

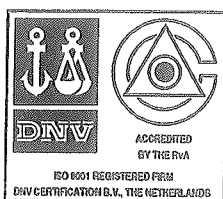
TNO report
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4th DME Workshop; DiMethyl Ether
as an Automotive Fuel
1 & 2 October 1998, Delft, The Netherlands
IEA/AMF Annex XIV

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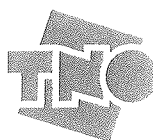
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The TNO Road-Vehicles Research Institute carries out
research and provides services in the field of road
vehicles and their components.
The primary areas of attention are Vehicle Dynamics,
Crash safety, Combustion Engines and Homologations.



Netherlands Organization for
Applied Scientific Research (TNO)

Abstract

The fourth workshop "Dimethylether as an automotive fuel" was held within the context of Annex XIV of Implementing Agreement: "Alternative Motor Fuels" of the International Energy Agency (IEA/AMF). Representatives of almost all companies and research organisations active in the automotive DME field were present.

The objectives of this workshop were:

- to present and discuss the progress of the various tasks within the annex;
- to exchange information.

During the workshop almost all of the seven tasks in the Annex reported good progress. Safety studies show that experiences with LPG can be used to a great extent to draw up safety regulations for DME. For some issues on the other hand, re-calculation with specific DME properties is necessary in order to prevent too stringent regulations for DME. Design studies have clearly identified the areas that need extra development effort. Preliminary results of the study into the production of DME from renewable feedstock show that the final production costs of bio-DME will be some five times higher than diesel, but approximately 20% lower when compared to bio-ethanol.

Since the next workshop (March 1999) will be the last within this Annex the need for continuation has been discussed. Continuation is preferred by most participants, but the focus should shift towards more laboratory tests.

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1 Introduction

This is the report of the fourth workshop on "DiMethyl-Ether (DME) as an automotive fuel".

A total of 5 workshops are planned. Except for the first all are held in the context of Annex XIV of IEA/AMF (International Energy Agency; Implementing Agreement "Alternative Motor Fuels"). The first one was jointly sponsored by the Dutch NOVEM and IEA/AMF.

The objective of Annex XIV is the investigation of subjects which are of general importance for the introduction of DME as an automotive fuel. The subjects focused on establishing a fuel quality standard and obtaining information on environmental and safety aspects.

Previous workshops:

- November 1996, TNO Delft, The Netherlands
- June 1997, TNO Delft, The Netherlands
- February 1998, Amoco Corporation Naperville, Illinois, USA

Where the first two workshops mainly addressed organisational issues, the third workshop served as a 'kick-off' for most of the tasks within the Annex. The fourth workshop served several purposes:

- to present and discuss the progress of the various tasks within the annex;
- to exchange information;
- to discuss the necessity and possibilities for continuation of the work after the next (and last) workshop.

The agenda of the workshop is included in Appendix B, all participants are listed in Appendix A.

2 Progress of the Annex / IEA matters

- A financial overview is included in Appendix C. The TNO costs for the co-ordination of the Annex until 24 August 1998 are USD 53,000 (total budget USD 120,000).
- Except for the USA, all parties have made their first financial contribution for Annex XIV (for the co-ordination and the cost-sharing part). The invoice for the second and last part (30%), will be sent in October/November 1998.
- The IEA/AMF executive committee expects a USD 2000 yearly contribution from the sponsors (Renault, PSA, IFP and AVL) to the IEA/AMF secretariat. Renault is probably willing to pay this, provided that they receive a copy of the IEA/AMF meeting reports.
- The sponsor agreements are now signed by both the companies and the IEA.
- The next workshop will be held in March 1999. This will be the last workshop within this Annex. Because of the importance of this work, a discussion over the continuation is added to the agenda.

3 Progress on the tasks

The annex is split up in seven main tasks:

1. Trade-of fuel quality versus costs
2. Safety investigation (both distribution and application in vehicles)
3. Design guidelines
4. DME from renewable feedstock
5. Life Cycle Analysis
6. Costs of DME infrastructure
7. Operating agent / workshops / newsletter

Since the last workshop almost all tasks have made good progress. In the next paragraphs you will find a more detailed description of the progress per task and the results of the discussions during the workshop.

3.1 Trade-of fuel quality versus costs (Haldor Topsoe)

The majority of activities in this task will be carried out in the period following this workshop since input from other tasks was required. During the third workshop a preliminary fuel quality standard was agreed upon (see previous workshop report).

The 2.5 % for water and methanol seem rather high right now. It will probably be better to chose maximum values closer to 100 ppm.

A report will become available within a couple of month.

3.2 Safety investigation (TNO)

The safety investigation is split-up into two parts:

1. DME vehicle safety assessment
2. DME distribution safety assessment.

3.2.1 DME vehicle safety assessment

Two main activities are carried out to assess the safety of a vehicle running on DME. First of all two fuel storage and supply systems for vehicles are subjected to a Failure Mode and Effect Analysis (FMEA). This FMEA is carried out in June 1998. Present were representatives of the chemical industry (AKZO), automobile industry (Renault) as well as one of TNO's experts on LPG safety issues. The FMEA was facilitated by TNO-MEP. The two systems assessed are an in tank pump system and the membrane-tank system as presented by AVL Powertrain on the previous workshop. A draft report is currently under evaluation by the participants of the FMEA. A final report will be available at the next workshop. The conclusions of this FMEA are also incorporated in the second part of this task, safety provisions for DME fuelling systems and their installation in vehicles. This part basically translates the European safety regulation on LPG (R67) to the specific aspects of DME. This results in a report providing actual rules for DME systems and the installation of such systems into a vehicle based on several decades of experience with LPG in Europe. A draft report is distributed at the workshop. Two topics are addressed during the workshop; maximum filling percentage and test pressures. In both cases it was decided to deviate from the LPG regulations (while maintaining the same safety level):

- A DME tank can be filled to 85%;
- The DME tank burst and test pressures should be approximately 20% lower than those of LPG.

These issues as well as other comments that are reported to TNO before November '98 will be incorporated into the final report.

3.2.2 DME distribution safety assessment

Similar to the safety investigation on vehicles TNO-MEP carried out a safety assessment on DME distribution. Based on the current legislation on LPG distribution in the Netherlands a translation is made to the particulars of DME. This resulted in a document covering the various aspects of DME distribution to service stations by means of tanker trucks. Most important remarks concerning this document at this time are:

- Some of the standards mentioned in the report may be out-dated. It would be very expensive to check this for all standards used in the report.
- The safety distances mentioned in the report are based on calculations valid for LPG. These distances are on the safe side for DME since the heat of combustion of LPG is 1.3 times higher than that of DME.
- The list of equipment is not adjusted for DME since no such list exists for DME. Most likely this list will be very similar for DME.

A draft version of this report will be distributed to interested participants shortly. During the discussions the question arose what status this document will have. It was suggested to have governmental authorities approve this document. In The Netherlands that would most probably lead to the situation where the government will ask TNO to look at it. Since the LPG-equivalent of this document is very well accepted, it was decided to add an overview of differences between the LPG and the DME version of the document. This will give the document extra added value while the status will be linked to that of the LPG version.

National Recourses Canada will have the report evaluated in light of Canadian regulations. Possibly a chapter will be added highlighting the differences between the European and North-American regulations.

TNO-MEP will distribute the draft report including the differences with the LPG version as soon as it's available. The final report will be available at the next workshop.

3.3 Design guidelines (AVL)

This task primarily consists of a FMEA focused on different types of fuel injection equipment. The method proposed by Renault at the previous workshop is adopted. To prevent overlap with the task 2 FMEA, first the boundary conditions are determined and agreed upon with task 2. Next, the systems definitions are all adapted to the same level of detail and to comparable functionality. After defining all possible states the actual FMEA is carried out, resulting in tables with possible failures, their occurrence, importance and detectability. After multiplying these three numbers a Risk Priority Number (RPN) evolves, pointing out those areas of a system that need further development.

At the workshop a draft report was ready. Since task 2 and task 3 deal with similar issues, it was decided to draw up some combined conclusions. Both tasks will include their own as well as the combined conclusions in their reports. Also task 3 will have the final report ready to present at the next workshop. Some of the task 3 conclusions as well as the combined conclusions are listed below:

- New technology gives a lot of high RPN numbers, but few real peaks. Adapted (Diesel) systems show relative low numbers, but with very high peaks;
- The purge system is a big worry;
- In development you need a purge system, but you might not want it in a final technology;
- The technical issues associated with implementing DME in Diesel engines are not insurmountable;

- The assessments made are based on Diesel and LPG technology, areas that require development are identified;
- Several different systems have been assessed. All were found technically feasible.

Next to the 3 systems assessed in this FMEA, 2 other systems are currently developed but were not included in this FMEA.

During the discussions about this subject it was mentioned that DME technology might be better compared to direct gasoline injection technology rather than comparing it to Diesel technology.

3.4 DME from renewable feedstock (Atrax Energi AB)

Good progress has been made in this task. The final report will most likely be ready in next December. The study is focused on an oxygen gasification plant of 600 tons a day with wood as feedstock. At this moment it looks that the gasification part of the process needs the most development. When all electrical power is generated within the plant the mass balance equals: 0.29 ton DME /ton dry wood and the energy balance is 0.49 GJ (DME) per GJ (wood).

With total investment costs between 330 and 440 USD, the total production cost adds up to some 500 USD per ton Bio-DME. This is approximately 5 times the production cost of (fossil) diesel fuel, but 20% cheaper than bio-ethanol.

3.5 Life Cycle Analysis (Innas)

It has been relatively easy to collect data on the application side vehicle emissions), much more effort has been put in the collection of production data. In the final report the results will be displayed as a range since no "exact" data exists. The draft report will not be distributed outside the task group because the preliminary results without all background information are easy to misinterpret. Discussed is the matter whether or not to use 'proven' data or 'expected' data. At this time it is believed that DME engines will have the same efficiency as diesel engines. The first 13-mode results of the Volvo DME bus engine show however a fuel (energy) consumption penalty of approximately 15% when compared to diesel.

In general one can say that at single points the efficiency of a DME engine has shown to be as good as a diesel engine. With the current status of the fuel injection equipment and the combustion optimisation, it is however not possible to achieve this throughout the entire engine map. It is expected that in the future DME engines will achieve the same efficiency levels as diesel engines. Therefore diesel efficiencies will be used in this LCA. The report is expected to be ready in March 1999.

3.6 Costs of DME infrastructure (Innas)

This task has just been started. Amoco, Atrax and Innas have already supplied information. In Tables 1 and 2 in Appendix E an overview is shown of parties, which are going to supply information on investment and operating costs, as agreed during the meeting. Innas will also look for additional information, including addressing IFP.

The time schedule for the completion of this task as agreed during the meeting is shown below.

1 Nov. 1998	Deadline for supplying new information.
1 Nov. - 1 Dec. 98	Process information.
1 Dec. 98 - 7 Jan. 99	Produce draft report.
7 Jan. 99	Distribute draft report for comments.
7 Jan. - 7 Feb. 99	All parties comment on draft report.
7 Feb. - 7 Mar. 99	Produce final report.

3.7 Newsletter

The first newsletter has been issued in June of this year. The next newsletter will follow in October / November of this year. Suggestions for topics are discussed:

1. Progress of tasks of Annex XIV.
2. Recent publications.
3. Preliminary results of the Volvo DME bus engine over the 13-mode test show interesting results. The emissions level of this engine was targeted at 50% of Euro-2. CO, HC and particulates are however much lower and NO_x just below 3 g/kWh.
4. NKK in Japan apparently has a demonstration vehicle running on DME. Statoil meets the company involved on 15 October. Harald Torgard will provide some material as soon as he returns.
5. In the PNGV project (USA), DME is considered as fuel. It would be nice to include some statements about this.

If material for 3 and 4 is available, it will also be included in the newsletter.

4 Dissemination of information of Annex XIV

The information consists of newsletters, workshop reports, task reports and possibly publications. Some sheets prepared for the discussion during the workshop, along with some comments, are presented in Appendix D.

An important conclusion was, that reports can be made available to interested companies after a delay period of 1 to 2 years. This is important to give an advantage to the companies who are financially supporting certain tasks, who can get the reports immediately. Reports concerning safety are public as soon as they are available.

TNO will prepare a proposal for dissemination of information for the IEA/AMF meeting in Japan, such that it can be approved by the IEA/AMF executive committee.

5 Continuation of the Annex

In general the participants were of the opinion that the work should be continued after the current project. In a follow up project there should be more focus on actual laboratory tests in order to obtain a general specification for suitable elastomers and to identify possible corrosion problems (due to methanol/water contamination).

The following overview of subjects to be addressed in a possible follow up project, is put together:

- Elastomers research:
 - AVL, Renault and Volvo to specify static and dynamic seals,
 - TNO to co-ordinate request for proposal.
- Corrosion research:
 - Laboratory tests with target fuel specification.
 - TNO to co-ordinate request for proposal.
- Fuel composition and (special) additives:
 - To monitor suitability of target fuel specification.
 - To investigate additives for:
 - increasing viscosity;
 - odorant;
 - lubricity.
 - AET to co-ordinate additives investigation.
- Injector development:
Annex group as platform to initiate projects
(possibly to be financed via European funds).
- Durability testing:
Collection of information and additional testing:
 - Fuel injection test rig(s);

- Engine bench testing;
- Vehicle field tests.

- Market introduction:
To work out plans for market introduction:
IEA/AFIS, Amoco, Renault, Topsoe and Statoil.

- Life Cycle Analysis:
Expansion of current work with bio-fuels.

TNO will present the plan of a follow up project, at the IEA/AMF meeting in Japan (20-22 October '98).

6 Presentations

Some presentations were given:

Dave Sabo of Amoco presented some highlights on the merger of Amoco into a newly formed BP first-tier US subsidiary. Sheets with background information are distributed at the workshop.

Amoco also signed an agreement to collaborate in the development, production and marketing of DME as a multi-purpose fuel for India.

Gary Webster of AET presented the progress on the tests with DME on a Cummins Engine. All sheets are distributed at the workshop.

Spencer Sorenson of Technical University Denmark mentioned activities on a spray combustion model as well as lubricity issues.

Jouke van der Weide of TNO briefly commented on TNO's activities in the field of DME as well as on alternative fuels more in general. He believes we need to:

- create awareness on the limited availability of conventional fuels;
- create awareness on the need of sustainability;
- create acceptance for higher energy costs;
- prepare for a wider range of fuels needing more flexible fuelling systems.

7 Final remarks

The date for the next (5th) workshop is determined to be from Wednesday March 24 (starting at 1:00 PM) through Friday March 26 (ending at noon).

An (adjusted) schematic for DME workshops, newsletters and IEA meetings is presented in Table 1.

Table 1: Expected dates for DME workshops, newsletters and IEA meetings

Workshops	Newsletters	IEA/AMF meetings
June 1997		
February 1998	June 1998	January 1998
October 1998	Oct./Nov. 1998	October 1998
March 1999	May 1999	July (?) 1999
	Oct./Nov. 1999	

Appendix A List of participants

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V	Ruud Verbeek	TNO WT	Schoemakerstraat 97 P.O.Box 6033 2600 JA Delft the Netherlands	verbeek@wt.tno.nl	31 15 269 63 69	31 15 261 23 41
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V = Present

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X	Lynn Blue	LaGrange Prod.	P.O.Box 658, Fremont IN USA	lbue@lpitanks.com	1 219 495 3025	1 219 495 7771
V	Willemlen Troelstra	Innas	Nikkelstraat 15 4823 AE Breda	innas@wxs.nl	31 76 5424080	31 76 5424090
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V	Hans Jaspers	Akzo Nobel	Postbus 247 3800 AE Amersfoort		31 33 467 63 15	31 33 467 61 57
V	Lars waidheim	TPS Termiska	Studsvik S-611 82 Nykoping Sweden	lars.waidheim@tps.se	46 155 22 13 82	46 8 646 01 26
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V = Present

X = Not Present

Appendix B Agenda 4th workshop "DiMethyl-Ether as an automotive fuel"

Day 1 8:30 Coffee

9:00 Opening / Agenda

9:15 Progress Annex, Ruud Verbeek
IEA matters, finances

9:45 Presentation and discussion results tasks:
Trade-off fuel quality versus costs
Safety study
Design guidelines
DME from renewable feedstock
Life cycle analysis
Costs of DME infrastructure
Newsletter

12:30 Lunch

13:30 Continuation presentations and discussions

15:00 Discussion tasks in separate groups

17:15 Conclusions, Agenda day 2

17:30 End of session, Dinner

Day 2 8:30 Opening

8:40 Dissemination of task reports and other information

9:15 Presentation task leaders: (remaining) activities and planning

10:15 Time for presentations

12:30 Lunch

13:30 Conclusions / final remarks / next workshop

14:00 End of the workshop

Appendix C Financial overview

Contribution Contracting Parties, Industry (& sponsors) in k-USD

	Task-sharing (in-kind & cash) ¹⁾	Cost-sharing	Total (k-USD)
<u>Contract. Parties:</u>			
USA	40	40	80
Finland	0	20	20
Norway	65	30	95
Denmark	65	25 ²⁾	90
Netherlands	75	10	85
Sweden	170	10	180
Canada	100	10	110
Japan		40	40
<u>Sponsors:</u>			
IFP / PSA / Renault	15 ³⁾	40	
AVL/	32	-	
Total	562	225	

1) mixture governmental and industrial contribution:
Akzo-Nobel, Amoco, Haldor Topsoe, Statoil, Volvo truck, Scania, BTL Transport AB, Växjö Energi AB, Linjebuss AB, Länstrafiken AB

2) via Haldor Topsoe

3) estimated

Appendix D Dissemination of information

Dissemination of information / reports of IEA/AMF Annex XIV
(comments during workshop in italics)

Newsletter:

- Hardcopy to companies and government representatives involved in Annex XIV
- Internet: Unrestricted

Workshop and Task reports:

Participating countries Annex XIV:

- Government representatives
- Companies participating in tasks
- Any company which requests them (at printing/handling costs).

After a delay period of 1 to 2 years !!

Sponsors:

- Companies from these countries with approval from sponsor
(at printing/handling costs).

After a delay period of 1 to 2 years !!

Reports task 2 and task 3; safety & design guidelines:

- Possibly unrestricted ?
- Hardcopy or internet version ?
- Possibly just summary in newsletter.

Publications:

- co-author or acknowledge parties that supplied information
- Also co-author IEA/AMF countries and sponsors !!*

Appendix E Task split-up for costs of DME infrastructure

Table 2: Tasks split-up for investment costs.

Investment (capital) costs	Atrax	Statoil	Akzo (via Innas)	Haldor Topsøe
Shipping (sea vessel)	X	X		
Intermediate storage		X		
Pipeline transport		X		
Rail tanker				
Road tanker		X		
Overland transportation				
Refuelling station		X		

Table 3: Tasks split-up for operating costs.

Operating costs	Atrax	Statoil	Akzo (via Innas)	Haldor Topsøe
Shipping (sea vessel)		X		X
Intermediate storage		X	X	
Pipeline transport				
Rail tanker		X		X
Road tanker		X		X
Overland transportation				
Refuelling station		X		

“Overland transportation” stands for a combination of the different steps of overland transportation.