SAFL Boundary Layer Wind Tunnel:

A NSF and NCED funded research facility.

1 Basic Information

1.1 Physical description

The wind tunnel is the large, blue wooden structure on the fourth (top) floor of SAFL. The original schematic of the wind tunnel is shown in figure 1. The tunnel forms a closed loop through which air is pumped by a large axial fan (2.4 m diameter driven by a 200 hp electric motor) that looks something like an airplane propeller. The wind tunnel has an overall plan length of 37.5 m with a main test section fetch-length over 15 m, an area contraction ratio of 6.6:1 and has an adjustable ceiling to accommodate various pressure gradients. See table 1 for a summary of dimensions. The tunnel has the option of being opened to the outside atmosphere at the East-end of the building (see figure 1) where there are two garage-like doors. In this way, we can introduce particulates into the tunnel without damaging the fan or clogging the flow management screens. There are two test sections, one large ($2.4\ m \times 2.4\ m$ cross-section) and the other main section ($1.7\ m \times 1.7\ m$ cross-section). The main section is where we conduct most of our research though the larger section has been used for applied studies such as testing wind-loading on windows and doors by the Andersen Window Company in the past. Speed up to 100 mph can be attained in the main test section, though for structural and maintenance reasons we normally operate the tunnel in the range of 20-30 mph (or 8-15 m/s).

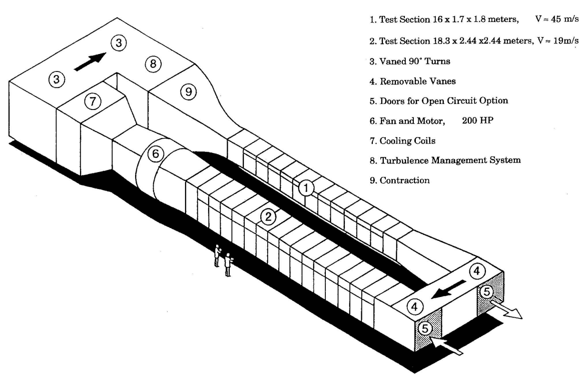

Figure 1: Original schematic of Saint Anthony Falls boundary layer wind tunnel.

1.2 History

This tunnel was designed by Prof. Cesar Farrell (retired as of 1998) and built by SAFL staff members and completed circa 1991. While this tunnel is very unique (only such tunnel in Minnesota), many other universities around the world have built and are currently building similar tunnels, for example Iowa State (also designed by C. Farrell). These tunnels are typically used in wind engineering and atmospheric studies.

2 Current Research

Research in this wind tunnel is conducted under the guidance of **Prof. Fernando Porté-Agel**. Current studies focus on basic research of turbulent boundary layers and **land-atmosphere interactions** with experiments designed specifically for evaluation and improvement of turbulence models

Plan Length		37.5 m
Main Test Section	Area	$1.7 \times 1.7 m^2$
	Wind Speed	2-45 m/s
	Contraction Ratio	6.6:1
	FreeStream Turb. Intensity	$< 0.3\%$
	Adjustable Roof	1.5-1.7 m
Larger Test Section	Area	$2.4 \times 2.4\ m^2$
	Wind Speed	1-18 m/s
Fan	Diameter	2.4 m
	Max. RPM	900
	Electric Motor	200 hp

Table 1: Basic facts about the SAFL boundary layer wind tunnel

used in numerical similations (**Large-Eddy Simulation**) of the **Atmospheric Boundary Layer (ABL)**. Most recently, flow over a roughness transition (using very coarse, 16-grit sandpaper) which mimics a land-surface change such as flow transition from over a forrest to over a lake. The graduate student currently working on these wind tunnel experiments is Matt Carper. There is a close collaboration between these experiments and numerical simulations being run by graduate student Rob Stoll on the large, parallel supercomputers at the Minnesota Supercomputing Institute (on the U of MN campus). Cooperation between research involving numerical simulations and experiments is essential to advance the understanding of the physics involed in land-atmosphere interactions which drives the transport of momentum, heat, water vapor and pollutants in the atmosphere.

3 Unique Measurements in the Wind Tunnel

The fundamental studies of turbulent boundary layers taking place in the SAFL wind tunnel use cutting edge experimental methods using, for example, **Particle Image Velocimetry (PIV)**. This state-of-the-art measuring technique enables us to obtain instanteneous, 3-component velocity measurements at very high-resolutions ($\sim 1\ mm$ spacing between velocity vectors) across a 2-dimensional plane. These measurements are made by seeding the air flow in the wind tunnel with tiny oil-droplets ($\sim 1\ \mu m$) that are illuminated by pulsing a high-powered laser (Nd:YAG) which is spread out into a 2-dimensional light-sheet. At the same instant that the laser sheet is pulsed and the particles are illuminated (see figure 3), a high-speed digitial (CCD) camera takes a picture of the particles. By comparing (through spatial correlation) two consecutive pictures of the same particles, the velocity field across the plane can be determined with high resolution and accuracy. All three components of velocity of the particles can be determined by adding a second camera and applying stereoscopic principles in the data analysis. These measurements using particle image velocimetry are essential to evaluating turbulence models due to their ability to spatially capture a flow-field which numerical simulations attempt to compute.

4 Past Applied Research

In previous years, the boundary layer wind tunnel has been used to perform applied studies involving wind engineering of large buildings. One such project was the study of proposed new bus station for downtown Minneapolis (see figure 4) and how the concentrated area of exhaust from the buses would affect the street level air quality (see figure below). Another project that took place in the wind tunnel was a study of the Moos Towers and Phillips-Wangensteen building complex around which high-speed street level wind gusts were commonplace due to poor planning (Senior Research Associate Chris Ellis could add more here since he was involved in this study). Yet another study which took place in the tunnel was that of drifting snow onto a roof and the effectiveness of roof

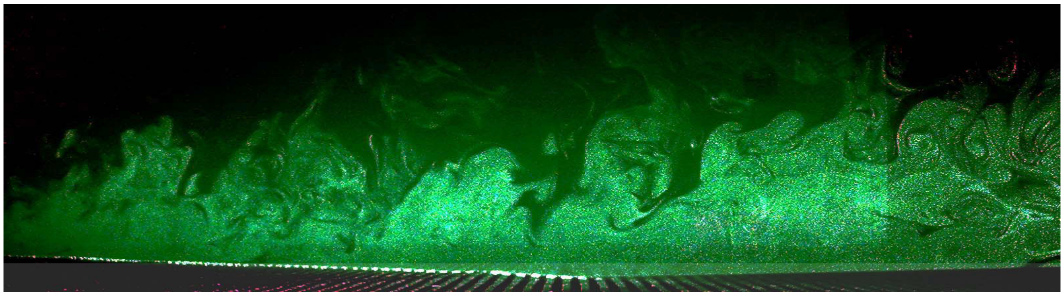

Figure 2: Visualization of a turbulent boundary layer (seeded with oil-droplets and illuminated with a laser sheet) in the boundary layer wind tunnel located at the St. Anthony Falls Laboratory (photo by M.A. Carper).

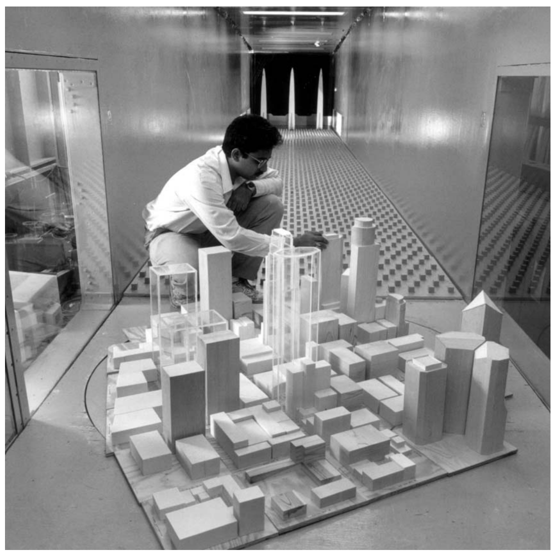

Figure 3: Photograph of model of downtown Minneapolis on a turning table in the SAFL boundary layer wind tunnel.

vents to keep snow out while still exchanging air with the outside.

With a recent influx of funding from the National Science Foundation (NSF) and the National Center for Earth-surface Dynamics (NCED) to do basic research, the applied projects in the wind tunnel have become less common. We still often collaborate with others in the U of MN community. Most notably a study of pollen transport by reserchers in the Department of Geology (Prof. Emi Ito) and a heat-transfer study of Spotted Owls' nests by researchers in the Department of Fisheries, Wildlife and Conservation Biology (Prof. R. Gutiérrez).