vane swirler. The addition of swirl, while improving flame stability, also increased local strain rates in the region of flame stabilisation so that the lean flammability limit increased with swirl number. Moderate rates of swirl added to the core or to the annular flow were, however, beneficial and eliminated the low frequency oscillation without a significant increase in the lean flammability limit. While swirl reduced the low frequency modulation in amplitude of the pressure signal, at times, it gave rise to a frequency of the order of 20 Hz of small amplitude. This frequency increased with bulk flow rate and swirl number, indicating that it was associated with the recirculation zone adjoining the sudden expansion, whose length decreased with swirl. Larger rates of swirl were not beneficial and led to a higher lean flammability limit as well as to an increase in the amplitude of oscillations associated with the natural acoustic frequencies of the combustor duct.

T-2A-4. MODELING OF URBAN CANOPY FLOWS IN A WATER CHANNEL

Marko PRINCEVAC, Xiangyi LI, and Hansheng PAN, *Department of Mechanical Engineering, University of California, U.S.A,* Detailed measurements of the flow within the modeled urban roughness sublayer were conducted in the water channel at the University of California, Riverside, and Laboratory for Environmental Flow Modeling. Building configurations simulating simple urban patterns were accomplished using highly polished acrylic models to minimize effects of refraction and attenuation of the laser sheet utilized by the TSI Particle Image Velocimetry (PIV) and the Planar Laser Induced Fluorescence (PLIF) systems. First, using a simple two building configuration the effects of channeling were studied and distribution of the turbulent kinetic energy was measured. Flow approach angle was 1, 3, 5 and 7 degrees and the investigated ratios of building heights to the street width were 0.5, 2 and 4 corresponding to the skimming flow, wake interference, and isolated wake regimes, respectively. The occurrence of flow channeling vs. flow recirculation in the street canyon was observed and the criteria for channeling occurrence was established. Second, flow within a simple 3 by 3 and 5 by 5 cubical building arrays were studied. This is the first time that such detailed measurements of the flow between the obstacles were performed. It was found that lateral array size has significant influence on initial dispersion within the array. Smaller array size leads to sideways flow channeling causing significant plume spread. This sideways channeling becomes less pronounced as array size increases. The sideways channeling becomes more intense when the mid-array building is higher.

14:30 ~ 15:50 (Room 102)

Experimental Techniques (II)

Session Chair : Prof. O. Mochizuki, Toyo Univ/Japan

T-2B-1. EXPERIMENTS WITH REAL SOURCE - SINK PAIRS

Sudhakar SUBUDHI, Jaywant H. ARAKERI, *Indian Institute of Science, Bangalore, India,* K. R.SREENIVAS, *Jawahar Nehru Center for Advanced Scientific Research, Bangalore, India,* This paper deals with the flow associated with a source and a sink. Such source-sink interactions occur in many situations including cooling of computer data centers. The source consists of fluid issuing out of a pipe and the sink is a pipe, through which fluid enters, that is kept some distance from the source pipe. The source and sink flow rates may not be same. Of concern is the percentage of source fluid that enters the sink. Experiments have been carried in a tank of size of 1200mm×430mm×415mm with its top side open to ambient. The working fluid is water. The source pipe ID is of 6mm and the sink pipe ID is of 10mm or 20mm. The horizontal and vertical separations between the source and sink pipes are adjustable. There are three types of geometries considered: (a) when source and sink have horizontal separation, (b) when source and sink have horizontal and vertical separations and (c) when source pipe and sink pipe are at right angles with each other. The Reynolds number (Re) was about 3200 based on the exit diameter of the source. This means that the jet was turbulent. Experiments were done with the sink flow rate equal to , lower or higher than the source flow rate . Potassium permanganate dye is used for flow visualization and from this visualization, the approximate flow rate of the sink for which all the source fluid was injected could be determined. To determine the efficiency (the fraction of source fluid that goes through the sink), titration method was used using HCL-NaOH as acid-base combination and Phenolphthalein as pH indicator. Flow visualization results and the efficiency values show that (a) the sink flow rate required for 100% efficiency increases if the horizontal separation between source and sink will increase for both sink diameters, (b) the sink flow rate required for 100% efficiency is lower for the case of 20 mm sink diameter than that of 10 mm sink diameter keeping the horizontal separation constant, (c) there is increase in the sink flow rate required for 100% efficiency with increase in the vertical separation between the source and the sink and (d) if the source and the sink are at 90^0 , then the sink flow rate required will be more compared to that of configuration with 0^0.

T-2B-2. ANALYSIS OF FLOW CHARACTERISTICS AROUND CROSS FLOW FAN OF ROOM AIR CONDITIONER USING VISUALIZATION TECHNIQUE

S. H. LEE, *Sungkyunkwan University, Korea*, S. U. NA, *Samsung Electronics, Korea*, G. KANG, *Samsung Electronics, Korea,* H. S. KO, *Sungkyunkwan University, Korea,* Whole flow fields of a room air conditioner (RAC) have been visualized by a Particle Image Velocimetry (PIV) technique to analyze the flow structure by various inlet and outlet angles, and to control an eccentric vortex which affects an efficiency and noise of the RAC. A test model with 5 stages of a cross flow fan has been manufactured and a transparent acryl has been installed at the side of the test model for the PIV experiment. The inlet and outlet flows and the flow inside the cross flow fan have been analyzed by varying the inlet grill angles and outlet blade angles. The movement of the eccentric vortex has been investigated experimentally by developing the measurement technique for the inner flow field of the cross flow fan, and the relationship between the control of the eccentric vortex and the inlet and outlet angles has been investigated in this study.

T-2B-3. UNSTEADY MEASUREMENTS OF TURBULENT BOUNDARY LAYER FLOW PAST A 2D SQUARE CYLINDER BY USING TR-PIV

L. L. SHI, J. J. WAN, Y. Z. LIU, *School of Mech. Eng., Shanghai Jiao Tong University, China,* The turbulent boundary layer flow past a 2D square cylinder flush-mounted on a plane wall was extensively measured in a view to comprehensively understand the unsteady behaviors buried in the separated and reattaching flow. A TR-PIV setup was established by integrating a 1.8W semiconductor continuous laser and a high-speed camera (APX, Japan). A low-speed recirculation water channel was constructed by acrylic 10mm in thickness; the water was circulated by an electro-magnetic pump (Iwaki, Japan). The cross-sectional size of the working section is 150mm in width and 200mm in height. A square cylinder 15mm in width and height was flush mounted on a false plate 30mm above the bottom wall of the water channel, spanning the width of the working section. The free-stream velocity of the water flow was 0.15m/s. A polymer particles with averaged diameter 10um was seeded into the water fluid, which were illuminated by a laser sheet 1mm in thickness (λ = 532nm). Distribution of the seeding particles at the region downstream of the cylinder was captured at the rate of 500Hz. Statistical characteristics of the turbulent separated and reattaching flow were analyzed in terms of time-averaged velocity field, turbulence intensity field, velocity spectrum and cross-spectrum of velocity fluctuation and distribution of the reverse-flow intermittency. Unsteady behaviors of the vortical structures buried in the separated and reattaching flow were obtained from auto- and cross-correlation of velocity fluctuations, and the conditionally-averaged velocity field. The POD analysis of the vortical structures was given in the present study.

T-2B-4. VOLUMETRIC 3 - COMPONENT MEASUREMENTS USING V3V – AN INNOVATIVE APPROACH TO INSTANTANEOUS 3D FLOW MEASUREMENT

Rajan MENON, *TSI Incorporated, USA,* Dan TROOLIN, *TSI Incorporated, USA,* Solving flow problems in industry and research requires quantitative information of the 3-dimensional instantaneous velocity vector field. Flow structures, vorticity fields and other flow properties and their spatial and temporal variation are extracted from the instantaneous velocity vector fields in a volumetric region. The new Volumetric 3-Component Velocimetry (V3V) system, described here, uses a unique image capture system with three apertures to measure the instantaneous flow velocities at thousands of points in a volume. Unlike other imaging techniques where multiple cameras are individually mounted on a frame, V3V system uses an integrated imaging system that does not need any focusing, aperture and/or tilt adjustment. And, the axis of the measuring region and the standoff distance for the V3V Camera probe are predefined. The measuring region size, in the shape of a cube, was 140 x 140 x 100 mm and the typical stand-off distance was 500 mm. To measure the velocity field in a volume, a volume illumination system using a pulsed YAG laser is employed. Images captured simultaneously through the three apertures of the V3V camera are combined and processed to get the three-dimensional location and displacements of the particles. The HYPERSTREAMING system provides