Fluid Mechanics Experiments in Oscillatory Flow
Volume II—Tabulated Data

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ABSTRACT

Results of a fluid mechanics measurement program in oscillating flow within a circular duct are presented. The program began with a survey of transition behavior over a range of oscillation frequency and magnitude and continued with a detailed study at a single operating point. Such measurements were made in support of Stirling engine development. Values of three dimensionless parameters, $Re_{\text{max}}$, $Re_{\omega}$, and $AR$, embody the velocity amplitude, frequency of oscillation and mean fluid displacement of the cycle, respectively. Measurements were first made over a range of these parameters which included operating points of all Stirling engines. Next, a case was studied with values of these parameters that are representative of the heat exchanger tubes in the heater section of NASA's Stirling cycle Space Power Research Engine (SPRE). Measurements were taken of the axial and radial components of ensemble-averaged velocity and rms-velocity fluctuation and the dominant Reynolds shear stress, at various radial positions for each of four axial stations. In each run, transition from laminar to turbulent flow, and its reverse, were identified and sufficient data was gathered to propose the transition mechanism. Models of laminar and turbulent boundary layers were used to process the data into wall coordinates and to evaluate skin friction coefficients. Such data aids in validating computational models and is useful in comparing oscillatory flow characteristics to those of fully-developed steady flow.

Data were taken with a contoured entry to each end of the test section and with flush square inlets so that the effects of test section inlet geometry on transition and turbulence are documented.

The following is presented in two volumes. Volume I contains the text of the report including figures and supporting appendices. Volume II contains data reduction program listings and tabulated data (including its graphical presentation).
ACKNOWLEDGEMENTS

The following work was sponsored by the Lewis Research Center of NASA under grant NASA/NAG3-598. The authors thank the grant monitors, James Dudenhoefer and Roy Tew for their guidance.

Consultation on instrumentation and 3D graphics was provided by Robert Hain, the comparison of data to steady-flow correlations in this report was done by Terry Johnson and much of the document preparation was with the aid of Phillip Tuma and Amy Johnson.
CONTENTS VOLUME I

ABSTRACT i

ACKNOWLEDGEMENTS ii

CONTENTS iii

NOMENCLATURE vi

LIST OF FIGURES ix

LIST OF TABLES xiii

1. INTRODUCTION 1
   1.1. Motivation 1
   1.2. Background 2
   1.3. Review of Oscillating Flow Research 3
       1.3.1. Laminar 3
       1.3.2. Transitional 4
       1.3.3. Turbulent 8

2. EXPERIMENTAL SETUP AND PROCEDURE 9
   2.1. Apparatus and Operating Range 9
       2.1.1. Dimensionless Operating Range 9
       2.1.2. Dimensional Operating Range 10
       2.1.3. Appartus 11
   2.2. Instrumentation 14
       2.2.1. Single-wire Probe 15
       2.2.2. Cross-wire Probe 16
   2.3. Calibration 18
   2.4. Data Acquisition 19
   2.5. Data Processing 22
       2.5.1. Probe Position 22
       2.5.2. Pressure Gradient Effect on Couette Flow Model 25
       2.5.3. Variation of Ambient Conditions 28
3. RESULTS

3.1. Qualification Tests

3.1.1. Variation in Flywheel Position.

3.1.2. Convergence of Velocity Measurements in Oscillating flow.


3.1.4. Repeatability of Transition Crank Position.

3.1.5. Steady-flow Results.

3.2. Exploration of Transition Mechanisms.

3.2.1. High-amplitude Cases.

3.2.2. Medium-amplitude Cases.

3.2.3. Low-amplitude Cases.

3.2.4. Similarity.

3.2.5. Convective Triggering of Transition.

3.2.6. Non-convective Triggering of Transition.

3.2.7. The Effects of Convectively and Non-convectively Triggered Transition.

3.2.8. Return to Laminar Flow.

3.3. SPRE Test Results with a Smooth (Nozzle) Entry.

3.3.1. Transition Mechanisms.

3.3.2. Results at s/d = 0.33 (Boundary Condition).

3.3.3. Results at s/d = 16.

3.3.4. Results at s/d = 30.

3.3.5. Results at s/d = 44.

3.3.6. Comparison of Profiles to Computational Data.

3.3.7. Modelling with Steady, Fully-Developed Flow Correlations

3.3.8. Comparison of Profiles to Computational Data.

3.4. Test Results with a Flush-square Entry.

4. CONCLUSIONS

5. REFERENCES

APPENDICES

A. Measurement Stations

B. Uncertainty Documentation
## CONTENTS VOLUME II

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>iii</td>
</tr>
<tr>
<td>NOMENCLATURE</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
</tbody>
</table>

### 1. DATA LISTINGS

- Single Wire Data: 1
- Cross-wire Data: 48
- Processed Data: 101

### 2. PROGRAM LISTINGS

- 127
## NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Units</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_R$</td>
<td></td>
<td>Relative amplitude of fluid displacement</td>
</tr>
<tr>
<td>$A^+$</td>
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<td>Empirical effective sublayer thickness for Van Driest model</td>
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<tr>
<td>$c_f$</td>
<td></td>
<td>Skin-friction coefficient</td>
</tr>
<tr>
<td>$D$</td>
<td>m</td>
<td>Piston diameter</td>
</tr>
<tr>
<td>$d$</td>
<td>m</td>
<td>Duct inner diameter</td>
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<tr>
<td>$f$</td>
<td>sec$^{-1}$</td>
<td>Frequency</td>
</tr>
<tr>
<td>$k_T$</td>
<td></td>
<td>Correction factor for tangential cooling of hot-wire sensor</td>
</tr>
<tr>
<td>$l$</td>
<td>m</td>
<td>Duct length</td>
</tr>
<tr>
<td>$P$</td>
<td>bar</td>
<td>Fluid static pressure</td>
</tr>
<tr>
<td>$p^+$</td>
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<td>Pressure gradient parameter</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>bar</td>
<td>Average pressure</td>
</tr>
<tr>
<td>$r$</td>
<td>m</td>
<td>Cross-stream coordinate, measured from the duct centerline</td>
</tr>
<tr>
<td>$R$</td>
<td>m</td>
<td>Pipe inner radius</td>
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<tr>
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<td></td>
<td>Reynolds number for steady flow, based on the duct diameter and the bulk-mean velocity</td>
</tr>
<tr>
<td>$Re_{max}$</td>
<td></td>
<td>Reynolds number based on the duct diameter and the amplitude of the bulk-mean velocity</td>
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<tr>
<td>$Re_\omega$</td>
<td>$\frac{\omega d^2}{4\nu_0}$</td>
<td>Kinetic Reynolds number, or Valensi number</td>
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<tr>
<td>$Re_\delta$</td>
<td>$u_{m,max} \frac{\delta}{\nu}$</td>
<td>Reynolds number based on the Stokes layer thickness</td>
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<td>$Re_{\delta_2}$</td>
<td>$\delta_2 u_m \sqrt{\nu}$</td>
<td>Momentum thickness Reynolds number</td>
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<tr>
<td>Symbol</td>
<td>Units</td>
<td>Explanation</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>s</td>
<td>m</td>
<td>Streamwise distance measured from open end of duct, or the stroke of the piston</td>
</tr>
<tr>
<td>Str = $\frac{\omega d}{u_{m,max} \cdot \text{Re}<em>{\max}} = \frac{4V_a}{\text{Re}</em>{\max}}$</td>
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<td>Strouhal Number</td>
</tr>
<tr>
<td>t</td>
<td>sec</td>
<td>Time</td>
</tr>
<tr>
<td>T</td>
<td>°C</td>
<td>Fluid temperature</td>
</tr>
<tr>
<td>u</td>
<td>m/sec</td>
<td>Instantaneous velocity</td>
</tr>
<tr>
<td>$\bar{u}$</td>
<td>m/sec</td>
<td>Streamwise component of ensemble-averaged velocity</td>
</tr>
<tr>
<td>$u'$ = $\sqrt{u'^2}$</td>
<td>m/sec</td>
<td>Streamwise component of rms-velocity fluctuation</td>
</tr>
<tr>
<td>$u_{\text{eff}}$</td>
<td>m/sec</td>
<td>Effective cooling velocity</td>
</tr>
<tr>
<td>$u_{\infty}$</td>
<td>m/sec</td>
<td>Freestream velocity</td>
</tr>
<tr>
<td>$u_m$</td>
<td>m/sec</td>
<td>Bulk-mean velocity</td>
</tr>
<tr>
<td>$u_{m,max}$</td>
<td>m/sec</td>
<td>Amplitude of the bulk-mean velocity</td>
</tr>
<tr>
<td>$u_n$</td>
<td>m/sec</td>
<td>Velocity component normal to sensor</td>
</tr>
<tr>
<td>$u_T$</td>
<td>m/sec</td>
<td>Velocity component tangential to sensor</td>
</tr>
<tr>
<td>$u_* = \sqrt{\frac{\tau_w}{\rho}}$</td>
<td>m/sec</td>
<td>Friction velocity</td>
</tr>
<tr>
<td>$u^+ = \frac{u}{u_*}$</td>
<td></td>
<td>Nondimensional velocity, in wall coordinates</td>
</tr>
<tr>
<td>$\bar{v}$</td>
<td>m/sec</td>
<td>Radial component of ensemble-averaged velocity</td>
</tr>
<tr>
<td>$v'$</td>
<td>m/sec</td>
<td>Radial component of rms-velocity fluctuation</td>
</tr>
<tr>
<td>$V$</td>
<td>volts</td>
<td>Transducer voltage</td>
</tr>
<tr>
<td>$V_a = \frac{\omega d^2}{4v}$</td>
<td></td>
<td>Valensi number</td>
</tr>
<tr>
<td>$-u'v'$</td>
<td>m$^2$/sec$^2$</td>
<td>Reynolds shear stress</td>
</tr>
<tr>
<td>x</td>
<td>m</td>
<td>Streamwise distance, measured from drive end of duct</td>
</tr>
<tr>
<td>Symbol</td>
<td>Units</td>
<td>Explanation</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>$x_m$</td>
<td>m</td>
<td>Amplitude of displacement of bulk fluid</td>
</tr>
<tr>
<td>$y$</td>
<td>m</td>
<td>Cross-stream coordinate, measured from the duct wall</td>
</tr>
</tbody>
</table>

$y^+ = \frac{y u_*}{n}$

Distance normal to the wall in inner coordinates

**Greek**

$\alpha = \sqrt{\alpha a}$

Womersely parameter

$\delta = (2 v / \omega)^{1/2}$

Stokes-layer thickness

$\delta_2$

Momentum thickness

$\theta$ (°)

Crank angle within the cycle

$\kappa$

Karman constant

$\mu$ N·sec/m$^2$

Dynamic viscosity

$\nu$

Kinematic viscosity

$\nu_0$

Kinematic viscosity at the reference state

$\rho$ kg/m$^3$

Density

$\tau$ Pa

Shear stress

$\psi = \overline{u'v'}/u'_w v'_w$

Correlation coefficient

$\omega = 2 \pi f$

Angular frequency

**Superscripts**

+ Wall coordinate

* Normalized quantity, except where used in friction velocity, $u_w$

**Subscripts**

$m$ Average over cross-section of duct

$max$ Maximum during one cycle

$o$ Reference state

$w$ At the wall
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ensemble-averaged velocity at s/d = 0.33.</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>Streamwise velocity fluctuation at s/d = 0.33.</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Streamwise turbulence intensity, u'/u, at s/d = 0.33.</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>Ensemble-averaged velocity at s/d = 16.</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>Streamwise velocity fluctuation at s/d = 16.</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Streamwise turbulence intensity, u'/u, at s/d = 16.</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Ensemble-averaged velocity at s/d = 30.</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Streamwise velocity fluctuation at s/d = 30</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Centerline view.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Streamwise velocity fluctuation at s/d = 30</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Near-wall view.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Streamwise turbulence intensity, u'/u, at s/d = 30.</td>
<td>36</td>
</tr>
<tr>
<td>11</td>
<td>Ensemble-averaged velocity at s/d = 44.</td>
<td>45</td>
</tr>
<tr>
<td>12</td>
<td>Streamwise velocity fluctuation at s/d = 44</td>
<td>46</td>
</tr>
<tr>
<td>13</td>
<td>Streamwise turbulence intensity, u'/u, at s/d = 44.</td>
<td>47</td>
</tr>
<tr>
<td>14</td>
<td>Streamwise velocity fluctuation at s/d = 0.033 (smoothed).</td>
<td>59</td>
</tr>
<tr>
<td>15</td>
<td>Radial velocity fluctuation at s/d = 0.33 (smoothed).</td>
<td>60</td>
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<tr>
<td>16</td>
<td>Reynolds shear stress at s/d = 0.33 (not smoothed).</td>
<td>61</td>
</tr>
<tr>
<td>17</td>
<td>Streamwise velocity fluctuation at s/d = 16 (smoothed).</td>
<td>72</td>
</tr>
<tr>
<td>18</td>
<td>Radial velocity fluctuation at s/d = 16 (smoothed).</td>
<td>73</td>
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<td>19</td>
<td>Reynolds shear stress at s/d = 16 (not smoothed).</td>
<td>74</td>
</tr>
<tr>
<td>20</td>
<td>Streamwise velocity fluctuation at s/d = 30 (smoothed).</td>
<td>85</td>
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<td>Radial velocity fluctuation at s/d = 30 (smoothed).</td>
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<td>22</td>
<td>Reynolds shear stress at s/d = 30 (not smoothed).</td>
<td>87</td>
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<td>23</td>
<td>Streamwise velocity fluctuation at s/d = 44 (smoothed).</td>
<td>98</td>
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<tr>
<td>24</td>
<td>Radial velocity fluctuation at s/d = 44 (smoothed).</td>
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<tr>
<td>25</td>
<td>Reynolds shear stress at s/d = 44 (not smoothed).</td>
<td>100</td>
</tr>
</tbody>
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DATA LISTINGS

I. SINGLE-WIRE DATA

SPRE Operating Point
Nozzle Inlet Geometry
$(\theta, \bar{u})$ $(\theta, u')$ $(\theta, u_m)$

<table>
<thead>
<tr>
<th>axial station</th>
<th>s/d</th>
<th>T ($^\circ$C)</th>
<th>P (bar)</th>
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<tr>
<td></td>
<td>0.33</td>
<td>25.68</td>
<td>0.980</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>25.29</td>
<td>0.991</td>
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<td></td>
<td>30</td>
<td>25.22</td>
<td>0.989</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>24.06</td>
<td>0.990</td>
</tr>
</tbody>
</table>

Note that the data are tabulated at every 4 degrees of crank position except within ±10 degrees of transition, for which the resolution is every 2 degrees.

II. SUPPLEMENTAL FIGURES

In order to supplement the three-dimensional figures which appear in the main body of the thesis, additional figures generated from the single-wire data have been included after the tabulated data for each of the four axial stations. At each station, plots are provided of the ensemble-averaged velocity, the streamwise rms-velocity fluctuation, and the turbulence intensity.
<table>
<thead>
<tr>
<th>$\theta$ (deg)</th>
<th>$\bar{u}$ (m/sec)</th>
<th>$u'$ (m/sec)</th>
<th>$\bar{u}$ (m/sec)</th>
<th>$u'$ (m/sec)</th>
<th>$\bar{u}$ (m/sec)</th>
<th>$u'$ (m/sec)</th>
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<td>100</td>
<td>0.5175</td>
<td>0.0095</td>
<td>0.6560</td>
<td>0.0059</td>
<td>0.8207</td>
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<td>0.0085</td>
<td>0.6017</td>
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<td>0.4790</td>
<td>0.0033</td>
<td>0.5804</td>
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<td>112</td>
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<td>0.0074</td>
<td>0.6561</td>
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<td>θ deg.</td>
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<td>r/R = 0.993</td>
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<td></td>
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<tr>
<td></td>
<td>̅u m/sec</td>
<td>̅u' m/sec</td>
<td>̅u m/sec</td>
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<td>̅u m/sec</td>
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<td>0.0649 0.0026</td>
<td>0.0700 0.0030</td>
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Figure 2: Streamwise velocity fluctuation at s/d = 0.33
Figure 3: Streamwise turbulence intensity, $u'/\bar{u}$, at $s/d = 0.33$
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Figure 4: Ensemble-averaged velocity at s/d = 16.
Figure 5: Streamwise velocity fluctuation at s/d = 16
Figure 6: Streamwise turbulence intensity, $u' / \bar{u}$, at $s/d = 16$

Note: The peaks appear lower than the actual data due to smoothing by the plotting package. The peak turbulence intensity is 1.02, at $158^\circ$ for $r/R = 0.983$. 
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Figure 7: Ensemble-averaged velocity at s/d = 30
Figure 8: Streamwise velocity fluctuation at s/d = 30
Centerline view
Figure 9: Streamwise velocity fluctuation at s/d = 30
Near-wall view
Figure 10: Streamwise turbulence intensity, $u'/\bar{u}$, at $s/d = 30$

Note: The peaks appear lower than the actual data due to smoothing by the plotting package. The peak turbulence intensity is 1.25, at $164^\circ$ for $r/R = 0.986$. 
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Figure 11: Ensemble-averaged velocity at s/d = 44
Figure 12: Streamwise velocity fluctuation at s/d = 44
Figure 13: Streamwise turbulence intensity, $u' / \bar{u}$, at $s/d = 44$

Note: The peaks appear lower than the actual data due to smoothing by the plotting package. The peak turbulence intensity is 1.30, at 164° for $r/R = 0.990$. 
I. CROSS-WIRE DATA

SPRE Operating Point
Nozzle Inlet Geometry

\((\theta, \bar{u})\) \((\theta, u')\) \((\theta, \bar{v})\) \((\theta, v')\) \((\theta, \bar{u}\bar{v}')\)

### Ambient Conditions

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Note that the data are tabulated at every 4 degrees of crank position except within \(\pm 10\) degrees of transition, for which the resolution is every 2 degrees.

II. SUPPLEMENTAL FIGURES

In order to supplement the three-dimensional figures which appear in the main body of the thesis, additional figures generated from the cross-wire data have been included after the tabulated data for each of the four axial stations. At each station, smoothed plots are provided of the streamwise and radial rms-velocity components, in addition to unsmoothed plots of the Reynolds shear stress.
CROSS-WIRE DATA

SPRE \hspace{1cm} s/d = 0.33

\[ r/R = 0.800 \]

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Figure 14: Streamwise velocity fluctuation at s/d = 0.33 (smoothed)
Figure 15: Radial velocity fluctuation at s/d = 0.33 (smoothed)
Figure 16: Reynolds shear stress at s/d = 0.33 (not smoothed)
## CROSS-WIRE DATA

**SPRE**  \( s/d = 16 \)

\[ r/R = 0.800 \]

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Figure 17: Streamwise velocity fluctuation at s/d = 16 (smoothed)
Figure 18: Radial velocity fluctuation at s/d = 16 (smoothed)
Figure 19: Reynolds shear stress at s/d = 16
(not smoothed)
CROSS-WIRE DATA

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84
Figure 20: Streamwise velocity fluctuation at s/d = 30 (smoothed)
Figure 21: Radial velocity fluctuation at $s/d = 30$ (smoothed)
Figure 22: Reynolds shear stress at s/d = 30 (not smoothed)
# CROSS-WIRE DATA

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\( r/R = 0.800 \)

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Figure 23: Streamwise velocity fluctuation at s/d = 44 (smoothed)
Figure 24: Radial velocity fluctuation at $s/d = 44$ (smoothed)
Figure 25: Reynolds shear stress at s/d = 44 (not smoothed)
PROCESSED DATA

I. Bulk-mean velocity, $u_m$, friction velocity, $u_\ast$, skin friction coefficient, $c_f$, and Couette flow model versus crank position, $\theta$

Note: The symbol in the "model" column indicates which of the Couette flow models, laminar (l) or turbulent (t), was used in processing.

$s/d = 0.33$

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II. Processed ($\theta$, $u^*$, $y^*$) Data: Experiment and Couette Flow Model
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I. Data Acquisition Program Listings

Note: All the programs were written in C and executed on a UNIX operating system.

CROSS
This is the main program for cross-wire data acquisition, adapted from the single-wire acquisition program, SINGLE, written by J. Seume (1988). It calls the subroutines ENTER_COND, SET_UP_VMX, and ACQUIREX.

ENTER_COND
This subroutine inputs the test conditions specific to the data set, including piston bore, pipe diameter, stroke, test section length, axial probe location, drive speed, and number of readings per cycle.

SET_UP_VMX
This subroutine sets up the NORLAND digital storage oscilloscope on the IEEE interface for data storage and transfer.

ACQUIREX
This subroutine acquires cross-wire anemometer data with the NORLAND, updates quantities for the calculation of streamwise and radial ensemble-averaged and fluctuating velocities, and velocity correlations, and stores them in a file.

AIR_STATEX
This subroutine is called by ACQUIREX and supplies ambient air conditions to the acquisition program.
II. Data Processing Program Listings

PROCESSX
This is the main program for the processing of cross-wire data into traces and profiles of both the streamwise and radial component of ensemble-averaged and rms-velocity fluctuations, and the Reynolds shear stress.

VEL_REDTURB
This data reduction program converts profiles of ensemble-averaged velocity into wall coordinates, iterating on the wall shear stress and y-offset to fit the data to the Couette flow model for turbulent-like flow, including the effect of pressure gradient.

DUPDYP
This subroutine is called by VEL_REDTURB and calculates the slope in wall coordinates based on the Van Driest mixing length model.

VEL_REDLAM
This data reduction program converts profiles of ensemble-averaged velocity into wall coordinates, iterating on the wall shear stress and y-offset to fit the data to the Couette flow model for laminar-like flow, including the effect of pressure gradient.
CROSS

#include <stdio.h>
#define void int

/* definition of external variables */
int ib3;
int mrad, lasrdr, lastcycle, iuerr, i rmserr;
int ndummy = 50;
int abort, diagnosis, add_to_set, m_cycle, oldfile, old_file = 0;
int no_inst;
int m_out = 0, m_out[20];
double mstroke, mbeq, mdiam, mlength, maxial, speed;
double t_dry, t_wet, p_atm;
int nread = 1, nlag = 0, mcycle = 0;
char filename[30];
char usage[] = "Usage: single [-a runid or -d or -m mcycle or -n or -o m_out n.
out[1...m_out]]\n";

main(argc,argv)
/* Data acquisition main program, "cross", for cross wire anemometer
measurements. G. Friedman, 8/80 */
/* The program is an adaptation of single.c, written by J. Seume for use
with single wires */

int argc;
char *argv[];
{
#include <string.h>

int i;

extern int abort, diagnosis, add_to_set, m_cycle, mcycle;
extern int no_inst;
extern int m_out, n_out[];
extern char filename[];

void set_up_vmx();
void enter_cond();
void acquirex();

/*
setvbuf (stdout,NULL,_IONBF,1); */
/* Set default values. */
diagnosis = 0;
add_to_set = 0;
m_cycle = 0;
no_inst = 0;

/* Read command line for control parameters. */
while(**argv == '-')
{
--argc;
switch(**argv)
{
    case 'a':
    /* Add to an already existing data set. */
        add_to_set = 1;
        strcpy(filename, "../usr/geoff/shdata/");
        strcpy(&filename[19], **argv);
        --argc;
        break;
    case 'd':
    /* Print out diagnostic information. */
        diagnosis = 1;
        break;
    case 'm':
    /* Set maximum number of cycles to be acquired
to a value different from the default
specified in acquire.c. */
        m_cycle = 1;
        mcycle = atoi(**argv);
        --argc;

        break;
}
break;

    case 'n':
        /* Do not access the A/D converter. */
        no_inst = 1;
        --argc;
        break;
    case 'o':
        /* Set maximum number of cycles to be acquired
to a value different from the default
specified in acquire.c. */
        m_out = atoi(*++argv);
        if (m_out > 9) {
            printf("m_out = \%d > 9 \=> Choose ", m_out);
            printf("m_out <= 9 \n\n");
        }
        for (i = 1; i <= m_out; i++) {
            n_out[i] = atoi(*++argv);
            if (diagnosis) printf("n_out[%d] = \%d\n", i, n_out[i]);
        }
        --argc;
        break;
    default:
        printf("\%s", usage);
        break;

#endif

/* *************************************************************/
/* Calls to the various subroutines */
/* Enter experimental conditions. */
enter_cond();
if (abort) goto the_end;
/* Set up A/D converter. */
if (! no_inst) set_up_vmx();
if (abort) goto the_end;

/* Acquire data and store them in file under
directory /usr/geoff/shdata */
aquirex();
if (abort) goto the_end;
/* Address for abort sequence. */
the_end;
enter_cond()
/* Enter nominal test conditions. */
{
#include <stdio.h>
#include <math.h>
#include <string.h>
#define NSTROKE 6
#define NBORE 4
#define NDIAM 3
#define NLENGTH 9
#define NAXIAL 21
#define IDLENGTH 10
#define NNDUMMY 50
#define MCYCLE 100
#define PI (4. * atan(1.0))
define NU 16.e-06 /* nominal kinematic viscosity */
extern int abort, add_to_set; /* = 1 => Add runs to an existing
set of data. */
extern int diagnosis;
extern int old_file;
extern int m_cycle, mcycle;
extern int oldfile; /* = 1 => File existed and will be updated. */
extern double mstroke, mbore, mdiam, mleng, maxial, speed;
extern int nread; /* number of readings per cycle */
extern int nlag; /* number of sample pulses (readings) by which TDC trigger
lags TDC */
extern char filename[];

FILE *storefile;

int i, istroke, ibore, idiam, ilength, iaxial, ispeed, inerr;
double Remax, Va, Ar, loverd, xoverl, xoverd, uavemax;
static double stroke[NSTROKE] = {0.0, 14.0, 9.0, 9.0, 4.95, 3.5};
static double lag_angle[NSTROKE] = {0.0, 0.0, 0.180, 0.0, 0.270, 0.0};
#ifdef
static double lag_angle = angle by which TDC trigger signal lags TDC */
static double bore[NBORE] = {0.0, 14.0, 8.5, 5.0};
/* Ideal diameters would be: {0.0, 14.0, 142.8, 409.5, 0.0}; */
static double diam[NDIAM] = {0.0, 1.5, 2.125};
static int nlengths[NDIAM][NLENGTH] =
{ {0},
  {0, 1, 2, 3, 4, 5, 6},
  {0, 7, 8},
};
static double length[NLENGTH] = {0.0, 42, 60, 80, 102.72, 120, 127.5, 59.5, 127.5}
static double axial[NLENGTH][NAXIAL] =
{ {0.0},
  {0, 1.5, 3.6, 12, 24, 30, 36.72, 48, 51, 36, 54, 57, 58.5},
  {0, 1.5, 3.6, 12, 24, 30, 36.48, 51, 36, 54, 57, 58.5, 66, 72, 78, 84, 87, 88.5},
  {0, 1.5, 3.6, 12, 24, 30, 36.48, 51, 36, 54, 57, 58.5, 72, 78, 72, 90, 96, 72, 99, 72, 101.22},
  {0, 1.5, 3.6, 12, 24, 30, 36.48, 51, 36, 54, 57, 58.5, 72, 96, 108, 114, 117, 118.5},
  {0, 1.5, 3.6, 12, 24, 30, 36.48, 51, 36, 54, 57, 58.5, 63.75, 72, 79, 5, 103.5, 115.5, 121.5, 124.5, 126},
  {0, 2.125, 4.25, 8.5, 17, 25.5, 29.75, 34.25, 51, 55, 25, 57.375},
  {0, 2.125, 4.25, 8.5, 17, 25.5, 29.75, 34.25, 51, 55, 25, 57.375, 63.75, 93.5, 110.5, 118.0, 123, 125, 125.375}
};
static char dummy[NNDUMMY]; /* dummy array to keep room for further
descriptors for runs */
char runid[10], resp[5];
char year[3], month[3];
if(! add_to_set) {

/* Set the maximum number of cycles to be acquired. */
if(!m_cycle) mcycle = MCYCLE;

/* Read run identification and check whether the corresponding
file already exists. */
for(inerr = 1; inerr; ) {
    printf("Enter run identification: \n\n1\n");
    printf("(Use the format mmddyy where: \n\n1\n"");
    printf(" and ss = a sequence number of the day’s\n\n1\n");
    printf(" ( runs)\n\n1\n");
    scanf("%s", runid);
    printf("mm = %s\n", runid[0], runid[1]);
    printf("dd = %s\n", runid[2], runid[3]);
    printf("yy = %s\n", runid[4], runid[5]);
    printf("ss = %s\n", runid[6], runid[7]);
    strcpy(filename, '/usr/geoff/shdata/');
    strcpy(&filename[18], runid);
    printf("The filename is '%s'\n\n1", filename);
    storefile = fopen(filename, "r+");
    if(storefile == NULL)
        printf("This file did not exist but may now \n\n1");
        fprintf("be created.\n\n1");
        oldfile = 0;
    else
        printf("This file exists and data may be added.\n\n1")
        oldfile = 1;
    printf("\n Entry correct? (y or n)\n\n1");
    scanf("%s", resp);
    if(resp[0] == ‘y’ || resp[0] == ‘Y’)
        (inerr = 0;)
    else if(resp[0] == ‘n’ || resp[0] == ‘N’)
        (inerr = 1;)
    else
        printf("Respond with y, Y for 'yes'");
        fprintf("or with n, N for 'no' next time.\n\n1");
}

if(! oldfile)
    printf("File has now been created.\n\n1");
storefile = fopen(filename, "a+");
fclose(storefile);

/* Read nominal test conditions from key board. */
if(! oldfile){
    printf("Enter nominal test conditions.\n\n1");
    for(inerr = 1; inerr; )
        (print("Stroke: \n\n1");
            printf("\n Code\n\n1");
            printf("\n Length\n\n1");
            printf("\n inches\n\n1");
            for(i = 1; i <= NSTROKE; i++)
                printf("%7.3f %7d\n\n1", stroke[i], i);
            printf("Enter code for stroke length.\n\n1");
            printf("If the desired stroke is not listed, \n\n1");
            printf("Enter a '0'.\n\n1");
        while (scanf("%d", &stroke) == 0) {
            getchar();
            printf("Enter an integer code number!\n\n1");
        }
        if(stroke == 0) {
            printf("Enter stroke value in inches.\n\n1");
            scanf("%lf", &stroke[0]);
        }
        printf("Stroke length = %7.3f", stroke[istroke]);
        printf("Entry correct? (y or n)\n\n1");
        scanf("%s", resp);
        if(resp[0] == ‘y’ || resp[0] == ‘Y’)
            inerr = 0;
        else if(resp[0] == ‘n’ || resp[0] == ‘N’)
            inerr = 1;
    else
        printf("Respond with y, Y for 'yes' ");
}
printf("or with n, N for 'no' next time.\n");
}
for(inerr = 1; inerr;
{
printf("nBore: \n");
printf(" bore code\n");
printf(" inches number\n");
for(i = 1; i <= NBORE-1; i = i + 1)
printf("\t%f \t%d\n", bore[i], i);
printf(" Enter code for bore.\n");
printf(" [If the desired bore is not listed, ]\n");
printf("enter a '0'.\n");
while(scanf("%d", &bore) == 0)
{
getchar();
printf(" Enter an integer code number!\n");
}
if(bore == 0)
{
printf(" Enter bore value in inches.\n");
scanf("%lf", &bore[0]);
printf(" Bore = %7.3f in\", bore[bore]);
printf(" Entry correct? (y or n)\n");
scanf("%s", resp);
if(resp[0] == 'y' && resp[0] == 'Y')
{ inerr = 0; }
else if(resp[0] == 'n' && resp[0] == 'N')
{ inerr = 1; }
else
{
printf(" Respond with y, Y for 'yes' \n");
printf(" or with n, N for 'no' next time.\n");
}
for(inerr = 1; inerr;
{
printf("nTube diameter: \n");
printf(" diameter code\n");
printf(" inches number\n");
for(i = 1; i <= NDIAM-1; i = i + 1)
printf("\t%f \t%d\n", diam[i], i);
printf(" Enter code for diameter.\n");
printf(" [If the desired diameter is not listed, ]\n");
printf("enter a '0'.\n");
while(scanf("%d", &diam) == 0)
{
getchar();
printf(" Enter an integer code number!\n");
}
if(diam == 0)
{
printf(" Enter diameter value in inches.\n");
scanf("%lf", &diam[0]);
printf(" Tube diameter = %7.3f in\", diam[diam]);
printf(" Entry correct? (y or n)\n");
scanf("%s", resp);
if(resp[0] == 'y' && resp[0] == 'Y')
{ inerr = 0; }
else if(resp[0] == 'n' && resp[0] == 'N')
{ inerr = 1; }
else
{
printf(" Respond with y, Y for 'yes' \n");
printf(" or with n, N for 'no' next time.\n");
}
for(inerr = 1; inerr;
{
printf("nTest section length: \n");
printf("tube\tc code\length\n");
printf(" length\number\t\over\n");
printf("\t\t\t\n", 
for(i = 1; i <= NLENGTH-1; i = i + 1)
printf("\t%f \t%\t\n", 
length[lengths[diam][i]], 
lengths[diam][i], 
length[lengths[diam][i]] / 
diam[diam]);
printf(" Enter code for test section length.\n");
printf(" [If the desired length is not listed, ]\n");
printf("enter a '0'.\n");
while(scanf("%d", &length) == 0)
{
getchar();
printf(" Enter an integer code number!\n");
}
if(length == 0)
for(inerr = 1; inerr; )
{printf("Axial probe location: \n");
 printf(" axial code\n");
 printf(" (inches)\n");
 printf(" Enter code for axial distance.\n");
 printf(" [If the desired distance is not listed, \n");
 printf(" enter a '0'.]\n");
 while( scanf("%d", &axial) == 0) {getchar();
 printf(" Enter an integer code number!\n");}
 if(axial == 0) {printf(" Enter axial distance in inches.\n");
 scanf("%lf", &axial[length][0]);}
 printf(" Probes location = %6.3f in\n",
 axial[length][axial]);
 printf(" Entry correct? (y or n)\n");
 scanf("%s", resp);
 if(resp[0] == 'y' || resp[0] == 'Y') {inerr = 0;}
 else if(resp[0] == 'n' || resp[0] == 'N') {inerr = 1;}
 else {printf(" Respond with y, Y for 'yes' ");
 printf(" or with n, N for 'no' next time.\n");}
}
/* The following lines is used to incorporate shaft-angle encoder signals with less than 720 pulses per revolution. */
for(inerr = 1; inerr; ) {
  printf("\nEnter number of readings per cycle:\n");
  while (scanf("%d", &read) == 0) {
    if (read) {
      printf(" Enter an integer number:\n");
      printf(" %d readings per cycle will be taken.\n", read);
      printf(" Divide 720 pulses by %f, \n", 720./double(nread));
    }
  }
  if(speed = (double) nread > 25.) {
    printf(" Frequency of readings is %f Hz!\n", speed = (double) nread);
  nlag = (int)((double)nread * lag_angle[istroke] / 360.);
  if(diagnosis) printf("lag angle = %lf, nlag = %d\n", lag_angle[istroke], nlag);
  printf(" Entry correct? (y or n)\n");
  scanf("%s", resp);
  if(resp[0] == 'y' && resp[0] == 'Y')
    { inerr = 0; }
  else if(resp[0] == 'n' && resp[0] == 'N')
    { inerr = 1; }
  else {
    printf(" Respond with y, Y for 'yes' ");
    printf(" or with n, N for 'no' next time.\n");
  }
  nread = 720;
  nlag = (int)(lag_angle[istroke]);
  if(diagnosis) printf("lag angle = %lf, nlag = %d\n", lag_angle[istroke], nlag);
}
/* Alternative: Dummy entry of shaft-angle encoder pulses. */
/* NOT USED: */
for(inerr = 1; inerr; ) {
  printf("\nEnter a 50 character comment line:\n");
  printf("(Use _ instead of blank spaces!)\n");
  for(i = 1; i <= 5; i++) printf("%d", i-1);
  printf("\n");
  scanf("%s", dummy);
  printf("Comment line: %s", dummy);
  printf("\n Entry correct? (y or n)\n");
  scanf("%s", resp);
  if(resp[0] == 'y' && resp[0] == 'Y')
    { inerr = 0; }
  else if(resp[0] == 'n' && resp[0] == 'N')
    { inerr = 1; }
  else {
    printf(" Respond with y, Y for 'yes' ");
    printf(" or with n, N for 'no' next time.\n");
  }
}
/* Convert to SI base units. */
stroke = stroke[istroke] * 0.0254;
bore = bore[ibore] * 0.0254;
diam = diam[iidiam] * 0.0254;
length = length[ilength] * 0.0254;
axial = axial[iaxial] * 0.0254;
/* Write runid and parameters to new data file. */
storefile = fopen(filename, "r+");
fwrite(runid, sizeof(char), 1, storefile);
fwrite(&stroke, sizeof(double), 1, storefile);
fwrite(&bore, sizeof(double), 1, storefile);
fwrite(&diam, sizeof(double), 1, storefile);
fwrite(&length, sizeof(double), 1, storefile);
fwrite(&axial, sizeof(double), 1, storefile);
fwrite(&speed, sizeof(double), 1, storefile);
fwrite(&nread, sizeof(int), 1, storefile);
if(! old_file) {
    fwrite(&cycle, sizeof(int), 1, storefile);
    fwrite(dummy, sizeof(char), NDUMMY, storefile);
}
fclose(storefile);
}  
else {
    /* Read parameters from old data file and provide a summary in English units. */
    storefile = fopen(filename, "r+");  
    fread(&runid, sizeof(char), 10, storefile);  
    fread(&stroke, sizeof(double), 1, storefile);  
    fread(&bore, sizeof(double), 1, storefile);  
    fread(&diameter, sizeof(double), 1, storefile);  
    fread(&length, sizeof(double), 1, storefile);  
    fread(&maxi, sizeof(double), 1, storefile);  
    fread(&speed, sizeof(double), 1, storefile);  
    fread(&read, sizeof(int), 1, storefile);  
    strncpy(year, &runid[4], 2);
    strncpy(month, &runid[0], 2);
    if(atol(year) == 88 && atol(month) < 6) old_file = 1;
    if(! old_file) {
        fread(&cycle, sizeof(int), 1, storefile);
        fread(dummy, sizeof(char), NDUMMY, storefile);  
    }
fclose(storefile);
    /* Determine the lag in terms of number of pulses. */
    for(i = 0; i < NSTROKE; i++) {
        if(stroke[i] > (0.95 * mstroke / 0.0254)  
            && stroke[i] < (1.05 * mstroke / 0.0254))  
            nlag = (int)((double)read * lag_angle[i]  
                / 560.);  
            istroke = i;
    }
    if(diagnosis) printf("lag angle = %lf, nlag = %d\n",  
        lag_angle[istroke], nlag);
printf("Input data summary in English units:\n");  
printf("stroke = %6.1f in\n", mstroke/0.0254);
printf("bore = %6.1f in\n", mmbore/0.0254);
printf("test section diameter = %6.1f in\n", mdiam/0.0254);
printf("test section length = %6.1f in\n", mlength/0.0254);
printf("axial location = %6.1f in\n", maxi/0.0254);
printf("drive shaft speed = %6.1f rpm\n", speed/240.);
printf("%d readings per cycle\n", read);
printf("[Divide 720 by %f.]\n", 720./double(read));
printf("%s\n", dummy);
printf("Type 'c <CR>' to continue.\n");
scanf("%s", resp);
}  
/* Echo print input data in SI units. */
printf("Input data summary in SI units:\n");
printf("stroke = %6.1f mm\n", mstroke*1000);
printf("bore = %6.1f mm\n", mmbore*1000);
printf("test section diameter = %6.1f mm\n", mdiam*1000);
printf("test section length = %6.1f mm\n", mlength*1000);
printf("axial location = %6.1f mm\n", maxi*1000);
printf("frequency = %6.3f Hz\n", speed);
/* estimate of the amplitude of the bulk-mean velocity */
printf("Estimated amplitude of the bulk-mean velocity = ");
usavemax = PI * speed * mstroke / (mmbore*mdiam) / (mdiam*mdiam);  
printf("%5.2f m/sec\n", usavemax);
/* Calculate and print similarity parameters. */
printf("Nominal similarity parameters:\n");
printf("Remax = %10.2e\n", Remax = PI*mmbore*speed*mstroke / (mdiam/NU));
printf("V = %6.1f\n", V = 0.5*PI*speed*mdiam/NU);
printf("A = %6.2f\n", A = mmbore/(mdiam*mdiam)*mstroke/mlength);
else {
    storefile = fopen(filename, "r+");
    if(storefile == NULL)
        {printf("This file does not exist.\n");
          abort = 1;}
    else {
        oldfile = 1;
        /* Read parameters from old data file. */
        fread(&wea, sizeof(char), 10, storefile);
        fread(&stroke, sizeof(double), 1, storefile);
        fread(&ambore, sizeof(double), 1, storefile);
        fread(&time, sizeof(double), 1, storefile);
        fread(&time, sizeof(double), 1, storefile);
        fread(&time, sizeof(double), 1, storefile);
        fread(&time, sizeof(int), 1, storefile);
        strcpy(year, &runid[4], 2);
        strcpy(month, &runid[0], 2);

        /* Determine the lag in terms of number of pulses. */
        for(i = 0; i <= NSTROKE; i++)
        {
            if(stroke[i] > (0.95 * stroke / 0.0254) |
               stroke[i] < (1.05 * stroke / 0.0254))
                {nlag = (int)((double)nread + lag_angle[i] / 360.);
                    istroke = i;
                }
        }
        if(diagnosis) printf("lag angle = %lf, nlag = %d\n",
                                 lag_angle[istroke], nlag);

        /* Check whether this is a file of the old format. */
        if(atoi(year) == 88 &
            atoi(month) < 6)
                {old_file = 1;
                    if(! old_file) fread(dummy, sizeof(char), NDUMMY, storefile);
                }
        fclose(storefile);
    }

}
SET_UP_VMX

set_up_vmx()
/* Set up NORLAND Prowler on IEEE interface. */
/* This program is an adaptation of set_up_vm for cross wires */
{
#include <gpiob.h>
#include <stdio.h>
#include <string.h>

extern int ib3;
char set3[100];
char resp[100];

/* Send message to screen. */
printf("NORLAND Prowler will now be configured.\n");

/* Identify device and set up interface. */
ib3 = ibfind("/dev/ib3"); /* Define device ID. */
ibtmo(ib3,14); /* Timeout = 30sec */

/* Set controls on device and check interface communications. */

/* Generate string of control commands to be sent to device. */
strcp(set3,"JLA"); /* Beep off */
strcat(set3,"Y"); /* ACQ. MODE */
strcat(set3,"\n"); /* TRIGGERED HOLD */
strcat(set3,"M4096"); /* BLOCK SIZE = 4096 */
strcat(set3,"L0"); /* SAMPLE INTERVAL = EXT. */
strcat(set3,"Z"); /* TRIGGER SETUP */
strcat(set3,"G4096"); /* EXTERNAL TRIGGER DELAY = 4096 */
strcat(set3,"ME"); /* SOURCE = EXTERNAL */
strcat(set3,"\n"); /* A SETUP */
strcat(set3,"\n"); /* ACTIVE */
strcat(set3,"C2="); /* RANGE = 2 */
strcat(set3,"E0="); /* BIAS = 0 */
strcat(set3,"GC"); /* COUPLING = DC */
strcat(set3,"\n"); /* B SETUP */
strcat(set3,"\n"); /* ACTIVE */
strcat(set3,"\n"); /* RANGE = 2 */
strcat(set3,"\n"); /* BIAS = 0 */
strcat(set3,"\n"); /* COUPLING = DC */

ibwrt(ib3,set3,strlen(set3)); /* Send string to device. */
while(ERR & ibsta){
  switch (iberr)
  {
    case 0:
    {printf("iberr = %d: operating system error\n", iberr);
      printf(" UNIX error code = %d\n", ibcnt);
      break;}
    case 1:
    {printf("iberr = %d: GPIB must be in charge.\n", iberr);
      break;}
    case 2:
    {printf("iberr = %d: Write function detected ", iberr);
      printf("no listeners.\n");
      break;}
    case 3:
    {printf("iberr = %d: interface board", iberr);
      printf(" not addressed correctly.\n");
      break;}
    case 4:
    {printf("iberr = %d: invalid arg. to fctn call\n", iberr);
      break;}
    case 5:
    {printf("iberr = %d: GPIB-board must be ", iberr);
      printf("System Active Controller.\n");
      break;}
    case 6:
    {printf("iberr = %d: communication failure\n", iberr);
      break;}
  }
}
{printf("iberr = %d: I/O operation aborted.\n", iberr);
 break;}
case 7:
 {printf("iberr = %d: Interface board does not ", iberr);
  printf("exist.\n");
  break;}
case 10:
 {printf("iberr = %d: I/O started before ", iberr);
  printf("previous operation completed. \n");
  break;}
case 11:
 {printf("iberr = %d: no capability for ", iberr);
  printf("operation\n");
  break;}
case 14:
 {printf("iberr = %d: command error during ", iberr);
  printf("device call\n");
  break;}
case 15:
 {printf("iberr = %d: Serial Poll status ", iberr);
  printf("byte lost\n");
  break;}
case 16:
 {printf("iberr = %d: SQR remains asserted.\n", iberr);
  break;}
}
printf(" => Check NORLAND and connections.\n");
printf(" Type 'c <CR>' when you are ready.\n");
scanf("%s",resp);
ibwrt(ib3,set3,strlen(set3)); /* Send string to device. */
acquirex()
/* This program acquires cross-wire anemometer data with a NORLAND Prowler
digital storage oscilloscope, updates quantities for the calculation of
mean and fluctuating velocities, and correlations, and stores them in
a file. G. Friedman, 8/90 */
/* This program is based on a version of acq_un.c, with wires A and B, written
by J. Seume, 1988 */
{
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <math.h>
#define MREAD 181 /* maximum number of data array entries */
define MREAD2 721 /* shaft-angle encoder angles in NORLAND arrays */
define MREAD3 903 /* ueffA storage for 180 pts x 5 cycles */
define AMAX 4096 /* number of entries in NORLAND data array */
define SMAAX 8452 /* maximum number of cycles */
define MCYCLE 50 /* maximum number of radial probe locations */
define STRNGL 30
#define NDIAGY 50 /* This parameter is also needed in air_statex. */
define PI 3.14159265
extern int lb3;
extern int diagnosis, m_cycle, old_file, no_inst;
extern int m_out, n_out[];
extern double mstroke, sbore, mdiam, mlength, maxial, speed;
extern double t_dry, t_wet, p_atm; /* air conditions during run */
extern int mread, mcycle;
extern int nlag; /* number of sample pulses (readings) by which the
TDC trigger lags TDC */
extern char *filename[];
FILE *storefile, *densfile;
FILE *umfile, *vmfile;
int inerr, /* error in input data */
irad, /* number of current radial probe location */
iusserr = 0, irmserr = 0, /*sequence number of angle at which
maximum error in mean and rms
occurred in this cycle */

next_round = 1, /* A "round" of data are those data points in the
NORLAND's buffer that represent a complete cycle. */
round,
new_rad = 1, /* number of cycles in the NORLAND's buffer */
morerad = 1, /* acquire at more radial locations */
final_pr = 0, /* = 1 => final printout, lastcy >= mcycle */
inter_pr = 0, /* = 1 => intermediate printout, m_out >= 1 */
iout = 1, /* index for n_out[] */
cycle, /* number of current cycle */
lastcy, /* number acquired at one radial location */
p_count, /* number of current crank location */

1,kcount, jcount, i_count, u_count, count3, /* auxiliary counters */
iter

double dist, distance, relrad, /* probe location */
accuracy = 0.005, /* accuracy of mean */
acalib, bcalib, ncalib, /* general calibration constants for
substitution of values below */

/ninv, /* inverse of ncalib */

/*
A wire calibrations */
/* calibration of 7/10/90, cross-wire #35333 for ujet <= 25 m/sec */
acalibA = 2.94834, bcalibA = 1.85552, ncalibA = 0.435,
acalibB = 3.18061, bcalibB = 1.86477, ncalibB = 0.435,
/* calibration of 6/20/90, cross-wire #35333 for ujet <= 17 m/sec
acalibA = 2.38501, bcalibA = 1.82568, ncalibA = 0.435,
acalibB = 3.15662, bcalibB = 1.91373, ncalibB = 0.435. */

/* calibration of cross-wire #44135 for 0.0 m/s to 17.5 m/s (3/14/90)
/* acalibA = 4.00797, bcalibA = 1.55612, ncalibA = .5,
acalibB = 4.00447, bcalibB = 1.41936, ncalibB = .5. */
/* calibration constants: 
E2 = acalib + bcalib * (veleff)^ncalib */

ref_temp = 27.2,    /* dry-bulb temperature at calibration 
in degrees Celsius */
ref_press = 0.991e+05, /* atmospheric pressure at calibration in Pa */
ref_dens, /* density at calibration */
veoffset, /* voltage that was subtracted from 
hot wire signal during conditioning */

vgainA = 1.0, vgainB = 1.0,
/* hot-wire bridge output voltage */
voltage, /* angle after TDC at which the TDC 
trigger is actuated (in degrees) */
trigang = 0.0, /* auxiliary variables */
base, argument, 
veleff, /* instantaneous effective velocity in m/s */
cycles, /* number of cycles processed at this point */
maxaerr = 0.0, /* accuracy of umean */
maxmerr = 0.0, /* auxiliary variable for um and vm */
um, /* auxiliary variables for u and v, 
vm. 
theta = 45.0, /* based upon ueffA and ueffB */
angle, /* theta, in radians */
kt = 0.135, /* coefficient for the tangential cooling, 
based on Champagne's work, for l/d = 330 */

ktAterm, ktBterm, /* terms from the iteration for u and v */
sint, cost, 
ueffAnew, ueffBnew, 
vnew, unew, 
epsilonA, epsilonB, 
rhsA, lhsA, rhsB, lhsB, 

off_set, /* auxiliary voltage offset variable */
voltcorr, /* voltage correction to account for 
ambient temperature difference between 
calibration and run */
t_sensor = 250.0, /* sensor temperature in degrees Celsius */
gas_const = 8315.0, /* universal gas constant in kg/kmol/K */
air_mwt = 28.96, /* molecular weight in kg/kmol for air 
with mole fractions of: 
N2 = 0.7808 
O2 = 0.2095 
Ar = 0.0096 */
density, /* current air density */
mean_dens, /* density at atmospheric pressure */

/* sum of instantaneous velocities, for u */
static double sumu[MREAD], 
also, values of umean[], re-sorted for 
lag in crank-angle */

sumv[MREAD], 
sumv2[MREAD], /* sum of squares of instantaneous velocities, 
also, values of urms[], re-sorted for 
lag in crank-angle */

sumuv[MREAD], /* sum of product of instantaneous velocities */
old_su[MREAD], old_su2[MREAD], /* current values 
of sumu, sumu2 */
old_sv[MREAD], old_sv2[MREAD], old_suv[MREAD], 
ueffA[MREAD3], ueffB, /* effective velocities from 
wires A and B, from which get u, v */
/* ensemble averaged velocity, also used to store the density correction factor */

#define mmean[MREAD]
#define vmean[MREAD]
#define urms[MREAD]
#define vms[MREAD]
#define upvp[MREAD]

char resp[5];
char status_byte;
char set3[STRLN], acquire[2], beeper_on[4];
static char set_range[100], rcmdA[STRLN], rcmdB[STRLN];

int *iptr, ifactor1, hexdigit, sign, ivalue;
int first_time;
int bit7, bit6, bit5, bit4, bit3, bit2, bit1, bit0;
int air_status();
double *dptr, factor1, factor2, factor, offset;
static char readstrA[SMAX], readstrB[SMAX], digit[2];
static char *ptrdstr;
static char dummy[NDUMMY], buffer[NDUMMY];

/* Prepare for communication with the NORLAND */

/* Generate strings for ACQUIRE and Beeper Off commands. */
strcpy(acquire, "R");
strcpy(beeper_on, "ILC");

/* Generate command string for data transfer from NORLAND of array A. */
strcpy(rcmdA, "\"");
strcpy(rcmdA, "K");
strcpy(rcmdA, "C");
strcpy(rcmdA, "G");
strcpy(rcmdA, "A");

/* Generate command string for data transfer from NORLAND of array B. */
strcpy(rcmdB, "\"");
strcpy(rcmdB, "K");
strcpy(rcmdB, "C");
strcpy(rcmdB, "G");
strcpy(rcmdB, "C");

/* Generate and send command string to reset the voltage ranges. */
strcpy(set_range, "\"");
strcpy(set_range, "5\"");
strcpy(set_range, "\"");
strcpy(set_range, "5\"");
ibv(1b3, set_range, strlen(set_range));

/* Input and print run information prior to entering the main loop for ensemble averaging */

/* Calculate number of cycles completely represented in one NORLAND buffer based upon 720 samples/cycle via the shaft angle encoder */

/* Print out nlag. */
if(diagnosis) printf("nlag = %d\n", nlag);

/* Print out cycles at which intermediate results are to be stored. */
if(diagnosis) {
    for(i = 1; i <= m_out; i++) {
        printf("n_out[%d] = %d\n", i, n_out[i]);
    }
}

/* Set the maximum number of cycles to be acquired. */
if(!m_cycle) mcycle = MCYCLE;

/* Convert temperatures from Celsius to Kelvin. */
ref_temp += 273.15;
t_sensor += 273.15;

/* Enter voltage offsets for wires A and B. */
for(count = 1; count<count2; count++){
for(inerr = 1; inerr; )
{
    if(count == 1)
        printf("\nVoltage offset for wire A: \n");
    printf("\nVoltage offset for wire B: \n");
    printf(" Enter absolute voltage value. \n");
    if(count == 1)
        scanf("%f", &voffsetA);
    else
        scanf("%f", &voffsetB);
    if(count == 1)
        printf(" Voltage offset = %f \n", voffsetA);
    printf(" Voltage offset = %f \n", voffsetB);
    printf(" Entry correction (y or n)\n");
    scanf("%s", resp);
    if(resp[0] == 'y' || resp[0] == 'Y')
        {inerr = 0;}
    else if(resp[0] == 'n' || resp[0] == 'N')
        {inerr = 1;}
    else
    {
        printf(" Respond with y, Y for 'yes' \n");
        printf(" or with n, N for 'no' next time. \n");
    }
}

/* The program assumes that theta = 45 degrees for the xwire probe. The iteration section must be changed if this
not the case. */
printf("\nNote that the program assumes theta = 45.\n");

*******************************************************************************
/* Loop for radial positions */
for( ; i; )
{
    /* Initialize arrays for summation and velocity calculation. */
    for(i = 0; i <= MREAD; i++)
        {sumu[i] = 0.0;
         sumv[i] = 0.0;
         sumu2[i] = 0.0;
         sumv2[i] = 0.0;
         sumuv[i] = 0.0;}

    /* Wake up the operator with a bell. */
    for(i = 0; i < 10; i++)
        printf("\n");

    /* Enter a comment line. */
    for(inerr = 1; inerr; )
    {
        printf("\nEnter a 50 character comment line: \n");
        printf("Use _ instead of blank spaces! \n");
        for(i = 1; i <= 5; i++)
            printf("1234567890\n");
        printf("\n");
        for(i = 1; i <= 6; i++)
            printf("%d", i-1);
        printf("\n");
        for(i = 0; i <= NDUMMY; i++)
            dummy[i] = '0';
        strcpy(dummy, "ensemble-averaged velocity: ");
        printf("hs", dummy);
        scanf("hs", buffer);
        strcat(dummy, buffer);
        printf("Comment line: \n%hs", dummy);
        printf("\nEntry correction? (y or n)\n");
        scanf("%s", resp);
        if(resp[0] == 'y' || resp[0] == 'Y')
            {inerr = 0;}
        else if(resp[0] == 'n' || resp[0] == 'N')
            {inerr = 1;}
        else
        {
            printf(" Respond with y, Y for 'yes' \n");
            printf(" or with n, N for 'no' next time. \n");
        }
    }

    /* Enter room air conditions. */
    if(! old_file) air_statex();

    /* Enter probe position. */

    143
for(inerr = 1; inerr; ){
    printf("radial probe location:
")
    printf("Code to enter wall distance in inches = '1'
")
    printf("Code to enter wall distance in mm = '2'
")
    printf("Code to enter radius as fraction ");
    printf("of the tube radius = '3'
")
    printf("Code to quit = '0'
")
    printf(" Enter code for entry.
")
    while(scanf("%d", &irad) == 0)
    {getchar();
     printf(" Enter an integer code number!
");}
    switch (irad)
    {
    case 0:
     {goto the_end;
     break;}
    case 1:
     {printf(" Enter wall distance in inches.
")
     scanf("%lf", &dist);
     distance = dist * 0.0254;
     break;}
    case 2:
     {printf(" Enter wall distance in mm.
")
     scanf("%lf", &dist);
     distance = dist / 1000.;
     break;}
    case 3:
     {printf(" Enter radius as a fraction of the ");
     printf(" tube radius.
")
     scanf("%lf", &relrad);
     distance = (1.0 - relrad) * 0.5 * mdiam;
     break;}
    }
    printf(" Wall distance = %7.4f inches
",
            distance / 0.0254);
    printf(" = %6.3g mm
",
            distance / 1000.);
    printf(" Radius / Tube Radius = %6.3g \n",
            1.0 - 2.0*distance/mdiam);
    printf(" Entry correct? (y or n)
")
    printf(" Enter 'y' to start acquisition.
")
    scanf("%s", resp);
    if(resp[0] == 'y' || resp[0] == 'Y')
    {inerr = 0;}
    else if(resp[0] == 'n' || resp[0] == 'N')
    {inerr = 1;}
    else
     {printf(" Respond with y, Y for 'yes' ");
     printf(" or with n, N for 'no' next time.
");
     }
}

/* If no instrument is available on the IEEE interface ... */
if(no_inst) goto the_end;

*************************************************************************

    Acquire data with NORLAND until the maximum number of cycles is reached

*************************************************************************

printf(" Data will be acquired now.
");

/* Set flag for acquisition of first round. */
first_time = 1;

/* Acquire and process as many rounds of data as requested. */
for(round = 1, next_round = 1; next_round; round++){

    /* Calculate density transient. */
   ref_dens = ref_press * air_melt / gas_const / ref_temp;

   if((densfile = fopen("densfile", "r")) != NULL) {
     fseek(densfile, 0L, 0);
     for(i = 0; i <= nread; i++) {
       if(! fread(&density, sizeof(double), 1, densfile)
printf("Reading of density failed.\n")

mean[i] = ref_dens / density;
}
fclose(densfile);
}
else {
  printf("densfile does not exist. p_atm assumed\n");
  mean_dens = p_atm * air_mwt / gas_const / t_dry;
  for(i = 0; i < nread; i++) {
    mean[i] = ref_dens / mean_dens;
  }
}

/* Send string to start acquisition. */
ibwt(ib3, acquire, strien(acquire));

/* Wait until NORLAND starts acquisition. */
/* (Loop to test whether NORLAND is already acquiring). */
do{
  ibsp(ib3, &status_byte);
  if(diagnosis)printf("status_byte = %o\n", status_byte)
}
while(!status_byte & 5);
if(diagnosis)printf("N started acquisition\n");

/* If this is the first acquisition at this radial position, do not attempt to process data. */
if(!first_time){
  if(diagnosis)printf("This is not the first time.\n");
/*/sites for tt0calb and ueffB, the effective cooling velocities */
  for(ucount = 1; ucount <= 2; ucount++){
    if(ucount == 1) {
      ncalib = ncalibA;
      ptrdstr = readstrA;
      acalib = acalibA;
      bcalib = bcalibA;
      voffset = voffsetA;
      vgain = vgainA;
    }
    else {
      ncalib = ncalibB;
      ptrdstr = readstrB;
      acalib = acalibB;
      bcalib = bcalibB;
      voffset = voffsetB;
      vgain = vgainB;
    }

    /* Evaluate Factor and Offset from data sent in XFAST binary format. See NORLAND Prowler manual volume 2 “Options for the Prowler”, pp.46-48. */

    /* Calculate Factor. */

    /* The first two hex digits (Word 1) represent the log to the base two, biased by 128, of the first factor of the Factor. */
    scanf(ptrdstr,"%2X",&factor1);

    /* Compute the first factor of the Factor. */
    factor1 = pow(2,((double)factor1 - 128.));

    /* The next six hex digits (Words 2, 3, 4) represent the sign and the base two fractions of the second factor of Factor. Calculate contributions to the second factor, hex-digit by hex-digit. */
    for(i=0, factor2=0; i<6; i++){
      strncpy(deck+(ptrdstr+2+i),1);
digit[1] = '\0';

/* Determine bit pattern corresponding to each hex-digit and calculate the second factor. */
scanf("%X",&hexdigit);
bit0 = hexdigit & 1;
bit1 = hexdigit & 2;
bit2 = hexdigit & 4;
bit3 = hexdigit & 8;
if(i==0){
    if(bit3)
        sign = -1;
    else
        sign = 1;
    bit3 = 1;
}
if(bit3) factor2 = factor2
    + pow(2.,-(double)(i4 + 1));
if(bit2) factor2 = factor2
    + pow(2.,-(double)(i4 + 2));
if(bit1) factor2 = factor2
    + pow(2.,-(double)(i4 + 3));
if(bit0) factor2 = factor2
    + pow(2.,-(double)(i4 + 4));
}
factor = (double) sign * factor1 = factor2;

/* Calculate Offset. */

/* The first two hex digits (Word 1) represent the log to the base two, biased by 128, of the first factor of the Offset. */
scanf((ptrdstr+6),"%2X",&factor1);

/* Compute the first factor of the Offset. */
factor1 = pow(2.,(double)factor1 - 128.));

/* The next six hex digits (Words 2, 3, 4) represent the sign and the base two fractions of the second factor of Offset. */
/* Calculate contributions to the second factor, hex-digit by hex-digit. */
for(i=0, factor2=0; i<6; i++){
    strncpy(digit,(ptrdstr+10+i),1);
    digit[1] = '\0';

    /* Determine bit pattern corresponding to each hex-digit and calculate the second factor. */
    scanf("%X",&hexdigit);
    bit0 = hexdigit & 1;
    bit1 = hexdigit & 2;
    bit2 = hexdigit & 4;
    bit3 = hexdigit & 8;
    if(i==0){
        if(bit3)
            sign = -1;
        else
            sign = 1;
        bit3 = 1;
    }
    if(bit3) factor2 = factor2
        + pow(2.,-(double)(i4 + 1));
    if(bit2) factor2 = factor2
        + pow(2.,-(double)(i4 + 2));
    if(bit1) factor2 = factor2
        + pow(2.,-(double)(i4 + 3));
    if(bit0) factor2 = factor2
        + pow(2.,-(double)(i4 + 4));
    }
offset = (double) sign * factor1 = factor2;
if(diagnosis)printf("offset = %f\n",offset);

146
if(diagnosis)printf("fraction and offset are calc\n");

/*/ ************************************ */
/*/ Evaluate individual data points */

icount = (MREAD2 - 1) / nread;
ninv = 1. / ncalib;
off_set = offset + voffset * vgain;
volt_corr = sqrt((t_sensor - ref_temp)
/ (t_sensor - t_dry)) / vgain;
angle = PI * theta / 180.;
sint = sin(angle);
cost = cos(angle);
jcount = 0;
for(i = 1, iptr = (int *)(ptrdstr+256);
    iptr < (int *)(ptrdstr+256+2*cy_in_buf*(MREAD2-1));
i++, iptr++){
    /* NOTE: Due to storage limitations, only every
    fourth point (2 degrees) is included, i.e.
    2 4 6 ... 180 182 ... 360 degrees */
    if(!(i % icount)){
        icount++;
        /* Calculate voltage value according to
        NORLAND Prowler manual pp.48-49 of 5/20/85. */
        /* voltage = ((double)(iptr-0X8000)*factor + off_set) * volt_corr;
        */
        /* Calculate instantaneous velocity. */
        /* King's Law with exponent other than 0.5 */
        if((base = voltage*voltage - acalib) > 0.0) {
            veleff = pow(base/bcalib,inv);
        }
        else { veleff = 0.0;
        }
        /* Correct velocity for static pressure. */
        /* Note: Currently, the density transient for the pressure
        correction is corrected for angular offset between
        piston TDC and TDC-marker in def_density; this also applies
        to acqu_u.c. 4/9/89 JS */
        veleff *= umean[jcount % (MREAD-1)];
        if(ucount == 1) ueffA[jcount] = veleff;
        else
            ueffB = veleff;
            lhaA = pow(ueffA[jcount],2.);
            lhaB = pow(ueffB,2.);
            v = sint * (ueffA[jcount] - ueffB);
            u = (ueffA[jcount] - v * sint) / cost;
            iter = 0;
        /* ************************************ */
        /* iteration to determine u and v instantaneous */
        do
        { iter++;
          ktAterm = pow((kt * sint * (u - v)),2.);
          ktBterm = pow((kt * cost * (u + v)),2.);
          ueffAnew = sqrt(lhaA - ktAterm);
          ueffBnew = sqrt(lhaB - ktBterm);
          vnew = sint * (ueffAnew - ueffBnew);
          unew = (ueffAnew - vnew * sint) / cost;
          epsilonA = fabs(vnew - v) / v;
          epsilonB = fabs(unew - u) / u;
          u = unew;
          v = vnew;
          if(iter > 2)
            printf("i = %d iter = %d epA = %f epB = %f\n",147

1, iter, epsilonA, epsilonB);
}
while ((epsilonA > .001) || (epsilonB > .001));
angle = jcount % (MREAD-1);
/* Update the summations */
sumu[angle] += u;
sumv[angle] += v;
sum2[angle] += (u*v);
sumv2[angle] += (v*w);
sumu2[angle] += (u*w);

/* Output v instantaneous to the file "vminst" */
if((angle == 179) && (1 < 750)){
    vmfile = fopen("/usr/geoff/proc/vminst","w");
    for(kcount = 1; kcount <= 179; kcount++)
        fprintf(vmfile,"%d\t\%lf\n",2 * kcount,sumv[kcount]);
    fflush(vmfile);
    fclose(vmfile);
    printf("\n\vminst file printed\n");
}
}
/* end of loop for ueffB */
/* end of loop for every 4th pt */
/* end of binary string breakdown loop */
/* end of uccount loop for ueffA and ueffB */
if(diagnosis)printf("data converted\n");

/* ****************************** */
/* Section to determine run status */
/* Should another buffer of data be acquired? */
if((lastcy = (round - 1) * cy_in_buf) > = cycle)
    next_round = 0;
    if(diagnosis) printf("next_round = %d\n", 
                    next_round);

    if(diagnosis)printf("wait for end of acquisition\n");
    if(diagnosis)printf("status_byte = %o\n", status_byte);

    /* Send message about current round. */
    printf("Data for round %d (cycle %d) processed.\n", 
    (round - 1), (round - 1) * cy_in_buf);

    /* Wait until NORLAND is done acquiring. */
    /* (Loop to test whether NORLAND is still acquiring.) */
    i = 0;
    do{
        ibsp(ib3, &status_byte);
        if(diagnosis){
            i += 1;
            if(i > 100){
                i = 0;
                printf("%o\n", status_byte);

            }
        }
    }

    while(status_byte & 5);
    if(diagnosis)printf("N stopped acquisition\n");
    if(diagnosis)printf("status_byte = %o\n", status_byte);

    /* If necessary, read results of data acquisition. */
    if(next_round){
        if(diagnosis)printf("reading of A will begin\n");
        /* Send command to read NORLAND buffer for Chan A. */
        ibwrt(ib3, rcmdA, strlen(rcmdA));
        /* Read data from NORLAND. */
        ibrd(ib3, readstrA, SMAX);
        if(diagnosis)printf("reading of A done\n");
        if(diagnosis)printf("status_byte = %o\n", status_byte);

    148
if(diagnosis)printf("reading of B will begin\n");
    /* Send command to read NORLAND buffer for Chan B. */
    ibwrt(ib3,rdcmdB,strlen(rcmdB));
    /* Read data from NORLAND. */
    ibrd(ib3,readstrB,SMAX);
if(diagnosis)printf("reading of B done\n");
}
if(diagnosis)printf("status_byte = \%d\n", status_byte);

/* Reset flag for first round of acquisition. */
if(first_time) first_time = 0;

/* Calculate the number of cycles stored and entered into the summation so far. */
cycles = (double)((round - 1) * cy_in_buf);
printf("cycles stored, summed = \%f\",cycles);

/* Set flags for printout and for updating sums. */
if(!next_round) {
    fin_pr = 1;
}
if(m_out >= 1 && iout <= m_out
    && cycles >= (double)n_out[iout]) {
    iout++;
    int_pr = 1;
}
if(fin_pr || int_pr) {
    printf("cycles = \%f\",cycles);
    /* *********************************************** */
    /* Calculate ensemble averaged velocities,
        rms velocity fluctuations, and shear stresses
        based on the summations */
    for(iangle = 1; iangle <= nread; iangle++){
        um = sumu[iangle] / cycles;
        umn[iangle] = um;
        vm = sumv[iangle] / cycles;
        vmean[iangle] = vm;
        if((argument = 1.0/(cycles - 1.0) *
            (sumu2[iangle] - um*umn*cycles) > 0.0)
            urms[iangle] = sqrt(argument);
        else urms[iangle] = 0.0;
        if((argument = 1.0/(cycles - 1.0) *
            (sumv2[iangle] - vm*vm*cycles) > 0.0)
            vrms[iangle] = sqrt(argument);
        else vrms[iangle] = 0.0;
        upvp[iangle] = 1.0/(cycles - 1.0) *
            (sumuv[iangle] - um*vm*cycles);
    }
}
if(int_pr) {
    /* Store sums in auxiliary arrays to be updated
        further during subsequent rounds. */
    for(iangle = 1; iangle <= nread; iangle++) {
        old_su[iangle] = sumu[iangle];
        old_sv[iangle] = sumv[iangle];
        old_su2[iangle] = sumu2[iangle];
        old_sv2[iangle] = sumv2[iangle];
        old_sum[iangle] = sumuv[iangle];
    }
}
if(fin_pr || int_pr) {
    if(diagnosis) printf("fin_pr = \%d, int_pr = \%d \n", fin_pr, int_pr);
    /* Sort entries in umean and urms arrays according to
        crank angle to account for angular offset
        between TDC and trigger. */
}
for(iangle = 1; iangle <= nread - nlag; iangle++){
    sumu[iangle + nlag] = umean[iangle];
    sumv[iangle + nlag] = vmean[iangle];
    sumu2[iangle + nlag] = urms[iangle];
    sumv2[iangle + nlag] = vrms[iangle];
    sumuv[iangle + nlag] = upvp[iangle];
}

for(iangle = nread - nlag + 1;
    iangle <= nread; iangle++){
    sumu[iangle + nlag - nread] = umean[iangle];
    sumv[iangle + nlag - nread] = vmean[iangle];
    sumu2[iangle + nlag - nread] = urms[iangle];
    sumv2[iangle + nlag - nread] = vrms[iangle];
    sumuv[iangle + nlag - nread] = upvp[iangle];
}

/* Store the results in a binary string */

if(diagnosis) printf("will open storefile\n");
storefile = fopen(filename, "r+");
if(diagnosis) printf("opened storefile\n");
if(storefile == NULL)
    printf("fopen failed\n");
/* Move to end of file. */
if(fseek(storefile,0L,2))
    printf("fseek failed\n");
if(fwrite(&distance,sizeof(double),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("distance = %f\n",distance);
if(fwrite(&accuracy,sizeof(double),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("accuracy = %f\n",accuracy);
if(fwrite(&lasty,sizeof(int),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("lasty = %d\n",lasty);
if(fwrite(&maxuerr,sizeof(double),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("maxuerr = %f\n",maxuerr);
if(fwrite(&iueerr,sizeof(int),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("iueerr = %d\n",iueerr);
if(fwrite(&mxrmerr,sizeof(double),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("mxrmerr = %f\n",mxrmerr);
if(fwrite(&irmserr,sizeof(int),1,storefile) != 1)
    printf("fwrite failed\n");
if(diagnosis) printf("irmserr = %d\n",irmserr);
if(fwrite(&sumu[1],sizeof(double),nread,storefile)
    != nread)
    printf("fwrite failed\n");
if(diagnosis) {
    for(count3 = 1; count3 <= 180; count3++)
        printf("sum[/] = %f\n",count3, sumu[count3]);
}
if(fwrite(&sumu2[1], sizeof(double), nread, storefile)
    != nread)
    printf("fwrite for sumu2 failed\n");
if(fwrite(&sumv[1], sizeof(double), nread, storefile)
    != nread)
    printf("fwrite for sumv failed\n");
if(fwrite(&sumv2[1], sizeof(double), nread, storefile)
    != nread)
    printf("fwrite for sumv2 failed\n");
if(fwrite(&sumuv[1], sizeof(double), nread, storefile)
    != nread)
    printf("fwrite for sumuv failed\n");
if(! old_file) {
    if(fwrite(&t_dry,sizeof(double),1,storefile)
        != 1) printf("fwrite for t_dry failed\n");
    if(fwrite(&t_wet,sizeof(double),1,storefile)
        != 1) printf("fwrite for t_wet failed\n");
    if(fwrite(&p_atm,sizeof(double),1,storefile)
        != 1) printf("fwrite for p_atm failed\n");
}
if(!1) printf("fwrite for p_atm failed\n");
if(fwrite(dummy,sizeof(char),NDUMMY,storefile) == NDUMMY) printf("fwrite for NDUMMY failed\n");
if(diagnosis) printf("Comment: %s\n", dummy);
if(diagnosis) printf("will close storefile\n");
if(fclose(storefile) == EOF) printf("fclose failed\n");
printf("Data were stored in file.\n");
if(fin_prt) {
/* Reset the sums used for averaging to zero for the 
next calculation of ensemble averages. */
for(iangle = 1; iangle <= nread; iangle++){
    sumu[iangle] = 0.0;
    sumv[iangle] = 0.0;
    sumu2[iangle] = 0.0;
    sumv2[iangle] = 0.0;
    sumuv[iangle] = 0.0;
}
out = 1;
/* Reset fin_prt to zero. */
fin_prt = 0;
}
if(int_prt) {
/* Reset the sums used for averaging to zero for the 
ongoing calculation of ensemble averages. */
for(iangle = 1; iangle <= nread; iangle++){
    sumu[iangle] = old_su[iangle];
    sumv[iangle] = old_sv[iangle];
    sumu2[iangle] = old_su2[iangle];
    sumv2[iangle] = old_sv2[iangle];
    sumuv[iangle] = old_suuv[iangle];
}
/* Reset int_prt to zero. */
int_prt = 0;
}
the_end: printf("No further data will be acquired.\n");
/* Acquirex program end */
*/
/*****************************/
AIR_STATEX

air_statex()
/ * Function to enter, or read from existing file, the ambient air
  conditions and to enter mean static air pressure in a file.
  Function adapted from air_statex.c for cross-wires 3/80 */
{
  #include <stdio.h>
  #include <string.h>

  #define STRLNG 30
  #define NDUMMY 50

  FILE *storefile;
  extern int diagnosis, oldfile;
  extern int nread; /* number of readings per cycle */
  extern char filename[];
  extern double t_dry, t_wet, p_atm; /* air conditions during run,
                                    stored in Kelvin and Pascal internally. */

  int inerr, /* error in input data */
  i /* auxiliary counter */;

  long offset;
  long sizeofheader, sizeofset;
  double gas_const = 8315., /* universal gas constant in kg/kmol/K */
                     air_mwt = 28.96, /* molecular weight in kg/kmol for air
                           with mole fractions of:
                           H2 = 0.7809
                           O2 = 0.2095
                           Ar = 0.0096 */

  density /* air density in kg/m^-3 */;

  char resp[STRLNG];
  /* Open storefile. */
  storefile = fopen(filename,"r");

  /* Enter ambient air conditions. */
  if(diagnosis) printf("oldfile = %d\n", oldfile);
  if(oldfile) {
    printf("Current ambient air conditions:\n");
    resp[0] = 'n';
  }
  else {
    printf("Enter ambient air conditions.\n");
    resp[0] = 'y';
    oldfile = 1;
  }
  switch(resp[0]) {
    case 'n': case 'N':{
      /* Determine the size of the header. */
      sizeofheader = (long)((10+NDUMMY)*sizeof(char)
                            + 6*sizeof(double)
                            + 2*sizeof(int));
      if(diagnosis) printf("sizeofheader = %ld\n", sizeofheader);
      /* Determine the size of a data set. */
      sizeofset = (long)((7*sizeof(double) + 3*sizeof(int)
                         + 2 * nread + sizeof(char)
                         + NDUMMY + sizeof(char)));
      /* Addition to size of a data set for cross wire */
      sizeofset += (long)(3 * nread + sizeof(double));
      if(diagnosis) printf("sizeofset = %ld\n", sizeofset);
      /* Determine offset of latest air data */
      fseek(storefile,0L,2); /* Move to end of file. */
if(diagnosis) printf("fseek 0 end ok\n");

/* Check whether there is an entry for the state of the air. Read the air data. */
offset = ftell(storefile);
if(diagnosis) printf("offset = %ld\n", offset);
if(offset >= sizeof(header + sizeofset) {  
  if(diagnosis) printf("ftell >\n");
  offset = (long)(3 * sizeof(double)  
    - NDUMMY = sizeof(char));
  fseek(storefile,offset,2);  
  offset = ftell(storefile);
  if(diagnosis) {
    printf("offset = %ld\n", offset);
    printf("errors before reading: ");
    if(feof(storefile)) printf("EOF\n");
    if(ferror(storefile)) printf("error\n");
  }
  if(fread(&t_dry,sizeof(double),1,storefile) != 1) {
    if(feof(storefile)) printf("EOF\n");
    if(ferror(storefile)) printf("error\n");
  }  
  else {  
    if(diagnosis) printf("fread of t_dry succ.\n");
  }
  if(fread(&t_wet,sizeof(double),1,storefile) != 1) {
    if(feof(storefile)) printf("EOF\n");
    if(ferror(storefile)) printf("error\n");
  }  
  else {  
    if(diagnosis) printf("fread of t_wet succ.\n");
  }
  if(fread(&p_atm,sizeof(double),1,storefile) != 1) {
    if(feof(storefile)) printf("EOF\n");
    if(ferror(storefile)) printf("error\n");
  }  
  else {  
    if(diagnosis) printf("fread of p_atm succ.\n");
  }
  printf("dry-bulb temperature = %lf deg.C\n",  
    t_dry - 273.15);
  printf("wet-bulb temperature = %lf deg.C\n",  
    t_wet - 273.15);
  printf("atmospheric pressure = %lf bar\n",  
    p_atm / 1.e+05);
  scanf("%ks", resp);
  if(resp[0] == 'y' && resp[0] == 'Y')
    break;
  }
else {  
  printf("There is no old entry of ambient air data.\n")
}
}

case 'y': case 'Y':{
  /* Enter ambient air conditions. */
  for(inerr = 1; inerr; ){  
    printf("Enter dry-bulb temperature (deg.C).\n");
    printf("Enter wet-bulb temperature (deg.C).\n");
    printf("Atmospheric pressure (bar).\n");
    scanf("%lf%lf%lf", &t_dry, &t_wet, &p_atm);
    printf("dry-bulb temperature = %lf deg.C\n",  
      t_dry);
    printf("wet-bulb temperature = %lf deg.C\n",  
      t_wet);
    printf("atmospheric pressure = %lf bar\n",  
      p_atm);
    t_dry += 273.15;
    t_wet += 273.15;
    p_atm *= 1.e+05;
    printf("Entry correct? (y/n)\n");
    scanf("%ks", resp);
    if(resp[0] == 'y' && resp[0] == 'Y')
      break;
  }
}
inerr = 0;
else if(resp[0] == 'n' || resp[0] == 'N')
  inerr = 1;
else {
  printf("Enter numbers and \n");
  printf("respond with y, Y for 'yes' \n");
  printf("or with n, N for 'no' next time. \n");
}
break;

fclose(storefile);
PROCESSX

/* "processx.c" processes two channel xwire measurement files.
G. Friedman, 8/80 */
/* Program is adapted from "process.c" written by J. Seume for single
 wire data processing */

#include <stdio.h>
#include <math.h>
#include <string.h>

#define MRAD 40
#define MREAD 181
#define IDLENGTH 10
#define NDUMMY 50
#define PI (4. * atan(1.0))
#define NU 16.e-06

char usage[] = "Usage: process [-f runid or -t position or -p time or\n -v or -a or -d or -w or -r or -R]\n";

main(argc,argv)
int argc;
char *argv[];
{
    FILE *storefile;
    FILE *tracefile;
    FILE *profile;
    FILE *avefile;
    FILE *idealfile;

    int write_all; /* Write to files the data for all active traces and
for profiles in increments of 30 degs of crank angle. */

    int diagnosis = 1; /* Print error diagnostics. */
    int fast = 1; /* Enter file i.d. from the command line,
skip echo print of run parameters. */
    int radial = 1; /* Process the radial velocity component v */
    int trace = 1; /* Generate data for a plot of the ensemble-averaged
mean-velocity fluctuation transient
at one radial location. */

    int profile = 1; /* Generate data for a plot of a mean-vel. profile */
    int average = 1; /* Generate data for a plot of the cross-sectional
mean mean-velocity transient (real and ideal). */
    int rms = 1; /* Process rms-velocity fluctuations instead of
ensemble-averaged velocities. */
    int Rs = 1; /* Process Reynolds' shear stress values */
    int position; /* Number of the radial position at which a trace shall
be plotted. */
    int itime; /* Number of the current crank angle. */
    int not_done = 1; /* Program is not ready to be terminated. */
    int old_file = 0; /* file format old or new? */
    int ierr, flag, iangle, nrad, nsort, i, j, irad;
    int mread; /* number of readings per cycle */
    int mcycle; /* maximum number of cycles to be acquired */
    int nangle = 12; /* number of angles at which profiles are to be plotted
when write_all = 1 */

    int lastcr, ierr, irmserr;
    long p, prtr[MRAD], offset;
    long sizeofheader, sizeofset;
    double angle; /* crank angle */
    double time; /* Integer crank angle at which a mean-velocity profile
shall be plotted. */
    double mstroke, mbore, mdiam, mlength, maxial, freq;
    double relrad;
    double Remax, Va, Ar, loverd, xoverl, xoverd, uavemax;
    double accuracy, maxuerr, maxrsrerr;
    static double distance, umean[MREAD], urms[MREAD], uave[MREAD];
    static double vmean[MREAD], vrms[MREAD], vave[MREAD], upvp[MREAD];
    static double dist[MRAD], value, unmpr[MREAD], ucl;
    double uptr; /* auxiliary variable to print umean, urms */
    double d, sortdist[MRAD];

    155
double umint, aint;  /* auxiliary radii */
double rmi, ri;  
 double fnull = 0.0;  
 double pi;  /* pi = 3.1415... */
 double air_viscosity(), air_cond(), air_cp(),
      air_density(), dry_air_density(), psat_water();
 double T_dry, T_wet, p_atm;
 double rho, rhod, hum_ratio, air_cont, rh, mu, nu, cond, cp, alpha, Pr;

char runid[10], resp[20], resp2[20], filename[30], title[NDUMMY], dummy[NDUMMY];
char tfname[10], tnumber[5], pfname[10], pnumber[5];
char year[3], month[3];

/* Calculate pi */
pi = PI;
printf("nread = %d
", nread);

/* Determine the sizes of header and data sets. */
sizeofheader = (long)(10*sizeof(char) + 6*sizeof(double))
      + sizeof(int);  /* size of the run information */
sizeofset = (long)(4*sizeof(double) + 3*sizeof(int)
      + 2 * nread * sizeof(double));  /* size of one data set */

/* Add to "sizeofset" the size of the 3 new arrays used in
the cross-wire measurements */
sizeofset += (long)(3 * nread * sizeof(double));

/* Set defaults for command line parameters. */
fast = 0;
radial = 0;
trace = 0;
profile = 0;
average = 0;
diagnosis = 0;
write_all = 0;
rms = 0;
Rss = 0;

/* Read the command line for control parameters. */
while(**argv == '-'){
    switch(**argv){
        case 'f':
            fast = 1;
            strcpy(runid,**argv);
            --argv;
            break;
        case 't':
            trace = 1;
            position = atoi(**argv);
            --argv;
            break;
        case 'v':
            radial = 1;
            --argv;
            break;
        case 'p':
            profile = 1;
            time = atof(**argv);
            --argv;
            break;
        case 'a':
            average = 1;
            --argv;
            break;
        case 'd':
            diagnosis = 1;
            --argv;
            break;
        case 'w':
            write_all = 1;
            --argv;

156
case 'r':
    rms = 1;
    --argc;
    break;
    
case 'R':
    Res = 1;
    --argc;
    break;
}
    
if(diagnosis)printf("trace position = %d\n",position);
for(not_done = 1; not_done; )
    if(! fast){
        
        /* Read run identification and check whether the corresponding 
         * file already exists. */
        for(inerr = 1; inerr; )
        {
            printf("\n\nEnter run identification: \n\n");
            printf("(Use the format mmddyy where: m\n");
            printf(" mm = month, dd = day, yy = year,\n");
            printf(" a sequence number of the day's\n");
            printf(" runs)\n");
            printf("Enter c to continue using the same ");
            printf("run.\n");
            printf("Enter s to stop the program.\n");
            scanf("%s", runid);
            if(runid[0] == 'c') goto the_end;
            else if(runid[0] == 's') goto the_end;
            
        } Print("Enter correct? (y or n or stop)\n");
            scanf("%s", resp);
        if(resp[0] == 'y' || resp[0] == 'Y')
            {inerr = 0;}
        else if(resp[0] == 'n' || resp[0] == 'N')
            continue;
        else if(resp[0] == 's' || resp[0] == 'S')
            {goto the_end;}
        
        printf("If you want to process instantaneous ");
        printf("or ensemble-averaged data or times,\n");
        printf("(=> enter 'm',\n");
        printf("If you want to process differences ");
        printf("or rms-fluctuations or angular velocity,\n");
        printf("(=> enter 'r',\n");
        printf("If you want to process Reynolds' ");
        printf("shear stress,\n");
        printf("(=> enter 'R',\n");
        scanf("%s", resp);
        
        if(resp[0] == 'm' || resp[0] == 'r')
            {printf("Enter a 'v' for radial velocity or any other ");
            printf("character for the axial velocity,\n");
            scanf("%s", resp2);
            if(resp2[0] == 'v') radial = 1;
        }
        if(resp[0] == 'm') rms = 0;
        else if(resp[0] == 'r') rms = 1;
else if(resp[0] == 'R') Rss = 1;
else{
    printf("Mean velocity will be processed.\n");
    Rss = 0;
    rms = 0;
}
else
    /* Take run i.d. from command line. */
    strcpy(filename,"/usr/geooff/shwdata/");
    strcpy(&filename[19],runid);
    storefile = fopen(filename, "r+");
    if(storefile == NULL){
        printf("This file does not exist.\n");
        goto the_end;
    }

    /* Read parameters from data file. */
    storefile = fopen(filename, "r+");
    fread(runid,sizeof(char),10,storefile);
    fread(&stroke,sizeof(double),1,storefile);
    fread(&bore,sizeof(double),1,storefile);
    fread(&length,sizeof(double),1,storefile);
    fread(&diameter,sizeof(double),1,storefile);
    fread(&freq,sizeof(double),1,storefile);
    fread(&read,sizeof(int),1,storefile);
    /* Check whether this is a file of the old format. */
    strcpy(year,&runid[4],2);
    strcpy(month,&runid[0],2);
    if(atol(year) == 68 && atol(month) < 6)
        old_file = 1;
    else
        old_file = 0;
    if(diagnosis) printf("old_file = %d\n",old_file);
    if(! old_file) {
        fread(&cycle,sizeof(int),1,storefile);
        fread(&title,sizeof(char),NDUMMY,storefile);
    }
    fseek(storefile,0L,0); /* rewind */

    /* Determine the sizes of header and data sets. */
    sizeofheader = (long)(10*sizeof(char) + 6*sizeof(double))
        + sizeof(int); /* size of the run information */
    sizeofset = (long)(4*sizeof(double) + 3*sizeof(int)
        + 2 * nread * sizeof(double)); /* size of one data set */

    if(! old_file) {
        sizeofheader += (long)(sizeof(int) + NDUMMY * sizeof(char));
        sizeofset += (long)(3 * sizeof(double) + NDUMMY * sizeof(char));
    }

    /* Add to "sizeofset" the size of the 3 new arrays used in
     * the cross-wire measurements */
    sizeofset += (long)(3 * nread * sizeof(double));

    /* Print title. */
    printf("\nTitle:\n");
    printf("%s\n", title);

    if(! fast){
        /* Print data summaries in English and SI units
         * and dimensionless form. */
        /* Echo print input data in English units. */
        printf("\nInput data summary in English units:\n");
        printf("stroke = %6.1f in\n", stroke/0.0254);
        printf("bore = %6.1f in\n", bore/0.0254);
        printf("test section diameter = %6.1f in\n",
            diameter/0.0254);
        printf("test section length = %6.1f in\n",
            length/0.0254);
        printf("axial location = %6.1f in\n",
            }
printf("drive shaft freq = \%5.1f rpm\n", freq=240.);
printf("%d readings taken per cycle\n", nread);
if(! old_file) {
    printf( "Maximum number of cycles ");
    printf(" to be acquired = %d\n", mcycle);
    printf(" Comment: %s", dummy);
}
printf("Type a character followed by \<CR\> to continue.\n\n");
if(scant("%s", resp));

/* Echo print input data in SI units. */
printf("\n Input data summary in SI units: \n\n");
printf(" stroke = \%6.1f mm\n", mstroke=1000);
printf(" bore = \%6.1f mm\n", mbore=1000);
printf(" test section diameter = \%6.1f mm\n", mdiam=1000);
printf(" test section length = \%6.1f mm\n", mlength=1000);
printf(" axial location = \%6.1f mm\n", maximal=1000);
printf(" frequency = \%5.3f Hz\n", freq);
printf(" \%d readings taken per cycle\n", nread);

/* estimate of the amplitude of the bulk-mean velocity */
avevmax = PI * freq * mstroke * (mbore*mbore) / (mdiam*mdiam);
printf("Estimate of the amplitude of the bulk-mean velocity ");
printf(=" \%5.2f m/sec\n", avevmax);

/* Calculate and print similarity parameters. */
printf(" Nominal similarity parameters: \n\n");
printf(" Remax = \%10.2e\n", Remax = PI*mbore*mbore*freq*mstroke / mdiam / NU);
printf(" Va = \%5.1f\n", Va = 0.5*PI*freq*mdiam*mdiam / NU);
printf(" Ar = \%5.2f\n", Ar = mbore*mbore/(mdiam*mdiam)*mstroke/length);
printf(" l/d = \%6.1f\n", lverd = length / mdiam);
printf(" x/l = \%6.3f\n", xoverl = maximal / mlength);
printf(" x/d = \%6.1f\n", xoverd = maximal / mdiam);

/* Reset control parameters. */
tr ace = 0;
profile = 0;
average = 0;

/* Enter type of output desired. */
for(inerr = 1; inerr; ){}
printf("Enter t for trace\n");
printf(" p for profile\n");
printf(" a for average\n");
scanf("%s", resp);
switch(resp[0])
{
case 't':
    trace = 1;
    printf("Trace will be plotted.\n");
    break;
case 'p':
    profile = 1;
    printf("Profile will be plotted.\n");
    break;
case 'a':
    average = 1;
    printf("Transient of bulk-mean \n");
    printf("quantity will be plotted.\n");
    break;
default:
    printf("Enter correct code letter.\n");
    break;
}
printf("\n Entry correct? (y or n)\n");
```c
#include "radial.h"

/* Scan the file for wall distance entries. */
fseek(storefile,sizeof(header),0); /* Rewind and move to
beginning of first data set. */
flag = 1;
nrad = 0;
i = 1;
while(flag != 0){
    flag = fread(&dist[i].sizeof(double),1,storefile);
    if(flag)
        {nrad = nrad + 1;
         if(diagnosis) printf("Read set %"%d"\n", nrad);
         rpct[i] = ftell(storefile)
             - (long) sizeof(double);
         fseek(storefile,sizeof(set)
             - (long) sizeof(double),1);
         }
        else
            {if(diagnosis) printf("flag = 0\n");}
        i = i + 1;
    }
    if(diagnosis) printf("# of radial data sets = %d\n",nrad);
    
    if(! fast){
        /* Echo list of radial data sets. */
        printf("There are %d radial data sets:\n", nrad);
        printf("data set:\n");
        printf("Number \tdistance \tdistance \t\radius /\n");
        printf("\t\t\t\t\t\t\t\t\t\t\n");
        printf("radius\n");
        for(i = 1; i <= nrad ; i++)
            {
            printf("%d %f %f %f\n",
               i, dist[i]*1000., dist[i]/0.0254,
               1. - 2.*dist[i]/mdiam,)
            }
        /* To remove data sets, substitute distance from the
wall by its negative value. */
        printf("Do you want to (de)activate any data set? ");
        printf("y or n\n");
        scanf("%s", resp);
        if(resp[0] == 'y' && resp[0] == 'Y'){
            printf("Enter numbers of sets to be ");
            printf("(de)activated. (Enter 's to ");
            printf("terminate.)\n");
            while(scanf("%s", resp))
            { if(resp[0] == 's') break;
                  i = atoi(resp);
                  dist[i] = - dist[i];
                  fseek(storefile,
                     sizeofset=(long)(i-1) +
                     sizeofheader,0);
                  fwrite(&dist[i].sizeof(double),1,storefile);
            }
```
if(trace){
    if(! fast){
        /* Choose a radial location at which the traces are to be plotted */
        printf("Enter number of the trace to be plotted.\n");
        while(scanf("%d", &position) != 0){
            getchar();
            printf("Enter the integer number ");
            printf("of the trace: \n");
        }
    }
    /* Move to the data set of this radial location */
    fseek(storefile,(long)(position-1)*sizeofset
        + sizeofheader,0); /* Move to beginning of desired data set */
    if(diagnosis)printf("sizeofset = %d\n",sizeofset);
    if(diagnosis)printf("sizeofheader = %d\n",sizeofheader);
    /* Read in the desired data set */
    fread(&distance,sizeof(double),1,storefile);
    fread(&accuracy,sizeof(double),1,storefile);
    fread(&lastc,sizeof(int),1,storefile);
    fread(&amaxuerr,sizeof(double),1,storefile);
    fread(&arerr,sizeof(int),1,storefile);
    fread(&xrmser,sizeof(double),1,storefile);
    fread(&lrmerr,sizeof(int),1,storefile);
    fread(&umean[1],sizeof(double),nread,storefile);
    fread(&urms[1],sizeof(double),nread,storefile);
    fread(&vmean[1],sizeof(double),nread,storefile);
    fread(&zrms[1],sizeof(double),nread,storefile);
    fread(&upvp[1],sizeof(double),nread,storefile);
    fread(&dry,sizeof(double),1,storefile);
    fread(&wet,sizeof(double),1,storefile);
    fread(&p_atm,sizeof(double),1,storefile);
    /* Read and print comment */
    fread(dummy,sizeof(char),NDUMMY,storefile);
    printf("Comment: %s\n", dummy);
    /* Print out air state for this trace */
    if(! old_file) {
        printf("Dry-bulb temperature = %f deg. C \n", T_dry - 273.15);
        printf("Wet-bulb temperature = %f deg. C \n", T_wet - 273.15);
        printf("Atmospheric pressure = %f bar \n", p_atm = 1.e-05);
    }
    /* Print out air properties for this trace */
    if(! old_file && (! fast))
        for(inerr = 1; inerr; ) {
            printf("Do you want to list property values? ");
            printf("(y or n)\n");
            scanf("%s", resp);
            if(resp[0] == 'y' || resp[0] == 'Y') {
                /* From humidity ratio, air content */
                scanf("Enter humidity ratio, air content ");
                printf("(\% kg/m^3) \n");
                printf("From psychrometric chart ");
                scanf("%lf\lf", &hum_ratio, &air_cont);
                rhod = dry_air_density(T_dry, p_atm);
                rho = (p_atm / 1.013e+05) * air_cont
                    * (1. + hum_ratio);
                printf("Air density (dry, humid) = %lg, %lg\n", rhod, rho);
            }
            etc...
        }
    return 0;
}
}
printf("Air density decrease ");
printf("due to humidity = \%g\n", 1 - rho / rhod) * 100.);
printf("Relative humidity = \%g\n", rh = 100. * hum_ratio * (p_atm - psat_water(T_dry)) / 0.822 / psat_water(T_dry));
printf("Air dynamic viscosity = \%g\n", mu = air_viscosity(T_dry));
printf("Air kinematic viscosity = \%g\n", nu = mu / rho);
printf("Air thermal conductivity = \%g\n", cond = air_cond(T_dry));
printf("Air specific heat at constant ");
printf("pressure = \%g\n", cp = air_cp(T_dry));
printf("Air thermal diffusivity = \%g\n", alpha = cond / rho / cp);
printf("Air Prandtl number = \%g\n", Pr = nu / alpha);
printf("Entry correct? ");
scanf("%s", resp);
if(resp[0] == 'y' || resp[0] == 'Y') {
inerr = 0;
}
else if(resp[0] == 'n' || resp[0] == 'N') {
inerr = 0;
}
else {
printf("Respond with y, Y for 'yes'; ");
printf("or with n, N for 'no'; ");
printf("or with s, S for 'stop' next time.\n";
}

/* Print data in column format to be plotted. */
tracefile = fopen("trace", "w");
for(i = 1; i <= nread; i++){
 if(rms) {
  if(!radial)
   [ uprt = urms[i];
   if(diagnosis) printf("processing upms\n");
  else
   [ uprt = vrms[i];
   if(diagnosis) printf("processing vrms\n");
  }
 else if(Rss)
   [ uprt = upvp[i];
   if(diagnosis) printf("processing upvp\n");
 else {
  [ uprt = umean[i];
  if(diagnosis) printf("processing umean\n");
  else
   [ uprt = vmean[i];
   if(diagnosis) printf("processing vmean\n");
  }
  fprintf(tracefile, "%f %f\n",
(double) i = 360. / (double) nread, uprt);
}
fclose(tracefile);
}
if(write_all){
 for(i = 1; i <= nread; i++){
/* Read and process non-deactivated traces. */
if(dist[i] > 0.0)
    
    /* Move to the data set of this radial location. */
    fseek(storefile,(long)(i-1)*sizeofset + sizeofheader,0); /* Move to
    beginning of desired data set. */
    
    /* Read in the desired data set. */
    fread(&distance,sizeof(double),1,storefile);
    fread(&accuracy,sizeof(double),1,storefile);
    fread(&lastcy,sizeof(int),1,storefile);
    fread(&maxuerr,sizeof(double),1,storefile);
    fread(&guerr,sizeof(int),1,storefile);
    fread(&nxrmser,sizeof(double),1,storefile);
    fread(&irt,sizeof(int),1,storefile);
    fread(&umean,sizeof(double),1,storefile);
    fread(&urms,sizeof(double),1,storefile);
    fread(&nread,sizeof(double),1,storefile);
    fread(&vmean,sizeof(double),1,storefile);
    fread(&vrm,sizeof(double),1,storefile);
    fread(&upvp,sizeof(double),1,storefile);
    
    /* Print data in column format to be plotted. */
    strcpy(tfname,"ttrace");
    printf(tfname,"%d",i);
    strcat(tfname,tfnumber);
    tracefile = fopen(tfname,"w");
    for(iangle = 1; iangle <= nread; iangle++)
        if(!sent)
            if(!radial)
                uprt = urms[iangle];
            else
                uprt = vrm[iangle];
        else if(!sent)
            uprt = upvp[iangle];
        else
            if(!radial)
                uprt = umean[iangle];
            else
                uprt = vmean[iangle];
    }
    printf(tracefile,"%f %f
",
            (double) iangle = 360. / (double) nread,
            uprt);
    }fclose(tracefile);)
    
    if(profile == average || write_all)
        /* Sort traces with increasing wall distance. */
        /* Write wall distances and data-set pointers into
           new arrays, omitting deactivated data sets. */
        for(i = 1, j = 1; i <= nread; i++)
            if(dist[i] > 0.0){
                sortdist[j] = dist[i];
                rptr[j] = rptr[i];
                j = j + 1;
            }
        nsort = j - 1;

        /* Rearrange the arrays. */
        /* (See section 6.1 of W. H. Press et al.: Numerical
           Recipes, Cambridge (UK) University Press 1986.) */
        for(j = 2; j <= nsort; j++)
            d = sortdist[j];
            p = rptr[j];
            for(i = j - 1; i >= 1; --i){
                if(sortdist[i] > d){
                    sortdist[i+1] = sortdist[i];
                    rptr[i+1] = rptr[i];
                }
            }
else goto sortmark;
}

sortmark:
    i = 0;
    sortdist[i+1] = d;
    rptr[i+1] = p;
}

if(diagnosis){
    printf("Sorting results:\n");
    printf("Sort distance \tsorted \n");
    for(i = 0; i <= nrad; i++)
        printf("%d \t%f \t%f \n", i, dist[i],
                sortdist[i]);
}

if(profile){
    if(! fast){
        /* Choose phase angle at which the profile is to
           be plotted. */
        printf("Enter the phase angle.\n");
        while(fscanf("%lf", &time) == 0){
            getchar();
            printf("Enter the integer ");
            printf("phase angle!\n");
        }
    }

    /* Calculate the offset from the beginning of the data
       set to the entry corresponding to the time of
       interest in the storage file. */
    /* If it is for u */
    if(!radial && !Rs) offset = (long)(3 * sizeof(int))
        + (long)(4 * sizeof(double))
        + (long)(rms * nread * sizeof(double))
        + (long)((time * (double)nread / 360. - 1.)
                = sizeof(double));
    /* If it is for v */
    else if(radial) offset = (long)(3 * sizeof(int))
        + (long)(4 * sizeof(double))
        + (long)(2 * nread * sizeof(double))
        + (long)(rms * nread * sizeof(double))
        + (long)((time * (double)nread / 360. - 1.)
                = sizeof(double));
    /* If it is for upvp */
    else if(Rs) offset = (long)(3 * sizeof(int))
        + (long)(4 * sizeof(double))
        + (long)(4 * nread * sizeof(double))
        + (long)((time * (double)nread / 360. - 1.)
                = sizeof(double));

    if(diagnosis){
        printf("offset of entry = %ld", offset);
        printf("nread = %d", nread);
        printf("time = %f", time);
        printf("rms = %d", rms);
        printf("Rs = %d", Rs);
        printf("radial = %d", radial);
    }

    /* Read entries from data storage file and write to
       plot file. */
    profile = fopen("profile", "w");
    fprintf(profile, "%f %g\n", 0.0, umprf[0] = 0.0);
    for(i = 1; i <= nsort; i++){
        /* Move to the entries corresponding
           to this phase angle. */
        fseek(storefile, (rptr[i] + offset), 0);
        /* Move to the desired entry. */
        fread(&umprf[i], sizeof(double), 1, storefile);
    }
}

164
/* Print data in column format to be plotted. */
fprintf(proffile, "%f %g\n",
    sortdist[i]/mdiam,
    umprf[i]);
}
fclose(proffile);
}

if(write_all){
    for(iangle = 1; iangle <= nangle; iangle++){
        /* Choose phase angle at which the profile is to
           be plotted (every 30 degrees). */
        time = (360.0/(double)nangle) * (double)iangle;

        /* Calculate the offset from the beginning of the data
           set to the entry corresponding to the time of
           interest in the storage file. */
        /* If it is for u */
        if(!radial & & !Rs) offset = (long)(3 * sizeof(int))
            + (long)(4 * sizeof(double))
            + (long)(rms * nread * sizeof(double))
            + (long)((time * (double)nread / 360.0 - 1.0)
                * sizeof(double));
        /* If it is for v */
        else if(radial)
            offset = (long)(3 * sizeof(int))
                + (long)(4 * sizeof(double))
                + (long)(2 * nread * sizeof(double))
                + (long)(rns * nread * sizeof(double))
                + (long)((time * (double)nread / 360.0 - 1.0)
                    * sizeof(double));
        /* If it is for upvp */
        else if(Rs)
            offset = (long)(3 * sizeof(int))
                + (long)(4 * sizeof(double))
                + (long)(2 * nread * sizeof(double))
                + (long)((time * (double)nread / 360.0 - 1.0)
                    * sizeof(double));

        /* Read entries from data storage file and write to
           plot file. */
        strcpy(pfnumber,"profile");
        sprintf(pfnumber,"%d", (int)time);
        strcat(pfnumber,pfnumber);
        proffile = fopen(pfnumber,"w");
        fprintf(proffile,"%f %f\n", 0.0, umprf[0] = 0.0);
        for(i = 1; i <= nsort; i++){
            /* Move to the entries corresponding
               to this phase angle. */
            fseek(storefile,(rptr[i] + offset),0); /* Move
               to the desired entry. */
            if(diagnosis){
                fread(&d,sizeof(double),1,storefile);
                printf("radius = %f\\n", d);
            }
        }
    /* Read in the desired entry. */
        fread(&umprf[i],sizeof(double),1,storefile);
    /* Print data in column format to be plotted. */
        fprintf(proffile, "%f %g\n",
            sortdist[i]/mdiam,
            umprf[i]);
    }
}
fclose(proffile);}
if(average){
    /* Open file for results of computation of the
cross-sectional average mean velocity. */
    avefile = fopen("avefile","w");
    if(avefile == NULL) printf("avefile was not opened.");
    idealfile = fopen("idealfile","w");
    if(idealfile == NULL) printf("idealfile was not opened.");

    /* Calculate cross-sectional area for averaging. */
    /* The integral excludes areas beyond the centerline. */
    aint = mdiam * mdiam / 8.;

    /* Vary time. */
    for(itime = 1; itime < nread; itime++){
        if(diagnosis) printf("itime =\n", itime);

        /* Calculate the offset from the beginning of the data
set to the entry corresponding to the time of
interest in the storage file. */

        /* If it is for u */
        if(!radial) offset = (long)(3 * sizeof(int))
            + (long)(4 * sizeof(double))
            + (long)(rns * nread * sizeof(double))
            + (long)((time * (double)nread / 360. - 1.)
                * sizeof(double));

        /* otherwise it is for v */
        else offset = (long)(3 * sizeof(int))
            + (long)(4 * sizeof(double))
            + (long)(2 * nread * sizeof(double))
            + (long)(rns * nread * sizeof(double))
            + (long)((time * (double)nread / 360. - 1.)
                * sizeof(double));

        /* Read the mean-velocity profile. */
        umprf[0] = 0.0; /* Set mean-velocity at the wall
to zero. */
        for(i = 1; i <= nsort; i++) sortdist[i] <= 0.5*mdiam; i++){
            /* Move to the entries corresponding
to this phase angle. */
            fseek(storefile,(ptr[i] + offset),0);

            /* Read in the desired entry. */
            fread(&umprf[i],sizeof(double),1,storefile);
            if(diagnosis){
                printf("velocity =%f\n", umprf[i]);
            }
        }

    /* Integrate profile at this time. */
    /* (Read the Oscillating Flow Experiment Log
entry of 3/15/88 for details on the integration.) */
    umint = 0.0; /* Set integral to zero. */
    /* The integral excludes areas beyond the
center-line. */
    for(i = 1; i <= nsort; i++){
        /* Integration between the far
wall and the center-line. */
        umint = umint + ((umprf[i-1] - umprf[i]) / (r1 - ri)
            * (r1*r1-r1)/3. - ri*r1*r1)/2. + ri*r1/r1/6.)
            + umprf[i]
            * 0.5 * (r1*r1-r1-ri));
    }
    if(diagnosis){

    }
}

}
else if(rim1 > 0.0 && ri < 0.0) {
    /* Integration to the center-line. */
    /* ucl = interpolated centerline velocity */
    ucl = (umprf[i] - umprf[i-1]) / (sortdist[i] - sortdist[i-1])
         * (0.5*mdiam - sortdist[i-1])
         + umprf[i];
    umint = umint
    + ((umprf[i-1] - ucl) / rim1
       * (rim1*rim1*rim1/3.)
       + ucl * 0.5 * rim1*rim1);
    break;
} else {
    /* Exclude integration from center-line to the near wall. */
    continue;
}
}

if(diagnosis){
    printf("itime = \d, umint = \f\n",
            itime, umint);
}

/* Calculate and store the mean-velocity averaged over the cross-section. */
fprintf(avefile, "\f*kg\n", (angle =
            360. * (double)itime / (double)nread),
            umint/aunit);
    if(diagnosis) printf("Writing to avefile complete.\n")
    fprintf(idealfile, "\f*zg\n",
            angle,
            pi = freq * mstroke =
            mbore*mbore / (mdiam*mdiam)
            = fabs(sin(pi*angle/180.));

    if(diagnosis) printf("Writing to files complete.\n")
    fclose(avefile);
    fclose(idealfile);
    if(diagnosis) printf("Files closed. \n");
}

if(fast) not_done = 0;
}

/* Wake up the operator with a bell. */
for(i = 0; i < 10; i++) printf("%c", '\007');

the_end;
/* End of the processing program "processx.c" */
}
VEL_REDTURB

/* vel_redturb
Converting (u,y) data profiles for turbulent-like portions of the cycle
into (u',y') by iterating on the wall shear stress and \( y \)-offset.
Results are stored in "upux"
The data is compared to curves which model the pressure-gradient effect.
Results are stored in "upupa"press"
G. Friedman, 10/90 */

main()
{
#include <stdio.h>
#include <string.h>
#include <math.h>

#define N 200
#define N2 10
#define YPMAX 49
#define TUBE_D 1.5
#define TUBE_R 0.75
#define N 28.96
#define R 6315
#define CONV 0.0254
#define STRLANG 30
#define STRLANG2 100
#define PI 3.14159265
#define LIMIT 15

FILE *profile,*datafile,*presfile;
int a,b,i,j,k,l,m,nerr;
double um[N],y[N],yorig[N],utau,uplus[N],yplus[N],ubm;
double yovd,u,yoffset,dudt,pplus,angle,tmp,lnum,aplus,factor;
double t,dry,p_atm,rho,nu,mu;
double h,hover2,s,x,sf,half,dupdyf
char filename[],theta[4],resp[STRLNG],syst[STRLNG2];
char syst2[STRLNG2];

printf("This program converts (u,y) data profiles into (upux,upupa)\n");
printf("by iterating on entered values of cf (tau wall) and yoffset\n");
printf("** Turbulent profiles **\n");
printf("Input the crank position of the profile to be converted\n");
scanf("%s",theta);
printf("theta = %s\n",theta);
printf("Input the crank position of the profile to be converted\n");
scanf("%f",angle);
printf("angle = %f\n",angle);
strncpy(filename,"/usr/geoff/proc/prof");strncpy(&filename[20],theta);
profile = fopen(filename,"r");
if(profile == NULL)
{printf("This file does not exist.\n");exit();
}
i = 1;
printf("Note that um is corrected by 1.0205 for the temperature error\n");
do{
 fscanf(profile,"%lf %lf", &yovd, &u);
mu[i] = u * 1.0205; /* u is in m/sec */
yor[i] = CONV * yovd * TUBE_D; /* convert y/d to meters */
printf("i = %d y = %lf u = %lf\n",i,yor[i],um[i]);i++;}
while (yovd < 0.5);fclose(profile);
printf("Enter t_dry (degr.C) and p_atm (bar): ");
scanf("%lf", &t_dry, &p_atm);
printf("t_dry = %lf degr.C p_atm = %lf bar\n", t_dry, p_atm);
t_dry += 273.15;
p_atm *= 1.0e+06;
rho = p_atm * M / t_dry;
printf("rho = %f\n", rho);
mu = 9.3277e-08 * t_dry - 1.2248e-05; /* viscosity at 1 atm */
mu *= (1.01325e+05 / p_atm);
printf("nu = %e\n",mu);
mu = mu / rho;
printf("nu = %e\n",nu);

/* **************************************** */
for(inerr = 1; inerr; ){
printf("Input the necessary y offset (in inches): ");
scanf("%lf", &yoffset);
printf("yoffset = %f\n",yoffset);
yoffset *= CONV;
for(k = 1; k <= i-1; k++){
    y[k] = yorig[k] - yoffset;
    /* printf("k = %d y = %f u = %lf\n",k,y[k],um[k]); */
    if(y[k] <= 0.0) y[k] = 0.0;
}
}

printf("Input utau\n");
scanf("%lf", &utau);
printf("utau = %lf\n",utau);
datafile = fopen("upyp","w");
for(j = 1; j <= i-1; j++)
    uplus[j] = um[j] / utau;
yplus[j] = y[j] * utau / nu;
    if(yplus[j] > 0.0)
        /* printf("j = %d yplus[j] = %f uplus[j] = %f\n",j,yplus[j],uplus[j]); */
        fprintf(datafile,"%f %f\n",yplus[j],uplus[j]);
fclose(datafile);

/* uplus vs. yplus determination for effects of p-gradient */
prefile = fopen("upypress","w");
uplus[1] = 1.0;
b = 1;
fprintf(prefile,"%d %f\n",b,uplus[1]);
dudt = -8.725 * cos(angle * PI / 180.);
pplus = (nu * dudt) / pow(utau,3.);
if(angle <= 90.0)
    factor = 30.175;
else
    factor = 20.59;
aplus = 25.0 / ((factor * ppplus) + 1.0);
if(aplus <= 0.0)
aplus = 1000;
printf("aplus = %f\n",aplus);

h = 0.1;
hover2 = 0.05;
/* loop to determine uplus vs. yplus */
for(m = 1;m <= YMAX;m++){
a = m;
b = a + 1;
a = 0.0;
    half = dupdyp((double)(a) + hover2,aplus);
for(l = 1;l <= (N2-1);l++)
    x = (double)a + (double)1*h;
    s = s + dupdyp(x,aplus);
    half = half + dupdyp(x + hover2,aplus);
sf = (h/6.0)*dupdyp((double)a,aplus) + 4.0*half + 2.0*s
   + dupdyp((double)b,aplus));
/* uplus determination */
uplus[b] = sf + uplus[a];
/* printf("yper = %d uplus[%d] = %f\n",b,b,uplus[b]); */
fprintf(presfile,"%d %f\n",b,uplus[b]);
}
close(presfile);

printf("\nScreen plot of velocities desired? y or n\n");
scanf("%s",resp);
if(resp[0] == 'y'){
  strcpy(syst,"graph -s -g 1 -x 1 1.1 100 ");
  strcat(syst,"-y 0 35 5 < upyp ; plot "");
  system(syst);
  strcat(syst2,"graph -s -g 1 -x 1 1.1 100 ");
  strcat(syst2,"-y 0 35 5 < upypress ; plot "");
  system(syst2);
  scanf("%s",resp);
  system("erase");
}

printf("Paper plot of velocities desired? y or n\n");
scanf("%s",resp);
if(resp[0] == 'y'){
  strcpy(syst,"graph -s -g 1 -x 1 1 1000 ");
  strcat(syst,"-y 0 35 5 < upyp ; plot -Thpib ");
  system(syst);
  strcat(syst2,"graph -s -g 0 -x 1 1 1000 ");
  strcat(syst2,"-y 0 35 5 < upypress ; plot -Thpib ");
  system(syst2);
}

printf("aplus = %f\n",aplus);
printf("Input the bulk mean velocity\n");
scanf("%lf",&ubm);
printf("ubm = %f\n",ubm);
printf("utau = %f\n",utau);
printf("cf = %f\n",pow((utau/ubm),2.) * 2.);

printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s",resp);
if(resp[0] == 'n') inerr = 0;
/* ************************************************************
 */
printf("rho = %f\n",rho);
printf("utau = %f\n",utau);
printf("utau * utau = %f\n",utau * utau);
printf("tawall = %f\n",utau * rho);
printf("ubm = %f\n",ubm);
printf("cf = %f\n",pow((utau/ubm),2.) * 2.);
printf("aplus = %f\n",aplus);
printf("yoffset = %f\n",yoffset);
/* end */
}
DUPDYP

```c
#include <math.h>
define KAPPA 0.41
define square(x) (x) * (x)
double dupdp(yplus,aplus)
double yplus,a-plus;
/* This function determines duplus/dyplus for the given yplus */
{
  double slope,arg1,arg2,arg3;
  double damping;
  damping = 1.0 - 1.0/exp(yplus/a-plus);
  /* Van Driest mixing length model with variable A */
  arg1 = square(KAPPA*yplus);
  arg2 = square(damping);
  arg3 = sqrt(1.0 + 4.0*arg1*arg2);
  slope = (-1.0 + arg3)/(2.0*arg1*arg2);
  return(slope);
}
```
VEL_REDLAM

/* vel_redlam
   Converts (u,y) data profiles in the laminar-like portions of the cycle
   into (u*,y*) coordinates by iterating on the wall shear stress and the
   y-offset. Results are stored in "upyp"
   Also generates a (u*,y*) curve based on a pressure-gradient influenced
   model for the Couette flow region. Results are stored in "upypress"
   G. Friedman, 10/80 */

main()
{
#include <stdio.h>
#include <string.h>
#include <math.h>

#define N 200
#define TUBE_D 1.5
#define TUBE_R 0.75
#define M 28.86
#define R 6315
#define CONV 0.0254
#define STRLNG 30
#define STRLNG2 100
#define F 5.14159265
#define LIMIT 16

FILE *profile,*datafile,*presfile;
int i,j,k,l,iner,rr;
double um[N],y[N],yorig[N].tau,uplus[N],yplus[N],ulm;
double yovd,u,yoffset,duct,const,angle,tmp,inum;
double t_dry,p_atm,rho,nu,md;
char filename[],theta[4],resp[STRLNG],syst[STRLNG2];
char syst2[2][STRLNG2];

printf("This program converts (u,y) data profiles into (uplus,yplus)\n");
printf("by iterating on entered values of tau wall and y-offset\n");
printf("# Laminar profiles \#\n");
printf("Input the crank position of the profile to be converted\n");
scanf("%s",theta);
printf("Input the crank angle of the profile to be converted\n");
scanf("%lf",&angle);
printf("angle = %lf\n",angle);
strncpy(filename,"/usr/geooff/proc/prof/\n");
strncpy(&filename[20],theta);
profile = fopen(filename,"r");
if(profile == NULL)
{
    printf("This file does not exist.\n");
    exit();
}

i = 1;
printf("u corrected by 1.0205\n");
do{
    fscanf(profile,"%lf %lf", &yovd, &u);
    um(i) = 1.0205 * u;
    yorig(i) = CONV * yovd * TUBE_D;
    printf("i = %d y = %lf u = %lf\n",i,yorig(i),um(i));
    i++;
} while (yovd < 0.5); /* ignore pts. beyond ctrlne */
fclose(profile);

printf("Enter t_dry (degr.C) and p_atm (bar)\n");
scanf("%lf%f", &t_dry, &p_atm);
printf("t_dry = %lf degr.C p_atm = %lf bar\n",t_dry,p_atm);
t_dry *= 273.15;
p_atm *= 1.0e+05;

172
rho = p_atm * M / R / t_dry;
printf("rho = %f\n", rho);
mu = 9.3277e-08 * t_dry - 1.2248e-05;  /* viscosity at 1 atm */
mu *= (1.01325e-05 / p_atm);
printf("\nmu = %e\n", mu);
mu = nu / rho;
printf("nu = %e\n", nu);

/*
 */
for(inerr = 1; inerr; ){
  printf("Input the necessary y offset (in inches):");
  scanf("%lf", &yoffset);
  yoffset = CONV;
  for(k = 1; k <= i-1; k++){
    y[k] = yorag[k] - yoffset;
    /* printf("k = %d y = %lf u = %lf\n", k, y[k], um[k]); */
    if(y[k] < 0.0) y[k] = 0.0;
  }
  printf("Input utau\n");
  scanf("%lf", &utau);
  printf("utau = %lf\n", utau);

  datafile = fopen("upyp", "w");
  for(j = 1; j <= i-1; j++){
    uplus[j] = um[j] / utau;
    yplus[j] = y[j] * utau / nu;
    /* printf("yplus = %lf uplus = %lf um = %lf\n",yplus[j],uplus[j],um[j]); */
    if(yplus[j] > 0.0)
      fprintf(datafile, "%f %f\n", yplus[j], uplus[j]);
  }
  fclose(datafile);

  presfile = fopen("upypress", "w");
  dudt = 6.725 * cos(angle * Pi / 180.);
  const = (nu * dudt) / (2 * pow(utau, 3));

  l = 0;
do{
  l++;
  uplus[l] = 1 - const * pow(1.0*l, 2.);
  lnum = 1;
  /*
    printf("lnyplus = %f uplus = %f",lnum,uplus[l]); */
  fprintf(presfile, "%f %f\n", lnum, uplus[l]);
}
fclose(presfile);

printf("ndudt = %f\n", dudt);
printf("const = %f\n", const);

printf("Screen plot of velocities desired? y or n\n");
scanf("%s", resp);
if(resp[0] == 'y'){
  strcopy(syst, "graph -s -g 1 -x 1 .1 100 ");
  system(syst);
  strcopy(syst2,"graph -s -g 1 -x 1 .1 100 ");
  system(syst2);
}

printf("Paper plot of velocities desired? y or n\n");
scanf("%s",resp);
if(resp[0] == 'y'){
  strcopy(syst, "graph -s -g 1 -x 1 .1 100 ");
  system(syst);
}
system(syst);
strcpy(syst2,"graph -s -g 0 -x 1 .1 100 ");
strcat(syst2,"-y 0 35 5 < upypress ; plot -Thpib");

printf("Input the bulk mean velocity\n");
scanf("%lf",&ubm);
printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s",resp);
if(resp[0] == 'n') inerr = 0;

printf("Input the bulk mean velocity\n");
scanf("%lf", &ubm);
printf("u_{au} = _f \n", utau);
printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s", resp);
if(resp[0] == 'n') inerr = 0;

/* ************************************************************ *
 printf("\nContinue the iteration on yoffset and utau?\n");
 scanf("%s", resp);
inerr = 0;
*/
printf("rho = _f \n", rho);
printf("u_{au} = _f \n", utau);
printf("u_{au} \times utau = _f \n", utau * utau);
printf("utau = utau \times _f \n", utau * utau);
printf("utau \times utau = _f \n", utau * utau);
printf("utau \times utau = _f \n", utau * utau);
printf("utau \times utau = _f \n", utau * utau);
printf("utau \times utau = _f \n", utau * utau);

printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s", resp);
inerr = 0;

printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s", resp);
inerr = 0;

printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s", resp);
inerr = 0;

printf("\nContinue the iteration on yoffset and utau?\n");
scanf("%s", resp);
inerr = 0;
Fluid Mechanics Experiments in Oscillatory Flow
Volume II—Tabulated Data

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Results of a fluid mechanics measurement program in oscillating flow within a circular duct are presented. The program began with a survey of transition behavior over a range of oscillation frequency and magnitude and continued with a detailed study at a single operating point. Such measurements were made in support of Stirling engine development. Values of three dimensionless parameters, $Re_{max}$, $Re_{av}$, and $Q$, embody the velocity amplitude, frequency of oscillation and mean fluid displacement of the cycle, respectively. Measurements were first made over a range of these parameters which included operating points of all Stirling engines. Next, a case was studied with values of these parameters that are representative of the heat exchanger tubes in the heater section of NASA’s Stirling cycle Space Power Research Engine (SPRE). Measurements were taken of the axial and radial components of ensemble-averaged velocity and rms-velocity fluctuation and the dominant Reynolds shear stress, at various radial positions for each of four axial stations. In each run, transition from laminar to turbulent flow, and its reverse, were identified and sufficient data was gathered to propose the transition mechanism. Models of laminar and turbulent boundary layers were used to process the data into wall coordinates and to evaluate skin friction coefficients. Such data aids in validating computational models and is useful in comparing oscillatory flow characteristics to those of fully-developed steady flow. Data were taken with a contoured entry to each end of the test section and with flush square inlets so that the effects of test section inlet geometry on transition and turbulence are documented. The following is presented in two volumes. Volume I contains the text of the report including figures and supporting appendices. Volume II contains data reduction program listings and tabulated data (including its graphical presentation).

Fluid mechanics; Oscillating flow; Stirling engines

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184

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