SOLID FUEL COMBUSTION CHAMBER PROGRESS REPORT XVI

July-December 1989

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Delft/Rijswijk, The Netherlands

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1. INTRODUCTION

In this Report an overview of the July-December 1989 period of the solid Fuel Combustion Chamber (SFCC) project (phase 2) is given. This project was initiated in 1982 and aims at developing a capability to predict the performance of SFCC's in order to be able to evaluate the SFCC for e.g. Solid Fuel RamJet (SFRJ) propulsion, hybrid rocket propulsion, turbine propulsion and for the clean combustion of waste materials. The planned work is directed at:

- Improving the knowledge of the combustion behaviour (i.e. regression behaviour, combustion efficiency, flame temperature and composition, flammability limits and combustion instability) in turbulent channel flows. Variables to be considered are: chamber pressure, mass flow, air temperature, and oxygen content of the air.

- Determining the effects of size, configuration variables (inlet shape, aft mixing chamber/bye-pass) and different fuels (including waste materials) on the combustion behaviour.

To this end, both experimental and theoretical research activities have been planned. A more detailed description of the project is given in [1-3].

Management, finances and personnel are discussed in Chapter 2.

Chapters 3 and 4 present an overview of the activities carried out by the theoretical and experimental working group, respectively.

An overview of the project status is given in Chapter 5, whereas an outline of the planned program for the next half year period is given in Chapter 6.

Chapter 7 reports on utilization aspects.

In Chapters 8 and 9, an overview on publications, reports, presentations and contacts are given.

Chapter 10 reports on student involvement in the project during this period.
2. MANAGEMENT ASPECTS, FINANCES AND PERSONNEL

In 1989, total expenditures amounted to approximately:

- kf 96 for small equipment and consumables
- kf 28 for computing (FAEDUT only)

Furthermore, approximately kf 100 was transferred from the budget for large investments to the budget for personnel. This was possible, since no further large investments were foreseen.

Current resources are (November 8, 1989):

- budget for small equipment and consumables: kf 44
- budget for large investments: kf 21

The budget for computing at FAEDUT for 1990 is kf 75 and includes approximately 30 hours on a Cray supercomputer (2 kf/hr).

Concerning personnel, it is reported that:

. During this period (starting from July 1, 1989) a total of 6 students have been involved in the project. Their activities have been guided by F. Dijkstra, P.J.M. Elands, T. Wijchers, J.P. de Wilde and B.T.C. Zandbergen, see also Chapter 10.

. Dr. T. Wijchers is currently employed by PMLTNO (Starting August 1, 1989).

. The contribution of J. v.d. Brand (technical assistant) has been reduced from 5 to 4 days per week.

. Starting from January 1, 1990, Ir. P.J.M. Elands' contribution to the project will be on a part-time basis.

For the next period, it is noted that the contract of F. Dijkstra with FAEDUT expires on June 1, 1990.
3. ACTIVITIES OF THE THEORETICAL WORKING GROUP (TWG)

During this period, the activities of the TWG mainly concentrated on the modelling of fuel pyrolysis. Furthermore, also some attention was given to vortex generated acoustics, chemical equilibrium calculations and chemical kinetics.

3.1. Study of physical processes (combustion)

3.1.1. Flow dynamics

- Vortex generated acoustics (B.T.C. Zandbergen)

From SFCC experiments, it is known that the combustion process in a SFCC is accompanied by the regular shedding of vortices near the step and by temperature and pressure oscillations. The latter two have about the same frequency as the vortex shedding and therefore are believed to be caused by this vortex shedding. Furthermore, it is known that, under certain conditions, these pressure and temperature oscillations are unstable, thus indicating combustion instability.

In order to determine whether this vortex shedding really can be the cause for combustion instability, the interaction between this vortex shedding and the pressure oscillations has been studied, theoretically, for a 'free-jet' configuration. This study was conducted by R. Poland, graduate student of FAEDUT, under the guidance or ir. G. Schouten (FAEDUT, Fluid Dynamics Section). The results of this study indicate that, for this configuration, vortex shedding can be ruled out as the cause for combustion instability. No conclusions could be made with respect to the SFCC geometry. Therefore, at the moment, ir. G. Schouten is working on a confined-jet model, which is believed to be a reasonable approximation of the SFCC.

3.1.2. Combustion chemistry

- Soot formation (P.J.M. Elands)

To allow detailed modelling of the radiative heat transfer occurring in a SFCC, detailed knowledge is required of the soot present in the SFCC. Therefore, several models for the determination of the soot concentration and the soot particle size have been studied. It is found that these models are not only fairly complex, but also of a highly empirical nature. The latter severely restricts the validity of the various models available. Because of this, it has been decided to postpone implementing a soot model in COPPEF, until significant advancements are made in the modelling of soot formation and destruction.

- Chemical kinetics (B.T.C. Zandbergen)

During this period, several reaction mechanisms for ethylene-oxygen combustion have been studied. As a result a new, more recent reaction mechanism has been selected and adapted for use with COPPEF. This mechanism predicts ignition times, which in general are a factor 5-10 faster than the ignition times predicted when using the old mechanism. The results of this study have been reported by W. Altheer, see also Chapter 10.
Chemical equilibrium (P.J.M. Elands)

In order to allow for the modelling of the influence of turbulence on combustion, it has been investigated whether weighting of the mass fractions can be used to model the interaction between turbulence and combustion. The results so far are negative.

3.1.3. Heat transfer (P.J.M. Elands)

- Radiative heat transfer.

In order to allow for a better comparison with experiments for which radiative heat transfer is not negligible, a simple radiative heat transfer model, in which the radiating combustion gases are considered as a radiating grey-body, has been incorporated in COPPEF. This model requires that both the emission coefficient and the radiation temperature are measured during the experiment.

- Convective heat transfer

The convective heat transfer model incorporated in COPPEF has been improved by taking into account the fact that the dynamic and kinematic viscosity are temperature dependent.

3.1.4. Fuel regression/pyrolysis (J.P. de Wilde)

The work of Ir. J.P. de Wilde on the modelling of fuel pyrolysis in connection with combustion and more particular fuel regression is progressing steadily. The aim of the work is to develop a theoretical model which allows for the determination of the heat of gasification of the solid fuel and the temperature and the composition of the gaseous fuel injected into the combustion chamber. The reason for the work is that, at the time that the study was initiated (September 1987), these data were taken rather arbitrarily.

At the beginning of this period, the following achievements had already been accomplished:

- A model has been set up relating fuel composition, fuel temperature and the heat of gasification.
- Based on the assumption that, during pyrolysis, only the monomer is formed, the heat of gasification of both PMMA and PE has been determined as a function of temperature.
- A time-independent model has been set up which gives the composition of the pyrolysis products of PMMA as a function of temperature.
- Using the above-mentioned time-independent model for the composition of PMMA, the heat of gasification of PMMA has been determined as a function of temperature.

During this period, attention mainly focused on:

- The development of a time-dependent lumped stoichiometric model which gives the composition of the pyrolysis products of PE as a function of temperature. Based on this model the heat of gasification of PE has been calculated, see Figure 1.
The development of a fuel pyrolysis model based on the assumption that the temperature at which pyrolysis occurs, the so-called pyrolysis temperature, is constant:

The main problem in developing this model for the SFCC is the determination of this temperature. One approach is to assume that this temperature is equal to the temperature which follows from an extrapolation of TGA-DSC experimental results. Based on this assumption, it was found that the pyrolysis temperature is approximately 1000 K for PMMA and 1100 K for PE.

Development of a model which allows for determining the temperature history of the fuel based on the use of TEMPROF:

TEMPROF is a numerical code, which allows for the calculation of the temperature history of a regressing solid fuel, assuming constant fuel properties and a constant inner wall temperature. As a first step in the development, TEMPROF has been adapted to allow for temperature dependent fuel properties. For this work, ir. J.P. de Wilde has been assisted by I. Croiset, see Chapter 3.

Based on the assumption that, during pyrolysis, only the monomer is formed, the heat of gasification of HTPB has been determined as a function of temperature:

It is found that for HTPB, assuming that the pyrolysis occurs at a temperature of 800 K, the heat of gasification is approximately 3200 kJ/kg.
For the next period, the following activities are planned:

- Verification of the TGA-DSC results.
- Development of a model, which allows for the calculation of fuel pyrolysis based on the assumption of a constant heating rate.
- Further development of the TEPROF-based model.
- Development of both a time-dependent and a lumped stoichiometric model for determining the composition of the pyrolysis products of PMMA.
- Determination of the effect of detailed pyrolysis modelling on SPCC performance prediction (in cooperation with ir. P.J.M. Elands).

3.2. Validation/verification of COPPEF (version 3.0)

In order to allow for a comparison with experimental data, several calculations have been made concerning the combustion of ethylene with air.

Heat transfer rates, which were obtained from a comparison of experimental temperature profiles with calculated profiles using Temprof, have also been used for comparison with COPPEF. This comparison showed a large discrepancy between the heat transfer rates determined from COPPEF and the rates determined from the experiments. The reason for this is not clear yet.

3.3. Programming and computing aspects

- Numerical routines (J.P. de Wilde and P.J.M. Elands)

Several numerical routines have been developed for calculating the heat of gasification and the composition of the pyrolysis products of PE and PMMA as a function of temperature.

From the fuel pyrolysis study it is known that, during pyrolysis, possibly not only the monomer is formed, but also other products. Because of this, COPPEF has been provisionally adapted to also allow different fuels to be blown in the chamber.

Chemical equilibrium has been implemented (provisionally) in COPPEF.

Machine-independent routines have been developed for the calculation of the beta and gamma functions which are used in the COPPEF computer code.

- Numerical methods

No work has been done to improve numerical methods.

- The user's manual (H. Ablij).

The comments have been incorporated in the preliminary version of the COPPEF computer code.
4. ACTIVITIES OF THE EXPERIMENTAL WORKING GROUP (EWG)

4.1. Experimental studies

4.1.1 Effect of operational variables (F. Dijkstra)

Available data on the regression rate and the combustion efficiency, as a function of the operational conditions (air mass flow and pressure), have been analyzed for PE and PMMA. Because of this, an extra 30 experiments are planned to get a more complete picture. Also, a special study has been initiated which aims at determining the flammability limits.

4.1.2. Effect of geometry and configuration variables (F. Dijkstra)

In the previous period, several experiments were conducted in order to determine the influence of the inlet geometry on the average (weighted) regression rate, the regression rate distribution and the combustion efficiency. Currently, these data are being analyzed.

4.1.3. High energetic fuels (F. Dijkstra)

Currently, the SFCC is evaluated for SFRJ propulsion. The aim is to get high regression rates and combustion efficiencies. The fuel used is HTPB or HTPB plus additives (e.g. aluminium and boron). The test conditions used, are comparable to the conditions which result for a ramjet powered flight. To date, several tests have been carried out. The results look promising, especially for HTPB with aluminium as an additive.

4.1.4. Fundamental studies (T. Wijchers)

A number of experiments have been carried out using the perspex flow model of the 2-D burner. These experiments were aimed at investigating whether the flow in the 2-D model is two-dimensional or not. Initial results indicate that the flow is reasonably two-dimensional, except for the turbulent component of the flow.

4.2. Experimental instrumentation

4.2.1. Diagnostics and measurement techniques

- USPET (F. Dijkstra)

Several tests have been conducted to verify whether it is possible to measure the instantaneous regression rate at more than one location along the grain (2 cm apart) without interference. The results confirmed that there is no interference between the different measurements.

The final report on the use of ultrasonics for regression rate measurements is in an advanced stage.

- LDV (T. Wijchers)

A memorandum on the use of LDV for gas flow measurements has been submitted for publication. The software to control the LDV measurements is now available. However, there are still some deficiencies in the software.
- Movable thermocouple (T. Wijchers)

The first phase of the development of the movable thermocouple has been completed. The results of this phase clearly showed the potential of the movable thermocouple to determine the temperature profile in a SFCC, except in the vicinity of the solid fuel surface. A disadvantage of the method is, however, that the method is very delicate and requires special skill.

- OSMA (T. Wijchers)

A proposal to modify the spectroscopic (OSMA) system, in order to allow the determination of the relative concentrations of CH and C, as a function of the location along the axis of the SFCC has been approved and a design has been made.

- Gas sampling device (J.P. de Wilde)

The construction of the gas sampling device, necessary to evaluate the pyrolysis modelling, has been completed. However, gas sampling tests have been delayed, due to the fact that the pressure gauge was damaged during calibration. A new pressure gauge is on order.

4.2.2. The experimental facility (F. Dijkstra)

- The three-way valve

During this period, it was found that the three-way valve was damaged. This was possibly due to the fact that, for some experiments, the vitiator was operated at exceptionally high temperatures. At the moment, the valve is being repaired. Furthermore, in future, the valve will be inspected more regularly.

- The ignition system.

As of shortage of manpower in the PMLTNO workshop, the development of the improved ignition system has again been delayed. Because of limited time available, it therefore has been decided (December 1989), in favour of the by-pass system, to halt the development of the improved ignition system completely. This will restrict the attainable massflow in the SFCC to about 1 kg/s.

- The inlet.

Together with the ignition system, also the development of the honeycomb structure, which has to improve the flow dynamics in the inlet, has been halted.

- The by-pass system.

Construction of the by-pass system has been delayed due to modifications in the design. These modifications were necessary because of the high cost of the initial design. Construction is now expected to be ready in the first quarter of 1990.
5 STATUS OF THE PROJECT

PHASE 1 ACHIEVEMENTS:

- Initial (theoretical) studies on the application of SFCC's for coal gasification, combustion of waste materials and ramjet propulsion.
- Development of connected pipe test facility, to allow testing of a prototype SFCC (blown mode).
- Development of prototype SFCC.
- Development of vitiation to allow ram inlet simulation.
- Development of SCMC to allow accurate determination and control of air mass flow.
- Initial development of a pyrometer for determining (mean) gas temperatures as a function of the location along the axis of the SFCC.
- Initial development of USPET for local instantaneous regression rate measurements.
- Theoretical determination of characteristic velocity and combustion temperature (as a function of the mixture ratio).
- Development of combustion chemistry model based on finite rate chemical kinetics (FRCK).
- Development of SFCC flow model (COPPEF) and integration with FRCK combustion chemistry model.
- Initial experimental determination of:
  . the weighted average regression rate and the combustion efficiency as a function of air mass flow, oxygen content, chamber pressure and step height.
  . local instantaneous regression rate.
  . soot production as a function of pressure.
  . temperature distribution.
  . gas composition (restricted to C\textsubscript{2}, CH and OH).

PHASE 2 ACHIEVEMENTS (UNTIL SO FAR)

- Development of combustion chemistry model based on the diffusion flame concept and integration in COPPEF.
- Inclusion of turbulence-chemistry interaction in COPPEF (diffusion flame model).
- Inclusion of a simple fuel pyrolysis model in COPPEF.
- Theoretical studies concerning the application of SFCC's for hybrid rocket propulsion and ramjet propulsion.
- Final development of USPET.
- Final development of (two-colour) pyrometer.
- Initial development of a movable thermocouple for local temperature measurements in a SFCC.
- Incorporation of a simple radiative heat transfer model in COPPEF.
- Determination of overall concentration of C\textsubscript{2}, CH and OH species.
- Extended measurements on the weighted average regression rate and combustion efficiency as a function of air mass flow, air temperature, chamber pressure step height and oxygen content of the air.
- Video showing vortex shedding.
- Development of a simple model to predict combustion instability based on the assumption that combustion instability is induced by vortices, which are formed at the sudden expansion near the step.
- Initial validation/evaluation of COPPEF.
ACHIEVEMENTS STILL TO BE FULFILLED DURING PHASE 2 (until March 1991):

- Determination of the flammability limits.
- Investigation of high energetic solid fuels.
- Further development of fuel pyrolysis model and incorporation in COPPEF.
- Investigation of the effects of by-pass configurations.
- Investigation of the effect of the inlet geometry.
- Incorporation of chemical equilibrium combustion model (STANJAN) in COPPEF.
- Flowfield (velocity) measurements (cold flow).
- Temperature distribution measurements.
- Determination of C₂ and CH species concentrations as a function of the position along the x-axis.
- Validation/evaluation of COPPEF.
6. **HALF YEAR WORKPLAN**

This chapter presents an outline of the planned program for the period January-June 1990. This plan is part of the planned program for the remaining of phase 2, which has been discussed at the 15th meeting of the user's committee on 8 December 1989.

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7. UTILIZATION ASPECTS AND SPIN-OFF

- Airbreathing propulsion.

NLR/SPE/PML study:
The scope of the study is to develop engineering know-how to design and construct ramjet type of engines for both launcher and missile propulsion. Study duration is approximately 5 years. Estimated costs are Mf1 10. Phase 0 has been successfully completed. Phase 1 is in progress, whereas phase 2 is in preparation. Part of phase 1 is the development of a high temperature (2000K) vitiator.

PMLTNO study:
PML has performed a study for the Dutch Ministry of Defence, concerning the use of solid fuel ramjet propulsion for 'small' projectiles. A request for further study is expected.

- Hybrid propulsion.

Although, it has been reported to the User's Committee that hybrid rocket propulsion offers several advantages compared to liquid rocket propulsion [3], no requests for further information have been received. Therefore, it is concluded that interest is minimal.

- Other.

SCMC:
Although, Dinfa has expressed strong interest in commercially developing the SCMC, Dinfa still hesitates to make the final decision. Therefore, as an alternative, Stork Servex has been asked, whether they are interested in commercially developing the SCMC. However, to date, no reaction has been received.

USPET:
A formal offer, concerning the sale of the FAEDUT/PMLTNO developed ultrasonic equipment, has been sent to Vikram Sarabhai Space Centre (India).

DLR (Germany) has expressed interest in the FAEDUT/PMLTNO developed ultrasonic equipment. Within the framework of the existing DNAP, an offer has been made to DLR to borrow our equipment (free of charge) for a period of one month in the first quarter of 1990.

Connected pipe testfacility:
Although Royal Ordnance (UK) has agreed with the terms mentioned in our offer to use our facility, no date has been set yet.

Study in cooperation with DLR:
DNAP (Germany): The study mainly concentrated on heat transfer. A final presentation of the results has been given at PMLTNO on 15 september 1989. The results will also be presented at the 1990 AIAA/ASME Thermophysics and Heat Transfer Conference in Seattle. Topics for further work are still subject of discussion.

Study in cooperation with NWC:
DEA (USA): The work mainly concentrated on the influence of the inlet geometry on the performance of the SFCC. The results will be presented at the 31st Annual Israel Conference on Aviation and Astronautics, Israel. Further work is still subject of discussion.

Rolls Royce/ESA(ESTEC) hydrogen combustion study:
No news has been received concerning our offer to conduct:

- a literature review on existing experimental H₂-air/oxygen combustion data.

- experiments on H₂-air combustion.

- an assessment of the use of Finite Rate Chemical Kinetics (FRCK) for combustion modelling.

This offer was made with respect to a request for proposal from Rolls Royce.

Information exchange agreement with Instituto Superior Tecnico (Portugal):
In 1989, FAEDUT and PMLTN0 reached an agreement with IST to exchange information on the modelling of heat and mass transfer in reacting flows. As part of this cooperation, ir. P.J.M. Elands has visited IST during the period 23-27 October 1989. A written account of the visit is available.
8. PUBLICATIONS AND PRESENTATIONS

Reports

1. SFCC no. 40  Geld, C.W.M. van der
   LR-513 "On the direct simulation of vortex shedding",

2. SFCC no. 54  Elands, P.J.M.
   LR-567 "The Modelling of Heat and Mass Transfer near
   PML 1988-C159 Solid Boundaries and Comparison with Experimental
   Results", November 1988.

3. SFCC no. 56  Wittenberg, H. et.al.
   LR-591 "Solid Fuel Combustion Chamber Progress Report XIV,

Publications in Journals and Conference Proceedings

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Presentations


In preparation

- Report on the validation of the ultrasonic pulse-echo technique for regression rate measurements in the SFCC.

- Memorandum 'Enthalpy and entropy of organic compounds from group contributions'.

- Article 'Combustion of polyethylene in a solid fuel ramjet - a comparison of computational and experimental results' for publication in 'Propulsion & Power'.

- Article 'A two-element thermocouple for local flame temperature measurements in a solid fuel combustor' for publication in 'Combustion & Flame'.

- Paper 'Effect of inlet geometry on the flow and combustion processes in a solid fuel ramjet'.

- Paper 'Theoretical and experimental performance of a solid fuel ramjet combustion cycle for hypersonic flight conditions'.

- Paper 'Heat transfer in a solid fuel ramjet combustor'.

- Paper 'Experimental and computational flammability limits in a solid fuel ramjet'.

- Paper 'Ultrasonic regression rate measurements in solid fuel ramjets'.

- Paper 'Fuel pyrolysis models for combustion calculations'.
9. CONTACTS

<table>
<thead>
<tr>
<th>Institute/Perssons</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLR Institute for Chemical propulsion &amp; Engineering Lampoldshausen, BRD Prof.dr. H.J. Sternfeld Dr.ing. R. Pein and Dipl.ing. F. Vinnemeier</td>
<td>Co-operative research (DNAP) To DLR: Visit by J.P. de Wilde. To DLR: Concept of abstract of paper on heat transfer in a solid fuel ramjet combustor. To DLR: Offer for borrowing ultrasonic equipment. From DLR: Visit for data exchange</td>
</tr>
<tr>
<td>DUT Fac. of Aerospace Eng. General Fluid Dynamics Section Delft, The Netherlands ir. G. Schouten</td>
<td>Study on the acoustics of the SFCC; study manager</td>
</tr>
<tr>
<td>HDOTNO Den Haag, The Netherlands Dr. D.W. Hoffmans</td>
<td>From HDO: Confirmation of patent SCMC.</td>
</tr>
<tr>
<td>Hogeschool Haarlem Sektor Techniek Haarlem, The Netherlands L.G.K. Können</td>
<td>To Haarlem: Request for student assistance for both theoretical and experimental work.</td>
</tr>
<tr>
<td>Herculus Bacchus Magna, Utah, USA Dr.C. Gardner</td>
<td>To Herculus: Request for information on ultrasonics.</td>
</tr>
</tbody>
</table>
Instituto Superior
Tecnico (IST)
Dep. of Mech. Engineering
Lisbon, Portugal
Prof. M.N.R. Nina and
Prof. M.G. Carvalho

From IST: Approval of proposed information exchange agreement.
To IST: Confirmation of visit of ir. P.J.M. Elands.

Technion-Israel Inst. of Technology
Faculty of Aerospace Eng.
Haifa, Israel
L. Banks-Sills

From Israel: Letter informing that our paper entitled 'Effect of Inlet Geometry on the Flow and Combustion Processes in a Solid Fuel Ramjet' has been accepted for presentation at the 31st Israel Annual Conference on Aviation and Astronautics.

Jet Propulsion Lab. (JPL)
Propulsion systems sect.
Pasadena, California, USA
Dr. L.D. Strand

To JPL: Visit of ing F. Dijkstra.
To JPL: Information on the use of USPET for regression rate measurements (as a result of the visit of ing F. Dijkstra).

Naval Weapons Center (NWC)
Propulsion Research
China lake, California, USA
Dr. K.C. Schadow and K. Wilson

From NWC: Visit of K. Wilson in order to prepare the co-operative paper on influence of inlet geometry on SFRJ combustor performance and to acquaint himself with USPET technology.

Royal Ordnance (RO)
Summerfield
Kidderminster
Worcestershire, UK
Dr. M.J. Chase

From RO: Telefax requesting an offer for conducting 3 trials.
To RO: Offer for conducting 3 trials.

SFCC User's Committee

15th meeting of the User's Committee. A detailed account of the meeting is available from STW

STW
Utrecht, The Netherlands
Dr. C. le Pair

From STW: Information concerning funds for traveling abroad.

Vikram Sarabhai Space Centre
Trivandrum, India
Dr. D. Deepak

To VSSC: Letter informing VSSC that we have limited approval to transfer USPET technology to India.
10. STUDENT INVOLVEMENT

During this period, the following students have contributed to the project:

Croiset, I.
Student FAEDUT:
Evaluation of TEMPROF for regression rate calculations, see Sec. 4.1.1.
Engineering thesis, starting date 5/2/'88.
Status: a report is being prepared.

Dorpema, H.
Student FAEDUT:
Development of a two-element thermocouple for gas temperature measurements in a SFCC and validation, see Sec. 4.2.1.
Status: completed

Calzone, R.F.
Student FAEDUT:
Study on methods to determine the flammability behaviour of SFCC's, see Chap. 4.
Engineering assignment, starting date 1/12/'89.
Status: A literature review is being conducted.

Poland, R.Y.C.M.
Student FAEDUT:
Combustion instability; eigen-frequencies and pressure oscillations, see Sec. 3.1.1.
Engineering thesis, starting date 1/10/'88.
Status: completed.

Ablij, H.
Student FAEDUT (student-assistent):
Update of the COPPEF user's manual, see Par. 3.2.
Starting date 14/1/'88.
Status: completed.

Altheer, W.
Student Rijswijk technical college:
Development of numerical routines and evaluation of new reaction scheme for ethylene, see Par. 3.3. and Sec. 3.1.2.
Apprentice work (3 months), starting date 1/12/'89.
Status: completed.
REFERENCES


ACRONYMS

BRD  Bundes Republik Deutschland (W. Germany)
CBU  Cray Billing Unit
COPPEF COmputer Program for calculation of (2D) Parabolic and Elliptic Flows
DLR  Deutsche Forschungs und Versuchsanstalt fur Luft- und Raumfahrt
DUT  Delft University of Technology
EWG  Experimental Working Group
FAEDUT Faculty of Aerospace Engineering, DUT
FRCK Finite Rate Chemical Kinetics
HDOFTNO Hoofdgroep Defensie Onderzoek, TNO (Defense Research Div., TNO)
HTPB Hydroxyl Terminated Poly Butadiene
LDV  Laser Doppler Velocimetry
NLR  National Aerospace Laboratory
NWC  Naval Weapons Centre
PE   PolyEth(yl)ene
PMMA PolyMethylMethAcrylate
PMLTNO Prins Maurits Laboratory, TNO
SCMC Sonic Control and Measuring Choke
SFCC Solid Fuel Combustion Chamber
SFRJ  Solid Fuel RamJet
SPE BV Stork Product Engineering BV
STW  Stichting voor de Technische Wetenschappen (Technology Foundation)
TNO  Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Organization for Applied Scientific Research)
TWG  Theoretical Working Group
UK   United Kingdom
USPET Ultra Sonic Pulse-Echo Technique
WGS  Werkgroep Gebruik Supercomputers (Working group for the use of supercomputers)