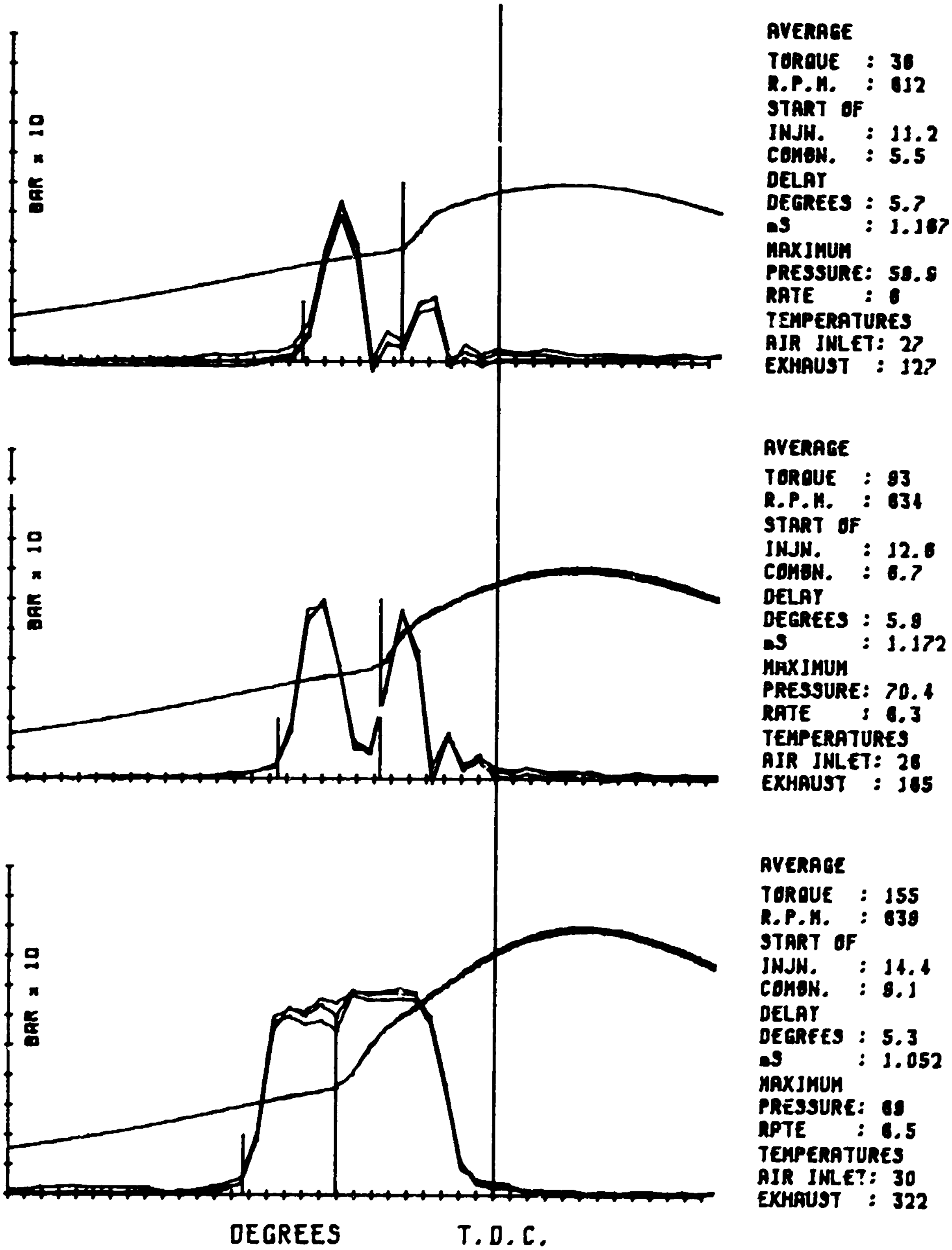
ENGINE : FORD 3000 CAPACITY: 2860	♦ 2000 R.P.M. ▫ 1400 R.P.M. ▲ 600 R.P.M. TEGDN3.9 FULL LOAD
EFFECT OF STATIC TIMING ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	FIG AP107



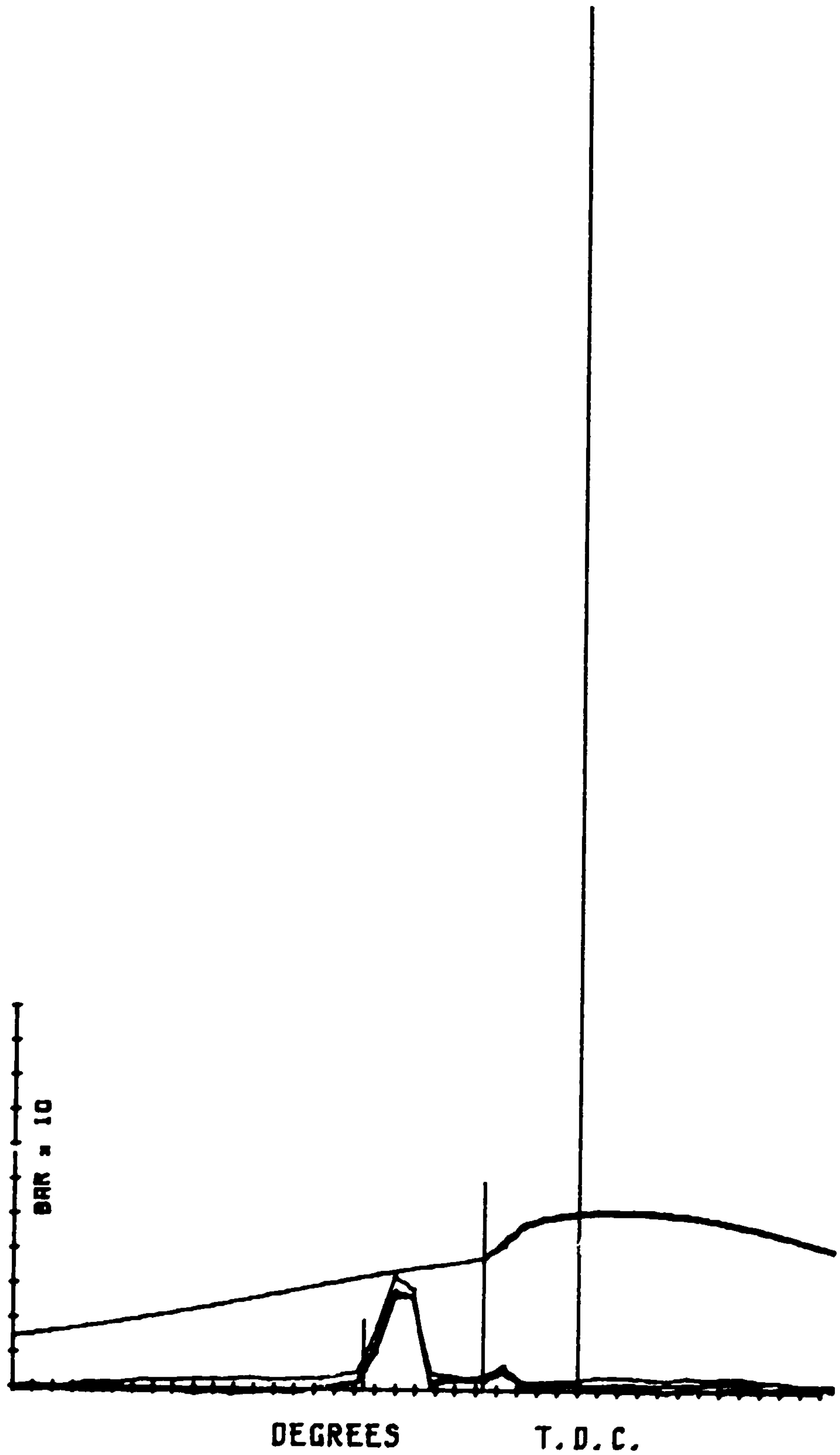
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID016	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP108



ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID016	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP109

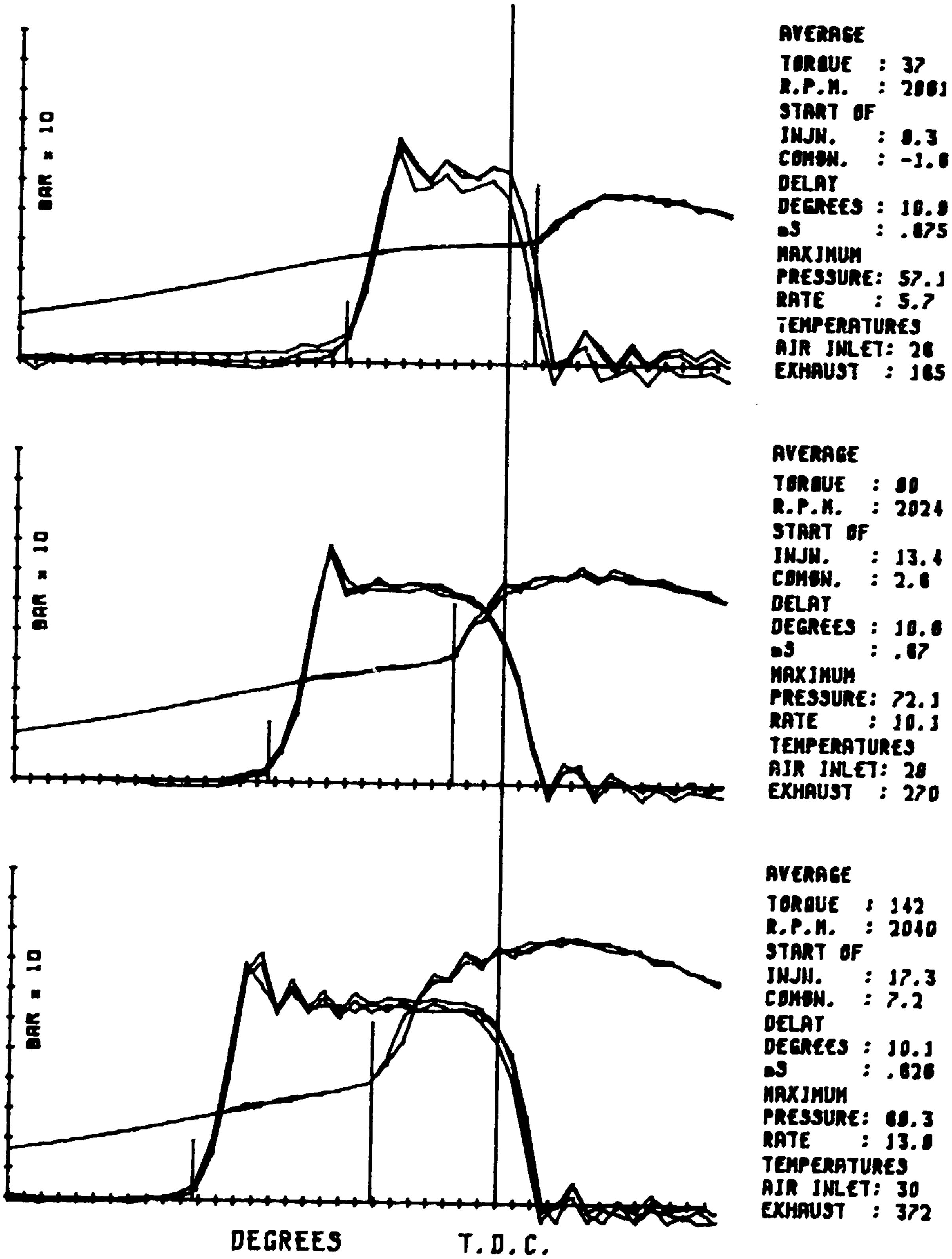


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID016	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP110

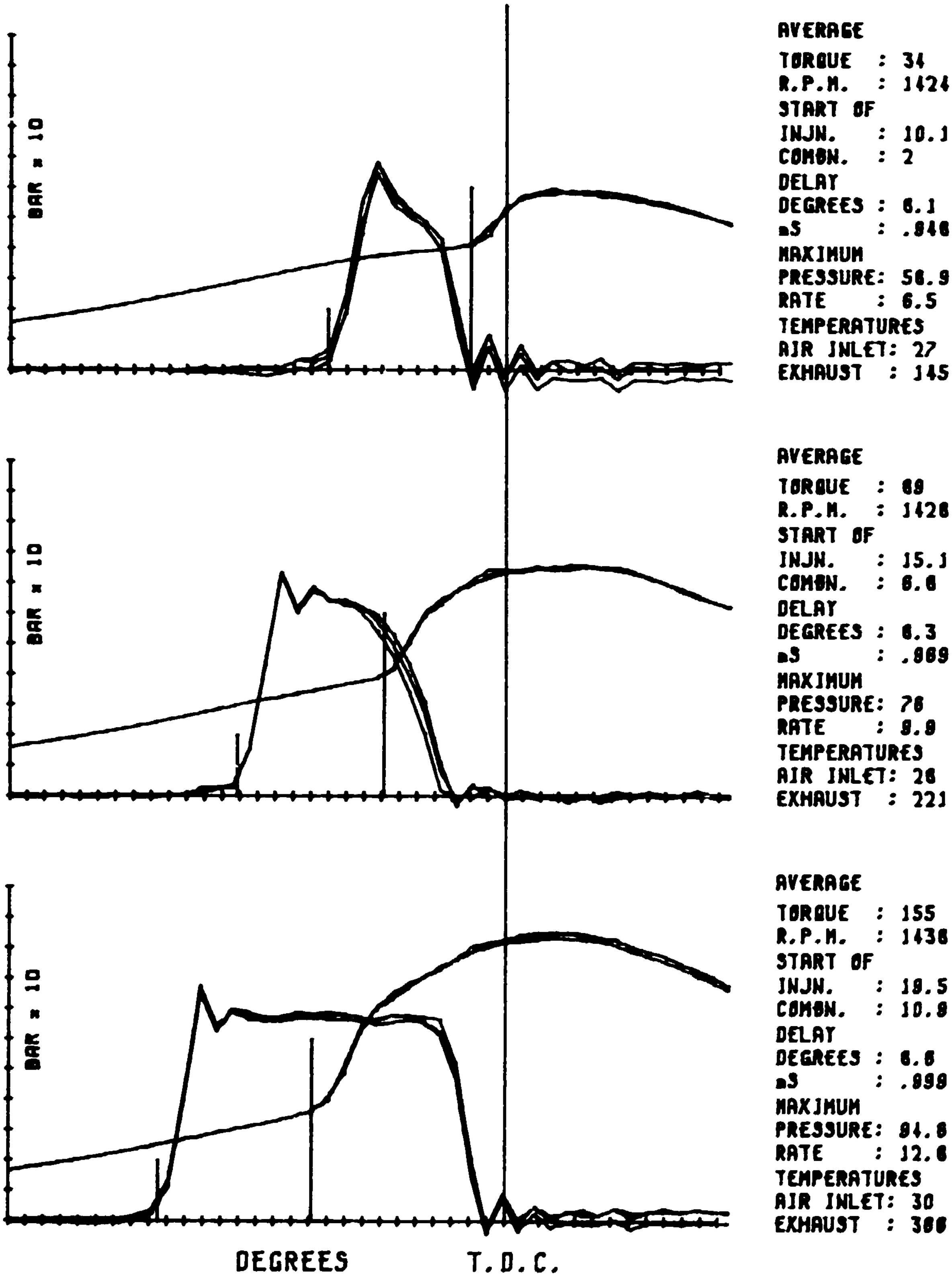


AVERAGE
TORQUE : 3
R.P.M. : 613
START OF
INJN. : 10.6
COMBN. : 4.6
DELAY
DEGREES : 6
mS : 1.215
MAXIMUM
PRESSURE: 51.7
RATE : 4.8
TEMPERATURES
AIR INLET: 26
EXHAUST : 83

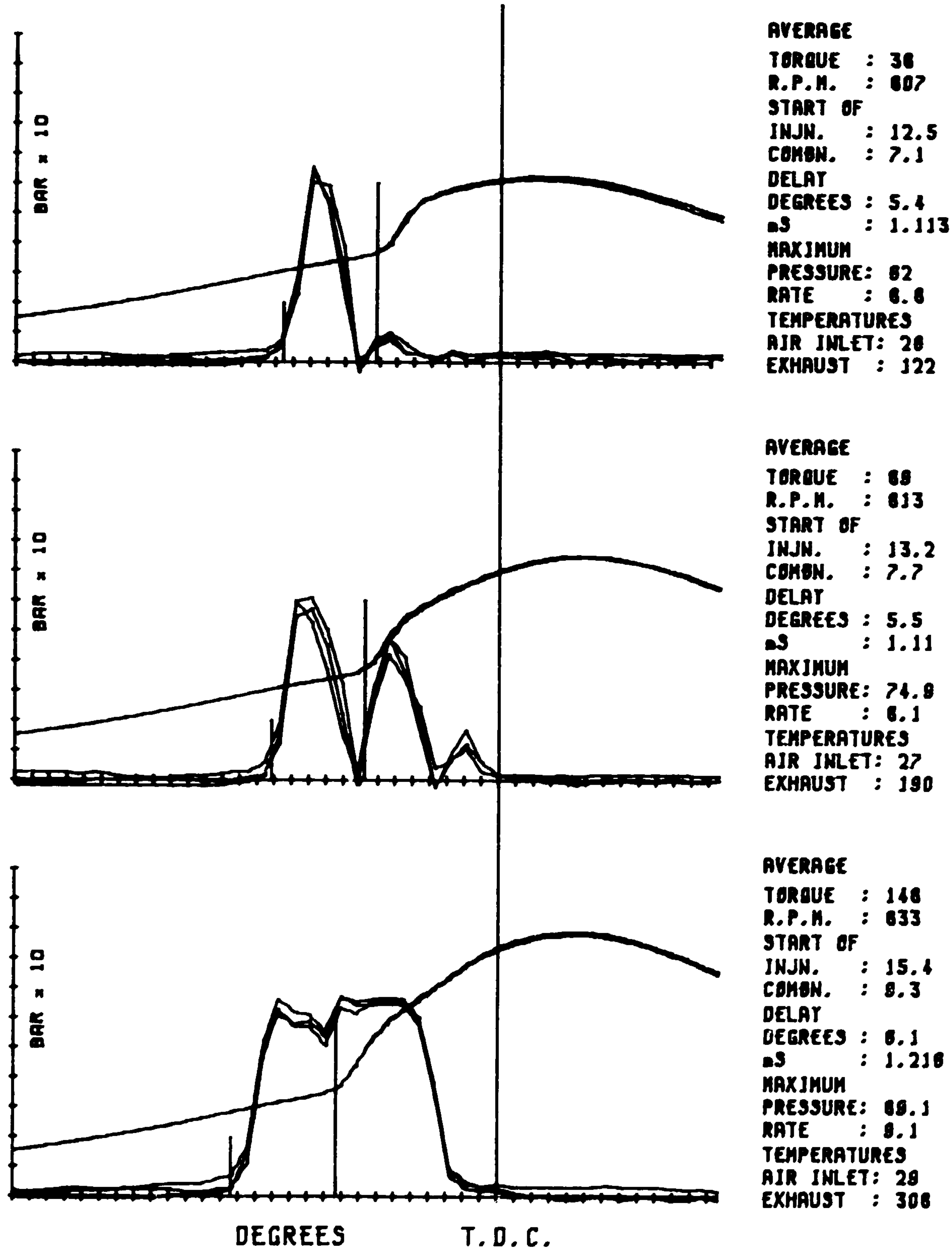
ENGINE : FORD 3000 CAPACITY : 2660	FUEL ID : DIST 100 C.V. : 42.75 DENSITY : .849
TEST ID. : UNID016	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP111



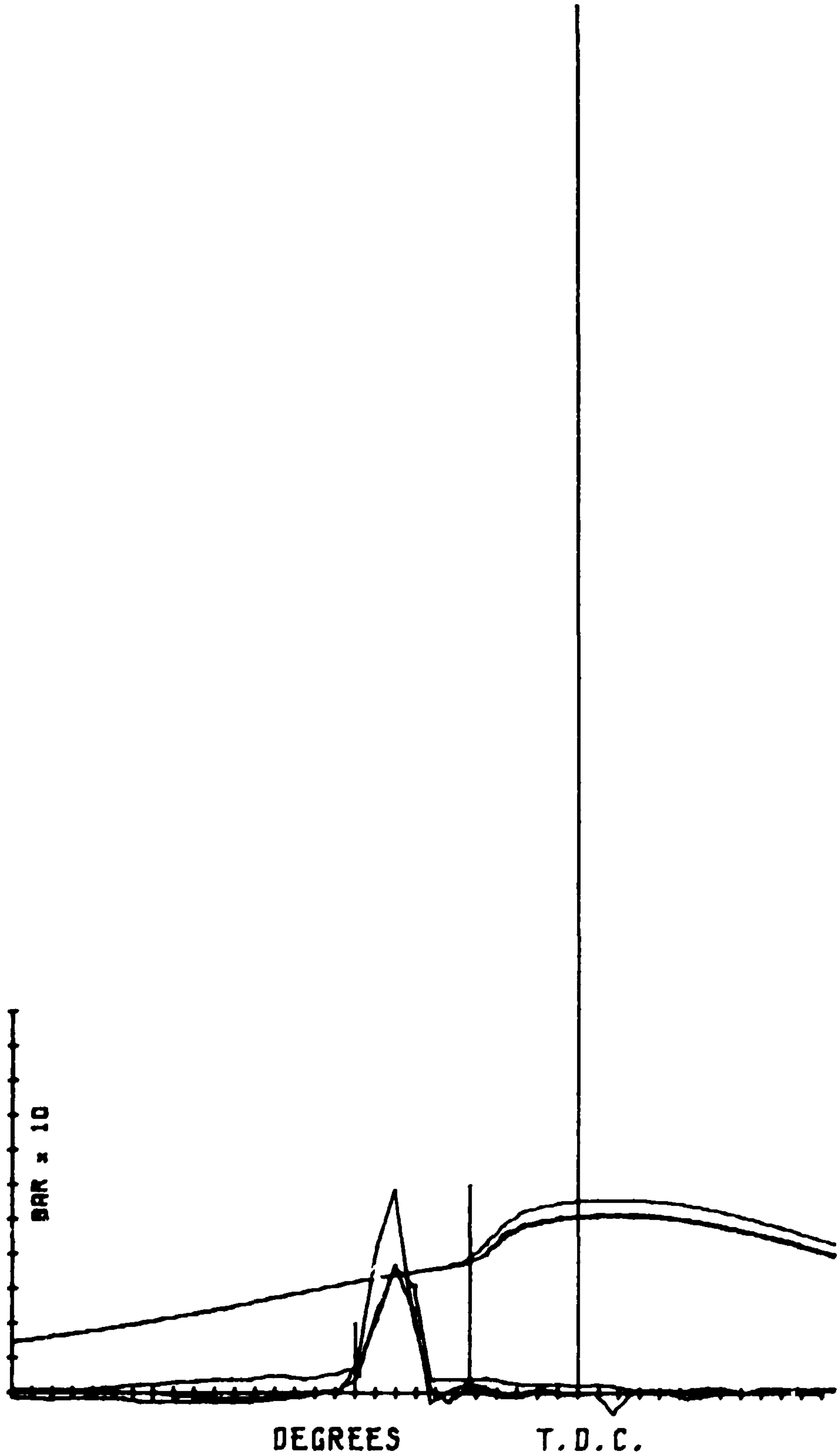
ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E25/3.9TEGDN C.V. : 37.66 DENSITY : .848
TEST ID. : UNID017	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP112



ENGINE : FØRD 3000 CAPACITY : 2860	FUEL ID : E25/3.9TEGDN C.V. : 37.66 DENSITY : .848
TEST ID. : UNID017	
REPEATABILITY ØF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP113

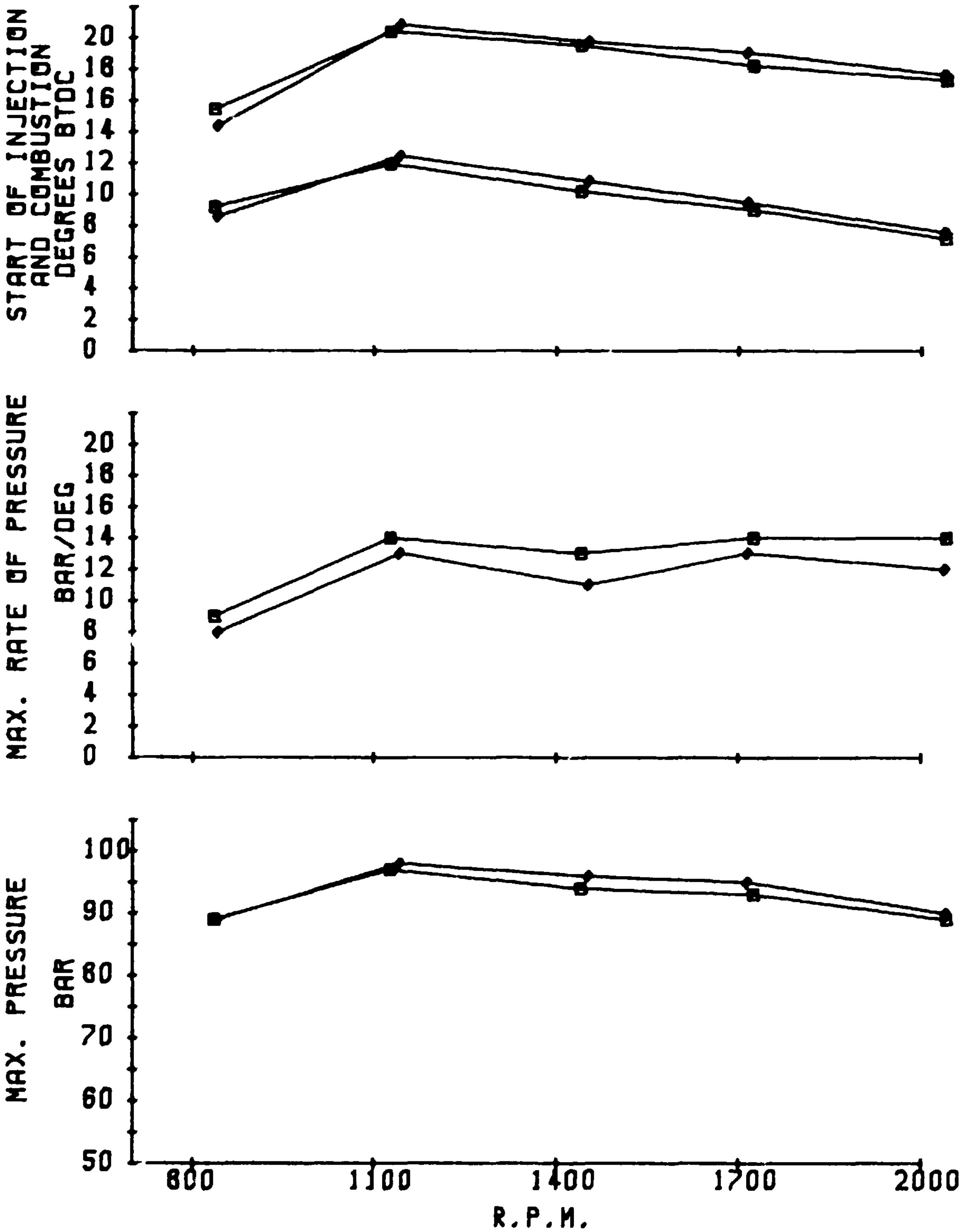


ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E25/3.9TEGDN C.V. : 37.66 DENSITY : .848
TEST ID. : UNID017	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP114

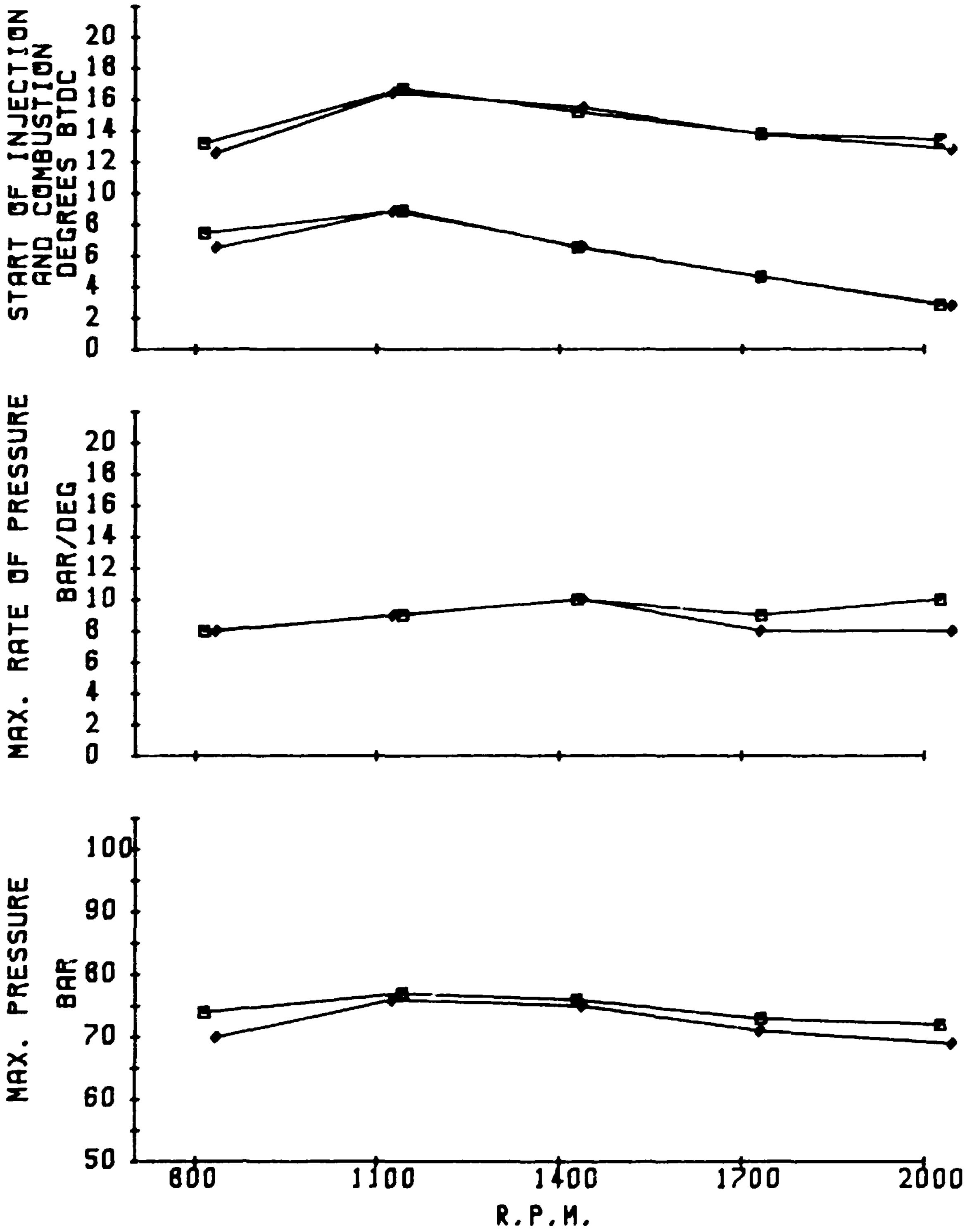


AVERAGE
TORQUE : 3
R.P.M. : 609
START OF
INJN. : 11
COMBN. : 5.3
DELAY
DEGREES : 5.7
mS : 1.176
MAXIMUM
PRESSURE: 53.8
RATE : 5.5
TEMPERATURES
AIR INLET: 26
EXHAUST : 82

ENGINE : FORD 3000 CAPACITY : 2860	FUEL ID : E25/3.9TEGDN C.V. : 37.66 DENSITY : .848
TEST ID. : UNID017	
REPEATABILITY OF NEEDLE LIFT AND CYLINDER PRESSURE	FIG AP115



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ▣ E25/3.9TEGDN
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	18 deg BTDC FULL LOAD
	FIG AP116



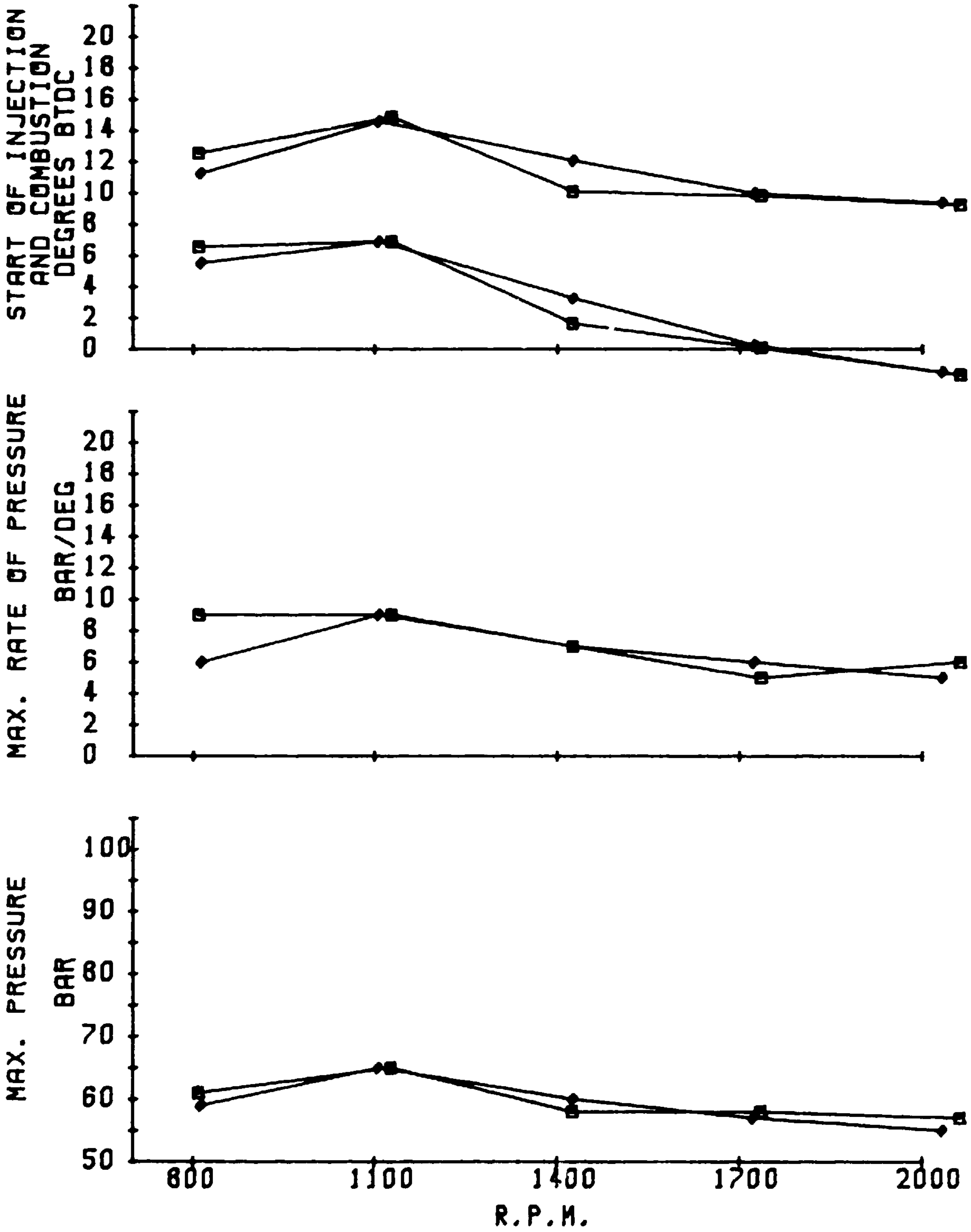
ENGINE : FORD 3000
CAPACITY: 2860

◆ DIST 100
▣ E25/3.9TEGON

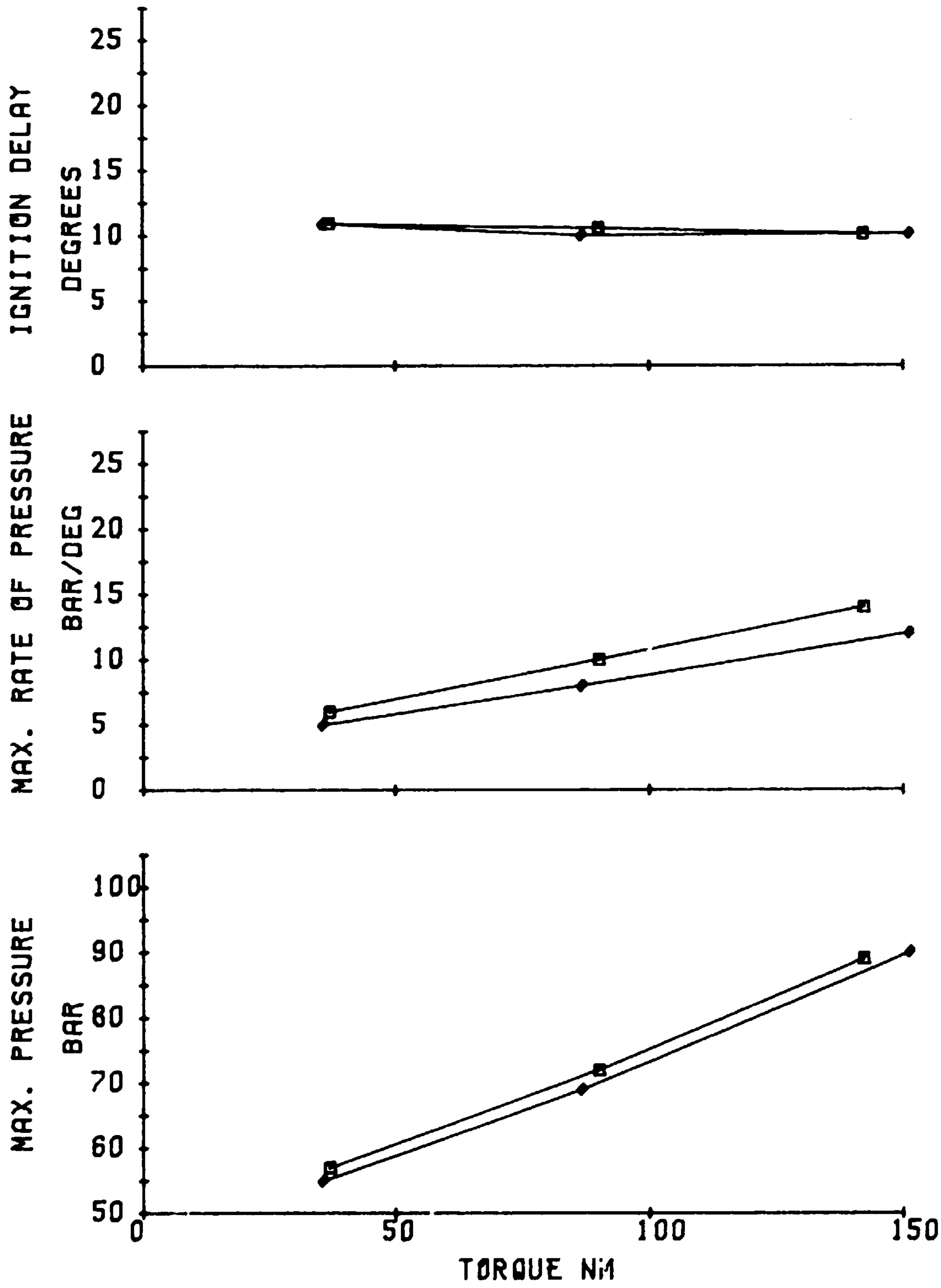
18 deg BTDC
2/3 LOAD

EFFECT OF TEGON ON
START OF: INJECTION, COMBUSTION,
MAX. PRESSURE & PRESSURE RATE

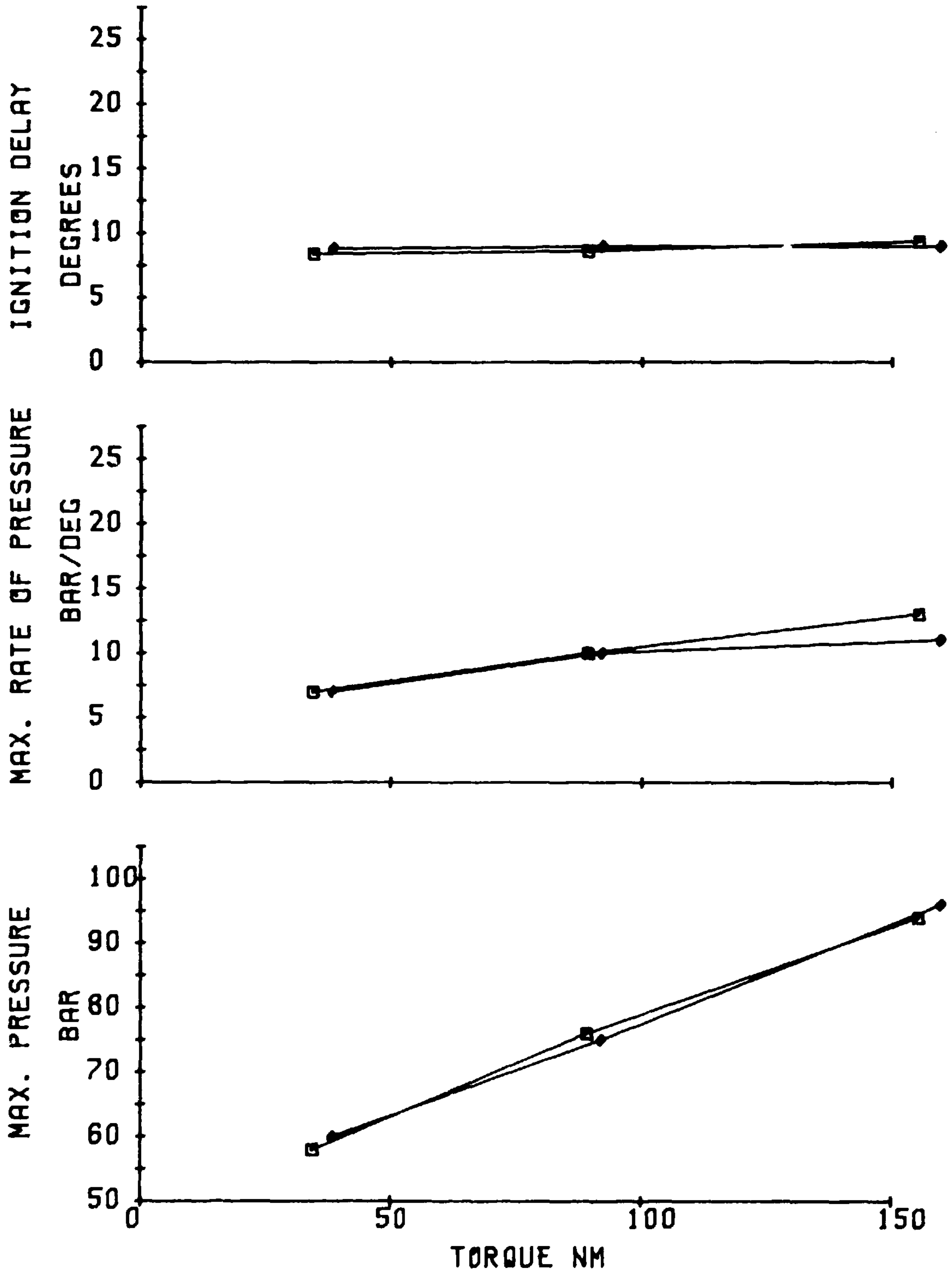
FIG AP117



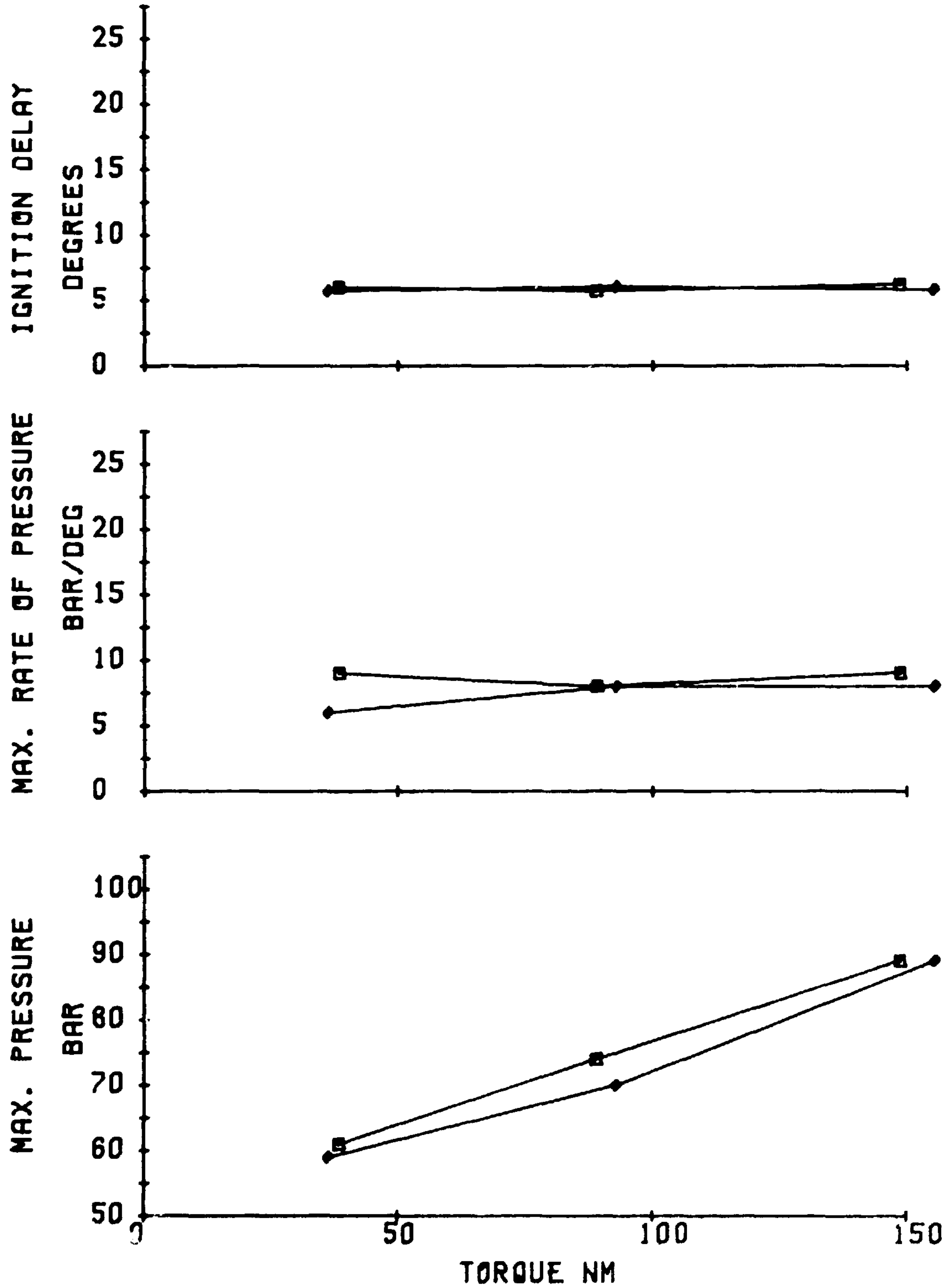
ENGINE : FORD 3000 CAPACITY: 2660	◆ DIST 100 ▣ E25/3.9TEGDN
EFFECT OF TEGDN ON START OF: INJECTION, COMBUSTION, MAX. PRESSURE & PRESSURE RATE	18 deg BTDC 1/3 LOAD FIG AP118



ENGINE : FORD 3000 CAPACITY: 2860	♦ DIST 100 ▫ E25/3.9TEGON
EFFECT OF TEGON ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	18 deg BTDC 2000 R.P.M. FIG AP119



ENGINE : FORD 3000 CAPACITY: 2660	◆ DIST 100 ▫ E25/3.9TEGDN
EFFECT OF TEGDN ON IGNITION DELAY, MAX. PRESSURE & PRESSURE RATE	18 deg BTDC 1400 R.P.M. FIG AP120



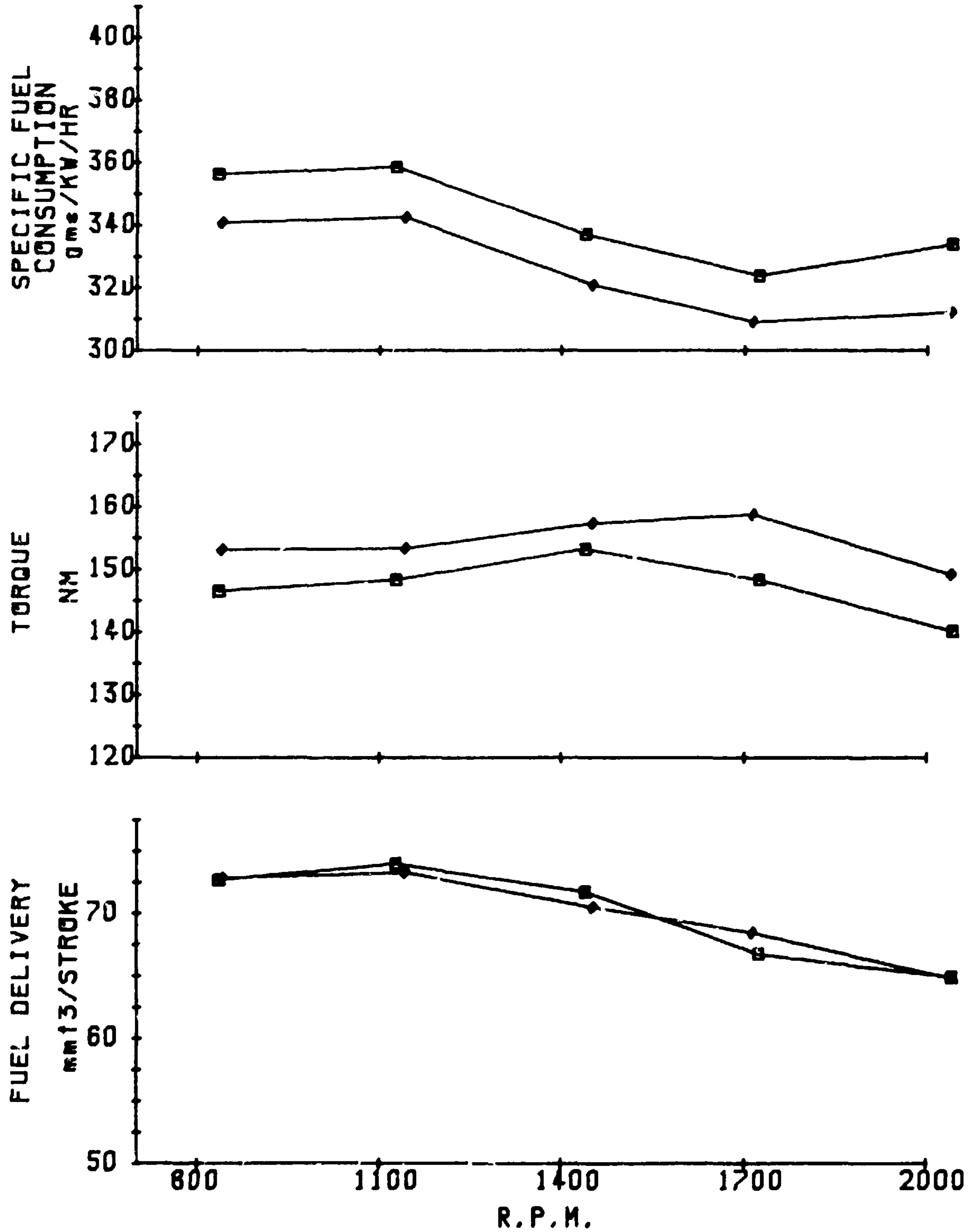
ENGINE : FORD 3000
CAPACITY: 2860

◆ DIST 100
◘ E25/3.9TEGON

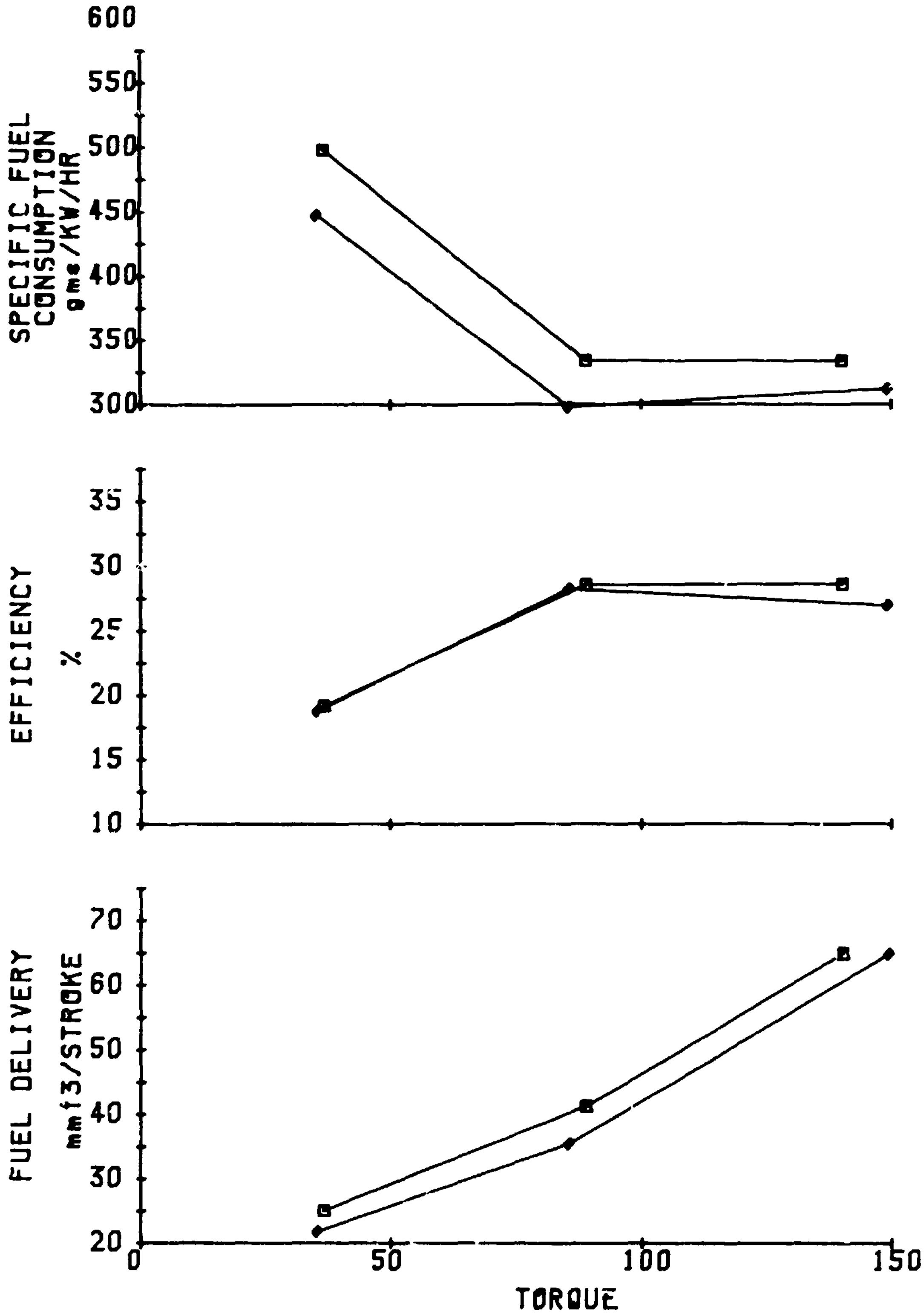
18 deg BTDC
800 R.P.M.

EFFECT OF TEGON ON
IGNITION DELAY,
MAX. PRESSURE & PRESSURE RATE

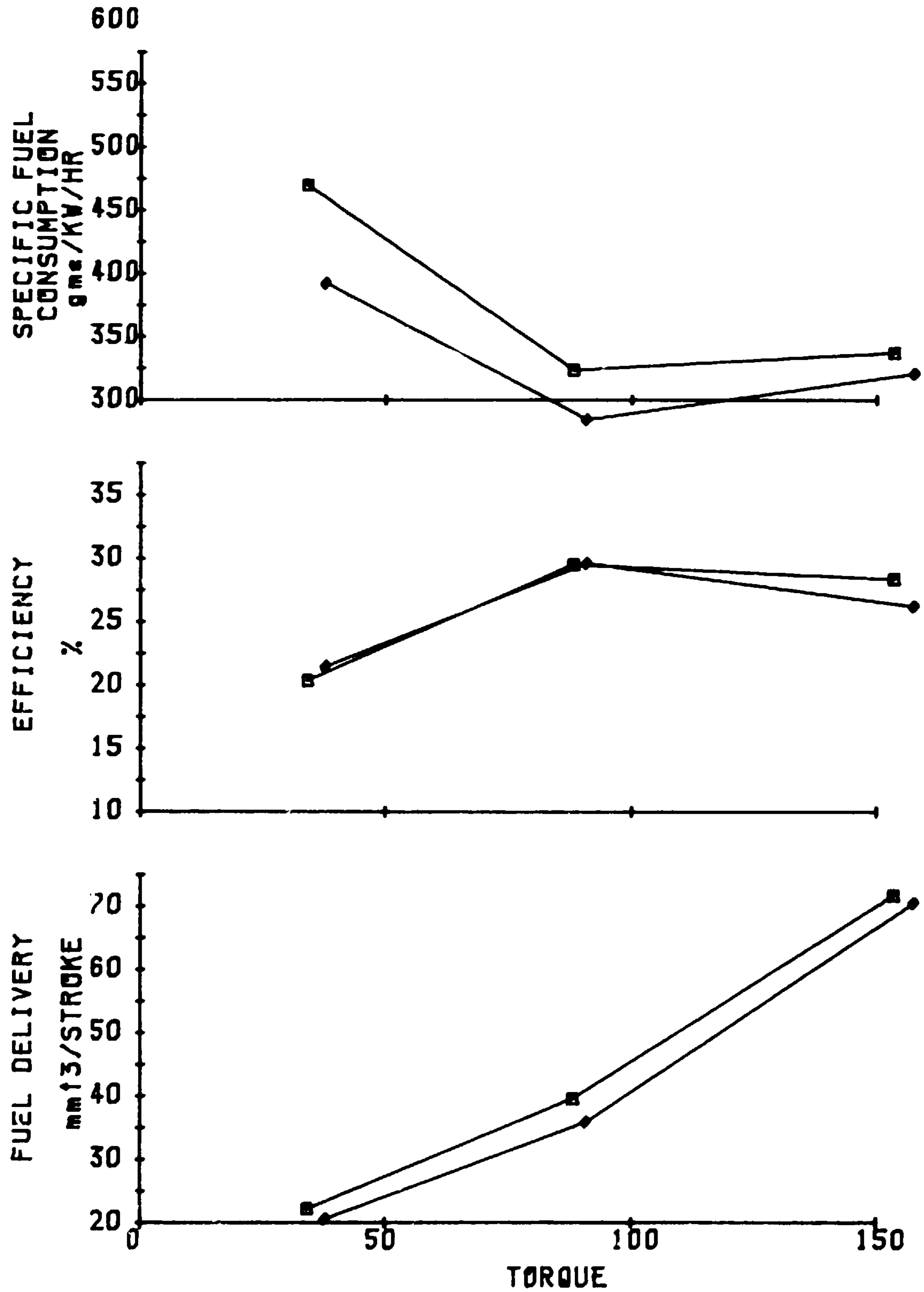
FIG AP121



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ■ E25/3.9TEGDN
EFFECT OF E25/3.9 TEGDN EMULSION ON INJECTION PUMP DELIVERY, TORQUE & S.F.C.	18 deg BTDC FULL LOAD FIG AP122



ENGINE : FORD 3000 CAPACITY: 2860	◆ DIST 100 ▣ E25/3.9TEGDN
EFFECT OF E25/3.9TEGDN EMULSION ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	18 deg BTDC 2000 R.P.M. FIG AP123



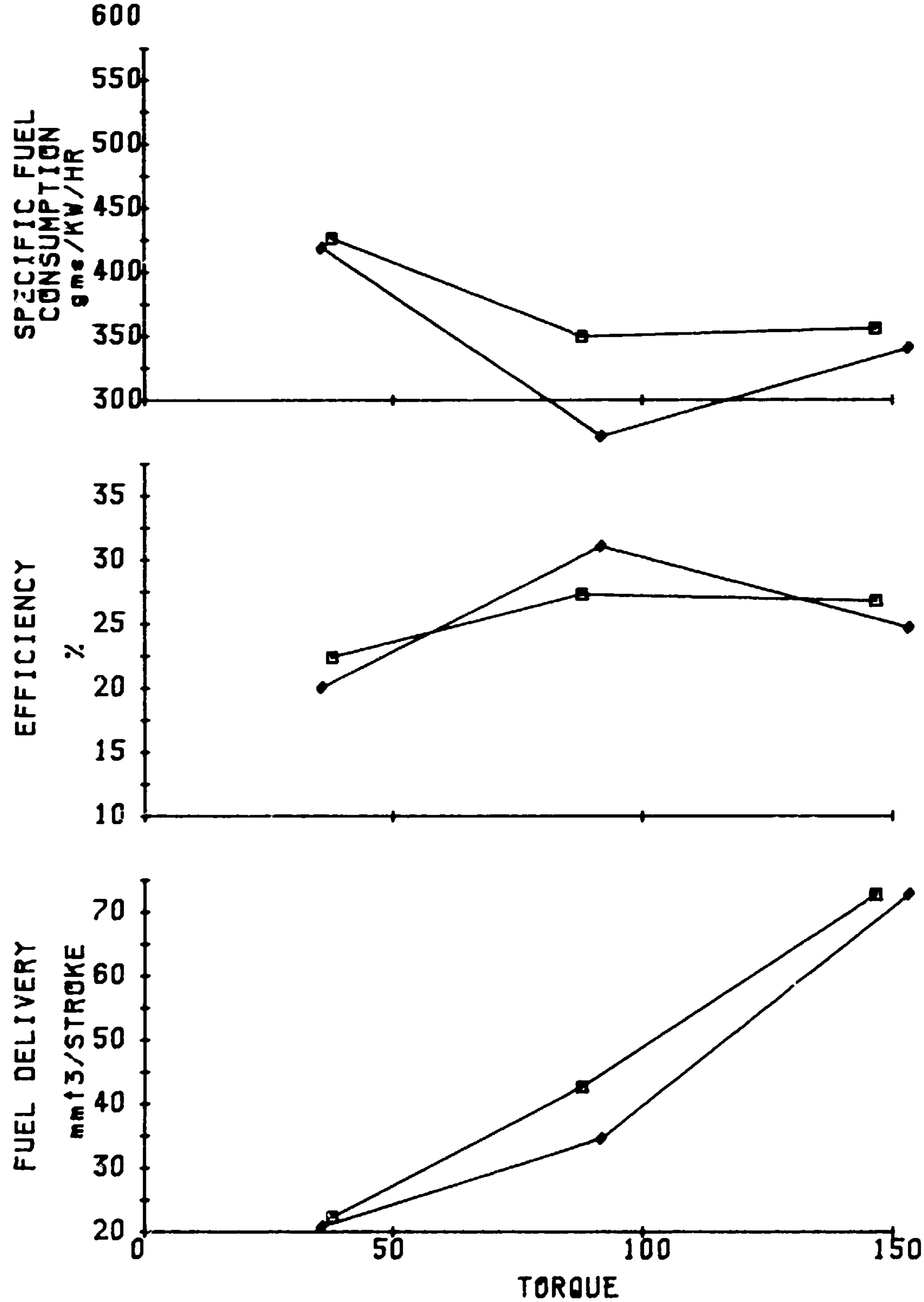
ENGINE : FORD 3000
CAPACITY: 2860

◆ DIST 100
▫ E25/3.9TEGDN

EFFECT OF E25/3.9TEGDN EMULSION ON
INJECTION PUMP DELIVERY,
EFFICIENCY & S.F.C.

18 deg BTDC
1400 R.P.M.

FIG AP124



ENGINE : FORD 3000 CAPACITY: 2860	♦ DIST 100 ▫ E25/3.9TEGDN
EFFECT OF E25/3.9TEGDN EMULSION ON INJECTION PUMP DELIVERY, EFFICIENCY & S.F.C.	18 deg BTDC 800 R.P.M. FIG AP125

8.2. Tables of Engine Test Results

Fuel	Load (nominal)	Speed rpm	Timing deg. BDTC	Test ID
DIST 100	FULL	ALL	20	UNIDO_0
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E20	FULL	ALL	"	UNIDO_1
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E20/2.6TEGDN	FULL	ALL	"	UNIDO_2
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E20/5.2TEGDN	FULL	ALL	"	UNIDO_4
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E20/0.2ION	FULL	ALL	"	UNIDO_5
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E20/0.4ION	FULL	ALL	"	UNIDO_6
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
DIST 100	FULL	ALL	"	UNIDO10
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
"	FULL	ALL	26	UNIDO11
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
"	FULL	ALL	14	UNIDO12
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"

Fuel	Load (nominal)	Speed rpm	Timing deg. BDTC	Test ID
E20/3.9TEGDN	FULL	ALI	14	UNIDO13
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
"	FULL	ALL	20	UNIDO14
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
"	FULL	ALL	26	UNIDO15
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
DIST 100	FULL	ALL	18	UNIDO16
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"
E25/3.9TEGDN	FULL	ALL	"	UNIDO17
"	2/3	"	"	"
"	1/3	"	"	"
"	IDLE	800	"	"

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	DISTILLATE	DIST 100	DATE	22/5/85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID	UNIDO 0
No CYL	3	CAL VALUE MJ/Kg	42.75		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

100 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N	17.48	18.29	18.47	18.28	18.46
Observed torque	NM	139.9	146.3	147.9	146.4	147.8
Observed speed	RPM	2010	1744	1453	1149	843
Observed power	KW	29.4	26.7	22.5	17.6	13.1
Air temperature	deg C	31.0	31.0	31.0	31.0	31.0
Barometric pressure	mBar	1020.5	1020.5	1020.3	1020.3	1020.3
Correction factor		0.993	0.993	0.994	0.994	0.994
Corrected torque	NM	139.0	145.4	146.9	145.4	146.8
Corrected power	KW	29.3	26.5	22.3	17.5	13.0
Fuel consumed	gms	79.7	84.3	87.1	89.2	88.3
Measurement time	seconds	30.390	34.790	41.590	52.590	71.580
Fuel mass flow	gms/sec	2.62	2.42	2.09	1.70	1.23
B.S.F.C.	gms/KW/hr	322.7	328.6	337.3	348.9	342.5
Thermal efficiency	%	26.1	25.6	25.0	24.1	24.6
Fuel temperature	deg C	42.0	42.0	42.0	42.0	42.0
Pump delivery/stroke	mm+3	63.3	67.4	69.9	71.6	70.9
	mgms	52.2	55.6	57.7	59.1	58.5
Start of injection deg.	max	20.3	21.9	22.8	22.7	16.4
	min	20.1	21.1	22.6	21.8	15.7
	mean	20.2	21.4	22.7	22.1	16.2
Start of combustion deg.	max	9.3	11.8	12.7	13.7	10.3
	min	9.1	10.8	12.6	13.6	10.0
	mean	9.1	11.1	12.6	13.6	10.1
Ignition delay deg	max	11.2	11.0	10.2	9.0	6.2
	min	11.0	10.0	10.0	8.2	5.7
	mean	11.1	10.3	10.1	8.4	6.1
Ignition delay ms	max	0.931	1.055	1.165	1.312	1.234
	min	0.913	0.960	1.147	1.189	1.122
	mean	0.922	0.989	1.154	1.225	1.202
Max. cylinder pressure	bar	90.5	95.1	96.2	95.2	88.0
Max. pressure rise	bar/deg	14.8	15.9	15.1	13.2	9.6
	bar/ms	178.6	166.3	131.3	91.3	48.4
Oil temperature	deg C	93.0	94.0	95.0	96.0	91.0
Water IN temperature	deg C	49.0	67.0	68.0	69.0	64.0
Water OUT temperature	deg C	82.0	82.0	81.0	83.0	82.0
Exhaust temperature	deg C	[illegible]	415.0	390.0	359.0	321.0

ENGINE TEST RESULTS

DATE 22/5/85
TEST ID : UNIDO_0

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc : 2860

FUEL
DISTILLATE DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DYNO TORQUE FACTOR 35.61

67 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load	N		11.06	10.85	11.08	11.20	11.17
Observed torque	NM		88.6	86.9	88.7	89.7	89.4
Observed speed	RPM		2029	1754	1459	1139	809
Observed power	KW		18.8	16.0	13.6	10.7	7.6
Air temperature	deg C		31.0	31.0	31.0	31.0	31.0
Barometric pressure	mBar		1020.3	1020.3	1020.3	1020.1	1020.1
Correction factor			0.994	0.994	0.994	0.994	0.994
Corrected torque	NM		88.0	86.3	88.2	89.1	88.8
Corrected power	KW		18.7	15.8	13.5	10.6	7.5
Fuel consumed	gms		46.6	44.8	45.0	46.5	45.4
Measurement time	seconds		29.990	34.590	41.590	53.190	74.580
Fuel mass flow	gms/sec		1.55	1.30	1.08	0.87	0.61
B.S.F.C.	gms/KW/hr		299.2	294.2	289.2	296.0	291.1
Thermal efficiency	%		28.1	28.6	29.1	28.4	28.9
Fuel temperature	deg C		41.0	42.0	42.0	42.0	42.0
Pump delivery/stroke	mm*3		37.1	35.8	36.0	37.2	36.5
	mgms		30.6	29.5	29.7	30.7	30.1
Start of injection deg.		max	15.8	16.6	17.5	19.1	16.3
		min	15.5	16.5	17.3	18.5	16.3
		mean	15.7	16.5	17.4	19.0	16.3
Start of combustion deg.		max	5.5	6.6	9.0	11.1	10.1
		min	4.6	6.4	8.3	10.9	10.0
		mean	5.1	6.5	8.5	11.0	10.1
Ignition delay	deg	max	11.2	10.2	9.1	8.2	6.3
		min	10.2	10.0	8.3	7.6	6.2
		mean	10.6	10.0	8.9	8.0	6.2
Ignition delay	ms	max	0.920	0.965	1.044	1.196	1.300
		min	0.836	0.946	0.953	1.107	1.275
		mean	0.867	0.951	1.022	1.165	1.287
Max. cylinder pressure	bar		70.4	73.5	75.4	79.3	73.4
Max. pressure rise	bar/deg		10.3	10.3	10.5	12.7	9.1
	bar/ms		125.6	108.7	92.0	87.1	44.3
Oil temperature	deg C		95.0	95.0	92.0	89.0	86.0
Water IN temperature	deg C		55.0	50.0	48.0	56.0	56.0
Water OUT temperature	deg C		79.0	77.0	77.0	81.0	82.0
Exhaust temperature	deg C		285.0	249.0	233.0	220.0	198.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	DISTILLATE	DIST 100	DATE	22/5/85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID	UNIDO_0
No CYL	3	CAL VALUE MJ/Kg	42.75		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
			33 % LOAD (Nominal) 20 deg BTDC				
Observed load	N		4.57	4 41	4.64	4.67	4.68
Observed torque	NM		36.6	35.3	37.1	37.4	37.4
Observed speed	RPM		2034	1732	1452	1148	818
Observed power	KW		7.8	6.4	5.6	4.5	3.2
Air temperature	deg C		32.0	31.0	31.0	29.0	31.0
Barometric pressure	mBar		1020.1	1020.1	1020.0	1019.9	1019.9
Correction factor			0.995	0.994	0.994	0.991	0.994
Corrected torque	NM		36.5	35.1	36.9	37.1	37.2
Corrected power	KW		7.8	6.4	5.6	4.5	3.2
Fuel consumed	gms		29.1	27.4	26.6	26.7	29.7
Measurement time	seconds		29.790	34.990	41.790	52.620	73.820
Fuel mass flow	gms/sec		0.98	0.78	0.64	0.51	0.40
B.S.F.C.	gms/KW/hr		452.8	442.6	408.7	410.0	454.5
Thermal efficiency	%		18.6	19.0	20.6	20.5	18.5
Fuel temperature	deg C		42.0	42.0	41.0	41.0	41.0
Pump delivery/stroke	mm+3		23.3	21.9	21.2	21.4	23.8
	mgms		19.2	18.1	17.5	17.7	19.7
Start of injection deg.		max	13.8	12.2	14.7	17.4	15.4
		min	13.1	12.0	14.7	16.6	14.7
		mean	13.3	12.1	14.7	17.0	15.0
Start of combustion deg.		max	2.1	2.8	5.6	9.2	8.5
		min	1.7	2.2	5.5	8.3	8.3
		mean	1.9	2.5	5.6	8.9	8.4
Ignition delay	deg	max	11.8	10.1	9.2	8.3	7.1
		min	11.2	9.3	9.1	7.6	6.4
		mean	11.4	9.6	9.2	8.1	6.7
Ignition delay	ms	max	0.968	0.970	1.056	1.209	1.440
		min	0.917	0.890	1.045	1.105	1.298
		mean	0.935	0.928	1.051	1.174	1.358
Max. cylinder pressure	bar		59.0	58.2	61.4	65.1	64.5
Max. pressure rise	bar/deg		6.2	6.1	7.5	9.1	8.2
	bar/ms		75.5	63.5	64.9	62.6	40.5
Oil temperature	deg C		89.0	89.0	86.0	87.0	82.0
Water IN temperature	deg C		51.0	50.0	52.0	51.0	52.0
Water OUT temperature	deg C		78.0	78.0	78.0	86.0	75.0
Exhaust temperature	deg C		197.0	173.0	154.0	144.0	140.0

ENGINE TEST RESULTS

PAGE 4

ENGINE		FUEL		
MAKE	FORD	DISTILLATE	DIST 100	DATE : 22/5/85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID : UNIDO 0
No CYL	3	CAL VALUE MJ/Kg	42.75	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load	N	:	0.32
Observed torque	NM	:	2.5
Observed speed	RPM	:	820
Observed power	KW	:	.2
Air temperature	deg C	:	28.0
Barometric pressure	mBar	:	1019.9
Correction factor		:	0.989
Corrected torque	NM	:	2.5
Corrected power	KW	:	.2
Fuel consumed	gms	:	14.7
Measurement time	seconds	:	73.570
Fuel mass flow	gms/sec	:	0.20
B.S.F.C.	gms/KW/hr	:	3348.5
Thermal efficiency	%	:	2.5
Fuel temperature	deg C	:	40.0
Pump delivery/stroke	mm↑3	:	11.8
	mgms	:	9.7
Start of injection deg.	max	:	15.4
	min	:	13.8
	mean	:	14.6
Start of combustion deg.	max	:	8.2
	min	:	7.3
	mean	:	7.8
Ignition delay deg	max	:	7.2
	min	:	6.5
	mean	:	6.8
Ignition delay ms	max	:	1.469
	min	:	1.317
	mean	:	1.379
Max. cylinder pressure	bar	:	55.9
Max. pressure rise	bar/deg	:	7.0
	bar/ms	:	34.7
Oil temperature	deg C	:	78.0
Water IN temperature	deg C	:	54.0
Water OUT temperature	deg C	:	73.0
Exhaust temperature	deg C	:	94.0

ENGINE TEST RESULTS PAGE 5

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20	DATE : 22/5/85
MODEL	3000	DENSITY Kg/l	0.845	TEST ID UNIDO_1
No CYL	3	CAL VALUE MJ/Kg :	38.83	
CAPACITY cc	2960			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 20 deg BTDC						
Observed load	N :	17.05	18.09	18.52	18.25	18.28
Observed torque	NM :	136.5	144.8	148.3	146.1	146.4
Observed speed	RPM :	2011	1742	1450	1153	849
Observed power	KW :	28.7	26.4	22.5	17.6	13.0
Air temperature	deg C :	31.0	34.0	32.0	32.0	31.0
Barometric pressure	mBar :	1019.8	1019.8	1019.8	1019.8	1019.8
Correction factor	:	0.994	0.999	0.996	0.996	0.994
Corrected torque	NM :	135.7	144.6	147.6	145.4	145.5
Corrected power	KW :	28.6	26.4	22.4	17.6	12.9
Fuel consumed	gms :	79.0	83.4	87.4	89.3	86.3
Measurement time	seconds :	30.400	34.790	41.790	52.590	71.180
Fuel mass flow	gms/sec :	2.60	2.40	2.09	1.70	1.21
B.S.F.C.	gms/KW/hr :	327.5	327.2	335.9	348.0	337.5
Thermal efficiency	% :	28.3	28.3	27.6	26.6	27.5
Fuel temperature	deg C :	37.0	37.0	37.0	38.0	40.0
Pump delivery/stroke	mm*3 :	62.6	66.7	69.9	71.4	69.5
	mgms :	51.7	55.0	57.7	58 9	57.1
Start of injection deg.	max :	20.1	22.0	22.7	23.6	18.1
	min :	20.0	21.1	21.9	22.8	17.4
	mean :	20.0	21.6	22.4	23.3	17.8
Start of combustion deg.	max :	7.3	9.2	10.9	12.0	10.1
	min :	7.2	9.0	10.1	11.8	10.0
	mean :	7.3	9.1	10.7	11.9	10.1
Ignition delay deg	max :	12.8	12.9	11.8	11.8	8.1
	min :	12.7	12.0	11.1	10.9	7.2
	mean :	12.8	[illegible]	11.6	11.4	7.7
Ignition delay ms	max :	1.060	1.233	1.361	1.701	1.584
	min :	1.052	1.149	1.275	1.575	1.418
	mean :	1.057	1.197	1.337	1.645	1.520
Max. cylinder pressure	bar :	92.7	95.5	97.1	96.4	89.8
Max. pressure rise	bar/deg :	19.5	19.3	22.2	19.6	13.4
	bar/ms :	235.8	202.1	192.9	135.5	68.4
Oil temperature	deg C :	81.0	87.0	91.0	89.0	86.0
Water IN temperature	deg C :	49.0	65.0	68.0	65.0	[illegible]
Water OUT temperature	deg C :	81.0	81.0	82.0	81.0	81.0
[illegible] temperature	deg C :	[illegible]	[illegible]	371.0	347.0	[illegible]

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20	DATE : 22/5/85
MODEL	3000	DENSITY Kg/l :	0.845	TEST ID : UNIDO_1
No CYL	3	CAL VALUE MJ/Kg	38.83	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
67 % LOAD (Nominal) 20 deg BTDC						
Observed load	N	11.09	11.07	11.07	11.13	11.54
Observed torque	NM :	88.8	88.7	88.6	89.1	92.4
Observed speed	RPM :	2042	1754	1444	1132	825
Observed power	KW :	19.0	16.3	13.4	10.6	8.0
Air temperature	deg C :	31.0	32.0	32.0	31.0	29.0
Barometric pressure	mBar :	1019.8	1019.8	1019.8	1019.8	1019.8
Correction factor	:	0.994	0.996	0.996	0.994	0.991
Corrected torque	NM :	88.2	88.3	88.3	88.5	91.5
Corrected power	KW :	18.9	16.2	13.3	10.5	7.9
Fuel consumed	gms :	51.4	49.6	49.3	51.3	50.8
Measurement time	seconds :	29.790	34.590	42.000	53.390	73.180
Fuel mass flow	gms/sec :	1.73	1.43	1.17	0.96	0.69
B.S.F.C.	gms/KW/hr :	329.2	318.5	316.6	329.7	316.0
Thermal efficiency	% :	28.2	29.1	29.3	28.1	29.3
Fuel temperature	deg C :	38.0	42.0	42.0	41.0	40.0
Pump delivery/stroke	mm*3 :	41.0	39.8	39.6	41.3	40.9
	mgms :	33.8	32.7	32.5	34.0	33.7
Start of injection deg.	max :	15.8	17.2	18.3	20.0	18.1
	min :	15.5	16.6	17.3	19.0	17.4
	mean :	15.6	17.0	17.7	19.3	17.7
Start of combustion deg.	max :	2.8	5.5	7.3	10.1	10.1
	min :	2.7	4.6	7.3	9.1	10.0
	mean :	2.8	5.0	7.3	9.5	10.0
Ignition delay deg	max :	13.0	12.3	11.0	10.1	8.0
	min :	12.7	11.7	10.1	9.1	7.4
	mean :	12.8	12.0	10.4	9.8	7.6
Ignition delay ms	max :	1.057	1.169	1.266	1.485	1.621
	min :	1.032	1.110	1.161	1.338	1.489
	mean :	1.042	1.138	1.706	1.445	1.542
Max. cylinder pressure	bar :	73.1	78.3	78.8	81.2	77.9
Max. pressure rise	bar/deg :	10.6	14.4	13.7	16.2	12.0
	bar/ms	129.9	151.6	119.0	109.9	59.3
Oil temperature	deg C :	91.0	93.0	91.0	91.0	86.0
Water IN temperature	deg C	55.0	51.0	52.0	53.0	56.0
Water OUT temperature	deg C :	78.0	78.0	78.0	79.0	80.0
Exhaust temperature	deg C	278.0	242.0	230.0	218.0	193.0

ENGINE TEST RESULTS

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc 2860

FUEL
EMULSION : E20
DENSITY Kg/l : 0.845
CAL VALUE MJ/Kg : 38.83

DATE : 22/5/85
TEST ID UNIDO 1

DYNO TORQUE FACTOR : 35.61

33 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			1700	1400	1100	800
Observed load	N	4.41	4.37	4.81	4.52	4.76
Observed torque	NM	35.3	35.0	38.5	36.7	38.1
Observed speed	RPM	2029	1729	1436	1145	825
Observed power	KW	7.5	6.3	5.8	4.4	3.3
Air temperature	deg C	29.0	29.0	29.0	29.0	28.0
Barometric pressure	mBar	1020.0	1020.0	1020.0	1020.0	1020.0
Correction factor		0.990	0.990	0.990	0.990	0.989
Corrected torque	NM	35.0	34.7	38.2	36.3	37.7
Corrected power	KW	7.4	6.3	5.7	4.4	3.3
Fuel consumed	gms	31.3	29.4	30.3	29.3	33.1
Measurement time	seconds	29.990	35.190	42.190	52.990	73.180
Fuel mass flow	gms/sec	1.04	0.84	0.72	0.55	0.45
B.S.F.C.	gms/KW/hr	506.0	479.4	450.3	457.0	499.9
Thermal efficiency	%	18.3	19.3	20.6	20.3	18.5
Fuel temperature	deg C	36.0	35.0	35.0	37.0	35.0
Pump delivery/stroke	mm↑3	24.9	23.4	24.2	23.4	26.5
	mgms	20.6	19.3	20.0	19.3	21.9
Start of injection deg.	max	13.8	13.1	15.6	18.4	19.1
	min	13.2	[illegible]	15.0	17.3	18.1
	mean	13.6	12.2	15.4	17.7	18.5
Start of combustion deg.	max	-.5	1.2	5.6	8.3	10.1
	min	-.7	1.0	5.4	8.2	10.0
	mean	-.6	1.1	5.5	8.3	10.1
Ignition delay deg	max	14.4	11.9	10.1	10.1	9.1
	min	13.7	10.7	9.4	9.0	8.0
	mean	14.1	11.2	9.8	9.4	8.4
Ignition delay ms	max	1.183	1.151	1.177	1.472	1.842
	min	1.130	1.033	1.086	1.317	1.610
	mean	1.161	1.076	1.143	1.374	1.705
Max. cylinder pressure	bar	61.5	61.4	65.3	67.2	67.0
Max. pressure rise	bar/deg	7.6	8.3	10.2	11.4	10.8
	bar/ms	91.9	86.1	87.5	78.3	53.2
Oil temperature	deg C	80.0	80.0	83.0	80.0	79.0
Water IN temperature	deg C	45.0	53.0	50.0	50.0	61.0
Water OUT temperature	deg C	78.0	79.0	80.0	83.0	66.0
Exhaust temperature	deg C	176.0	[illegible]	155.0	142.0	135.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20	DATE : 22/5/85
MODEL	2000	Kg/l	0.845	TEST ID UNIDO 1
No CYL	3	VALUE MJ/Kg	38.83	
CAPACITY cc	2960			DYNO TORQUE FACTOR : 33.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 22 deg BTDC

Observed load	N	0.32
Observed torque	NM	2.6
Observed speed	RPM	832
Observed power	KW	.2
Air temperature	deg C	29.0
Barometric pressure	mBar	1020.0
Correction factor		0.990
Corrected torque	NM	2.6
Corrected power	KW	.2
Fuel consumed	gms	15.9
Measurement time	seconds	72.610
Fuel mass flow	gms/sec	0.22
S.F.C.	gms/KW/hr	3523.2
Thermal efficiency	%	2.6
Fuel temperature	deg C	35.0
Pump delivery/stroke	mm+3	12.7
	mgms	10.5
Start of injection deg.	max	16.6
	min	15.6
	mean	16.3
Start of combustion deg.	max	8.4
	min	7.3
	mean	8.0
Ignition delay deg	max	8.7
	min	8.0
	mean	8.3
Ignition delay ms	max	1.749
	min	1.600
	mean	1.656
Max. cylinder pressure	bar	52.6
Max. pressure rise	bar/deg	5.4
	bar/ms	27.2
Oil temperature	deg C	79.0
Water IN temperature	deg C	51.0
Water OUT temperature	deg C	74.0
Exhaust temperature	deg C	94.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20/2.6TEGDN	DATE 22/5/85
MODEL	3000	DENSITY Kg/l	0.848	TEST ID : UNIDO_2
No CYL	3	CAL VALUE MJ/Kg	38.69	
CAPACITY cc	2960			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		100 % LOAD (Nominal)	20 deg BTDC			
Observed load	N :	16.60	18.01	18.03	18.15	18.18
Observed torque	NM :	132.9	144.2	144.4	145.3	145.4
Observed speed	RPM	2056	1752	1445	1144	836
Observed power	KW :	28.6	26.4	21.8	17.4	12.7
Air temperature	deg C :	28.0	34.0	29.0	32.0	31.0
Barometric pressure	mBar :	1020.4	1020.5	1020.5	1020.5	1020.5
Correction factor	:	0.989	0.998	0.990	0.995	0.993
Corrected torque	NM :	131.4	143.9	143.0	144.6	144.4
Corrected power	KW	28.3	26.4	21.6	17.3	12.6
Fuel consumed	gms :	79.2	83.5	88.2	89.9	88.1
Measurement time	seconds :	29.590	34.590	41.990	52.990	72.180
Fuel mass flow	gms/sec :	2.68	2.41	2.10	1.70	1.22
B.S.F.C.	gms/KW/hr :	340.6	329.1	350.0	352.8	347.4
Thermal efficiency	% :	27.3	28.3	26.6	26.4	26.8
Fuel temperature	deg C :	34.0	36.0	36.0	39.0	39.0
Pump delivery/stroke	mm*3 :	62.7	66.5	70.2	71.8	70.6
	mgms :	52.1	55.1	58.2	59.3	58.4
Start of injection deg.	max :	20.3	21.7	22.8	23.6	18.2
	min :	20.1	21.1	21.9	22.7	18.1
	mean :	20.2	21.2	22.4	23.0	18.1
Start of combustion deg.	max :	8.3	11.0	12.9	13.8	11.9
	min :	8.2	10.8	11.8	13.6	11.0
	mean :	8.2	10.9	12.4	13.7	11.5
Ignition delay deg	max :	12.0	10.8	10.9	10.0	7.1
	min :	11.9	10.1	9.1	9.0	6.2
	mean :	11.9	10.3	10.0	9.3	6.6
Ignition delay ms	max :	0.975	1.031	1.260	1.458	1.416
	min :	0.963	0.962	1.050	1.318	1.236
	mean :	0.969	0.983	1.153	1.355	1.311
Max. cylinder pressure	bar :	89.6	93.7	95.5	95.6	89.3
Max. pressure rise	bar/deg	16.4	17.5	17.8	15.0	10.2
	bar/ms :	202.7	183.9	154.1	103.0	51.3
Oil temperature	deg C	84.0	88.0	88.0	89.0	89.0
Water IN temperature	deg C	39.0	63.0	63.0	63.0	62.0
Water OUT temperature	deg C	79.0	80.0	79.0	80.0	80.0
Exhaust temperature	deg C	364.[illegible]	[illegible]	[illegible]	34[illegible]	314.[illegible]

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	E20/2.6TEGDN	DATE 22/5/85
MODEL	3000	DENSITY Kg/l :	0.848	TEST ID UNIDO_2
No CYL	3	CAL VALUE MJ/Kg	38.69	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

67 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N :	11.06	11.20	10.93	11.41	11.22
Observed torque	NM :	88.6	89.6	87.5	91.4	89.8
Observed speed	RPM :	2064	1734	1443	1139	823
Observed power	KW :	19.1	16.3	13.2	10.9	7.7
Air temperature	deg C :	30.0	31.0	30.0	30.0	30.0
Barometric pressure	mBar :	1020.5	1020.5	1020.5	1020.5	1020.5
Correction factor	:	0.992	0.993	0.992	0.992	0.992
Corrected torque	NM :	87.8	89.1	86.8	90.6	89.1
Corrected power	KW :	19.0	16.2	13.1	10.8	7.7
Fuel consumed	gms :	50.5	49.0	47.9	51.4	54.9
Measurement time	seconds :	29.590	34.990	41.990	53.190	73.380
Fuel mass flow	gms/sec :	1.71	1.40	1.14	0.97	0.75
B.S.F.C.	gms/KW/hr	323.6	311.8	313.1	321.8	350.9
Thermal efficiency	% :	28.8	29.8	29.7	28.9	26.5
Fuel temperature	deg C :	40.0	39.0	40.0	40.0	39.0
Pump delivery/stroke	mm+3 :	40.1	39.1	38.3	41.1	44.0
	mgms :	33.1	32.3	31.6	33.9	36.4
Start of injection deg.	max :	16.0	17.6	18.2	20.1	18.1
	min :	14.7	16.5	17.4	20.0	17.5
	mean :	15.5	17.2	17.6	20.0	17.8
Start of combustion deg.	max :	4.8	7.4	8.5	11.9	11.9
	min :	4.5	7.3	8.2	11.0	11.0
	mean :	4.6	7.3	8.3	11.2	11.5
Ignition delay deg	max :	11.2	10.3	9.9	9.0	7.2
	min :	10.0	9.2	8.9	8.2	5.7
	mean :	10.9	9.9	9.3	8.8	6.3
Ignition delay ms	max :	0.902	0.987	1.147	1.321	1.450
	min :	0.803	0.886	1.032	1.204	1.145
	mean :	0.877	0.949	1.071	1.292	1.280
Max. cylinder pressure	bar :	71.1	75.8	77.2	80.6	78.9
Max. pressure rise	bar/deg :	10.4	9.9	11.7	13.2	9.5
	bar/ms :	129.4	102.6	101.6	90.1	47.0
Oil temperature	deg C :	93.0	94.0	92.0	89.0	84.0
Water IN temperature	deg C :	53.0	50.0	49.0	53.0	54.0
Water OUT temperature	deg C :	79.0	77.0	80.0	80.0	84.0
Exhaust temperature	deg C	277.0	247.0	226.0	219.0	205.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	EMULSION :	E20/2.6TEGDN	DATE :	22/5/85
MODEL	3000	DENSITY Kg/l :	0.848	TEST ID :	UNIDO_2
No CYL	3	CAL VALUE MJ/Kg :	38.69		
CAPACITY cc :	2860			DYNO TORQUE FACTOR	35.61

33 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load	N		4.41	4.26	4.41	4.69	4.64
Observed torque	NM		35.3	34.1	35.3	37.6	37.2
Observed speed	RPM		2029	1742	1436	1123	849
Observed power	KW		7.5	6.2	5.3	4.4	3.3
Air temperature	deg C		29.0	29.0	28.0	30.0	30.0
Barometric pressure	mBar		1020.5	1020.5	1020.5	1020.8	1020.9
Correction factor			0.990	0.990	0.989	0.992	0.992
Corrected torque	NM		35.0	33.8	34.9	37.2	36.8
Corrected power	KW		7.4	6.2	5.3	4.4	3.3
Fuel consumed	gms		32.2	29.3	29.8	27.2	33.8
Measurement time	seconds		29.930	34.790	42.190	53.790	71.180
Fuel mass flow	gms/sec		1.07	0.84	0.71	0.51	0.47
B.S.F.C.	gms/KW/hr		520.3	491.9	484.0	415.5	522.0
Thermal efficiency	%		17.9	18.9	19.2	22.4	17.8
Fuel temperature	deg C		39.0	39.0	39.0	39.0	39.0
Pump delivery/stroke	mm†3		25.6	23.4	23.8	21.8	27.1
	mgms		21.2	19.3	19.7	18.0	22.4
Start of injection deg.		max	13.2	12.2	13.7	17.3	17.4
		min	12.8	12.1	12.8	17.3	17.2
		mean	13.1	12.1	13.4	17.3	17.3
Start of combustion deg.		max	1.1	2.1	4.8	9.2	11.0
		min	1.0	1.9	4.7	9.1	10.1
		mean	1.1	2.0	4.7	9.1	10.8
Ignition delay	deg	max	12.1	10.2	9.0	8.2	7.2
		min	11.8	10.0	8.1	8.1	6.2
		mean	12.0	10.1	8.7	8.2	6.6
Ignition delay	ms	max	0.991	0.977	1.049	1.220	1.419
		min	0.969	0.961	0.941	1.195	1.226
		mean	0.983	0.969	1.007	1.211	1.290
Max. cylinder pressure	bar		58.8	59.3	61.1	65.8	68.3
Max. pressure rise	bar/deg		7.7	6.9	7.5	8.9	10.7
	bar/ms		93.9	72.5	65.0	59.7	54.4
Oil temperature	deg C		88.0	89.0	88.0	84.0	84.0
Water IN temperature	deg C		40.0	40.0	44.0	54.0	53.0
Water OUT temperature	deg C		76.0	75.0	75.0	76.0	81.0
Exhaust temperature	deg C		191.0	168.0	153.0	135.0	138.0

ENGINE TEST RESULTS

PAGE 12

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20/2.61FGDN	DATE 22/5/85
MODEL	3000	DENSITY Kg/l :	0.848	TEST ID : UNIDO_2
No CYL	3	CAL VALUE MJ/Kg	38.69	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load	N	0.31
Observed torque	NM	2.5
Observed speed	RPM	830
Observed power	KW	.2
Air temperature	deg C :	29.0
Barometric pressure	mBar :	1020.8
Correction factor	:	0.990
Corrected torque	NM :	2.5
Corrected power	KW	.2
Fuel consumed	gms	16.9
Measurement time	seconds	72.760
Fuel mass flow	gms/sec	0.23
B.S.F.C.	gms/KW/hr	3867.[illegible]
Thermal efficiency	%	2.4
Fuel temperature	deg C :	40.0
Pump delivery/stroke	mm↑3 :	13.6
	mgms :	11.[illegible]
Start of injection deg.	max :	16.3
	min :	15.4
	mean	15.[illegible]
Start of combustion deg.	max :	9.2
	min	8.3
	mean :	9.0
Ignition delay deg	max	7.1
	min	6.4
	mean :	6.9
Ignition delay ms	max	1.425
	min	1.292
	mean :	1.385
Max. cylinder pressure	bar	54.4
Max. pressure rise	bar/deg :	6.8
	bar/ms	33.9
Oil temperature	deg C	80.0
Water IN temperature	deg C	65.0
Water OUT temperature	deg C	76.0
Exhaust temperature	deg C	100.0

ENGINE		FUEL		
MAKE :	FORD	EMULSION :	E20/5.2TEGDN	DATE : 22/5/85
MODEL :	2000	DENSITY Kg/l :	0.850	TEST ID : UNIDO_4
No CYL	3	CAL VALUE MJ/Kg :	38.55	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 20 deg BTDC						
Observed load	N :	17.01	17.88	18.19	18.32	18.32
Observed torque	NM :	136.2	143.1	145.7	146.6	146.7
Observed speed	RPM :	2015	1739	1438	1139	830
Observed power	KW :	28.7	26.1	21.9	17.5	12.8
Air temperature	deg C :	30.0	30.0	31.0	32.0	29.0
Barometric pressure	mBar :	1021.0	1021.1	1021.1	1021.1	1021.2
Correction factor	:	0.992	0.991	0.993	0.995	0.990
Corrected torque	NM :	135.0	141.9	144.7	145.9	145.2
Corrected power	KW :	28.5	25.8	21.8	17.4	12.6
Fuel consumed	gms :	81.4	85.4	90.1	91.1	89.3
Measurement time	seconds :	30.130	34.990	42.190	53.190	72.780
Fuel mass flow	gms/sec :	2.70	2.44	2.14	1.71	1.23
B.S.F.C.	gms/KW/hr	340.6	340.0	353.0	354.3	350.0
Thermal efficiency	% :	27.4	27.5	26.5	26.4	26.7
Fuel temperature	deg C :	33.0	34.0	35.0	37.0	38.0
Pump delivery/stroke	mm^3 :	64.2	67.4	71.4	72.4	71.3
	mgms :	53.5	56.1	59.4	60.1	59.1
Start of injection deg.	max :	20.3	22.0	22.7	23.6	19.1
	min :	19.2	21.0	22.0	22.7	18.4
	mean :	19.9	21.6	22.4	23.2	18.7
Start of combustion deg.	max :	10.0	11.9	12.8	14.6	12.8
	min :	9.2	11.0	12.7	14.5	12.7
	mean :	9.7	11.7	12.7	14.5	12.8
Ignition delay deg	max :	10.7	10.2	10.0	9.1	6.3
	min :	10.1	9.2	9.2	8.2	5.6
	mean :	10.3	9.9	9.6	8.7	5.9
Ignition delay ms	max :	0.882	0.979	1.165	1.326	1.265
	min	0.833	0.883	1.061	1.192	1.129
	mean	0.849	0.949	1.118	1.271	1.187
Max. cylinder pressure	bar	88.8	93.6	94.4	96.3	90.8
Max. pressure rise	bar/deg	12.7	13.2	13.7	13.1	10.5
	bar/ms	153.9	137.8	118.2	89.6	52.3
Oil temperature	deg C	83.0	87.0	88.0	87.0	88.0
Water IN temperature	deg C	57.0	63.0	65.0	64.0	61.0
Water OUT temperature	deg C	79.0	80.0	80.0	81.0	79.0
Exhaust temperature	deg C	393.0	395.0	377.0	349.0	315.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	E20/5.2TEGDN	DATE : 22/5/85
MODEL	3000	DENSITY Kg/l	0.850	TEST ID : UNIDO_4
No CYL	3	CAL VALUE MJ/Kg	38.55	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

67 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load	N		11.23	11.11	11.14	11.15	11.63
Observed torque	NM		89.9	89.0	89.2	89.3	93.1
Observed speed	RPM		2101	1739	1443	1119	829
Observed power	KW		19.8	16.2	13.5	10.5	8.1
Air temperature	deg C		28.0	28.0	29.0	28.0	27.0
Barometric pressure	mBar		1021.2	1021.0	1021.0	1021.0	1021.0
Correction factor			0.988	0.988	0.990	0.988	0.987
Corrected torque	NM		88.8	87.9	88.3	88.2	91.9
Corrected power	KW		19.5	16.0	13.3	10.3	8.0
Fuel consumed	gms		54.9	48.7	49.1	50.0	51.0
Measurement time	seconds		28.990	34.990	41.990	53.990	72.780
Fuel mass flow	gms/sec		1.89	1.39	1.17	0.93	0.70
B.S.F.C.	gms/KW/hr		348.9	312.9	315.4	322.5	316.2
Thermal efficiency	%		26.8	29.8	29.6	29.0	29.5
Fuel temperature	deg C		38.0	38.0	39.0	39.0	39.0
Pump delivery/stroke	mm+3		43.5	38.6	39.1	40.0	40.8
	mgms		36.1	32.0	32.4	33.1	33.8
Start of injection deg.		max	16.8	17.3	18.1	19.9	19.0
		min	15.9	16.5	17.4	19.2	18.5
		mean	16.3	16.7	17.8	19.6	18.8
Start of combustion deg.		max	6.5	7.4	9.2	11.9	12.8
		min	5.4	7.3	9.1	11.8	12.7
		mean	5.7	7.3	9.2	11.8	12.7
Ignition delay	deg	max	11.3	9.9	8.9	8.1	6.3
		min	9.4	9.1	8.2	7.3	5.7
		mean	10.6	9.3	8.6	7.7	6.1
Ignition delay	ms	max	0.898	0.954	1.026	1.207	1.267
		min	0.749	0.873	0.946	1.081	1.148
		mean	0.839	0.896	0.995	1.154	1.216
Max. cylinder pressure	bar		72.2	74.8	77.3	80.3	77.6
Max. pressure rise	bar/deg		9.9	10.4	9.8	12.1	10.7
	bar/ms		124.2	108.3	84.6	80.9	53.5
Oil temperature	deg C		93.0	92.0	90.0	87.0	85.0
Water IN temperature	deg C		51.0	48.0	47.0	52.0	55.0
Water OUT temperature	deg C		80.0	79.0	79.0	79.0	83.0
Exhaust temperature	deg C		285.0	246.0	231.0	213.0	198.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	E20/5.2TEGDN	DATE : 22/3/85
MODEL :	3000	DENSITY Kg/l :	0.850	TEST ID : UNIDO_4
No CYL :	3	CAL VALUE MJ/Kg :	38.55	
CAPACITY cc :	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		33 % LOAD (Nominal)		20 deg BTDC		
Observed load	N	4.21	4.43	4.32	4.32	4.60
Observed torque	NM :	33.7	35.5	34.6	34.6	36.8
Observed speed	RPM :	2028	1734	1439	1139	826
Observed power	KW :	7.2	6.4	5.2	4.1	3.2
Air temperature	deg C :	27.0	28.0	29.0	28.0	28.0
Barometric pressure	mBar :	1021.2	1021.3	1021.2	1021.5	1021.5
Correction factor		0.986	0.988	0.990	0.988	0.988
Corrected torque	NM :	33.2	35.0	34.2	34.2	36.4
Corrected power	KW :	7.1	6.4	5.2	4.1	3.1
Fuel consumed	gms :	30.5	30.9	28.7	32.4	31.4
Measurement time	seconds	30.000	34.990	41.990	53.190	73.160
Fuel mass flow	gms/sec :	1.02	0.88	0.68	0.61	0.43
B.S.F.C.	gms/KW/hr :	518.4	499.8	477.5	537.7	490.8
Thermal efficiency	%	18.0	18.7	19.6	17.4	19.0
Fuel temperature	deg C	39.0	36.0	38.0	38.0	35.0
Pump delivery/stroke	mm*3 :	24.2	24.5	22.9	25.8	25.0
	mgms	20.1	20.4	19.0	21.4	20.8
Start of injection deg.	max :	13.1	12.1	13.0	18.1	18.9
	min	12.8	12.0	12.0	17.4	18.2
	mean :	12.9	12.0	12.2	17.6	18.4
Start of combustion deg.	max :	2.4	3.8	4.6	10.1	11.9
	min	1.9	2.9	3.8	9.9	11.8
	mean	2.1	3.4	4.0	10.0	11.9
Ignition delay deg	max	11.1	9.2	8.4	8.1	7.1
	min :	10.6	8.2	8.0	7.4	6.3
	mean	10.9	8.6	8.2	7.6	6.5
Ignition delay ms	max :	0.913	0.885	0.970	1.178	1.429
	min :	0.870	0.789	0.931	1.076	1.273
	mean :	0.892	0.825	0.951	1.105	1.317
Max. cylinder pressure	bar :	58.1	60.2	58.1	68.7	65.0
Max. pressure rise	bar/deg :	5.9	6.6	6.3	9.4	9.4
	bar/ms :	71.4	63.6	54.8	64.0	46.7
Oil temperature	deg C :	88.0	88.0	89.0	85.0	84.0
Water IN temperature	deg C	47.0	48.0	51.0	35.0	34.0
Water OUT temperature	deg C	80.0	80.0	62.0	76.0	75.0
Exhaust temperature	deg C	190.0	171.0	152.0	144.0	133.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	E20/5.2TEGDN	DATE : 22/3/85
MODEL	3000	DENSITY Kg/l :	0.850	TEST ID : UNIDO 4
No CYL	3	CAL VALUE MJ/Kg :	38.55	
CAPACITY cc :	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load	N	0.31
Observed torque	NM :	2.5
Observed speed	RPM :	828
Observed power	KW :	.2
Air temperature	deg C :	28.0
Barometric pressure	mBar :	1021.5
Correction factor	:	0.988
Corrected torque	NM :	2.5
Corrected power	KW :	.2
Fuel consumed	gms :	16.8
Measurement time	seconds :	72.940
Fuel mass flow	gms/sec :	0.23
B.S.F.C.	gms/KW/hr :	3852.5
Thermal efficiency	% :	2.4
Fuel temperature	deg C :	34.0
Pump delivery/stroke	mm+3 :	13.4
	mgms :	11.1
Start of injection deg.	max :	17.6
	min :	17.1
	mean :	17.3
Start of combustion deg.	max :	10.2
	min :	10.1
	mean :	10.1
Ignition delay deg	max :	7.5
	min :	7.0
	mean :	7.2
Ignition delay ms	max :	1.504
	min :	1.415
	mean :	1.452
Max. cylinder pressure	bar :	56.5
Max. pressure rise	bar/deg :	6.4
	bar/ms :	31.6
Oil temperature	deg C :	79.0
Water IN temperature	deg C :	34.0
Water OUT temperature	deg C :	74.0
Exhaust temperature	deg C	97.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION	E20/.2ION	DATE : 22/5/85
MODEL	3000	DENSITY Kg/l	0.845	TEST ID : UNIDO_5
No CYL	3	CAL VALUE MJ/Kg	38.83	
CAPACITY cc :	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 20 deg BTDC						
Observed load	N	17.36	18.08	18.41	18.57	18.57
Observed torque	NM	139.0	144.8	147.4	148.7	148.6
Observed speed	RPM	2017	1751	1459	1140	839
Observed power	KW	29.4	26.5	22.5	17.7	13.1
Air temperature	deg C	34.0	30.0	32.0	30.0	28.0
Barometric pressure	mBar	1021.5	1021.5	1021.5	1021.5	1021.5
Correction factor		0.998	0.991	0.994	0.991	0.988
Corrected torque	NM	138.6	143.5	146.6	147.3	146.8
Corrected power	KW	29.3	26.3	22.4	17.6	12.9
Fuel consumed	gms	78.7	83.5	88.9	90.2	87.7
Measurement time	seconds	30.190	34.790	41.590	52.990	71.980
Fuel mass flow	gms/sec	2.61	2.40	2.14	1.70	1.22
B.S.F.C.	gms/KW/hr	320.4	328.5	343.8	348.3	340.1
Thermal efficiency	%	28.9	28.2	27.0	26.6	27.3
Fuel temperature	deg C	34.0	37.0	38.0	38.0	38.0
Pump delivery/stroke	mm³	62.4	66.5	7[illegible].1	72.4	70.5
	mgms	51.7	54.8	58.6	59.7	58.1
Start of injection deg.	max	20.3	21.8	22.7	23.4	18.2
	min	20.0	21.0	21.8	22.7	17.6
	mean	20.1	21.2	22.3	23.0	18.1
Start of combustion deg.	max	8.3	10.0	11.8	12.8	11.1
	min	8.1	9.9	10.9	12.7	11.0
	mean	8.2	10.0	11.3	12.8	11.0
Ignition delay deg	max	12.2	11.8	11.8	10.6	7.3
	min	11.7	11.0	10.0	9.9	6.6
	mean	11.9	11.2	11.0	10.2	7.0
Ignition delay ms	max	1.007	1.121	1.343	1.554	1.444
	min	0.967	1.043	1.142	1.446	1.305
	mean	0.980	1.064	1.261	1.495	1.400
Max. cylinder pressure	bar	92.4	95.1	96.3	98.0	91.5
Max. pressure rise	bar/deg	19.6	17.8	22.0	18.7	12.2
	bar/ms	237.4	187.4	192.4	127.9	61.6
Oil temperature	deg C	88.0	92.0	92.0	92.0	87.0
Water IN temperature	deg C	63.0	66.0	66.0	66.0	61.0
Water OUT temperature	deg C	83.0	83.0	83.0	81.0	82.0
Exhaust temperature	deg C	390.0	380.0	376.0	350.0	317.0

ENGINE TEST RESULTS

DATE : 22/5/85
TEST ID : UNIDO_5

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2860

FUEL	
EMULSION	E20/.2ION
DENSITY Kg/l	0.845
CAL VALUE MJ/Kg	38.83

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
67 % LOAD (Nominal) 20 deg BTDC							
Observed load	N		10.82	10.94	11.13	11.41	11.61
Observed torque	NM		86.6	87.6	89.1	91.3	93.0
Observed speed	RPM		2017	1744	1436	1132	832
Observed power	KW		18.3	16.0	13.4	10.8	8.1
Air temperature	deg C		29.0	27.0	28.0	28.0	29.0
Barometric pressure	mBar		1021.5	1021.5	1021.5	1021.5	1021.7
Correction factor			0.990	0.986	0.988	0.988	0.989
Corrected torque	NM		85.7	86.4	88.0	90.2	92.0
Corrected power	KW		18.1	15.8	13.2	10.7	8.0
Fuel consumed	gms		48.5	47.8	48.1	49.2	51.6
Measurement time	seconds		30.190	34.790	42.190	53.390	72.580
Fuel mass flow	gms/sec		1.61	1.37	1.14	0.92	0.71
B.S.F.C.	gms/KW/hr		319.4	313.5	309.9	310.3	319.1
Thermal efficiency	%		29.0	29.6	29.9	29.9	29.1
Fuel temperature	deg C		38.0	38.0	39.0	38.0	39.0
Pump delivery/stroke	mm+3		38.6	38.2	38.6	39.5	41.5
	mgms		31.9	31.5	31.7	32.6	34.2
Start of injection deg.		max	15.9	17.1	18.2	19.8	19.1
		min	14.7	16.4	17.3	19.1	18.1
		mean	15.2	16.7	17.6	19.4	18.7
Start of combustion deg.		max	3.8	5.6	8.3	11.0	11.9
		min	3.6	5.5	8.1	10.1	10.9
		mean	3.7	5.5	8.2	10.8	11.2
Ignition delay	deg	max	12.2	11.6	9.9	8.9	8.1
		min	10.9	10.8	9.1	8.1	7.1
		mean	11.5	11.1	9.3	8.6	7.5
Ignition delay	ms	max	1.007	1.107	1.147	1.318	1.616
		min	0.901	1.034	1.057	1.195	1.430
		mean	0.951	1.065	1.083	1.263	1.505
Max. cylinder pressure	bar		72.3	75.7	78.8	80.7	79.5
Max. pressure rise	bar/deg		11.5	10.6	12.0	14.4	11.5
	bar/ms		139.2	110.7	103.1	97.5	57.2
Oil temperature	deg C		93.0	92.0	92.0	87.0	88.0
Water IN temperature	deg C		52.0	47.0	48.0	52.0	56.0
Water OUT temperature	deg C		79.0	79.0	79.0	78.0	83.0
Exhaust temperature	deg C		267.0	238.0	224.0	209.0	201.0

ENGINE TEST RESULTS

DATE : 22/3/85
TEST ID : UNIDO_5

ENGINE
MAKE : FORD
MODEL : 3000
No CYL : 3
CAPACITY cc : 2860

FUEL
EMULSION : E20/.2ION
DENSITY Kg/l 0.845
CAL VALUE MJ/Kg 38.83

DYNO TORQUE FACTOR : 35.61

33 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load	N		4.55	4.07	4.35	4.66	4.44
Observed torque	NM		36.4	32.6	34.8	37.3	35.5
Observed speed	RPM		2017	1734	1423	1132	827
Observed power	KW		7.7	5.9	5.2	4.4	3.1
Air temperature	deg C		27.0	28.0	28.0	28.0	27.0
Barometric pressure	mBar		1021.6	1021.5	1021.5	1021.5	1021.5
Correction factor			0.986	0.988	0.988	0.988	0.986
Corrected torque	NM		35.9	32.2	34.4	36.8	35.1
Corrected power	KW		7.6	5.8	5.1	4.4	3.0
Fuel consumed	gms		31.6	28.1	29.1	28.3	30.1
Measurement time	seconds		30.190	34.980	42.590	53.390	72.980
Fuel mass flow	gms/sec		1.05	0.80	0.68	0.53	0.41
B.S.F.C.	gms/KW/hr		496.9	495.1	479.5	437.3	489.1
Thermal efficiency	%		18.7	18.7	19.3	21.2	19.0
Fuel temperature	deg C		39.0	38.0	38.0	37.0	37.0
Pump delivery/stroke	mm+3		25.2	22.5	23.3	22.7	24.2
	mgms		20.8	18.5	19.2	18.7	19.9
Start of injection	deg.	max :	13.2	12.1	13.1	17.5	18.1
		min :	13.0	11.9	12.0	17.2	17.4
		mean	13.1	12.1	12.6	17.4	17.9
Start of combustion	deg.	max :	1.1	1.9	3.9	9.2	11.0
		min :	.3	1.2	2.9	8.3	10.1
		mean	.5	1.5	3.4	8.5	10.3
Ignition delay	deg	max	12.9	10.9	9.9	9.2	8.0
		min :	11.9	10.1	8	8.2	7.1
		mean	12.6	10.5	9.[illegible]	8.9	7.6
Ignition delay	ms	max :	1.063	1.050	1.164	1.361	1.614
		min	0.986	0.975	0.951	1.210	1.428
		mean :	1.041	1.013	1.068	1.307	1.525
Max. cylinder pressure	bar :		61.3	59.9	61.0	66.3	65.6
Max. pressure rise	bar/deg :		6.8	6.7	8.5	10.1	9.9
	bar/ms		82.9	70.2	72.7	68.4	49.3
Oil temperature	deg C		87.0	87.0	88.0	83.0	82.0
Water IN temperature	deg C		40.0	50.0	51.0	35.0	33.0
Water OUT temperature	deg C		77.0	79.0	63.0	75.0	78.0
Exhaust temperature	deg C		190.0	162.0	151.0	136.0	129.0

ENGINE TEST RESULTS

PAGE 20

ENGINE		**FUEL**		DATE :	22/3/85
MAKE	FORD	EMULSION	E20/.21CN	TEST ID	UNIDO 5
MODEL	3000	DENSITY Kg/l	0.845		
No CYL	3	CAL VALUE MJ/Kg	38.83		
CAPACITY cc	2860			DYNO TORQUE FACTOR :	35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load		N	0.32
Observed torque		NM	2.5
Observed speed		RPM	821
Observed power		KW	.2
Air temperature		deg C	27.0
Barometric pressure		mBar	1021.5
Correction factor			0.986
Corrected torque		NM	2.5
Corrected power		KW	.2
Fuel consumed		gms	15.4
Measurement time		seconds	73.580
Fuel mass flow		gms/sec	0.21
B.S.F.C.		gms/KW/hr	3513.9
Thermal efficiency		%	2.6
Fuel temperature		deg C	37.0
Pump delivery/stroke		mm+3	12.4
		mgms	10.2
Start of injection deg.		max	17.1
		min	15.8
		mean	16.5
Start of combustion deg.		max	9.2
		min	8.3
		mean	8.8
Ignition delay	deg	max	8.1
		min	7.2
		mean	7.7
Ignition delay	ms	max	1.652
		min	1.466
		mean	1.554
Max. cylinder pressure		bar	55.6
Max. pressure rise		bar/deg	7.2
		bar/ms	35.7
Oil temperature		deg C	81.0
Water IN temperature		deg C	52.0
Water OUT temperature		deg C	74.0
Exhaust temperature		deg C	94.0

ENGINE		FUEL			
MAKE	FORD	EMULSION	E20/.4ION	DATE :	22/3/85
MODEL :	3000	DENSITY Kg/l :	0.845	TEST ID	UNIDO_6
No CYL	3	CAL VALUE MJ/Kg :	38.83		
CAPACITY cc	2960			DYNO TORQUE FACTOR :	35.61

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
			100 % LOAD (Nominal)		20 deg BTDC		
Observed load	N		17.20	18.11	18.50	18.61	18.62
Observed torque	NM		137.7	145.0	148.1	149.0	149.1
Observed speed	RPM		2015	1714	1438	1136	836
Observed power	KW		29.1	26.0	22.3	17.7	13.1
Air temperature	deg C		27.0	30.0	30.0	30.0	29.0
Barometric pressure	mBar		1021.5	1021.5	1021.5	1021.5	1021.5
Correction factor			0.986	0.991	0.991	0.991	0.990
Corrected torque	NM		135.8	143.7	146.8	147.6	147.5
Corrected power	KW		28.7	25.8	22.1	17.6	12.9
Fuel consumed	gms		79.5	84.0	89.6	90.3	87.8
Measurement time	seconds		30.190	35.390	42.190	53.190	72.180
Fuel mass flow	gms/sec		2.63	2.37	2.12	1.70	1.22
B.S.F.C.	gms/KW/hr		330.8	331.2	345.9	348.0	339.0
Thermal efficiency	%		28.0	28.0	26.8	26.6	27.3
Fuel temperature	deg C		33.0	33.0	34.0	34.0	35.0
Pump delivery/stroke	mm+3		63.1	66.8	71.4	72.2	70.3
	mgms		52.3	55.4	59.1	58.8	58.2
Start of injection	deg.	max	20.3	22.0	22.7	22.8	18.1
		min	20.0	21.8	22.6	22.7	17.5
		mean	20.1	21.9	22.7	22.8	18.0
Start of combustion	deg.	max	8.3	10.8	11.9	13.6	11.0
		min	8.2	10.0	11.8	13.6	10.9
		mean	8.2	10.2	11.9	13.6	11.0
Ignition delay	deg	max	12.1	11.9	10.9	9.2	7.2
		min	11.6	11.0	10.8	9.1	6.5
		mean	11.9	11.7	10.8	9.1	7.0
Ignition delay	ms	max	1.001	1.158	1.261	1.348	1.426
		min	0.962	1.072	1.248	1.339	1.297
		mean	0.982	1.135	1.254	1.342	1.390
Max. cylinder pressure	bar		91.9	95.9	96.9	97.9	91.3
Max. pressure rise	bar/deg		18.3	16.7	17.4	16.6	12.8
	bar/ms		220.8	171.9	150.3	113.2	64.4
Oil temperature	deg C		82.0	88.0	87.0	87.0	87.0
Water IN temperature	deg C		49.0	62.0	65.0	66.0	61.0
Water OUT temperature	deg C		78.0	81.0	81.0	79.0	79.0
Exhaust temperature	deg C		[illegible]	374.0	375.0	349.0	313.0

ENGINE TEST RESULTS

PAGE 22

DATE : 22/3/85
TEST ID : UNIDO_6

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc 2860

FUEL
EMULSION E20/.410N
DENSITY Kg/l 0.845
CAL VALUE MJ/Kg 38.83

DYNO TORQUE FACTOR 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		67 % LOAD (Nominal)	20 deg BTDC			
Observed load	N :	11.13	11.43	11.27	11.17	11.33
Observed torque	NM :	89.1	91.5	90.2	89.4	90.7
Observed speed	RPM	2042	1731	1443	1140	823
Observed power	KW :	19.1	16.6	13.6	10.7	7.8
Air temperature	deg C :	28.0	28.0	27.0	28.0	27.0
Barometric pressure	mBar :	1021.5	1021.5	1021.5	1021.5	1021.5
Correction factor		0.988	0.988	0.986	0.988	0.986
Corrected torque	NM	88.0	90.4	89.0	88.3	89.5
Corrected power	KW	18.8	16.4	13.5	10.5	7.7
Fuel consumed	gms	50.2	49.0	48.2	49.9	55.1
Measurement time	seconds :	29.800	35.000	41.990	52.990	73.380
Fuel mass flow	gms/sec :	1.68	1.40	1.15	0.94	0.75
B.S.F.C.	gms/KW/hr	322.2	307.6	307.2	321.4	350.4
Thermal efficiency	%	28.8	30.1	30.2	28.8	26.5
Fuel temperature	deg C :	38.0	38.0	37.0	38.0	37.0
Pump delivery/stroke	mm+3 :	40.0	39.2	38.6	40.1	44.2
	mgms :	33.0	32.3	31.8	33.0	36.5
Start of injection deg.	max :	16.2	17.4	18.2	20.0	18.4
	min :	14.6	16.7	17.3	19.1	18.1
	mean :	15.4	17.0	17.8	19.4	18.2
Start of combustion deg.	max :	4.7	7.4	8.3	11.0	11.8
	min :	3.7	6.3	8.2	10.9	11.0
	mean :	4.0	6.6	8.3	10.9	11.2
Ignition delay deg	max :	12.0	10.9	9.8	9.0	7.3
	min :	10.7	10.0	9.1	8.2	6.3
	mean :	11.5	10.4	9.5	8.5	7.0
Ignition delay ms	max :	0.979	1.054	1.136	1.312	1.476
	min :	0.876	0.964	1.048	1.203	1.274
	mean :	0.935	1.005	1.101	1.246	1.421
Max. cylinder pressure	bar :	74.5	76.6	78.7	81.1	80.9
Max. pressure rise	bar/deg :	11.0	11.3	12.1	13.6	10.1
	bar/ms :	134.4	117.0	105.0	92.7	49.9
Oil temperature	deg C :	91.0	91.0	87.0	88.0	82.0
Water IN temperature	deg C :	53.0	47.0	47.0	51.0	55.0
Water OUT temperature	deg C	78.0	79.0	79.0	79.0	82.0
Exhaust temperature	deg C	269.0	242.0	227.0	209.0	207.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE :	FORD	EMULSION :	E20/.4ION	DATE :	22/3/85
MODEL :	3000	DENSITY Kg/l :	0.845	TEST ID :	UNIDO_6
No CYL :	3	CAL VALUE MJ/Kg :	38.83		
CAPACITY cc :	2860			DYNO TORQUE FACTOR :	35.61

33 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N	4.25	4.38	4.37	4.59	4.62
Observed torque	NM	34.0	35.0	35.0	36.7	37.0
Observed speed	RPM	2042	1744	1436	1122	834
Observed power	KW	7.3	6.4	5.3	4.3	3.2
Air temperature	deg C	28.0	28.0	28.0	27.0	27.0
Barometric pressure	mBar	1021.5	1021.5	1021.5	1021.5	1021.5
Correction factor		0.988	0.988	0.988	0.986	0.986
Corrected torque	NM	33.6	34.6	34.6	36.2	36.5
Corrected power	KW	7.2	6.3	5.2	4.3	3.2
Fuel consumed	gms	30.2	28.4	27.6	26.9	30.0
Measurement time	seconds	29.790	34.790	42.190	53.780	72.380
Fuel mass flow	gms/sec	1.01	0.82	0.65	0.50	0.41
B.S.F.C.	gms/KW/hr	508.1	464.8	453.0	422.9	468.2
Thermal efficiency	%	18.2	19.9	20.5	21.9	19.8
Fuel temperature	deg C	37.0	37.0	38.0	37.0	37.0
Pump delivery/stroke	mm+3	24.1	22.7	22.1	21.6	24.1
	mgms	19.9	18.7	18.2	17.8	19.9
Start of injection deg.	max	13.3	12.6	12.1	17.5	18.1
	min	13.1	11.9	11.8	17.2	17.3
	mean	13.2	12.1	12.0	17.3	17.7
Start of combustion deg.	max	1.4	2.9	3.0	9.2	10.9
	min	1.0	2.0	2.8	9.1	10.1
	mean	1.1	2.2	2.9	9.1	10.3
Ignition delay deg	max	12.2	10.5	9.2	8.3	7.9
	min	11.8	9.0	8.9	8.1	7.2
	mean	12.0	9.9	9.0	8.2	7.4
Ignition delay ms	max	0.992	1.008	1.073	1.235	1.585
	min	0.964	0.865	1.032	1.204	1.436
	mean	0.982	0.943	1.050	1.215	1.479
Max. cylinder pressure	bar	60.5	60.7	59.1	64.9	65.5
Max. pressure rise	bar/deg	7.5	7.8	7.8	9.2	10.1
	bar/ms	92.1	82.1	66.9	61.8	50.4
Oil temperature	deg C	88.0	87.0	88.0	83.0	82.0
Water IN temperature	deg C	47.0	51.0	53.0	52.0	53.0
Water OUT temperature	deg C	79.0	78.0	77.0	78.0	65.0
Exhaust temperature	deg C	187.0	165.0	148.0	133.0	129.0

ENGINE TEST RESULTS

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc 2860

FUEL
EMULSION : E20/.4ION
DENSITY Kg/l : 0.845
CAL VALUE MJ/Kg : 38.83

DATE : 22/3/85
TEST ID : UNIDO_6

DYNO TORQUE FACTOR 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load	N	0.31
Observed torque	NM	2.5
Observed speed	RPM	823
Observed power	KW :	.2
Air temperature	deg C	26.0
Barometric pressure	mBar :	1021.5
Correction factor	:	0.985
Corrected torque	NM	2.5
Corrected power	KW :	.2
Fuel consumed	gms	15.6
Measurement time	seconds	73.380
Fuel mass flow	gms/sec	0.21
B.S.F.C.	gms/KW/hr	3579.1
Thermal efficiency	%	2.6
Fuel temperature	deg C	37.0
Pump delivery/stroke	mm*3 :	12.5
	mgms :	10.3
Start of injection deg.	max	16.5
	min	15.1
	mean :	15.8
Start of combustion deg.	max :	9.1
	min :	7.7
	mean :	8.5
Ignition delay deg	max	7.5
	min :	7.1
	mean	7.3
Ignition delay ms	max :	1.516
	min :	1.447
	mean :	1.478
Max. cylinder pressure	bar	55.2
Max. pressure rise	bar/deg	6.9
	bar/ms	33.8
Oil temperature	deg C	78.0
Water IN temperature	deg C	59.0
Water OUT temperature	deg C	76.0
Exhaust temperature	deg C	92.0

ENGINE TEST RESULTS

DATE . 10/5/85
TEST ID : UNID010

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2860

FUEL	
DISTILLATE :	DIST 100
DENSITY Kg/l :	0.849
CAL VALUE MJ/Kg :	42.75

DYNO TORQUE FACTOR 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		100 % LOAD (Nominal)	20 deg BTDC			
Observed load	N	18.09	19.13	19.24	19.47	19.48
Observed torque	NM	144.8	153.2	154.1	155.9	155.9
Observed speed	RPM	2054	1750	1432	1149	844
Observed power	KW	31.2	28.1	23.1	18.8	13.8
Air temperature	deg C	31.0	31.0	30.0	30.0	29.0
Barometric pressure	mBar	1023.2	1023.2	1023.2	1023.1	1023.1
Correction factor		0.992	0.992	0.990	0.990	0.989
Corrected torque	NM	143.7	151.9	152.5	154.4	154.2
Corrected power	KW	30.9	27.8	22.9	18.6	13.6
Fuel consumed	gms	83.5	85.9	89.7	91.3	90.1
Measurement time	seconds	29.590	34.590	42.190	52.590	71.580
Fuel mass flow	gms/sec	2.82	2.48	2.13	1.74	1.26
B.S.F.C.	gms/KW/hr	328.8	321.1	334.6	336.5	332.5
Thermal efficiency	%	25.6	26.2	25.2	25.0	25.3
Fuel temperature	deg C	30.0	32.0	32.0	31.0	31.0
Pump delivery/stroke	mm+3	65.8	69.1	71.2	72.4	71.5
	mgms	55.0	56.8	59.4	60.4	59.6
Start of injection deg.	max	21.2	21.9	22.8	23.6	19.9
	min	20.3	21.8	22.7	23.5	19.3
	mean	20.8	21.9	22.7	23.5	19.8
Start of combustion deg.	max	10.0	11.0	12.8	14.6	12.8
	min	9.1	10.9	12.7	13.8	12.7
	mean	9.5	10.9	12.8	14.4	12.7
Ignition delay deg	max	12.0	11.0	10.0	9.8	7.2
	min	10.9	10.9	9.9	8.9	6.6
	mean	11.4	10.9	10.0	9.2	7.1
Ignition delay ms	max	0.975	1.046	1.170	1.419	1.431
	min	0.882	1.033	1.151	1.297	1.295
	mean	0.924	1.040	1.159	1.329	1.397
Max. cylinder pressure	bar	95.4	99.0	99.5	101.0	95.7
Max. pressure rise	bar/deg	15.5	16.3	15.7	14.6	12.1
	bar/ms	191.5	171.1	134.5	101.0	61.1
Oil temperature	deg C	86.0	92.0	93.0	92.0	90.0
Water IN temperature	deg C	63.0	67.0	69.0	68.0	64.0
Water OUT temperature	deg C	85.0	85.0	84.0	84.0	84.0
Exhaust temperature	deg C	[illegible]	415.0	405.0	366.0	327.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	DISTILLATE	DIST 100	DATE : 10/5/85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID UNID010
No CYL	3	CAL VALUE MJ/Kg	42.75	
CAPACITY cc	2960			DYNO TORQUE FACTOR 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		67 % LOAD (Nominal)		20 deg BTDC		
Observed load	N	11.22	11.10	11.13	11.27	11.19
Observed torque	NM	89.8	88.9	89.1	90.2	89.6
Observed speed	RPM	2050	1747	1447	1136	833
Observed power	KW	19.3	16.3	13.5	10.7	7.8
Air temperature	deg C	30.0	29.0	29.0	30.0	28.0
Barometric pressure	mBar	1022.1	1022.2	1022.2	1022.2	1022.2
Correction factor		0.991	0.989	0.989	0.991	0.987
Corrected torque	NM	89.0	87.9	88.1	89.4	88.4
Corrected power	KW	19.1	16.1	13.4	10.6	7.7
Fuel consumed	gms	45.8	44.6	43.5	46.6	49.1
Measurement time	seconds	29.590	34.790	41.790	53.190	72.380
Fuel mass flow	gms/sec	1.55	1.28	1.04	0.88	0.68
B.S.F.C.	gms/KW/hr	291.7	286.9	280.5	296.6	316.5
Thermal efficiency	%	28.9	29.4	30.0	28.4	26.6
Fuel temperature	deg C	32.0	32.0	33.0	33.0	33.0
Pump delivery/stroke	mm*3	36.2	35.2	34.5	37.0	39.1
	mgms	30.2	29.4	28.8	30.9	32.6
Start of injection deg.	max	15.8	16.5	18.1	20.0	18.1
	min	15.6	16.4	17.3	19.2	17.3
	mean	15.7	16.4	17.5	19.7	17.7
Start of combustion deg.	max	5.5	7.4	9.1	11.8	11.0
	min	4.6	6.5	8.2	11.0	10.9
	mean	4.9	6.9	8.6	11.5	11.0
Ignition delay deg	max	11.2	9.9	9.2	8.9	7.2
	min	10.1	9.0	8.3	7.5	6.4
	mean	10.8	9.6	8.9	8.2	6.7
Ignition delay ms	max	0.908	0.949	1.054	1.305	1.431
	min	0.818	0.854	0.958	1.099	1.283
	mean	0.881	0.914	1.025	1.201	1.344
Max. cylinder pressure	bar	73.4	76.0	78.0	83.5	79.8
Max. pressure rise	bar/deg	10.1	10.4	10.7	12.7	9.1
	bar/ms	124.8	108.9	92.9	86.9	45.6
Oil temperature	deg C	89.0	89.0	89.0	87.0	85.0
Water IN temperature	deg C	51.0	44.0	43.0	42.0	44.0
Water OUT temperature	deg C	80.0	78.0	79.0	80.0	79.0
Exhaust temperature	deg C	279.0	242.0	225.0	211.0	200.0

ENGINE TEST RESULTS

DATE 10/5/85
TEST ID : UNID010

ENGINE
MAKE : FORD
MODEL : 3000
No CYL : 3
CAPACITY cc 2960

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg 42.75

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
33 % LOAD (Nominal) 20 deg BTDC						
Observed load	N	4.35	4.16	4.46	4.61	4.58
Observed torque	NM	34.8	33.3	35.7	36.9	36.6
Observed speed	RPM	2044	1732	1436	1127	843
Observed power	KW	7.5	6.0	5.4	4.4	3.2
Air temperature	deg C	28.0	28.0	28.0	28.0	28.0
Barometric pressure	mBar	1022.2	1022.2	1022.2	1022.2	1022.2
Correction factor		0.987	0.987	0.987	0.987	0.987
Corrected torque	NM	34.4	32.9	35.3	36.4	36.2
Corrected power	KW	7.4	6.0	5.3	4.3	3.2
Fuel consumed	gms	27.7	25.7	25.5	28.3	29.1
Measurement time	seconds	29.790	34.990	42.190	53.590	71.580
Fuel mass flow	gms/sec	0.93	0.73	0.60	0.53	0.41
B.S.F.C.	gms/KW/hr	454.5	442.8	410.3	442.1	458.0
Thermal efficiency	%	18.5	19.0	20.5	19.0	18.4
Fuel temperature	deg C	32.0	33.0	33.0	33.0	32.0
Pump delivery/stroke	mm↑3	21.8	20.4	20.2	22.5	23.1
	mgms	18.2	17.0	16.8	18.7	19.3
Start of injection deg.	max	13.2	12.9	14.8	18.2	17.2
	min	11.2	12.2	14.6	17.3	16.4
	mean	12.4	12.6	14.7	17.5	16.7
Start of combustion deg.	max	2.0	3.0	5.7	10.0	10.0
	min	1.1	2.1	5.5	9.1	10.0
	mean	1.4	2.6	5.6	9.3	10.0
Ignition delay deg	max	11.9	10.6	9.2	8.3	7.2
	min	10.0	9.3	8.9	8.2	6.3
	mean	11.0	10.0	9.0	8.2	6.7
Ignition delay ms	max	0.969	1.024	1.062	1.230	1.431
	min	0.818	0.900	1.032	1.207	1.253
	mean	0.898	0.966	1.049	1.214	1.331
Max. cylinder pressure	bar	60.1	59.4	63.2	68.2	66.4
Max. pressure rise	bar/deg	6.1	6.9	8.3	10.1	9.4
	bar/ms	74.9	71.7	71.9	68.3	47.4
Oil temperature	deg C	86.0	86.0	86.0	84.0	83.0
Water IN temperature	deg C	39.0	42.0	52.0	53.0	57.0
Water OUT temperature	deg C	77.0	77.0	78.0	82.0	79.0
Exhaust temperature	deg C	187.0	165.0	151.0	142.0	[illegible]

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	DISTILLATE	DIST 100	DATE	10/5/85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID :	UNID010
No CYL	3	CAL VALUE MJ/Kg	42.75	DYNO TORQUE FACTOR	35.61
CAPACITY cc	2860				

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 20 deg BTDC

Observed load	N	0.38
Observed torque	NM	3.0
Observed speed	RPM	819
Observed power	KW	.3
Air temperature	deg C	28.0
Barometric pressure	mBar	1022.2
Correction factor		0.987
Corrected torque	NM	3.0
Corrected power	KW	.3
Fuel consumed	gms	14.5
Measurement time	seconds	73.580
Fuel mass flow	gms/sec	0.20
B.S.F.C.	gms/KW/hr	2788.2
Thermal efficiency	%	3.0
Fuel temperature	deg C	32.0
Pump delivery/stroke	mm*3	11.5
	mgms	9.6
Start of injection deg.	max	17.2
	min	14.9
	mean	16.1
Start of combustion deg.	max	9.2
	min	7.5
	mean	8.6
Ignition delay deg	max	8.1
	min	7.0
	mean	7.4
Ignition delay ms	max	1.647
	min	1.421
	mean	1.510
Max. cylinder pressure	bar	56.9
Max. pressure rise	bar/deg	7.7
	bar/ms	37.6
Oil temperature	deg C	81.0
Water IN temperature	deg C	67.0
Water OUT temperature	deg C	65.0
Exhaust temperature	deg C	97.0

ENGI.. TEST RESULTS

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc : 2860

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 10:05:85
TEST ID : UNIDO11

DYNO TORQUE FACTOR : 35.01

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 26 deg BTDC						
Observed load	N	16.30	17.77	17.75	18.04	18.30
Observed torque	NM	130.5	142.3	142.1	144.5	146.5
Observed speed	RPM	2050	1744	1435	1136	826
Observed power	KW	28.0	26.0	21.4	17.2	12.7
Air temperature	deg C	30.0	31.0	30.0	30.0	29.0
Barometric pressure	mBar	1022.2	1022.2	1022.2	1022.2	1022.2
Correction factor		0.991	0.992	0.991	0.991	0.989
Corrected torque	NM	129.3	141.2	140.8	143.1	144.9
Corrected power	KW	27.8	25.8	21.2	17.0	12.5
Fuel consumed	gms	80.4	86.1	89.2	91.1	89.7
Measurement time	seconds	29.590	34.790	42.190	53.190	72.980
Fuel mass flow	gms/sec	2.72	2.47	2.11	1.71	1.23
B.S.F.C.	gms/KW/hr	352.5	345.5	359.8	362.2	353.0
Thermal efficiency	%	23.9	24.4	23.4	23.3	23.9
Fuel temperature	deg C	32.0	32.0	33.0	32.0	33.0
Pump delivery/stroke	mm*3	63.6	68.1	70.8	72.3	71.4
	mgms	53.0	56.8	58.9	60.3	59.5
Start of injection deg.	max	25.6	27.5	28.1	28.1	22.7
	min	25.5	27.2	27.3	28.0	22.0
	mean	25.6	27.3	27.7	28.1	22.4
Start of combustion deg.	max	12.7	14.5	15.4	16.4	14.6
	min	11.9	13.6	15.3	16.3	14.6
	mean	12.5	13.8	15.4	16.4	14.6
Ignition delay deg	max	13.7	13.8	12.7	11.8	8.0
	min	12.8	12.7	12.0	11.6	7.4
	mean	13.1	13.5	12.4	11.6	7.8
Ignition delay ms	max	1.116	1.322	1.470	1.726	1.618
	min	1.044	1.215	1.390	1.696	1.490
	mean	1.063	1.288	1.437	1.709	1.567
Max. cylinder pressure	bar	99.5	102.0	102.7	101.8	96.7
Max. pressure rise	bar/deg	22.0	20.2	19.1	21.6	13.7
	bar/ms	270.0	211.5	164.3	147.1	68.1
Oil temperature	deg C	84.0	89.0	90.0	89.0	88.0
Water IN temperature	deg C	64.0	71.0	74.0	74.0	72.0
Water OUT temperature	deg C	83.0	84.0	84.0	84.0	83.0
Exhaust temperature	deg C	410.0	412.0	397.0	355.0	324.0

ENGINE TEST RESULTS

PAGE 30

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc 2960

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 10.05.85
TEST ID UNID011

DYNO TORQUE FACTOR 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
67 % LOAD (Nominal) 26 deg BTDC						
Observed load	N	11.46	10.84	11.38	11.45	11.27
Observed torque	NM :	91.8	86.8	91.1	91.6	90.2
Observed speed	RPM	2050	1738	1432	1152	815
Observed power	KW :	19.7	15.8	13.7	11.1	7.7
Air temperature	deg C :	29.0	29.0	30.0	29.0	29.0
Barometric pressure	mBar :	1022.2	1022.2	1022.2	1022.2	1022.2
Correction factor	:	0.989	0.989	0.991	0.989	0.989
Corrected torque	NM :	90.8	85.9	90.3	90.6	89.3
Corrected power	KW :	19.5	15.6	13.5	10.9	7.6
Fuel consumed	gms :	48.4	45.1	47.8	48.3	53.4
Measurement time	seconds	29.590	34.790	42.190	52.390	73.980
Fuel mass flow	gms/sec :	1.64	1.30	1.13	0.92	0.72
B.S.F.C.	gms/KW/hr	302.2	298.5	301.3	303.5	341.1
Thermal efficiency	% :	27.9	28.2	27.9	27.7	24.7
Fuel temperature	deg C :	33.0	33.0	34.0	34.0	33.0
Pump delivery/stroke	mm*3 :	38.3	35.8	38.0	38.5	42.5
	mgms :	31.9	29.8	31.6	32.0	35.4
Start of injection deg.	max :	21.2	21.9	23.7	24.5	22.7
	min :	20.8	21.7	23.5	24.4	22.6
	mean :	21.1	21.8	23.6	24.5	22.7
Start of combustion deg.	max :	9.1	10.9	12.7	14.6	14.6
	min :	9.0	10.0	12.7	14.5	14.5
	mean :	9.1	10.7	12.7	14.5	14.6
Ignition delay deg	max :	12.0	11.9	11.0	10.0	8.2
	min :	11.8	10.8	10.8	9.9	8.0
	mean :	12.0	11.1	10.9	9.9	8.1
Ignition delay ms	max :	0.979	1.137	1.280	1.444	1.677
	min :	0.959	1.035	1.256	1.430	1.635
	mean :	0.972	1.068	1.268	1.437	1.663
Max. cylinder pressure	bar :	80.3	82.3	85.2	86.0	84.2
Max. pressure rise	bar/deg :	12.5	13.9	14.1	15.2	13.5
	bar/ms :	153.6	144.6	120.9	104.8	66.0
Oil temperature	deg C :	90.0	91.0	91.0	88.0	87.0
Water IN temperature	deg C :	63.0	54.0	50.0	48.0	47.0
Water OUT temperature	deg C :	80.0	79.0	79.0	79.0	79.0
Exhaust temperature	deg C	297.0	250.0	239.0	220.0	212.0

ENGINE TEST RESULTS

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc : 2860

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 10:05:85
TEST ID : UNID011

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
33 % LOAD (Nominal) 26 deg BTDC						
Observed load	N	4.66	4.19	4.25	4.42	4.51
Observed torque	NM	37.3	33.5	34.0	35.3	36.1
Observed speed	RPM	2046	1744	1425	1129	822
Observed power	KW	8.0	6.1	5.1	4.2	3.1
Air temperature	deg C	29.0	28.0	28.0	28.0	28.0
Barometric pressure	mBar	1022.2	1022.2	1022.2	1022.2	1022.2
Correction factor		0.989	0.987	0.987	0.987	0.987
Corrected torque	NM	36.9	33.1	33.6	34.9	35.7
Corrected power	KW	7.9	6.0	5.0	4.1	3.1
Fuel consumed	gms	29.4	26.1	25.9	26.3	26.7
Measurement time	seconds	29.790	34.790	42.390	53.390	73.380
Fuel mass flow	gms/sec	0.99	0.75	0.61	0.49	0.36
B.S.F.C.	gms/KW/hr	448.9	447.1	439.0	429.6	426.7
Thermal efficiency	%	18.8	18.8	19.2	19.6	19.7
Fuel temperature	deg C	33.0	33.0	33.0	33.0	33.0
Pump delivery/stroke	mm↑3	23.2	20.7	20.6	20.9	21.3
	mgms	19.3	17.2	17.1	17.4	17.7
Start of injection deg.	max	18.6	17.5	20.0	22.7	20.9
	min	17.7	17.3	19.9	21.8	20.8
	mean	18.1	17.5	20.0	22.5	20.9
Start of combustion deg.	max	5.7	6.5	9.2	12.7	12.7
	min	5.5	6.4	9.1	11.8	12.7
	mean	5.6	6.5	9.1	12.2	12.7
Ignition delay deg	max	13.1	11.1	10.9	10.8	8.2
	min	12.0	10.8	10.8	9.9	8.1
	mean	12.5	11.0	10.8	10.3	8.1
Ignition delay ms	max	1.067	1.056	1.273	1.598	1.659
	min	0.977	1.037	1.261	1.464	1.649
	mean	1.015	1.051	1.267	1.522	1.653
Max. cylinder pressure	bar	66.9	64.0	66.9	69.6	67.2
Max. pressure rise	bar/deg	8.3	7.5	9.6	10.8	9.1
	bar/ms	101.9	78.6	81.9	73.5	45.0
Oil temperature	deg C	87.0	87.0	87.0	85.0	84.0
Water IN temperature	deg C	41.0	37.0	35.0	38.0	43.0
Water OUT temperature	deg C	78.0	77.0	77.0	77.0	77.0
Exhaust temperature	deg C	193.0	169.0	151.0	136.0	[illegible]

ENGINE TEST RESULTS

DATE : 10 05 85
TEST ID : UNIDO11

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2860

FUEL	
DISTILLATE :	DIST 100
DENSITY Kg/l	0.849
CAL VALUE MJ/Kg :	42.75

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 26 deg BTDC

Observed load	N	0.37
Observed torque	NM	2.9
Observed speed	RPM	826
Observed power	KW :	.3
Air temperature	deg C	27.0
Barometric pressure	mBar	1022.2
Correction factor		0.986
Corrected torque	NM	2.9
Corrected power	KW :	.3
Fuel consumed	gms	14.3
Measurement time	seconds	72.990
Fuel mass flow	gms/sec	0.20
B.S.F.C.	gms/KW/hr	2811.5
Thermal efficiency	%	3.0
Fuel temperature	deg C	32.0
Pump delivery/stroke	mm+3	11.4
	mgms	9.5
Start of injection deg.	max :	21.6
	min :	19.8
	mean :	20.2
Start of combustion deg.	max :	11.8
	min :	10.9
	mean	11.1
Ignition delay deg	max :	9.8
	min :	8.8
	mean :	9.1
Ignition delay ms	max :	1.980
	min :	1.773
	mean	1.842
Max. cylinder pressure	bar :	52.4
Max. pressure rise	bar/deg :	5.3
	bar/ms :	26.5
Oil temperature	deg C :	81.0
Water IN temperature	deg C	47.0
Water OUT temperature	deg C	75.0
Exhaust temperature	deg C	99.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	DISTILLATE	DIST 100	DATE	10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID	UNID012
No CYL	3	CAL VALUE MJ/Kg	42.75		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 14 deg BTDC						
Observed load	N	19.05	20.42	20.76	20.85	20.58
Observed torque	NM	152.5	163.5	166.2	166.9	164.7
Observed speed	RPM	2052	1711	1428	1137	825
Observed power	KW	32.8	29.3	24.9	19.9	14.2
Air temperature	deg C	29.0	31.0	30.0	31.0	29.0
Barometric pressure	mBar	1022.3	1022.2	1022.2	1022.3	1022.2
Correction factor		0.989	0.992	0.991	0.992	0.989
Corrected torque	NM	150.9	162.2	164.7	165.6	162.9
Corrected power	KW	32.4	29.1	24.6	19.7	14.1
Fuel consumed	gms	80.1	86.0	89.1	91.3	89.8
Measurement time	seconds	29.590	35.390	42.390	53.190	72.980
Fuel mass flow	gms/sec	2.71	2.43	2.10	1.72	1.23
B.S.F.C.	gms/KW/hr	300.6	301.0	307.2	313.3	314.5
Thermal efficiency	%	28.0	28.0	27.4	26.9	26.8
Fuel temperature	deg C	32.0	33.0	32.0	34.0	33.0
Pump delivery/stroke	mm†3	63.3	68.2	70.6	72.6	71.6
	mgms	52.8	56.8	58.9	60.4	59.6
Start of injection deg.	max	14.0	15.6	16.4	16.4	11.0
	min	13.9	14.8	15.7	16.4	10.1
	mean	13.9	15.4	16.2	16.4	10.5
Start of combustion deg.	max	4.7	7.3	8.3	10.0	5.6
	min	4.5	6.5	8.2	9.2	5.5
	mean	4.6	7.0	8.2	9.5	5.6
Ignition delay deg	max	9.4	9.0	8.2	7.2	5.4
	min	9.2	8.1	7.4	6.4	4.6
	mean	9.3	8.4	8.0	6.9	4.9
Ignition delay ms	max	0.766	0.880	0.955	1.058	1.095
	min	0.749	0.793	0.865	0.937	0.930
	mean	0.758	0.822	0.933	1.008	0.993
Max. cylinder pressure	bar	81.5	88.0	89.8	90.8	79.9
Max. pressure rise	bar/deg	11.2	11.3	11.0	9.5	7.0
	bar/ms	137.9	115.7	94.6	65.1	34.7
Oil temperature	deg C	87.0	89.0	89.0	89.0	86.0
Water IN temperature	deg C	59.0	67.0	68.0	69.0	65.0
Water OUT temperature	deg C	82.0	83.0	81.0	82.0	81.0
Exhaust temperature	deg C	424.0	420.0	408.0	354.0	319.0

ENGINE TEST RESULTS

ENGINE

MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc : 2960

FUEL

DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 10:05:85
TEST ID : UNID012

DYNO TORQUE FACTOR : 35.61

67 % LOAD (Nominal) 14 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N	11.07	10.97	11.15	11.55	11.93
Observed torque	NM :	88.7	87.8	89.2	92.4	95.5
Observed speed	RPM :	2050	1740	1450	1136	813
Observed power	KW :	19.0	16.0	13.6	11.0	8.1
Air temperature	deg C :	30.0	29.0	29.0	28.0	28.0
Barometric pressure	mBar :	1022.3	1022.3	1022.3	1022.3	1022.3
Correction factor		0.991	0.989	0.989	0.987	0.987
Corrected torque	NM :	87.9	86.8	88.3	91.3	94.3
Corrected power	KW	18.9	15.8	13.4	10.9	8.0
Fuel consumed	gms	45.9	43.5	43.7	45.7	48.2
Measurement time	seconds :	29.590	34.790	41.790	53.190	74.180
Fuel mass flow	gms/sec	1.55	1.25	1.05	0.86	0.65
B.S.F.C.	gms/KW/hr	296.2	284.4	280.9	284.9	291.4
Thermal efficiency	%	28.4	29.6	30.0	29.6	28.9
Fuel temperature	deg C :	34.0	34.0	34.0	34.0	33.0
Pump delivery/stroke	mm*3 :	36.4	34.5	34.7	36.4	38.4
	mgms :	30.3	28.7	28.8	30.3	32.0
Start of injection deg.	max :	9.3	10.2	11.0	13.7	10.9
	min :	8.6	10.2	10.9	12.7	10.2
	mean :	9.1	10.2	11.0	13.0	10.8
Start of combustion deg.	max :	-.6	1.3	3.1	6.6	5.6
	min :	-1.7	1.0	2.9	6.4	5.5
	mean :	-1.4	1.1	2.9	6.5	5.6
Ignition delay deg	max	11.0	9.2	8.2	7.2	5.4
	min :	9.9	8.9	7.8	6.3	4.6
	mean :	10.5	9.1	8.0	6.5	5.0
Ignition delay ms	max :	0.892	0.881	0.937	1.051	1.107
	min :	0.803	0.856	0.896	0.919	0.946
	mean :	0.856	0.869	0.923	0.951	1.035
Max. cylinder pressure	bar :	60.3	64.7	66.8	74.2	69.1
Max. pressure rise	bar/deg :	7.1	7.7	8.2	10.0	8.2
	bar/ms :	87.7	80.6	71.6	68.2	40.2
Oil temperature	deg C :	88.0	89.0	89.0	87.0	84.0
Water IN temperature	deg C :	49.0	45.0	43.0	41.0	40.0
Water OUT temperature	deg C :	79.0	78.0	78.0	78.0	77.0
Exhaust temperature	deg C	278.0	248.0	229.0	211.0	193.0

ENGINE TEST RESULTS

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2860

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 10:05:85
TEST ID : UNID012

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		33 % LOAD (Nominal)	14 deg BTDC			
Observed load	N	4.68	3.96	4.55	4.44	4.25
Observed torque	NM :	37.5	31.7	36.4	35.5	34.0
Observed speed	RPM :	2031	1745	1430	1133	797
Observed power	KW :	8.0	5.8	5.4	4.2	2.8
Air temperature	deg C :	28.0	29.0	28.0	28.0	27.0
Barometric pressure	mBar :	1022.3	1022.3	1022.2	1022.2	1022.2
Correction factor	:	0.987	0.989	0.987	0.987	0.986
Corrected torque	NM	37.0	31.4	35.9	35.1	33.5
Corrected power	KW	7.9	5.7	5.4	4.2	2.8
Fuel consumed	gms	29.3	25.2	26.1	27.3	26.9
Measurement time	seconds	29.990	34.790	42.390	53.390	75.750
Fuel mass flow	gms/sec :	0.98	0.72	0.62	0.51	0.36
B.S.F.C.	gms/KW/hr	446.9	454.9	411.9	442.4	457.0
Thermal efficiency	%	18.8	18.5	20.4	19.0	18.4
Fuel temperature	deg C	34.0	34.0	34.0	33.0	32.0
Pump delivery/stroke	mm†3	23.1	20.0	20.7	21.7	21.4
	mgms :	19.2	16.6	17.2	18.1	17.8
Start of injection deg.	max	7.6	6.4	8.4	11.0	10.0
	min :	5.9	5.7	8.2	10.9	9.2
	mean :	6.9	5.9	8.3	11.0	9.5
Start of combustion deg.	max :	-5.0	-4.1	.3	4.7	4.6
	min :	-5.7	-5.1	-.6	3.8	3.7
	mean :	-5.4	-4.5	-.1	4.0	4.0
Ignition delay deg	max :	12.7	10.8	8.9	7.2	6.1
	min :	11.6	9.9	8.0	6.3	4.9
	mean	12.3	10.4	8.4	7.0	5.5
Ignition delay ms	max :	1.039	1.032	1.041	1.060	1.277
	min :	0.954	0.948	0.933	0.929	1.025
	mean :	1.012	0.989	0.982	1.026	1.148
Max. cylinder pressure	bar	49.3	49.9	56.6	61.7	58.2
Max. pressure rise	bar/deg :	3.4	3.9	6.8	8.1	7.7
	bar/ms	41.0	40.3	58.4	55.3	36.7
Oil temperature	deg C :	87.0	87.0	86.0	84.0	82.0
Water IN temperature	deg C	34.0	34.0	35.0	41.0	51.0
Water OUT temperature	deg C	77.0	77.0	76.0	76.0	77.0
Exhaust temperature	deg C	200.0	169.0	154.0	142.0	129.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	DISTILLATE :	DIST 100	DATE	10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID	UNIDO12
No CYL	3	CAL VALUE MJ/Kg	42.75		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 14 deg BTDC

Observed load	N	0.35
Observed torque	NM	2.8
Observed speed	RPM	828
Observed power	KW	.2
Air temperature	deg C	27.0
Barometric pressure	mBar	1022.3
Correction factor		0.986
Corrected torque	NM	2.8
Corrected power	KW	.2
Fuel consumed	gms	13.7
Measurement time	seconds	72.750
Fuel mass flow	gms/sec	0.19
B.S.F.C.	gms/KW/hr	2826.4
Thermal efficiency	%	3.0
Fuel temperature	deg C :	32.0
Pump delivery/stroke	mm＊3 :	10.9
	mgms :	9.1
Start of injection deg.	max :	10.0
	min :	8.2
	mean :	9.1
Start of combustion deg.	max :	3.8
	min :	2.0
	mean :	2.9
Ignition delay deg	max :	6.3
	min :	6.2
	mean :	6.2
Ignition delay ms	max :	1.274
	min :	1.241
	mean :	1.257
Max. cylinder pressure	bar :	52.3
Max. pressure rise	bar/deg :	6.3
	bar/ms :	31.3
Oil temperature	deg C :	79.0
Water IN temperature	deg C :	52.0
Water OUT temperature	deg C	75.0
Exhaust temperature	deg C	34.0

ENGINE TEST RESULTS

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2960

FUEL

EMULSION :	TEGDN3.9
DENSITY Kg/l :	0.849
CAL VALUE MJ/Kg :	38.62

DATE 10:05 85
TEST ID : UNIDO13

DYNO TORQUE FACTOR 35.61

100 % LOAD (Nominal) 14 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N	18.58	19.58	19.90	19.66	19.23
Observed torque	NM	148.7	156.7	159.3	157.4	154.0
Observed speed	RPM	2031	1709	1446	1132	823
Observed power	KW	31.6	28.0	24.1	18.7	13.3
Air temperature	deg C	29.0	30.0	30.0	30.0	29.0
Barometric pressure	mBar	1022.2	1022.2	1022.2	1022.2	1022.5
Correction factor		0.989	0.991	0.991	0.991	0.989
Corrected torque	NM	147.1	155.3	157.9	155.9	[illegible].3
Corrected power	KW	31.3	27.8	23.9	18.5	13.1
Fuel consumed	gms	81.6	86.2	89.0	91.0	87.0
Measurement time	seconds	29.990	35.390	41.990	53.[illegible]	73.180
Fuel mass flow	gms/sec	2.72	2.44	2.12	1.70	1.19
B.S.F.C.	gms/KW/hr	313.1	315.5	319.2	332.1	326.0
Thermal efficiency	%	29.8	29.5	29.2	28.1	[illegible].6
Fuel temperature	deg C	30.0	30.0	30.0	32.0	32.0
Pump delivery/stroke	mm*3	64.1	68.2	70.2	72.3	[illegible].3
	mgms	53.6	57.0	58.6	60.2	57.8
Start of injection deg.	max	13.9	15.6	16.4	17.3	11.9
	min	13.7	14.7	15.5	16.5	11.8
	mean	13.8	15.1	16.0	17.1	11.9
Start of combustion deg.	max	4.8	7.4	8.4	10.1	6.6
	min	4.6	6.5	8.2	10.0	6.5
	mean	4.7	7.1	8.2	10.1	6.6
Ignition delay deg	max	9.3	8.3	8.2	7.3	5.3
	min	9.0	7.3	7.1	6.5	5.2
	mean	9.1	7.9	7.8	7.0	5.3
Ignition delay ms	max	0.763	0.811	0.941	1.069	1.077
	min	0.737	0.708	0.819	0.951	1.053
	mean	0.750	0.771	0.895	1.035	1.065
Max. cylinder pressure	bar	81.5	86.6	88.6	90.3	[illegible].6
Max. pressure rise	bar/deg	10.5	11.6	10.0	10.0	8.0
	bar/ms	127.4	118.8	93.5	68.2	39.6
Oil temperature	deg C	94.0	88.0	88.0	87.0	86.0
Water IN temperature	deg C	46.0	58.0	62.0	64.0	[illegible]
Water OUT temperature	deg C	90.0	90.0	80.0	91.0	81.0
Exhaust temperature	deg C	376.0	383.0	378.0	340	[illegible]

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	EMULSION :	TEGDN3.9	DATE	10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID	UNID013
No CYL	3	CAL VALUE MJ/Kg :	38.62		
CAPACITY cc	2960			DYNO TORQUE FACTOR	35.61

67 % LOAD (Nominal) 14 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N	10.82	11.38	11.52	11.51	11.61
Observed torque	NM :	86.6	90.9	92.3	92.2	[illegible]
Observed speed	RPM	2042	1744	1440	1145	813
Observed power	KW :	18.5	16.6	13.9	11.0	7.9
Air temperature	deg C :	28.0	28.0	28.0	29.0	28.0
Barometric pressure	mBar :	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor	:	0.987	0.987	0.987	0.989	0.987
Corrected torque	NM	85.5	89.8	91.1	91.2	91.7
Corrected power	KW	18.3	16.4	13.7	10.9	7.8
Fuel consumed	gms	49.5	49.0	49.0	49.4	52.2
Measurement time	seconds	29.790	34.790	42.000	52.790	74.180
Fuel mass flow	gms/sec :	1.66	1.41	1.17	0.94	0.70
B.S.F.C.	gms/KW/hr	327.1	309.4	305.8	308.4	324.4
Thermal efficiency	%	28.5	30.1	30.5	30.2	28.7
Fuel temperature	deg C	32.0	32.0	32.0	32.0	32.0
Pump delivery/stroke	mm*3	39.0	38.8	38.9	39.2	41.5
	mgms	32.5	32.3	32.4	32.7	34.6
Start of injection deg.	max :	9.3	11.1	12.1	13.6	12.7
	min	8.5	10.3	11.2	12.9	12.1
	mean :	9.0	10.9	11.8	13.3	12.4
Start of combustion deg.	max :	-.7	2.0	4.0	6.5	7.4
	min	-1.4	2.0	3.7	6.4	7.3
	mean	-.9	2.0	3.8	6.5	7.3
Ignition delay deg	max	10.0	9.2	8.4	7.1	5.3
	min :	9.2	8.3	7.5	6.4	4.8
	mean :	9.8	8.9	8.0	6.8	5.1
Ignition delay ms	max :	0.817	0.878	0.970	1.033	1.088
	min :	0.752	0.794	0.866	0.925	0.987
	mean :	0.803	0.848	0.930	0.989	1.040
Max. cylinder pressure	bar :	61.3	65.6	69.6	73.7	72.6
Max. pressure rise	bar/deg :	6.6	7.3	8.3	9.3	10.5
	bar/ms :	80.4	76.6	71.6	63.7	51.2
Oil temperature	deg C :	87.0	87.0	86.0	85.0	83.0
Water IN temperature	deg C :	53.0	47.0	43.0	41.0	40.0
Water OUT temperature	deg C :	78.0	78.0	77.0	77.0	77.0
Exhaust temperature	deg C	277.0	248.0	229.0	209.0	197.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	EMULSION	TEGDN3.9	DATE	10 05 85
MODEL :	3000	DENSITY Kg/l :	0.849	TEST ID	UNIDO13
No CYL	3	CAL VALUE MJ/Kg :	38.62		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
33 % LOAD (Nominal) 14 deg BTDC						
Observed load	N	4.09	4.08	4.28	4.54	4.75
Observed torque	NM	32.8	32.6	34.3	36.3	38.1
Observed speed	RPM	2044	1727	1432	1135	823
Observed power	KW	7.0	5.9	5.1	4.3	3.3
Air temperature	deg C	28.0	26.0	27.0	28.0	28.0
Barometric pressure	mBar	1022.5	1022.5	1022.5	1022.5	[illegible].5
Correction factor		0.987	0.984	0.986	0.987	0.987
Corrected torque	NM	32.3	32.1	33.8	35.9	37.6
Corrected power	KW	6.9	5.8	5.1	4.3	3.2
Fuel consumed	gms	30.0	28.2	27.4	28.2	27.0
Measurement time	seconds	29.790	35.190	42.190	53.190	73.380
Fuel mass flow	gms/sec	1.01	0.80	0.65	0.53	0.37
B.S.F.C.	gms/KW/hr	523.6	496.5	461.7	447.6	409.3
Thermal efficiency	%	17.8	18.8	20.2	20.8	22.8
Fuel temperature	deg C	33.0	32.0	32.0	33.0	32.0
Pump delivery/stroke	mm*3	23.7	22.3	21.8	22.4	21.5
	mgms	19.7	18.6	18.1	18.7	17.9
Start of injection deg.	max	6.5	5.8	5.7	11.1	11.7
	min	6.2	4.8	5.6	10.4	11.1
	mean	6.4	5.5	5.6	10.9	11.3
Start of combustion deg.	max	-5.2	-4.1	-2.9	3.9	6.4
	min	-6.6	-4.7	-3.5	3.7	5.6
	mean	-5.9	-4.3	-3.1	3.8	5.8
Ignition delay deg	max	13.1	10.5	9.1	7.2	5.7
	min	11.6	9.1	8.5	6.6	5.3
	mean	12.3	9.9	8.8	7.1	5.5
Ignition delay ms	max	1.067	1.014	1.057	1.083	1.160
	min	0.948	0.879	0.986	0.971	1.073
	mean	1.005	0.953	1.020	1.040	1.122
Max. cylinder pressure	bar	48.7	50.3	51.6	61.5	60.8
Max. pressure rise	bar/deg	3.6	4.1	4.5	7.6	9.2
	bar/ms	44.3	42.3	39.0	51.6	45.3
Oil temperature	deg C	85.0	85.0	84.0	83.0	81.0
Water IN temperature	deg C	35.0	34.0	39.0	44.0	53.0
Water OUT temperature	deg C	76.0	75.0	76.0	76.0	77.0
Exhaust temperature	deg C	190.0	163.0	150.0	137.0	126.0

ENGINE TEST RESULTS

DATE . 10 05 85
TEST ID : UNID013

ENGINE	
MAKE	FORD
MODEL	3000
No CYL	3
CAPACITY cc	2860

FUEL	
EMULSION :	TEGDN3.9
DENSITY Kg/l :	0.849
CAL VALUE MJ/Kg :	38.62

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 14 deg BTDC

Observed load		N	0.37
Observed torque		NM	3.0
Observed speed		RPM	824
Observed power		KW	.3
Air temperature		deg C	27.0
Barometric pressure		mBar	1022.5
Correction factor			0.986
Corrected torque		NM	2.9
Corrected power		KW	.3
Fuel consumed		gms	14.9
Measurement time		seconds	73.210
Fuel mass flow		gms/sec	0.20
B.S.F.C.		gms/KW/hr	2915.9
Thermal efficiency		%	3.2
Fuel temperature		deg C	32.0
Pump delivery/stroke		mm*3	11.9
		mgms	9.9
Start of injection deg.		max	10.0
		min	9.2
		mean :	9.7
Start of combustion deg.		max :	4.7
		min	3.8
		mean	4.0
Ignition delay	deg	max :	6.1
		min :	5.4
		mean :	5.7
Ignition delay	ms	max :	1.242
		min :	1.083
		mean	1.152
Max. cylinder pressure		bar .	52.1
Max. pressure rise		bar/deg :	5.7
		bar/ms :	28.3
Oil temperature		deg C .	79.0
Water IN temperature		deg C	52.0
Water OUT temperature		deg C	75.0
Exhaust temperature		deg C	97.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	EMULSION :	TEGDN3.9	DATE	10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID	UNID014
No CYL	3	CAL VALUE MJ/Kg :	38.62		
CAPACITY cc	2860			DYNO TORQUE FACTOR	35.61

100 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load	N		17.46	18.77	18.98	19.02	18.64
Observed torque	NM		139.8	150.3	152.0	152.3	149.2
Observed speed	RPM		2027	1727	1435	1136	834
Observed power	KW		29.7	27.2	22.8	18.1	13.0
Air temperature	deg C		29.0	30.0	30.0	31.0	29.0
Barometric pressure	mBar		1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor			0.989	0.991	0.991	0.992	0.989
Corrected torque	NM		138.2	148.9	150.5	151.1	147.6
Corrected power	KW		29.3	26.9	22.6	18.0	12.9
Fuel consumed	gms		80.2	85.9	89.7	91.3	89.0
Measurement time	seconds		29.990	35.190	42.190	53.190	72.380
Fuel mass flow	gms/sec		2.67	2.44	2.13	1.72	1.23
B.S.F.C.	gms/KW/hr		328.1	326.4	338.4	343.8	343.5
Thermal efficiency	%		28.4	28.6	27.5	27.1	27.1
Fuel temperature	deg C		32.0	32.0	32.0	33.0	32.0
Pump delivery/stroke	mm*3		63.3	67.8	71.1	72.6	70.7
	mgms		52.8	56.5	59.3	60.4	59.0
Start of injection deg.		max	19.3	21.0	21.8	22.7	17.3
		min	19.2	20.9	21.8	21.9	16.6
		mean	19.2	20.9	21.8	22.2	17.1
Start of combustion deg.		max	9.1	11.1	12.7	13.9	11.1
		min	8.3	10.9	11.8	13.6	10.9
		mean	8.6	11.0	12.1	13.7	11.0
Ignition delay	deg	max	10.9	10.1	10.0	9.0	6.3
		min	10.1	9.8	9.1	8.2	5.6
		mean	10.6	10.0	9.7	8.5	6.1
Ignition delay	ms	max	0.898	0.970	1.161	1.319	1.265
		min	0.833	0.949	1.061	1.206	1.127
		mean	0.873	0.963	1.125	1.250	1.228
Max. cylinder pressure	bar		90.8	95.2	95.9	97.8	90.6
Max. pressure rise	bar/deg		13.8	14.5	15.0	14.9	10.5
	bar/ms		167.6	149.8	128.8	101.2	52.3
Oil temperature	deg C		82.0	85.0	87.0	87.0	85.0
Water in temperature	deg C		46.0	59.0	63.0	65.0	63.0
Water OUT temperature	deg C		80.0	81.0	81.0	82.0	81.0
Exhaust temperature	deg C		361.0	372.0	372.0	345.0	305.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	TEGDN3.9	DATE : 10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID : UNID014
No CYL	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2960			DYNO TORQUE FACTOR 35.61

67 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N :	10.99	11.32	10.62	11.23	10.96
Observed torque	NM :	88.0	90.6	85.0	89.9	87.8
Observed speed	RPM :	2038	1745	1446	1132	819
Observed power	KW :	18.8	16.6	12.9	10.7	7.5
Air temperature	deg C :	29.0	29.0	29.0	28.0	28.0
Barometric pressure	mBar :	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor	:	0.989	0.989	0.989	0.987	0.987
Corrected torque	NM :	87.0	89.6	84.1	88.8	86.7
Corrected power	KW :	18.6	16.4	12.7	10.5	7.4
Fuel consumed	gms :	50.8	49.0	46.8	48.0	52.0
Measurement time	seconds	29.790	34.790	41.790	53.390	73.580
Fuel mass flow	gms/sec	1.71	1.41	1.12	0.90	0.71
B.S.F.C.	gms/KW/hr :	330.7	309.6	316.8	307.7	342.4
Thermal efficiency	% :	28.2	30.1	29.4	30.3	27.2
Fuel temperature	deg C :	32.0	33.0	32.0	32.0	32.0
Pump delivery/stroke	mm↑3 :	40.1	38.8	37.2	38.1	41.4
	mgms :	33.5	32.3	31.0	31.8	34.5
Start of injection deg.	max :	14.9	16.5	17.3	18.9	18.2
	min :	14.7	15.5	16.5	18.2	17.2
	mean :	14.8	16.0	17.1	18.4	17.6
Start of combustion deg.	max :	4.7	7.3	8.3	11.1	11.0
	min :	3.7	6.4	8.2	10.9	10.9
	mean :	4.1	6.6	8.3	11.0	11.0
Ignition delay deg	max :	11.0	10.0	9.1	7.9	7.3
	min :	10.2	9.1	8.3	7.1	6.2
	mean :	10.7	9.3	8.8	7.4	6.6
Ignition delay ms	max :	0.900	0.953	1.047	1.170	1.476
	min :	0.835	0.868	0.957	1.047	1.270
	mean :	0.872	0.889	1.018	1.089	1.351
Max. cylinder pressure	bar :	71.2	75.4	76.7	79.2	78.9
Max. pressure rise	bar/deg :	9.8	9.3	9.9	10.8	10.4
	bar/ms :	119.6	97.4	85.8	73.2	51.3
Oil temperature	deg C :	87.0	88.0	87.0	86.0	84.0
Water IN temperature	deg C :	55.0	49.0	45.0	43.0	42.0
Water OUT temperature	deg C :	80.0	78.0	78.0	77.0	78.0
Exhaust temperature	deg C :	275.0	244.0	222.0	200.0	192.0

ENGINE TEST RESULTS

ENGINE		FUEL		DATE : 10 05 85
MAKE	FORD	EMULSION :	TEGDN3.9	TEST ID UNID014
MODEL	3000	DENSITY Kg/l :	0.849	
No CYL	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2960			DYNO TORQUE FACTOR 35.61

33 % LOAD (Nominal) 20 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N :	4.53	4.43	4.41	4.45	4.28
Observed torque	NM :	36.3	35.5	35.3	35.6	34.3
Observed speed	RPM :	2032	1744	1440	1129	807
Observed power	KW	7.7	6.5	5.3	4.2	2.9
Air temperature	deg C :	29.0	28.0	27.0	28.0	27.0
Barometric pressure	mBar :	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor		0.989	0.987	0.986	0.987	0.986
Corrected torque	NM :	35.9	35.0	34.8	35.1	33.8
Corrected power	KW :	7.6	6.4	5.2	4.2	2.9
Fuel consumed	gms :	31.6	29.1	28.4	30.7	31.3
Measurement time	seconds	29.970	34.790	41.990	53.550	74.780
Fuel mass flow	gms/sec	1.05	0.84	0.68	0.57	0.42
B.S.F.C.	gms/KW/hr :	497.3	470.7	464.4	496.6	527.6
Thermal efficiency	% :	18.7	19.8	20.1	18.8	17.7
Fuel temperature	deg C	32.0	33.0	32.0	32.0	32.0
Pump delivery/stroke	mm↑3 :	24.9	23.0	22.5	24.4	24.9
	mgms :	20.8	19.2	18.8	20.3	20.7
Start of injection deg.	max :	12.7	11.2	11.9	17.2	17.2
	min :	12.3	11.1	11.1	16.5	16.3
	mean :	12.4	11.2	11.7	16.9	16.6
Start of combustion deg.	max :	1.2	2.1	3.8	9.3	10.9
	min	1.0	2.0	3.0	9.1	10.0
	mean	1.1	2.1	3.6	9.2	10.3
Ignition delay deg	max :	11.5	9.2	8.2	8.0	6.5
	min :	11.2	9.0	8.1	7.2	6.2
	mean :	11.3	9.1	8.1	7.7	6.3
Ignition delay ms	max :	0.943	0.881	0.949	1.186	1.344
	min :	0.919	0.856	0.933	1.067	1.288
	mean :	0.931	0.870	0.940	1.141	1.309
Max. cylinder pressure	bar :	60.1	60.2	60.5	68.6	66.5
Max. pressure rise	bar/deg :	7.6	6.1	6.9	9.8	9.4
	bar/ms :	93.0	64.0	59.3	66.6	45.6
Oil temperature	deg C	85.0	86.0	85.0	84.0	82.0
Water IN temperature	deg C	38.0	37.0	40.0	49.0	52.0
Water OUT temperature	deg C	77.0	76.0	77.0	78.0	77.0
Exhaust temperature	deg C :	186.0	167.0	149.0	139.0	131.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE	FORD	EMULSION	TEGDN3.9	DATE	10 05 85
MODEL	3000	DENSITY Kg/l	0.849	TEST ID	UNID014
No CYL	[illegible]	CAL VALUE MJ/Kg :	38.62		
CAPACITY cc	2960			DYNO TORQUE FACTOR	35.61

ENGINE SPEED (NOMINAL) 900

IDLE CONDITION 20 deg BTDC

Observed load	N	0.34
Observed torque	NM	2.7
Observed speed	RPM	818
Observed power	KW	.2
Air temperature	deg C	27.0
Barometric pressure	mBar	1022.5
Correction factor		0.986
Corrected torque	NM	2.7
Corrected power	KW	.2
Fuel consumed	gms	15.5
Measurement time	seconds	73.610
Fuel mass flow	gms/sec	0.21
B.S.F.C.	gms/KW/hr	3316.0
Thermal efficiency	%	2.8
Fuel temperature	deg C	32.0
Pump delivery/stroke	mm↑3	12.3
	mgms	10.3
Start of injection deg.	max	15.5
	min	14.6
	mean	15.0
Start of combustion deg.	max	9.2
	min :	8.2
	mean	8.5
Ignition delay deg	max :	7.2
	min	6.2
	mean	6.5
Ignition delay ms	max	1.458
	min	1.263
	mean	1.327
Max. cylinder pressure	bar :	56.1
Max. pressure rise	bar/deg :	7.1
	bar/ms :	34.7
Oil temperature	deg C :	80.0
Water IN temperature	deg C :	51.0
Water OUT temperature	deg C	76.0
Exhaust temperature	deg C	93.0

ENGINE		FUEL		
MAKE	FORD	EMULSION :	TEGDN3.9	DATE : 10 05 85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID : UNID015
No CYL	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		100 % LOAD (Nominal) 26 deg BTDC				
Observed load	N	15.92	17.82	17.78	18.04	18.10
Observed torque	NM	127.4	142.7	142.3	144.5	144.9
Observed speed	RPM	2019	1732	1447	1119	814
Observed power	KW	26.9	25.9	21.6	16.9	12.4
Air temperature	deg C	29.0	29.0	29.0	30.0	28.0
Barometric pressure	mBar	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor		0.989	0.989	0.989	0.991	0.987
Corrected torque	NM	126.0	141.1	140.8	143.1	143.0
Corrected power	KW	26.6	25.6	21.3	16.8	12.2
Fuel consumed	gms	80.5	85.6	89.5	91.4	89.2
Measurement time	seconds	30.190	34.990	41.790	53.990	73.900
Fuel mass flow	gms/sec	2.67	2.45	2.14	1.69	1.21
B.S.F.C.	gms/KW/hr	360.3	344.2	361.4	363.4	355.9
Thermal efficiency	%	25.9	27.1	25.8	25.6	26.2
Fuel temperature	deg C	31.0	31.0	31.0	32.0	31.0
Pump delivery/stroke	mm+3	63.3	67.7	70.9	72.6	71.0
	mgms	52.8	56.5	59.2	60.5	59.2
Start of injection deg.	max	24.7	26.4	27.3	28.0	22.6
	min	24.5	26.3	27.1	27.2	21.7
	mean	24.6	26.4	27.2	27.7	21.9
Start of combustion deg.	max	12.0	14.7	15.4	16.4	14.6
	min	11.8	13.6	14.5	16.3	14.5
	mean	11.9	14.1	15.2	16.4	14.6
Ignition delay deg	max	12.9	12.7	12.7	11.6	8.0
	min	12.6	11.6	11.7	10.8	7.1
	mean	12.7	12.3	12.0	11.3	7.4
Ignition delay ms	max	1.065	1.226	1.457	1.733	1.640
	min	1.044	1.120	1.348	1.615	1.462
	mean	1.052	1.183	1.379	1.687	1.508
Max. cylinder pressure	bar	97.4	100.7	101.7	101.7	95.0
Max. pressure rise	bar/deg	19.4	20.3	20.2	21.7	12.2
	bar/ms	234.7	210.6	175.5	145.9	59.4
Oil temperature	deg C	83.0	87.0	88.0	89.0	87.0
Water IN temperature	deg C	58.0	65.0	68.0	71.0	68.0
Water OUT temperature	deg C	81.0	82.0	83.0	83.0	83.0
Exhaust temperature	deg C	377.0	373.0	369.0	341.0	309.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	TEGDN3.9	DATE : 10.05.85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID : UNID015
N: CYL	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

67 % LOAD (Nominal) 26 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N :	11.37	10.46	11.41	11.10	10.97
Observed torque	NM :	91.0	83.8	91.3	88.9	87.9
Observed speed	RPM :	2033	1738	1427	1139	808
Observed power	KW :	19.4	15.3	13.6	10.6	7.4
Air temperature	deg C :	29.0	29.0	28.0	28.0	28.0
Barometric pressure	mBar :	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor		0.989	0.989	0.987	0.987	0.987
Corrected torque	NM :	90.0	82.8	90.2	87.7	86.7
Corrected power	KW :	19.2	15.1	13.5	10.5	7.3
Fuel consumed	gms :	52.9	48.9	52.2	51.7	51.1
Measurement time	seconds :	29.990	34.790	42.390	52.990	74.590
Fuel mass flow	gms/sec :	1.76	1.41	1.23	0.98	0.69
B.S.F.C.	gms/KW/hr :	331.3	335.5	329.1	335.6	335.9
Thermal efficiency	% :	28.1	27.8	28.3	27.8	27.8
Fuel temperature	deg C :	32.0	32.0	33.0	33.0	33.0
Pump delivery/stroke	mm+3 :	41.6	38.8	41.5	41.1	40.7
	mgms :	34.7	32.3	34.5	34.3	33.9
Start of injection deg.	max :	21.0	22.0	23.5	24.5	22.6
	min :	20.9	21.0	22.7	23.8	21.8
	mean :	21.0	21.7	23.0	24.3	22.3
Start of combustion deg.	max :	9.1	10.1	12.8	14.7	14.6
	min :	8.3	9.9	12.0	13.6	13.7
	mean :	8.9	10.0	12.6	14.4	14.1
Ignition delay deg	max :	12.7	12.1	10.8	10.7	8.8
	min :	11.8	10.8	9.9	9.2	7.5
	mean :	12.0	11.7	10.4	9.8	8.2
Ignition delay ms	max :	1.042	1.155	1.263	1.571	1.819
	min :	0.969	1.038	1.159	1.344	1.542
	mean :	0.986	1.120	1.219	1.438	1.698
Max. cylinder pressure	bar :	82.2	83.2	85.4	85.3	81.3
Max. pressure rise	bar/deg :	12.6	12.6	14.5	15.5	11.1
	bar/ms :	154.0	131.4	123.9	105.7	53.9
Oil temperature	deg C :	90.0	90.0	90.0	88.0	87.0
Water IN temperature	deg C :	54.0	48.0	45.0	45.0	46.0
Water OUT temperature	deg C :	80.0	79.0	79.0	80.0	80.0
Exhaust temperature	deg C :	271.0	237.0	232.0	213.0	195.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	TEGDN3.9	DATE : 10:05:85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID : UNID015
No CYL	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

33 % LOAD (Nominal) 26 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load		N	4.75	4.23	4.65	4.47	4.70
Observed torque		NM	38.0	33.9	37.2	35.8	37.6
Observed speed		RPM	2038	1732	1442	1130	821
Observed power		KW	8.1	6.1	5.6	4.2	3.2
Air temperature		deg C	27.0	27.0	27.0	27.0	27.0
Barometric pressure		mBar	1022.5	1022.5	1022.5	1022.5	1022.5
Correction factor			0.986	0.986	0.986	0.986	0.986
Corrected torque		NM	37.5	33.4	36.7	35.3	37.1
Corrected power		KW	8.0	6.1	5.5	4.2	3.2
Fuel consumed		gms	32.3	29.7	29.5	30.1	35.1
Measurement time		seconds	29.790	34.990	41.990	53.590	73.380
Fuel mass flow		gms/sec	1.08	0.85	0.70	0.56	0.48
B.S.F.C.		gms/KW/hr	488.3	504.5	456.5	484.3	540.1
Thermal efficiency		%	19.1	18.5	20.4	19.2	17.3
Fuel temperature		deg C	33.0	33.0	32.0	32.0	32.0
Pump delivery/stroke		mm+3	25.5	23.5	23.4	23.9	28.0
		mgms	21.3	19.6	19.5	19.9	23.3
Start of injection deg.		max	18.3	17.5	18.2	22.6	22.6
		min	17.8	16.5	17.3	21.9	22.5
		mean	18.1	16.9	17.6	22.3	22.6
Start of combustion deg.		max	5.7	6.6	9.3	12.9	14.6
		min	5.6	6.4	8.2	11.9	13.7
		mean	5.6	6.5	8.4	12.6	13.9
Ignition delay	deg	max	12.7	10.9	9.9	10.0	8.9
		min	12.1	10.0	8.9	9.1	8.0
		mean	12.5	10.4	9.2	9.7	8.7
Ignition delay	ms	max	1.036	1.053	1.141	1.474	1.806
		min	0.987	0.965	1.029	1.336	1.621
		mean	1.020	1.001	1.064	1.435	1.761
Max. cylinder pressure		bar	67.9	66.3	65.8	70.2	71.4
Max. pressure rise		bar/deg	8.6	8.6	8.9	10.0	10.8
		bar/ms	105.6	89.5	76.7	67.9	53.3
Oil temperature		deg C	87.0	87.0	87.0	85.0	84.0
Water IN temperature		deg C	41.0	41.0	49.0	54.0	53.0
Water OUT temperature		deg C	78.0	78.0	78.0	80.0	83.0
Exhaust temperature		deg C	187.0	165.0	150.0	139.0	[illegible]

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	TEGDN3.9	DATE : 10:05:85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID : UNIDO15
No CYL :	3	CAL VALUE MJ/Kg :	38.62	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 26 deg BTDC

Observed load	N		0.37
Observed torque	NM		3.0
Observed speed	RPM		829
Observed power	KW		.3
Air temperature	deg C		26.0
Barometric pressure	mBar		1022.6
Correction factor			0.984
Corrected torque	NM		2.9
Corrected power	KW		.3
Fuel consumed	gms		15.8
Measurement time	seconds		72.780
Fuel mass flow	gms/sec		0.22
B.S.F.C.	gms/KW/hr		3086.9
Thermal efficiency	%		3.0
Fuel temperature	deg C		31.0
Pump delivery/stroke	mm*3		12.5
	mgms		10.5
Start of injection deg.		max	20.9
		min	20.2
		mean	20.7
Start of combustion deg.		max	12.8
		min	11.9
		mean	12.1
Ignition delay	deg	max	8.9
		min	8.1
		mean	8.6
Ignition delay	ms	max	1.784
		min	1.624
		mean	1.723
Max. cylinder pressure	bar		57.2
Max. pressure rise	bar/deg		6.4
	bar/ms		31.9
Oil temperature	deg C		79.0
Water IN temperature	deg C		62.0
Water OUT temperature	deg C		69.0
Exhaust temperature	deg C		89.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE :	FORD	DISTILLATE :	DIST 100	DATE : 14/6/85
MODEL :	3000	DENSITY Kg/l :	0.849	TEST ID : UNID018
No CYL :	3	CAL VALUE MJ/Kg :	42.75	
CAPACITY cc :	2860			DYNO TORQUE FACTOR : 35.61

100 % LOAD (Nominal) 18 deg BTDC

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
Observed load		N	18.89	20.11	19.93	19.42	19.40
Observed torque		NM	151.2	161.0	159.6	155.5	155.3
Observed speed		RPM	2038	1714	1452	1142	839
Observed power		KW	32.3	28.9	24.3	18.6	13.6
Air temperature		deg C	32.0	32.0	33.0	30.0	30.0
Barometric pressure		mBar	1021.5	1021.5	1021.5	1021.5	1021.5
Correction factor			0.994	0.994	0.996	0.991	0.991
Corrected torque		NM	150.4	160.1	159.0	154.1	153.9
Corrected power		KW	32.1	28.7	24.2	18.4	13.5
Fuel consumed		gms	82.8	86.6	89.1	92.5	91.5
Measurement time		seconds	30.000	35.390	41.790	52.990	71.780
Fuel mass flow		gms/sec	2.76	2.45	2.13	1.75	1.27
B.S.F.C.		gms/KW/hr	309.6	306.5	317.7	340.9	339.2
Thermal efficiency		%	27.2	27.5	26.5	24.7	24.8
Fuel temperature		deg C	30.0	32.0	33.0	32.0	32.0
Pump delivery/stroke		mm*3	64.8	68.5	70.5	73.3	72.9
		mgms	54.2	57.1	58.8	61.1	60.8
Start of injection deg.		max	18.2	19.1	19.9	20.9	14.6
		min	17.4	19.0	19.2	20.8	13.9
		mean	17.7	19.1	19.8	20.8	14.4
Start of combustion deg.		max	8.2	10.1	10.9	12.8	9.2
		min	7.3	9.1	10.8	11.9	9.1
		mean	7.7	9.6	10.8	12.6	9.1
Ignition delay	deg	max	10.9	10.0	9.1	8.9	5.5
		min	9.3	9.0	8.4	8.1	4.8
		mean	10.0	9.4	8.9	8.3	5.3
Ignition delay	ms	max	0.888	0.968	1.047	1.301	1.091
		min	0.758	0.877	0.964	1.178	0.955
		mean	0.818	0.916	1.025	1.208	1.052
Max. cylinder pressure		bar	90.8	95.5	96.9	98.6	89.0
Max. pressure rise		bar/deg	13.6	14.3	12.4	14.1	9.4
		bar/ms	166.8	147.1	108.0	96.6	47.5
Oil temperature		deg C	83.0	94.0	94.0	92.0	89.0
Water IN temperature		deg C	55.0	68.0	69.0	68.0	67.0
Water OUT temperature		deg C	85.0	87.0	87.0	86.0	86.0
Exhaust temperature		deg C	420.0	412.0	400.0	360.0	322.0

ENGINE TEST RESULTS

ENGINE
MAKE : FORD
MODEL 3000
No CYL 3
CAPACITY cc 2960

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 14/6/85
TEST ID : UNIDO16

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)			2000	1700	1400	1100	800
			67 % LOAD (Nominal)		18 deg BTDC		
Observed load	N		10.82	10.86	11.49	10.39	11.59
Observed torque	NM		86.7	86.9	92.0	83.2	92.8
Observed speed	RPM		2044	1732	1438	1127	835
Observed power	KW		18.6	15.8	13.8	9.8	8.1
Air temperature	deg C		30.0	30.0	29.0	29.0	28.0
Barometric pressure	mBar		1021.0	1021.0	1021.0	1021.0	1021.0
Correction factor			0.992	0.992	0.990	0.990	0.988
Corrected torque	NM		85.9	86.2	91.0	82.4	91.7
Corrected power	KW		18.4	15.6	13.7	9.7	8.0
Fuel consumed	gms		45.1	44.0	45.5	41.9	43.5
Measurement time	seconds		29.790	34.990	42.190	53.590	72.180
Fuel mass flow	gms/sec		1.51	1.26	1.08	0.78	0.60
B.S.F.C.	gms/KW/hr		290.3	289.6	283.2	289.5	270.7
Thermal efficiency	%		28.4	29.1	29.7	29.1	31.1
Fuel temperature	deg C		32.0	33.0	32.0	32.0	31.0
Pump delivery/stroke	mm†3		35.5	34.9	36.0	33.3	34.6
	mgms		29.6	29.0	30.0	27.7	28.9
Start of injection deg.		max	12.9	13.8	15.5	16.4	12.7
		min	12.6	13.7	15.4	16.4	12.0
		mean	12.8	13.7	15.5	16.4	12.6
Start of combustion deg.		max	2.8	4.7	6.6	9.1	6.6
		min	2.8	4.6	6.5	8.4	6.5
		mean	2.8	4.6	6.5	9.0	6.5
Ignition delay	deg	max	10.1	9.2	9.0	7.9	6.2
		min	9.8	9.0	8.8	7.2	5.5
		mean	10.0	9.1	8.9	7.4	6.0
Ignition delay	ms	max	0.820	0.881	1.043	1.175	1.237
		min	0.798	0.867	1.023	1.070	1.103
		mean	0.814	0.876	1.035	1.099	1.203
Max. cylinder pressure	bar		69.2	71.9	75.0	76.5	70.4
Max. pressure rise	bar/deg		8.6	9.2	10.6	10.2	9.2
	bar/ms		105.7	95.3	91.8	69.0	46.0
Oil temperature	deg C		90.0	91.0	90.0	88.0	86.0
Water IN temperature	deg C		52.0	45.0	40.0	40.0	39.0
Water OUT temperature	deg C		83.0	82.0	81.0	81.0	81.0
Exhaust temperature	deg C		269.0	239.0	226.0	196.0	185.0

ENGINE TEST RESULTS

ENGINE
MAKE FORD
MODEL 3000
No CYL 3
CAPACITY cc 2960

FUEL
DISTILLATE : DIST 100
DENSITY Kg/l : 0.849
CAL VALUE MJ/Kg : 42.75

DATE : 14/6/85
TEST ID : UNID016

DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
33 % LOAD (Nominal) 18 deg BTDC						
Observed load	N :	4.44	4.55	4.77	4.56	4.51
Observed torque	NM :	35.5	36.5	38.2	36.5	36.1
Observed speed	RPM	2033	1724	1427	1106	813
Observed power	KW	7.6	6.6	5.7	4.2	3.1
Air temperature	deg C :	29.0	29.0	28.0	28.0	27.0
Barometric pressure	mBar :	1021.0	1021.0	1021.0	1021.0	1021.0
Correction factor	:	0.990	0.990	0.988	0.988	0.987
Corrected torque	NM	35.2	36.1	37.7	36.1	35.7
Corrected power	KW	7.5	6.5	5.6	4.2	3.0
Fuel consumed	gms :	27.8	27.0	26.0	28.2	26.2
Measurement time	seconds :	29.990	35.190	42.390	54.590	74.180
Fuel mass flow	gms/sec :	0.93	0.77	0.61	0.52	0.35
B.S.F.C.	gms/KW/hr :	445.9	423.9	391.8	444.8	419.0
Thermal efficiency	% :	18.9	19.9	21.5	18.9	20.1
Fuel temperature	deg C :	32.0	32.0	32.0	31.0	31.0
Pump delivery/stroke	mm3 :	21.9	21.4	20.6	22.4	20.8
	mgms :	18.2	17.8	17.2	18.7	17.4
Start of injection deg.	max :	9.5	10.1	12.1	15.4	11.9
	min :	9.3	9.5	12.0	13.7	11.0
	mean :	9.4	10.0	12.1	14.6	11.2
Start of combustion deg.	max :	-1.0	.4	3.9	7.4	5.5
	min :	-1.6	.1	3.0	6.5	5.5
	mean :	-1.4	.3	3.4	6.9	5.5
Ignition delay deg	max :	11.1	9.9	9.1	8.0	6.4
	min :	10.4	9.1	8.2	7.2	5.5
	mean :	10.8	9.7	8.7	7.7	5.7
Ignition delay ms	max :	0.907	0.962	1.062	1.210	1.313
	min :	0.855	0.881	0.955	1.091	1.123
	mean :	0.887	0.940	1.016	1.160	1.167
Max. cylinder pressure	bar :	55.5	57.9	60.5	65.4	59.9
Max. pressure rise	bar/deg :	5.6	6.5	7.9	9.8	6.7
	bar/ms :	68.4	67.6	67.8	64.7	32.8
Oil temperature	deg C :	88.0	89.0	87.0	84.0	83.0
Water IN temperature	deg C :	43.0	38.0	36.0	34.0	[illegible]
Water OUT temperature	deg C :	81.0	79.0	79.0	79.0	78.0
Exhaust temperature	deg C :	184.0	167.0	151.0	136.0	127.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	DISTILLATE :	DIST 100	DATE : 14/6/85
MODEL	3000	DENSITY Kg/l :	0.849	TEST ID UNIDO16
No CYL	3	CAL VALUE MJ/Kg :	42.75	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL) 800

		IDLE CONDITION	18 deg BTDC
Observed load		N	0.38
Observed torque		NM	3.1
Observed speed		RPM	814
Observed power		KW	.3
Air temperature		deg C	26.0
Barometric pressure		mBar	1021.0
Correction factor		:	0.985
Corrected torque		NM :	3.0
Corrected power		KW :	.3
Fuel consumed		gms	14.0
Measurement time		seconds :	74.010
Fuel mass flow		gms/sec	0.19
B.S.F.C.		gms/KW/hr	2642.6
Thermal efficiency		% :	3.2
Fuel temperature		deg C	30.0
Pump delivery/stroke		mm*3 :	11.1
		mgms	9.3
Start of injection deg.		max :	10.9
		min :	10.4
		mean :	10.6
Start of combustion deg.		max :	4.7
		min :	4.1
		mean :	4.5
Ignition delay	deg	max :	6.3
		min :	5.9
		mean :	6.1
Ignition delay	ms	max :	1.288
		min :	1.203
		mean :	1.239
Max. cylinder pressure		bar :	51.7
Max. pressure rise		bar/deg :	5.5
		bar/ms :	26.8
Oil temperature		deg C :	80.0
Water IN temperature		deg C :	38.0
Water OUT temperature		deg C	76.0
Exhaust temperature		deg C :	93.0

ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE	FORD	EMULSION :	E25/3.9TEGDN	DATE 14/6/85
MODEL	3000	DENSITY Kg/l :	0.848	TEST ID : UNID017
No CYL	3	CAL VALUE MJ/Kg :	37.66	
CAPACITY cc	2860			DYNO TORQUE FACTOR : 35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
100 % LOAD (Nominal) 18 deg BTDC						
Observed load	N	17.73	18.77	19.39	18.77	18.55
Observed torque	NM	141.9	150.3	155.2	150.3	148.5
Observed speed	RPM	2040	1724	1439	1126	833
Observed power	KW	30.3	27.1	23.4	17.7	13.0
Air temperature	deg C	30.0	29.0	30.0	29.0	29.0
Barometric pressure	mBar	1020.0	1020.0	1020.0	1020.0	1020.0
Correction factor		0.992	0.990	0.992	0.990	0.990
Corrected torque	NM	140.8	148.9	154.0	148.9	147.1
Corrected power	KW	30.1	26.9	23.2	17.6	12.8
Fuel consumed	gms	82.7	84.8	90.8	93.4	91.6
Measurement time	seconds	29.790	35.190	42.000	53.590	72.380
Fuel mass flow	gms/sec	2.78	2.41	2.16	1.74	1.27
B.S.F.C.	gms/KW/hr	332.2	322.9	335.4	357.4	355.1
Thermal efficiency	%	28.8	29.6	28.5	26.7	26.9
Fuel temperature	deg C	26.0	27.0	27.0	28.0	29.0
Pump delivery/stroke	mm*3	64.9	66.8	71.8	74.0	72.7
	mgms	54.4	55.9	60.1	61.9	60.8
Start of injection deg.	max	17.4	18.3	20.0	21.0	15.5
	min	17.3	18.2	19.2	20.0	15.3
	mean	17.3	18.2	19.5	20.4	15.4
Start of combustion deg.	max	7.2	9.8	10.9	12.9	9.3
	min	7.2	9.1	10.1	11.8	9.2
	mean	7.2	9.3	10.7	12.1	9.2
Ignition delay deg	max	10.1	9.1	9.9	9.1	6.3
	min	10.1	8.4	8.3	7.2	6.1
	mean	10.1	9.0	8.8	8.3	6.2
Ignition delay ms	max	0.829	0.884	1.143	1.352	1.268
	min	0.823	0.817	0.965	1.065	1.220
	mean	0.826	0.868	1.020	1.228	1.245
Max. cylinder pressure	bar	89.3	93.3	94.6	97.1	89.1
Max. pressure rise	bar/deg	15.5	15.4	14.2	15.5	10.1
	bar/ms	189.7	159.3	122.6	104.9	50.7
Oil temperature	deg C	77.0	82.0	83.0	84.0	83.0
Water IN temperature	deg C	50.0	57.0	61.0	63.0	63.0
Water OUT temperature	deg C	82.0	82.0	82.0	83.0	83.0
Exhaust temperature	deg C	372.0	364.0	366.0	336.0	308.0

ENGINE TEST RESULTS

ENGINE
MAKE : FORD
MODEL : 3000
No CYL : 3
CAPACITY cc : 2860

FUEL
EMULSION : E25/3.5TEGDN
DENSITY Kg/l : 0.848
CAL VALUE MJ/Kg : 37.66

DATE : 14/6/85
TEST ID : UNID017

DYNO TORQUE FACTOR : 35.61

67 % LOAD (Nominal) 18 deg BTDC

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
Observed load	N :	11.23	11.00	11.13	11.45	11.10
Observed torque	NM :	89.9	88.1	89.1	91.7	88.9
Observed speed	RPM :	2025	1732	1428	1141	814
Observed power	KW :	19.1	16.0	13.3	11.0	7.6
Air temperature	deg C :	29.0	28.0	28.0	28.0	27.0
Barometric pressure	mBar :	1020.0	1020.0	1020.0	1020.0	1020.0
Correction factor	:	0.990	0.989	0.989	0.989	0.987
Corrected torque	NM :	89.0	87.1	88.1	90.7	87.7
Corrected power	KW :	18.9	15.8	13.2	10.8	7.5
Fuel consumed	gms :	52.4	50.3	50.1	49.8	53.9
Measurement time	seconds :	29.990	34.990	42.390	52.990	74.180
Fuel mass flow	gms/sec :	1.75	1.44	1.18	0.94	0.73
B.S.F.C.	gms/KW/hr :	333.2	327.6	323.0	312.2	350.0
Thermal efficiency	% :	28.7	29.2	29.6	30.6	27.3
Fuel temperature	deg C :	29.0	30.0	30.0	30.0	30.0
Pump delivery/stroke	mm^3 :	41.3	39.8	39.7	39.5	42.8
	mgms :	34.5	33.2	33.1	32.9	35.7
Start of injection deg.	max :	13.7	13.8	15.4	17.1	13.7
	min :	13.0	13.7	14.8	16.4	12.8
	mean :	13.4	13.8	15.1	16.6	13.2
Start of combustion deg.	max :	2.9	4.7	7.3	9.3	8.2
	min :	2.8	4.6	6.4	8.4	7.4
	mean :	2.8	4.6	6.7	9.1	7.6
Ignition delay deg	max :	10.8	9.2	8.9	8.0	6.2
	min :	10.2	9.0	7.6	7.3	4.7
	mean :	10.6	9.1	8.5	7.6	5.6
Ignition delay ms	max :	0.892	0.884	1.043	1.167	1.276
	min :	0.838	0.869	0.885	1.064	0.957
	mean :	0.870	0.877	0.988	1.108	1.138
Max. cylinder pressure	bar :	72.1	73.7	76.0	77.7	74.9
Max. pressure rise	bar/deg :	11.2	9.5	11.0	10.0	9.0
	bar/ms :	136.3	98.2	94.1	68.7	43.9
Oil temperature	deg C :	85.0	87.0	87.0	85.0	84.0
Water IN temperature	deg C :	51.0	45.0	43.0	42.0	42.0
Water OUT temperature	deg C :	81.0	80.0	79.0	79.0	79.0
Exhaust temperature	deg C :	270.0	236.0	221.0	201.0	190.0

ENGINE TEST RESULTS

ENGINE		FUEL			
MAKE :	FORD	EMULSION :	E25/3.9TEGDN	DATE :	14/6/85
MODEL :	3000	DENSITY Kg/l :	0.848	TEST ID :	UNID017
No CYL :	3	CAL VALUE MJ/Kg :	37.66		
CAPACITY cc :	2860			DYNO TORQUE FACTOR :	35.61

ENGINE SPEED (NOMINAL)		2000	1700	1400	1100	800
		33 % LOAD (Nominal)	18 deg BTDC			
Observed load	N :	4.59	4.50	4.29	4.72	4.77
Observed torque	NM :	36.7	36.0	34.3	37.8	38.2
Observed speed	RPM :	2062	1734	1424	1125	807
Observed power	KW :	7.9	6.5	5.1	4.4	3.2
Air temperature	deg C :	28.0	28.0	27.0	27.0	26.0
Barometric pressure	mBar :	1020.0	1020.0	1020.0	1020.0	1020.0
Correction factor	:	0.989	0.989	0.987	0.987	0.986
Corrected torque	NM :	36.3	35.6	33.9	37.3	37.6
Corrected power	KW :	7.8	6.5	5.1	4.4	3.2
Fuel consumed	gms :	31.8	30.2	28.1	32.3	28.2
Measurement time	seconds :	29.390	34.990	42.590	53.590	74.780
Fuel mass flow	gms/sec :	1.08	0.86	0.66	0.60	0.38
B.S.F.C.	gms/KW/hr :	496.7	480.6	469.6	494.1	427.1
Thermal efficiency	% :	19.2	19.9	20.4	19.3	22.4
Fuel temperature	deg C :	31.0	30.0	30.0	30.0	29.0
Pump delivery/stroke	mm+3 :	25.2	23.9	22.2	25.7	22.4
	mgms :	21.0	19.9	18.5	21.4	18.7
Start of injection deg.	max :	9.3	10.1	10.1	15.5	12.8
	min :	9.2	9.3	10.1	14.6	12.1
	mean :	9.3	9.8	10.1	14.9	12.5
Start of combustion deg.	max :	-1.4	.3	2.0	7.4	7.3
	min :	-1.7	.2	1.1	7.3	6.5
	mean :	-1.6	.2	1.8	7.4	6.8
Ignition delay deg	max :	11.0	10.0	8.9	8.1	6.3
	min :	10.6	9.0	8.0	7.3	4.8
	mean :	10.8	9.6	8.3	7.5	5.7
Ignition delay ms	max :	0.887	0.960	1.045	1.203	1.295
	min :	0.859	0.868	0.937	1.076	0.996
	mean :	0.875	0.924	0.968	1.110	1.177
Max. cylinder pressure	bar :	57.1	58.2	58.9	65.8	62.0
Max. pressure rise	bar/deg :	6.3	6.0	7.2	9.5	9.7
	bar/ms :	78.0	62.8	61.8	64.0	47.1
Oil temperature	deg C :	85.0	86.0	85.0	83.0	81.0
Water IN temperature	deg C :	42.0	33.0	30.0	29.0	30.0
Water OUT temperature	deg C	79.0	78.0	78.0	78.0	77.0
Exhaust temperature	deg C :	185.0	164.0	145.0	139.0	122.0

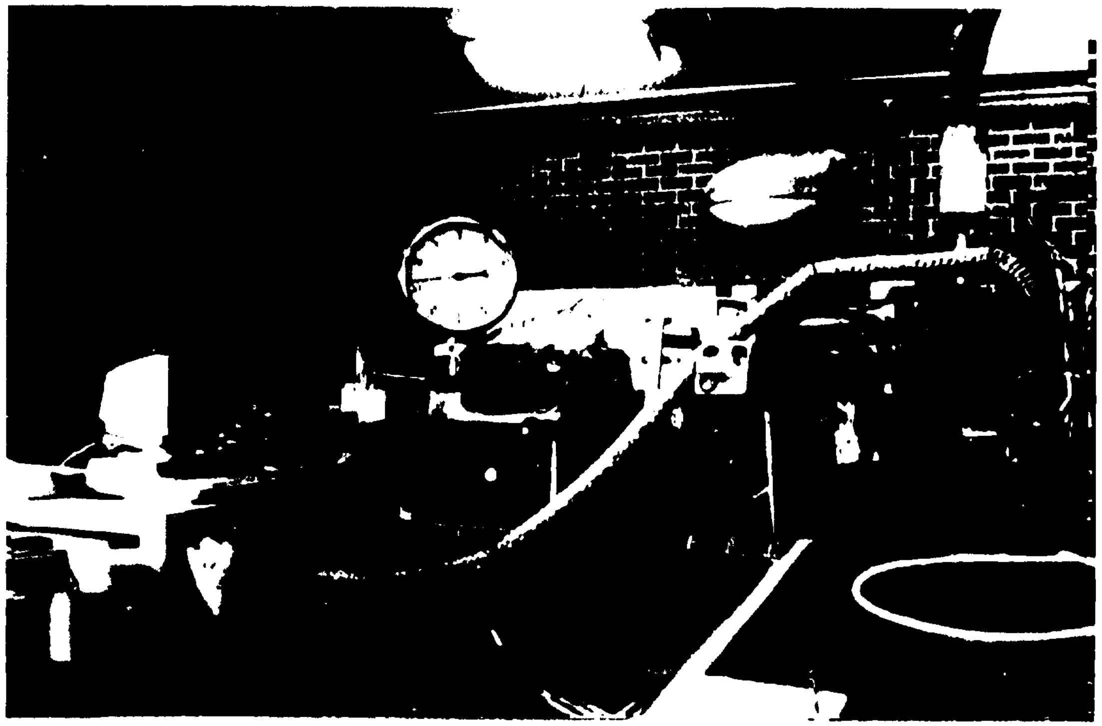
ENGINE TEST RESULTS

ENGINE		FUEL		
MAKE :	FORD	EMULSION :	E25/3.9TEGDN	DATE : 14/6/85
MODEL :	3000	DENSITY Kg/l :	0.848	TEST ID : UNID017
No CYL :	3	CAL VALUE MJ/Kg :	37.66	
CAPACITY cc :	2860			DYNO TORQUE FACTOR : 35.61

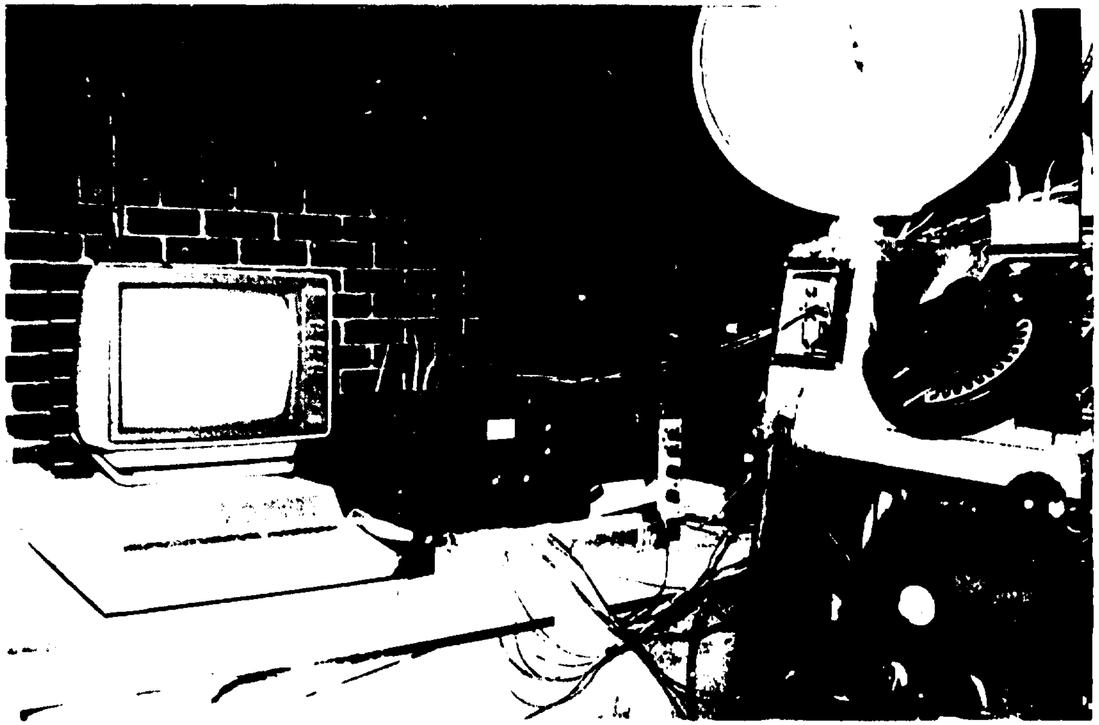
ENGINE SPEED (NOMINAL) 800

IDLE CONDITION 18 deg BTDC

Observed load		N :	0.34
Observed torque		NM :	2.7
Observed speed		RPM :	809
Observed power		KW :	.2
Air temperature		deg C :	26.0
Barometric pressure		mBar :	1020.0
Correction factor		:	0.986
Corrected torque		NM :	2.7
Corrected power		KW :	.2
Fuel consumed		gms :	15.6
Measurement time		seconds :	74.420
Fuel mass flow		gms/sec :	0.21
B.S.F.C.		gms/KW/hr :	3355.3
Thermal efficiency		% :	2.8
Fuel temperature		deg C :	30.0
Pump delivery/stroke		mm↑3 :	12.4
		mgms :	10.4
Start of injection	deg.	max :	11.1
		min :	10.9
		mean :	11.0
Start of combustion	deg.	max :	5.6
		min :	4.8
		mean :	5.3
Ignition delay	deg	max :	6.1
		min :	5.4
		mean :	5.7
Ignition delay	ms	max :	1.266
		min :	1.115
		mean :	1.176
Max. cylinder pressure		bar :	53.6
Max. pressure rise		bar/deg :	6.1
		bar/ms :	29.7
Oil temperature		deg C :	79.0
Water IN temperature		deg C :	33.0
Water OUT temperature		deg C :	76.0
Exhaust temperature		deg C :	92.0

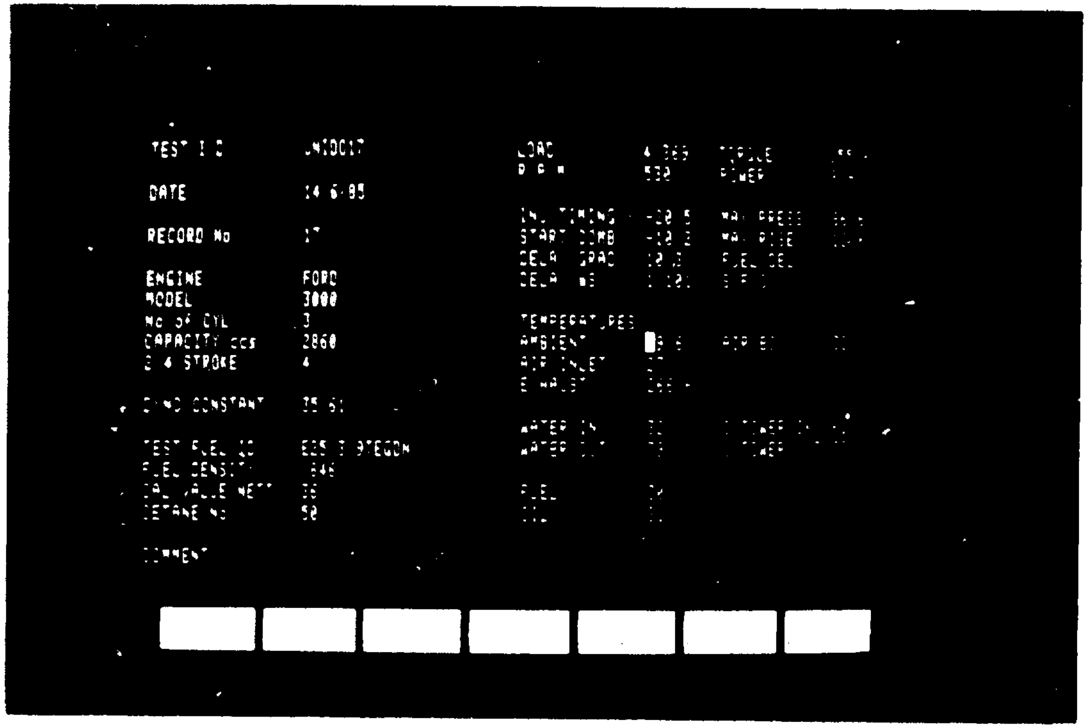


Ph.G.1 - An overall view of the diesel engine test bed and fuel evaluation test equipment as used for this UNIDO project. Photograph shows the data aquisition and control computer and the other instrumentation sitting on the hot air box,at left, the dynomometer, centre and the diesel engine to the right.

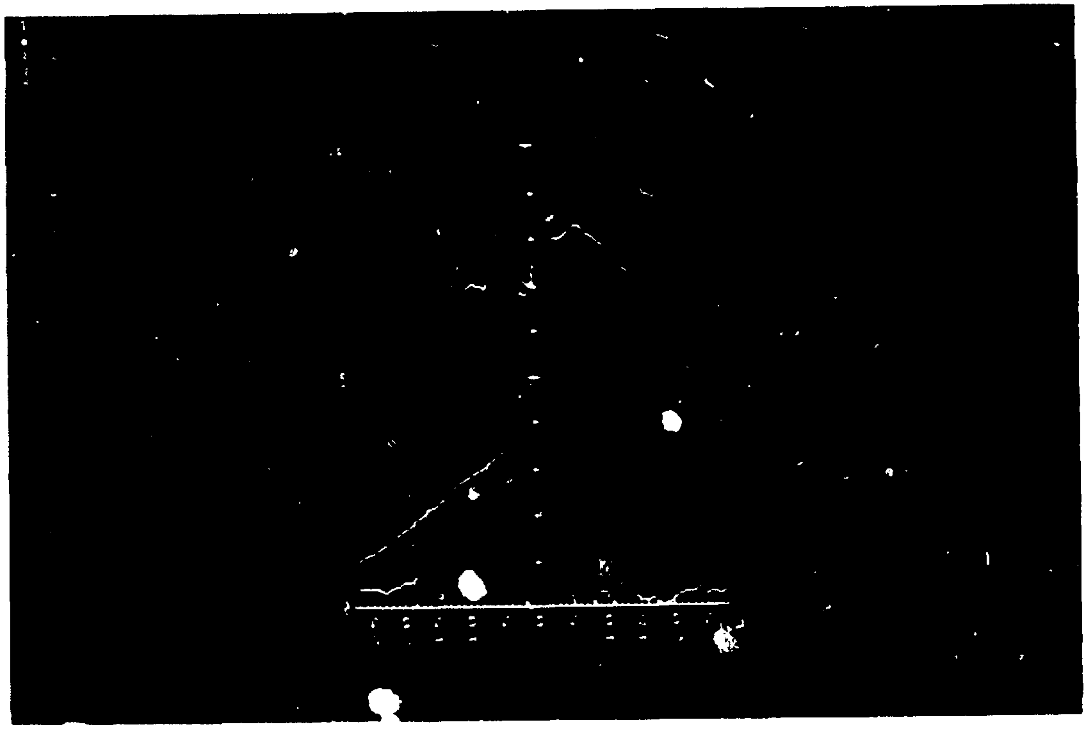


Ph.G.2 - Close up view showing the Hewlett Packard 86B computer and the Apace Research Ltd interface (black box) with the dynomometer partially visible on the right hand side.

Ph.G.3 - Fuel mass measurement system- showing a 2 litre glass beaker containing emulsion sitting on a Mettler electronic balance. Fuel feed pumps are visible to the left.



Ph.G.4 - This photograph shows the video screen of the computer displaying the many variables measured by the instrumentation as well as the selectable control functons along the bottom of the screen(inverse video).



Ph.G.5 - Another view of the video monitor with the PLOT function selected, displaying the cylinder pressure and needle lift traces.