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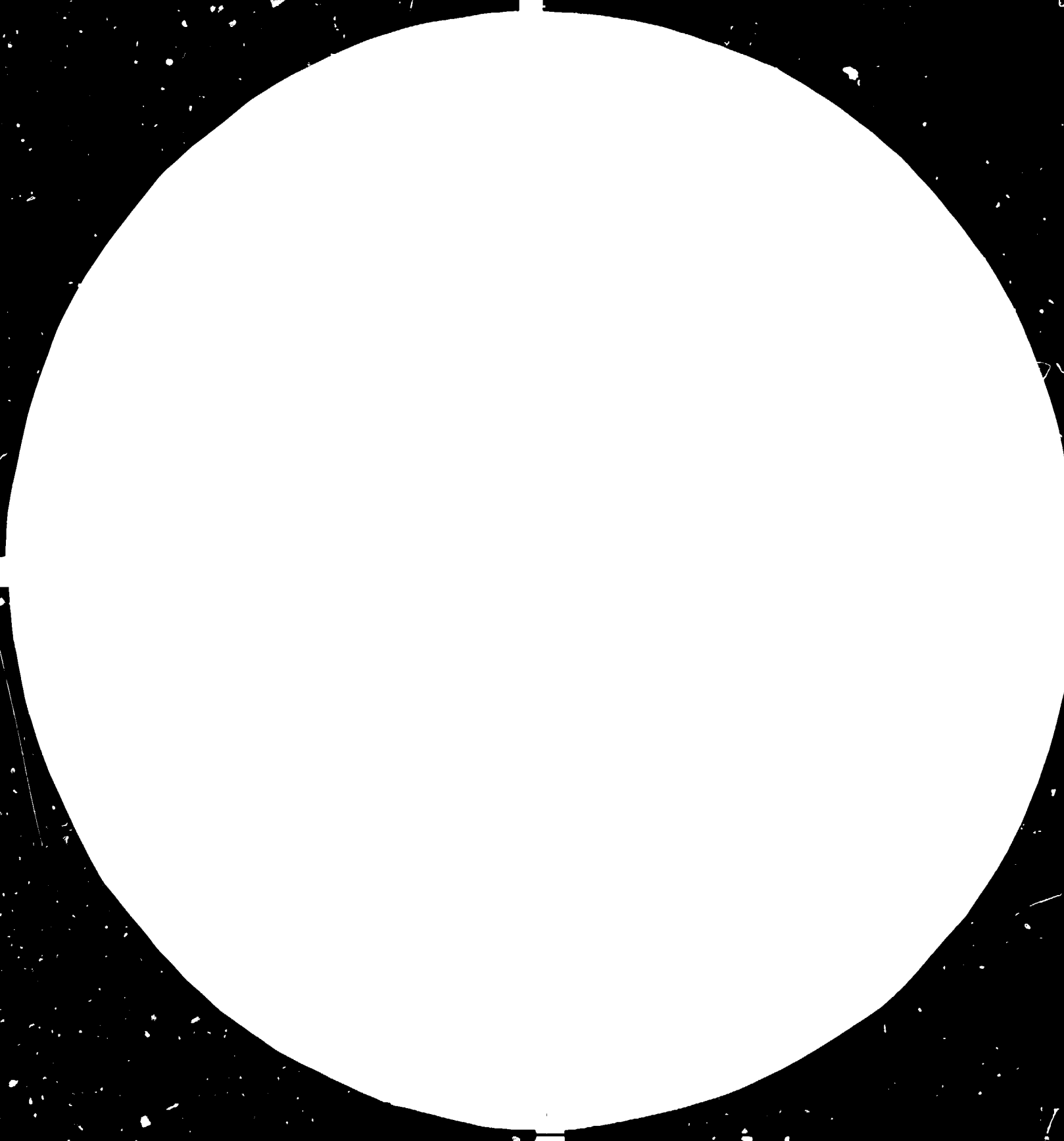

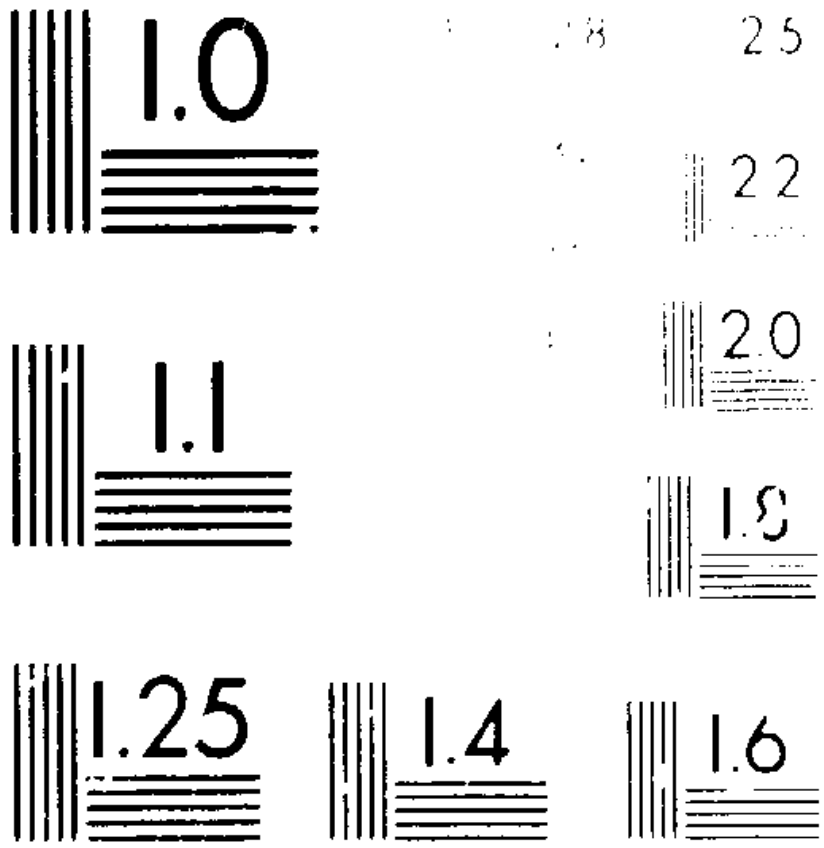
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JUNE 1984
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APPLICATION OF ALTERNATIVE FUELS FOR INTERNAL COMBUSTION ENGINES

DP/IND/82/001

MISSION REPORT*

Prepared for the Government of India,
by the United Nations Development Organization,
acting as Executive Agency for the United Nations Development Program

Based on the work of Mr. Pierre Eyzat,
Expert in Combustion Studies in Spark Ignition Engines
under post 11-03
from 4-16 December 1983

United Nations Industrial Development Organization
Vienna

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This mission report will not repeat the opinions and general comments on the program given in Mr. Riffle's report since we agree with his conclusions. On the other hand, this mission went further in examinating the scientific and technological problems raised by the program. The methodology used, consisting in describing the French approach, followed by an analysis of IIP projects, effectively explained the differences and revealed the fields in which an exchange of information, or even collaboration, would be the most effective.

1. The French Case

1.1. Approach to Energy and Synfuels

The French choices correspond to the following table which shows that nuclear energy is effectively the most important alternative energy source in France between now and 1990-2000. It can be seen that most of the future oil will have to be devoted to uses in transportation and petrochemicals. This is leading, in particular, to a search, as in India, for a wider use of the average cut in diesel engines.

Likewise as in India, the most probable synfuel for France in the long run is methanol. In this respect, the "Carburol" (alcohol fuel) program launched in France to prepare the conditions for the progressive inclusion of alcohols in fuels provides a useful experiment for India. Indeed, because of the extensive research done in particular in Brazil, West Germany, the United States, Sweden, etc., an abundant literature exists on this subject. France has thus been able to pursue a program at a marginal cost (about FF 12 million in all). Experience has shown that this pilot program has provided indispensable conclusions which are specific to the French market. For example, some parts of the distribution network will have to be the object

of special precautions (plastics which are particularly poorly suited to the use of methanol).

1.2. Methanol and Spark-Ignition Engines

Research has been done on:

a) Existing engines in which the acceptable maximum — for reasons of excessive impoverishment — has been defined as being 3% methanol and 2% tertiary butyl alcohol.

b) Adapted engines M15 - M50 - M90.

c) A flexible engine. The motive behind this was based on the difficulties of defining a European policy with regard to the composition of fuel. The flexible-engine approach consisted in imagining that the different European countries each had its own policy. Therefore, the use of control electronics should enable the flexible engine to automatically adapt the spark advance and the air/fuel mixture without any intervention by the driver. The prototype vehicle should be ready in July 1984.

1.3. Methanol and Diesel Engines

Solutions such as mixtures, dual fuel and hot-spot ignition have been the subject of a project of limited amplitude. Indeed:

a) Mixtures quickly create a vapor phase inside tanks, and this phase is within the limits of flammability. Furthermore, such products do not respect French legislation concerning the flash point.

b) A hot-spot engine would have required long and costly development to protect the preheated sparkplug from the intense steam of fresh air from the chamber. This is a problem of finding a solution to the case of an engine driven by the vehicle on downgrades.

c) Dual fuel or a pilot amount of diesel fuel corresponding to the idling flow rate ignites carbureted methanol and provides a substitution rate varying from 85% to 0% depending on the charge. It is on this last field that French efforts have particularly concentrated. It should be noted, however, that, in addition to methanol, considerable research has been done on vegetable oils which benefit from a natural cetane number that is fully suited to diesel engines.

2. The Indian Case

For very different reasons, the technical problem raised for refining and transportation as a whole is identical to the French case. Non-commercial energy sources and coal condemn oil to be used with a high priority for transportation. Likewise, the most obvious replacement for oil is methanol. This fact is valid on an international level, but it is confirmed for India which has appreciable coal reserves.

On the basis of this premise, considerable differences compared to the French situation justify giving priority to quite appreciably different research projects.

2.1. The Diesel/Methanol Pair and Combustion

In the first place, diesel fuel, which represents 13% of the consumption of petroleum products in France, represents 48% in India. An initial important consequence lies in the obviously wider product specifications in India than in France. The essential fact is surely the cetane number, which is 42 in India and 50 in France.

Secondly, gasoline represents only 6% of consumption in India as against 23% in France, and the octane specification is also lower in India. Therefore, the use of the most probable replacement will preferentially be directed toward diesel fuel, whereas the scenario in France is more marginal and reserved to the hypothesis of a blockade.

The position of India, concerning the diesel/methanol pair, is entirely unique because even Brazil, which had considered this hypothesis at one time, has finally settled on the diesel/vegetable-oil pair (Prooleo Plan).

A very important conclusion from this analysis is that, as opposed to other fields in which India can benefit from research done in the world (for example, for the alcohol/four-stroke spark-ignition engine pair), in seeking to find an adaptation, India will often have to do pioneering research with regard to the diesel/methanol pair. This analysis leads to the priority recommendation that a fundamental combustion laboratory* be created to deal with engine problems.

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* This recommendation has already had results since Dr. Pundir will define the specifications for this laboratory after the one-month advanced-training session he is now undergoing at IFP in Dr. de Soete's laboratory.

Naturally, autoignition in a diesel engine also results from physical vaporization and diffusion processes. The research done by Dr. Pundir's team on the methanol injector jet in which the droplet population is characterized by a laser system is original and is progressing satisfactorily. It must be encouraged.

Likewise, the research being done on hot-surface ignition, which is producing encouraging results, must be pursued. During the technical lectures by IFP, the expert nonetheless had an opportunity to drawn the attention of his audience to the operating conditions of a driven engine which can cool the hot surface too much.

2.2. The Environment, Two-Stroke Engines and Methanol

Unburned-hydrocarbons emissions by a two-stroke engine are extremely high (10 times those of a four-stroke engine). Of course, average emissions in India are slight, but in downtown areas and by replacing unburned hydrocarbons from gasoline by methanol and aldehydes, the problem risks being considered as serious by specialists.

Without wanting to embark on a legislative act which is beyond his competence, the expert recommends that:

. Whereas the two-stroke engine remains the most widespread engine, it would be well to examine problems raised by adapting a catalytic muffler to two-stroke engines consuming methanol*.

. For future engines, an examination is being made of the possibility of introducing small four-stroke engines as a replacement for current two-stroke engines.

2.3. Fleet Tests

French experience has shown that fleet tests are very useful because they reveal the specific parameters of a country. During French experiments, in particular with regard to the distribution network, we revealed problems which had not appeared in tests

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* To this effect, a prototype monolithic muffler was sent to IFP in February 1984.

performed abroad. The same will probably be true in India. This recommendation has already had results in that a diesel fleet test has already been begun, as was confirmed to us by Dr. Singhal, Director of the IIP Applications Division, during his recent trip to France.

In particular, because diesel-fuel/methanol mixtures are involved, the expert drew the attention of the audience to the safety problems raised by the vapor phase of diesel-fuel/methanol mixtures. Generally, safety problems are solved by prohibiting the propagation of combustion by:

. a too lean gas phase (case of diesel fuel),
. a too rich gas phase (case of gasoline).

Mixtures made without precautions would be, a priori, inside these zones. Therefore, this fact should be taken into consideration in finding solutions or imposing specific precautions.

General Conclusions and proposals

The program is well founded for India and is primarily managed and developed by IIP. I share the major conclusions of the report submitted by Dr. Riffe, which therefore, I will not repeat. The following recommendations are more specifically made :

1. Taking into account that conversion of two-cycle and diesel engines for pure methanol operation has more drawbacks, care must be taken not to eliminate the possibility of the four cycle S.I. engine which can be adapted to power both two wheelers and trucks.

2. Due to very probable environmental limitations regarding the potentialy high level of unburned methanol in two stroke exhaust, future development of exhaust system with a monolythic support inserted is better.

3. For safety reasons, special study aimed at defining Diesel oil-Methanol blend, having vapour phase, which is out of flammability limits in tanks, must be undertaken.

4. It is proposed that IIP should soon start a preliminary fleet test with an M15 blend on a limited number of two-wheeler vehicles, in order to have the preliminary experience and be well prepared, eventually, for defining new research goals.

5. It is considered to be necessary to study and optimise diesel combustion of methanol in a single cylinder engine having the characterics, namely bore, of a truck engine. To define and obtain this single cylinder engine, still better collaboration between IIP and India engine manufacturers may be needed.

Additional technical comments for application of methanol to the diesel engine and in small 2-stroke engines are enclosed as Annexes I and II.

LIST OF ANNEXES

Annex I

APPLICATION OF METHANOL TO DIESEL ENGINE

From the discussions on methanol use in diesel engines, studies on the following areas are suggested.

1. Neat Methanol Operation on Truck and Buses

a/ For the use of glow plug concept, a study of the efficiency of electric circuiting unit of a diesel vehicle and to relate it to the actual electric power requirement of the glow plug is required. The system for direct use of alternator to supply energy to the glow plug has to be improved.

b/ Studies are required to evaluate the electrical power requirements of glow plug during conditions when engine is to restart after downhill driving of a vehicle. After downhill driving of a vehicle the power required for glowplug to restart will be quite high as it will be cooled by the intake air and due to absence of combustion. Intake throttling and exhaust braking also need be studied to reduce the glowplug energy and its effect on vehicle braking requirements during downhill operation.

c/ To investigate some ways of protecting the glowplug from very intense aerodynamic flow in the engine cylinder.

d/ The bore of the engine for study should be similar to the bore size of the engine that are being used in trucks and buses in India.

e/ Some other systems with use of spark plug with charge startification must be explored for engines of such applications

2. Part Use of Alcohols in Diesel Engines

i/ Use of methanol-diesel blends though preferable from the point of least possible modifications required to the engine, a check on the concentration of methanol vapours in the air space inside the fuel tank must be made in order to see whether it forms an inflammable mixture or not.

ii/ As an initial measure, use of a simplified intake air methanol fumigation system would be desirable. Fleet tests should be done on this aspect.

STUDIES ON METHANOL USE IN 2-STROKE ENGINES

The studies to be undertaken on methanol utilization in 2-stroke SI engines that are being used in two and three wheeler vehicles in India, were discussed. The following studies were identified and suggested.

1. Considerable effort should be oriented towards use of methanol-gasoline blends in two stroke engines. It is suggested that fleet trials should be started on at least 25-30 vehicles for about a period of one year to study driveability, lubrication and wear problems with the blends. The fuel properties like volatility characteristics etc. could be finalized from these studies. Most probable blend for the studies would be one containing 15% methanol.

2. Studies on evaluating trapped mass in two-stroke engine should be initiated. These can be initiated either using theoretical models or by adopting proper experimental techniques. Particularly the total sampling system developed at Wisconsin University for Diesel pollution studies seems worth being adopted for these studies.

3. Studies related to development of a catalytic muffler for use with neat alcohol operation may be initiated. For pure methanol use the exhaust pipe at least must be fitted with a monolithic support (without catalysts deposited on it) in order to check the necessary exhaust pipe adjustments/tuning which is critical for 2 cycle combustion.

4. Simplified modelling studies starting from a one-dimensional approach taking into account wave phenomena in exhaust pipe may be initiated for these engines.

5. Search for a suitable lubricant able to be mixed and remain stable with pure methanol will continue.

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ACTIONS RELATED TO THE ON-GOING PROJECT

A letter has been sent to IIP the 7 February 1984. Major related actions are recalled below :

1. A precise mapping of the DIGITAP interface which will make your special adaptation easier.

2. Regarding angle encoder, SFIM is now manufacturing a special type using fiber optics which will solve your noise problem on two-stroke test.

3. Information written by our catalyst specialist giving you advice and a relevant literature selection.

4. Stay of IIP engineer :

   . Two-stroke simulation
   . Jet penetration.

5. Definition of the way we use for Calibrating Absolute Pressure on two cycle.

6. A set of information regarding courses by ENSPM Engine Section.

7. Dr. PUNDIR stay at IFP during June 1984.

Mission Schedule

. Sunday, 4 December: departure from Paris

. Monday, 5 December: arrival in New Delhi and talks with UNIDO officials. Examination of expert's report by Mr. Riffle.

. Tuesday, 6 December: travel to Dehra Dun and organization of work at IIP.

. Wednesday 7 to Wednesday 14 December : lectures on the principal French and IFP research projects in relation with combustion engines and alternative fuels, with examination of IIP projects.

. Thursday, 15 December: submission of synthesis report and talks with UNIDO officials.

. Friday, 16 December: return to Paris.