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ICS –UNIDO

and

UNIVERSITY OF CAPE COAST
LASER AND FIBRE OPTICS CENTRE

Workshop on

"COMBUSTION DIAGNOSTICS AND OPTICAL TECHNIQUES"

ORGANISED BY:

Laser and Fibre Optics Centre,
Department of Physics,
University of Cape Coast.

IN COLLABORATION WITH:

Tema Oil Refinery (TOR) TEMA,
Volta River Authority (VRA), TEMA.
Volta Aluminium Company (VALCO) Tema
Ghana National Petroleum Commission GNPC., Accra.
Department of Mechanical Engineering, Kwame Nkrumah University of Science Technology (KNUST) Kumasi, Ghana
Oil Companies.

Cape Coast, Ghana.

5th - 10th July, 1999.

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ICS-INTERNATIONAL WORKSHOP ON COMBUSTION DIAGNOSTICS AND OPTICAL TECHNIQUES, COCONUT GROVE BEACH RESORT 5 - 10 JULY, 1999

The International Workshop on Combustion Diagnostics and Optical Techniques to be held Sub-Saharan Africa, Ghana in Africa on 5th to 10th July, 1999 is a follow up of an Expert Group Meeting organised by the International Centre for Science and High Technology (ICS - UNIDO) in Trieste (Italy) in June, 1998.

The workshop is opened to scientists, researchers, engineers, environmentalists from Universities, Research Institutes, Industries and Government agencies in Africa. In all sixty participants would be coming from Algeria, Rwanda, Nigeria, Cote d'Ivoire, Ghana, Senegal, Sudan and United States of America. Lecturers engaged in this workshop are coming from The United Kingdom, France, Ghana, Italy and Hungary.

The workshop aims at promoting closer links between industries and research institutions; providing the know-how of optical and imaging diagnostics of on line monitoring of plant performance; encouraging the exchange of ideas between experts in developed and developing countries; creating awareness in combustion systems and the consequence of their emission. In order to fulfil the above aims, plenary lectures would be given and practical sessions would be organised. In addition, the workshop will examine the current activities and future prospects of Optical Physics in both pure and applied research.

This International Workshop is being organised by International Centre for Science and Technology ICS and UNIDO in collaboration with Tema Oil Refinery, (TOR), Ghana National Petroleum Corporation, Volta River Authority, Volta Aluminium Company, Department of Mechanical Engineering of Kwame Nkrumah University of Science and Technology amd also Laser and Fibre Optics Centre, University of Cape Coast.

The theme of the workshop, Combustion Diagnostics and Optical Techniques, tends to suggest that various topics on combustion system would be discussed and the use of optical methods to monitor the performance of the combustion process. also considered.

Combustion processes include small and large scale reactors, steady and unsteady processes, atmospheric as well as pressurised units, representing all kinds of industrial equipment from large furnaces in power generating plants, to small in-house burners for heating, gas turbines, automotive and aircraft engines, aerospace propulsion devices, and even undesired combustion processes such as fires and explosions.

Major activities in combustion systems for stationery sources (thermal plants, industrial processes, fuel combustion) and dynamic source (transportation) tend to be dictated by the following parameters such as:

a) fuel formulation
b) engine refinements
c) age of combustors and burners
d) flame characterisation
e) efficiency in energy conversion

Most stationery internal combustion engines are used to generate electric power, to pump gas or other fluids, or to compress air for pneumatic machinery. Smaller uses include irrigation, mining and hoisting and nuclear power plant emergency cooling water pump operation. Vehicular movements also do cause emissions of some gases.

The major emissions associated with such combustion systems include oxides of sulphur, Carbon Monoxide, Particulate Matter (dust, smoke, fly, ash, mist); hydrocarbons (hexane, benzene, methane butane etc) oxide of nitrogen, hydrogen fluoride. The Poly-aromatic hydrocarbon pollution in air on the other hand, have some health hazards to the populace.

Monitoring such gases, however, provides accurate emission data, data input for modelling and information about plant performance.

We realise from the foregoing that the useful energy being produced has some pollution-related issues associated with it. There is therefore the need to undertake programmes aimed at diffusing awareness of the pollution consequences due to an increasing energy demand. This awareness should be stimulated at the level of advanced experts of technology, and managers of the wider economy of the nation.

The ultimate goal therefore is to provide steps towards higher efficiency and less polluting combustion systems. This process require the development of local expertise in combustion control for keeping in a correct operation the already existing plants, as well as for upgrading and retrofit of old installations. It is also needed to develop a research field which could address the development of instrumentation using high technology to assess the health effects of exposure to PAH pollution in air particulates.

In order to be abreast with such problems and be in a position to solve them, it is essential to concentrate on measures for the prevention, or at least the limitation of pollution towards optimisation and improvement of the used combustion equipment and technologies. It is sad however, to note that though industries and mines in Ghana have the will to undertake such measurements, there is lack of equipment to monitor the gas releases.

The workshop has been able to identify various methods of monitoring the combustion processes. Some of the emissions from these industries are inaccessible and as such the use of traditional monitoring techniques seem to be inadequate. Optical diagnostics, which induce minimal perturbation to a system and pursues non-contact probing provides information with high sensitivity and selectivity. There is the urgent need to explore other techniques that have no constraints in terms of access to the source of pollutants. In this regard, Laser techniques represent a possible

alternative for the detection, and monitoring of gases(in high temperature regime) from combustion systems for improved efficiency and good performance. The Laser measurement and probing techniques depend on Emission and Absorption Spectrometry, Laser Induced Fluorescence.

The workshop is therefore seeking for possible redress to these emission problems by linking up with research institutes such as Environmental Protection Agency, Centre for Scientific and Industrial Research, (CSIR), energy Board and the Universities come out with projects for our national development.
We are also aware that in Ghana, major air pollutants are currently not effectively monitored. The reason may be technical or logistics. The workshop has therefore provided a forum for all avenues of improving upon monitoring system, and for identified drawing of research to ensure clean combustion technologies as Ghana gradually develops industrially. The two industrial cities at Tema and Takoradi and the capital Accra should consider effective ways of controlling atmospheric pollutants. In addition activities in mining towns like Obuasi and Tarkwa should be closely monitored to ensure improved efficiency in energy conversion.

Research work has been going on in our cities and industrial sites and we hope that a consensus will be reached at this workshop to have a better co-ordination among scientists, technologists and researchers to work towards achieving cleaner combustion systems.. The workshop is therefore looking forward to initiating programmes to have NOx combustion controls, and optimised combustion operation to regulate ozone and acid rain effects. Other options for combustion controls based on selective catalytic reduction and selective non-catalytic reduction would be considered. Ironically, greater control on NOx emissions increase the emissions of Carbon Monoxide and Carbon dioxide. The release of such gases in greater quantities (Green house effect) has caused climatic variations leading to global warming.

The workshop is expected to deliberate on most of these issues and seek for redress to make our environment a comfortable place for human habitation

BY DR. P.K. BUAH-BASSUAH
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ICS International Workshop on

"COMBUSTION DIAGNOSTICS AND OPTICAL TECHNIQUES"

Cape Coast, Ghana,
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University of Science and Technology, Kumasi

BACKGROUND:

A number of human activities give rise to air pollutants. In developing countries, the major activities in this category are transportation (vehicular), fuel combustion for stationery for stationery sources (thermal plants), industrial processes, solid waste disposal and burning of wild forest fires (agricultural). The following major emissions associated with the above activities are: oxides of sulphur (sulphur dioxide, sulphur); carbon monoxide; particulate (dust, smoke, fly ash, mist); hydrocarbons (hexane, benzene, methane, butane etc); oxides of nitrogen; hydrogen fluoride are currently not being monitored. The reason for this situation may be twofold: one being technical and the other is logistics.

In Ghana the major sources of the hydrocarbon, oxides of nitrogen and sulphur from combustion processes are the petroleum refining plant and the numerous marketing

outlets of petroleum products. Vehicular transport also contributes to oxides of nitrogen into the atmosphere. The point source of emission of these pollutants from the refinery as well as those of steel smelters for example may be many feet above the ground or not easily accessible with the use of traditional monitoring techniques. The fundamental problem of all industries and mining areas in Ghana is the lack of equipment to monitor the gas releases. There is therefore the urgent need to explore other techniques that have no constraints in terms of access to the source of pollutants. In this regard laser techniques represent a possible alternative for the detection, prevention and monitoring of gases from combustion systems.

JUSTIFICATION:

The workshop is a follow-up of the Expert Group Meeting on Combustion Diagnostics and Imaging Techniques which took place at ICT, Trieste (Italy) in June 1998 and the ICS Training Course on Laser Diagnostics and Imaging Techniques, 1-5 March 1999. The workshop will examine current activities and future prospects of laser diagnostics in combustion, promote closer links between mines, industries and research institutions to encourage the exchange of ideas between experts in developed and developing countries.

OBJECTIVES:

- To promote closer links between industries and research institutions.
- To provide the know-how of optical and imaging diagnostics of on line monitoring of plant performance.
- To encourage the exchange of ideas between experts in developed and developing countries.
- To create awareness in combustion systems and the consequence of their emission.

OUTPUTS:

- 25 participants trained in the use of optical techniques in combustion diagnostics

PROFILE OF PARTICIPANTS:

The workshop is open to young scientists, researchers, engineers and environmentalists from universities, research institutes, industries and Government Agencies in Africa.

PROFILE OF RESOURCE PERSONS:

High level scientists from research institutions and laboratories in the field of combustion diagnostics:

1. Laser Diagnostics of Combustion
   Prof. Paul Ewart, Clarendon. Oxford Institute of Laser Sciences, Oxford (United Kingdom)

2. Industrial Methods for Combustion Processes
Prof. Jean Pierre Martin, Laboratoire d'Energetique Moleculaire et Macroscopie, Combustion CNRS et Ecole Centrale Paris (France)

3. Theoretical Development and Computer Modelling of Combustion
Dr. Denise Veynante, Laboratoire d'Energetique Moleculaire et Macroscopie, Combustion CNRS et Ecole Centrale Paris, Paris (France)

4. Laser Techniques I, II and III
Prof. Mohy S. Mansour, Mechanical Power Engineering Dept., The University of Cairo, Cairo (Egypt)

5. Optical Diagnostics in Combustion and Monitoring of Atmosphere
Dr. Piero Mazzinghi, National Institute of Optics (INO), Florence, (Italy)

6. Laboratory session
Dr. Miltcho Danailov, Laboratory for Laser and Optical Fibres, c/o Elettra, Synchrotron Radiation Facility, Trieste (Italy)

7. Laboratory session
Dr. Pal Apai, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest (Hungary)

8. Analysis of Combustion Processes.
Prof. F.O. Akuffo, KNUST, Kumasi (Ghana)

9. Combustion Modelling
Dr. Abeku Brew-Hammond, Dept. of Mechanical Engineering, University of Science and Technology, Kumasi, (Ghana)

10. Optical Diagnostics of Pollution
Dr. P.K. Buah-Bassuah, Laser and Fibre Optics Centre (LAFOC), Department of Physics, University of Cape Coast, Cape Coast, Ghana.

11. Case Study
Representative of mine industry

TENTATIVE PROGRAMME

LECTURES:

- **Air pollution due to combustion**
- **Modelling of combustion diagnostics**
- **Optical measurements methods**
- **Absorption and emission spectrometry**
- **Laser probing of combustion**

Laboratory sessions:

- **Imaging of flame to determine OH spectra**
- **LDV to monitor spray droplets**
- **Mach Zhender interferometer to monitor flame from Bunsen Burner**
- **Soot absorption**
- **Flame emission spectroscopy**

Visits:

- **Visit to Volta Aluminium Company**
- **Visit to Tema Oil Refinery**

DOCUMENTATION:

The documents available for the International Workshop will be:

1. Aide-Memoire of the training course
2. Programme
3. List of participants and lectures
4. Lecture notes, manuals and abstracts

LANGUAGE:

The International Workshop will be conducted in English. Participants should have a good command of this language.

VENUE:

The International Workshop will take place from 5 to 10 July, 1999 at the Conference Room of the Coconut Grove Beach Resort, Elmina, near Cape Coast (at about 175 km west of Accra).

FINANCIAL ADMINISTRATIVE ARRANGEMENTS

For those invited by ICS to participate in the training course, round-trip air-economy transportation from the airport of departure will be arrange and prepaid tickets issues where necessary. Accommodation will be made available in hotels in Cape Coast. A commuter bus will be provided for the transportation of participants and lecturers from the airport to Cape Coast and from the hotel to the workshop centre and return.

The participants will be required to bear all expenses in their home country incidental to travel abroad, including expenditures for passport, visa and any other miscellaneous items.

ICS will not assume responsibility for any of the following costs which may be incurred by the participants while attending the meeting:

1. compensation for salary or related allowances during the period of the event;

2. any costs incurred with respect to insurance, medical bills and hospitalization fees;

3. compensation in the event of death, disability or illness;

4. loss or damage to personal property of participants while attending the event.

VISA ARRANGEMENTS

Where applicable, participants are requested to arrange for their visa as early as possible at the Embassy of Ghana in their home country. In case of difficulties, please advise the contact person mentioned below.

LOCAL ORGANIZER AND CONTACT PERSON

Dr. P.K. Buah-Bassuah
Laser and Fibre Optics Centre (LAFOC)
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University of Cape Coast
Cape Coast, Ghana
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PROGRAMME

ICS International Workshop on
"COMBUSTION DIAGNOSTICS AND OPTICAL TECHNIQUES"
Cape Coast, Ghana,
5 - 10 July, 1999

PROGRAMME

SUNDAY, 4 JULY, 1999

09.00 - 12.00	Visit to Kakum Forest
12.00 - 14.00	Lunch Break
15.00 - 17.30	Visit to Elmina Castle

MONDAY, 5 JULY, 1999

08.00 - 08.50	Registration
09.00 - 10.30	<u>OPENING CEREMONY</u> Conference Room, Coconut Grove Beach Resort **Chairman: Mr. W.S. Parker** Chief Executive, Tema Oil Refinery Limited (TOR)
08.50 - 09.00	Invited Guests seated at the Conference Hall
09.00 - 09.10	**Introduction of Chairman and Invited Guest** **Dr. P.K. Buah-Bassuah** Local Organiser and Coordinator
09.10 - 09.20	**Chairman's response**
09.20 - 09.30	**Welcome Address: Prof. S.K. Adjepong,** Vice Chancellor, U.C.C.
09.30 - 09.40	**Goodwill message** a. ICS - UNIDO
09.40 -09.55	**Short Address: Hon. Lt. Col. C.K. Agbenaza (rtd)** Central Regional Minister
09.55 - 10.10	**Short Address: Hon. Cletus Avoka** Minister of Environment Science and Tech.
10.10 - 10.25	**Keynote Address: Hon. Ohene Kena** Minister of Mines and Energy
10.25 - 10.30	**Chairman's Closing Remarks**
10.30 - 10.35	**Vote of Thanks - Ms. Catherine Asante-Poku, TOR, Tema.**
10.35 - 11.00	Coffee Break

	<u>Morning Session I</u>
11.00 - 13.00	**Laboratory Session I** Visit to the Laser and Fibre Optics Centre by Dignitaries and Invited Guests.
13.00 - 14.30	**Lunch Break** <u>Afternoon Session I</u> **Chairman: Mr. W.S. Parker** Chief Executive, TOR
14.30 - 15.30	LECTURE 1 **Topic:** Combustion Process, What is it? **Speaker: Prof. F. Akuffo**
15.30 - 16.30	LECTURE 2 **Topic:** Principles of Laser Diagnostics for Combustion **Speaker: Prof. P. Ewart**
16.30 - 17.00	Coffee Break
17.00 - 18.00	<u>Afternoon Session II</u> **Chairman: Prof. J.P. Martin** Paris, France LECTURE 3 **Topic:** Monitoring air pollutants with spectroscopic techniques **Speaker: Prof. P. Mazzinghi**
19.00	**Reception:** **VENUE: Vice Chancellor Lodge** Vice Chancellor, U.C.C. & Chief Executive of TOR to host.

TUESDAY, 6 JULY, 1999

	<u>Morning Session II</u> **Chairman: Prof. F.O. Akuffo** Dean, Sch. of Eng. KNUST, Kumasi.
09.00 - 10.00	LECTURE 4 **Topic:** Applications of Laser Diagnostics in Flames and Engines **Speaker: Prof. P. Ewart**
10.00 - 11.00	LECTURE 5 **Topic:** Optical diagnostics of air pollutants, **Speaker: Prof. P. Mazzinghi**
11.00 - 11.30	Coffee Break

	<u>Morning Session III</u>
	Chairman: Prof. F.O. Akuffo
	Dean, Sch. of Eng. KNUST, Kumasi.
	LECTURE 6
11.30 - 12.30	**Topic:** Advanced Measuring Techniques in Flames; Flow, Field and temperature measurements
	Speaker: Prof. M. Mansour
12.30 - 14.00	Lunch Break
	<u>Afternoon Session III</u>
	Chairman: Prof. A. Ayensu
	INSS, CSIR, Accra.
	LECTURE 7
14.00 - 15.00	**Topic:** Combustion modelling -
	Speaker: Dr. A. Brew Hammond
15.00 - 15.30	Coffee Break
15.30 - 18.30	Laboratory Session II
20.00	Conference Dinner

WEDNESDAY, 7 JULY, 1999

	<u>Morning Session IV</u>
	Chairman: Prof. Mazzinghi
	INO, Firenze, Italy
	LECTURE 8
09.00 - 10.00	**Topic:** Introduction to Turbulent Combustion
	Speaker: Dr. D. Veynante
	LECTURE 9
10.00 - 11.00	**Topic:** Monitoring air pollutants in combustion,
	Speaker: Dr. P. K. Buah-Bassuah
11.00 - 11.30	Coffee Break
	<u>Morning Session V</u>
	Chairman: Dr. D.K. Dodoo
	Dept. of Chemistry, U.C.C.
	LECTURE 10
11.30 - 12.30	**Topic:** Needs for Optical Measurements in Combustion Processes for Energy Efficiency Improvement and Pollution Abatments
	Speaker: Prof. J.P. Martin
12.30 - 14.00	Lunch Break
	<u>Afternoon Session III</u>
	Chairman: Dr. S.Y. Mensah
	Head, Dept. of Physics, U.C.C. Cape Coast.

	LECTURE 11
14.00 - 15.00	**Topic**: Advanced Measuring techniques in Flames; major and minor species concentration measurements
	Speaker: **Prof. M. Mansour**
15.00 - 15.30	Laboratory Session III
20.00	Supper and Entertainment

THURSDAY, 8 JULY, 1999

05.00 - 16.30	Excursion to Tema and visit to Tema Oil Refinery (TOR) and Volta Aluminium Company (VALCO)
18.30 - 20.00	Dinner

FRIDAY, 9 JULY, 1999

	Morning Session VI
	Chairman: Dr. P.K. Buah-Bassuah
	Local Organiser/Coordinator, LAFOC, U.C.C. Cape Coast.
08.00 - 09.00	Round table conference (Resolution)
	Morning Session VII
	Chairman: Prof. Aba Andam
	Head, Dept. of Physics, KNUST, Kumasi.
	LECTURE 12
09.00-10.00	**Topic:** Turbulent Combustion Modelling: - Classical Reynolds averaging approaches - Large Eddy Simulations.
	Speaker: **Dr. Veynante**
	LECTURE 13
10.00 - 11.15	**Topic** (i) Improvement of the Modeling of Industrial Furnaces and Processes following Experimental Observations (ii) Analysis of Domestic Gas appliances for hot water production by Laser Induced Fluorescence and Fourier Transform Emission Spectroscopy Measurements.
	Speaker: **Prof. J.P. Martin**
11.15 - 11.30	Coffee Break
	Morning Session VIII
	Chairman: Dr. A. Owusu
	Dept of Physics, U.C.C. Cape Coast.
	LECTURE 14
11.30 - 12.30	**Topic**: Combustion processes in Oil Refinery
	Speaker: **Ing. K. K. Ditsa**
	LECTURE 15
12.30 - 13.00	**Topic**: CO_2 - TEA Laser-Based Lidar Dial system for the detection of hydrocarbon pollution in the atmosphere.

Speaker: Dr. Taib Gasmi

13.00 - 14.00 Lunch Break

Afternoon Session IV
Chairman: Prof. K. Yankson
Dean, Fac. of Science, U.C.C., Cape Coast.
LECTURE 16

14.00 - 14.30 **Topic:** Combustion processes in thermal plant and Energy generation: Takoradi Thermal Power Plant
Speaker: Ing. Stephen K. Doku

LECTURE 17

14.30 - 15.00 **Topic:** Combustion processes in Energy production: A case study in GNPC.
Speaker:

15.00 - 15.30 Coffee Break

15.30 - 18.30 Laboratory session IV

19.30 Dinner

SATURDAY, 10 JULY, 1999

Morning Session IX
Chairman: Mr. D.L. Lamptey
Head, Dept. of Agric. Engineer, U.C.C. Cape Coast.

CASE STUDY 1

08.30 - 09.00 **Topic:** Combustion processes of Diesel Engines in Manganese Mining activities
Speaker: Paul Wonkyi

LECTURE 18

09.00 - 09.30 **Topic:** Particle Image Velocimetry of Premixed Methane - Air Flames
Speaker: Prof. Yaw D. Yeboah

CASE STUDY 2

10.00 - 10.30 **Topic:** Aethalometer Applications for real time Monitoring of Combustion-derived Aerosol Carbon
Speaker: Dr. F. A. Akeredolu

10.00 - 11.00 Coffee Break

Morning Session X
Chairman: Mr. Brown Acquaye
Regional Fire Officer, Cape Coast
LECTURE 19

11.00 - 11.30 **Topic:** Combustion Processes Monitoring by the Environmental Protection Agency.
Speaker: Mr. Dyson T. Jumpah

LECTURE 20

11.30 - 12.00 **Topic:** Laser Doppler Velocimetry and High-Speed Video Imaging for Combustion and Emission Control Research -

Speaker: Prof. Yaw D. Yeboah

CASE STUDY 3

12.00 - 12.30 **Topic:** Pollutants from Combustion

Speaker: Mr. B. Addo

GAG Iduaprem Tarkwa

CLOSING CEREMONY

12.30-13.25		**Chairman: Prof. Y.S. Boafo** Pro Vice-Chancellor, University of Cape Coast Cape Coast
12.30-1235		Introduction of Chairman **Mr. Kofi Anane-Fenin** Dept. of Physics,U.C.C, Cape Coast
12.35-12.40		Chairman's Remarks
12.40-12.50	-	Short Address and Communiqué **Dr. P.K. Buah-Bassuah** Local Organiser/Co-ordinator, LAFOC
12.50-13.10	-	**Guest Speaker:** Address: **Mr. Tsatsu Tsikata** Chief Executive Ghana National Petroleum Corporation, Tema.
13.10 - 13.20	-	Chairman's Closing Remarks
13.20 - 13.25	-	Vote of Thanks : **Mr. P.K. Mensah**
13.30 - 14.30	-	Lunch
15.00	-	**D E P A R T U R E**

F. O. AKUFFO
SCHOOL OF ENGINEERING
UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI, GHANA

PRINCIPLES OF LASER DIAGNOSTICS FOR COMBUSTION

PAUL EWART
OXFORD INSTITUTE OF LASER SCIENCE
CLARENDON LABORATORY
OXFORD UNIVERSITY
OXFORD OX1 3PU
UNITED KINGDOM

ABSTRACT

Linear and non-linear optical diagnostic methods are outlined to explain the underlying physical principles Laser Induced Fluorescence, LIF; Coherent Anti-Stokes Raman Scattering CARS; Degenerate Four Wave Mixing, DFWM and related laser induced grating methods together with Polarization Spectroscopy, PS, are reviewed. The measurement of the important combustion parameters, especially temperature and species concentration, using these techniques is outlined Applications of these techniques to measurements in flames and engines are describe are described to illustrate their operation and relative merits for particular situations.

OPTICAL TECHNIQUES FOR DIAGNOSTICS OF COMBUSTION

Piero Mazzinghi
Istituto Nazionale di Ottica, Firenze, Italy

Abstract

Optical diagnostics techniques are the most powerful tools for the understanding of combustion processes and the detection of combustion products. Their main advantages are related to the minimal perturbation induced to the system, and to the non contact probing, which allows measurement in extreme temperature, pressure, and chemical environment, as that in flames.

An additional advantage is the possibility of most optical techniques to operate in image mode, allowing the geometrical localization of the parameter of interest.

Many optical interaction processes between optical radiation and gases can be used for this purposes, including emission, absorption, fluorescence, elastic and inelastic scattering.

The presentation will review all this processes, the experimental techniques, and the relative equipment, focusing on the simplest measurements which can be easily performed in the laboratories in developing countries. Some of the measurement will be also possible as training experiments, suitable to be performed with the equipment already existing in the Laser and Fibre Optics Centre of the University of Cape Coast. Indication will be aslo given on how to design, build and calibrate simple systems, like an optical pyrometer and an infrared radiometer, with minimal investment, using readily available parts and components.

Procedures and formulae for the extraction of Physical (temperature, pressure) and Chemical (molecular species) parameters from emission and transmission spectra will be also given, including a demonstration of use of the high resolution molecular database HITRAN.

An introduction to the Tunable Diode Laser Absorption Spectroscopy (TDLAS) will be also given, including the principles of Wavelength Modulation Spectroscopy (WMS).

Other Laser induced processes, as Laser Induced Fluorescence (LIF) as well as Brillouin and Raman scattering will be also presented, for applications not only in the direct analysis of the combustion process, but also concerning the analysis of the combustion products, possibly leading to environmental pollution.

In addition to the environmental application of the above mentioned , the two main optical remote sensing techniques will be discussed, namely the Differential Optical Absorption Spectroscopy (DOAS) and the Differential Absorption Lidar (DIAL).

COMBUSTION PROCESS AT VALCO

Ebenezer Avotri
Valco, Tema

1. Oil Supply

Oil to Valco for our furnaces is from the Tema Oil Refinery (TOR) by road using tankers. The oil is Bunker 'C' Residual Oil, viscosity at 100°F of 74 SSU with a Heat Value of 19,302 BTU/lb. The oil is delivered into two reservoir tanks with a capacity of 500,000 gallons each. The steam jackets in these tanks keep the oil hot to temperatures of 100°F. The oil is now pumped through electrically heat tracer pipes into smaller storage steam jacketed tanks at the usage points. Temperatures on these tanks can be adjusted depending on weather conditions.

The standby oil system is the Diesel fuel. To serve as

i. Standby oil for furnaces
ii. Crude Heating System
iii. To shut down furnaces

2. Burners

Valco has seven CHARGING (MELTING) Furnaces and 3 (three) Holding Furnaces. See attached. Scrap/Molten metal are charged into the Melting furnaces and transferred into the Holding furnaces from where it is cast into billets and rolling ingots after attaining appropriate conditions of temperature, chemistry, etc.

Capabilities of '214' Oil Burners

i. Eliminate Carbon buildup
ii. Reduce routine maintenance
iii. Maintain controlled furnace atmosphere
iv. Operate from very lean to rich mixture (air/oil ratio)
v. Hold positive or negative furnace pressure
vi. Provide stable burning with light or heavy oil

Series 214 Oil Burners are Nozzle-Mix Sealed-In burners for operation on light or heavy oil. These burners are capable of operating with equal proficiency throughout a wide temperature range – from low temperature ovens to high temperature forge and melt furnaces (about 760°C).

3. Air Supply

Valco uses combustion blowers with capacities in the attached.

Purpose

The purpose of the air supply is to support the combustion system. These are mounted on the mezzanine above each furnace. They supply sufficient volume and pressure to obtain correct combustion with the burners mounted on furnaces. All fans are rated at 24 OSI discharge pressure. The fans run at constant speeds and produce a constant amount of air and no controls are installed to vary their operation. The combustion air is broken into two groups:

i. Main air
ii. Atomizing air

The Main Air leaves the fan and is controlled by actionator motors/valves to the burners to obtain desired pressures and flows.

The Atomizing Air arrives at the burner at a slightly lower than the discharge pressure of the blower (24 OSI) to break the stream of fuel oil into tiny particles for better oil/air mixer resulting in better combustion.

4. Burner Safety (Burner Sensor)

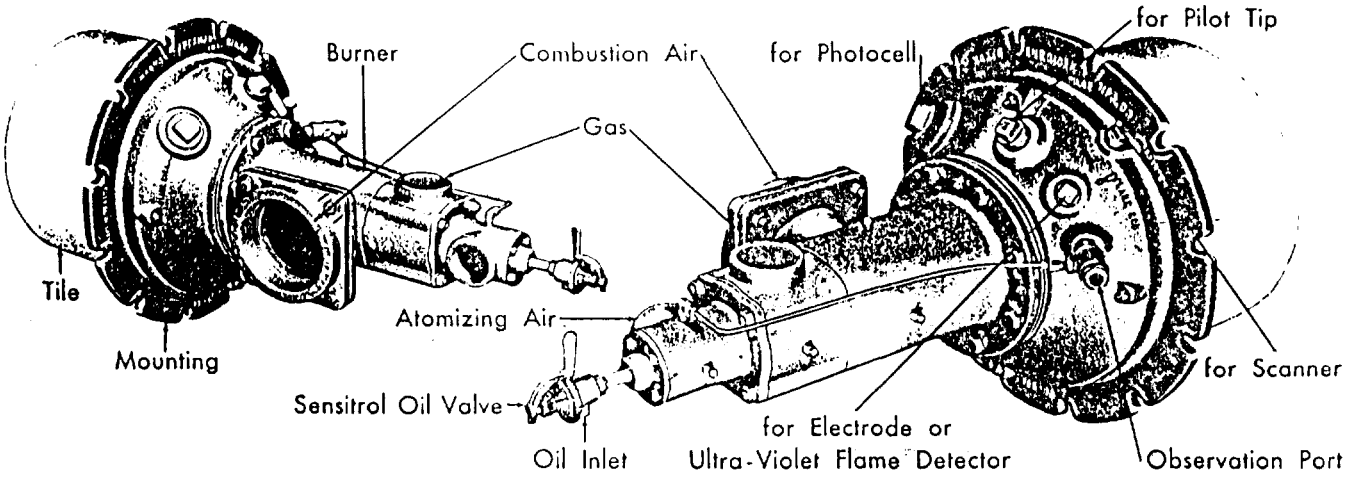
The furnace safe operation is maintained by a flame detector by insuring that fuel is being burnt as it flows out of the burner. The flame detector (PC II Scanner-4915) is wired to the control relay for the safety solenoid valve, so if the flame is not detected, the safety solenoid valve closes.

NORTH AMERICAN MFG. CO.
4455 East 71st Street
CLEVELAND, OHIO 44105

Insert in the
DUAL-FUEL BURNERS
section of your North American catalog

BULLETIN 214
JUNE, 1964

NORTH AMERICAN'S
Series 214 FIRE·ALL Dual-Fuel BURNERS



ULTRA-STABLE COMBUSTION

Flames keep burning even under adverse conditions, allowing burner to:

Burn with very lean or very rich settings.
Maintain controlled furnace atmosphere.
Operate in cold tight furnaces.
Use excess air for product temperature uniformity.

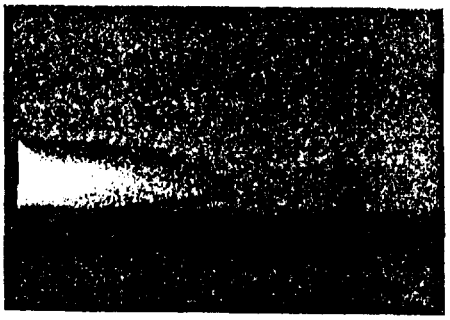
UNCONDITIONAL COMBUSTION

Versatile burners operate dependably under a wide variety of conditions with:

Any gas, any oil—change without disturbing process operation.
Positive or negative furnace pressure.
Rich or lean fuel/air ratio.
Wide turndown range.

EASY OPERATION—MINIMUM MAINTENANCE

Tile stable—safe, easy light-up.
Quick disconnect atomizer.
Observation port, pilot, flame safety.
No carbon build-up.



Gas and light oil flames (gas at left) for 214-6 FIRE•ALL Dual-Fuel Burner with 16 osi main and atomizing air at the burner. White lines on pipe above flame indicate 1 foot intervals.

ADVANCED LASER TECHNIQUES FOR COMBUSTION DIAGNOSTICS

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Abstract

Combustion is one of the most complicated technologies especially in turbulent medium. Combustion diagnostic requires advanced instantaneous and simultaneous measuring techniques for flow field and reactive scalar measurements. Lasers offered a unique tool for quantitative non-intrusive techniques in turbulent and even in supersonic flames. The development of laser based techniques has achieved great success in the last three decades of this century. Our improved understanding of turbulent combustion is due to the developed laser techniques.

In turbulent flames, the flow field affects greatly the combustion process. Information about the flow field is thus of great importance to the understanding of turbulent combustion. The flow field is often three-dimensional and can be described by velocity measurements for one and multi-components of the velocity vector, or imaging for instantaneous flow field picture.

The most commonly known velocity measurements laser-based techniques in reacting flows are laser Doppler velocimetry (LDV), for single or two points measurements, and recently a particle imaging velicimetry (PIV), for instantaneous flow field data. LDV technique provides the time history of the local velocity variations and thus turbulence intensity. It can also be used for length scale measurements using simultaneous two-point measurement technique. PIV technique provides instantaneous 2-D maps of the flow field and thus vorticity can be calculated.

Measurements of instantaneous and simultaneous species concentration, major, intermediate and radicals, provide useful data for studying the chemistry of the flame. In addition to the flow field information and temperature, a full description of the flame structure may be possible. Laser-based techniques for scalar measurements are based on different phenomenon as laser interacts with matter. The most known phenomena are elastic scattering, in-elastic scattering, laser absorption and fluorescence, Each of these phenomena are related to the status and concentration of the gaseous molecules within the measuring volume. Temperature and major and minor species concentration measurements techniques have been developed based on these phenomena.

The present lectures are focussed on the most advanced laser-based measuring techniques for combustion diagnostics that are able to provide spatially and temporally resolved measurements. Single point, one-dimensional, imaging and three-dimensional techniques are also discussed. The attached lecture notes cover some details of these techniques and can thus be used to follow the lectures.

DR. ABEEKU BREW-HAMMOND
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TURBULENT COMBUSTION MODELLING: CLASSICAL REYNOLDS AVERAGING APPROACHES

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GRANDE VOIE DE VIGNE F.
CHATENAY MALABRY CEDEX
FRANCE

Numerical simulations of practical systems are generally based on averaged balance equations for momentum, species mass fractions and energy. The objective of modelling is to propose phenomenological closures for these equations. The main difficulty in turbulent combustion modelling comes from the interaction between turbulent flow field and heat release. A large range of time and length scales is encountered; turbulent scales such as the turbulent kinetic energy, integral or Kolmogorov length scales and chemical length scales (flame thickness, chemical time scales).

Various modelling quantities have been introduced to describe turbulent combustion (probability density functions, flame surface density, scale dissipation,..). The physical meaning of these concepts, their use in turbulent combustion closure models and their extraction from experimental measurements will be discussed. The existing relations between quite different approaches will also be emphasised.

INTRODUCTION TO TURBULENT COMBUSTION

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Combustion is a widely used technique in energy transformation and is encountered in many practical systems such as heaters, domestic and industrial furnaces, thermal power plants, automotive or aeronautic engines, rocket engines. In most applications, combustion occurs in turbulent gaseous flows. Combustion may be characterised by a strong and irreversible heat release taking place in very thin zones. The combustion reaction rate is also highly non-linear leading to modelling difficulties.

The scope of this first lecture is to briefly recall some fundamental aspects of combustion phenomena; premixed and non-premixed situations, laminar and turbulent flames, combustion instabilities and to emphasise the difficulties encountered in turbulent combustion understanding and modelling. These fundamental phenomena will be illustrated from description of simple laboratory experiments.

TURBULENT COMBUSTION MODELLING: LARGE EDDY SIMULATIONS

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In large eddy simulations (LES), the largest turbulent structures in the flow field (typically the structures larger than the computational mesh size) are explicitly computed whereas only the effects of the small ones are modelled. Large eddy simulation (LES) appears today as a very attractive approach to describe turbulent combustion. In fact, most reacting flows exhibits large-scale coherent structures, especially when combustion instabilities, due to a coupling between heat release, hydrodynamic flow and acoustic waves, occur. The knowledge of large-scale turbulent motions is very interesting to describe the effects of the unresolved smaller ones, because subgrid scale modelling is generally based on similarity assumptions between large and small scales. Accordingly, the combustion/turbulence interaction, the key phenomena in turbulent combustion, should be better described using LES.

Nevertheless, LES are, up to now, just starting for turbulent combustion description and are still limited to feasibility studies. New modelling closures have to be proposed but may involve approaches similar to the ones used in Reynolds averaging contest. New numerical solvers have to be more precise. LES are also challenging for experimental validations: more precise experimental data (typically, instantaneous two or three-dimensional instantaneous fields of relevant quantities such as velocity, mass fractions,..) have to be processed to extract resolved (i.e. predicted in numerical simulations) and unresolved (i.e. to be modelled) contributions.

MONITORING AIR POLLUTANTS IN COMBUSTION

P. K. BUAH-BASSUAH
LASER AND FIBRE OPTICS CENTRE
DEPARTMENT OF PHYSICS
UNIVERSITY OF CAPE COAST
CAPE COAST
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ABSTRACT

An attempt is being made to explore possible sources of emissions from the operation of Combustion Systems (mobile and stationery sources) and the need to use laser to monitor the emission gases and other pollutants from the activities of some industries in Ghana.

NEEDS FOR OPTICAL MEASUREMENTS IN COMBUSTION PROCESSES FOR ENERGY EFFICIENCY IMPROVEMENT AND POLLUTION ABATEMENTS

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ABSTRACT

The detailed modelling of combustion processes and of industrial furnaces is not yet by the numerical tools presently available : the models do not contains all the physical and chemical information needed for a correct modelling. Moreover, even if these knowledge were available the computing power of the machines and the computing time necessary to solve the problems would not be reasonable. Thus approximations and simplifications need to be done so that results must be validated nearly for each application. In a large number of cases, the model itself has to be adjusted for each application in "real life". The test must be done by measuring different key parameters (temperature, velocity field, molecular concentrations, $\vec{S}$). In parallel to mechanical traditional techniques which are intrusive, optical non-intrusive techniques can be used. These techniques give access to temperature, molecular or radical concentrations, velocity and can give local information, follow time evolutions of the parameters, or global or averaged values. Some of the techniques will be presented.

ANALYSIS OF DOMESTIC GAS APPLIANCES FOR HOT WATER PRODUCTION BY LASER INDUCED FLUORESCENCE AND FOURIER TRANSFORM EMISSION SPECTROSCOPY MEASUREMENTS

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ABSTRACT

In order to test the results of the combustion code describing the flames in a domestic gas appliance, we have performed several measurements of temperature and species concentrations in the flame by optical diagnostics. The results will be used to demonstrate the applicability and the validity of those obtained by different techniques. The flame front have been detected by spontaneous emission of OH, CH, and C2 radical and also by planer laser induced fluorescence of OH. Temperature and CO, CO_2 and H_2O molecule fields have been measured by emission Fourier Transform Infrared Spectroscopy.

CASE STUDY ON COMBUSTION PROCESSES AT TEMA OIL REFINERY (TOR) LIMITED

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ABSTRACT

The presentation focuses on current combustion technology and practices at Tema Oil Refinery (TOR) Ltd. as well as the on-going efforts to improve efficiency with a view to reducing environmental emissions.

TOR's combustion systems - boilers, furnaces and associated auxiliary equipment are described. Combustion fuels and burner management systems and the control of these to ensure efficiency are presented. Monitoring and measuring techniques to ensure compliance with environmental requirements as well as TOR's own safety requirements vis-a-vis international codes and practices are also discussed.

IMPROVEMENT OF THE MODELLING OF INDUSTRIAL FURNACES AND PROCESSES FOLLOWING EXPERIMENTAL OBSERVATION

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Perlite rock is a volcanic mineral which can be expended when heated rapidly at a temperature larger than 800°C. The expanded material is then a very good thermal and sound insulating material. It can also be used in agriculture to retain water in the ground.

For building and construction material applications, expanded perlite of uniform density and well controlled size distribution is required. A computer code capable of predicting the combustion, the expansion process and the particle trajectories inside a vertical industrial furnace can serve in improving the quality of the final expended product and in optimizing the energy consumption inside the furnace by regulating the combustion parameters.

In order to adapt the combustion code measurements of temperature, velocity and concentrations of CO_2 have been performed. the improvement of the code will be presented.

CO_2-TEA LASER-BASED LIDAR DIAL SYSTEM FOR THE DETECTION OF HYDROCARBON POLLUTION IN THE ATMOSPHERE

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ABSTRACT

We present the technology and the configuration of the home build Lidar Dial system. Compaign results will also be presented for the case of Ethylene, Ammonia. and possibly Ozone. Long path integrated measurements of these pollutants against a topographic target will be discussed.

CASE STUDY ON COMBUSTION PROCESSES IN THERMAL PLANT AND ENERGY GENERATION - TAKORADI THERMAL POWER PLANT

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1.0 INTRODUCTION:

In view of the high rate of growth in domestic load demand, the VRA generation system is no longer able to reliably meet the domestic load, the contractual obligations to Volta Aluminium Company (VALCO) and satisfy the export market. The total energy supplied from the mainly hydro system was 6400 GWh in 1993, 6130 GWh in 1994, 6114 GWh in 1995 and 6627 GWh in 1996. These levels did not only exceed the firm energy capacity of the generation system (estimated to be about 4800 GWh/year) but also, it exceeded the system long-term average annual energy generating capability of about 6100 GWh.

The Ghana Generation Planning Study (1985) identified Combustion Turbines as the most attractive generation expansion option to the existing all hydro system. The 300 MW Combined Cycle generating plant at Takoradi Thermal Power Plant, Aboadze forms the initial phase of an optimized long-term generation expansion plan to ensure that VRA's power supply obligations can be reliably met. The plant has dual firing capability to burn Light Crude Oil (LCO) as well as natural gas, but is initially using LCO as the primary fuel.

2.0 SYSTEM OVERVIEW

Background

Most stored or latent energy, a form of internal energy, is released in the form of thermal energy or heat, Coal, fuel oil natural gas and nuclear particles are examples of products with stored energy that can be released primarily in the form of heat. The issue is how to convert the thermal energy into useful work. Combustion turbine/generators, steam generating systems and thermo-electric converters are examples of methods whereby heat energy is converted into useful work. We are interested in the combustion turbine cycle and how it is used to convert thermal energy into useful work.

Principle

The combustion turbine engine draws in a quantity of air, compresses it, mixes it with fuel, burns the mixture and then expands the hot gases. The combustion system is designed to achieve the most efficient combustion of the air/fuel oil mixture so that the maximum possible heat energy is extracted from the fuel. The expansion of the hot gases through the turbine produces useful work used to rotate the shaft, driving the axial compressor and synchronous generator.

Gas turbine exhaust gases are either used as the energy sources for a Heat Recovery Steam Generator during combined cycle operation, or released through a stack to the atmosphere in simple cycle operation.

Combustion Process

Whereas higher combustion temperatures are required in order to increase the thermal energy derived from the fuel, adverse maintenance effect, environmental impact and hot gas path material thermal withstand capabilities are limiting factors. Strict control of the turbine firing temperature is thus effected by the control system regulation of the fuel flow.

Among the key parameters that are monitored in the effort to manage the combustion process are inlet air temperature, compressor discharge pressure, fuel flow rate, flame, wheelspace temperatures, exhaust temperatures and exhaust temperature spread.

Continuous emission monitoring systems are in place to ensure emissions are within environmental requirements. Borescope inspections are carried out to observe signs of hot corrosion on the hot gas components before damage occurs.

The paper will discuss the Plant's experiences in managing the aforementioned as part of an overall power generation business.

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Optimization of NOx Removal in a Non-Thermal Plasma Discharge System

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Nitrogen oxides (NOx), a group of gaseous pollutants produced primarily by combustion processes, have been shown to contribute to photochemical smog, acid rain and ground-level ozone. As awareness of the detrimental effects of NOx grows, regulations limiting NOx emissions are becoming increasingly more stringent. Non-Thermal Plasma Discharge (NTPD) has been identified as a promising technology for NOx removal. As part of a program to optimize a NTPD for NOx removal, an investigation of the effects of discharge gap width, input power, feed gas composition, and residence time on the electrical and chemical processes that occur in a dielectric barrier discharge was undertaken. The experimental methods and results, especially on the effects of gap spacing, are presented and discussed.

LASER DOPPLER VELOCIMETRY AND HIGH-SPEED VIDEO IMAGING SYSTEM FOR COMBUSTION AND EMISSION CONTROL RESEARCH

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ABSTRACT

Laser Doppler Velocimetry (LDV), which provides point measurements of velocity over time, and high-speed video imaging are two powerful diagnostics for flow visualization of combustion and emission control processes. LDV was used to study an axially forced turbulent premixed methane-air jet flame and the results of the LDV studies compared to those obtained with particle image velocimetry (PTV). In addition, the application of a high-speed video imaging system, Kodak EktaPro Motion Analyzer, to study droplet combustion behaviour under supercritical conditions and non-thermal plasma discharge for NOx removal and control are presented and discussed.

AETHALOMETER APPLICATIONS FOR REAL-TIME MONITORING OF COMBUSTION-DERIVED AEROSOL CARBON

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ABSTRACT

The paper review the combustion process, the formation of elemental carbon and its potential usefulness as a tracer for combustion of carbonaceous fuels. It further review the methods available for the measurement of elemental carbon. These methods include optical techniques, photoacoustic techniques, and combined thermal/optical techniques. It discusses in detail an instrument for real-time measurement of elemental (black) carbon - the aethalometer, developed at the Lawrence Berkeley Laboratory, USA.

The physical configuration details of the instrument and the datalogger programmes written by the authors for its field use are presented. Typical results obtained from a major field testing of the instrument are presented. The possible application of the aethalometer in combustion diagnostics is discussed.

PARTICLE IMAGE VELOCIMETRY MEASUREMENTS OF PREMIXED METHANE-AIR FLAMES

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ABSTRACT

Particle Image Velocimetry (PIV) is technique for measuring instantaneous velocity over an arca (global measurement) in comparison to point velocity measurement over time using Laser Doppler Velocimetry (LDV). PIV provides information on flow visualization and associated structure such as velocity map/distribution, streamlines and vorticity. In this study, PTV was used for the first time to study an axially forced turbulent premixed methane-air jet flame. The PIV measurements were taken with a
532 nm narrow-band filter to reduce the radiation from the flame. The experimental methods and results of the study are presented and discussed.

COMBUSTION PROCESSES MONITORING BY THE ENVIRONMENTAL PROTECTION AGENCY (EPA)

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ABSTRACT

Air pollution in Ghana has traditionally been associated with industrial activities, domestic wood fuel burning, bush burning and solid wastes burning at 'landfills'/dumping sites. The EPA has over the years been monitoring emissions from these sources using active samplers. The monitoring sites include industrials, commercial and residential.

In recent years, the consumption of fossil fuels by the transport sector and its associated air emissions have grown significantly to match or exceed other sources of the most of the important pollutants. In the urban areas vehicle exhaust emission have become the dominant sources of air pollutants.

The EPA has identified and procured the appropriate vehicle exhaust emission diagnosis equipment. Further, the Agency has proposed a collaborative programme for a national monitoring and control of air pollution from motor vehicles. A pilot vehicle exhaust emission-testing programme using diagnostic gas analyser was launched recently by the EPA. Prior to, the EPA has developed procedure for vehicle exhaust emission diagnosis.