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Summary of Work Accomplished

    The main emphasis of this quarter has been to test the effects
of suction in a controlled environment with the emulated wall eddy
structure. A study of the curved working wall of the test section
in the Görtler Wind Tunnel showed that there were sufficient
stresses within the plexiglas that cutting elongated slits for
suction would probably cause the surface to develop step-type
roughnesses. Thus several individual holes were initially drilled
along the streamline direction in a spanwise region between two
vortices. Air was withdrawn through this series of holes to provide
a semi-continuous region of suction. Differing rates of suction
through these holes were used to explore the effects upon the eddy
structure. These preliminary results were obtained using
visualization; i.e. smoke as introduced via a smoke wire into the
boundary layer. Images were captured using a video camera and
analyzed to determine the best suction rates.

    The preliminary results showed that suction had a large effect
upon individual streaks of low speed fluid. Without the suction,
the low speed region lying in the upwelling zone between two
streamwise vortices was broken down by a secondary instability.
This instability typically caused the low speed fluid marked with
the smoke to oscillate from side to side in a manifestation of an
inflectional instability in the spanwise direction as found and
reported earlier in this research. With increasing distance
downstream, the oscillation amplitude grew very rapidly until it
broke down into complete turbulence.

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Application of the suction under an individual streak altered this breakdown process in three aspects. First a small amount of suction(i.e. c_q[1]≈ 0.0003)would cause the breakdown region to move downstream as expected; i.e. the transition was delayed. However the amount of suction required to accomplish this was an order of magnitude smaller than expected. Secondly as the suction increased, the breakdown of the low speed region continued to be delayed further downstream until it became contaminated by the oscillations of its neighbors. That is, the breakdown of the neighboring low speed streaks grew to sufficient amplitudes that the stabilized low speed streak became contaminated via receptivity from its neighbors. This continued until the suction coefficient reached an amplitude of approximately c_q = 0.003. Thirdly, increasing the suction rate further such that c_q > 0.003 promoted a breakdown further upstream. That is, the suction caused an earlier breakdown of the low speed region than without any suction at all. In this case it seemed that the suction was so large that it appeared as a large disturbance to the flow and thus acted as an "inverse roughness" element so that the normal mode of breakdown was bypassed and another mode of instability intervened.

Two other tasks were accomplished during this quarter. First the earlier work on the emulated boundary layer was written up for publication and has been submitted to the Journal of Fluid Mechanics. Secondly a new graduate student is preparing the water channel to study the effects of suction under a fully developed turbulent boundary layer. Much of the work accomplished during this quarter has been to familiarize himself with the Laser Doppler Anemometer and the flow facility. No suction has been employed in the water channel during this quarter.

Future Work

During the next quarter, different combinations and patterns of the suction will be applied in the emulated boundary layer to ascertain more fully the effects of suction on the wall eddy structure. Further work will continue to implement the turbulent boundary layer suction facility.

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[1]The suction coefficient, c_q is defined as the average normal velocity to the wall divided by the freestream velocity; $c_q = \bar{v}_w/U_\infty$.

An Investigation of Nonlinear

Interactions in

Wall Bounded Turbulent Flows

Semi-Annual Report for the Period

10/01/91-03/31/92,

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University of Southern California

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This reporting period has been used to complete an analysis of the velocity and temperature fields obtained previously in direct numerical simulations of wall bounded turbulent convection and to initialize an analysis of these fields using their decomposition into large and small scale components.

The results of the analysis are summarized below and are described in more detail in a manuscript "Numerical Simulations of Soft Thermal Turbulence" by S. L. Christie and J. A. Domaradzki, recently submitted for publication to the Physics of Fluids. Direct numerical simulations of turbulent Rayleigh-Bénard convection were performed in large aspect ratio boxes to examine the characteristics of convection in the range of Rayleigh numbers corresponding to soft turbulence regime in the Chicago group classification. A measured exponent in the power law dependence of Nusselt number on Rayleigh number is 0.274, closer to the value 2/7 found in a small aspect ratio cell at the University of Chicago for the hard turbulence regime than the 1/3 obtained there for soft turbulence. The probablity distributions of temperature fluctuations T' in the convective core do not exhibit a unique functional form. Gaussian, exponential, and mixed Gaussian-exponential forms are observed (see figs. 1a - 1c). Further, we show that a transition in the functional form of the T' pdf can be produced by changing the as-

pect ratio of the computational box without changing Rayleigh number at all (see fig. 2). These results are in agreement with other studies which have indicated that the hard/soft characterization of turbulent convection may partially reflect as yet not fully understood distinctions between convective turbulence in large and small aspect ratio cells.

Our research plans for the immediate future are to make an additional computer run in which the temperature and velocity histograms will be constructed for the large and the small scales of turbulence separately by an appropriate decomposition of these fields. This procedure should help to evaluate our hypothesis that the large scales are responsible for the Gaussian statistics and the small scales for the exponential pdfs.
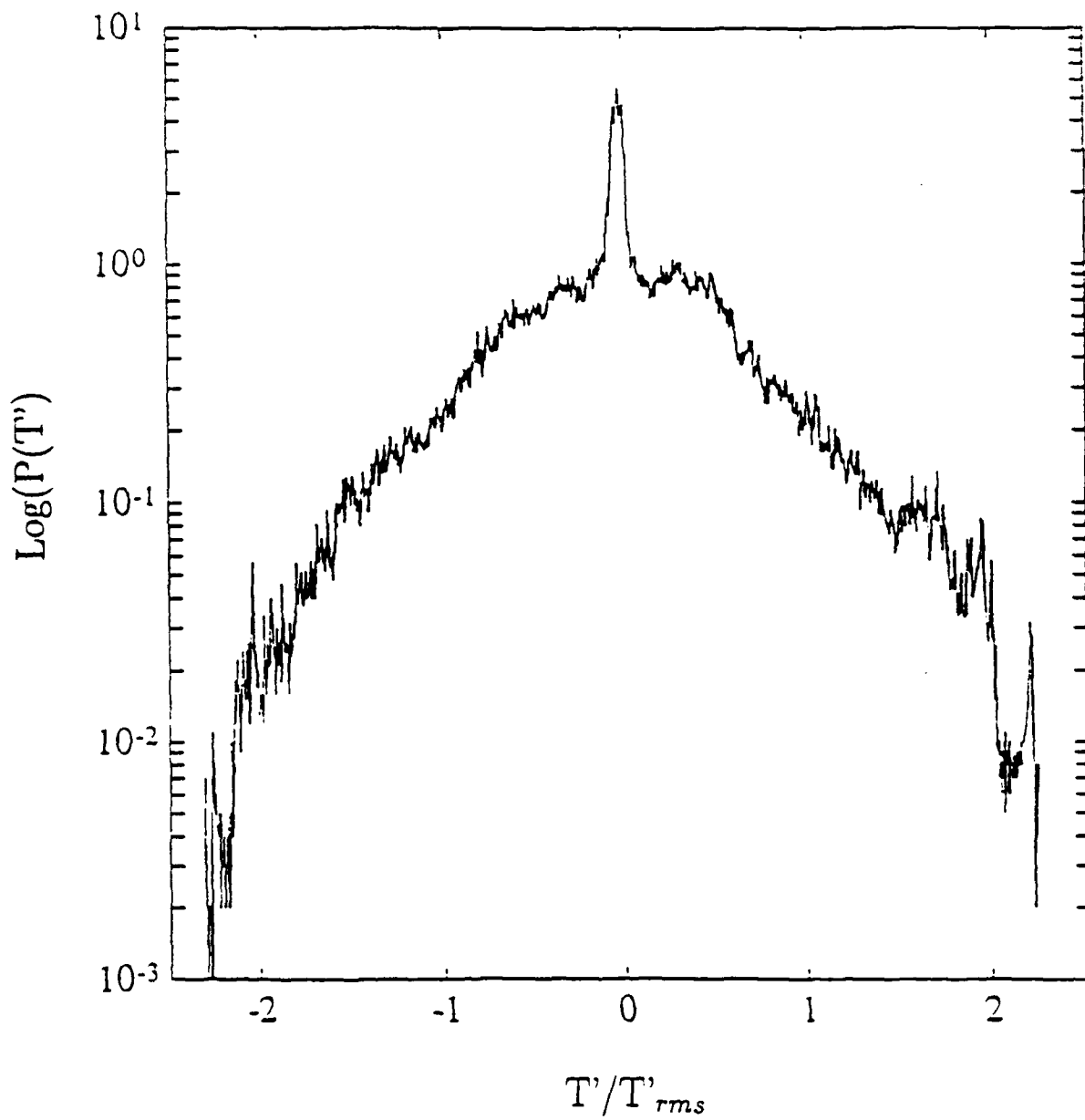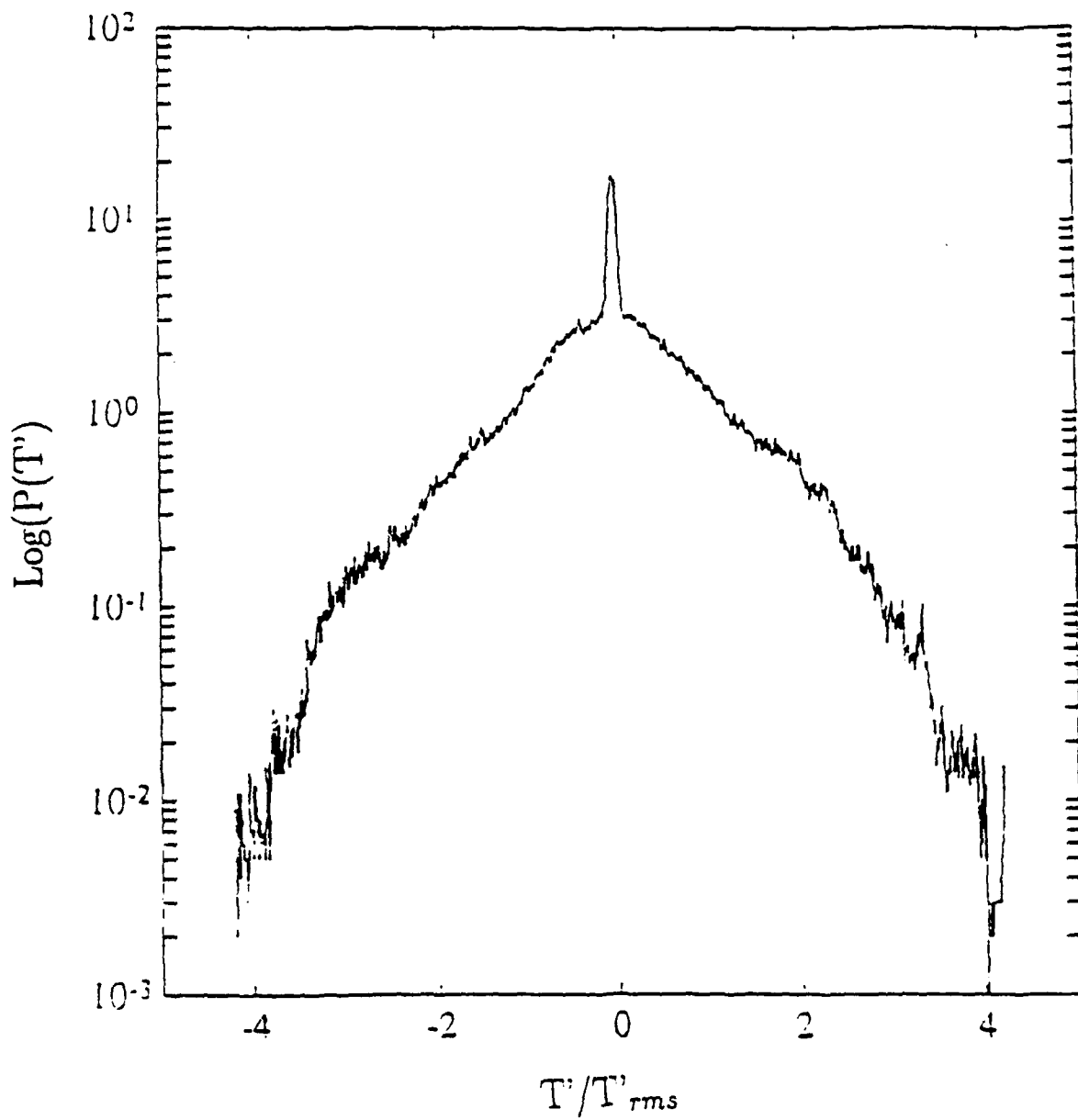
Figure 1: Temperature Fluctuation histograms taken midway between the walls for a) Ra=2.5x10^5 b) Ra=3.8x10^5 c) Ra=6.3x10^5

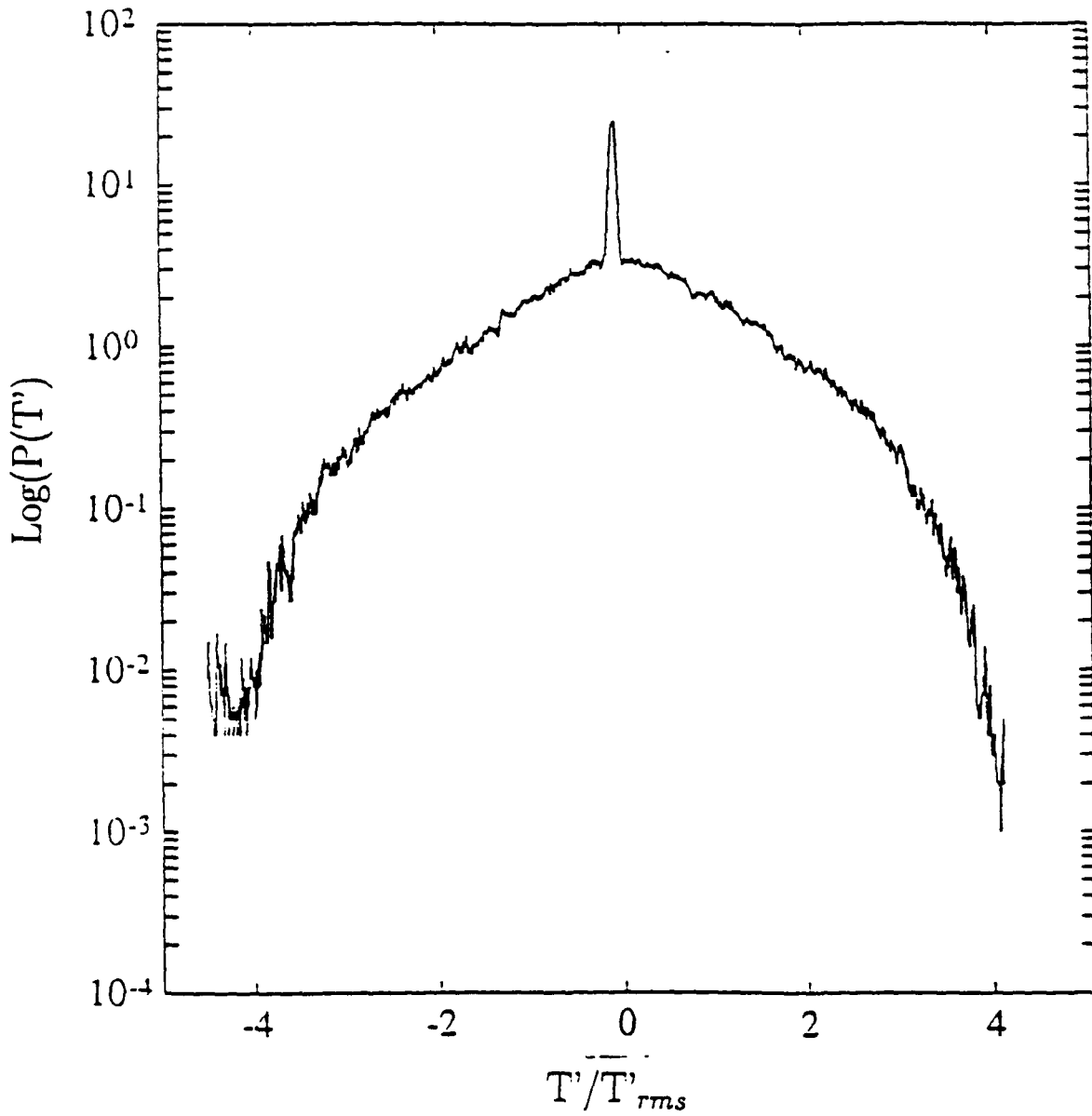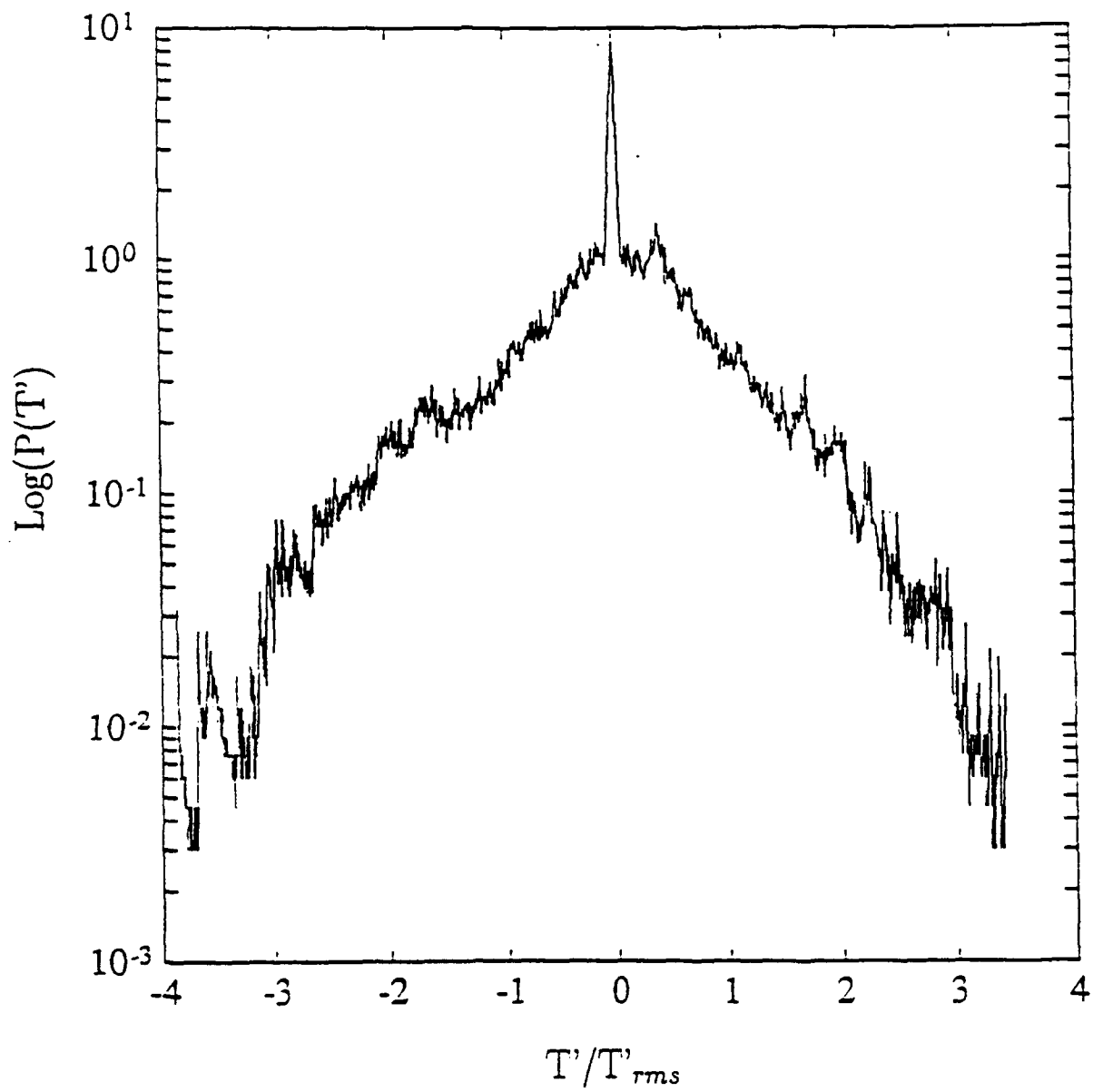Figure 1 : Temperature Fluctuation histograms taken midway between the walls for a) Ra=2.5x10⁵ b) Ra=3.8x10⁵ c) Ra=6.3x10⁵

Figure 1. Temperature Fluctuation histograms taken midway between the walls for a) Ra=2.5x10⁵ b) Ra=3.8x10⁵ c) Ra=6.3x10⁵

Figure 2: T' pdf from our simulation at Ra=6.3x10⁵ and AR=3. This is to be compared to fig. 1c at the same Ra and AR=6.

Objective

The objective is to perform final experimental $2D$ turbulence runs, with sufficient resolution in space and time so that the likely scales of interest in the interaction with the wake stratification are covered. It is planned to complete this work by June, when the wake/stratified turbulence problem can be addressed.

Progress

The experiment has been completely reworked so that much more precise control can be realised over the initial conditions that initial results have indicated to be of importance. The floor and sides of the tank have been refinished and leveled, and density profiles, $\rho(z)$ can now be made by removal of fluid from 80 holes aligned in z. Illumination is provided either with a custom designed, air-cooled, light sheet, or from angled overhead lights. The latter technique is successful only if all surface particles are removed, the former only if refractive index matching is very careful between fluid layers.

The automated image processing technique works on any digitised image, from video or other sources, and current results indicate that sufficient scale resolution to resolve smaller scale motions in such a large facility (*i.e.* in order to resolve a large range of scales), can only be achieved by scanning of photographic slide images. This process can be performed automatically, is affordable, and is being implemented.

Plans

The final experimental data for the stratified, homgeneous turbulence regime will involve synchronised video and photographic images, for low and high resolution respectively. The low resolution is sufficient to cover measurements of decay rates and global statistical properties, and such data can be acquired for long times. The high resolution images will allow the small-scale transfer mechanisms to be investigated indirectly by localised spectral energy measurements.

Objective
To test the implementation of an artificial neural network controller for generating suction in a turbulent boundary layer. The initial stage of the work is to design and build a new, small facility, and to investigate the various possible neural network designs and implementations.

Progress
The facility has been designed and is under construction. Since full funding did not begin until late '91, construction could not begin until this date. The 10cm x 5cm test section is about 60 cm in length, and the boundary layer can be visualised with aluminum dust, when the low speed streaks appear as dark areas. Photsensitive diode arrays encode this cross-channel variation in grey scale and serves as input to the neural net.

In planning and researching the neural net design, it has become clear that the neural net architecture must be carefully thought out to satisfy certain requirements. In particular, the success or failure could well hinge on the ability to store in temporary memory the recent time history of the inputs and their associated weights. In other words, the response can be to an unsteady signal, not simply an instantaneous pattern. It is possible to design a hybrid net, composed of two connected parts, one of which responds on a fast time scale to instantaneous inputs and changes weight coefficients accordingly, and the other which changes weights relatively slowly, this constituting the slow-varying local memory. This local memory is an associative memory which effects the outcome of the faster units by some interface function. There are various possible choices for this interface function and there does not seem to be a rational method for determining the optimum form. Research will continue on this topic, pending completion of the apparatus.

Plans
The water channel must be completed and flow quality assured. The suction control strategy, given the presence of a low speed streak, will be determined with assistance from Dr's R. Myose and R. Blackwelder at USC, who are working on suction control of a Goertler boundary layer.
The next step for the neural net design will be to investigate more closely the time-varying properties of the controller in real time.

Grant No. N00014-92-J-1062

USC 53-4514-1558

Title: Dynamics of the Upper Mixed Layer: Convection Wave Coupling

P.I.s: Maxworthy, T. and Redekopp L.G.
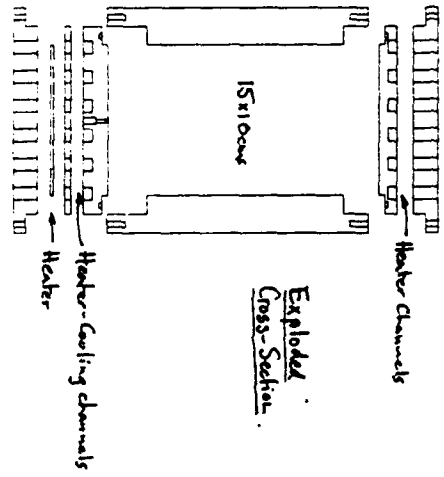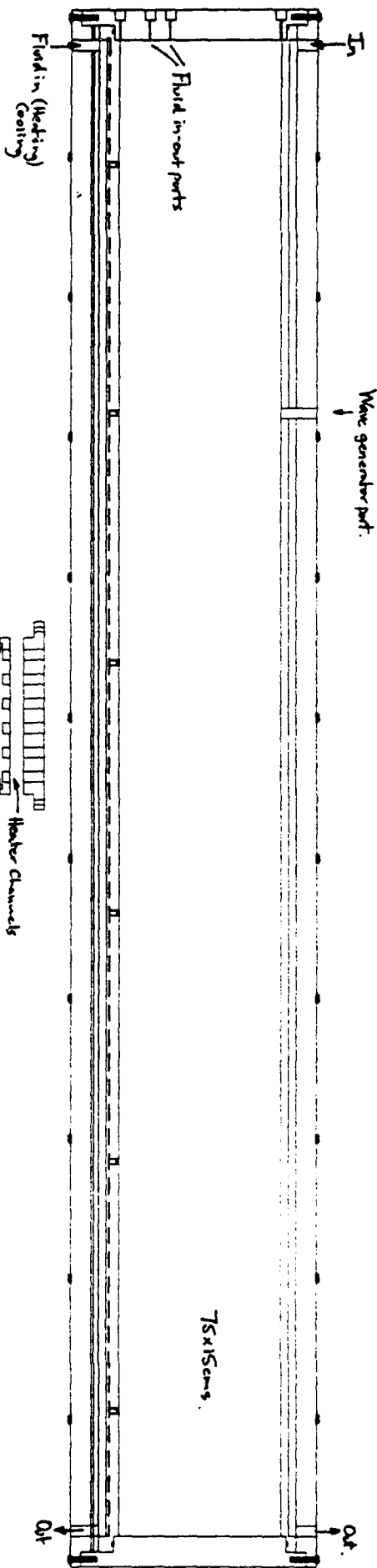
Quarter Report, Task 5

Period: 10/01/91 - 01/01/92

Theoretical Studies

The weekly nonlinear equations describing the one-space-dimensional version of the interaction of convection and internal gravity waves have been derived. Coefficients of these equations are being computed as well as the nature if the bifurcation to an interacting state.

Experimental Studies

The experimental cell has been designed (see attached) and is presently being fabricated. A second constant temperature bath has been purchased. We anticipate that the apparatus will be in operating condition by mid May.

Fluid in (Heating)
(Cooling)

Fluid in-out ports

In

Wire generator port.

Heater Channels

15 x 10 cms

Exploded
Cross-Section.

Heater-Cooling channels

Heater

75 x 15 cms.

Sketch of Experimental Apparatus.
Task 5

Out

Out