Measurement of Liquid Film Behaviour on a Rotating Disc using Electrical Resistance Techniques

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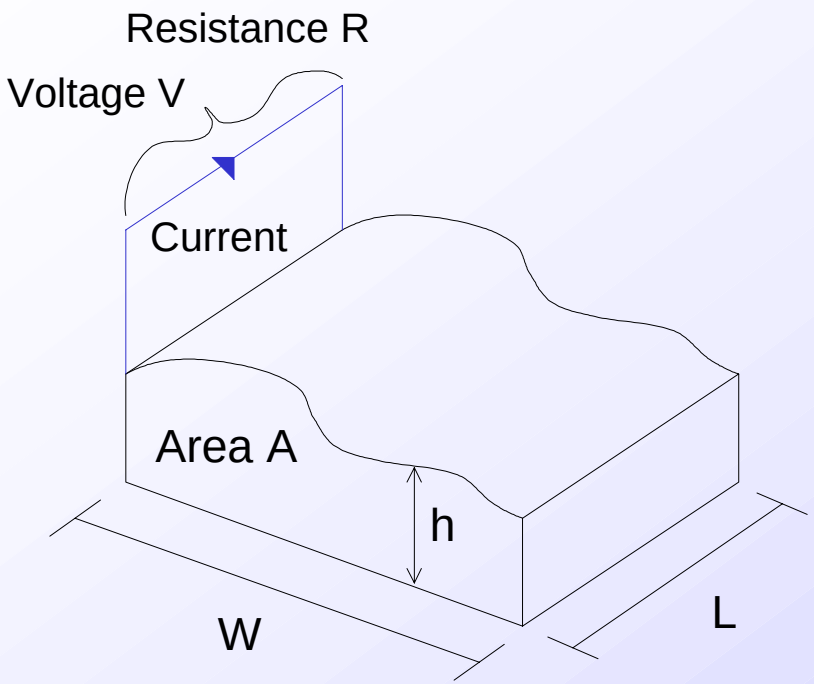
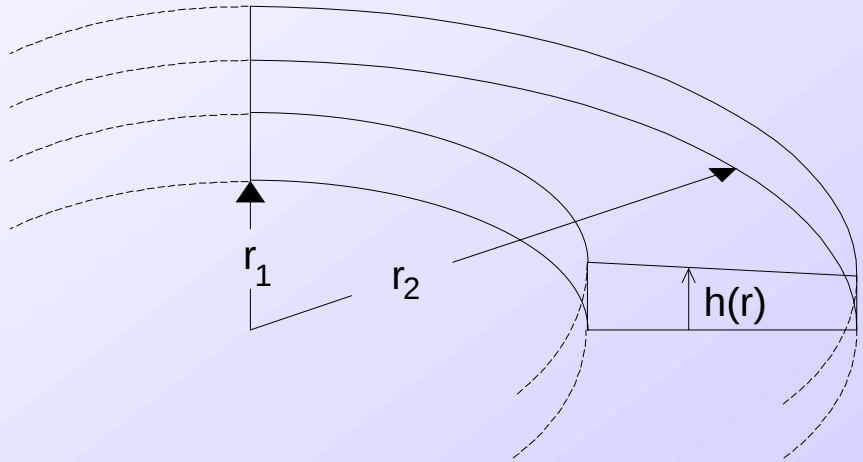
Research Areas Presented

- Measurement of **Film Thickness** from Electrical Resistance.
- Measurement of **Residence Time** from Tracer Response.
- Calculation of **Spin-Up** Zone.

Calculation of Film Thickness From Electrical Resistance

Principles of Film Thickness Measurement



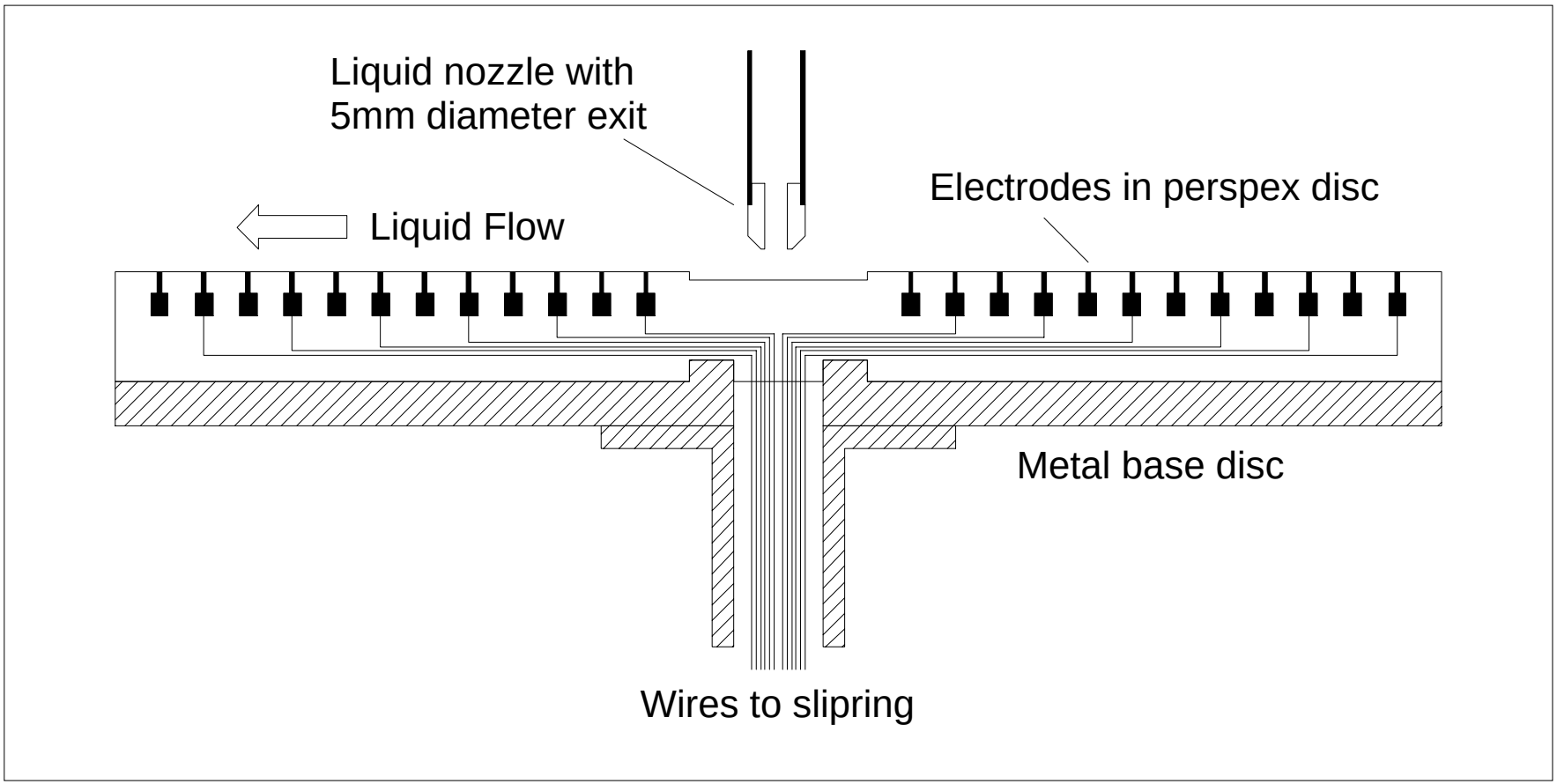


$$R = \frac{kL}{A}\tau$$

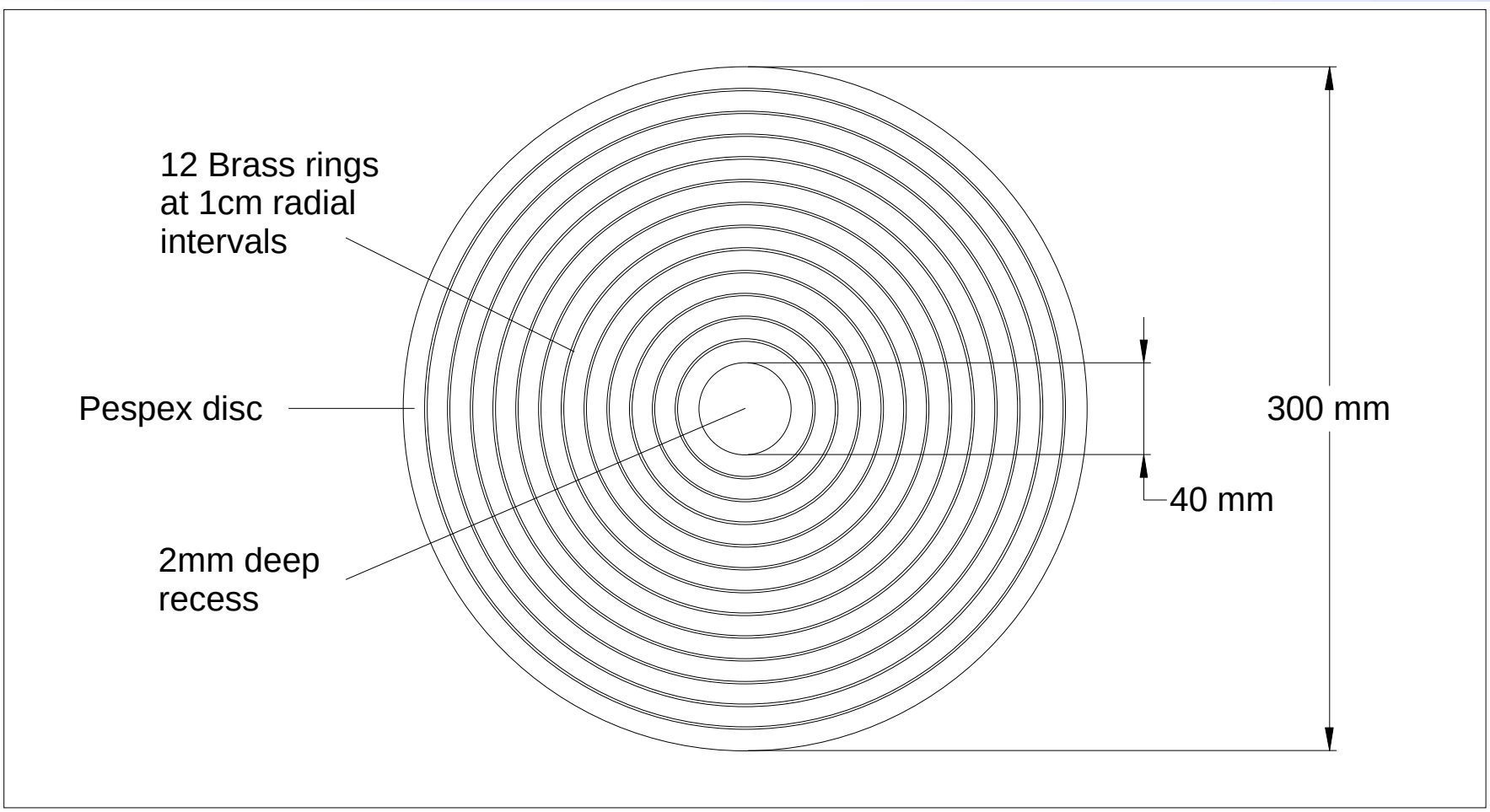
$$R = k.\ln\left(\frac{r_2}{r_1}\right).\frac{\tau}{h_R}$$

$$h_R \approx h\left(\frac{r_2 + r_1}{2}\right)$$

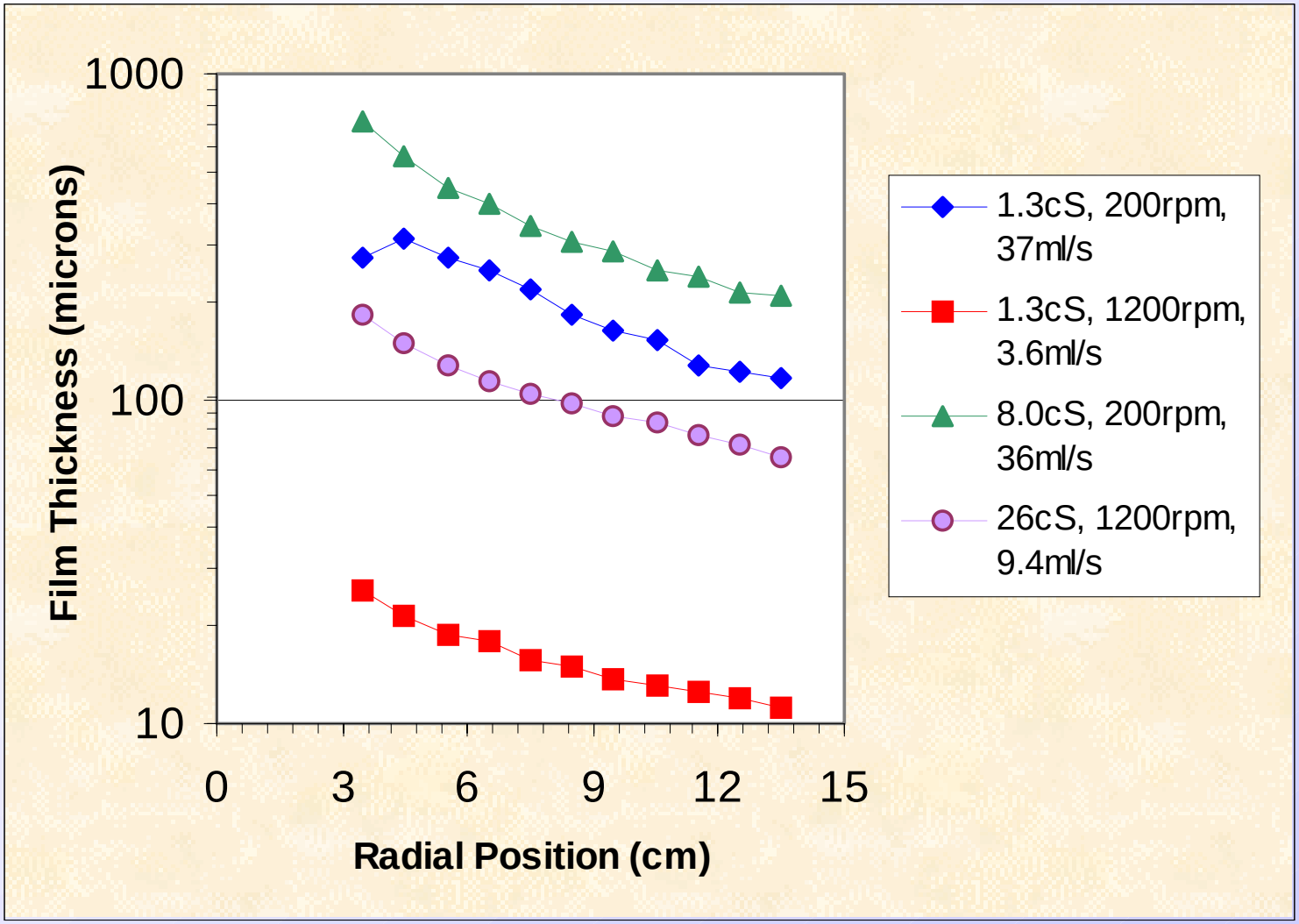
Side View of Spinning Disc



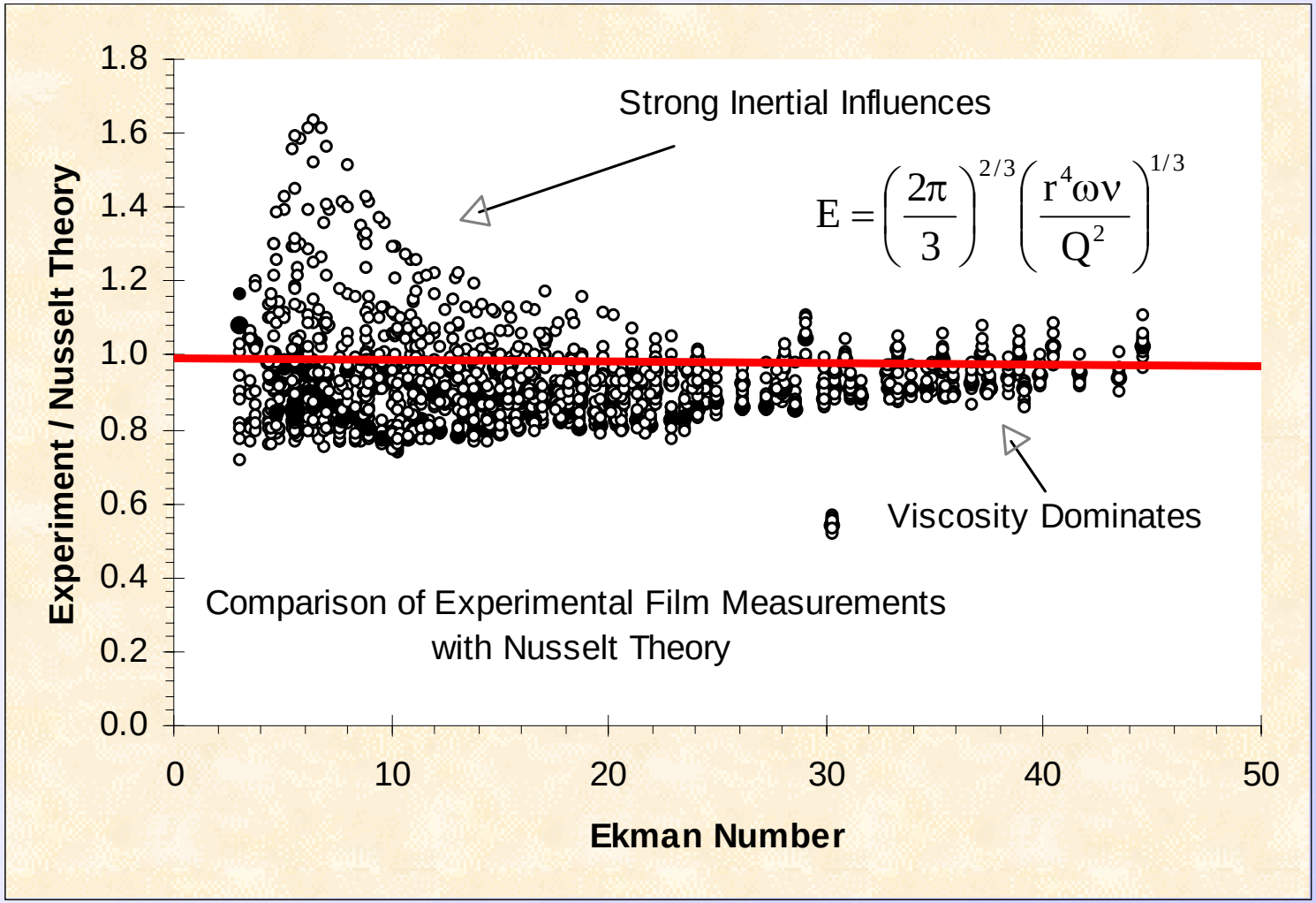
Plan View of Spinning Disc



Examples of Measurement Profiles



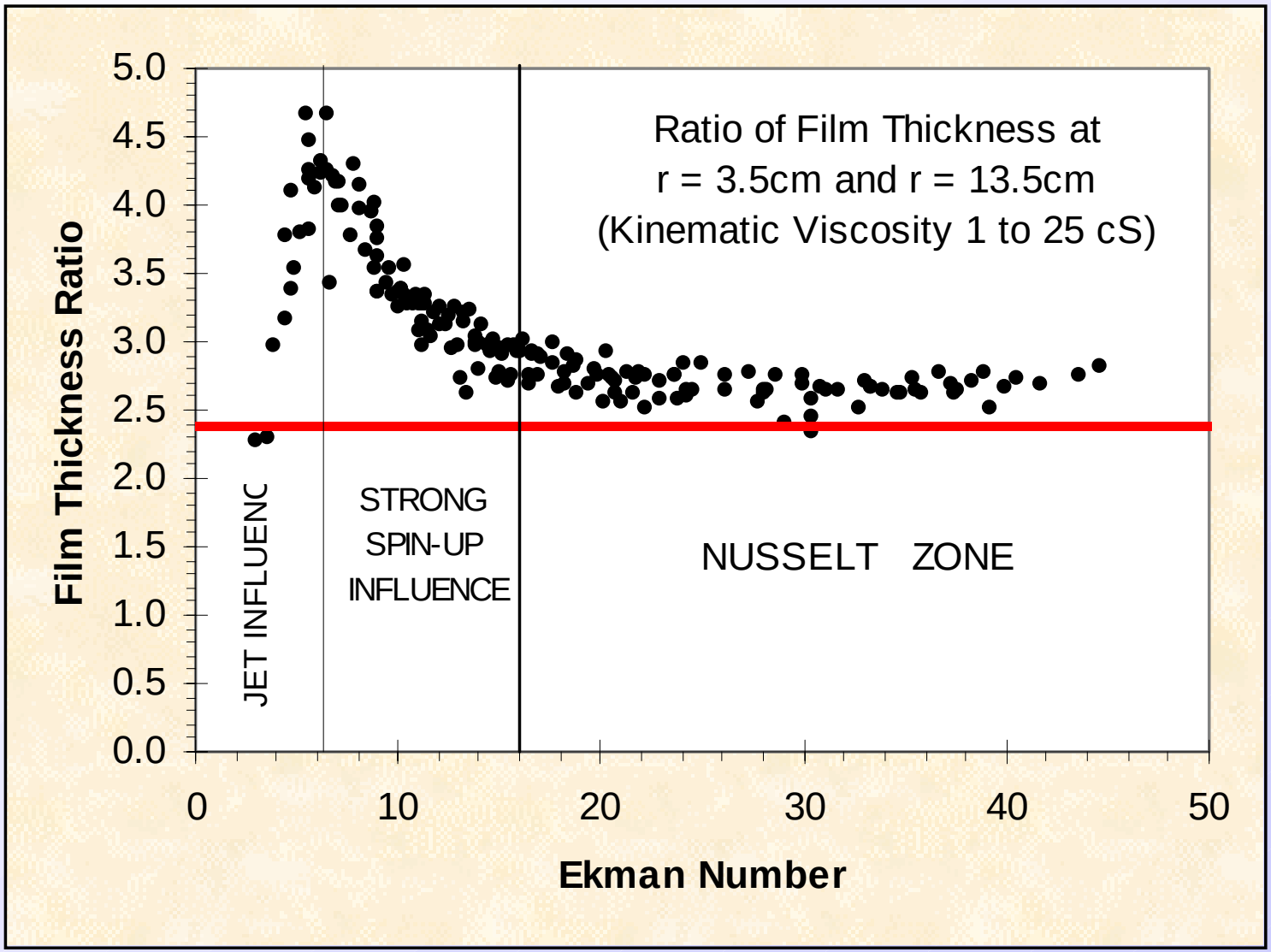
Comparison with Nusselt Model



Small ← E → large

Inertia Dominates ← **E** → **Viscosity Dominates**

Zones of Influence on the Disc

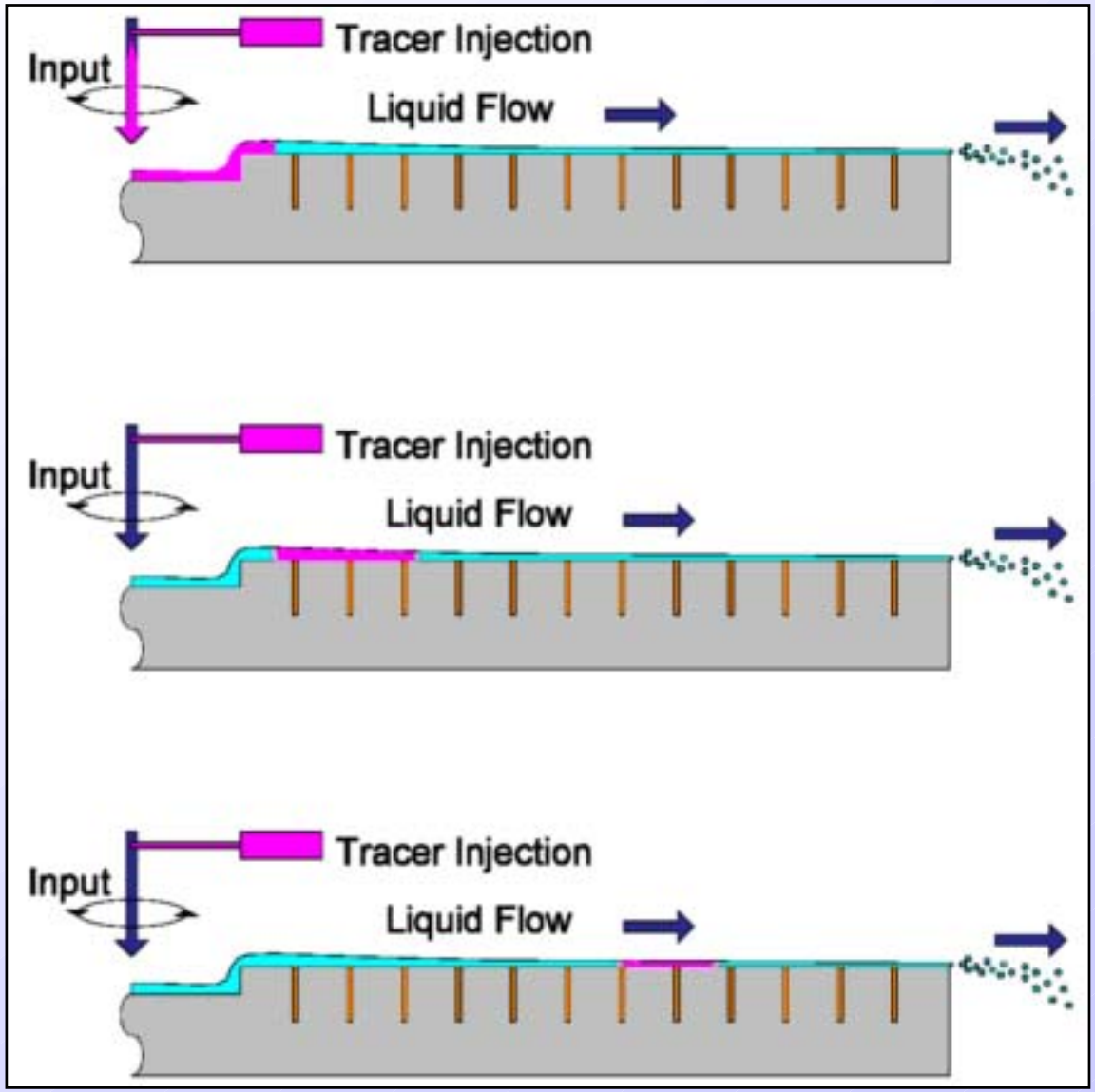


Measurement of Residence Time from Tracer Response

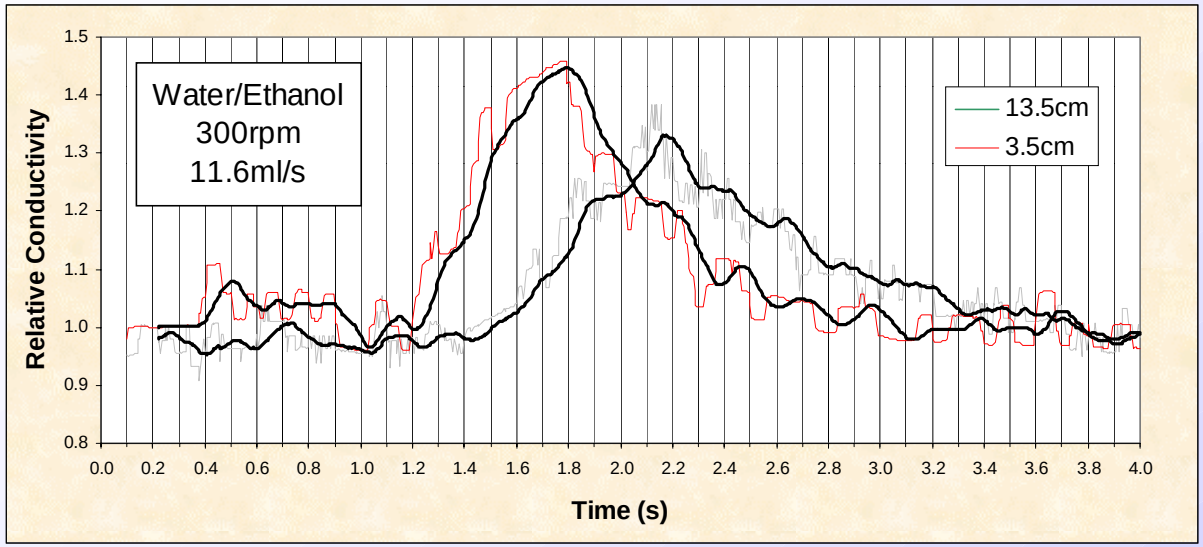
Tracer Response Technique

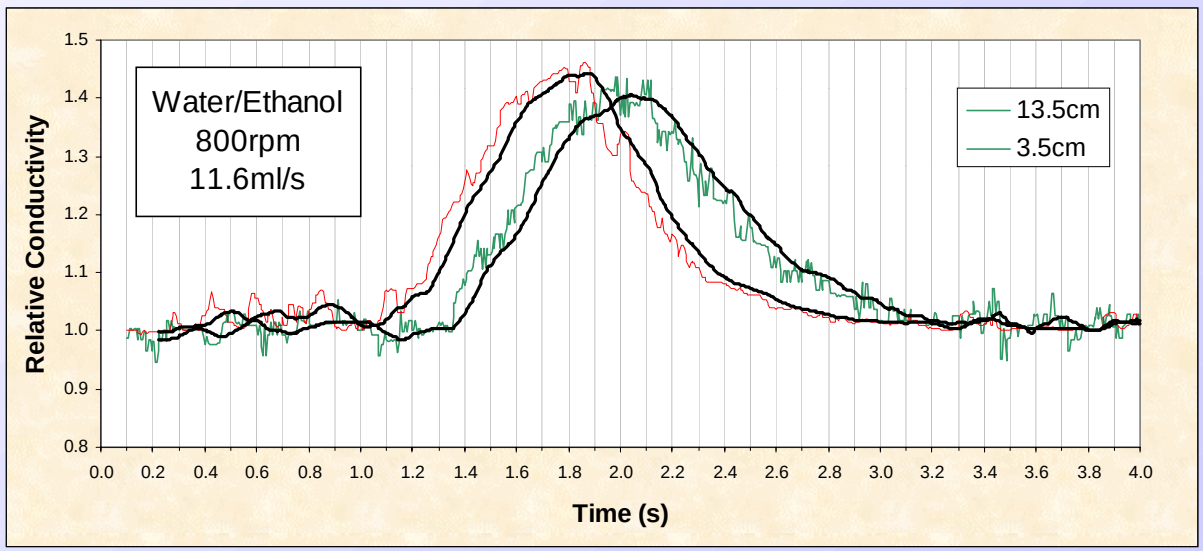
Uses the Same Electrodes as the Film Thickness Measurement System

Readings Taken at up to 6250Hz



Examples of Tracer Response Profiles





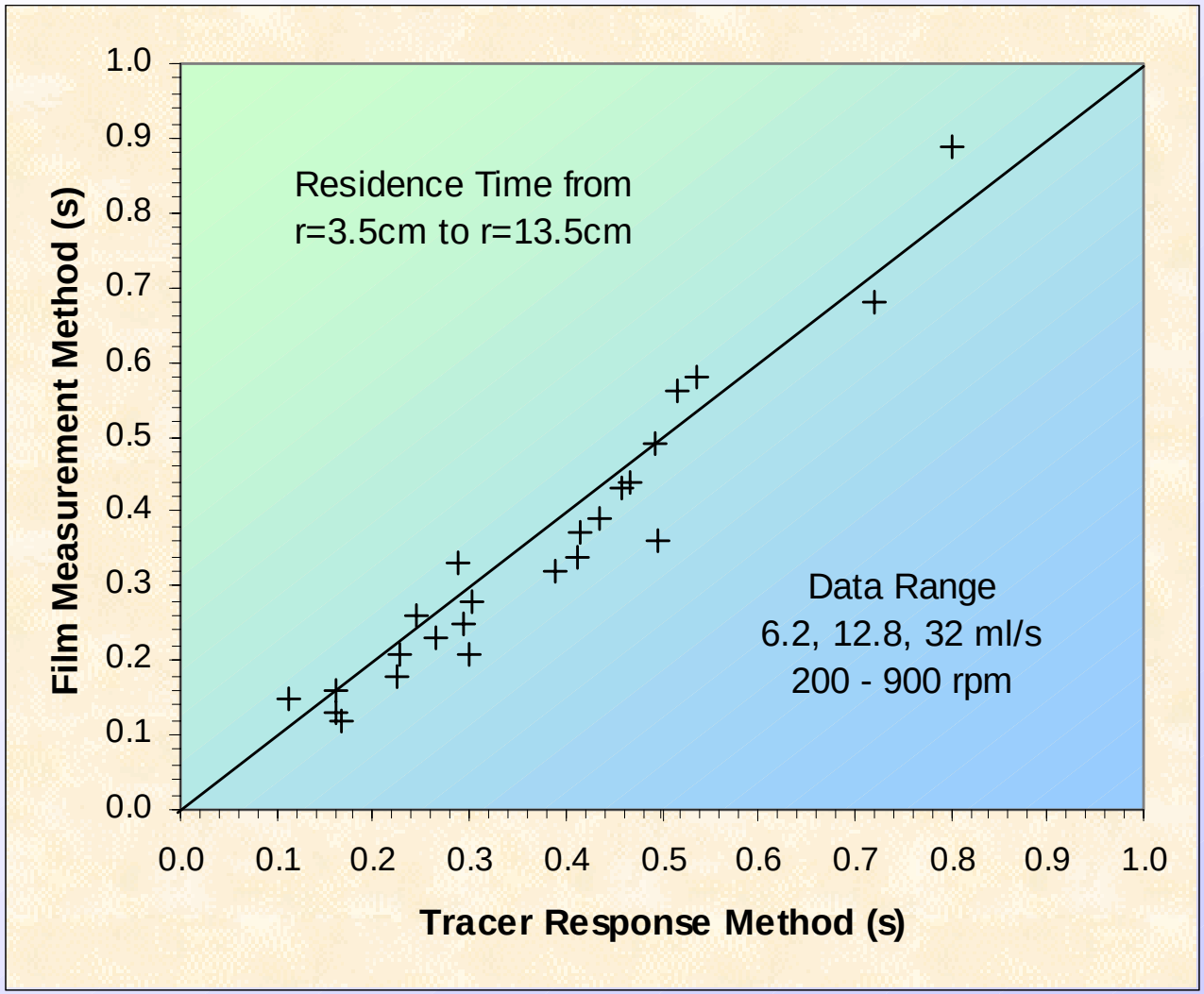
Calculating Response Time

- Base line conductivity was subtracted.
- “Normal Distribution” was fitted to the data.
- Difference in means was used as the response time.

Comparing with Film Thickness

- Radial velocity was calculated from film thickness.
- Transit time from inner to outer electrodes calculated from velocity data.
- Results used to compare accuracy of both techniques.

Comparison of Measurement Techniques



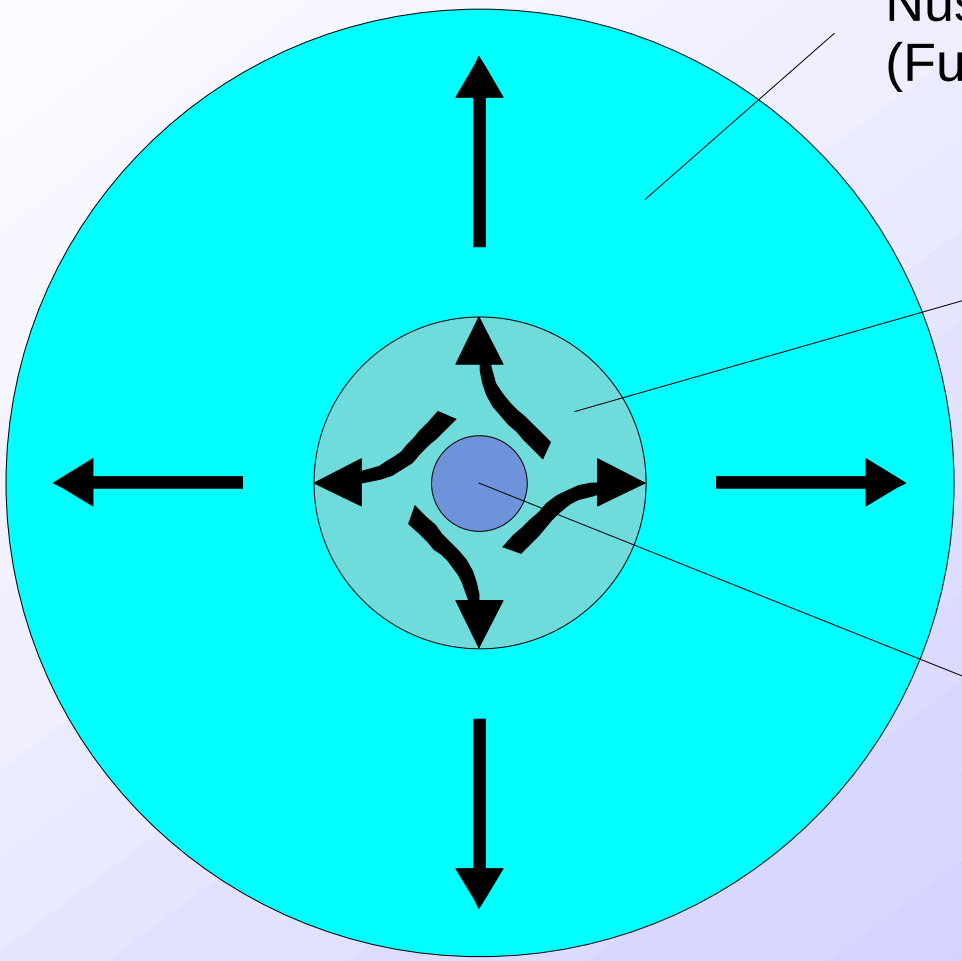
Liquid Used = Water/Ethanol Solution

Examination of Velocity Data From Film Thickness

and

The Calculation of Spin-Up Zone

Zones of Behaviour on the SDR

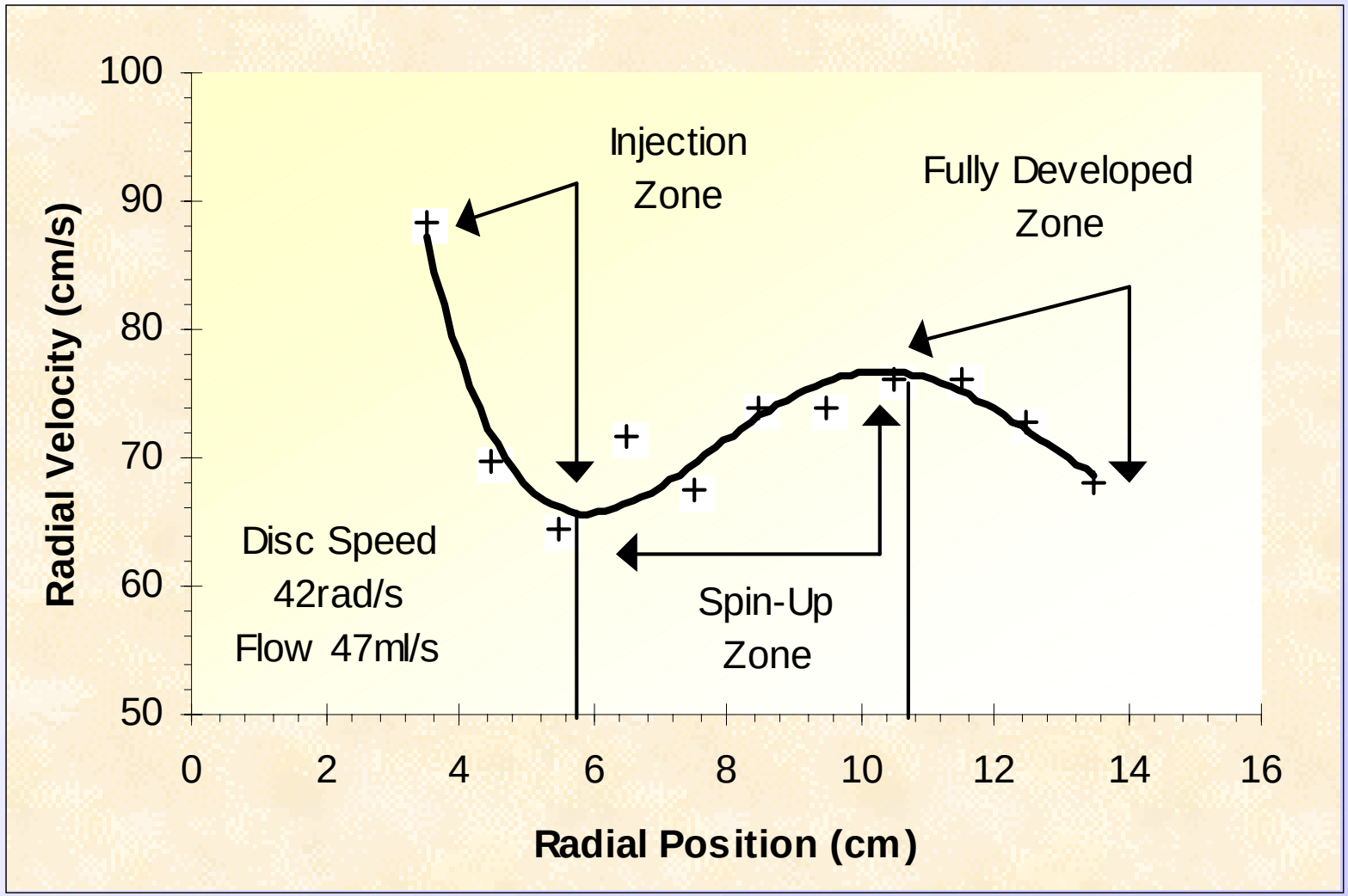


Motion Relative to the Spinning Disc

What is Useful About Calculating These Zones?

- It allows us to know where the disc is “spun-up” and following the Nusselt model for film thickness.
- It allows us to know how far out significant tangential motion (relative to the disc) extends.
- It is another engineering tool to use in disc design.

Radial Velocity in Different Zones



Empirical Calculation of Spin-Up Zone

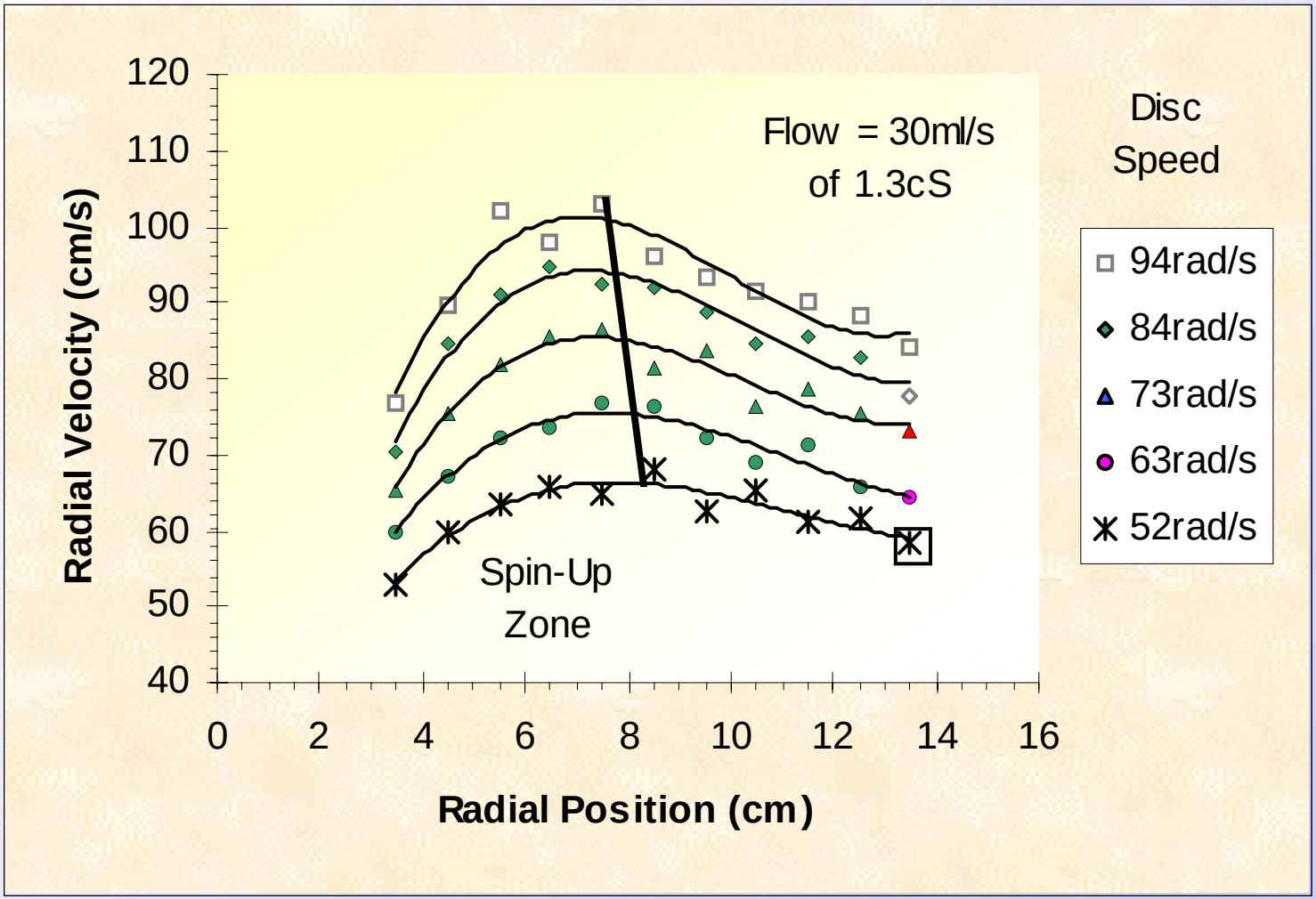
Length Scale $\lambda = \left(\frac{Q^2}{\omega \nu} \right)^{1/4}$

$$\frac{du'}{dr'} = 0 \quad \text{and} \quad \frac{d^2u'}{dr'^2} < 0 \qquad \text{at} \qquad r = r_{spin}$$

Spin-Up Radius

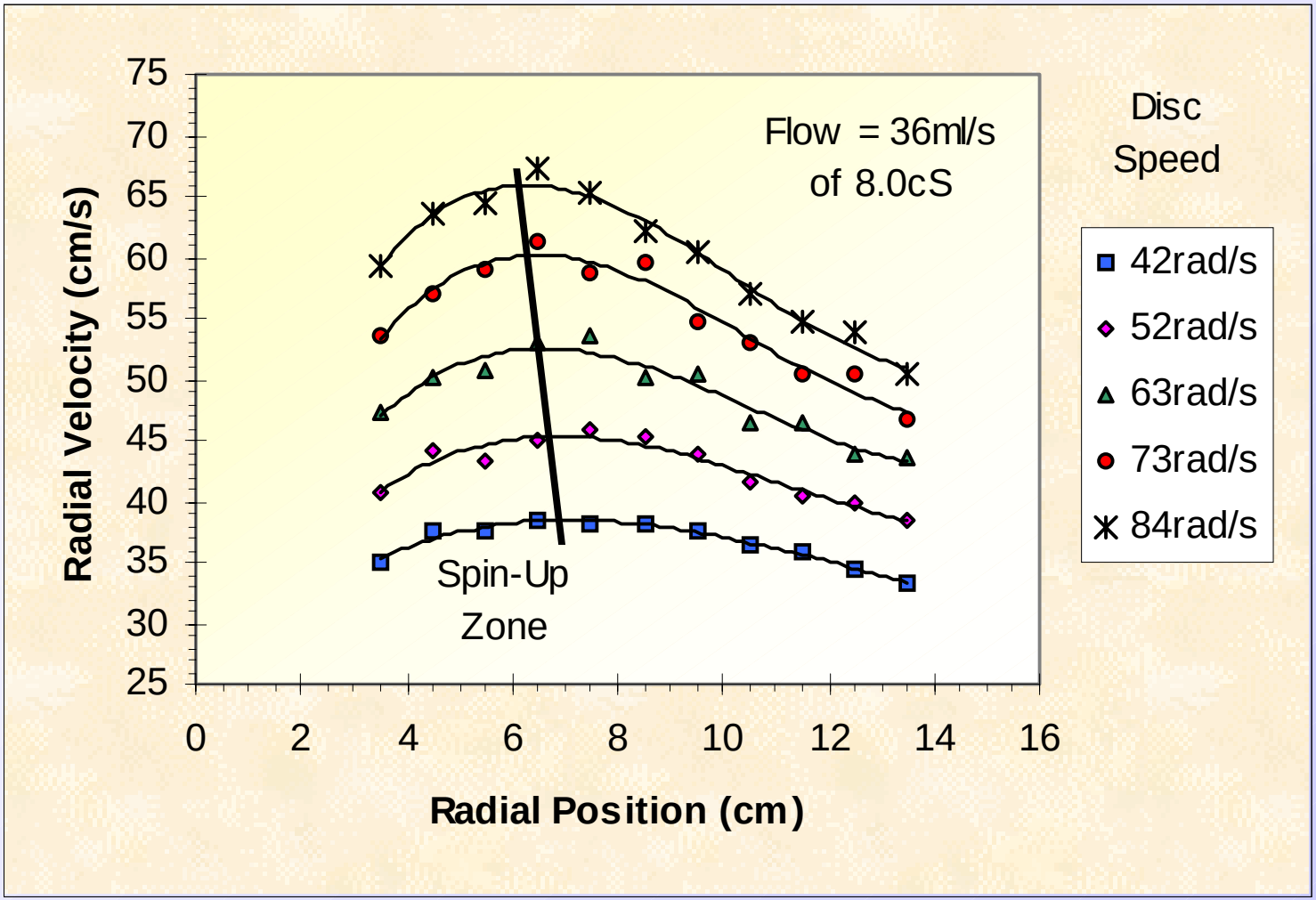
$$r_{spin} = \left(\alpha \lambda^2 \right)^{1/3} \qquad \text{with} \quad \alpha = 15.8\text{cm}$$

Comparison of Calculation with Data



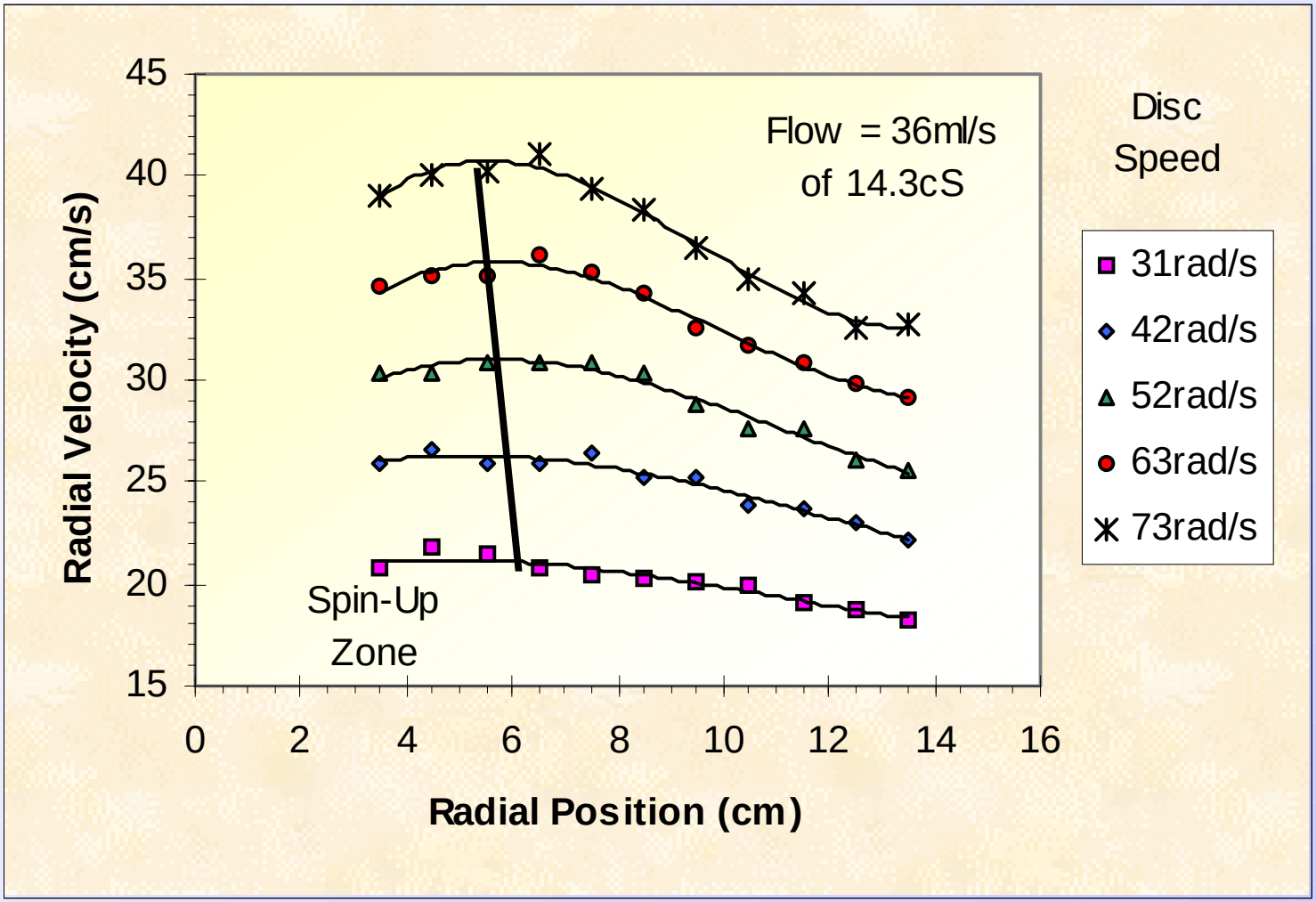
Low Viscosity : 1.3cP

Comparison of Calculation with Data



Medium Viscosity : 8.0cP

Comparison of Calculation with Data



Medium Viscosity : 14.3cP

Conclusions

- Electrical resistance measurements can be used to monitor film thickness over a spinning disc in real time.
- Tracer response may be used on the same system to provide an independent measurements to validate the technique.
- Spin-Up zone can be examined using this technique.
- Beyond the spin-up zone the Nusselt model may be used with reasonable accuracy.

Current and Future Work

- Local measurement of surface waves using small electrodes.
- Incorporation of system into a metal disc.
- Extension of technique to measurement of other factors.