



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

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# Research Areas Presented

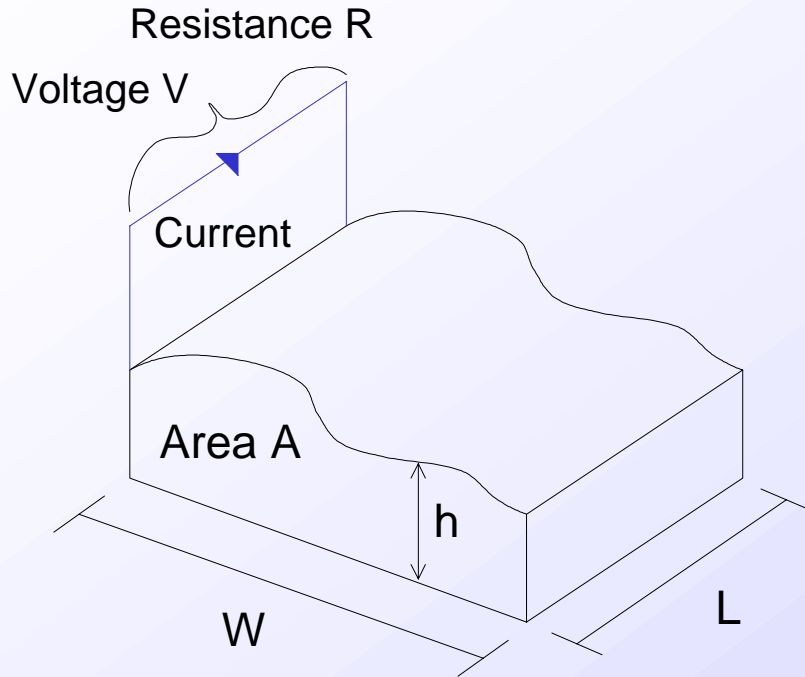
- Measurement of **Film Thickness** from Electrical Resistance.
- Measurement of **Residence Time** from Tracer Response.
- Calculation of **Spin-Up Zone**.



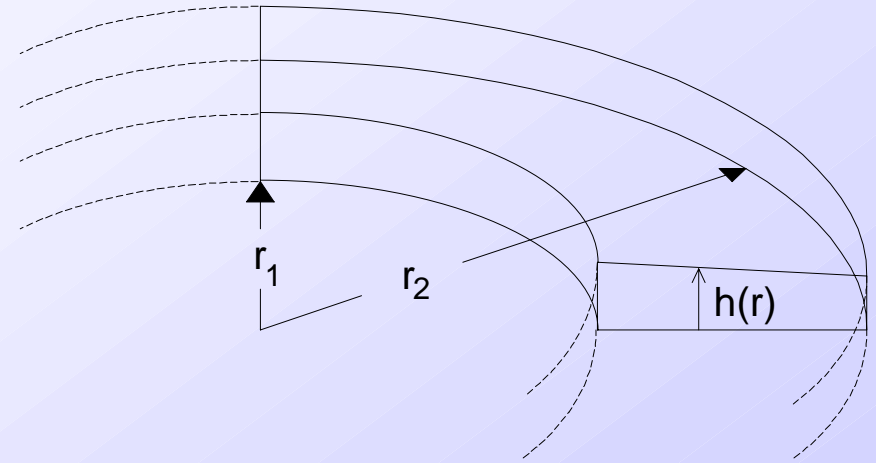
# **Calculation of Film Thickness From Electrical Resistance**



# Principles of Film Thickness Measurement



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

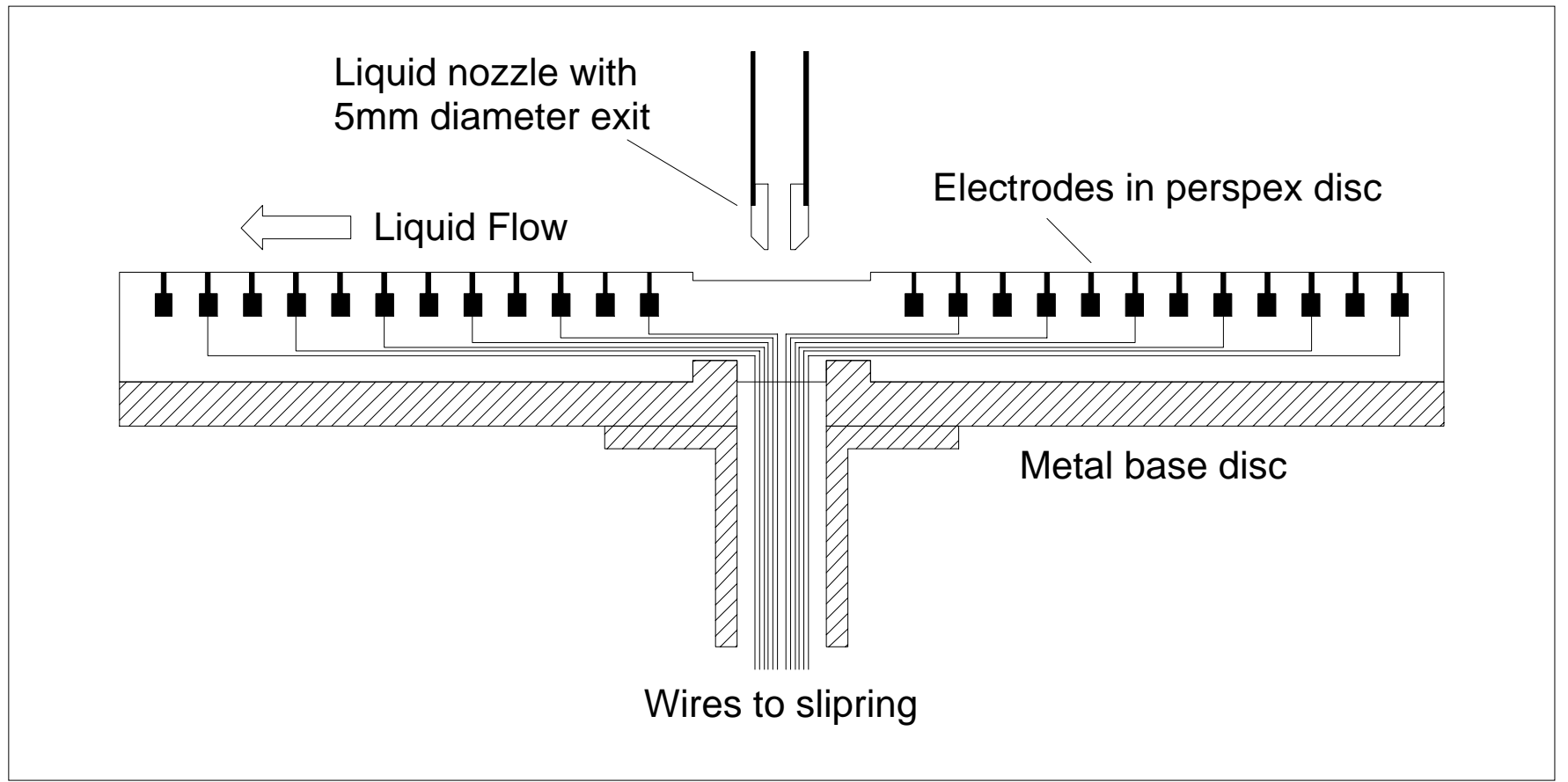


$$R = k \cdot \ln \left( \frac{r_2}{r_1} \right) \cdot \frac{\tau}{h_R}$$

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

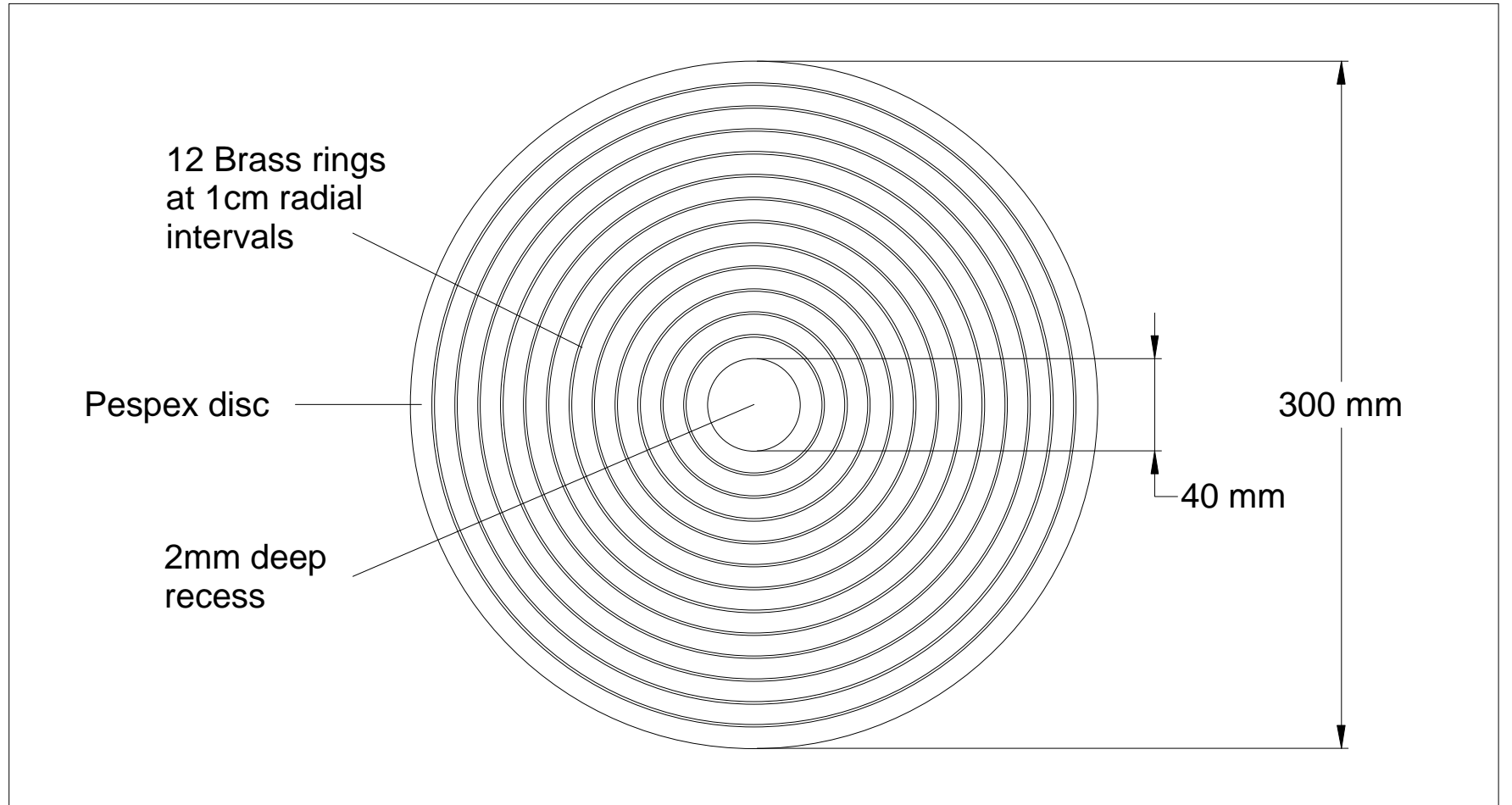


# Side View of Spinning Disc



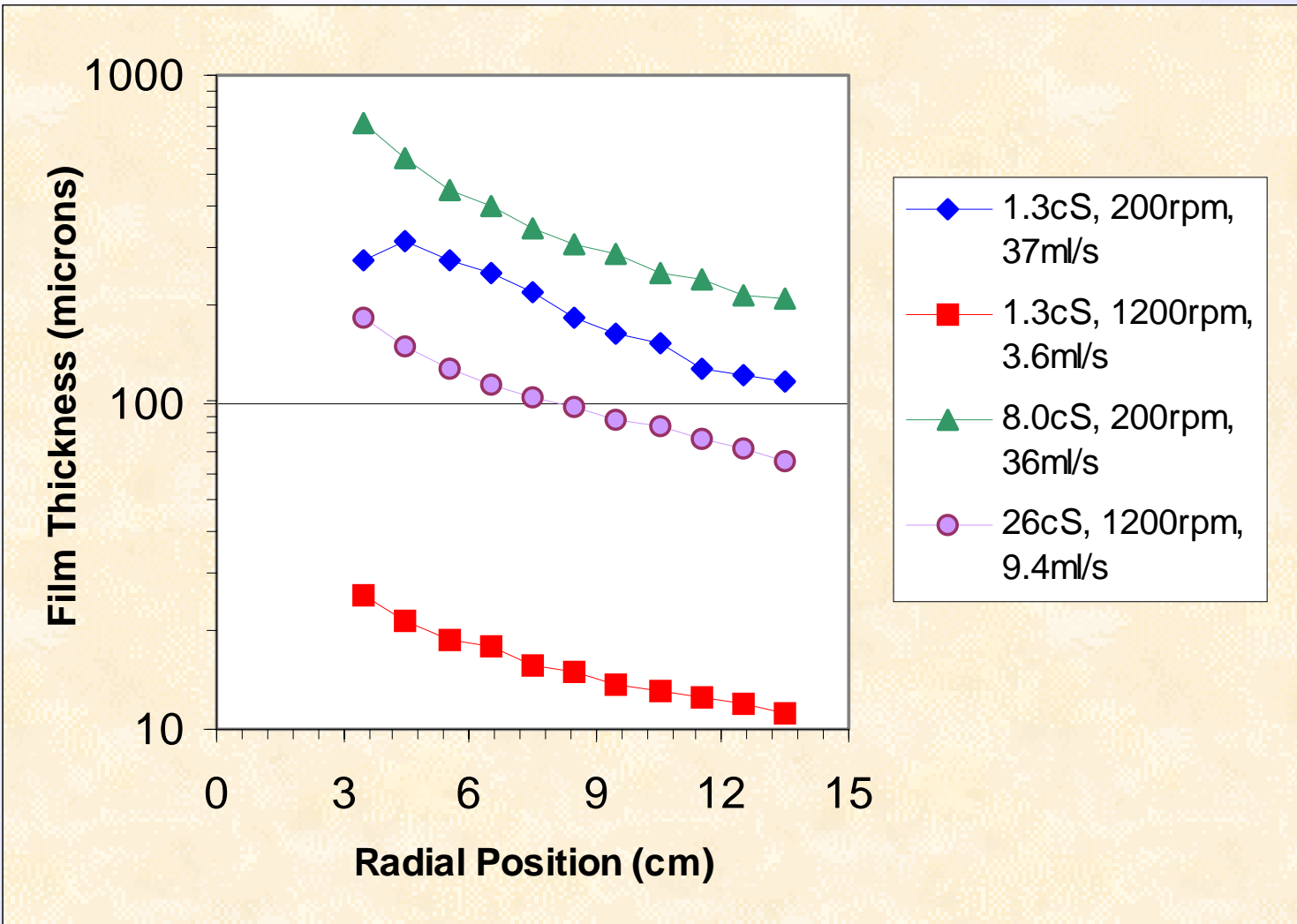


# Plan View of Spinning Disc



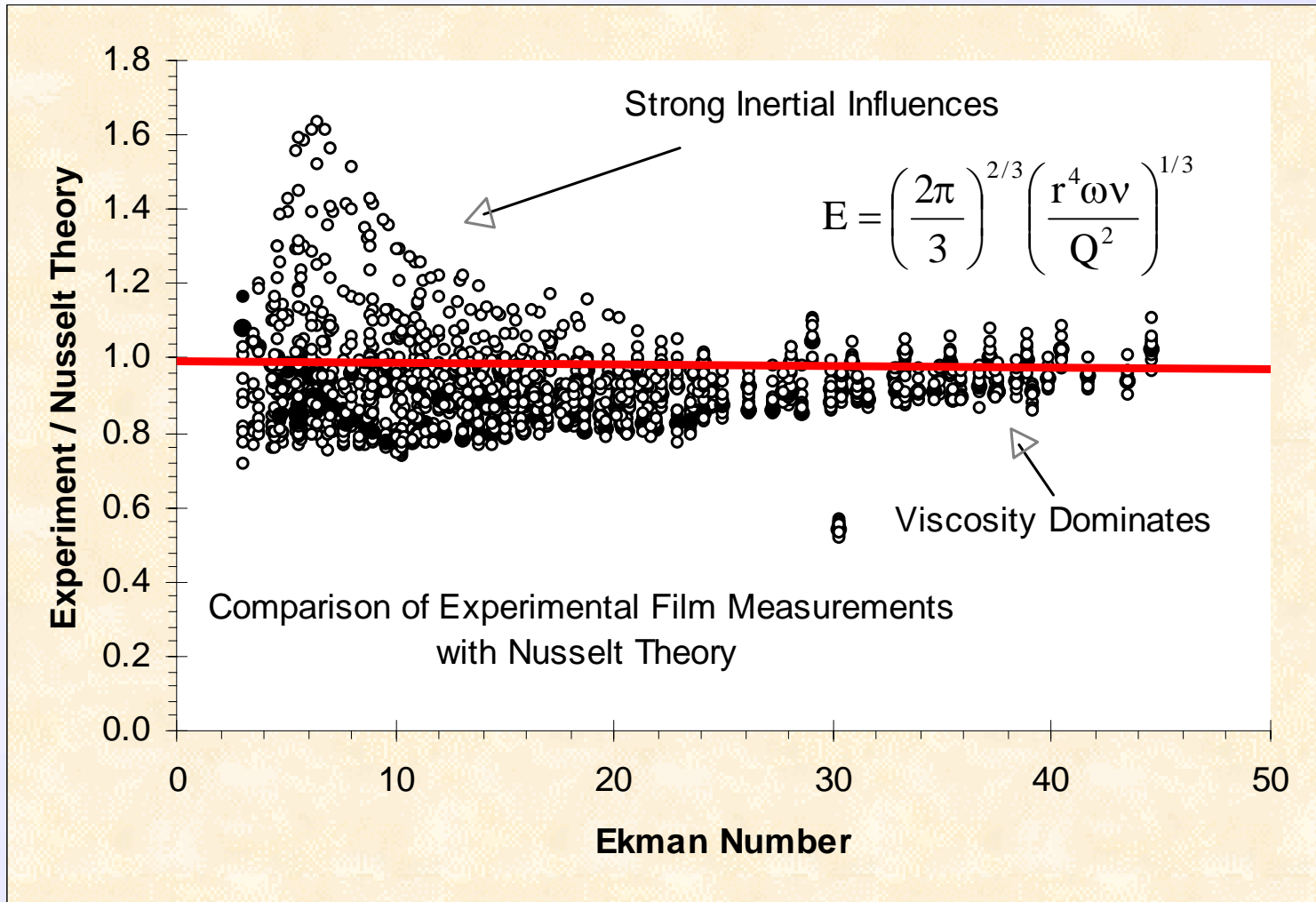


# Examples of Measurement Profiles





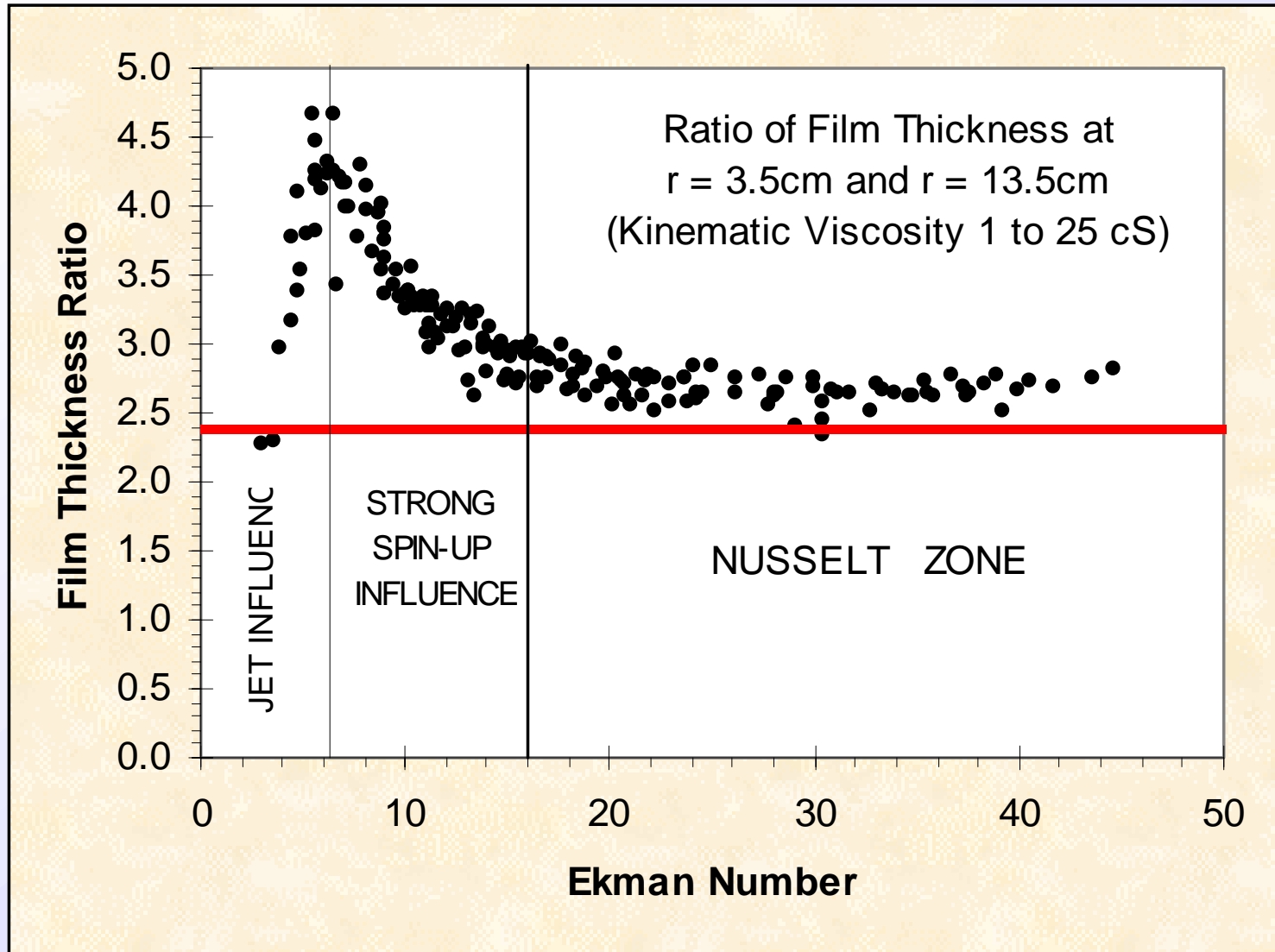
# Comparison with Nusselt Model



Inertia Dominates ← Small  $E$  large → Viscosity Dominates



# Zones of Influence on the Disc





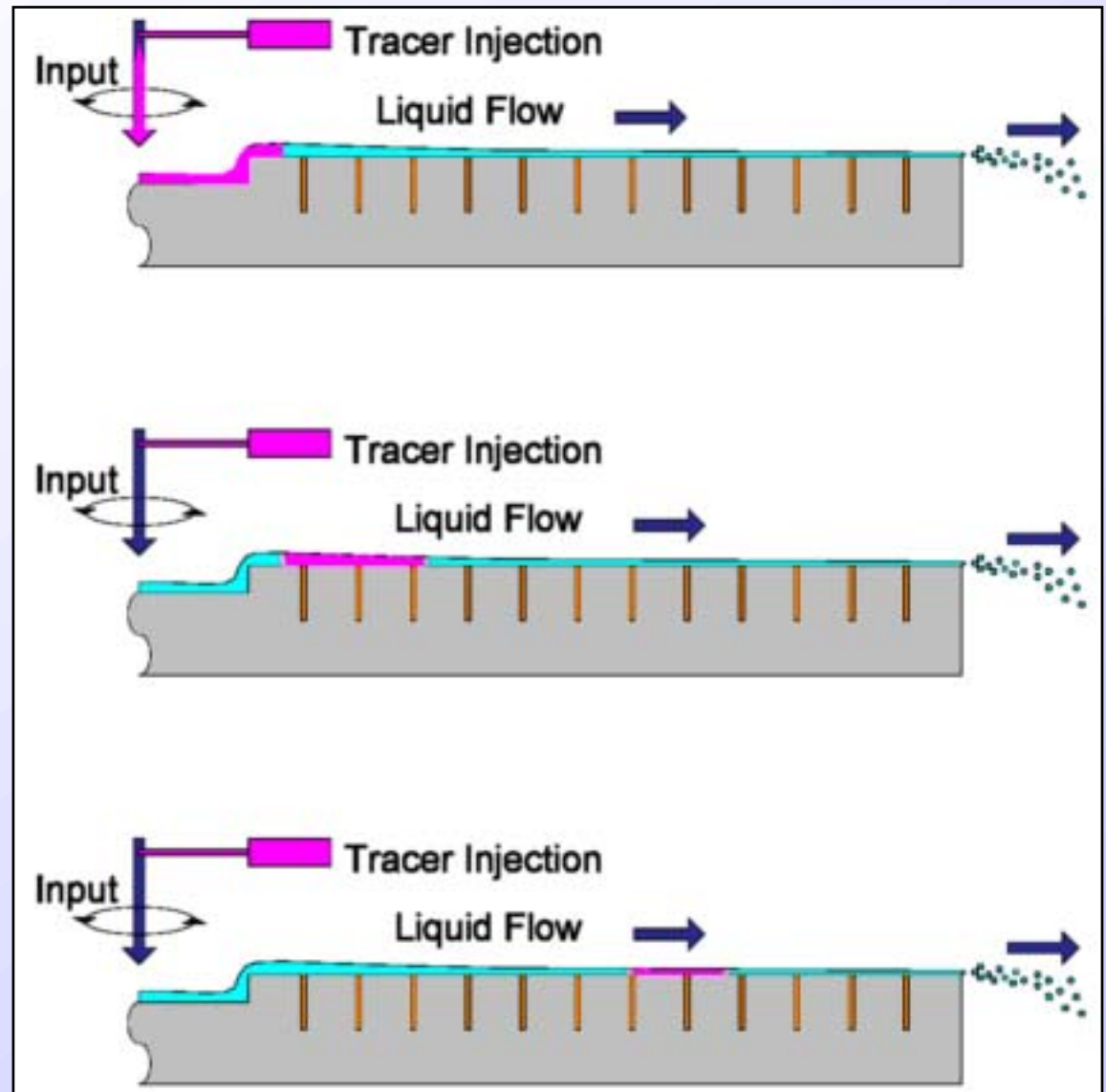
# **Measurement of Residence Time from Tracer Response**



# Tracer Response Technique

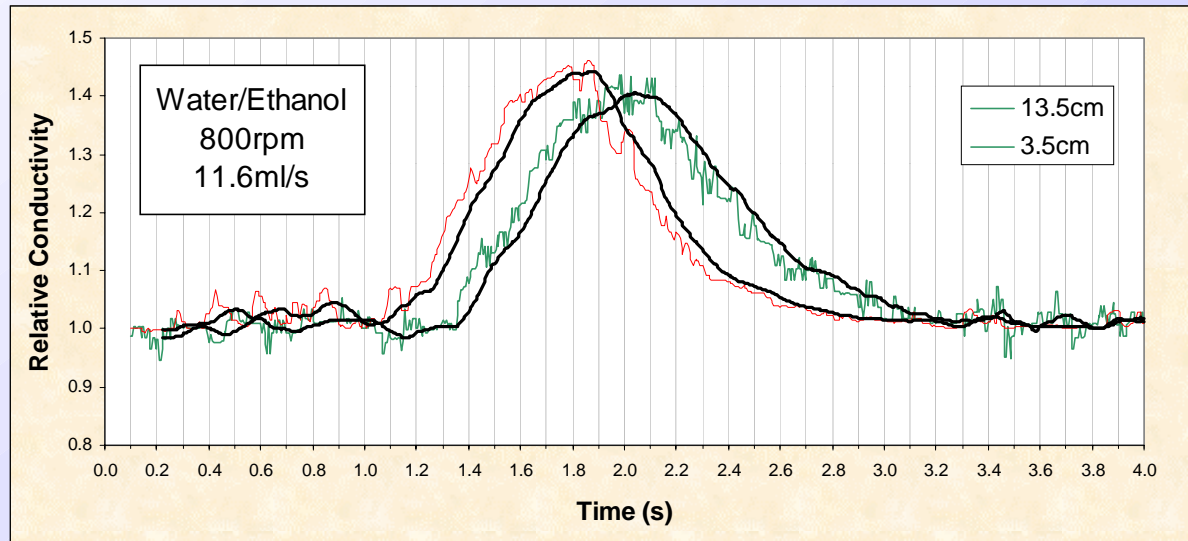
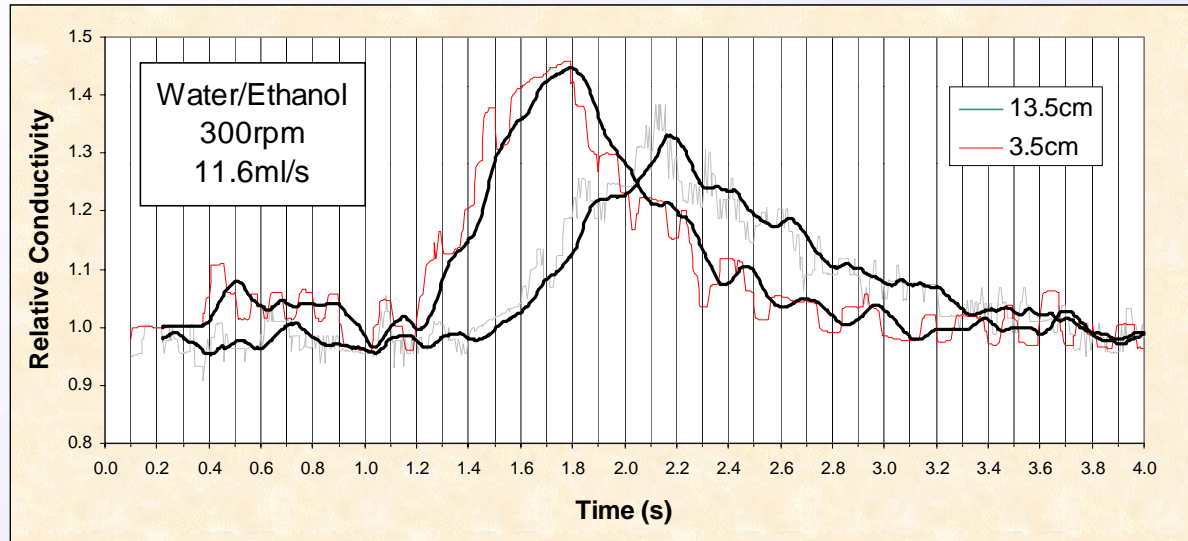
Uses the Same  
Electrodes as the  
Film Thickness  
Measurement  
System

Readings Taken  
at up to 6250Hz





# Examples of Tracer Response Profiles





# Calculating Response Time

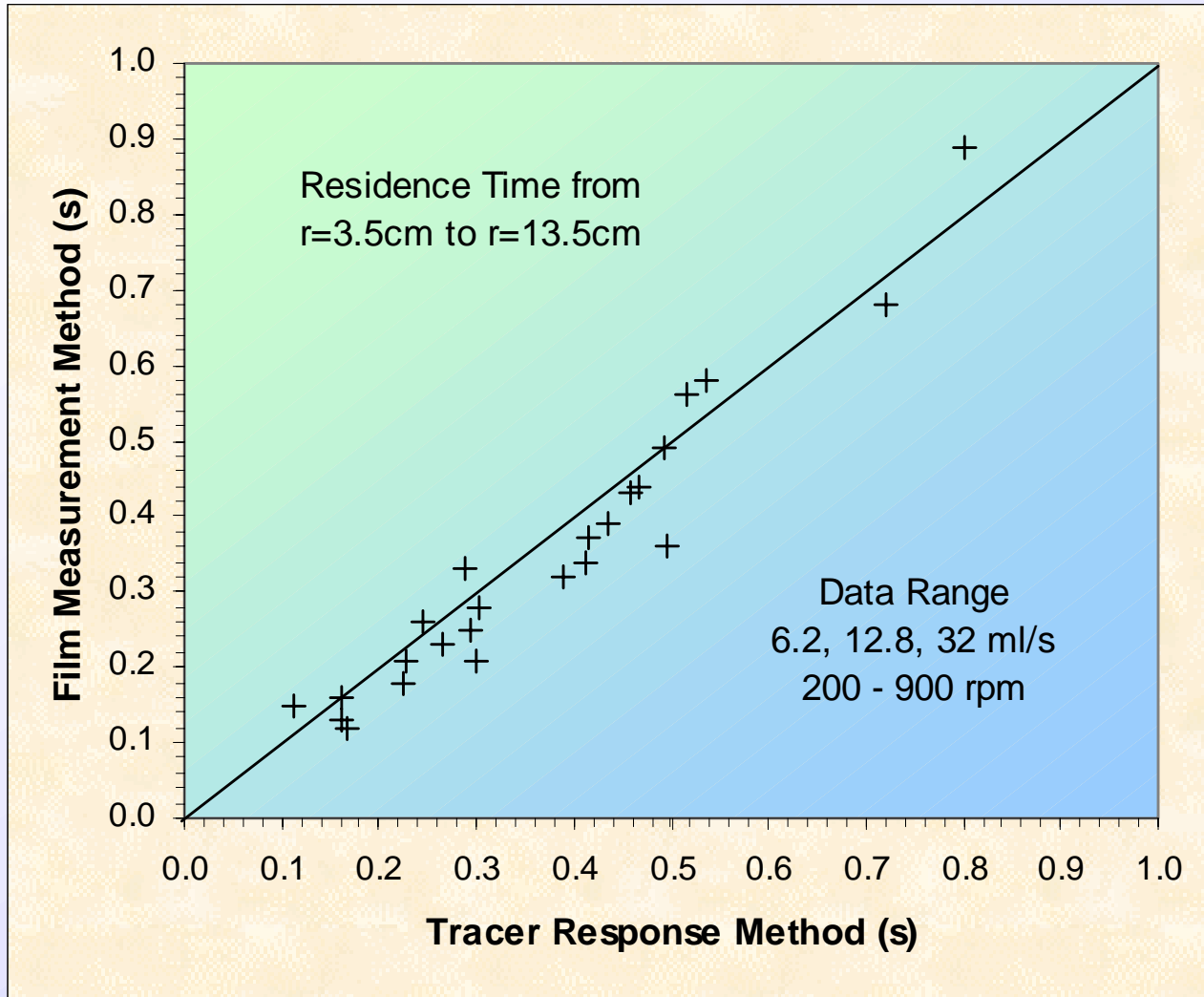
- Base line conductivity was subtracted.
- “Normal Distribution” was fitted to the data.
- Difference in means was used as the response time.

## 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



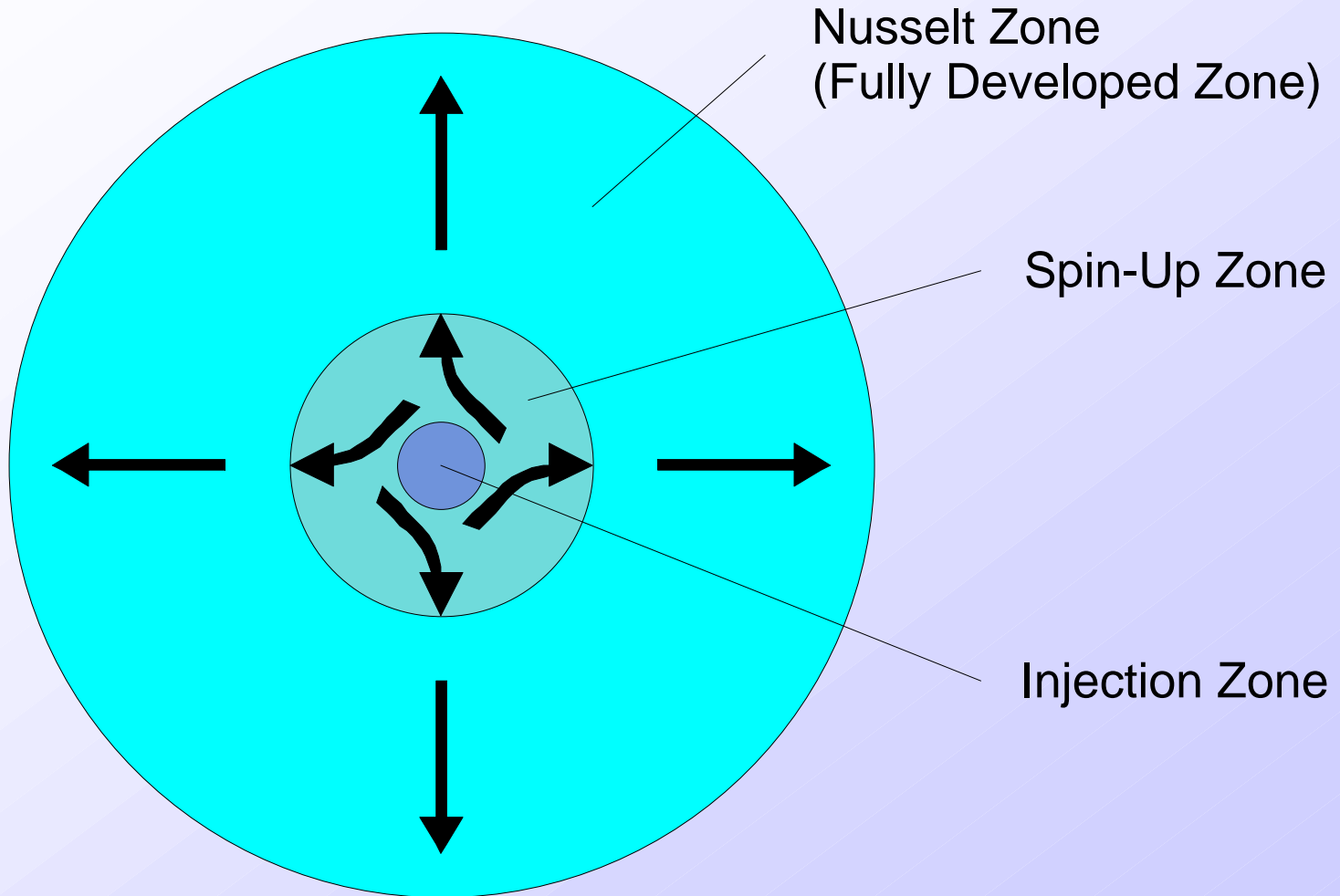
# **Examination of Velocity Data From Film Thickness**

**and**

# **The Calculation of Spin-Up Zone**



# Zones of Behaviour on the SDR



Motion Relative to the Spinning Disc

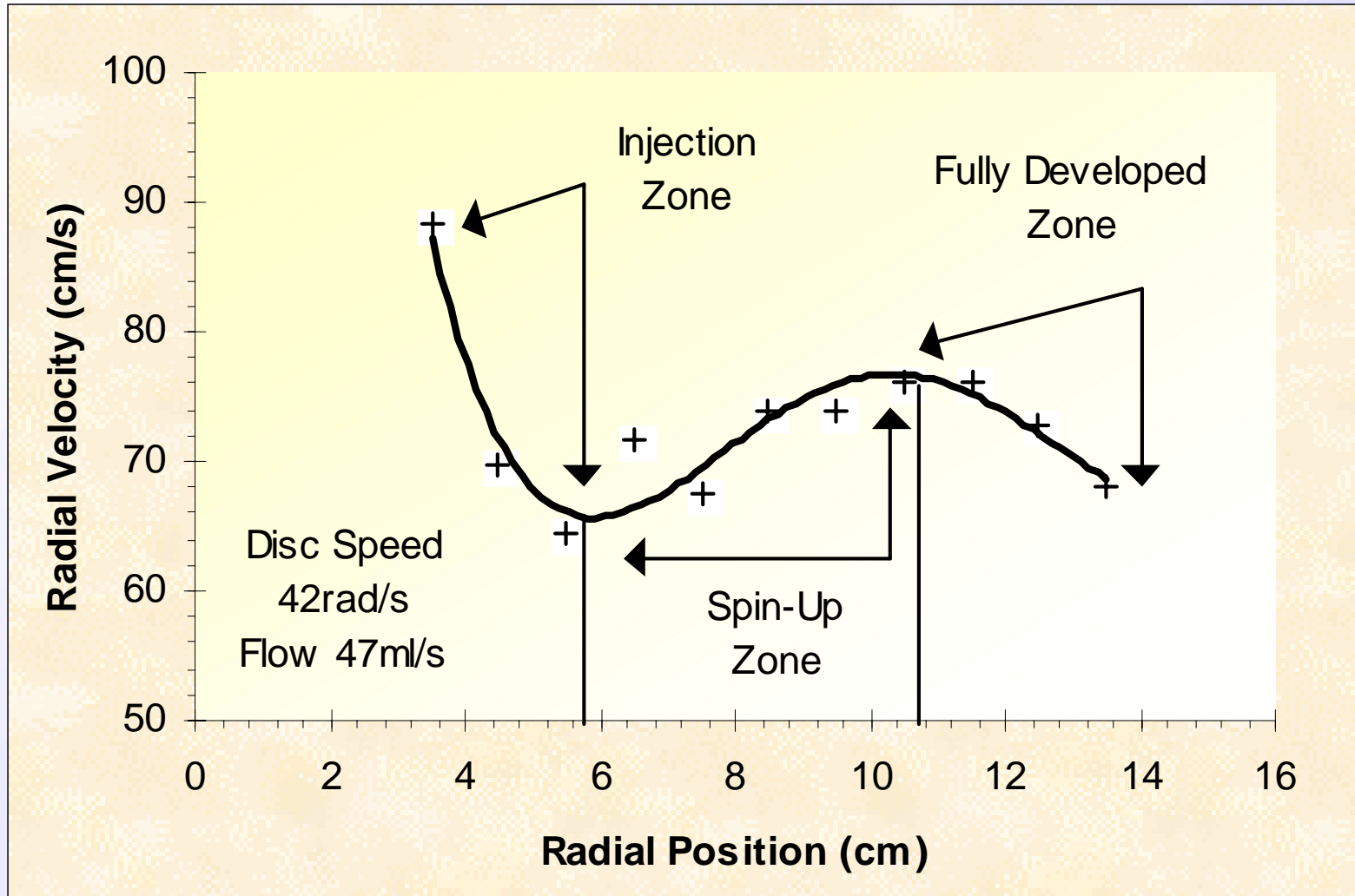


# What is Useful About Calculating These Zones?

- 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  $\lambda = \left( \frac{Q^2}{\omega v} \right)^{1/4}$

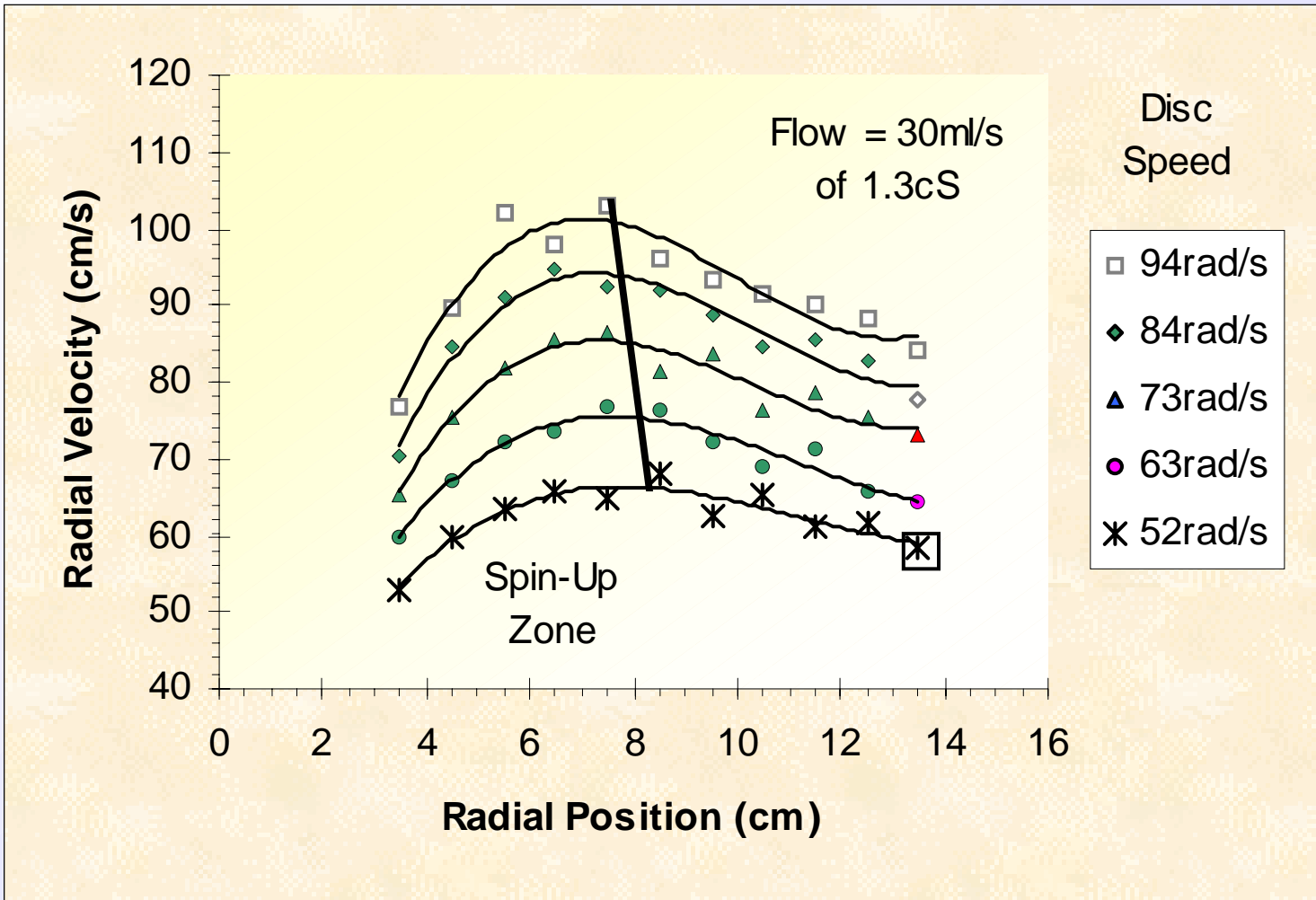
$$\frac{du'}{dr'} = 0 \quad \text{and} \quad \frac{d^2u'}{dr'^2} < 0 \quad \text{at} \quad r = r_{\text{spin}}$$

Spin-Up Radius

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



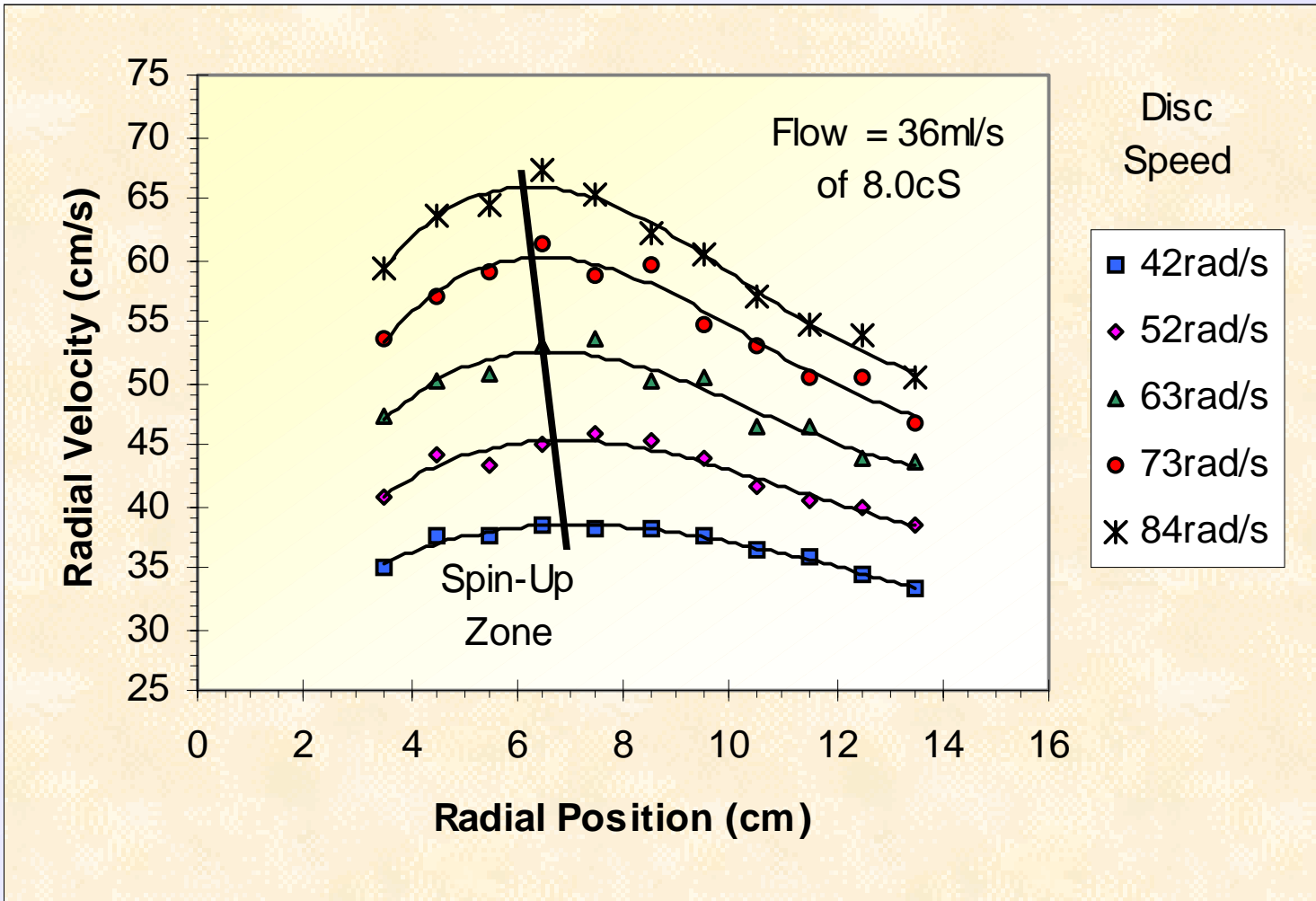
# Comparison of Calculation with Data



Low Viscosity : 1.3cP



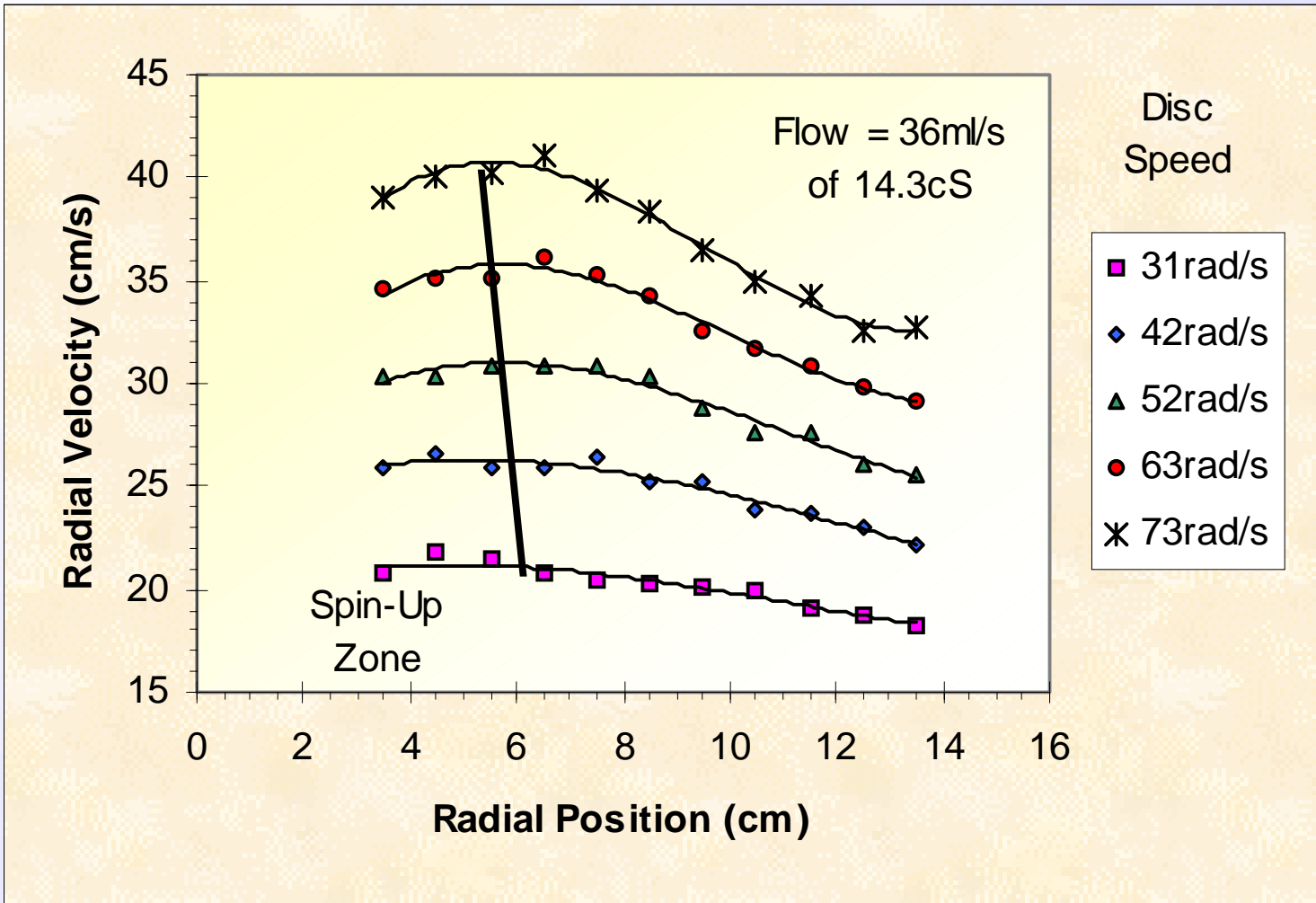
# Comparison of Calculation with Data



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.