Technical Report Writing

- This week in lab
  - Your second experiment
  - Read manual, take online class
  - Meet with your team (not same as team for experiment 1)
  - Visit the lab
  - Prepare your logbook, email to your TA
  - No report on this second experiment
- Next week in class
  - Investigating the dynamic response of a beam structure
  - Read the experiment 6 manual section

Report Admin

- Your graded first report will be returned to you by your TA in lab this week.
- The grade you get for this first submission counts for only 25% of the total report grade.
  - TAs have been instructed to grade carefully at a common standard consistent with the ultimate expectations of the course.
  - Your grade may not be as high as you had hoped, but…
  - You should get lots of feedback on how to fix that in your second submission.
  - Hold on to your graded report. You will need to hand it in with your revised version.
- Second submission is due after 1 week. Cannot score less on the second submission than the first.

Approaching your report

1. *Respect the value of what you did.*
2. *Rethink what your experiment really showed.*
3. *Make your report obvious to understand.*
4. *Use detail where you need it and be honest.*
5. *Make an effort consistent with the value of what you have done.*

Respect the value of what you did

- Pre-requisite of all aspects of a good report
- You need to respect (be excited/be interested in) what you have done to have the motivation to analyze, plot and write it up properly
- Don't be put off by imperfections. All experiments:
  - are done on imperfect facilities
  - with instrumentation that has problems
  - do not proceed as planned
  - do not achieve original objectives
  - do not have enough time
  - involve blunders.

  Your experiment is just as good as any that preceded it

Respect the value of what you did
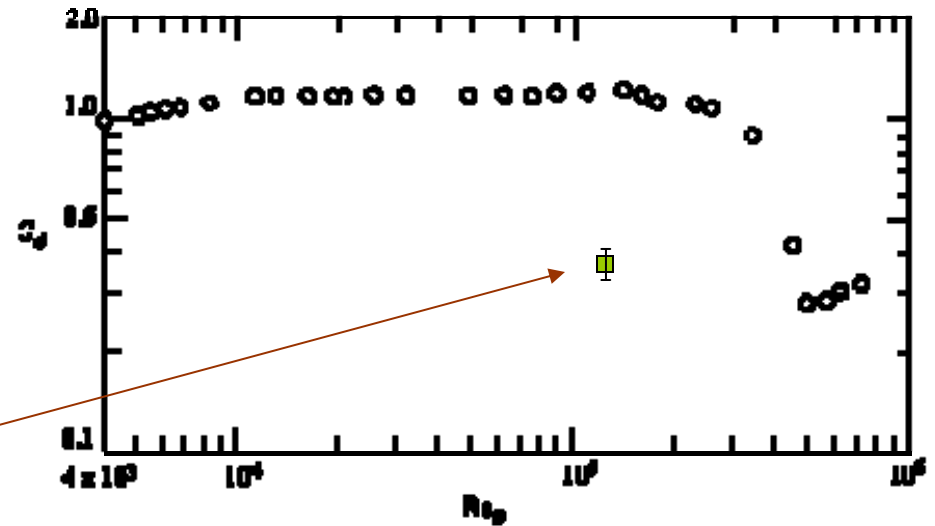
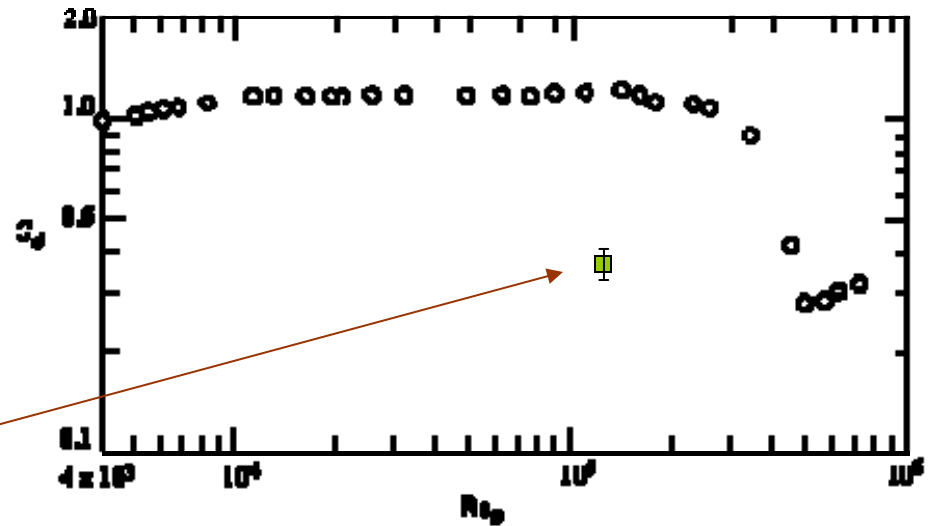Figure 3. Drag coefficient on a circular cylinder as a function of Reynolds number.

What do you take from this?
- I'd better check my calculation
- Measurement is bad/inaccurate,
- Instrumentation was bad, tunnel is flawed
- Really wanted supercritical Re, but TA didn't allow this
- Bob misread the manometer

…(what I did was worthless)

Respect the value of what you did
Rethink what your experiment really showed

Figure 3. Drag coefficient on a circular cylinder as a function of Reynolds number.

What should you take from this?
- I'd better check my calculation
- Measurement is good and as accurate as my uncertainty estimate
- Clearly the cylinder is behaving differently than Bertin and Smith's
- There must be something new/different here, this could be important
- Bob is a good guy

Example Experiment

- The open-jet wind tunnel with a Clark Y wing model
- Model has end-plates, variable angle of attack

Example Experiment

- The open-jet wind tunnel with a Clark Y wing model
- Model has end-plates, variable angle of attack
- Equipment to measure the properties of air, dimensions of everything.

Example Experiment

- The open-jet wind tunnel with a Clark Y wing model
- Model has end-plates, variable angle of attack
- Equipment to measure the properties of air, dimensions of everything.
- Material for making performing oil-flow visualizations (TiO_2, kerosine, oleic acid, pots brushes etc)

Example Experiment

- The open-jet wind tunnel with a Clark Y wing model
- Model has end-plates, variable angle of attack
- Equipment to measure the properties of air, dimensions of everything.
- Material for making performing oil-flow visualizations (TiO_2, kerosine, oleic acid, pots brushes etc)
- Digital cameras, computers.
- Instructions and practice on what to do with this stuff.
- An online class giving general background
- Suggestions for goals.

Logbook Objectives

- Determine stall location as a function of angle of attack
- Determine stall location as a function of Reynolds number
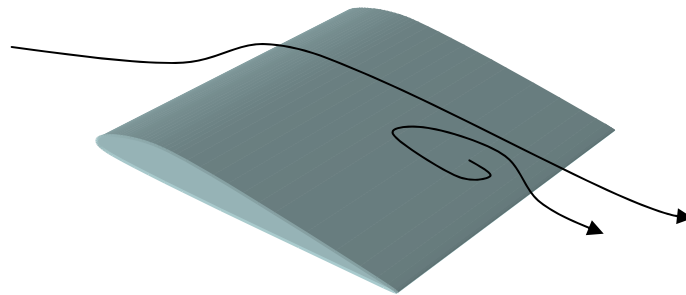
How it worked out…

- Slow and at first sight not too good
- Getting model numbers of everything, dimensions and details, doing logbook and preparing oil took much longer than expected, leaving too little time
- Airfoil was knocked early on, possibly changing angle of attack (not measured)
- Oil flows looked like a mess
- Only managed to do 3 Reynolds numbers at 1 angle of attack
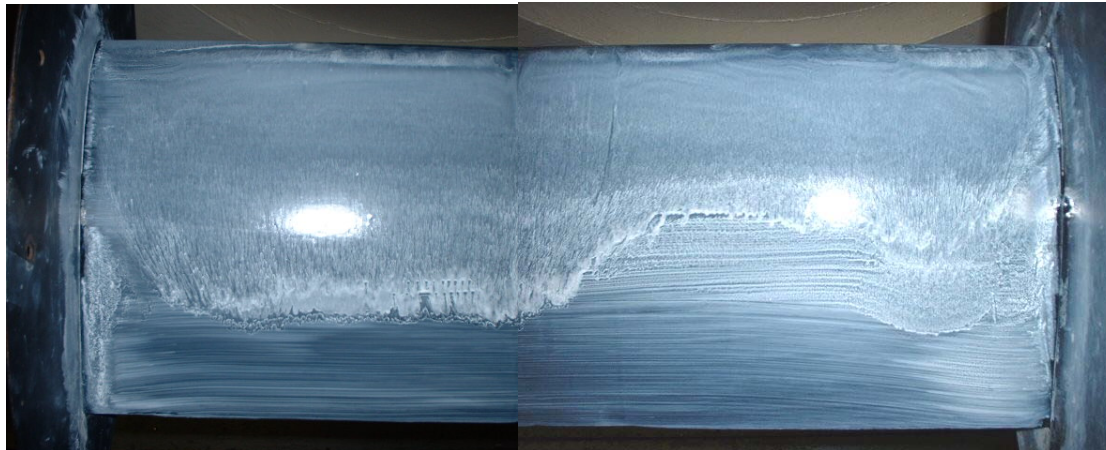
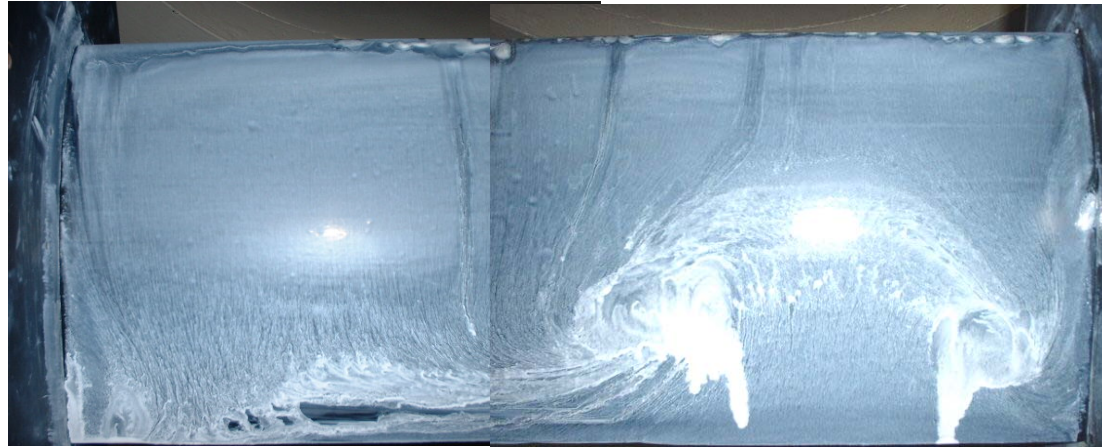22° angle of attack

Re=334000
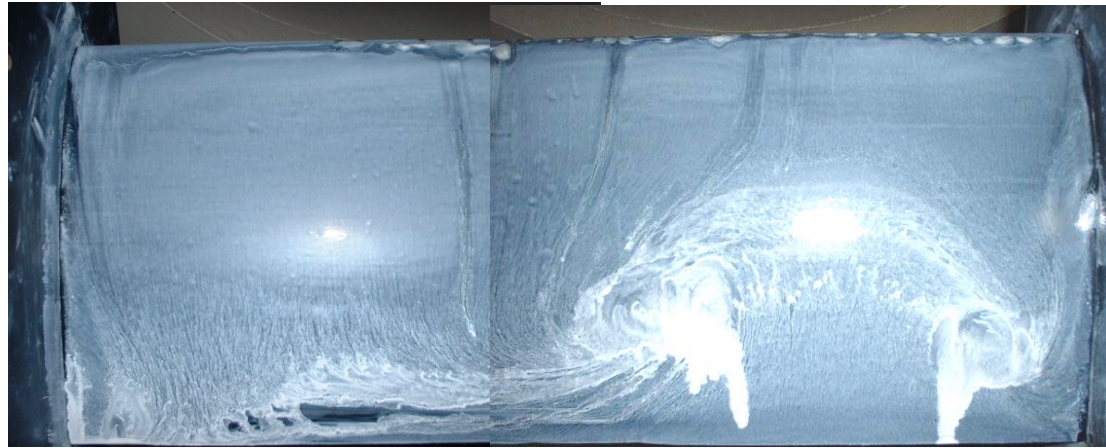
Re=222000
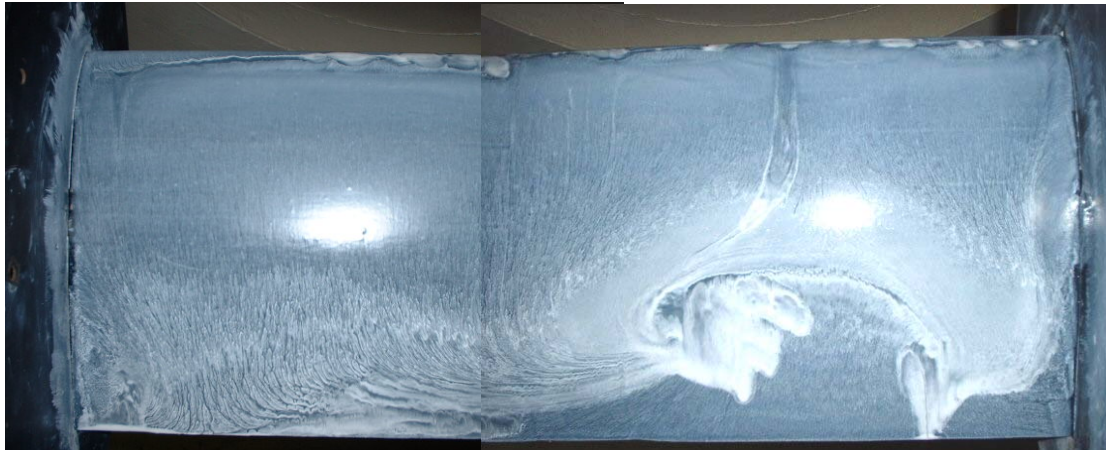
Re=116000

"Respect the value of what you did."
"Rethink what your experiment really showed"

Flow *is* a mess :
• It's very 3D, there are different flow features all over the place
It shouldn't be this way. This is important.
• The oil clearly isn't moving with the flow in some places, but just running down the airfoil

"Respect the value of what you did."
"Rethink what your experiment really showed"
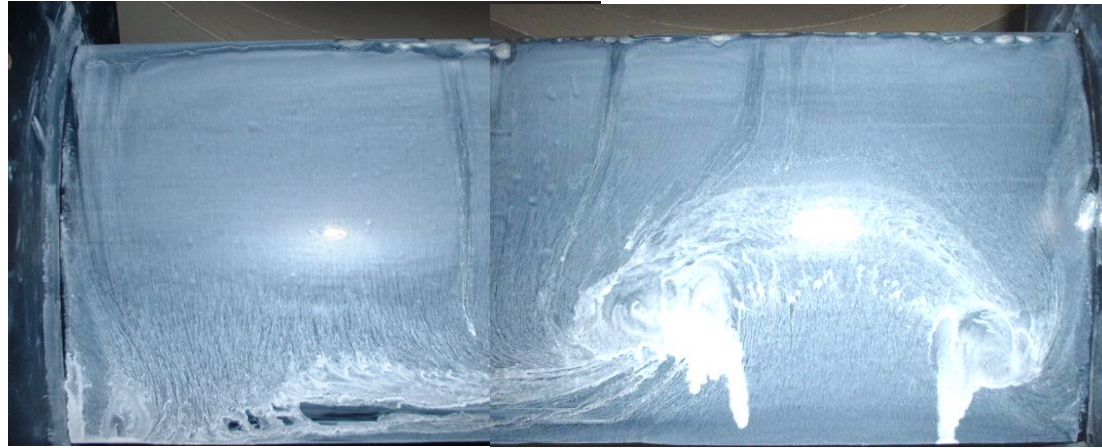
So we **change our objectives**:
- To determine the three-dimensional structure of stall patterns on a Clark Y airfoil.
- To evaluate the effects of Reynolds number on those patterns.
- To test the feasibility of performing oil-flow visualizations on an inclined surface at a range of speeds.

Analyze/plot the results

- Normalize your results.
  - E.g. turn your pressures into pressure coefficients, divide velocities by free stream, normalize distances (on beam length, test section size, cylinder diameter, airfoil chord…). Define coordinates.
- Compute parameters, results, theory, uncertainties (Drag, Stiffness, Re, measure data off photos…)
- Plot results.
  - Separately,
  - On top of each other for different conditions
  - With theory, on top of data taken off curves of others…
- Annotate, label graphs, pictures plots

"Make an effort consistent with the value of what you have done"

Photo and…
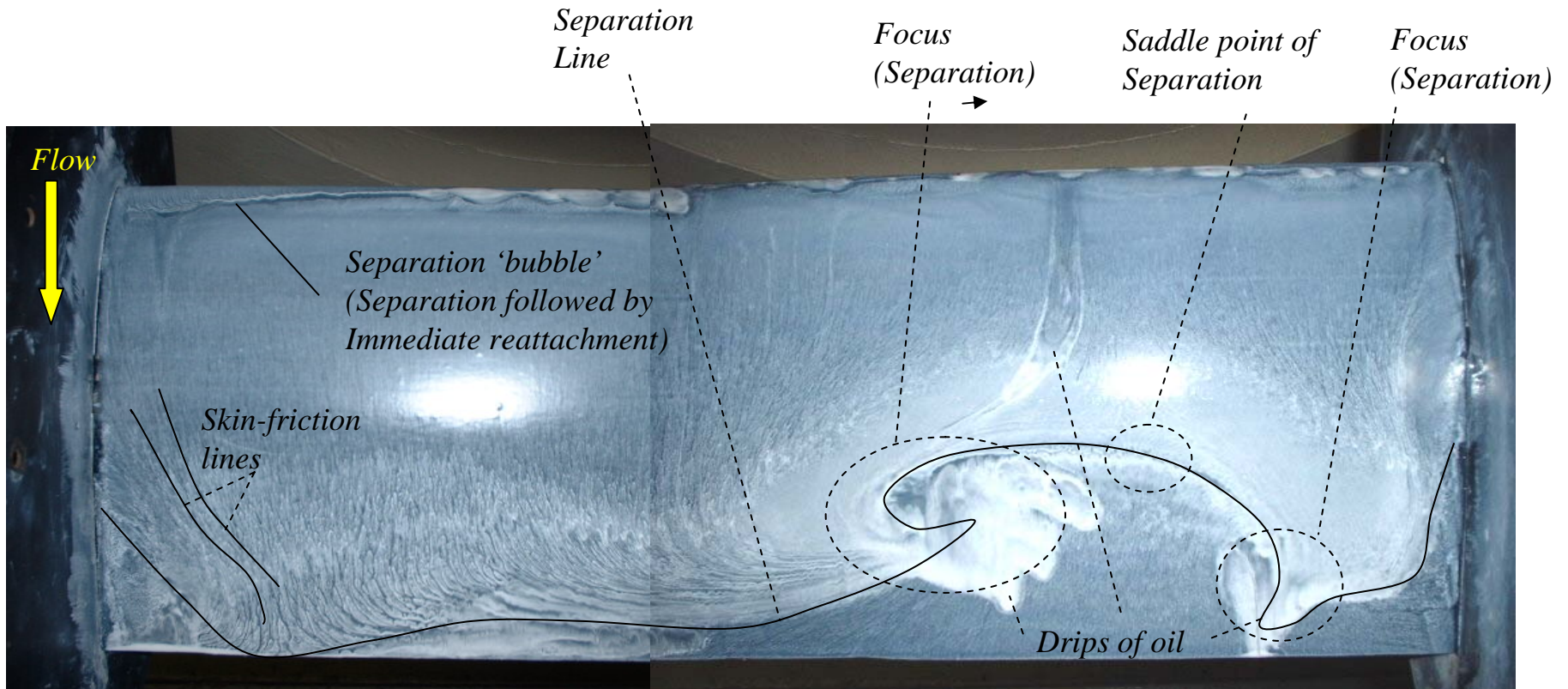
Did similar pictures at other Reynolds numbers. Also extracted separation line geometry (x/c, z/c) at two highest Re and plotted these results together on same axes, so as to make a direct comparison.
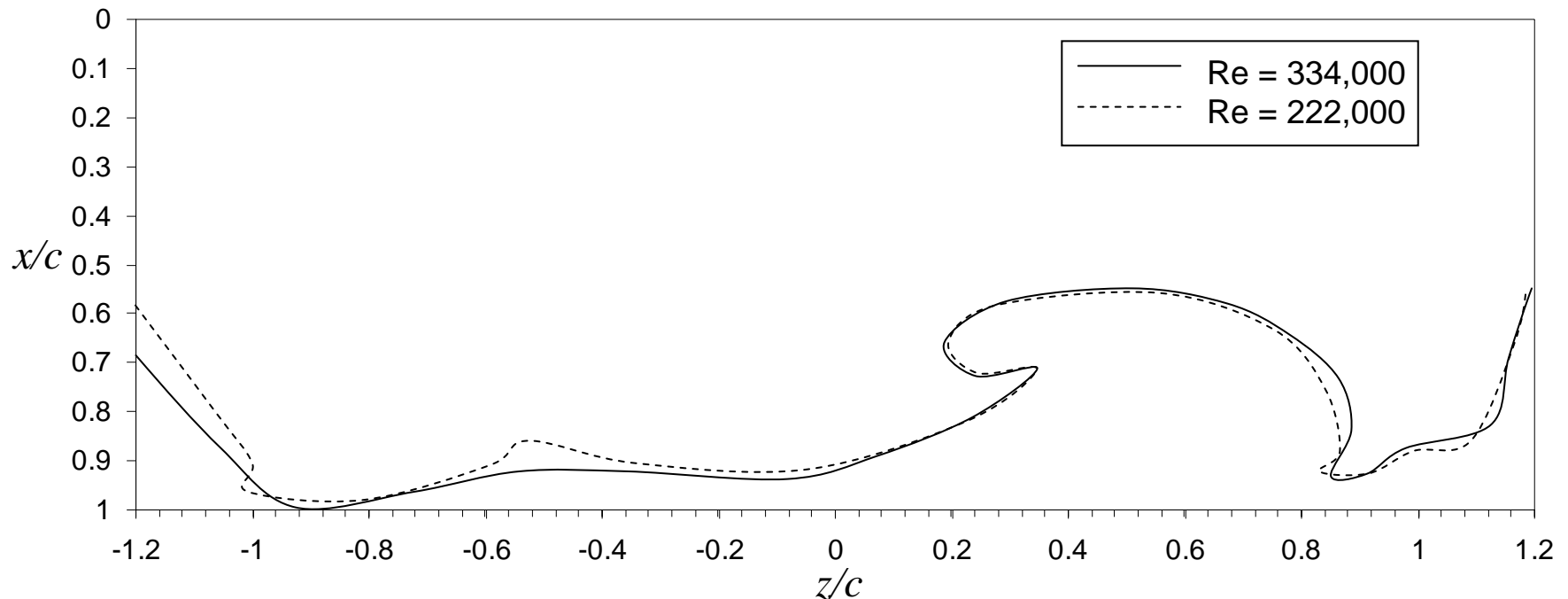
…Plot

- • Don't always have to do plots Bill Gates' way:
  - – Used curve drawing in PowerPoint to take separation lines off photos
  - – Added blank axis from Excel (or could have used Matlab)

Standard Report Organization

1. **Introduction**
   - Objectives
   - Summary of how aims achieved
   - Background to technical area of experiment or techniques.
2. **Apparatus and Techniques**
   - Descriptions of apparatus, instrumentation, how used
   - Labeled, dimensioned diagrams or photos
   - Primary uncertainties
3. **Results and Discussion**
   - Presentation of results in figures, tables with description of axes, analysis procedures
   - Uncertainties in results
   - Description of what's on the plots, tables, uncertainties and of what it means
   - Conclusions you can draw from the results
4. **Conclusions**
   - Short summary of what was done.
   - Numbered statements summarizing what was learned
- **References**
- **Appendix**

1. Introduction

The aims of this experiment were;

(1) To determine the three-dimensional structure of stall patterns on a Clark Y airfoil.
(2) To evaluate the effects of Reynolds number on those patterns.
(3) To test the feasibility of performing oil-flow visualizations on an inclined surface at a range of speeds.

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- *Make your writing obvious*
- Strong goals are those that are specific, and imply some useful gain in knowledge to the reader.
- Weak goals tend to be general or local, and therefore not much use to anyone.
  - To make flow visualizations of a Clark Y airfoil
  - To study the Clark Y airfoil flow
  - To gain experience of the oil-flow visualization technique
  - To analyze and plot flow visualizations
  - To complete experiment 2

Explanation of how aims achieved

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To attain these objectives the Virginia Tech open-jet wind tunnel was used. The flow over a Clark Y airfoil model at 22 degrees angle of attack was studied for chord Reynolds numbers between 116,000 and 334,000. At this angle of attack flow over the airfoil is partially stalled. The flow was studied using oil-flow visualization, which revealed a complex Reynolds number dependent separation pattern. These visualizations also revealed some of the limitations of the oil-flow visualization technique itself.

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- The purpose of this is to give the reader a good idea of what to expect in the rest of the report.
- A few sentences are enough. Mention techniques and approach in summary form only, specifics belong in section 2

Background

The oil-flow visualization technique is described by Barlow *et al.* (1999). An oil-flow visualization is performed by…Different techniques include… Some problems with the oil-flow visualization can occur when…

Understanding stall and the manner in which it develops is obviously important to the design of lifting vehicles…Stall occurs when the flow over the suction surface of an airfoil…

The shape of the Clark Y airfoil is notable for its flat lower surface….

- The purpose of the background is to give context to your objectives. It should discuss things that are known in general and not be a specific description of what you did.
- Draw on the course manual (and references on reserve), past courses/books, online classes for material.
- You can complete the intro with an overview of what's in the rest of the report

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2. Apparatus and Techniques

2.1 Open jet tunnel

The Virginia Tech open-jet wind tunnel was used for th[...] test section of this tunnel (figure ??) is nominally 3-feet (912mm) i[...] empty test section is known (Devenport, 2006) to be slightly non-u[...]

Free stream velocity in the tunnel was monitored using [...] located… The pressure difference sensed by the probe was measur[...] digital manometer with an estimated accuracy of 0.1Pa, and related [...] Bernoulli's equation.

$$U_\infty = \sqrt{2\frac{p_{0\infty} - p_\infty}{\rho}}$$

Here $p_{0\infty}$ and p_∞ are the free stream stagnation and static pressures [...] density (determined separately, see below), and U_∞ the free stream[...]

Flow temperature was monitored using … with an accu[...]

2.2 Airfoil Model

A Clark Y airfoil model (figure ??), with a chord of ?? [...] 2.5, was mounted in the test section with its span horizontal and pe[...] direction. The leading edge was located ??±?? mm downstream of [...] could be rotated to angle of attack about…   Angle of attack was i[...] of… using a…

2.3 Oil flow visualization

Oil flow visualization was performed using a mixture o[...]

2.4 Other items of equipment

Visualizations were recorded using a Fuji Fine Pix… D[...]


- Text can be understood w/o looking at figures
- The detail needs to be on all the things that matter to your objectives In this case:
- the tunnel test section, its flow quality and monitoring
- all the model details (real shape surface imperfections, where/how it was positioned). Would need dimensioned diagram to show mounting, test section and probe arrangement.
- how the oil flow vis was made and applied. Etc…
- Often useful to define a coordinate system and origin early on, to make referring to positions and orientations easier

Example Photo / Diagram
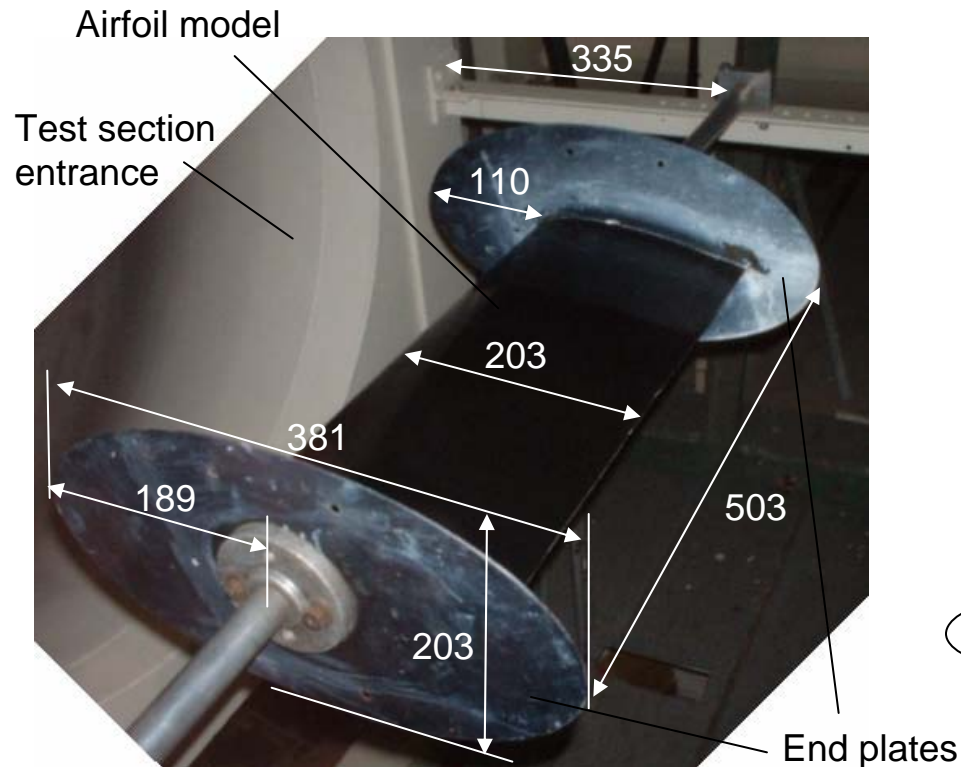
Figure 4. Airfoil model mounted in the test section. Flow is from left to right. All dimensions in mm.
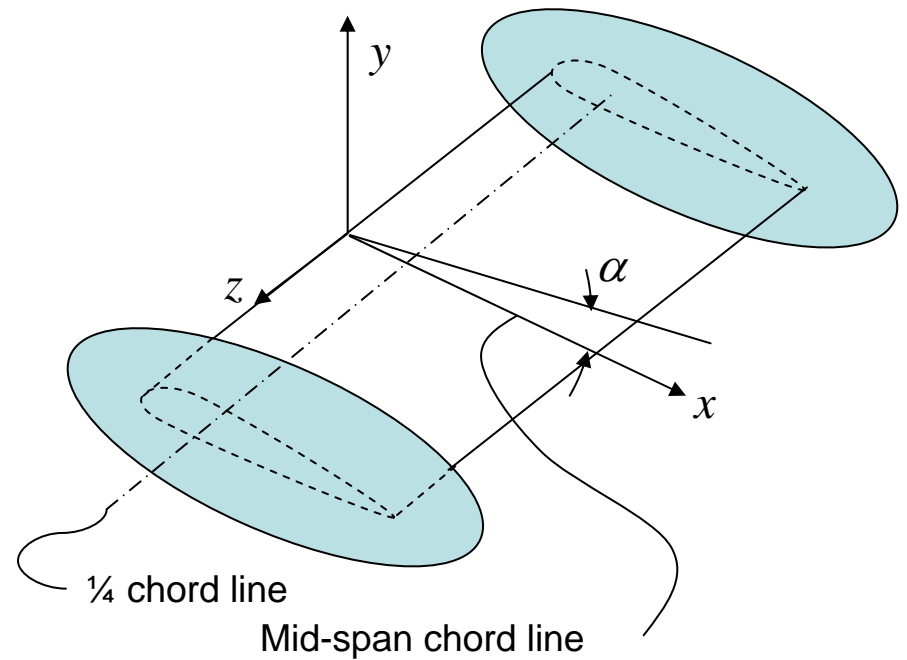
Figure 5. Coordinate system definition. Coordinate x lies along the chord. Airfoil rotates to angle of attack about the quarter chord line (axis of the support shaft seen in figure 4).

- Figures/tables can be understood by themselves without reading text

2. Apparatus and Techniques

2.1 <u>Open jet tunnel</u>

The Virginia Tech open-jet wind tunnel was used for the oil-flow visualizations. The test section of this tunnel (figure ??) is nominally 3-feet (912mm) in diameter and… Flow in the empty test section is known (Devenport, 2006) to be slightly non-uniform, with…

Free stream velocity in the tunnel was monitored using a ?? diameter Pitot-static probe located… The pressure difference sensed by the probe was measured using a Dwyer mode T744A digital manometer with an estimated accuracy of 0.1Pa, and related to the flow velocity using Bernoulli's equation.

$$U_\infty = \sqrt{2\frac{p_{0\infty} - p_\infty}{\rho}} \tag{1}$$

Here $p_{0\infty}$ and p_∞ are the free stream stagnation and static pressures sampled by the probe, ρ is the density (determined separately, see below), and U_∞ the free stream velocity…. Flow temperature was monitored using … with an accuracy of….

2.2 Airfoil Model

A Clark Y airfoil model (figure ??), with a chord of ?? ±?? mm and an aspect ratio of 2.5, was mounted in the test section with its span horizontal and perpendicular to the flow direction. The leading edge was located ??±?? mm downstream of ... Endplates… The model _____ attack about… Angle of attack was initially set with an uncertainty

Use italics, proper subscripts and greek for math symbols in text. Explain symbols in the text.

Use equation editor for equations

___cation _____ _____ ____ture of…
___nt
___ere recorded using a Fuji Fine Pix… Distances were measured using…

Being honest

Angle of attack was set initially with an uncertainty of 0.5 degrees using a Polycast #36 inclinometer

Angle of attack was initially set with an uncertainty of 0.5 degrees using a Polycast #36 inclinometer. However, the airfoil was subsequently jolted, changing the angle of attack by as much as 2 degrees. This jeopardized the success of this experiment and introduces doubt into the results.

Angle of attack was initially set with an uncertainty of 0.5 degrees using a Polycast #36 inclinometer. However, the airfoil was subsequently jolted, possibly changing the angle of attack before the flow visualizations presented in this report were performed. It is believed therefore that the angle of attack may be as much as 2 degrees different than the nominal values given in this report. This should be borne in mind in interpreting the results.

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Results and Discussion

The flow over a Clark Y airfoil model at 22±2 degrees angle of attack was visualized for chord Reynolds numbers of…. The uncertainty in Reynolds number, computed in the Appendix was ????. Composite flow visualization photographs are shown in figures 7 through ??. The photos have been labeled to identify…. Note that in all these figures flow is from top to bottom, and the pictures show the suction side of the model. Separation line geometry obtained… plotted for the two highest Reynolds number in figure ??. These show chordwise location of separation plotted against…

Perhaps the most striking feature of the higher Reynolds number visualizations (figures ?? and ??) are how three-dimensional and asymmetric the stall patterns are. The stall pattern is dominated by two separation foci that sit asymmetrically at… . An aspect ratio of 2.5, even with endplates is clearly insufficient to ensure two-dimensional flow. The asymmetry suggests a significant sensitivity in this flow to imperfections in the wind-tunnel flow itself. As noted earlier, studies of the empty test section flow (Devenport, 2006) have shown... Other features include… Effects of Reynolds number can be seen in… This effect can also be seen in figure ?? where separation line geometry…

The flow visualization performed at the lowest Reynolds number (figure ??), clearly shows some of the limitations of this technique. At the low speed used here the flow of oil is insufficient and the flow pattern is never fully established… The effects of gravity are also…

- Text can be understood without looking at figures, and figures without looking at text

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Conclusions

The flow over a partially stalled Clark Y airfoil of aspect ratio 2.5 at an angle of attack of 22 degrees was studied using the surface oil flow visualization technique. The effects of Reynolds number on the stall pattern from 116000 to 334000 were examined. Some limitations of the oil-flow visualization technique were observed. The following conclusions are drawn.

(1) The stall pattern is strongly three dimensional and asymmetric across the airfoil span, and is dominated by two separation foci that …

(2) An aspect ratio of 2.5, even with endplates, is clearly insufficient to ensure two-dimensional behavior in an airfoil flow of this type.

(3) The asymmetry of the stall pattern suggests that stalled flow is sensitive to disturbances, such as non-uniformity in the wind tunnel flow.

(4) The major effect of Reynolds number on this flow is…

(5) The present results suggest that oil-flow visualizations of the present type are impractical for flow speeds less than… and that even above this speed gravity can significantly influence the flow pattern.

- Relate to aims
- Stands alone (can understand w/o reading report)

References

REFERENCES

Barlow J. B., Rae W. H. and Pope A., 1999, *Low Speed Wind Tunnel Testing*, Wiley, New York.

Devenport W. J., 2006, *AOE 3054 Experimental Methods Course Manual. Experiment 8 – Flow over Clark Y Airfoil* , A.O.E. Department, Virginia Tech. Blacksburg VA.

- Reference list comes after conclusions and before any appendices
- Only items referenced should be listed
- Should be ordered alphabetically by first authors last name

Appendix

Uncertainties in measurements were calculated for 20:1 odds. Sources of uncertainty included the accuracy with which the digital manometer could be read, and the resolution of the thermometer and barometer used to measure atmospheric conditions. Specific uncertainties in these primary measurements are given in section 2. To obtain uncertainties in results R derived from these measurements, uncertainties were combined using the root sum square equation,

$$\delta(R) = \sqrt{\left(\frac{\partial R}{\partial a}\delta(a)\right)^2 + \left(\frac{\partial R}{\partial b}\delta(b)\right)^2 + \left(\frac{\partial R}{\partial c}\delta(c)\right)^2 + ...} \qquad (7)$$

where a, b, c… are the measurements on which R depends. Partial derivatives were estimated numerically, the whole calculation being performed using a spreadsheet table. Calculations for the uncertainty in Reynolds number and free stream velocity, are given in tables 4 and 5 below, respectively.

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- Need to have an explanation to accompany uncertainty calculation tables – see sample report for table format.
- Can have other appendices for other items (data tables etc.) but these need to be explained to.
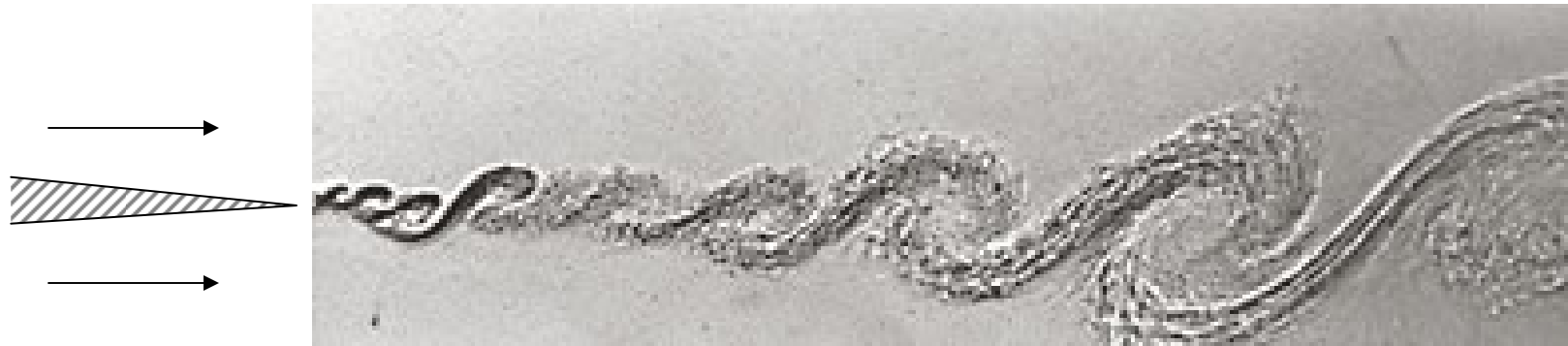
Moody Diagram (1944)

Smits *et al. 2003-2005*

http://www.lmnoeng.com/moody.htm
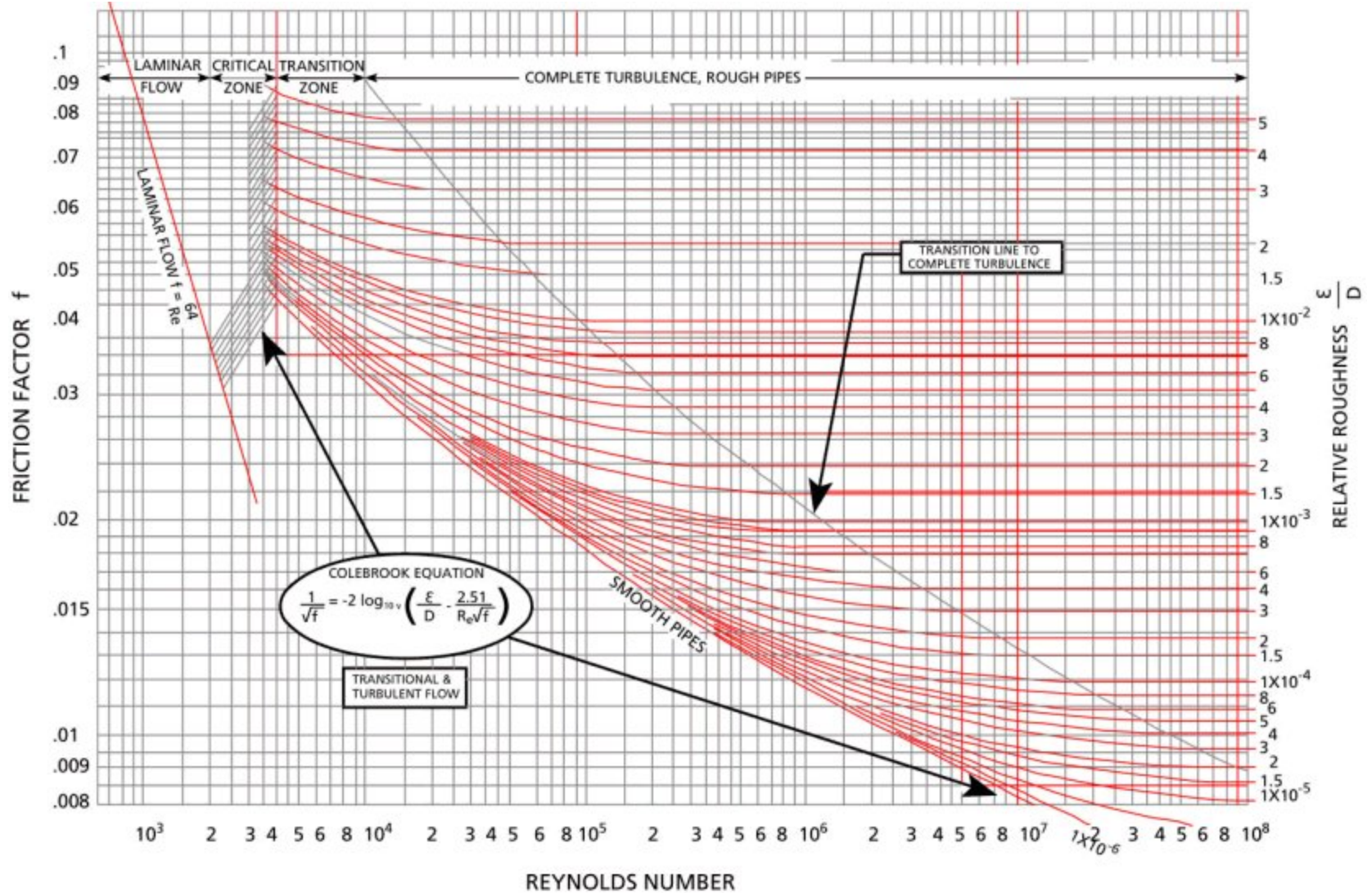
Brown and Roshko (1974)

CALTECH

Wanted to study mixing between streams of different gases (N and He).

Initial objective was to "determine effects of density ratio on mixing between streams". But experiment never yielded enough data to meet this objective (only 3 useful data points).

Experiment revolutionized understanding of turbulence (and thus 90% of all things aerodynamic)

Technical Report Writing

- This week in lab
  - Your second experiment
  - Read manual, take online class
  - Meet with your team (not same as team for experiment 1)
  - Visit the lab
  - Prepare your logbook, email to your TA
  - No report on this second experiment
- Next week in class
  - Investigating the dynamic response of a beam structure
  - Read the experiment 6 manual section