NISTIR 6242

ANNUAL CONFERENCE ON FIRE RESEARCH
Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

NISTIR 6242

ANNUAL CONFERENCE ON FIRE RESEARCH
Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

October, 1998
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

U.S. Department of Commerce
William M. Daley, *Secretary*
Technology Administration
Gary Bachula, *Acting Under Secretary for Technology*
National Institute of Standards and Technology
Raymond G. Kammer, *Director*

Spatial and Temporal Resolution of Buoyant Flows

Sheldon R. Tieszen[1], Timothy J. O'Hern[1], Robert W. Schefer[2], Elizabeth J. Weckman[3]
[1]Sandia National Laboratories, Albuquerque, NM 87185-0836
[2]Sandia National Laboratories, Livermore, CA 94550
[3]University of Waterloo, Waterloo, Ontario, Canada

Progress has been made in diagnostics to simultaneously resolve scalar and momentum fields in two dimensions as a function of time for buoyant flows. The motivation for obtaining such data is the validation of numerical simulation tools. Data has been acquired for a one-meter diameter source for a helium plume, and hydrogen and methane fires. Data processing is currently in progress.

The experiments were conducted in a heavily modified existing facility now called the Fire Laboratory for the Accreditation of Models and Experimentation (FLAME). It is nominally a cube 6 meters on a side with an upward sloping roof leading to a square chimney 2.3 meters on a side. A one-meter diameter plume source was created within the FLAME facility 2.45 meters above the floor. A gas manifold system supplies the plume source with up to about 0.5 m/s of helium, hydrogen, methane, and/or other diluents. Various flow straighteners, the last being 2.5 cm of stainless steel honeycomb with 3 mm cells, are used to create a uniform flow at the plume source.

It was desired to create as close as possible the conditions corresponding to a plume (or fire) source on an infinitely flat plane in an otherwise quiescent atmosphere within the FLAME facility. A numerical simulation tool was used to design the interior so that the lower half of the facility is a cylindrical geometry with an annular air duct near the floor of the facility facing upward with the plume. An annular disk with inner radius of ½ meter and outer radius of 1 meter surrounds the plume source. Calculations show this disk acts as an effective floor plane forcing the annular air flow to cross it radially inward, thereby creating the desired flow pattern.

Diagnostics include flow field measurements above the plume source and boundary condition measurements on the inflow and outflow boundaries. The flow field measurements include particle image velocimetry (PIV) and planar laser induced fluorescence (PLIF). These measurements are taken across a vertical plane that contains the centerline of the plume source. The field of view is approximately 1.5 meters wide by 1 meter high. The vertical measurement plane is created by expanding a 0.3 Joule/pulse, 308 nm, UV excimer laser beam into a light sheet. PIV images are due to laser light scattered off of seed particles in the flow. Various seed particles were used both within the plume and in the surrounding flow. For helium plumes, PLIF images were created by mixing nominally 2% by volume acetone into the plume. No PLIF images were obtained in hydrogen fires. However, in the methane flames, PLIF images corresponding to the flame zones were recorded. It is believe these images are due to the formation of Poly-Aromatic-Hydrocarbons (PAH's) found in such flames.

The pulse rate on the laser is controlled by camera equipment with a maximum pulse rate of 200 pulses per second. Both the PIV and PLIF signatures are imaged with 35 mm Photosonics 4ML movie cameras at up to 200 frames/second. Tmax 400 ASA black and white film is used to record the data. The film is subsequently scanned at nominally a 1200 by 1800 pixel resolution for each frame. Nominally 2500 frames per camera/per test are recorded. To obtain PIV images in the UV, quartz lenses are used on the camera. To obtain PLIF it was found necessary to use an image intensifier to amplify the signal for the helium tests. Boundary condition diagnostics include flow velocity, temperature, and humidity for the air flow, mass flow rate, temperature and species concentration for the plume source, and momentum and temperature for the exit plane. Temperature measurements were also made on the facility walls.

Data for three test conditions have been acquired. The first is a methane fire with a mass flow rate per unit area of nominally 0.065 kg/m2-sec, which corresponds to that for a large JP-8 pool fire. The second is for a hydrogen fire with the same nominal heat release as the methane flame, about 2 MW. The third is for a helium plume with the same nominal cold inlet Richardson number as the methane fire, about 700.

Raw data will be shown for each of these tests. The nominal puffing frequency for these tests is 1.5 puffs/sec. The fire data was recorded at 200 frames/sec and the helium at nominally 120 frames per sec. Hence, the dynamics of the formation and advection of vortical structures is readily viewable in the films. The buildup of large coherent structures within the first diameter of the plume/fire results in very strong radial indraw of air. This radial indraw results in a deflection of the surface of the plume/fire near the toe of the plume/fire toward the centerline. In this position, the baroclinic generation of vorticity is less than when the plume/fire surface is oriented more vertically. As the large vortex is advected away from the surface, the plume/fire surface moves more into the vertical and baroclinic generation is strong. The mixing layer thickens and the structures amalgamate to become a coherent vortex. The process then repeats itself.

The data is currently being processed for the purpose of creating validation data sets for numerical simulation tools. The data has advantages over previous studies that employ laser doppler velocimetry (LDV) to obtain the velocity field. LDV has been the standard for use in developing/validating Reynolds-Averaged Navier Stokes (RANS) turbulence models which rely on single-point closure assumptions. LDV data is time-resolved only in a point-wise sense. The current data is temporally resolved simultaneously at all points in the two-dimensional plane of the laser sheet. Therefore, the data can be used for the validation of Large Eddy Simulation (LES) approaches and develop multipoint closure models, as well as, be processed for validation of conventional RANS and Unsteady-RANS approaches.