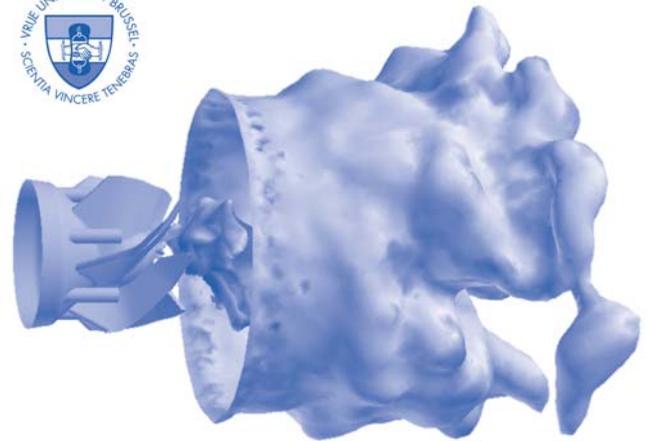




# CLEAN COMBUSTORS FOR INDUSTRIAL GAS TURBINES

**CAME-GT**

THEMATIC NETWORK FOR CLEANER & MORE EFFICIENT GAS TURBINES



*February 9 - 13, 2004*

VON KARMAN INSTITUTE FOR FLUID DYNAMICS

72, Chaussée de Waterloo

1640 Rhode-Saint-Genèse, Belgium

Tel : +32 (0)2 359 96 04 - Fax : +32 (0)2 359 96 00

e-mail : [secretariat@vki.ac.be](mailto:secretariat@vki.ac.be) - web site : <http://www.vki.ac.be>

## INTRODUCTION

Environmental concerns are becoming more important and increasingly severe regulations are being applied to limit pollutant emissions. Gas turbines contribute significantly to CO and NO<sub>x</sub> emissions. For this reason, the design of clean combustors is of primary importance. This Lectures Series intends to give an overview of the necessary tools to perform the design of a clean combustor with particular emphasis on industrial gas turbines. The course will start with an overview of the different types of industrial gas turbines and their place in energy production. The different fuels, including alternative fuels, will be described and emission regulations will be discussed.

An introduction to the chemistry of combustion will then be given. This will cover the destruction of hydrocarbons, the formation of CO and NO<sub>x</sub>, and the effects of pressure, temperature and stoichiometry. Possible solutions to minimize pollutant production will be proposed.

Regarding computational fluid dynamics techniques, emphasis will be placed on the application of Large Eddy Simulation (LES) to flow in combustors. Next, numerical techniques for acoustic codes will be described. Finally, computational results will be presented for two cases: a laboratory burner and a pilot burner designed for 'quiet' combustion (i.e. with controlled levels of instabilities).

## Timetable

### Monday 9 February 2004

08:45 REGISTRATION

*Prof. M. Carbonaro, Director, von Karman Institute*

09:00 WELCOME ADDRESS

*Iskender Gökalp, CNRS,*

*Laboratoire de Combustion et Systèmes Réactifs, Orléans, France*

09:30-10:45 **INDUSTRIAL GAS TURBINES AND FUELS**

11:00-12:15 **EMISSION REGULATIONS**

*Thierry Poinot, Institut de Mécanique des Fluides de Toulouse, France*

14:00-15:15 **MODERN CFD METHODS: LES**

15:45-17:00 **MODERN CFD METHODS: acoustic codes**

17:00 WELCOME RECEPTION

### Tuesday 10 February 2004

*Thierry Poinot*

09:00-10:15 **MODERN CFD METHODS: examples**

*Alexander Konnov, Vrije Universiteit Brussel, Belgium*

10:45-12:00 **COMBUSTION CHEMISTRY: hydrocarbon destruction, CO formation**

14:00-15:15 **COMBUSTION CHEMISTRY: NO<sub>x</sub> formation and kinetics**

15:45-17:00 **COMBUSTION CHEMISTRY: NO<sub>x</sub> formation and kinetics**

Regarding experimental techniques, a large portion of the course will be dedicated to optical techniques (PIV, CARS, LIF, PDPA, LDA, IR-pyrometry, flame visualisation). Thermocouple measurements and exhaust gas sampling techniques for gas analysis will also be described. The session will conclude with the description of experiments in combustors such as a natural gas fired heavy-duty combustor, a liquid fuel fired aero engine combustor and IR pyrometry on film cooled combustor walls.

Finally, technical aspects of clean combustion systems will be presented. This will cover combustor design basics, fuel injection systems for gas and oil, staging concepts, NO<sub>x</sub> abatement strategies, heat transfer, cooling, combustor dynamics and means to control instabilities.

The Director of this Lecture Series is Dr. Rémy Dénois of the von Karman Institute. The lectures are organized in collaboration with the Education Cluster (Pr Jacques De Ruyck at the VUB) of the thematic network CAME-GT (Cleaner And More Efficient Gas Turbines), led by David Pollard, ALSTOM. The lecturers are specialists from universities and industry.

### Wednesday 11 February 2004

*Rainer Koch, Universität Karlsruhe, Germany*

09:00-10:15 **EXPERIMENTAL TECHNIQUES : PIV, LIF, CARS, Pyrometry, PDPA**

10:45-12:00 **EXPERIMENTAL TECHNIQUES : gas sampling techniques**

### Thursday 12 February 2004

*Rainer Koch*

09:00-10:15 **EXPERIMENTAL TECHNIQUES : examples of experiments**

*Werner Krebs, Siemens, Germany*

10:45-12:00 **TECHNICAL COMBUSTION SYSTEMS:**

**requirements for clean combustors**

*Peter Flohr, ALSTOM Power, Switzerland*

14:00-15:15 **TECHNICAL COMBUSTION SYSTEMS:**

**basics, fuel injection techniques**

15:45-17:00 **TECHNICAL COMBUSTION SYSTEMS:**

**staging and pollutant abatement strategies**

### Friday 13 February 2004

*Werner Krebs*

09:00-10:15 **TECHNICAL COMBUSTION SYSTEMS:**

**heat transfer and cooling**

10:45-12:00 **TECHNICAL COMBUSTION SYSTEMS:**

**combustion dynamics and control**

Lunch will be taken from 12h30 to 13h45, Friday included. Coffee breaks are scheduled each morning and afternoon.

*Please pass this announcement to someone who may be interested if you are unable to attend the Lecture Series yourself*



- INTRODUCTION TO MEASUREMENT TECHNIQUES  
(OCTOBER 6-10, 2003)
  - INTRODUCTION TO MAGNETO-FLUID DYNAMICS  
FOR AEROSPACE APPLICATIONS  
(OCTOBER 27-30, 2003)
  - LOW RE AERODYNAMICS ON AIRCRAFT INCLUDING  
APPLICATIONS IN EMERGING UAV TECHNOLOGY - RTO-AVT-VKI LS  
(NOVEMBER 24-28, 2003)
  - INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS  
(JANUARY 12-16, 2004)
  - TURBINE BLADE TIP DESIGN & TIP CLEARANCE TREATMENT  
(JANUARY 19-23, 2004)
  - CLEAN COMBUSTORS FOR INDUSTRIAL GAS TURBINES  
(FEBRUARY 9-13, 2004)
  - ADVANCED MEASUREMENT TECHNIQUES FOR  
AERO ENGINES & STATIONARY GAS TURBINES  
(MARCH 1-5, 2004)
  - ADVANCES IN AEROACOUSTICS & APPLICATIONS  
(MARCH 15-19, 2004)
  - INTRODUCTION TO TURBULENCE MODELING  
(MARCH 22-26, 2004)
  - HEAT TRANSFER AND INVERSE ANALYSIS - RTO-AVT-VKI LS  
(APRIL 26-30, 2004)
  - CRITICAL TECHNOLOGIES FOR HYPERSONIC  
VEHICLE DEVELOPMENT - RTO-AVT-VKI LS  
(MAY 10-14, 2004)
  - 34<sup>TH</sup> COMPUTATIONAL FLUID DYNAMICS -  
AEROELASTICITY & MULTIDISCIPLINARY OPTIMIZATION  
(MAY 24-28, 2004)
-

## COURSE FEE

The full fee for the lecture series is 1200 €. A fee of 900 € (25% reduction) is applicable to citizens of NATO Countries except Canada, Denmark, Greece, The Netherlands and UK. The fee includes printed notes, transport between VKI and the recommended hotels, lunches, beverages, and administrative costs.

## FELLOWSHIPS

To encourage greater participation in our Lecture Series programme by university members, the Institute has established a limited number of VKI Lecture Series Fellowships for participants from NATO countries\*. The recipient of a fellowship is entitled to attend the Lecture Series at a reduced fee, which will be of 450 € for assistants not having a Ph.D. degree and for Ph.D. candidates, or 225 € for undergraduate students. These reduced fees are also available for NATO citizens\* coming from a university in another country.

The request to be considered for an award must accompany the application to attend the Lecture Series, and the applicant must provide a recommendation letter from his or her professor; if not done so, the request will not be taken into consideration. All possible alternative sources of funding should be investigated before aid is requested under this scheme, so that those most in need will benefit.

\*except Canada, Denmark, Greece, The Netherlands and UK.

## Accommodation & Transport

Participants are advised to make their reservations as early as possible through VKI ([secretariat@vki.ac.be](mailto:secretariat@vki.ac.be)) in order to benefit from special rates offered by the recommended hotels listed below. Daily rates include all charges and continental breakfast.

### Hôtel des Colonies\*\*\*

<http://www.hotel-des-colonies.be> Single: 90 € / Double: 100 €

### Hôtel Vendôme\*\*\*L

<http://www.hotel-vendome.be> Single: 95 € / Double: 115 €

### Tulip Inn\*\*\*

<http://www.tulipinnbb.be> Single: 99 € / Double: 109 €

### Comfort Art Hôtel Siru\*\*\*

<http://www.comforthotelsiru.com> Single: 100 € / Double: 115 €

### Hilton Brussels City\*\*\*\*

<http://www.hilton.com> Single: 135 € / Double: 161 €

A youth hostel, *the Sleepwell* is within walking distance of the recommended hotels. We invite you to make your own reservation through their website e-mail : <http://www.sleepwell.be>

## METHODS OF PAYMENT

Payment 2 weeks prior to the beginning of the course (name and course title clearly indicated) by bank transfer to our account Nr 210-0315330-35 at Fortis Bank, avenue de la Forêt de Soignes 322, 1640 Rhode-Saint-Genèse, Belgium, IBAN BE57 2100 3153 3035 (strongly recommended).

Late registration can be paid cash in EURO, or by VISA or Eurocard at the beginning of the course.

Payment must be the equivalent of the fee at the prevailing rate of exchange.

## PROCEEDINGS

Lectures will be given in English and printed notes will be distributed during registration.

Proceedings of other lecture series may be purchased at VKI (e-mail : [vanhaelen@vki.ac.be](mailto:vanhaelen@vki.ac.be) or fax : 32 2 359 96 00). Information can be found on <http://www.vki.ac.be>.

## HOW TO REGISTER

It is highly recommended to send the registration/hotel reservation form at the latest 15 days before the beginning of the course. A letter of acceptance and additional information will be sent on receipt of the application form.

The hotels situated in Brussels are all within walking distance from the Gare du Nord and the Place Rogier. A train service links the airport with the Gare du Nord (15' journey). Complete your journey to the hotel/youth hostel on foot or by taxi. Each morning and evening, bus transport will be provided between the Place Rogier and the von Karman Institute, located in Rhode-Saint-Genèse, a suburb south of Brussels.

For those who travel by private car or want to be closer to the Institute, we recommend :

### Auberge de Waterloo\*\*\*\*

e-mail: [aubergedewaterloo@skynet.be](mailto:aubergedewaterloo@skynet.be)

Single: 106 € / Double: 118 €

Fax : +32 (0)2 358 38 06

Tel : +32 (0)2 358 35 80

Chaussée de Waterloo 212 - 1640 Rhode-Saint-Genèse

This hotel, which is about 1,5 km from the Institute, is about 12 km from the center of Brussels. Special transport between this hotel and VKI can be provided (contact the hotel reception upon arrival).

*For more information about the localization of the Institute and the hotels, please visit our website on <http://www.vki.ac.be>.*

# APPLICATION FOR ADMISSION TO VKI LECTURE SERIES

Lecture Series Title : .....

Family name : ..... First name : ..... Nationality : .....

Name & full address of organization, institution or university : .....

.....

.....

Telephone nr. : ..... Fax nr. : .....

Position or title : ..... e-mail : .....

Asking a reduced fee and joining a recommendation letter as :  Undergraduate student  Ph. D. candidate or University assistant

## HOTEL RESERVATION *(if applicable)*

I require accommodation at Hotel..... for ..... person(s)

Single : ..... Double : ..... Date of arrival : .....

I shall require transport to and from the Institute  Date of departure : .....

I do not require transport to and from the Institute

Please indicate any special needs (e.g. vegetarian, ...) : .....

Date : ..... Signature : .....

Please mail under cover to VKI