P9 Combustion Sensors for Measuring the Primary Zone Equivalence Ratio

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Abstract

Variations in the equivalence ratio between individual nozzles in lean premixed combustors can severely limit the ability to achieve low NO_x , low CO, stable combustion. The objectives of this research are to develop sensors that can measure the primary zone equivalence ratio in the individual nozzles of a lean premixed combustor and to demonstrate their use on an actual operational, lean premixed combustor and to demonstrate their use on an actual, operational, lean premixed combustor.

The research will be carried out in three phases. The first phase involves an extensive literature survey and evaluation of techniques that could potentially be used to measure the primary zone equivalence ratio in an actual engine. Based on the results of this survey and evaluation, as well as input from the industrial members of the AGTSR Program and FETC, two techniques will be selected for further study in phase two.

The second phase involves implementation, testing, and evaluation of the two techniques selected in phase one in an existing high pressure (10 atm), high inlet temperature (1000K), single-nozzle combustor test facility at Penn state. These tests will be used to assess the resolution, accuracy, and repeatability of the techniques, as well at their robustness under simulated gas turbine combustion conditions. Based on the results of these results of these tests and input from the industrial members of the AGTSR Program and FETC, one technique will be selected for further study in phase three.

The third phase involves implementation, testing, and evaluation of the sensor technique selected in phase two in full-scale, single-nozzle test facilities made available by the industrial members of the AGTSR Program and FETC. These tests will be conducted using prototype, lean premixed combustor nozzles. To date, UTRC and Westinghouse have been contacted and have expressed their interest in participating in this project and in making their full-scale, single-nozzle test facilities available for phase three testing. The other industrial members of the AGTSR Program and FETC will also be contacted in the near future.

The outcome of the research will be the development of a sensor technique for measuring the primary zone equivalence ration in lean premixed combustors, and the demonstration of that sensor in actual full-scale combustor tests. This sensor will provide the capability for measuring the equivalence ratio in the individual nozzles of a lean premixed combustor and, as such, will be valuable for assessing the degree to which nozzle-to-nozzle variations are limiting combustor performance. This sensor will also have the potential for being used in a control system for

monitoring and regulating the equivalence ratio in the individual nozzles of a lean premixed combustor in order to allow optimization of low $N0_x$, low CO, stable combustors.

SENSORS FOR MEASURING PRIMARY ZONE EQUIVALENCE RATIO IN LEAN PREMIXED COMBUSTORS

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OBJECTIVES

- To conduct an extensive survey, and evaluation, of various techniques which can potentially be used to measure the primary zone equivalence ratio in lean premixed combustors.

- Select two of the most promising sensor techniques, and implement and evaluate them in an existing and operational high pressure, single-nozzle combustor facility at Penn State.

- Implement, test and evaluate the most promising sensor technique in prototype lean premixed nozzles in the full-scale, single-nozzle combustor facilities made available by the industrial members of the **AGTSR Program** and **FETC**.

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APPROACH

In the first phase of the research, the criteria for evaluating the various sensor techniques will include:

- Ability to achieve an equivalence ratio measurement resolution of 0.005
- Ability to achieve an equivalence ratio measurement accuracy of ± 0.01
- Temporal response characteristics
- Potential for use in an actual combustor (e.g., robustness, access, etc.)
- Sensitivity to incomplete fuel-air mixing
- Ability to be implemented on a variety of nozzle configurations
- The effect on other aspects of combustor performance
- Potential for detecting light-off
- Potential for use as an active control sensor for preventing combustion instabilities

After the evaluation is completed, two sensor techniques will be selected for in-depth evaluation and testing in the second and third phases of the program.

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DELIVERABLES AND SCHEDULE

Year 1

- Complete literature survey and selection of the two most promising sensor techniques for further study
- Design, implement, test, and evaluate the first of the selected sensor techniques in the high pressure, single-nozzle combustor at Penn State under lean premixed conditions

Year 2

- Design, implement, test, and evaluate the second sensor technique in the Penn State combustor
- Select the most promising sensor technique for further study
- Plan for implementing the most promising sensor technique in full-scale, single-nozzle combustor test rigs made available by the industrial members of the **AGTSR Program** and **FETC**

Year 3

- Implement, test, and evaluate the most promising sensor technique in proto-type lean premixed nozzles in the full-scale, single-nozzle combustor test rigs made available for this purpose by the industrial members of the **AGTSR Program** and **FETC**

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The collaboration with the industrial members of the **AGTSR Program** and **FETC** will include the following specific interactions:

- In the first quarter, Penn State personnel will visit interested industrial members of **AGTSR Program** and **FETC** to discuss the survey results, and to solicit input related to the sensor technique selection.
- Near the end of second year, Penn State personnel will visit interested industrial members of **AGTSR Program** and **FETC**
  - to discuss phase two testing results;
  - to solicit input related to the selection of the best sensor technique for phase three testing;
  - to discuss the possibility of implementing and testing the selected technique in their full-scale, single-nozzle test facilities.
- In the third year, extensive interaction will occur between Penn State personnel and the engineers from the companies involved in phase three testing.
- Penn State personnel will be actively involved (on-site) in the setup and testing of the sensor technique in the full-scale, single-nozzle facilities at the industrial sites.

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INDUSTRIAL INTERACTION (CONTD.)

To date, **United Technologies Research Center (UTRC)** and **Westinghouse Power generation** have indicated an interest in participating in the development, testing and evaluation of the sensor technique, and in providing full-scale, single-nozzle facilities for the phase three testing of the selectedprimary zone equivalence ratio sensor technique. The other **AGTSR Program** industrial members and **FETC** will be contacted in the near future regarding their interest in participating in this project.

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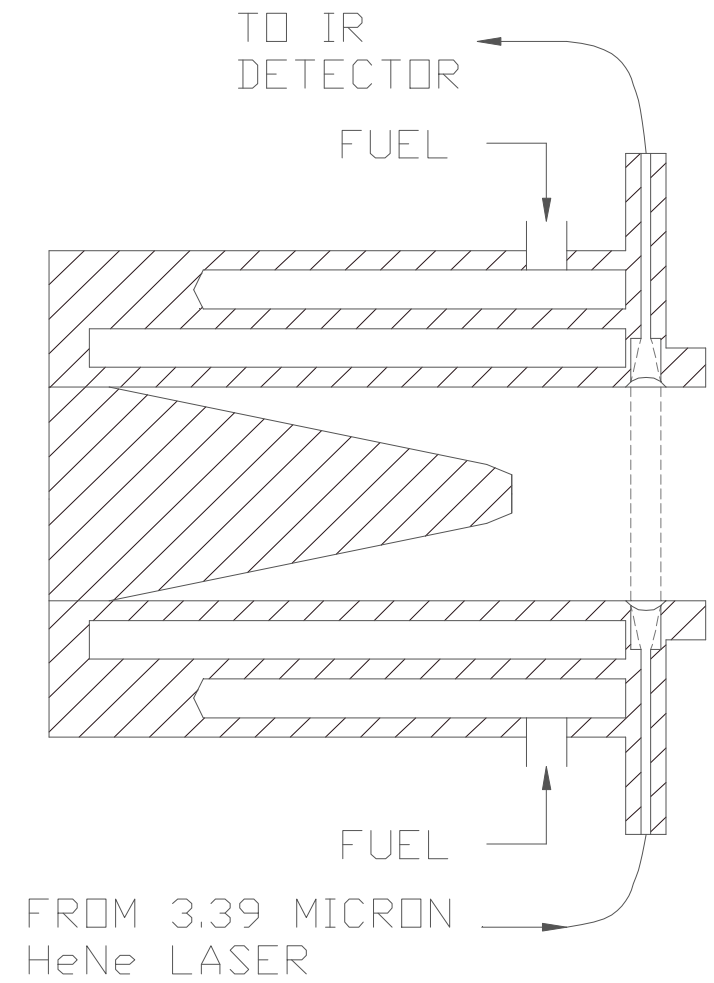
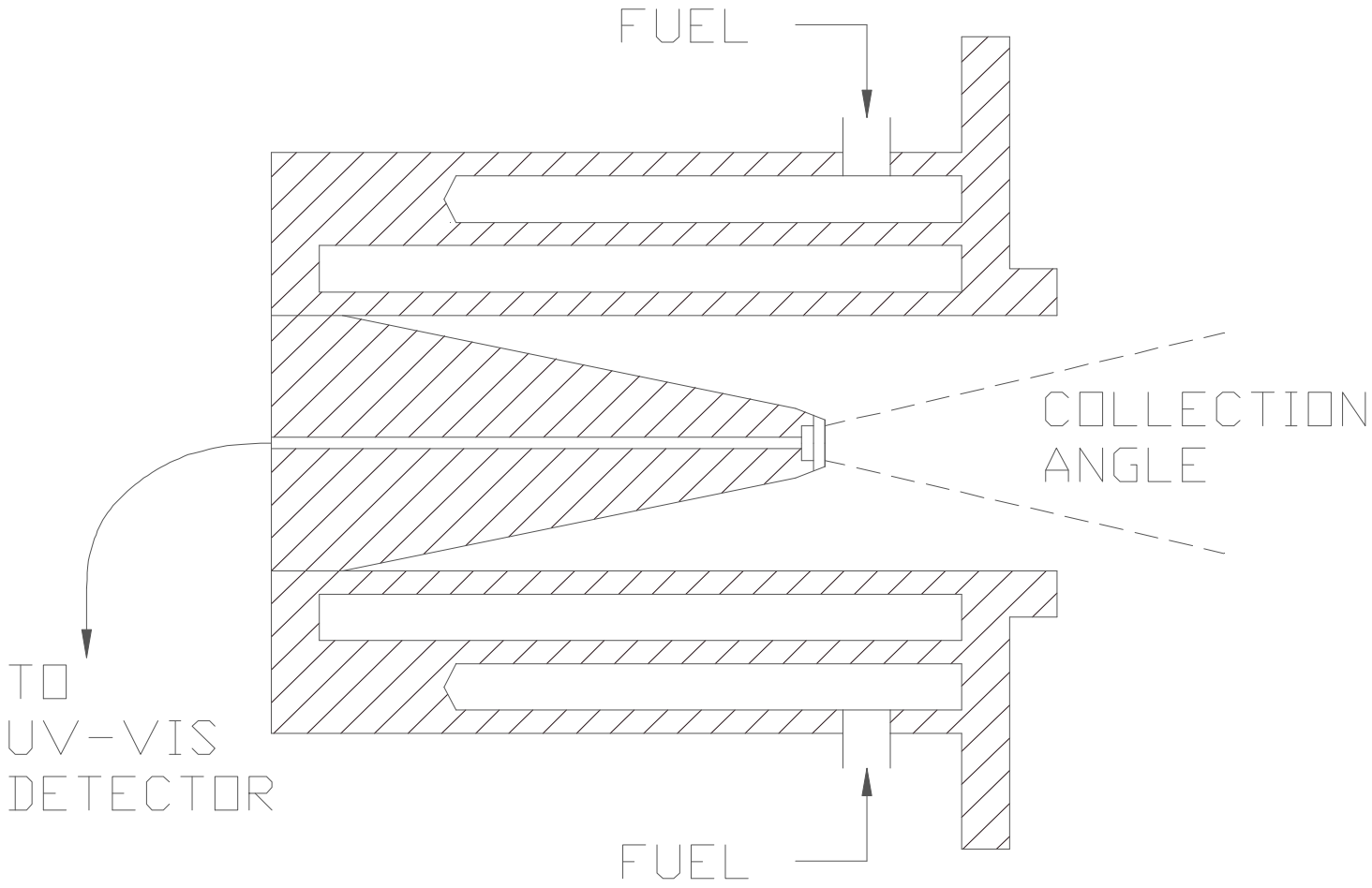
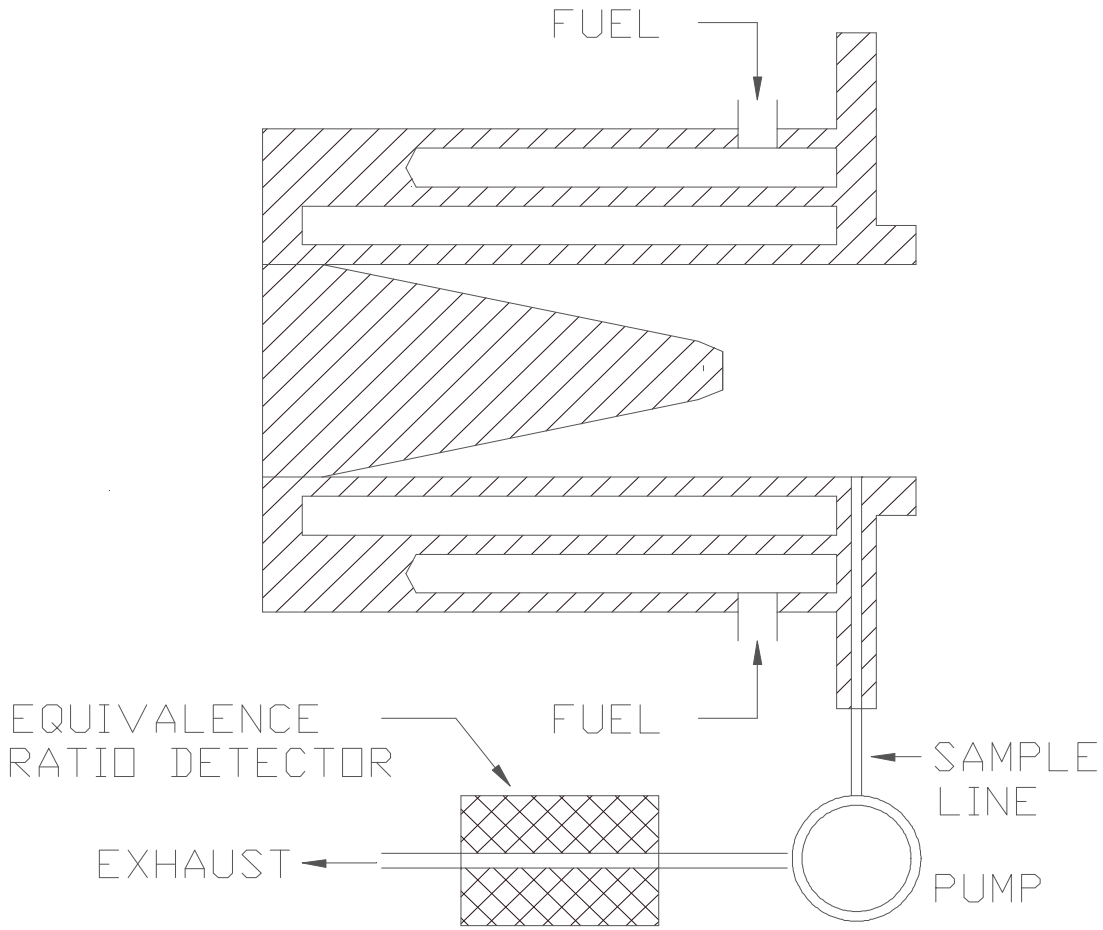


INFRARED ABSORBTION TECHNIQUE IMPLEMENTED ON A PRATT & WHITNEY TE92 NOZZLE

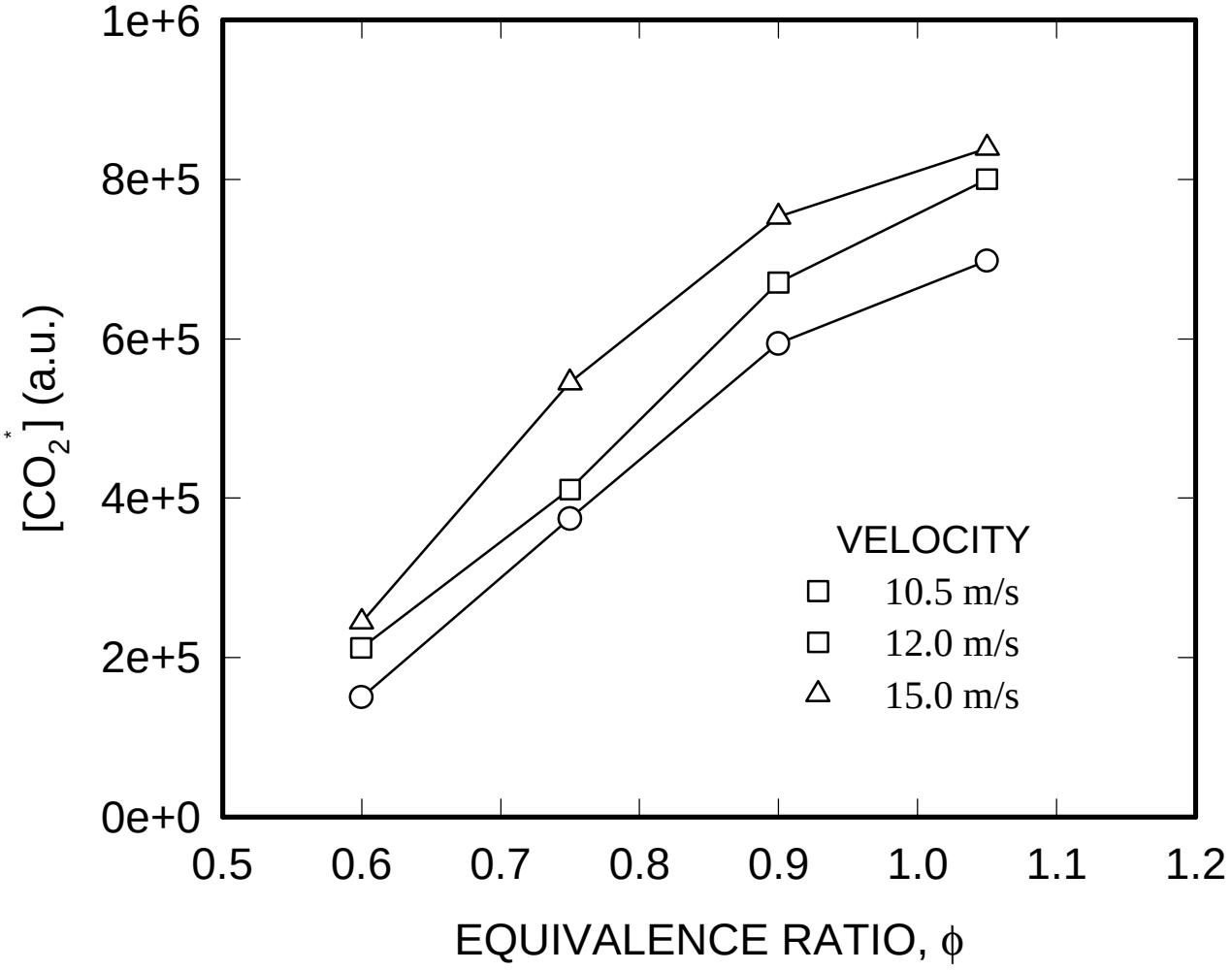


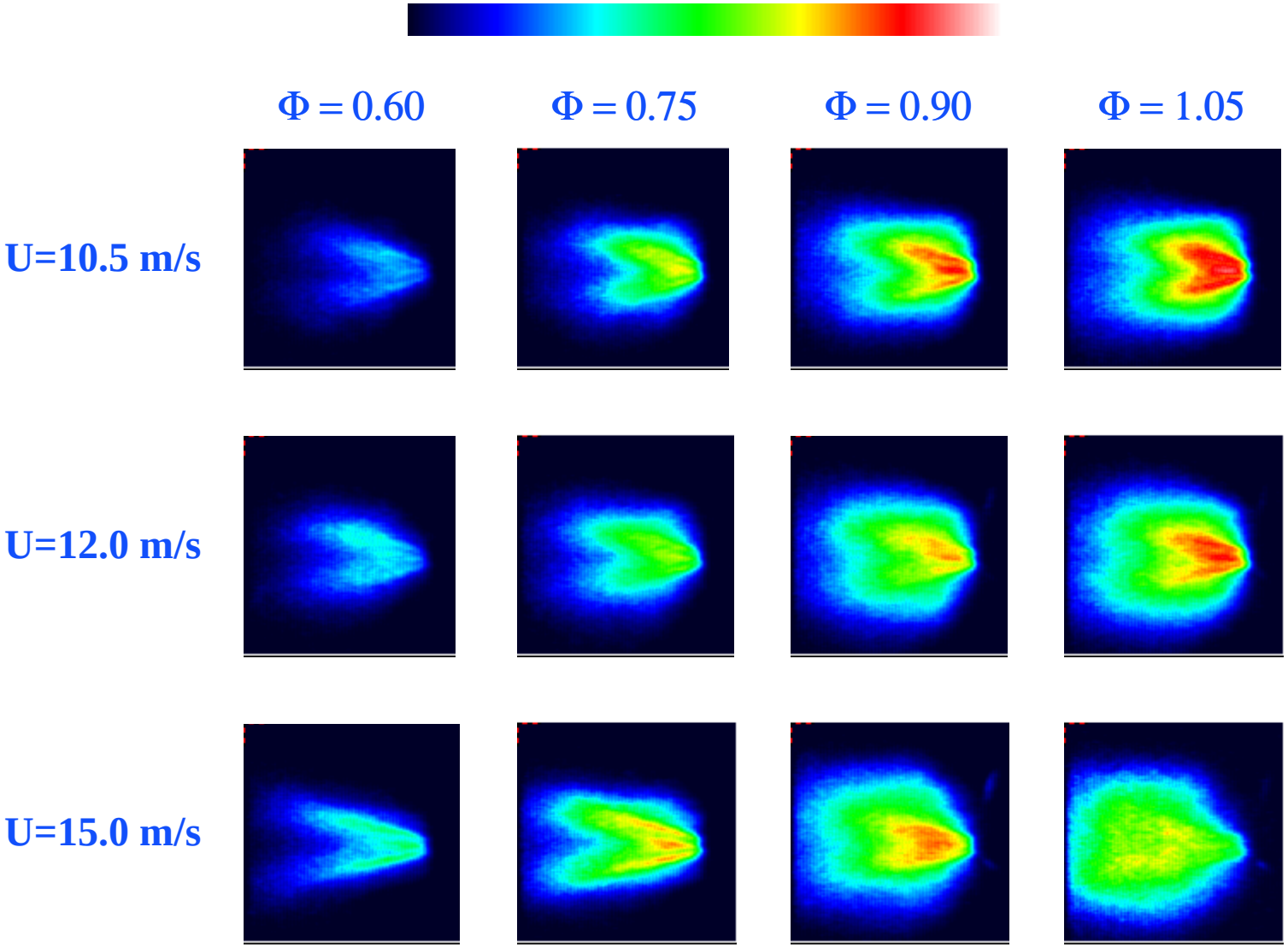
UV-VIS FLAME EMISSION MEASUREMENT TECHNIQUE
IMPLEMENTED ON A PRATT & WHITNEY TE92 NOZZLE



GAS SAMPLING TECHNIQUE IMPLEMENTED ON A PRATT & WHITNEY TE92 NOZZLE

CHEMILUMINESCENCE INTENSITY Vs. EQUIVALENCE RATIO





Averaged images of flame chemiluminescence at different flow velocities and equivalence ratios in a dump combustor