View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

N84 20551

SATURATED LASER FLUORESCENCE IN TURBULENT SOOTING FLAMES AT HIGH PRESSURE

Galen B. King
Campbell D. Carter
Normand M. Laurendeau

Flame Diagnostics Laboratory
School of Mechanical Engineering
Purdue University

The primary objective of this project is to develop a quantitative, single pulse, laser-saturated fluorescence (LSF) technique for measurement of radical species concentrations in practical flames. The species of immediate interest is the hydroxyl radical. Measurements will be made in both turbulent premixed and diffusion flames at pressures between 1 and 20 atm. Interferences from Mie scattering will be assessed by doping with particles or by controlling soot loading through variation of equivalence ratio and fuel type. The efficacy of the LSF method at high pressure will be addressed by comparing fluorescence and absorption measurements in a premixed, laminar flat flame at 1-20 atm.

Signal-averaging over many laser shots is sufficient to determine the local concentration of radical species in laminar flames. However, for turbulent flames, single pulse measurements are more appropriate since a statistically significant number of laser pulses is needed to determine the probability distribution function (PDF). PDFs can be analyzed to give true average properties and true local kinetics in turbulent, chemically reactive flows.

PROGRESS OF WORK

The construction phase of the high-pressure facility is nearing completion. This includes the fabrication of not only the high-pressure vessel, but also the optical table in which the pressure vessel is mounted and other support systems, including the high pressure burners and the gas flow control system.

The pressure vessel is constructed from a 109 cm long by 20 cm ID stainless steel tube, to which four 6.4 cm ID tubes are welded. Slip-on flanges are welded at the ends of these smaller tubes to hold the optical windows. Central to the design of the pressure vessel is the use of an internal burner-translation system rather than translation of the entire vessel to access the various points in the flame. This arrangement allows two dimensional movement of the burner within the pressure vessel. Maximum travel is greater than 11 cm in the vertical and 3.8 cm in the horizontal directions. The translation stage is driven by stepper motors which are in turn controlled by an Apple computer. The position of the burner is monitored with two linear transducers and a pressure transducer monitors the pressure within

the vessel. By counting the number of steps sent to the stepper motors, the position of the burner may be controlled to better than 3 μm in both travel directions.

Because of its size and mass, the pressure vessel will be located between two optical bread boards rather than on top of a single optical table. A framework to support the pressure vessel has been added to an existing table base and the optical bread boards have been mounted on the table framework. Additional modifications to the table are now underway, including (1) a cylindrical plexiglas shield to protect laboratory personnel in case of pressure failure and (2) steel plates which will surround the vessel to form a flat surface between the bread boards. A small winch is also being mounted in the ceiling of the laboratory to aid in movement of the pressure vessel during experiments.

Although initial plans for the high-pressure flame facility called for control of gases by mass flow transducers, a simpler gas flow control system will be used at this time. This strategy will allow greater variation in burner type during the exploratory stage of our research. The control system we have constructed uses ordinary regulators and rotometers. This system, while simple and easily varied, is limited to a useful pressure range of 10 atm. Therefore, we plan to eventually add mass flow controllers to the flame facility.

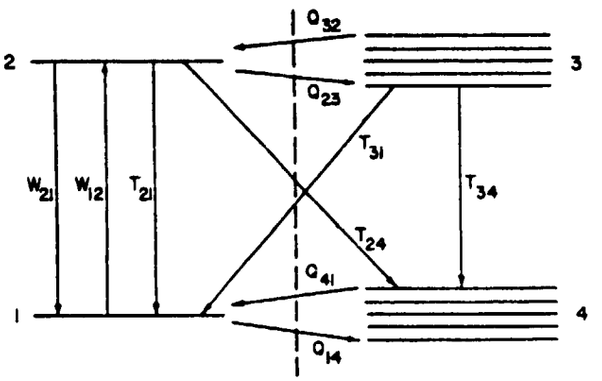
Two burners have been designed for initial testing of the high pressure flame facility. The first is a premixed water-cooled burner constructed with a Hasteloy, hexagonal-pattern, flame holder. The main body of this burner has been constructed and work is now in progress to shape the flame holder. A second flat flame burner is being built by McKenna Products. This burner is a scaled down version of their standard water-cooled sintered bronze, flate flame burner. The flame diameter for both burners is approximately 3 cm to avoid self-absorption problems at high pressure.

Significant advances have also been made in our ability to measure single-pulse OH radical concentrations in turbulent flames. Measurements of superequilibrium hydroxyl concentrations in nonpremixed flames at 1 atm using LSF have been made in a collaborative interaction between the Flame Diagnostics Laboratory at Purdue University and Corporate Research and Development at General Electric Company. The results of this study were presented at the 1983 Fall Meeting of the Western States Section of the Combustion Institute and a paper has been submitted to the Twentieth International Symposium on Combustion.

An improvement has also been made in our sampling technique as we can now discriminate against bad laser shots. With the use of a second sampling oscilloscope, the power level of the laser pulse is monitored and fed into a computer along with the fluorescence signal. We are currently using this technique for measurements of PAHs and will eventually incorporate it into our procedure for generating PDFs. In this method, the analogue-to-digital converter and both sampling oscilloscopes are triggered by the laser pulse and thus single pulse data for both the laser power and the fluorescence signal can be collected. Data points in which the laser pulse shape or energy level are not satisfactory are then eliminated from the data set.

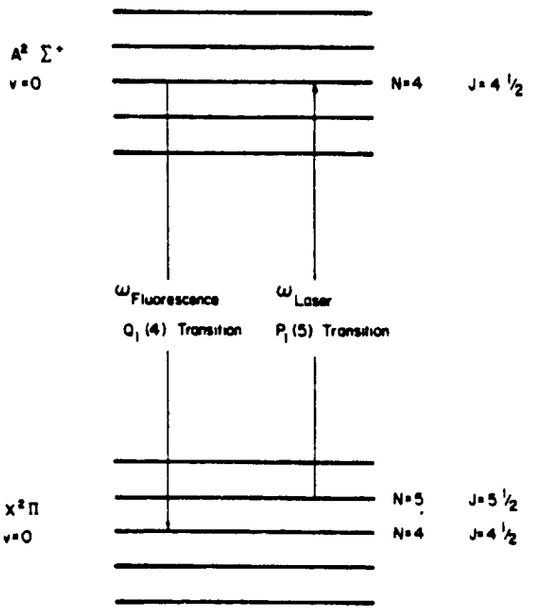
BALANCED CROSS-RATE MODEL

ORIGINAL PAGE IS
OF POOR QUALITY



Laser-Coupled Rotational Levels

Rotational Levels Indirectly Affected by the Laser Pumping



System Rate and Conservation Equations

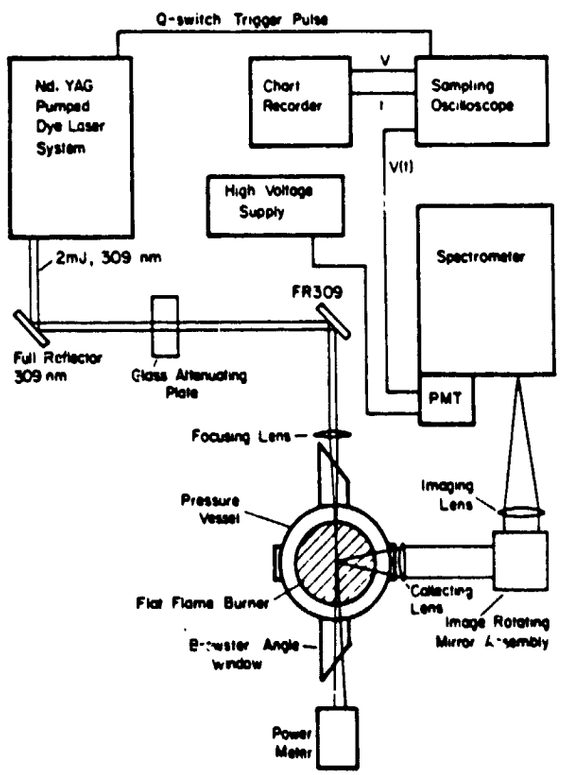
$$\dot{N}_1 = -N_1(W_{12}+Q_{14}) + N_2(W_{21}+T_{21}) + N_3T_{31} + N_4Q_{41}$$

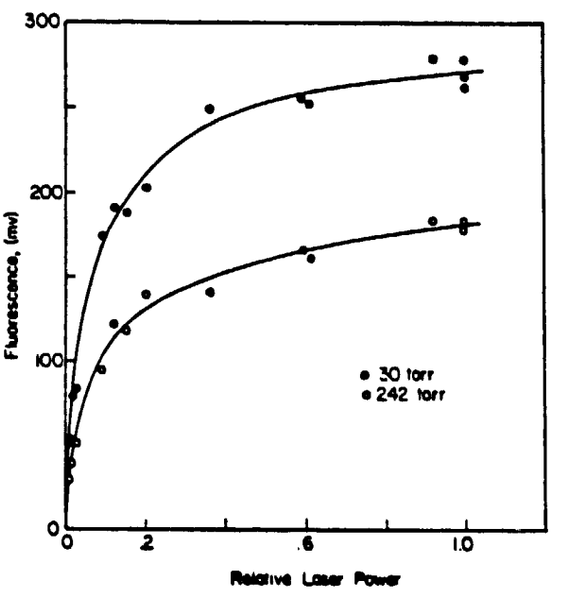
$$\dot{N}_2 = N_1W_{12} - N_2(W_{21}+T_{21}+T_{24}+Q_{23}) + N_3Q_{32}$$

$$\dot{N}_3 = N_2Q_{23} - N_3(T_{31}+T_{34}+Q_{32})$$

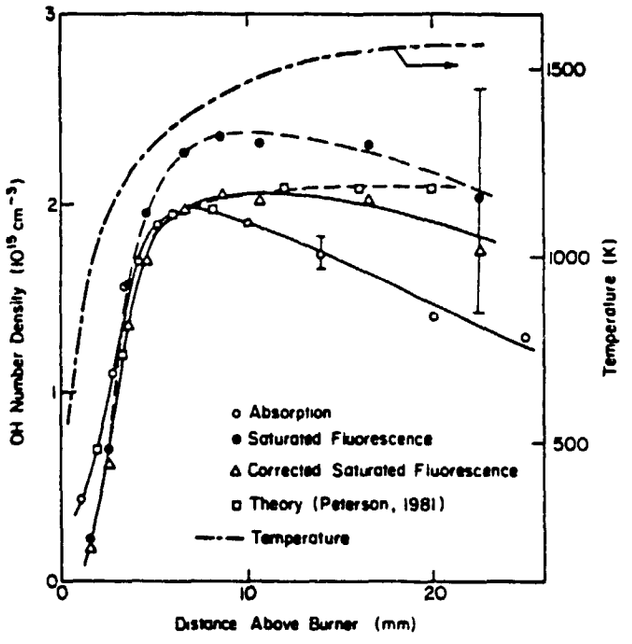
$$N_T = N_1^0 + N_4^0 = N_1 + N_2 + N_3 + N_4$$

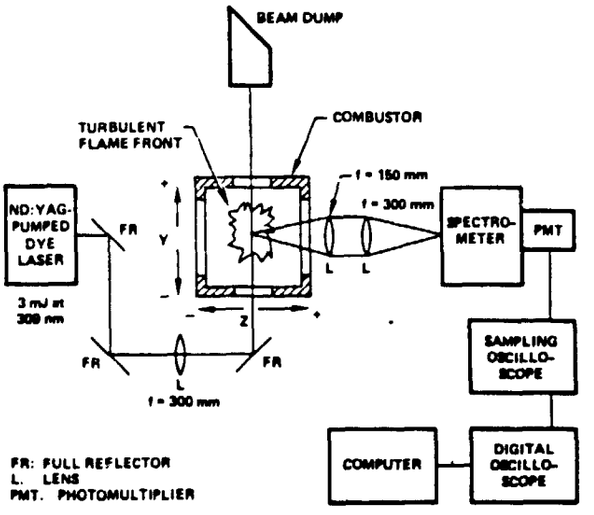
$$T_{ik} = Q_{ik} + A_{ik}$$

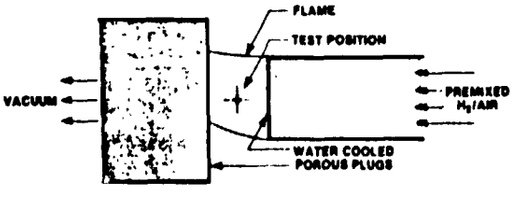




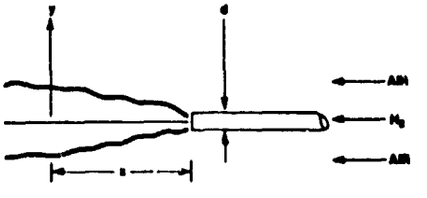
ORIGINAL PAGE IS
OF POOR QUALITY



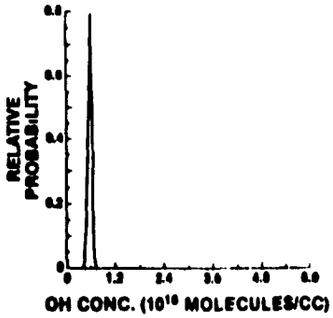


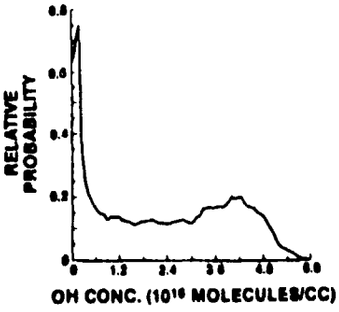


LAMINAR PREMIXED FLAME $\phi = 1$

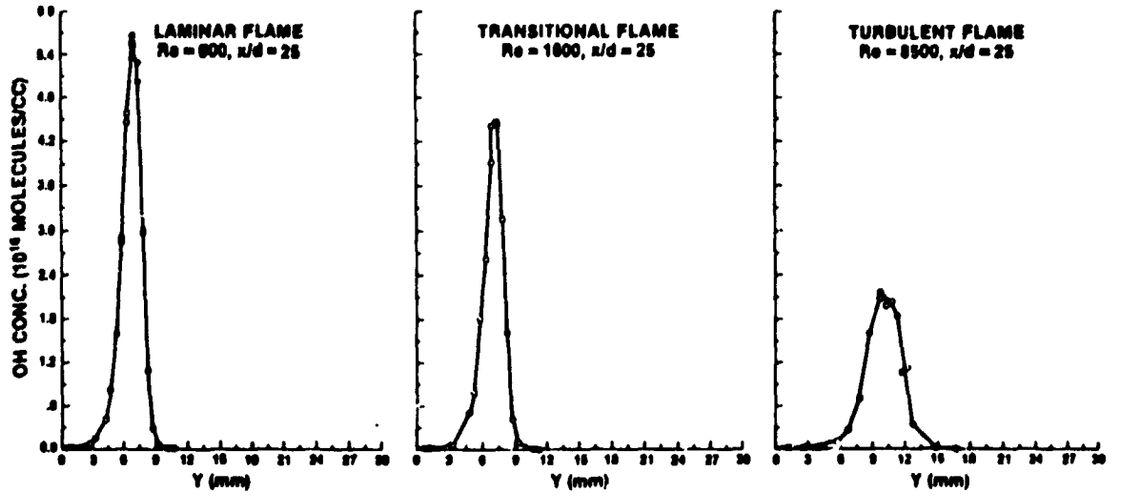


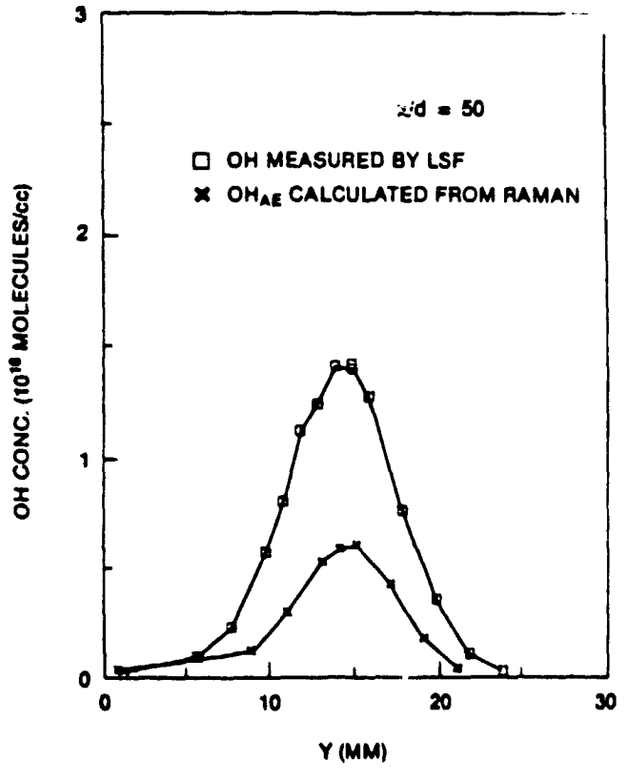
TURBULENT DIFFUSION FLAME Re = 8500
x/d = 25 y/d = 7.5

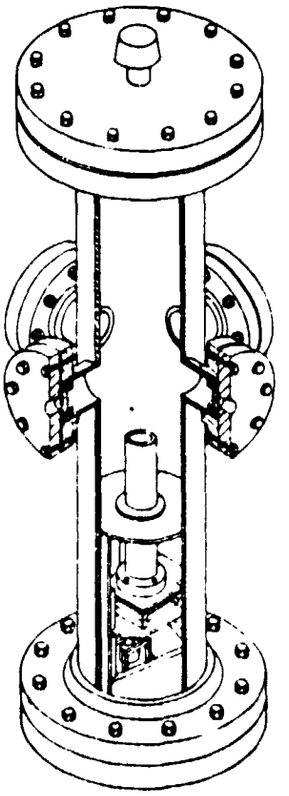
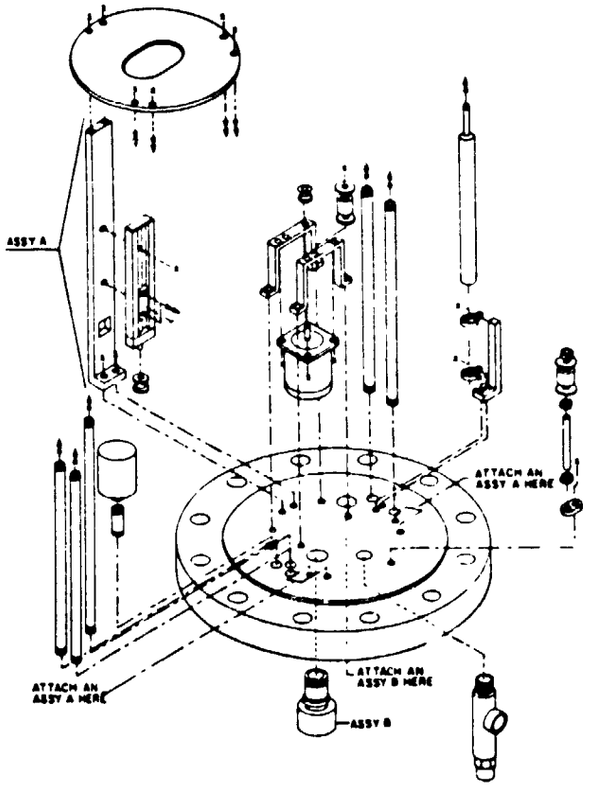
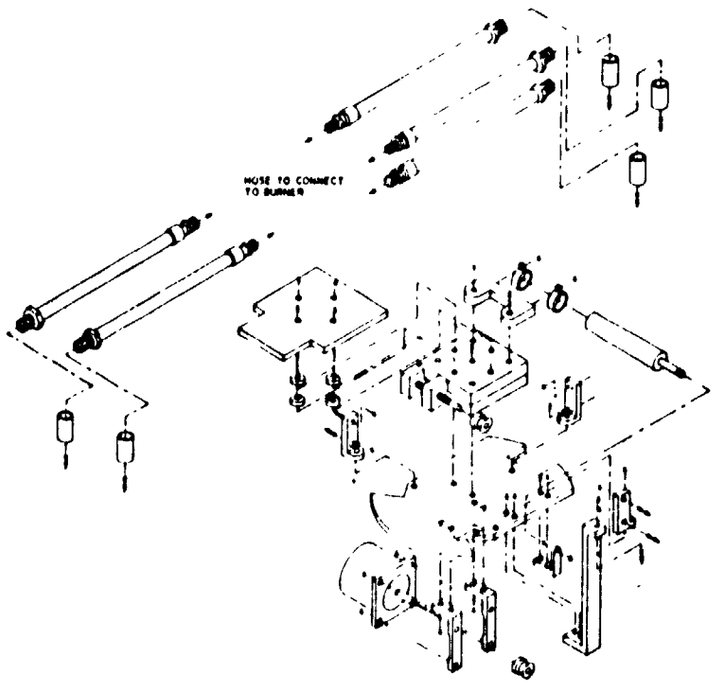
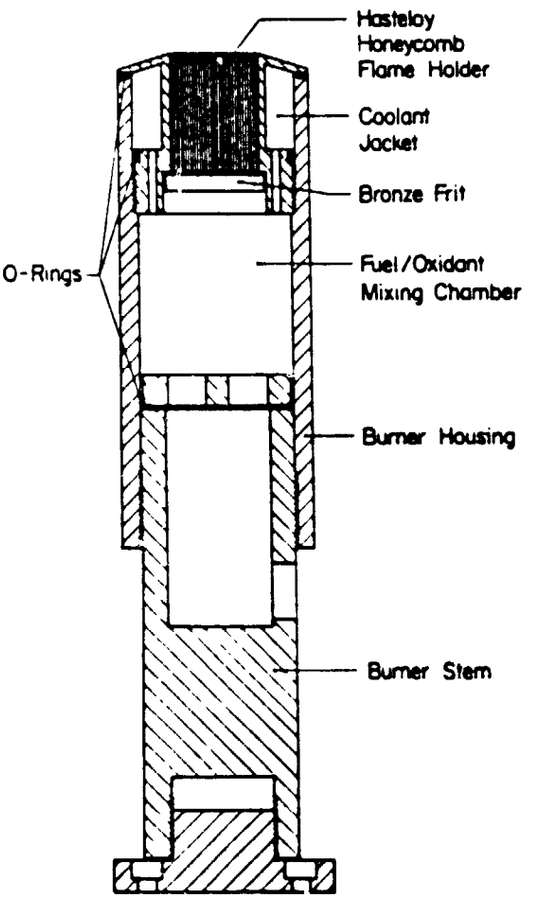




ORIGINAL PAGE IS
OF POOR QUALITY







ORIGINAL PAGE IS
OF POOR QUALITY