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

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APPLICATION OF ALTERNATIVE FUELS FOR INTERNAL COMBUSTION ENGINES, IIP, DEHRA DUN

DP/IND/82/001

INDIA

Terminal report *

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Mr S. Singhal
National Project Coordinator

Backstopping officer: H. Seidel, Engineering Industries

United Nations Industrial Development Organization
Vienna

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I. INTRODUCTION

1. This terminal report briefly presents an analysis of the project's implementation and results. It describes the activities, outputs and the extent of achievement of the project's objectives, and concludes with recommendations concerning steps to aid possible future developments and utilization of results by the Government or other agencies.

2. Consumption of petroleum products in 1986-87 has been over 40 mT showing a growth rate of almost 8% in the past few years. It appears that shortfall between indigenous supply and demand is likely to widen due to constraints of increased indigenous production. The need to look intensively into use of alternative sources of energy is therefore acutely felt. The possible alternative fuels for transport sector are more difficult and perhaps critical. In the Indian context, since diesel oils form a major component of product demand and the bulk of motor gasoline is used for the small two-cycle S.I.engine, the use of alternative fuels is required first for these applications.

3. UNIDO was named the Executing Agency and the Council of Scientific and Industrial Research (CSIR) was designated the Government implmenting agency.

4. The project commenced on the stipulated date, i.e. July 1982. The project duration was extended by one year upto June 1987 without additional budgetary requirements, on the recommendation of the Tripartite Review meeting held in December 1985.

The international component of the planned input of US $ 1,970,530 was revised upward by TPR in November 1983 to US $ 2,204,792 and as per the latest budget revision (code 'L') to US $ 2,110,545. The counterpart contribution planned to be Rs.17,146,260 was not revised although the actual inputs, because of the one year extension, are estimated to be considerably higher.

II OBJECTIVES OF THE PROJECT

5. The petroleum products consumption slate in India, unlike that in most other countries, is weighed heavily in favour of diesel fuels, it being almost 35 percent of total demand. Additionally, about 60-65 percent of motor gasoline is required for use in the small 2 stroke cycle air cooled S.I. engines, used typically in most motor cycles, mopeds, scooters and three wheelers. As seen earlier, the short fall between demand and indigenous production appears to be increasing. This imparts specific emphasis on the need to look for alternative fuels and generate technology for their use, particularly for use in diesel engines and in small two cycle engines. Unlike in the developed countries, where the emphasis for developing alternative fuel use is mainly for the passenger car application i.e., for the four stroke S.I. engine, the Indian application is distinctly different. Thus the logic for work in India would be centred around the need for indepth investigations, on making possible the use of alternative fuels for such engines.

6. Use of alcohols, particularly methanol, appears to be attractive in this context, particularly for India, as the resource base for their production is wide-spread, and technological considerations for its manufacture comparatively easier. The Engines Laboratory of the Indian Institute of Petroleum (IIP) was identified to be appropriate for carrying out the project activities because of its established background, basic facilities, and manpower expertise. It has good contacts with the petroleum and the engine industry, and with various other organisations.

7. The Development Objective and the Immediate Objectives were defined as follows:

A. Development Objective

The development objective is to reduce dependence on petroleum products and achieve consequent savings in the country's scarce foreign exchange resources by use of alternative fuels based on indigenous materials, for engines employed in transport and agricultural sectors in India.

B. Immediate Objectives

Immediate objectives of the project are:

1. Development and establishment of technology for utilization of alcohols (Methanol) as alternative fuels for I.C. engines, particularly for Diesel Engines and 2-stroke Engines.

2. Training of national project staff and engineers from the industry on various aspects of engine combustion and lubrication with the use of alcohol fuels in Internal Combustion (IC) engines.

3. Collection and dissemination of technical information to the user and the industry in related areas.

8. The objectives of the project were conceptualized to be achieved in three stages.

i) Part-use of alcohols, to the extent possible, as a replacement for petroleum fuels in current designs of engines and on-road vehicles.

ii) Optimization of above designs through minor engine modifications for maximizing the part-use of fuel alcohol.

iii) Use of neat methanol in engines, generally through major modifications in engine designs.

III. ACTIVITIES CARRIED OUT AND OUTPUTS ACHIEVED

9. The project activities were reviewed periodically for their content and targets both by the PAC and by the TPR. Marginal increases were mde in the contents of the activities and the target dates revised both to account for the extended project duration as well as enhanced activities. The activities were generally divided into preparatory activities and project activities. These were planned to be carried cut through the project personnel, international experts and consultants, and through UNIDO (the executing agency), and the CSIR (the Government implementing agency). A brief summary of the identified activities according to which the project was implemented are given below:

A) Preparatory Activities

i) Budgetary action and financial appropriation to provide counterpart funds.

ii) Discussions between national project engineers and leading organisations engaged in R&D/production activities on engines to finalize programme of work related to use of alcohol fuels in engines.

iii) Identification of a) International experts and consultants; b) sources of supply of indigenous equipment and equipment to be procured from international market and c) places for fellowship training.

iv) Literature study on the subject of utilization of alcohol fuels in engines.

v) Finalizing specifications of the equipment to be procured from indigenous and from international market.

vi) Formation of project team

B) Project Activities

i) Placement of orders for the equipment

ii) At the suggestion of the UNDP, a Project Advisory Committee, was formed to give advice and for interaction on the suitability of the proposed main directions of the project activities and for help in securing collaboration from industry for implementation of the scientific & technical activities of the project. The terms of reference & membership of the PAC is given at Annexure I.

iii) Preparation of Report on scientific analysis of the current engine designs and methods applied for the use of alcohol fuels and a prespective for adoption of new techniques for maximising the use of alcohol fuels.

iv) Discussions of IIP engineers with international experts to finalize the direction of studies for alcohol fuels on the aspects of fuel introduction, combustion, exhaust emissions, lubrication and wear, field studies, performance, etc.

v) Installation and commissioning of equipment and facilities.

vi) Design and development of alcohol induction systems/ devices for part utilization of alcohol fuels in existing designs of engines.

vii) Combustion and performance studies on 4-stroke diesel and 2-stroke S.I. engines for part replacement of alcohol fuels with designed system/devices and their optimization.

viii) Communication of project findings to the industry and necessary assistance to the industry for development of prototype systems/devices for part replacement of petroleum fuels by alcohols and their adoption on existing designs of 4stroke diesel and 2-stroke S.I. engines.

ix) Design and development of new system/devices for induction and combustion of neat alcohol in 4-stroke diesel and 2-stroke
S.I. engines.

x) Studies on engine performance with neat alcohol fuels.

xi) Communication of project findings to the industry and necessary asistance to the industry for development and fabrication of prototype of neat alcohol engines.

xii) Finalization of design of neat alcohol engine.

xiii) Development of alcohol fuel specifications.

10. It was seen that availabiliity of appropriate experts was less than adequate. It is felt that this was due to two significant factors: a) the needs of the project were highly specific and in areas of comparatively recent advances in technology; b) the availability of consultants for the time periods visualized originally was not feasible as the bulk of the experts identified were from organizations of industrial nature.

As a result of these constraints consultants/experts were invited for comparatively short periods, and, where feasible, were invited to repeat their missions after an appropriate gap, to maintain continuity of the scientific activities of the project. Thus 7 of the experts visited the project for a total of 20 missions. Care was taken to interact and brief the experts concerning their missions in some detail and well before their arrival on the project. As a result some of the experts generally came well prepared and some of them even brought necessary material like soft-ware, components, reports of analysis, test lubricants, etc. with them. It is felt that by adopting this approach, what was envisaged to be done could be achieved with the reduced m/m of experts. ..... The list of experts is given at Annexure II.

This resulted in not only a lower cost of this component to the project, but the effective involvement of experts/consultants was for a longer duration.

The list of experts is given at Annexure II. A provision of 13 international experts and consultants for a total of 93 m/m was made in the project document. 13 Experts/consultants served the project for a total of 50 m/m.

11. A list of scientific and technical personnel of I.I.P. directly involved in the project activities is given at Annexure III. The list also gives their academic attainments.

12. Eleven project engineers received fellowship training abroad at centres of higher learning and five visits were made by senior professionals to study recent advances in utilization of alcohols ..... in engines. Details of these are given at Annexure IV and V In addition, two project engineers received equipment training at the manufacturer's end and five senior project engineers were deputed to attend international conferences in this area. Details are given at Annexure VI.

The fellowship programmes were specific and generally involved the fellows on on-going research projects at the place of training. In most cases, a joint research paper, published internationally, resulted, signifying the level at which the work was carried out.

13. Procurement of equipment was carried out by UNDP, through UNIDO, and by I.I.P. (the Government counterpart funds). In the Project Budget an amount of around US $ 1,200,000 is allotted for the UNDP equipment component. Main items of equipment procured are listed at Annexure VII. Brief description of this

equipment is given in Section 16 of the Report. Apart from the equipment listed in Annexure VII considerable quantity of reference materials and spares have also been purchased through UNDP funds. Total cost of equipment supplied under UNDP makes up around $ 1,397,425. Some comments on implementation of the equipment component of the Project's Budget are as below:

a) Prior to sending a requisition on major pieces of equipment, the Project Management carried out preperatory work including the following steps:

i) identification of a scientific programme where a given equipment would be utilised and listing requirements of the equipment;

ii) inviting quotations from manufacturers and their detailed analysis;

iii) preparation of specific recommendations for a given equipment.

The concept of purchase of equipment was such that where feasible only the core equipment was acquired and the facility built around it. An example of this is the basic combustion bomb, and the equipment for aldehyde emission measurement.

b) In most cases the installation and commissioning of equipment was done by the project engineers. In some cases, help of vendors was also sought. It is worth mentioning that most of the equipment was commissioned satisfactorily. However, some equipment got damaged in transportation and it took considerable time to get replacements and then commissioning it. A case in point is of the Wear Profilometer and the high speed camera which got damaged in transit and took more than 2 years in getting the replacement/commissioning.

Equipment procured through IIP funds is given at Annexure VIII. Additionally, Rs.10.6 lakhs were spent on spares, fuels, lubricants and some other consumables. Another Rs.18 lakhs were allotted as Government counterpart contribution for the purchase of a diesel power generating set, for the exclusive use of the project, as the electric power supply in this part of country was not satisfactory. This has since been acquired and is likely to be commissioned shortly.

14. Interaction with the PAC, the TPR, international experts and consultants, Indian industry, academic institutes and others necessitated marginal corrections in project outputs' definition and time targets. The revised outputs are given at Annexure IX. The scientific and technical work of the project to meet the defined outputs was grouped under six heads. Highlight of this work are given below:

A. Part Utilisation of Methanol in Diesel Engines

i) Analysis of options for part substitution by alcohols in diesel engines. Dual-injection, in-situ alcohol-diesel mixture injection, emulsions and fumigation were examined for basic feasibility, system design, engine performance, ease of handling, safety, power output and energy consumption, emissions, degree of fuel substitution, retrofit ability, etc.

ii) Methanol aspiration was adopted as the final choice for detailed investigations. Here the good ignition quality of diesel was utilised to secure the combustion of alcohols. A system for fumigation in existing designs of automotive diesel engines was finalised, fabricated and extensive performance studies carried out both on laboratory test stands as well as on vehicles.

iii) Lubrication studies on methanol fumigated engines carried out include back to back trials for engine deposits, durability, lubricant degradation and wear. Examination of various , including of some newer oil formulations (some procured from abroad) and detailed investigations on face and side wear of piston rings using radiotracers, were carried out.

iv) Fumigation concept was tried out in various designs of engines, on two of these, seminars were conducted with the manufacturers of engines and on one of these, the manufacturer initiated his own trials.

v) Pilot field trials were started with two different agencies. Based upon this detailed trials, one on a fleet of 25 buses, and one on 10 of another make have been initiated. As a part of this exercise, an intensive effort was put in to optimise the design of the fumigation device, which is now under production for trial purposes.

vi) Recently a laboratory supercharged diesel engine has also been converted for methanol fumigation to give an insight into possible conversion of turbocharged engines typically employed in railroad locomotive use. Interaction with the Indian Railways has also been initiated.

B. Part Utilisation of Methanol in Small Two-stroke Engines and Vehicles

vii) In case of S.I. engines, use of small 2-stroke engines in the country is increasing at a fast rate. A need was therefore, felt to restrict studies on part substitution of motor gasoline to small 2-stroke engines only. This segment consumes more than 50 percent of motor gasoline consumed in the country.

viii) The use of alcohol-gasoline blend on existing designs of 2-stroke engine was found to give no hardware problem and M12 blend was finalized for detailed laboratory investigations.

ix) Laboratory investigations on M12 blend indicated satisfactory engine performance, engine life and good all weather startability.

x) Field trials on fleet of 14 vehicles comprising vehicles of various makes of mopeds, scooters and motor cycles were carried out for 150,000 Kms. These trials indicated wide acceptability of M12 blend. It gave engine performance, all weather acceptability and life of different engine components comparable to motor gasolines Extended field trials subsequently on three selected vehicles demonstrated acceptability of M12 blend even further. A total of 170,000 Kms has been accumulated.

xi) Wear of C.I. ring was found excessive in some cases, which was overcome by use of chrome plated rings.

xii) It is suggested that use of M12 blend can be introduced in certain parts of the country as a normal fuel for small two-stroke engined vehicles.

C. Utilisation of Neat Methanol in Diesel Engines

xiii) Study of various approaches for neat methanol fuelling of heavy duty engines was examined. These included glow-plug ignited in-cylinder injection of methanol, methanol vapour engine, compression ignition of heated intake charge, and later port injection methanol engine. All of these have been investigated upto various stages.

xiv) Out of various approaches to use neat methanol in diesel (heavy duty) engines, glow-plug assisted ignition approach was selected for detailed investigations. These included:

(i) Effect of glow-plug location and projection,

(ii) Effect of injection duration, pressure, nozzle hole size, plunger diameter etc.,

(iii) Effect of low heat transfer piston materials e.g. cast iron, CSZ coated piston,

(iv) Intake air throttling and exhaust gas residuals,

Influence of the above parameters on glow-plug energy requirement, glow-plug temperature, energy consumption, power output and emissions was investigated. The engine operated successfully at glow-plug energy as low as 65W at high loads with improved engine efficiency.

xv) Lubrication and wear studies on fuel injection system and cylinder liner and ring wear were conducted through long duration tests and also using radiotracer technique. Wear of engine components was similar to that with diesel.

xvi) A six cylinder truck diesel engine was converted to spark ignited methanol vapour engine. Methanol vapour engine optimization could not be continued as Hardware modifications required need extensive time and assistance from engine manufacturers.

xvii) A 'single cylinder glow-plug ignited engine' prototype is ready and has been working successfully in the laboratory. More than 500 hours running has been completed. Further improvements on engine performance through the use of air-gap piston are now being studied. This concept is also being extended to a three-cylinder tractor engine in collaboration with an engine builder.

D. Utilisation of Neat Methanol in Small Two-stroke Engines and Vehicles

xviii) Fuel 90% (90% Methanol + 10% Motor gasoline) was finalized for studies on 2-stroke engines.

xix) Necessary hardware modifications were identified and one make engine was converted for operation on methanol.

xx) Extensive laboratory studies were carried out covering aspects of performance, combustion, energy requirement, lubrication and emission.

xxi) A scooter was run in field, for examining driveability, fuel consumption, acceleration, cold startability and lubricant compatibility and engine wear. Mating parts were evaluated for wear at 6,000 kms and 10,000 kms. The fuel consumption on energy basis was found to be comparable and it gave comparable performance on other aspects too.

xxii) Basic studies were also carried out to understand abnormal combustion phenomenon in methanol fuelled 2-stroke engines.

It was felt that detailed study would be carried out on a combustion bomb. A test rig for combustion bomb with necessary instrumentation was designed, fabricated and commissioned. Studies are in progress.

xxiii) Lubrication requirement of methanol fuelled engines was studied Lubricants for methanol fuel are being developed.

xxiv) Engine of a different make was modified and fitted on a vehicle. This vehicle has also accumulated 6,000 kms on road. It has given acceptable performance on all parameters.

xxv) A moped engine was also converted to operate on neat methanol. This engine is ready for field trials.

xxvi) As a means to reduce unburned fuel emission in methanol fuelled two-stroke engine, a new concept of "selective exhaust gas recirculation" was developed. Further studies on this system is in progress.

E. Corrosion and Material Compatibility Studies with Fuel Methanol

xxvii) Corrosion behaviour of various metals, commonly used in the fabrication of indigenous engines has been studied by means of various laboratory techniques, e.g. static immersion tests, galvanic studies, boiling methanol tests, etc. The metals and alloys investigated were Zamak, brass, lead, aluminium, cast iron, mild steel, etc.

xxviii) Metal incompatibility of some engine components such as carburettor floats, needle valve tip, crankcase rubber seals, etc., experienced during the tests was resolved by use of Teflon floats, brass needle valve tip, etc.

xxix) Use of inhibitors in methanol as a means of corrosion control of engine components was studied. Three of the five inhibitors studied were specifically meant for oxygenated fuels and their gasoline blends.

xxx) The quality of methanol as obtained from different sources with respect to its corrosivity was also looked into. Properties like specific conductivity, impurities like presence of chlorides which can accelerate electrolytic corrosion of metals/alloys, dissolved oxygen which takes part in cathodic depolarisation reaction, etc. was evaluated.

xxxi) Brief work on engine wear in the presence of inhibitors in fuel was also tried.

xxxii) Dramatic reduction in corrosion of aluminium, magnesium and its alloys in the presence of certain amount of water in methanol, as reported in literature was investigated again. Consequently, water addition to methanol was suggested to all aspects of project work, including field trials.

F. Information Collection and Dissemination

xxxiii) Various data base services like NIPER, USA, CA search, DOE,etc. were subscribed to collect technical information on work being carried out internationally on alcohol fuel utilization of engines/vehicles. This information was circulated to the project engineers and others involved in similar activities within the country.

xxxiv) A periodic technical bulletin, Alcohol Fuels: Engine Application, was brought out. These included information related to international developments; engine application, process & production aspects of alcohol fuels and feature articles on aspects/studies specifically carried out on the project at IIP. One of the special issues included bibliography of work done in the country on alcohol fuel application in engines during the last decade.

xxxiv) The project findings have continuously been communicated to industry and other government agencies by technical presentation, demonstrations, training of personnel, discussions, etc. As a result, two state road transport undertakings have started proving trials on diesel engined passenger bus fleets.

xxxv) For detailed discussions and interaction for exchange of knowledge amongst researcher, academicians, engineers from industry and other organizations related to alcohol fuel application in engines following workshops and conferences were organised at the Institute.

i) Workshop on "Small Two-Stroke: Utilization of Fuels and Lubricants", March 1983.

ii) Workshop on "Perspective of Alcohol Fuel Utilization in Engines", October, 1984

iii) "National Conference on I.C. Engines and Combustion," November, 1985.

The proceedings of each of these were published.

xxxvi) Short training programmes for automotive industry were organised. The training was mostly need based in the form of specific presentations to the engine builders, oil industry and user industry. The aspects covered included desirability of alcohol fuels, their usefulness in our context, limitations and related aspects.

15. From the foregoing it is seen that the outputs as listed in the PMEDC have been successfully completed, and generally their magnitude has been more than planned with intended quality. Specifically the targets achieved against each output are considered to be as given below:-

Output 1	As planned
Output 2	As planned
Output 3.1	More than planned
Output 3.2	As planned
Output 3.3	Much more than planned
Output 3.4	Much more than planned
Output 3.5	More than planned
Output 4.1	As planned
Output 4.2	Less than planned
Output 4.3	As planned
Output 4.4	As planned
Output 5	As planned
Output 6(i)	As planned
Output 6(ii)	More than planned
Output 7	As planned

A further significant output of the project is considered to be the papers and technical reports which have been published or presented at both national and international levels. It is seen that more than 47 papers and 72 reports have already been produced on work done in this area at IIP. These are listed at Annexure X and XI. It may also be noted that additional publications will continue to come out as more results of studies come in and are processed.

16. Facilities and Equipment

Following major facilities and equipment have been commissioned during the implementation of the project. It may be noted that all the equipment and facilities are now commissioned and are currently being utilised.

Ricardo Hydra Single Cylinder Research Engine

This research engine (Fig.1) is a robust machine capable of operation at conditions representative of modern engines. It is single cylinder four cycle engine with an electric dynamometer. Control of the set is from a remote control desk from which motoring can also be initiated. The engine can be built in many different forms including gasoline, methanol and diesel versions and has cylinder head arrangements for various combinations of bore and stroke, compression ratio, within a limited range. Direct injection version has a special cylinder head for pilot fuel injection also. In addition it has a provision of using a piston with quartz window and other arrangements for high speed combustion photography. Test bed is equipped with cooling module for oil and water, air flow measurement pressure pick up arrangement etc.

[redacted]

The wear profilometer (Fig.2) comprises a measuring and recording unit; and a tracing unit. This is capable of computing a number of surface texture parameters and can record roughness as well as flatness profiles. The instrument is used for measuring wear and wear profiles of cylinder.

[redacted]

It is designed to be used for the performance evaluation and [redacted] tractors of cars and heavy duty vehicles. The dynamometer (Fig.3) provides a safer, reliable forced dissipation facility [redacted] the laboratory. It simulates vehicle inertia ranging from [redacted] kg. to [redacted] kg wt. in increments of 5 kg under cruising, constant speed and different gradients. Road characteristics of 20 vehicles can be stored for road power simulation. The engine can absorb 112 kW power for continuous and 168 kW intermittent operations with a minimum speed of 125 kph without fly wheels engagement. The driver's aid programme contains 5 different driving cycles. The dynamometer is controlled by Digital Equipment Corpn. LSI 11/23 based microcomputer through a VDU system.

Combustion Bomb

The facility (Fig.4) has been set up by IIP project engineers. The bomb is to be used for basic combustion studies related to ignition, flame propogation etc. Accurately metered fuel and air mixtures can be introduced into the combustion chamber. It has the provision for high speed photography by shadographic technique with the help of laser source and optical arrangements.

Digital Analyser

It is used for acquisition and real time processing of measured data of various engine parameters like pressure of intake, exhaust, cylinder, crankcase, fuel injection pump injector, injection needle and valve lift. This system (Fig.5) has 16 channels which permits fast acquisition, display, extensive, processing, computation and storage of the data obtained.

D.C.Dynamometers

These dynamometers (a view given in Fig.6) are intended to be used for both motoring and loading the engines. These are flexible, easy to use system which recover output shaft energy of engine through swinging frame D.C. machines. The power and torque curves of gasoline as well as diesel engines can be covered on the same test rig to allow a wide variety of engines to be tested. Other features include advance servo throttle control, closed loop speed and torque control.

Noise Level Meter Model 2209

This meter of Bruel Kjaer (Fig.7) is intended for the measurement of noise and vibration of different type of engines in use.

[illegible] Smoke Meter Model [illegible]

The instrument (Fig.8) measures automatically the soot content in diesel exhaust gases (in Bosch unit) at pre-defined periodicity by filtration technique.

High Speed Gas Sampling System - Model [illegible]

The system (Fig.9) consists of high speed hydraulic electro-magnetic gas sampling valve with valve system detector, and control unit and crank pulse generator enabling sampling valve to operate at desired timing and duration. The system used for sampling gases from engine cylinder or in exhaust for their analysis and finding out histories of variation during the working cycle.

The Mettler DL 20 Compact Titrator

The titrator (Fig.10) is intended for the determination of Neutralization value of lubricating oils. This is an important criteria in judging the quality of lubricating oils partricularly of the crankcse oils.

Transient Mode Simulation Dynamometer

This is a fully integrated, micro-processor controlled aquisition system (Fig.11) with automatic controls of various engine functions. The system has more than 25 standard test residents in its memory and has facility to generate additional automatic test programmes. The dynamometer has a unique facility of transient testing of engine.

High Speed Camera

The camera, HYCAM-II (Fig.12) is intended to be used for high speed photography of combustion events in a combustion chamber. It has a speed of 20-11000 full frame/Sec. The micro-processor controlled Digitizing Unit supplied with the camera is used for evaluating the photographed events.

Knock Intensity Meter

This instrument measures knock in vehicles being tested on chassis dynamometer, engines assembled on the test bed or on road. The equipment consists of an accelerometer which records vibrations caused by detonation and an electronic equipment which elaborates the signals passed on by the accelerometer.

Laser Source

A Spectra-Physics Series 2000 argon-ion laser system for shadowgraphy of combustion events, using a combustion bomb and high speed camera for photography, has been commissioned. The laser has an output of 3W, which is split to a green line of 1.2W.

Ricardo Swirl Meter

It is used for measuring swirl inside the combustion chamber. This would facilitate in studying the mechanism of air-fuel mixing and related characteristics.

Hydrocarbon Analyser

Horiba Model Mexa-1120 TFI-H is intended for measurement of total hydrocarbons in the engines and automobile exhaust. It is suitable for measuring sample gas containing high boiling point hydrocarbons. The detection range is 0-20,000 ppm as C_3. It supplements other laboratory equipment for emission measurement.

Wave Form Analyzer

SD375 Dynamic analyzer, with a signal correlator in time, amplitude, fequency upto 100 KHZ, is intended to be used for noise, vibration studies of vehicles, engines including turbulence studies in conjunction with hot wire anemometry system. It can carry out spectrum analyses of the pressure time histories of I.C.engine combustion chamber for RMS magnitude, power spectrum, auto-circulation etc.

High Pressure Differential Scanning Calorimeter

Dupont Model 9900 is a thermal analysis system with data reduction capability. It is intended to be used to measure heat of reaction, which is direct manifestation of the physico-chemical processes that are actually occuring in the petroleum products. The data obtained for various products can be correlated. The technique is used to study the interaction and mechanisms of base stocks and additives.

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Fig.1 RICARDO HYDRA RESEARCH ENGINE FOR BASIC RESEARCH AND STUDIES WITH DIFFERENT FUELS.

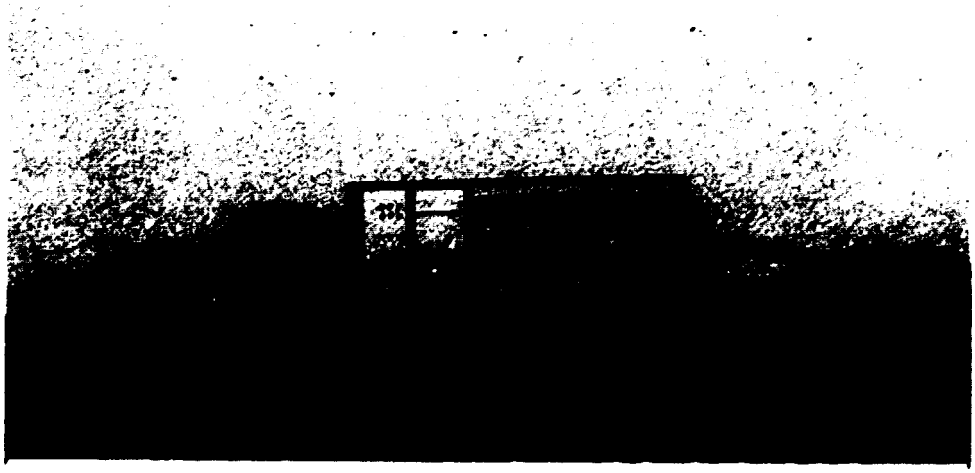

Fig. 2 WEAR PROFILOMETER - MODEL MMB 50/350/S-MI FOR SURFACE TEXTURE STUDIES OF CYLINDER LINERS

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Fig. 3 HEAVY DUTY CHASSIS DYNAMOMETER, FOR ROAD CONDITIONS SIMULATION OF HEAVY DUTY VEHICLES

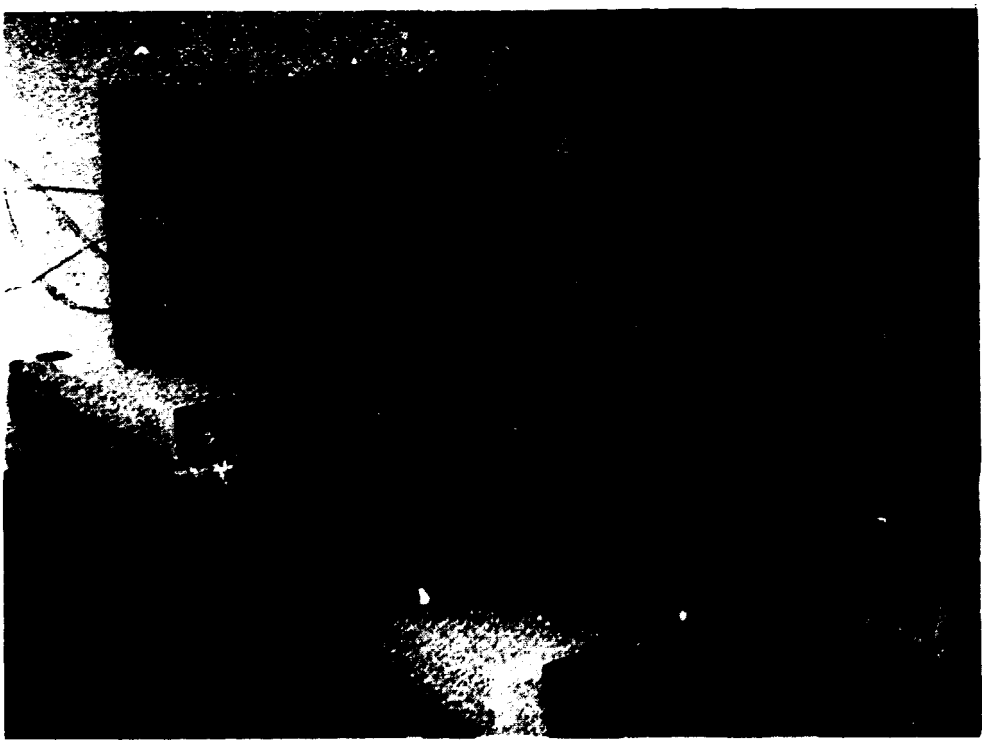

Fig. 4 COMBUSTION BOMB: A FACILITY DEVELOPED LOCALLY FOR BASIC COMBUSTION STUDIES

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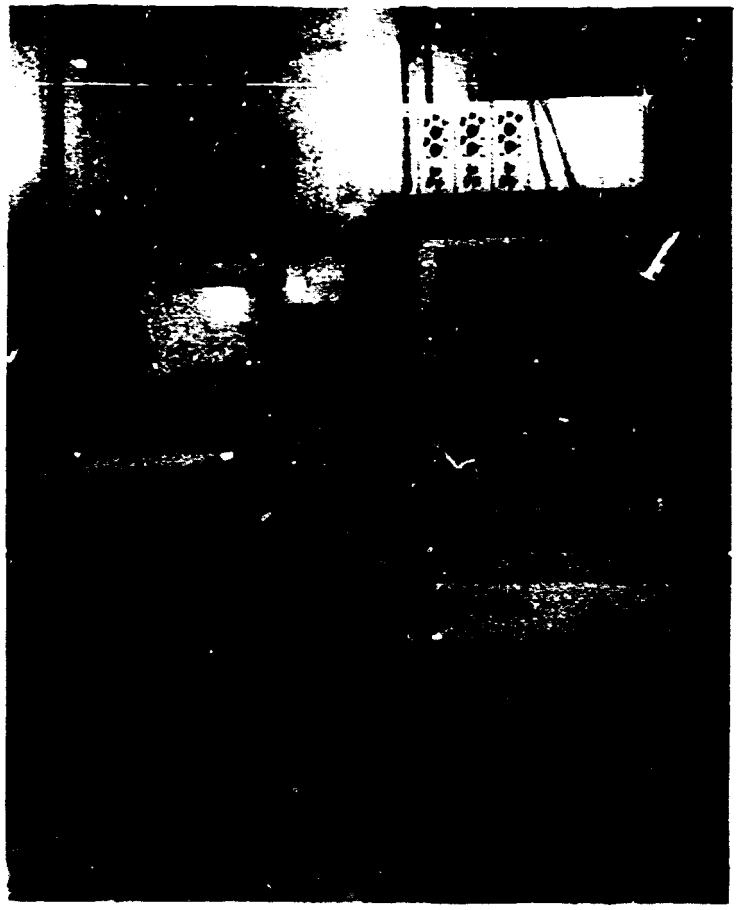

Fig. 5 DIGITAL ANALYSER - MODEL 657, AN ONLINE DATA ACQUISITION SYSTEM FOR ENGINES

Fig. 6 D.C.DYNAMOMETER WITH FACILITY OF MOTORING AND LOADING

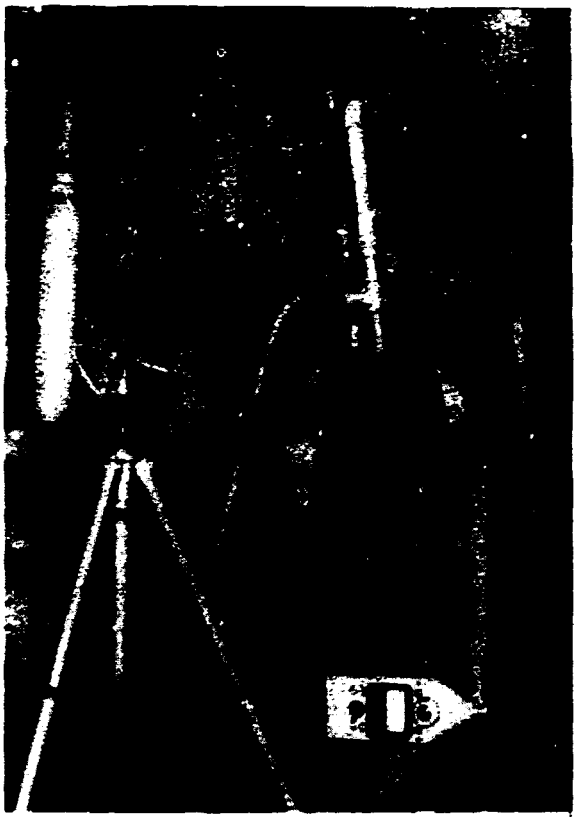

Fig. 7 NOISE LEVEL METER - MODEL 2209 FOR MEASUREMENT OF NOISE AND VIBRATION

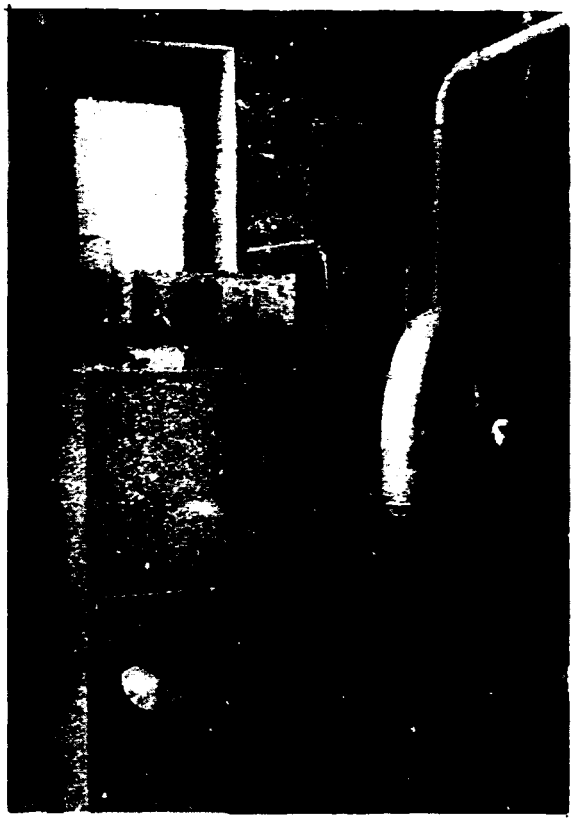

Fig. 8 SMOKE METER - MODEL 409E FOR MEASUREMENT OF SOOT IN DIESEL ENGINE EXHAUST

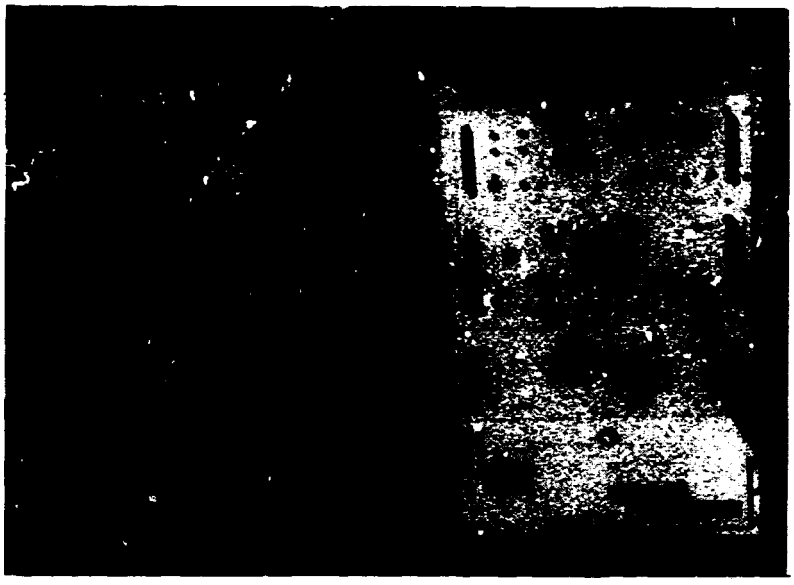

Fig. 9 HIGH SPEED GAS SAMPLING SYSTEM - MODEL GSD10
FOR SAMPLING GASES FROM ENGINE CYLINDER/EXHAUST

Fig. 10 COMPACT TITRATOR - MODEL DL20

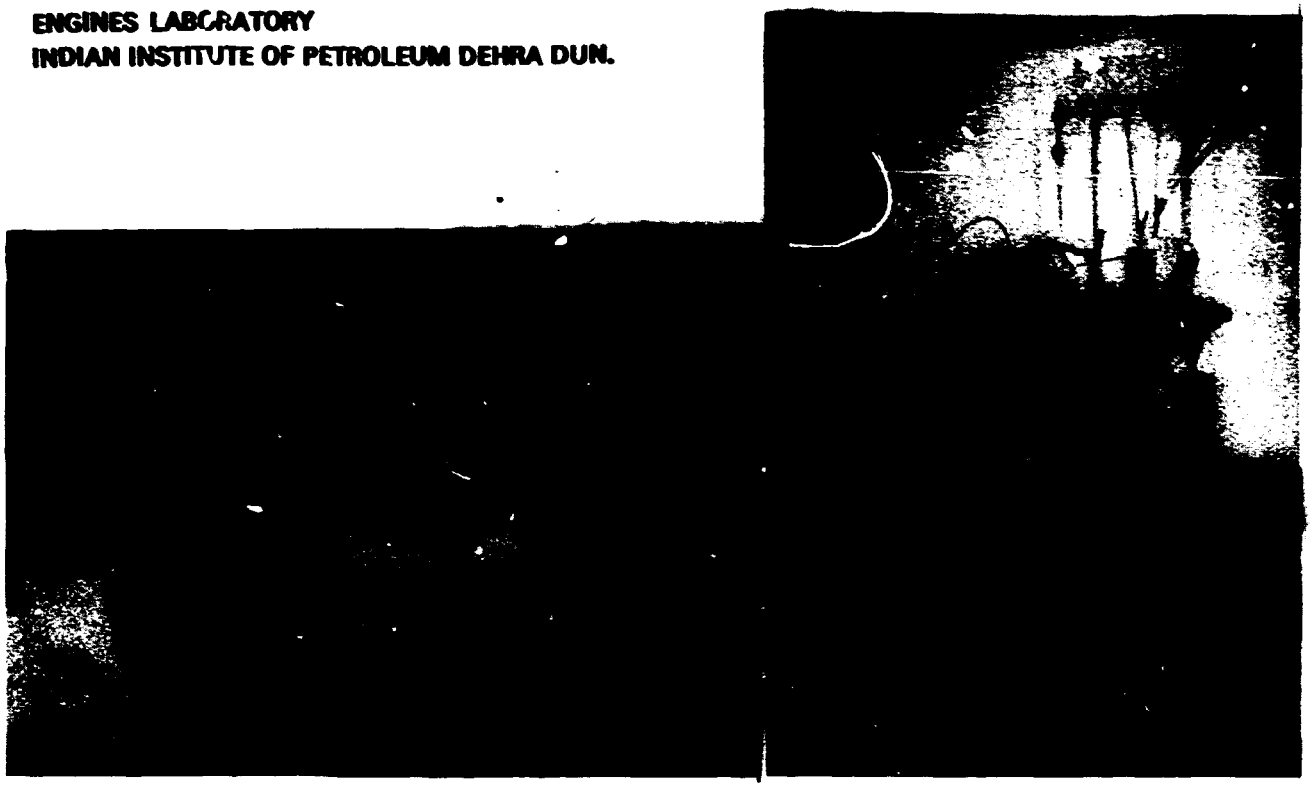

Fig.11 TRANSIENT MODE SIMULATION DYNAMOMETER - MODEL SF 901C
A MICROPROCESSOR CONTROLLED ACQUISITION
SYSTEM FOR TRANSIENT TESTING OF ENGINES

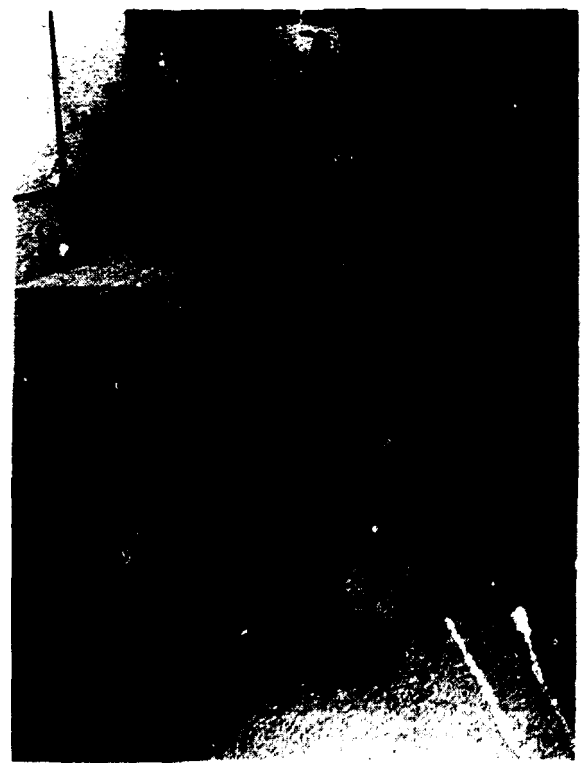

Fig.12 HIGH SPEED CAMERA - MODEL HYCAM II:
FOR HIGH SPEED PHOTOGRAPHY OF COMBUSTION
EVENTS IN A COMBUSTION CHAMBER

ENGINES LABORATORY
INDIAN INSTITUTE OF PETROLEUM DEHRA DUN.

Fig.13 A FLEET OF M12 & FLEET OF METHANOL VEHICLES (2-STROKE)

ENGINES LABORATORY
INDIAN INSTITUTE OF PETROLEUM DEHRA DUN.

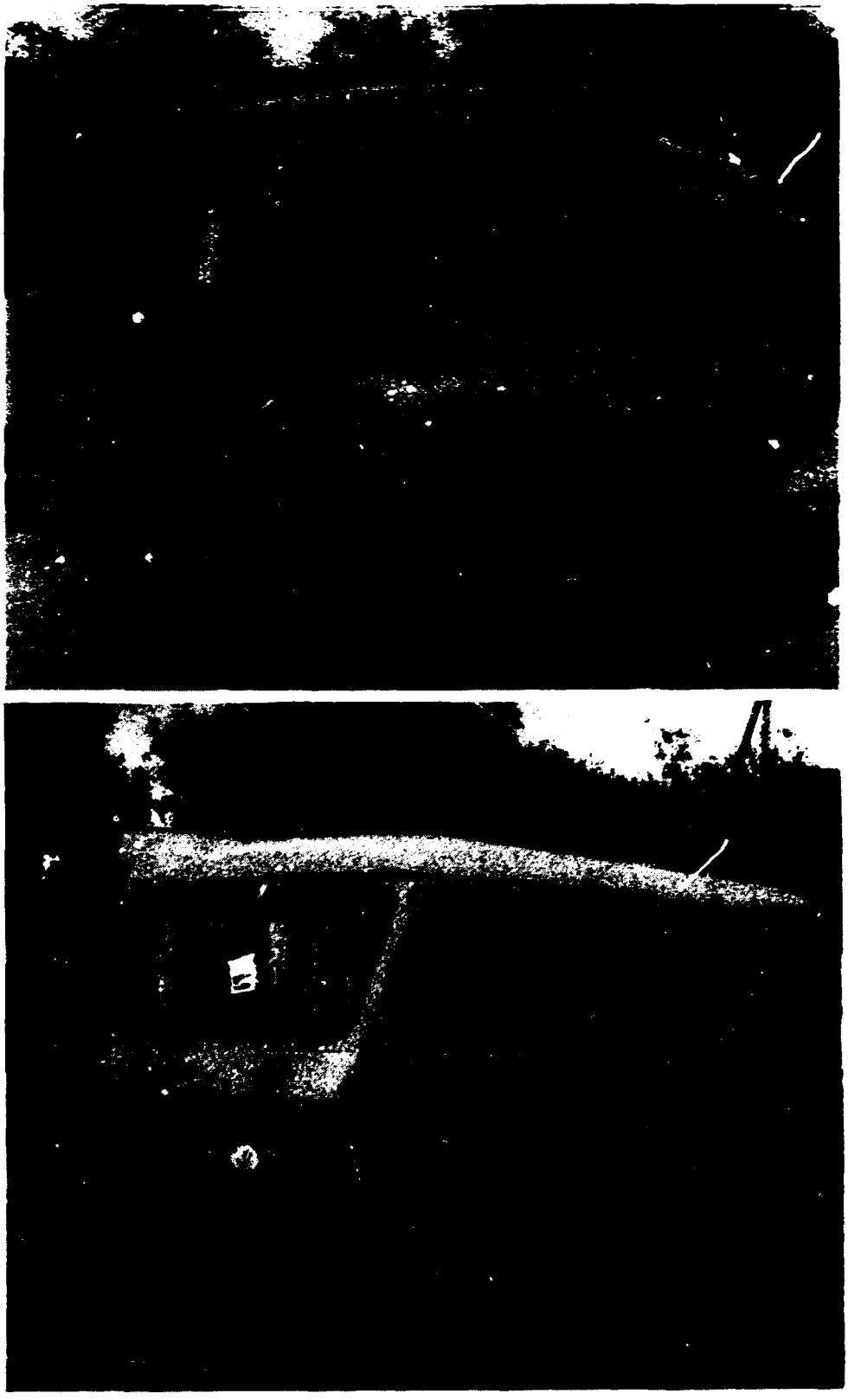

Fig.14 DIESEL METHANOL BUSES

UV-Spectrophotometer

It is intended for measurements of aldehydes in the exhaust of alcohol fueled engines. Shimadzu model UV-240, with micro-computer controlled graphic-printer, has higher data processing capability such as spectrum memory and wave form analysis.

Eddy Current Dynamometers

Three E.C.Dynamometers were acquired for accurate engine performance evaluation. These have special features like speed, torque and power control. The range of measurement varies for 0.5 KW to 300 KW, covering engines of moped class to heavy duty diesel engines.

Logic Analyser

Enertec model 7610 is intended for trouble shooting of microprocessor based or any other digital circuit. It has 32 data channels, 3 external (plus 1 internal) clock and 5 clock qualifier channels. Data storage capacity is 1 K per channel. The display is selected to be either in time domain or data domain.

Standard Gas Divider

This is intended to be used to prepare calibration gases required for engine exhaust gas analysers. It can dilute the available concentration upto 16 percent by using inert gases. The device can also be used to make gas mixtures.

IV ACHIEVEMENT OF OBJECTIVES

17. There is now a considerable awareness of the fact that petroleum is a depleting resource. Some estimates put its continued easy availability for another approximately 34 years only. The future energy scenarios clearly indicate a need of alternative fuels, particularly for on-board applications. The project's achievement of objectives is seen in this context. Although fluctuations in price and availability of petroleum may continue, in the Indian context the availability of alternatives would clearly reduce dependence on petroleum and make the job of energy planners easier.

18. The project has demonstrated utilization of part methanol as blends in two stroke S.I. engines, and as a bi-fuel system in diesel engines. Extensive laboratory work on various parameters generated confidence for limited field trials to be undertaken. A 150,000 cumulative kilometers trial on M12 blend was successfully undertaken on fourteen 2-stroke vehicles, and two multi-agency demonstration projects have been contracted for running diesel buses in commercial operation using the IIP developed bi-fuel system. On the neat methanol front 2-stroke engines and vehicles have been successfully run for extended durations in the laboratory and three different concepts of neat methanol fueled diesel engines were developed in the laboratory. This demonstrates that initial work on development and establishment of technology, for possible utilization of methanol or other alcohols on a much bigger scale, has been done.

The activities undertaken in the laboratory were of a nature that has gave opportunity for extensive and indepth study on various aspects of engine combustionm and lubrication worth the use of alcohol fuels. This capability has been utilized for extensive interaction with engineers from the industry on this and various allied matters. The training of national project staff has been supplemented by exposure and involvement on various recent trends and developments the world-over through visits and work at some of these centres of emerging technologies. It is felt that a more than adequate base now exists to take up further research in the laboratory and extension work elsewhere.

Adequate contacts have also been established for possible future interaction in this area. However, continued interactions are necessary to keep these links alive. It is considered an achievement of the project that a wide base of awareness and information has been established in the country with organizations of the petroleum industry, the engine building industry, the organized user industry, Government bodies, associated R&D institutions, and with producers of methanol. In the evantuality of wide scale

methanol use in the country as an engine fuel this will play a significant role. The project has been pleased to receive several enquiries in this area and considers this to be an achievement of the objectives of the project. The Alcohol Fuel Newsletter brought out during the life time of the project was complimented for its content and presentation.

19. The above mentioned achievements of immediate objectives of the project signify that a base now exists for meeting the development objectives of the project on reducing dependence on petroleum products by use of alternative fuels for engines employed in transport, agricultural and other sectors in India. The furtherance and materialization of the development objectives depends much on the socio-economic trends prevailent in the country. This means that the Government and its statement of policy in this regard will decide possible adoption in the country of such technological developments. It is therefore imperative for the Government through its appropriate agencies to take stock of the situation and formulate their views.

V FINDINGS

20. Oil supply problems of the last 15 years have shown that world's energy demands cannot be satisfied from present energy sources. A promising answer in the field of automotive transportation is the use of liquid alcohol fuels, particularly methanol, as it can be produced from natural gas, coal and bio-mass. Worldwide research and development has shown how methanol offers a way to displace large volumes of oil in conventional designs of I.C. Engines. Methanol as a blending component in gasoline in S.I. Engines is a complete success. For C.I. engines also, the methanol option appears to be the best. Hereit can be used either in the bi-fuel mode or by itself. It is generally agreed that a dedicated engine is the best alternative from the point of view of energy conversion and alcohol fuels have emerged as an encouraging alternative to petroleum fuels the world over, particularly in USA, Europe, Canada, Japan, Brazil and New Zealand. Several fleets are now in operation in these countries, replacing significant quantities of petroleum fuels. Neat methanol fuelled vehicles are in commercial use particularly in the state of California where needed legislation was passed to make it effective in 1977, 1981 and 1983. A major initiative has also been launched by Japan and New Zealand to demonstrate its use on trucks and buses.

21. Keeping in view the abnormal demand for diesel fuel in the country, it has been demonstrated that fleet use of methanol, for upto 20% replacement of diesel fuel using the IIP bi-fuel device, can now be done. This reduces smoke emissions, makes the engine run a little cooler and even shows marginal improvements in energy efficiency. Such engines can run without problems on existing quality levels ofengine crank case oils without showing adverse lubricant degradation. Such bi-fuel devices can be adopted for almost any kind of stationary or automotive diesel engine.

22. The methanol-gasoline blends is the preferred route for part utilisation of methanol in the current designs of small two-stroke engines and vehicles. The methanol-gasoline blend consisting of 12 percent alcohols can be used in all on-road vehicles without any deterioration in vehicle performance and driveability. The M12 blends also does not require any change in materials, and lubricants. The project has demonstrated that M12 blends can be introduced in the country on a wide scale for scooters, moped and motorcycles.

23. It was seen that use of neat methanol in diesel engines is possible with a positive source of ignition. A laboratory prototype using glow-plug assisted ignition gave satisfactory performance except at light loads where the glowplug energy requirements were high and thermal efficiency poor. Atomization in methanol spray is much finer than in diesel and the injection system needs several modifications to provide satisfactory injection characteristics. Injection system wear was seen to be about 30% higher

and addition of 1% castor oil did not help. A 6-cylinder truck diesel engine was also converted for operation as a methanol-vapour, S.I. engine. Studies revealed that major design changes are required which need participation of engine manufacturers. Of all the possible routes of neat methanol operation of diesel engines, glow plug ignition and spark ignition (FM type) have the highest potential for application to production engines. Piston ring wear was also higher in methanol fuelled engine with conventional diesel engine crankcase oils which however, could be brought down to diesel engine level through the use of specially formulated lubricants.

24. Neat methanol operated two stroke engines were developed by modifying carburetion and optimizing ignition. Some rubber components were also replaced studies were carried out on combustion, lubrication, performance and durability. Two new lubricant formulations were tried satisfactorily. It was observed that compression ratio of the methanol engine is limited by abnormal and knocking combustion. Although the unburnt fuel emission (UBF) is similar to that of gasoline.

The antiknock properties of methanol as determined by conventional methods (CFR engine rating) are not suitable for methanol operated engines. Abnormal combustion phenomenon is more severe than 4-stroke application due to auto-ignition of methanol with hot residual gases. To study this phenomenon basic studies were conducted using the combustion bomb.

25. One of the serious problems associated with the use of alcohol as engine fuel is the corrosion of metals, alloysand other materials. To address this problem, the corrosion behaviour of various indigeneous engine fuel handling metals in contact with methanol has been studied by means of various laboratory techniques. Static emersion tests have demonstrated that lead (plugs in carburettor) and aluminium alloys (crankcase) corroded severly. The carburettor components such as Zamak and Brass jets were found to be tarnished. From the preliminary galvanic studies, the metals and alloys could be arranged in the order of increasing anodic character. Material incompatibility of some of the engine components e.g. carburettor float, needle valve tips and crankcase rubber seals were experienced during engine tests. These problems however, could be resolved by use of teflon floats and brass needle valve tip, etc. Presence of some water in methanol also reduced the corrosion rate of Aluminium alloys. A three point polarisation method was employed to assess the comparative performance ofthe corrosion inhibitors for methanol. Although, laboratory simulations could be achieved for fuel system components such as carburettor, simulations were not possible for ring/cylinder combination due to high operating temperature conditions in an engine. However, one of the potential corrosion inhibitors was studied on one engine test bench under cylic operating conditions. This additive was shown to control. Corrosion inhibitors were also taken up for study. They helped control the corrosion of fuel system materials as well as improve the overall wear characteristics during engine tests. The field trials further suggested that chromium plated rings were effective in controlling methanol related wear without adversely affecting the cylinder wear. Studies were also conducted on a rig employing a M.S.fuel tank and a pump for recirculation.

26. It was seen that issues pertaining to safety and toxicity with use of methanol fuel are of serious nature and need detailed understanding, particularly when considering large scale field applications. Measures adopted for increasing safety in laboratory and field use therefore included admixture with 10 percent motor gasoline, addition of taste odour and colouring agents as well as requisite education of concerned personnel.

27. It was found that information collection and dissemination, particularly as carried out by the project through newsletter, conference and workshops, seminars, and individual interaction, has resulted in considerable awareness about the role of fuel methanol. As a consequence of this awareness two multi-agency and demonstration projects could be started in the country. Interest from other organizations has also been expressed.

28. Methanol has shown advantages as a substitute to lead in motor gasoline and is being used as a Octane booster. Methanol also indicates environmental benefits with reduction in NO_x formation and particulate emission. It is also believed that use of methanol would significantly reduce levels of Ozone oxidants and other secondary pollutants like peroxyacetyl nitrates to alleviate problems of photo-chemical smog.

29. Government's continued interest in the use of methanol fuels for the transport sector is, however, seen by the support received from the Department of Non Conventional Energy Sources, and by the Oil Industries Development Board in contracting field studies on use of methanol in commercial fleets through Indian Institute of Petroleum. These are multi-agency projects involving several additional public sector organizations. The feasibility of use of alcohol fuels is additionally being examined by the recently formed "High Power Committee on use of Alternative Fuels for Surface Transport".

30. It is seen that such large scale and indepth exposure on subject of methanol utilization has considerably increased the capability of project engineers to handle further issues and investigations related to utilization of alternative fuels. Advanced facilities capable of carrying out research and other investigations related to combustion lubrication, emission, performances, wear and durability, etc. has also been created. It is thus seen that the project has developed a sound base for theoretical analytical and experimental work which can even be utilized as a centre for further work.

31. It is seen that the engine builders and organised users have shown a keen interest in methanol use on engines but, at the same time, they have also been looking at possible statements from the Government on its view concerning the future of this fuel in the country. It is felt that their interest in methanol is largely due to the uncertainities and difficulties foreseen in managing the petroleum fuel supplies in the country. Links with the industry for future use of results achieved are therefore clearly dependent upon a thought out national policy. This so far has been lacking and may delay the successful achievement of the long term project objectives.

32. It is seen that the perception of the national project engineers received considerable help in project's implementation from the personnel of the international agencies i.e. UNIDO and UNDP, and from the various consultants and experts who were associated with the conduct of the project. Similarly out of normal assistance was also received from the C.S.I.R. in quickly agreeing to and granting a substantial additional sum of a Power generating set.

VI. RECOMMENDATIONS

33. A considerable increase in awareness related to utilization of alcohol fuels in engines is perceived with the Government and with the industry, but links with local industry for future use of results achieved are entirely dependent upon a thought-out national policy. This so far has been lacking and may delay the successful achievement of the long term project objectives. This issue, therefore, needs the attention of the Government. It is recommended that an indepth feasibility, taking into account a long term perspective, project results and economics, should be undertaken by the Government. If necessary, this should also consider a plan for first introduction of methanol fuels in the country, keeping in mind the parallel developments needed both for the production of methanol and with the user and engine industry for its utilization. It is felt that, as implemented by some other countries, initial appropriate fiscal incentives could also be considered, for a possible eventual switching to this fuel option.

34. The current project has resulted in establishment of several high technology facilities and generation of enough expertise at Engines Laboratory of IIP for carrying out R&D work in the area of alternative fuel utilization. This could be utilized for studies on other alternative fuels of importance and use to the Indian situation. It is seen that small and large natural gas fields are now being continuously discovered in India and at a certain stage use of natural gas and other fuels derived from it may have to be considered in heavy vehicles to replace diesel. It is known that the nature of work for this purpose has many commonalities with the one carried out by this project on utilisation of alcohol fuels. Thus the momentum reached in this project could be maintained and gainfully employed. Such work would generate a data base for a good comparison between competing alternatives such that appropriate utilisation of country's resources could be made. UNIDO is already supporting studies on conversion of coal to some gaseous and liquid fuels as well as other projects on inter-fuel conversions. It is therefore recommended that a view be taken and studies as suggested above be considered for taking up with the Indian Institute of Petroleum to derive maximum benefits and best returns from utilisation of funds.

35. Further investigations both of a theoretical and of an applied nature and information dissemination should be continued by IIP on the project subject even after completion of project and should be encouraged. This is particularly stressed in view of the excellent work done by the project on this front and the impressive results produced, some of which have even exceeded the projects' mandate.

36. In light of the well recognized achievements of Indian Institute of Petroleum in developing the application of alternative fuels particularly alcohols for I.C.engines, it is felt that India has a potential to interact with other developing and industrialized countries and organisations, which should be gainfully employed. Some recommendations to achieve this can be as follows:

i) To transform the India UNDP/UNIDO IPF national project DP/IND/82/001 "Application of Alternative Fuels (methanol) for I.C.Engines" into a global project;

ii) To establish satellite industry oriented R&D progammes in interested developing countries (on a geographic basis) and develop a programme network;

iii) to establish industry oriented R&D interlink between institutions/manufacturers of industrialized and developing countries;

iv) To train staff (both of R&D institutions and manufacturers of I.C.engines);

v) Future development of technology utilization of methanol as a fuel for I.C. engines, particularly diesel engines and two-stroke engines;

vi) Promotion of technology transfer to other interested developing countries and establishment of national industry oriented programmes in this area;

vii) Collection and dissemination of technical information to users and the industry in related areas.

37. Experimental facilities set up and expertise provided under the project, have created a good basis for initiating new internationally assisted projects to tackle industrial problems in the area of fuel and lubricant utilization in engines. Since the projects' implementation and management by the national staff was highly satisfactory, their capability to do so well in future should be made use of.

ANNEXURE I

Terms of Reference of Project Advisory Committee

1. To consider and advise on the suitability of the proposed main directions of the project activities for attaining the stated objectives.

2. To help in securing collaboration from industry in implementation of the project.

3. To advise on the dissemination of information to the industry and other users.

4. To apprise the government and industry of the results and achievements of the project with a veiw to their practical utilization.

Membership

1. Director, Automotive Research Association of India, Pune.
2. Professor, Internal Combustion Engines, IIT, Madras.
3. Director, Engineering Research Centre, TELCO, Pune
4. General Manager, Eicher (Tractors) Scientific Research Centre, Faridabad.
5. Manager, R&D, Scooters India Ltd., Lucknow
6. Manager, R&D, Bajaj Auto Ltd., Pune
7. Secretary, Commission of Additional Sources of Energy, Government of India, New Delhi
8. CSIR through Director, Indian Institute of Petroleum
9. National Project Coordinator

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ANNEXURE-II

INTERNATIONAL PERSONNEL

S.No.	Area of expertise	Name	Country	Duration	m/m
1.	Design and development of I.C. Engines	Dr. A. Kowalewicz	Poland	March'83-Aug'83	6
2.	Fuel introduction in I.C. Engines	Prof. A.J. Cernej	Yugoslavia	Sep'83-Sep'83	1
3.	Combustion studies in S.I. Engines	Dr. P. Eyzat	France	Dec'83-Dec'83	0.5
4.	-	Prof. R.K. Pefley	U.S.A.	Nov'83-Nov'83	0.5
5.	Fuel introeduction in I.C. Engines	Prof. A.J. Cernej	Yugoslavia	Sep'84-Sep'84	1
6.	-	Prof. R.K. Pefley	U.S.A.	Oct'84-Oct'84	0.5
7.	Combustion studies in I.C.Engines	Dr. A.S. Khatchian	U.S.S.R.	Oct'84-Mar'85	6
8.	Lubrication and wear characteristics of I.C. Engines	Mr. H.C. Wolff	F.R.G.	DEc'84-June'85	6
9.	Combustion studies in S.I. Engines	Dr. S. Radzimirski	Poland	Jan'85-June'85	6
10.	Heat transfer modelling in I.C. Engines	Dr. A. Lesikiewicz	Poland	Sep'85-Oct'85	0.5
11.	Lubrication requirements of two-stroke engines	Mr. E. Vieilledent	France	Oct'85-Dec'85	2
12.	Lubrication and wear characteristics of I.C.Engines	Mr.H.C.Wolff	FRG	Nov'85	0.2

13.	Combustion studies in I. C. Engines	Dr. G.G. De Soete
14.	-	Prof. R.K. Pefley
15.	Combustion studies in S. I. Engines	Dr. S. Radzimirski
16.	Mathematical modelling studies in Alcohol Fuelled Engines	Dr. Louis H. Browning
17.	Lubrication requirement of two-stroke engines	Mr. E. Vieilledent
18.	Combustion studies in S. I. Engines	Dr. S. Radzimirski
19.	Combustion studies in I. C. Engines	Dr. G.G. De Soete
20.	Fuel introduction in I.C. Engines	Prof. A.J. Cernej
21.	Design and development of I.C. Engines	Prof. V.O.Kuentscher
22.	Combustion studies in S.I. Engines	Dr. S.Radzimirski
23.	Utilization of Alcohol Fuel in I.C.Engine	Dr. G.A. Karim
24.	Mathematical modelling studies in Alcohol Fueled Engines	Dr. Louis H. Browning
25.	Mathematical modelling studies in Alcohol Fueled Engines	Prof. R.K.Pefley
26.	Combustion Studies in I.C. Engines	Dr.G.G.De Soete

France	Nov'85-Dec'85	1
U. S. A.	Nov'85-Nov'85	0.5
Poland	Dec'85-Feb'86	3
U. S. A.	Dec'86-Dec'86	0.75
France	Oct'86-Dec'86	2
Poland	Nov'86-Jan'87	3
France	Nov'86-Dec'86	1
Yugoslavia	Jan'87-Apr'87	3
G.D.R.	Feb'87-Apr'87	2
Poland	May'87-Jun'87	2
Canada	May'87	0.3
U.S.A.	Jun'87	0.75
U.S.A.	Jun'87	0.50
France	Oct'87	0.75

ANNEXURE III

NATIONAL PERSONNEL

Dr.I.B.Gulati, Project Director	Director (Upto Dec 85)	M.Sc.(Tech) Ph.D.
Dr.R.Krishna, Project Director	Director (From Jan 86)	B.E.Chem Engg., M.Sc., Ph.D., C.Eng., F.I.Chem E., M.I.I.Chem.E.
Mr.S.Singhal, Project Coordinator	Head, Petroleum Products Application Division	B.Sc. B.Tech.(Mech.Engg) M.S. (App. Phy. Sc.)

Project Team

Name	Position	Qualifications	Professional Experience Yrs.
S.Singhal	Head, Pet.Prod. App. Div.	B.Sc;B.Tech.(Mech.Engg) M.S. (App. Phy. Sc)	22
B.P.Pundir	Project Coordinator	B.Sc.,B.E.(Mech.Engg),PG.Dip. M.S.(Mech Engg.), Ph.D.	19
P.C.Nautiyal	Project Leader	B.Sc.(Mech.Engg), Ph.D.	18
K.K.Gandhi	Project Leader	B.Sc.(Mech.Engg)	18
S.K.Jain	Research Engineer	F.I.E.(Mech.Engg)	22
R.K.Sharma	Research Engineer	B.Sc.,A.M.Ae S.I.(Aero.Engg)	23
R.L.Mendiratta	Research Engineer	B.Sc.(Mech.Engg)	14
M.Saxena	Project Leader	B.Sc.(Mech.Engg) M.Tech (Thermal Engg.)	11
Mathew Abraham	Project Leader	B.Sc.(Mech.Engg) M.Tech(Mech.Engg.)	11
M.N.Bandooni	Research Engineer	Diploma (Mech.Engg.) AMIAE (Auto.Engg)	24
C.Ramachandran	Research Engineer	Diploma (Aero.Engg.)	22
P.B.Semwal	Data Processing Incharge	M.Sc.(Maths)	16
Dinesh Kumar	Research Engineer	B.E.(Mech.Engg)	10
J.Sharma	Research Engineer	B.Sc.(Mech.Engg)	9
A.K.Aigal	Research Engineer	B.E.(Mech.Engg)	7
S.K.Singal	Research Engineer	B.Sc.(Mech.Engg) M.Tech.(Thermal Engg.)	7
Sudhakar Das	Research Engineer	B.Sc.(Mech.Engg)	6
S.N.Bhattacharjee	Research Engineer	B.Sc.(Mech.Engg)	6
A.K.Jain	Research Engineer	B.E.(Mech.Engg)	6
M.Gupta	Research Engineer	B.E.(Mech.Engg)	6
A.K.Gondal	Research Engineer	B.E.(Mech.Engg)	6
S.Maji	Research Engineer	B.Sc.(Mech.Engg)	6
A.Jayaraman	Research Chemist	M.Sc., M.S.(Chemistry)	13
P.G.Khanwalkar	Instrumentation Engineer	B.Tech.(Electronics Engg)	11

STUDY TOURS

ANNEXURE IV

Sl.No.	NAME	PLACE	M/M
1.	A.K.Jain	University of Santa Clara, California, USA	4 (Jun-Sep 84)
2.	Dinesh Kumar	University of Manchester, Institute of Science and Technology, Manchester, UK	6 (Apr-Sep 84)
3.	P.C.Nautiyal	Ontario Research Foundation, Canada	6 (Jun-Dec 84)
4.	A.K.Aigal	University of Sheffield, U.K.	3 (May-Jul 85)
5.	A.K.Gondal	Institut fur Angewandle, Verscheiss forschung, (I.A.V.F.), KARLSRUHE, FRG	6 (Oct 85 - Mar 86)
6.	M.Gupta	Purdue University, West Lafayette, IN, USA	5 (Nov 85 - Mar 86)
7.	J.Sharma	University of Engineering, Zwickau, GDR	4 (Jul-Oct 86)
8.	S.Maji	University of Engineering, Zwickau, GDR	4 (Jul-Oct 86)
9.	S.K.Singal	Moscow Automobile and Road Institute (MADI) Moscow (U.S.S.R.)	2.6 (Sep-Nov 86)
10.	S.N.Bhattacharjee	Southwest Research Institute, San Antonio, Texas, USA	4 (Feb-May 87)
11.	S.Das	National Research Council of Canada, Ottawa Ontario - K1A OR6, Canada	5 (Mar-Jul 87)

ANNEXURE V

STUDY TOURS

S.NO.	NAME	PARTICULARS	PERIOD (MONTHS)
1.	Dr.I.B.Gulati	VI International Conference on Alcohol Fuels, Ottawa, Canada; Univ. of Santa Clara, USA; Ford Motors, Detroit, USA; US Department of Energy, Washington, USA, UNDP, New York, USA	1.0 (May - Jun 1984)
2.	Mr.S.Singhal	XX FISITA Congress, UNIDO & Tech. Univ., Vienna, Austria; Ricardo & Co. UK; IFP, France; VI International Conference on Alcohol Fuels, Ottawa, Canada; Ford Motors, USA; Univ. of Santa Clara, USA; Lubrizol Laboratories, Cleaveland, USA; NIPER, Bartlesille, USA; SWRI, San Antonio, USA.	1.5 (May - Jun 1984)
3.	Dr.B.P.Pundir	VI International Conference on Alcohol Fuels, Ottawa, Canada; Canada; Ford Motors, USA; Univ. of Santa Clara, USA; I.F.P. France.	1.5 (May - Jun 1984)
4.	Mr.K.K.Gandhi	VI International Conference on Alcohol Fuels, Ottawa, Canada; Trans. Research Centre of Ohio, USA; Univ. of Santa Clara, USA.	0.5 (May 1984)
5.	Mr.S.K.Jain	Second International CEC Symposium on Performance Evaluation of Fuels and Lubricants, Wolfsburg, FRG; DGMK, Hamburg, FRG; Shell Engine Testing Laboratory, Hamburg, FRG; TUV, Rheinland, FRG; Daimler Benz, Stutgart, FRG; AVL, Graz, Austria.	0.5 (Jun 1985)

ANNEXURE VI

EQUIPMENT TRAINING AND CONFERENCE TOURS

SL.NO.	NAME	FIELD OF STUDY	PERIOD (MONTHS)
Equipment Training			
1.	Mr.H.S.Sewak	Consine Dynamics Ltd. UK. (Heavy Duty Chassis Dynamometer)	0.5 (Oct 1985)
2.	Mr.P.G.Khanwalkar	A.V.L. Graz, Austria (Digital Analyser)	0.5 (Oct 1985)
Conference Tours			
1.	Mr.K.K.Gandhi	Second International Symposium on Performance Evaluation of Fuels and Lubricants, Wolfsburg, FRG	0.2 (Jun 1985)
2.	Mr.S.Singhal	Third International Pacific Conference, Jakarta, Indonesia	0.2 (Nov 1985)
3.	Dr.P.C.Nautiyal	Third International Pacific Conference, Jakarta, Indonesia	0.2 (Nov 1985)
4.	Dr.B.P.Pundir	SAE Fuels & Lubricants Meeting, USA; VII International Symposium on Alcohol Fuels Technology, Paris, France.	0.5 (Oct 1986)
5.	Mr.M.Abraham	VII International Symposium on Alcohol Fuel Technology, Paris; IFP, France.	0.5 (Oct - Nov 1986)

ANNEXURE VII

MAIN ITEMS OF EQUIPMENT PROCURED

Equipment	Approx Cost (US $)
Diesel Research Engine	299,350
Wear Profilometer	40,145
Heavy Duty Chassis Dynamometer	253,640
Transient Mode Dynamometer	50,640
Digital EngineAnalyzer	126,130
D.C.Dynamometers	134,434
High Speed Gas Sampling System	32,123
Logic Analyzer	19,200
Wave Form Analyzer	19,015
Fuel Flow Meters	35,585
Noise Level Meter	11,395
Strip Chart Recorder	16,765
Laser Source	31,245
Eddy Current Dynamometers	49,465
Temperature Recorder	6,280
Pressure Transducers & Calibration Equipment	19,350
Humidity Meter	1,670
Charge Amplifier	1,725
Laminar Air Flow Meters	4,400
Standard Gas Divider	8,609
High Speed Camera	53,775
Spark Plug Fouling Tester	3,460
Impulse Swirl Meter	6,836
Camera 35 mm	1,375
Knock Intensity Meter	4,760
CVS Venturi	4,288
Titrator	7,560
AVL Smoke Meter	7,100
Zero Resistance Meter	3,680
Digital Oscilloscope	13,560

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Portable CO_2 Analyzer	3,200
HC/CO Gas Analyser	4,675
Hydrocarbon Analyzer	47,000
Differential Scanning Calorimeter	47,937
Total	1,397,425

ANNEXURE VIII

MAJOR ITEMS OF EQUIPMENT PROCURED UNDER GOVERNMENT COUNTERPART FUNDS (THROUGH IIP)

A)	NCM-EXPENDABLE EQUIPMENT PROCURED	Rupees
1.	Two wheeled Vehicles (Scooter, Motorcycle, Moped)	49,674
2.	Battery Charger	8,455
3.	Conversion Kit for LPG	2,25,178
4.	Measuring instruments	18,517
5.	Dynamometers	2,07,966
6.	Temperature Indicators	2,13,936
7.	Time Delay Unit	1,708
8.	Electronic Instruments	25,714
9.	Electronic watch & Stop watch	11,017
10.	Card Printing Punch & Computer items	52,171
11.	Engine (Tata & Matador)	1,26,392
12.	Digital Techometer	70,680
13.	Fuel Pumps	51,306
14.	Two wheeled Vehicle Engines	58,552
15.	Digital Indicator for Dynamometers	10,098
16.	Automotive Vehicles (Tata & Standard Buses)	3,69,700
17.	Cacillation Control	19,877
18.	Voltage Stabilizers/Transformers	33,096
19.	Humidity & Temperature Indicators	39,922
20.	Techno generator & time sequence generator	78,634
21.	Compact Scanner	4,800
22.	Illuminated Magnifiers	3,666
23.	Engine Cranking Devices	39,180

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24.	Programmable Load Control Unit for Dynamometer	90,500
25.	Air Blowers	17,340
26.	Programmable dynamometers	2,31,500
27.	Digital load indication systems with load cells	23,000
28.	Fuel Injection Pump	7,500
29.	Methanol induction systems	19,500
30.	Engine Components	4,90,000
31.	Oscilloscope	38,220
32.	Driving Cycle Analyzers	52,900
33.	Equipment for report preparation	2,10,000
	TOTAL:	28,90,700

ANNEXURE IX

REVISED OUTPUTS

1.	A report on the analysis of the current engine designs and methods which could be applied for use of alcohols. The perspective for adoption of new techniques for maximising the use of alcohols in engines would be brought out in this report.	Dec. 1983
2.	The following major facilities would have been established and commissioned for R&D investigations:	
	i) A single cylinder research diesel engine	Jan. 1986
	ii) A test rig for fuel injection characteristics	June, 1986
	iii) Equipment for wear measurement of engine liner and bearings	June, 1986
	iv) An instrumented bomb for combustion studies	June, 1986
	v) Measurements of aldehydes & other engine emissions	Dec. 1986
	vi) Chassis Dynamometer for Heavy Duty Vehicles	Nov. 1984
3.	Modified engines incorporated the devices/systems for part use of alcohol fuels, to assist the industry for prototype fabrication of optimised subsystem.	
	3.1 Specifications of identified devices/systems for part utilization of alcohol in current design of diesel engines.	June, 1984
	3.2 Specifications of identified systems for part utilization of alcohol in current design of 2-stroke engines.	June, 1984
	3.3 Modified diesel engine/test vehicles incorporating the device/system developed and optimized for part utilization of alcohol.	Continuous
	3.4 Modified 2-stroke test vehicle incorporating the system developed and optimized for part utilization of alcohol.	Continuous
	3.5 Communication of project findings to the industry for incorporating the required modifications in 4-stroke diesel and small 2-stroke engines/vehicles for part utilization of alcohol fuel.	Continuous

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4.	Technical know-how and system design for operation of (a) Diesel engines; (b) Two-stroke SI engines on maximum replacement by alcohol.	
	4.1 Laboratory prototype of 4-stroke & 2-stroke engines developed for utilization of straight alcohol.	Dec. 1985
	4.2 Communication of the project findings to the industry for development and fabrication of alcohol fueled engines.	June, 1986
	4.3 Specifications of optimized system for utilization of straight alcohol in 4-stroke C.I. engines.	Dec. 1986
	4.4 Specifications of optimized systems for utilization of straight alcohol in 2-stroke SI engines.	Dec. 1986
5.	Specifications of alcohol fuels for use in IC engines:	Continuous
6.	i) Fifteen research engineers at IIP trained for carrying out studies in the area of alternative fuel technology, out of which eleven will also undergo specialized training abroad.	
	ii) Ten engineers of petroleum and user industries trained, on utilization of alcohol fuels in engines.	
7.	Dissemination of information to industry through regular circulation of:	
	a) Relevant technical materials	
	b) Information letter to high-light various aspects of utilization of alternative fuels, and through	Oct. 1983 continuous
	c) A workshop in March, 1983 and September/Oct. 1984 and National/International Seminar in Oct./Nov. 1985.	

ANNEXURE X

PUBLICATIONS ON ALCOHOL FUEL UTILIZATION IN IC ENGINES

1. Abnormal Combustion in 2 Stroke Spark Ignited Methanol Engine, S.Maji, Mathew Abrhama, B.P.Pundir, S.Radzimirski. SAE, International Congress and Exposition, Feb.1988.

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3. Some Experience on the Operation of Scooter and Moped Engines using Methanol fuel, S.Maji, Mathew Abraham, B.P.Pundir, Ibid.

4. Experimental Investigation of Droplet Distribution in Diesel and Methanol Spray of High Pressure Injector, A.K.Aigal, B.P.Pundir, Ibid.

5. Combustion Rates Analysis for a Surface Ignited Methanol fuelled Engine, S.K.Singal, P.B.Semwal, Dinesh Kumar, B.P.Pundir, Ibid.

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7. Some Lubrication Problems Associated with the Use of Methanol Gasoline Blends in S.I.Engines, P.C.Nautiyal, M.N.Bandooni, G.A.Sivasankaran, National Conference on Industrial Tribology, Bombay, Dec.1986

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9. Performance Studies of Oils for Neat Methanol Fuelled Small 2-Stroke SI Engine, R.L.Mendiratta, S.Singhal, Ibid.

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17. High Pressure, Injection and Atomization Characteristics of Methanol, A.K.Aigal, B.P.Pundir, A.S.Khatchian, SAE International Off Highway and Powerplant Congress and Exposition Milwaukee, Wisconsin, Sept. 1986, Paper No.861167.

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ANNEXURE XI

TECHNICAL REPORTS ON ALCOHOL FUEL UTILIZATION IN I.C. ENGINES

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