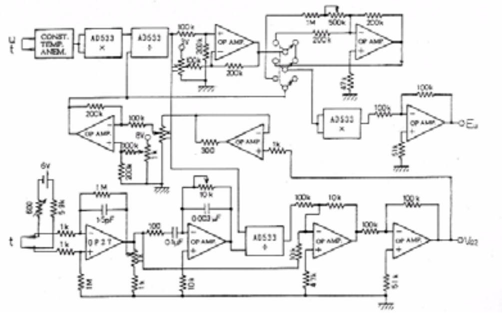
A tribute to the memory of Prof. Yasutaka NAGANO

Professor Nagano, the former chair of the JSME Thermal Engineering Division, passed away at the age of 71 on June 6, 2015. We shall always remember him, his gentle smile and his excellent contribution to the studies of turbulent heat transfer, e.g., turbulence measurement using hot- and cold-wire techniques, two-equation turbulence modeling and direct numerical simulations.

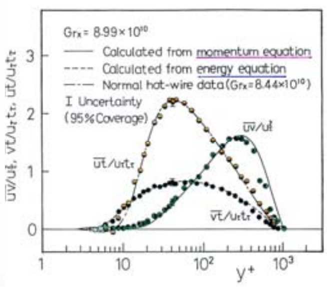
THMT-5 at Dubrovnik on September 29, 2006

Main achievements

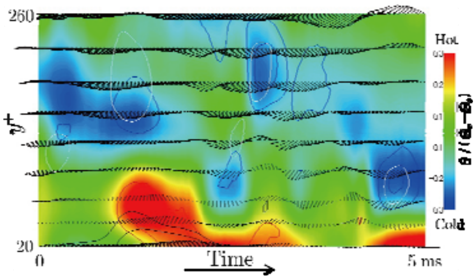
Simultaneous measurement of velocity and temperature fluctuations



Analog circuit for simultaneous measurement of velocity and temperature fluctuations (*JHT*, 1978)



Reynolds shear stress and turbulent heat fluxes in natural convection TBL (*IJHMT*, 1988)

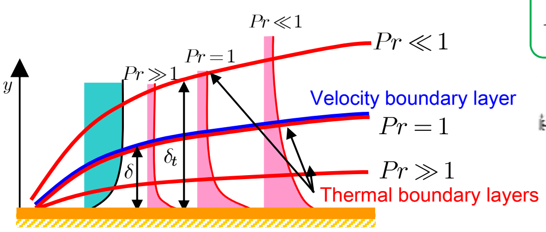


Instantaneous velocity vectors and temperature fluctuations measured by multi-wire probe composed of submicron cold-wires (*IJHFF*, 2008)

Accurate prediction of complex turbulent heat transfer by the two-equation model

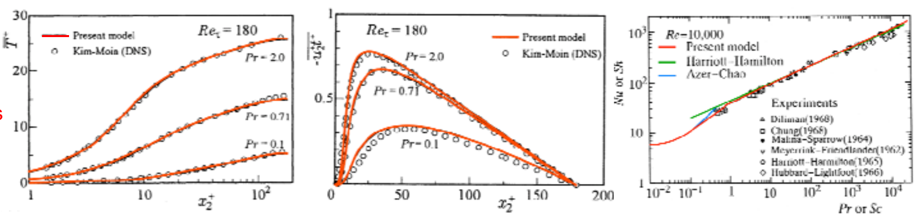
- Two-equation model for heat transfer $-\overline{u_j\theta} = \alpha_t \dfrac{\partial \Theta}{\partial x_j}$
- Modeling of eddy diffusivity for heat $\alpha_t = C_\lambda f_\lambda (k^2/\varepsilon) f(R)$

$$R = \frac{\tau_\theta}{\tau_u} = \frac{k_\theta/\varepsilon_\theta}{k/\varepsilon}$$



What about the turbulent Prandtl number?

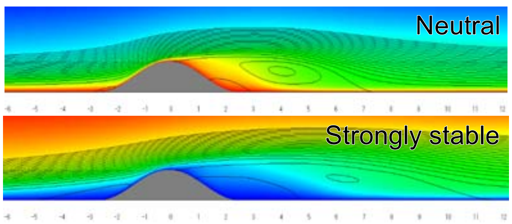
The eddy diffusivity for heat is modeled using the time scale ratio *R* (see the left column) without using the *turbulent Prandtl number.* This novel formulation at the two-equation level not only increases the universality of numerical calculation of turbulent heat transfer but also provides reliable predictions of the variance of temperature fluctuations.



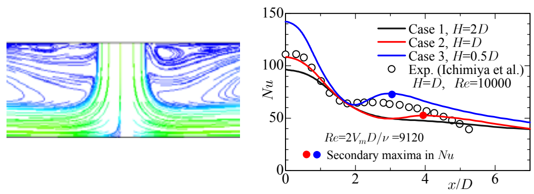
Predictions of various Prandtl number fluids (*PF*, 1996)

Detailed understanding of turbulent heat transfer by DNS

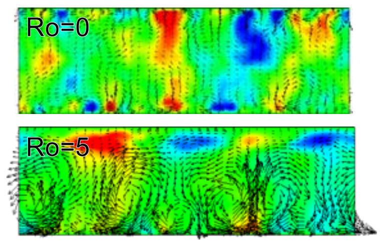
Direct numerical simulation (DNS) enables us to elucidate turbulent heat transfer phenomena in the vicinity of the wall.



DNS based on the finite-difference method for thermally-stratified turbulent boundary layer over a 2-dimensional hill (*ICJWSF*, 2013)



DNS for turbulent heat transfer in plane impinging jet (*IJHFF*, 2004)



Streamwise averaged velocity vectors and temperature fluctuations in non-rotating /rotating channel flows by DNS of spectral method (*JoT*, 2003)

Professor Yasutaka Nagano
— Main research fields and key achievements —

I. Experimental Investigation of Turbulent Transport Phenomena

Hishida, M. and Nagano, Y. (1978). Simultaneous measurements of velocity and temperature in nonisothermal flows. *J. Heat Transfer*, **100** (2), 340-345.

Hishida, M. and Nagano, Y. (1979). Structure of turbulent velocity and temperature fluctuations in fully developed pipe flow. *J. Heat Transfer*, **101** (1), 15-22.

Hishida, M. and Nagano, Y. (1988). Turbulence measurements with symmetrically bent V-shaped hot-wires. Part 1: principles of operation. *J. Fluids Engng.*, **110** (3), 264-269.

Nagano, Y. and Tagawa, M. (1988). Statistical characteristics of wall turbulence with a passive scalar. *J. Fluid Mech.*, **196**, 157-185.

Tsuji, T. and Nagano, Y. (1988). Characteristics of a turbulent natural convection boundary layer along a vertical flat plate. *Int. J. Heat Mass Transfer*, **31** (8), 1723-1734.

Tsuji, T. and Nagano, Y. (1988). Turbulence measurements in a natural convection boundary layer along a vertical flat plate. *Int. J. Heat Mass Transfer*, **31** (10), 2101-2111.

Tsuji, T. Nagano, Y., and Tagawa, M. (1992). Frequency response and instantaneous temperature profile of cold-wire sensors for fluid temperature fluctuation measurements. *Exp. Fluids*, **13** (2-3), 171-178.

Nagano, Y., Tagawa, M. and Tsuji, T. (1993). Effects of adverse pressure gradients on mean flows and turbulence statistics in a boundary layer. In *Turbulent Shear Flows 8* (pp. 7-21). Springer.

Nagano, Y. and Tsuji, T. (1994). Recent developments in hot- and cold-wire techniques for measurements in turbulent shear flows near walls. *Exp. Therm. Fluid Sci.*, **9** (2), 94-110.

Nagano, Y. and Tagawa, M. (1995). Coherent motions and heat transfer in a wall turbulent shear flow. *J. Fluid Mech.*, **305**, 127-157.

Nagano, Y., Tsuji, T. and Houra, T. (1998). Structure of turbulent boundary layer subjected to adverse pressure gradient. *Int. J. Heat Fluid Flow*, **19** (5), 563-572.

Houra, T. and Nagano, Y. (2008). Spatio-temporal turbulent structures of thermal boundary layer subjected to non-equilibrium adverse pressure gradient. *Int. J. Heat Fluid Flow*, **29** (3), 591-601.

II. Modeling of Turbulent Heat and Momentum Transfer

Nagano, Y. and Hishida, M. (1987). Improved form of the k-ε model for wall turbulent shear flows. *J. Fluids Engng.*, **109** (2), 156-160.

Nagano, Y. and Kim, C. (1988). A two-equation model for heat transport in wall turbulent shear flows. *J. Heat Transfer*, **110** (3), 583-589.

Nagano, Y. and Tagawa, M. (1990). An improved k-ε model for boundary layer flows. *J. Fluids Engng.*, **112** (1), 33-39.

Nagano, Y. and Tagawa, M. (1990). A structural turbulence model for triple products of velocity and scalar. *J. Fluid Mech.*, **215**, 639-657.

Abe, K., Kondoh T., and Nagano, Y. (1994). A new turbulence model for predicting fluid flow and heat transfer in separating and reattaching flows—I. Flow field calculations. *Int. J. Heat Mass Transfer*, **37** (1), 139-151.

Abe, K., Kondoh, T. and Nagano, Y. (1995). A new turbulence model for predicting fluid flow and heat transfer in separating and reattaching flows—II. Thermal field calculations. *Int. J. Heat Mass Transfer*, **38** (8), 1467-1481.

Nagano, Y. and Shimada, M. (1996). Development of a two-equation heat transfer model based on direct simulations of turbulent flows with different Prandtl numbers. *Phys. Fluids*, **8** (12), 3379-3402.

III. DNS and LES of Turbulent Heat and Fluid Flows

Matsumoto, A., Nagano, Y. and Tsuji, T. (1991). Direct numerical simulation of homogeneous turbulent shear flow. In *5th Numerical Fluid Dynamics Symp.* (Vol. 1, pp. 361-364).

Iida, O. and Nagano, Y. (1999). Coherent structure and heat transfer in geostrophic flow under density stratification. *Phys. Fluids*, **11** (2), 368-377.

Hattori, H. and Nagano, Y. (2004). Direct numerical simulation of turbulent heat transfer in plane impinging jet. *Int. J. Heat Fluid Flow*, **25** (5), 749-758.

Nagano, Y., Hattori, H. and Houra, T. (2004). DNS of velocity and thermal fields in turbulent channel flow with transverse-rib roughness. *Int. J. Heat Fluid Flow*, **25** (3), 393-403.

Inagaki, M., Kondoh, T. and Nagano, Y. (2005). A mixed-time-scale SGS model with fixed model-parameters for practical LES. *J. Fluids Engng.*, **127** (1), 1-13.

Hattori, H., Houra, T. and Nagano, Y. (2007). Direct numerical simulation of stable and unstable turbulent thermal boundary layers. *Int. J. Heat Fluid Flow*, **28** (6), 1262-1271.