Rotating Liquid-Liquid Contactor Measuring Hold-up

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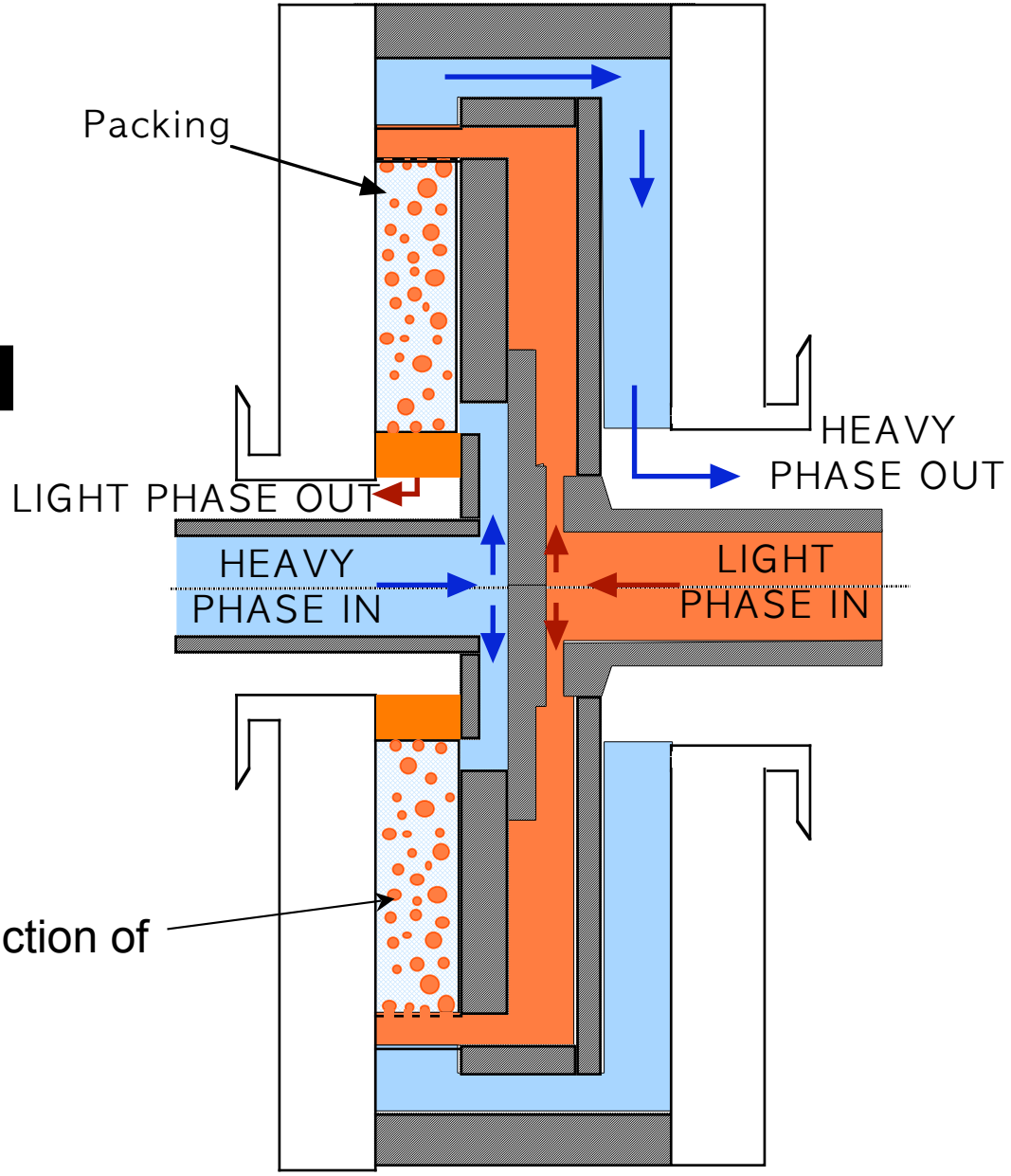
Outline

- Column hydrodynamics
- Matched refractive index (MRI) systems
- Experimental setup and systems studied
- Results
- Conclusions and future work

Flooded Rotating Packed Bed

Heavy phase is a liquid

Light phase is gas or liquid



The hold-up is the volume fraction of the dispersed phase ()

Hydrodynamics of Flooded RPB

- In any column with counter-current two-phase flow the hydrodynamics are studied to determine:
  - **The flooding limit**
  - **The area for mass transfer**

$$a = \frac{6\varepsilon}{d}$$

a = area for mass transfer ($m^2\ m^{-3}$)

d = drop/bubble diameter (m)

Hydrodynamics of Flooded RPB

- In non-rotating contactors the drop size is predicted from equations of the form:

$$d = \square\sqrt{\frac{\square}{\square\square g}}$$

- The hold-up is estimated using the slip velocity equation:

$$\frac{U_D}{\square} + \frac{U_C}{(1\square\square)} = U_S = U_o(1\square\square)^n \; ?$$

U_0 - characteristic velocity = f(□,□,□,packing characteristics)

Hydrodynamics of Flooded RPB

- In a rotating packed bed, drop diameter, velocity and dispersed phase hold-up change with radius.

- These changes are modelled using a population balance.

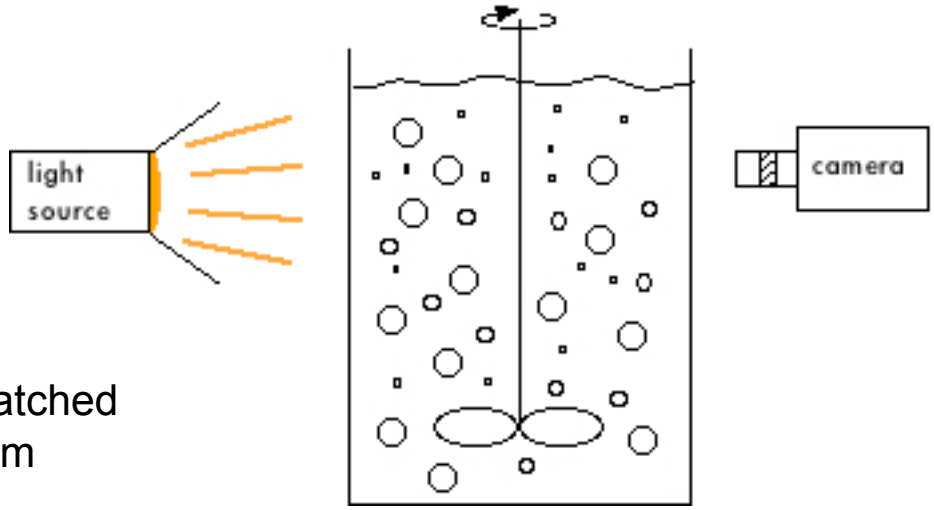
$$\frac{\partial n_i}{\partial r} = \frac{1}{U_i}(B - D) - \frac{n_i}{r} - \frac{n_i}{U_i}\frac{\partial U_i}{\partial r}$$

n_i = number of drops per unit volume belonging to class i

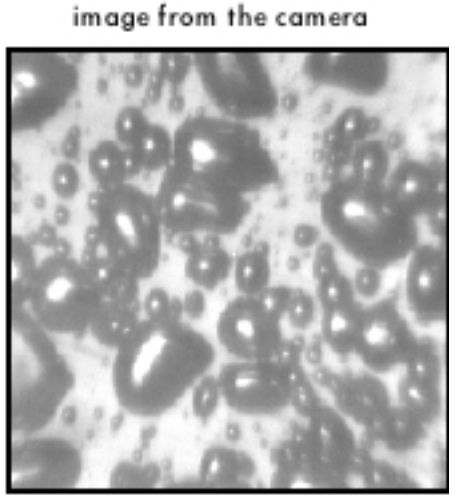
U_i = velocity with which the drops move through the packing

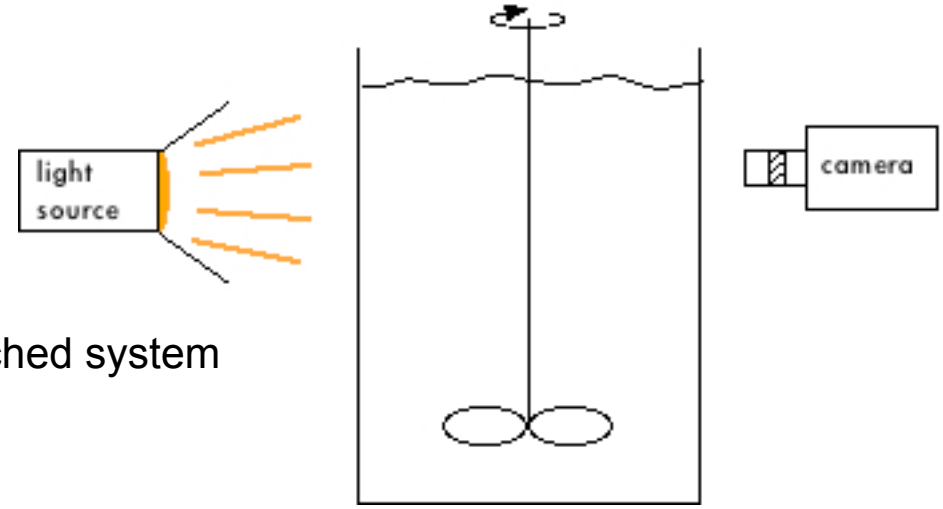
- Hold-up and drop size measurements improve the understanding of drop breakage and coalescence.

Matched Refractive Index

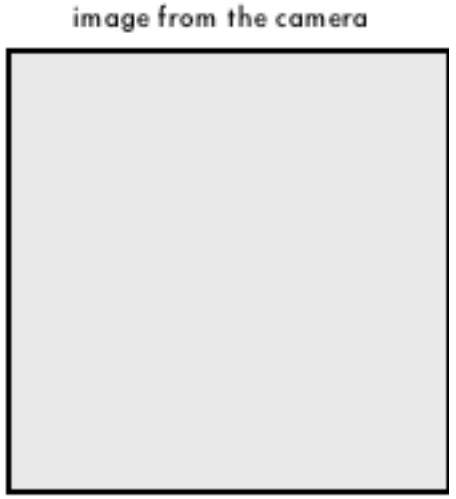


Unmatched system

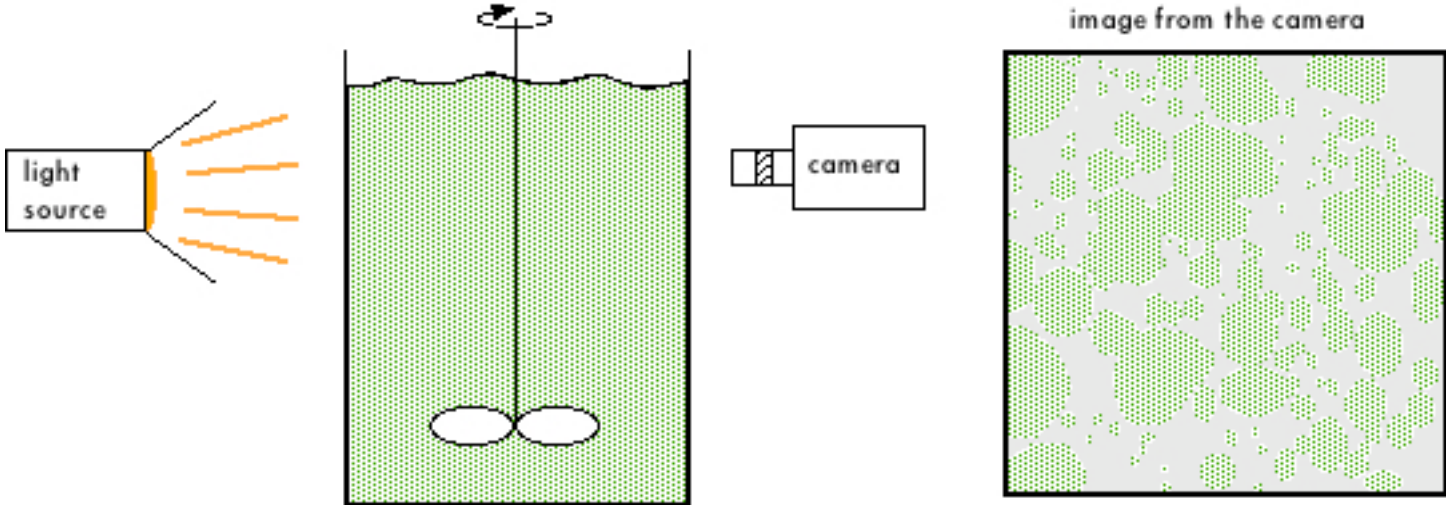




Matched system



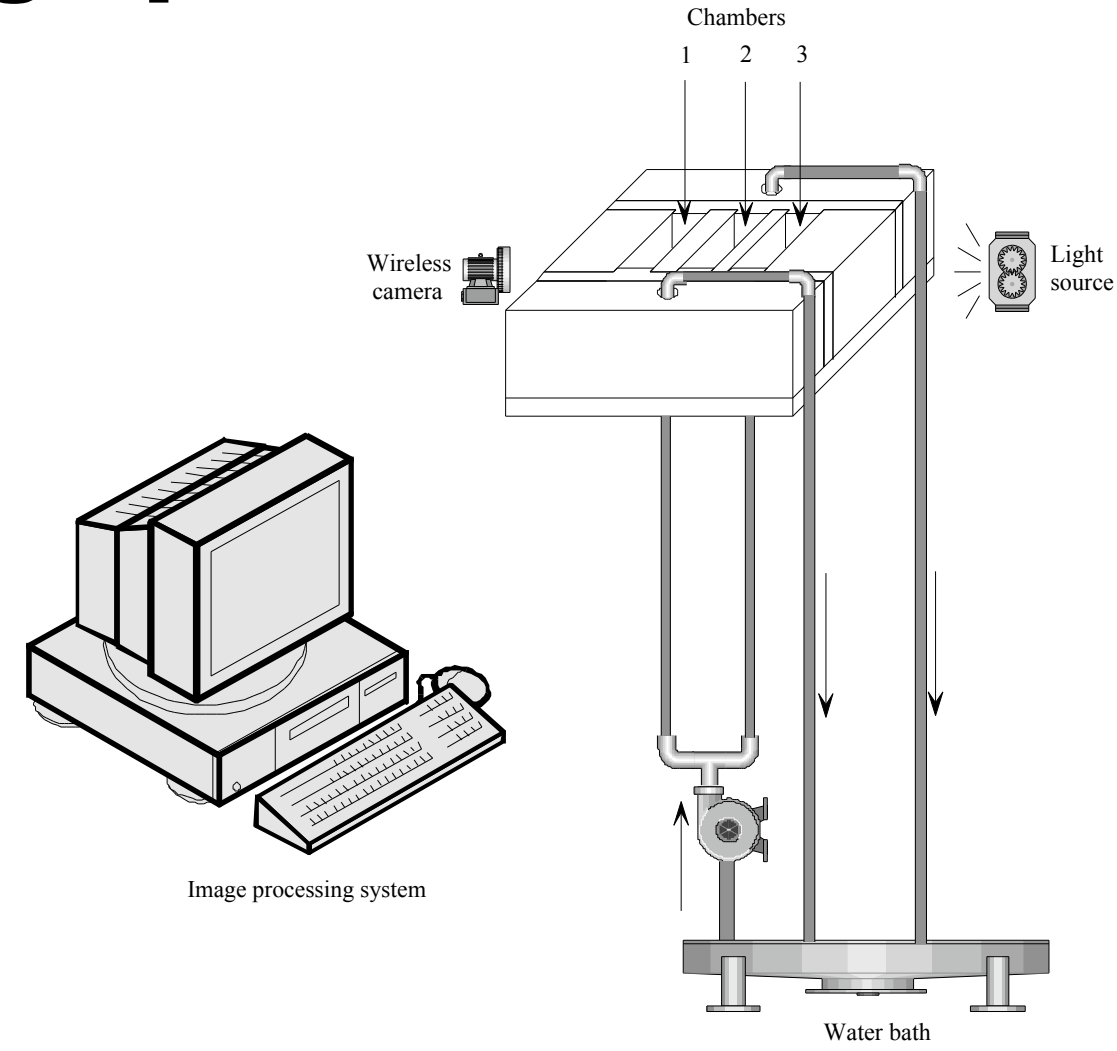
Matched Refractive Index



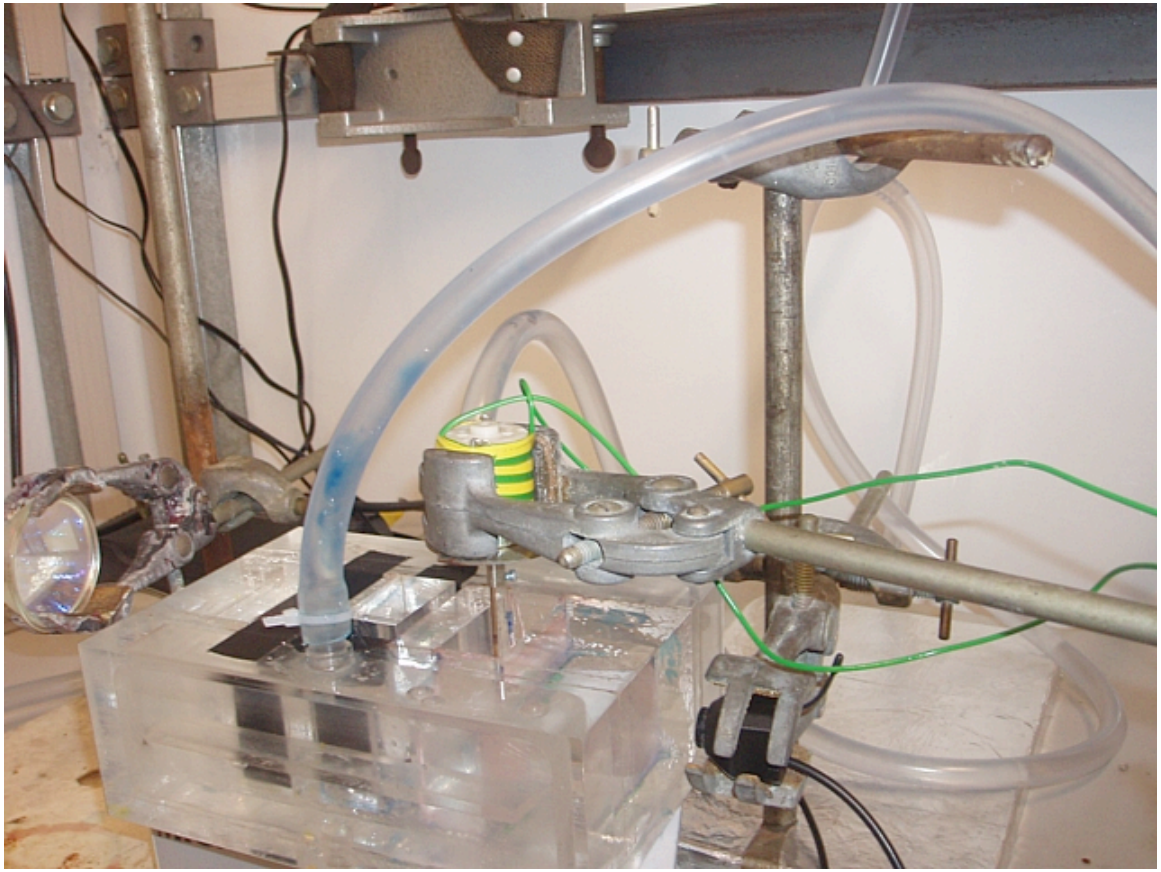
Matched system + dye

light absorbed hold up

Setting up the MRI Measurement



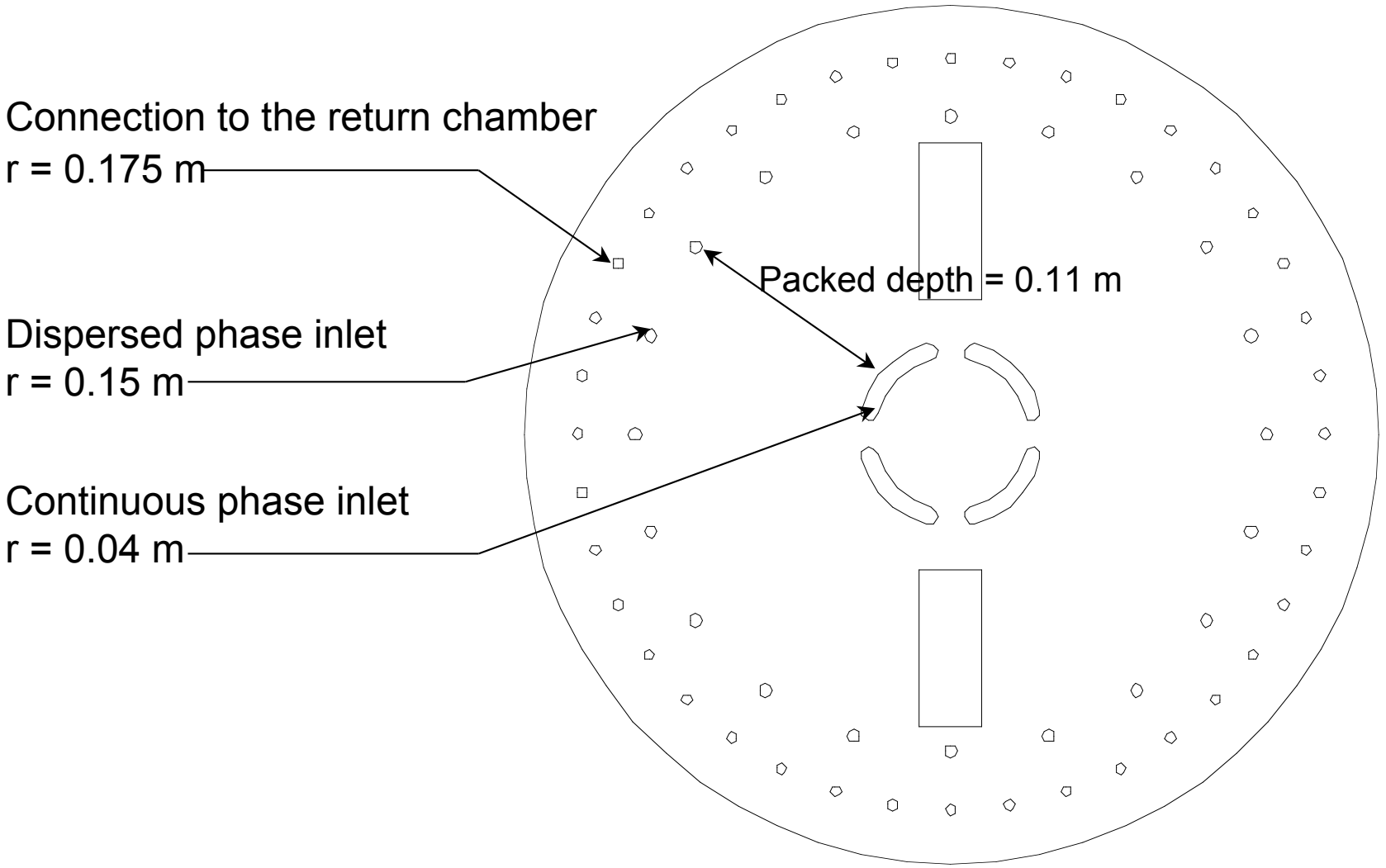
Setting up the MRI Measurement



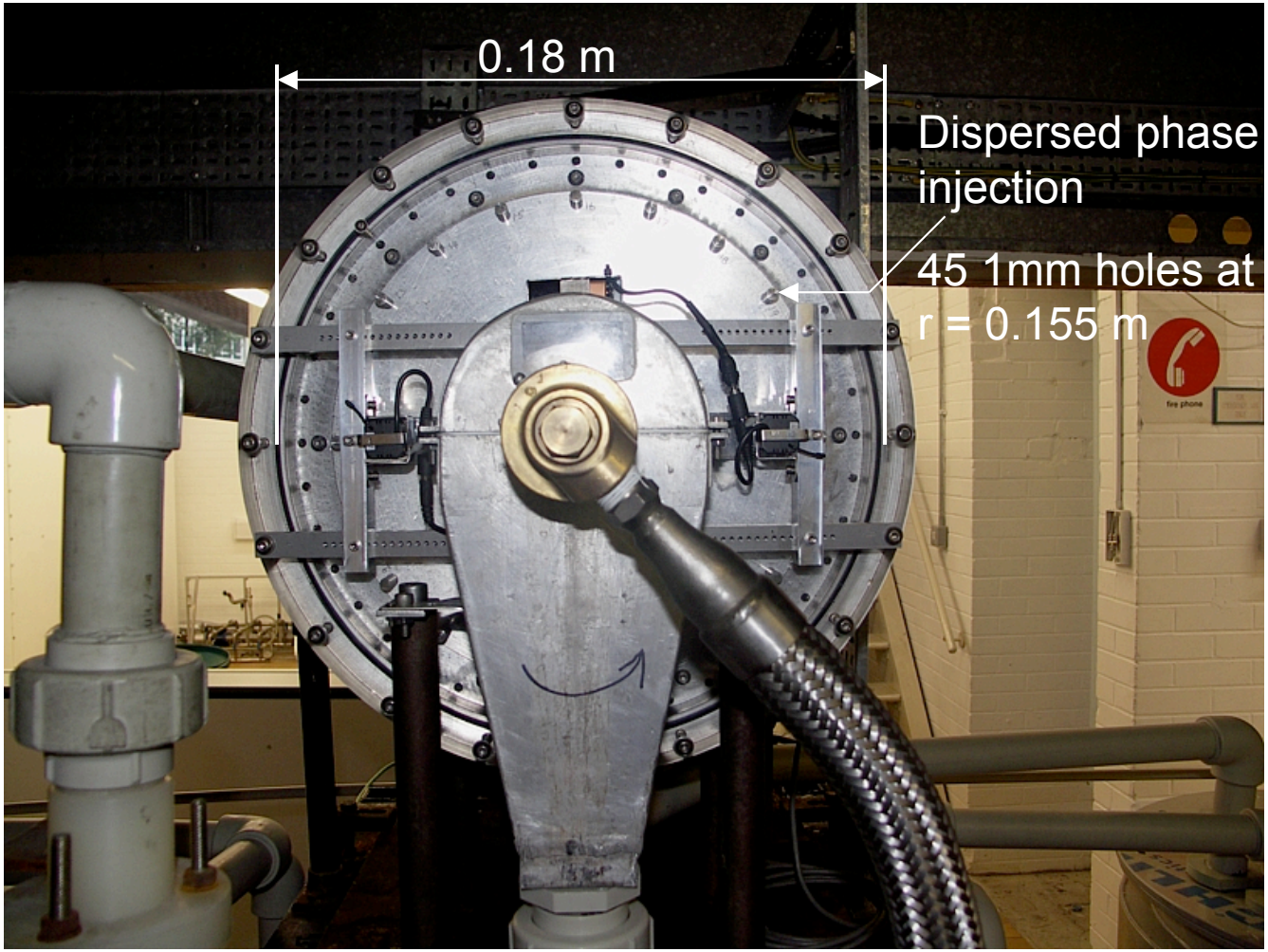
Properties of Test Systems

	The systems	[kg/m^3]	[mPas]	T [^{o}C]	n	□□ kg m^{-3}	□ [mN/m]
1	Dodecane	742.6	1.28	28.5	1.42	483	39
	50 wt % sucrose solution	1225.6	10.51				
2	Butanol	846	3.36	23	1.39	199	17.5
	Water +4M Ammonium thiocyanate	1045	1.7				

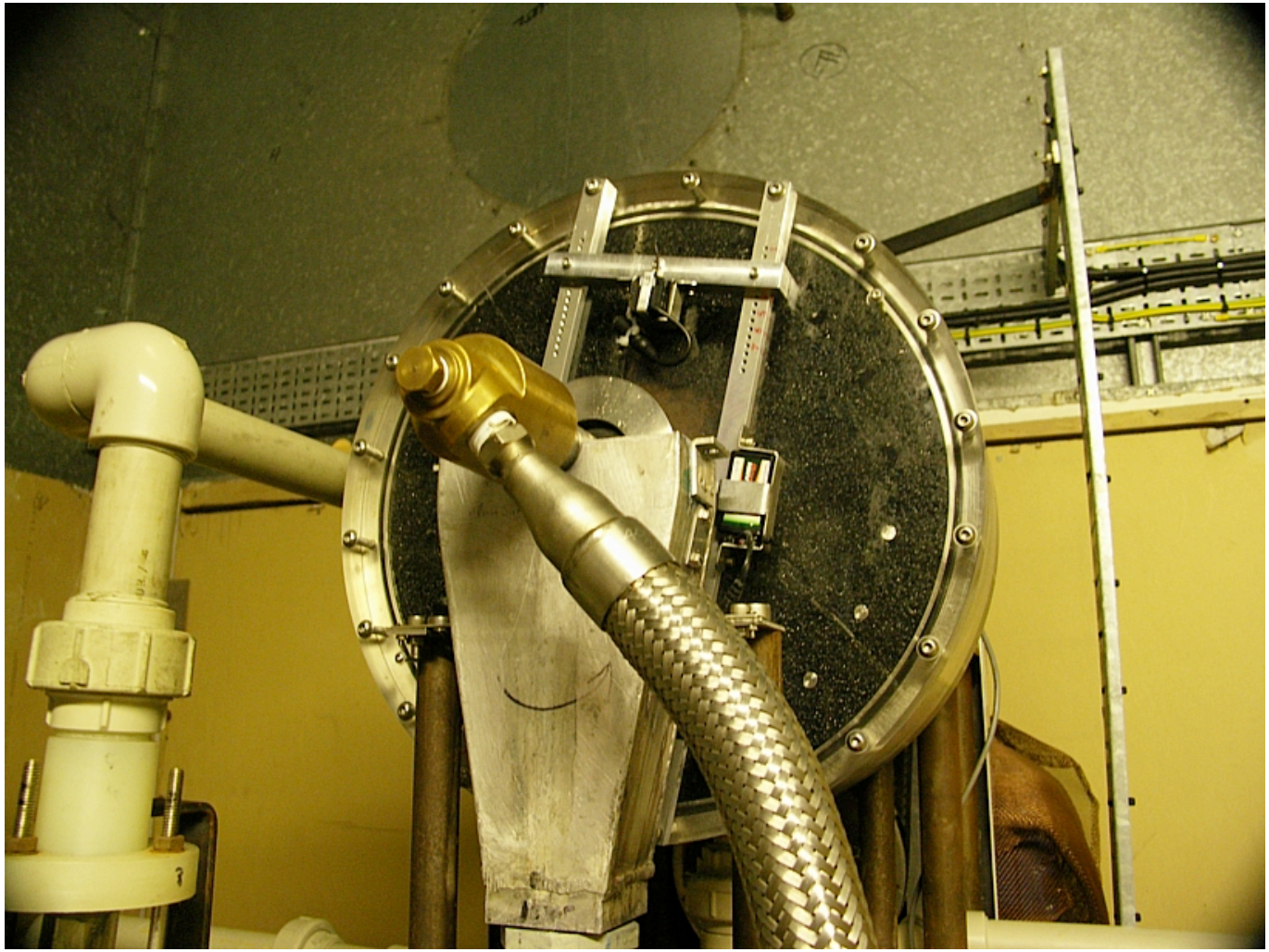
Layout of the Rotor



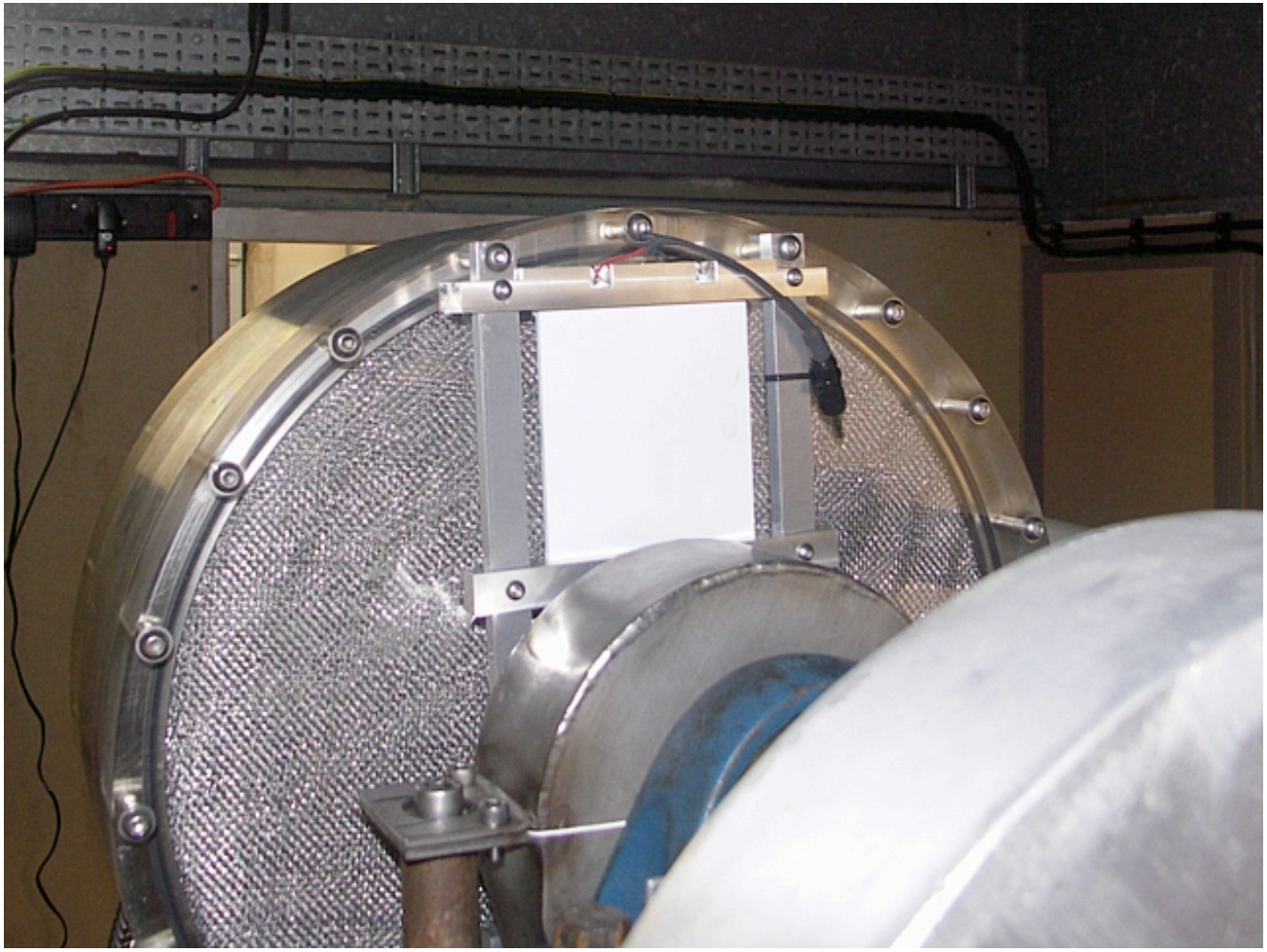
Lighting and Camera System



Camera & Lighting System

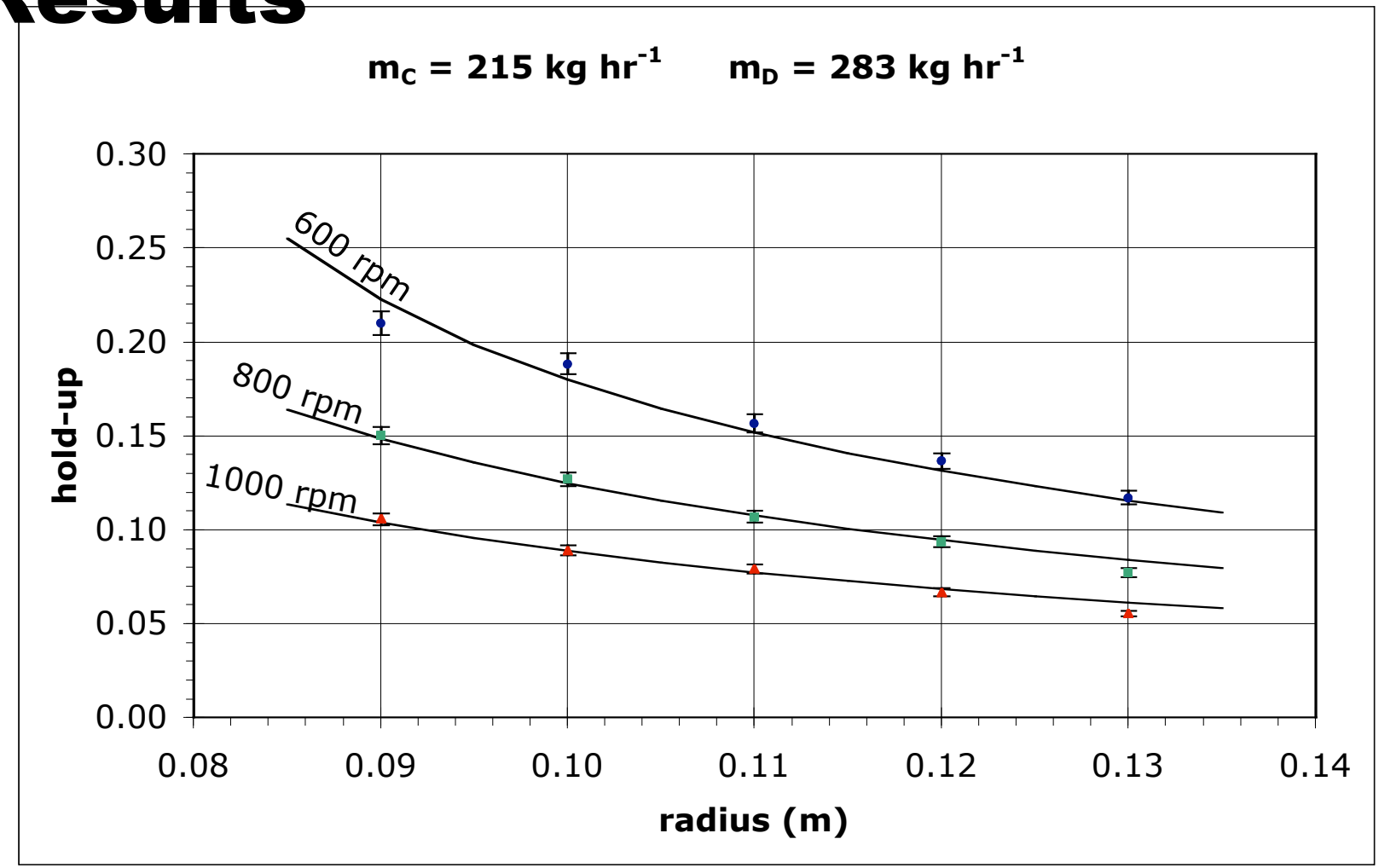


Camera & Lighting System

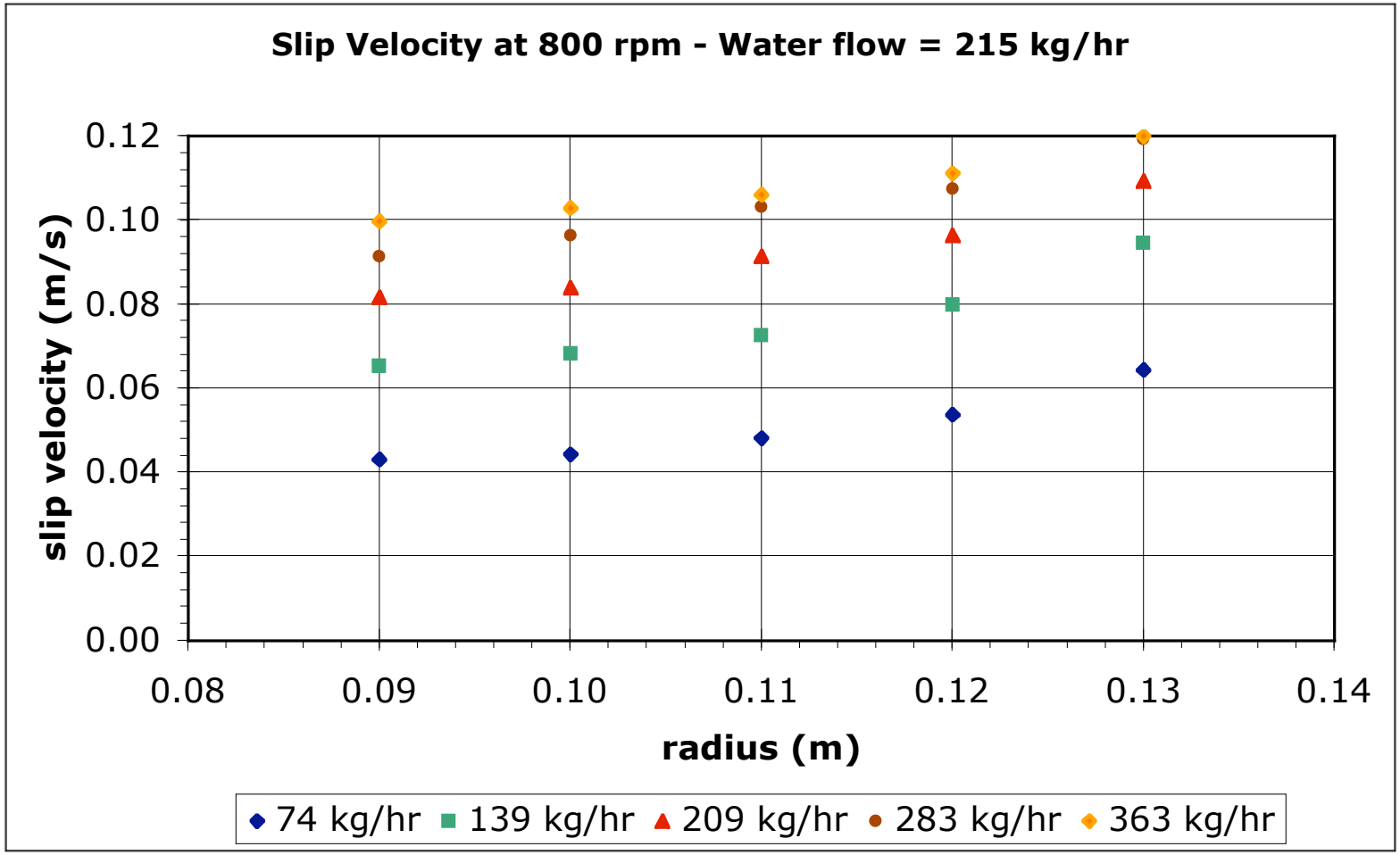


Camera and Lighting System

Results


m_C = 215 kg hr^{-1}
m_D = 283 kg hr^{-1}
hold-up
0.30
0.25
0.20
0.15
0.10
0.05
0.00
600 rpm
800 rpm
1000 rpm
0.08
0.09
0.10
0.11
0.12
0.13
0.14
radius (m)

Results


Slip Velocity at 800 rpm - Water flow = 215 kg/hr
slip velocity (m/s)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.08
0.09
0.10
0.11
0.12
0.13
0.14
radius (m)
74 kg/hr
139 kg/hr
209 kg/hr
283 kg/hr
363 kg/hr

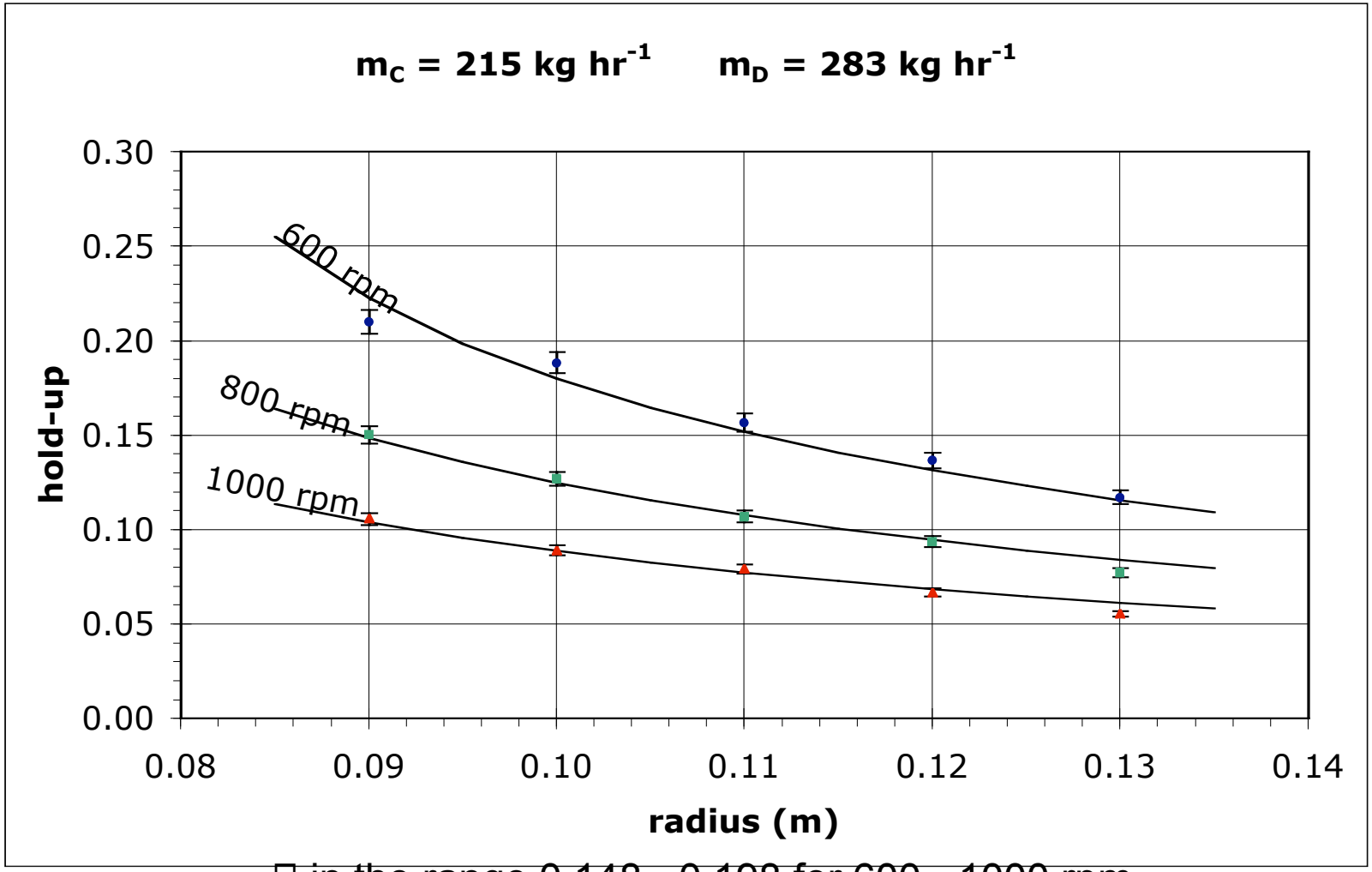
Results - Simple Model

- The superficial velocities of the continuous and dispersed phases and the hold-up are related using the slip velocity.

$$\frac{U_D}{\phi} + \frac{U_C}{(1-\phi)} = U_S = \alpha U_T (1-\phi)$$

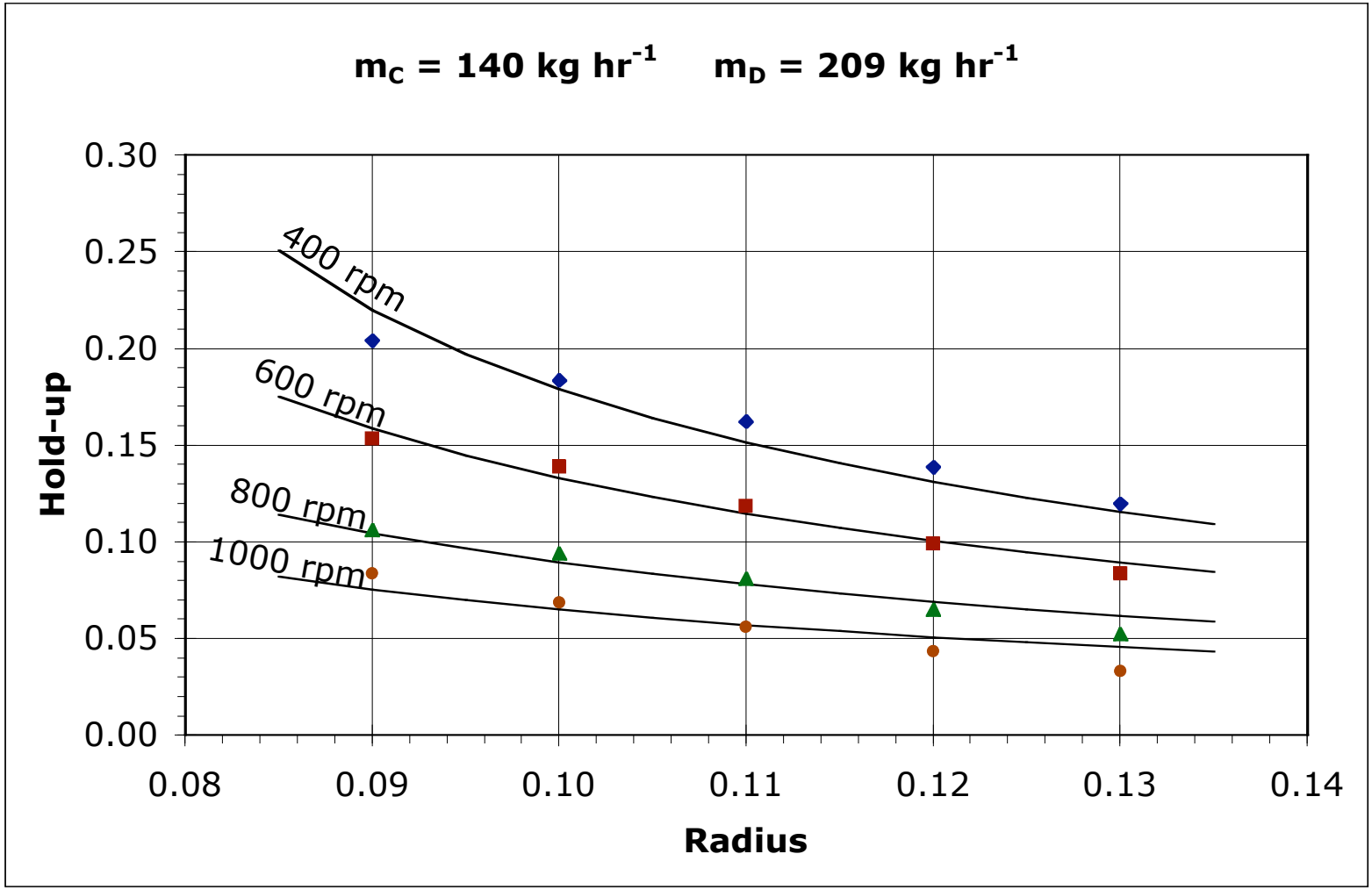
- The terminal velocity of the drops is multiplied by some fraction α (0-1).
- The drop size is estimated using the equilibrium drop size model.

Results



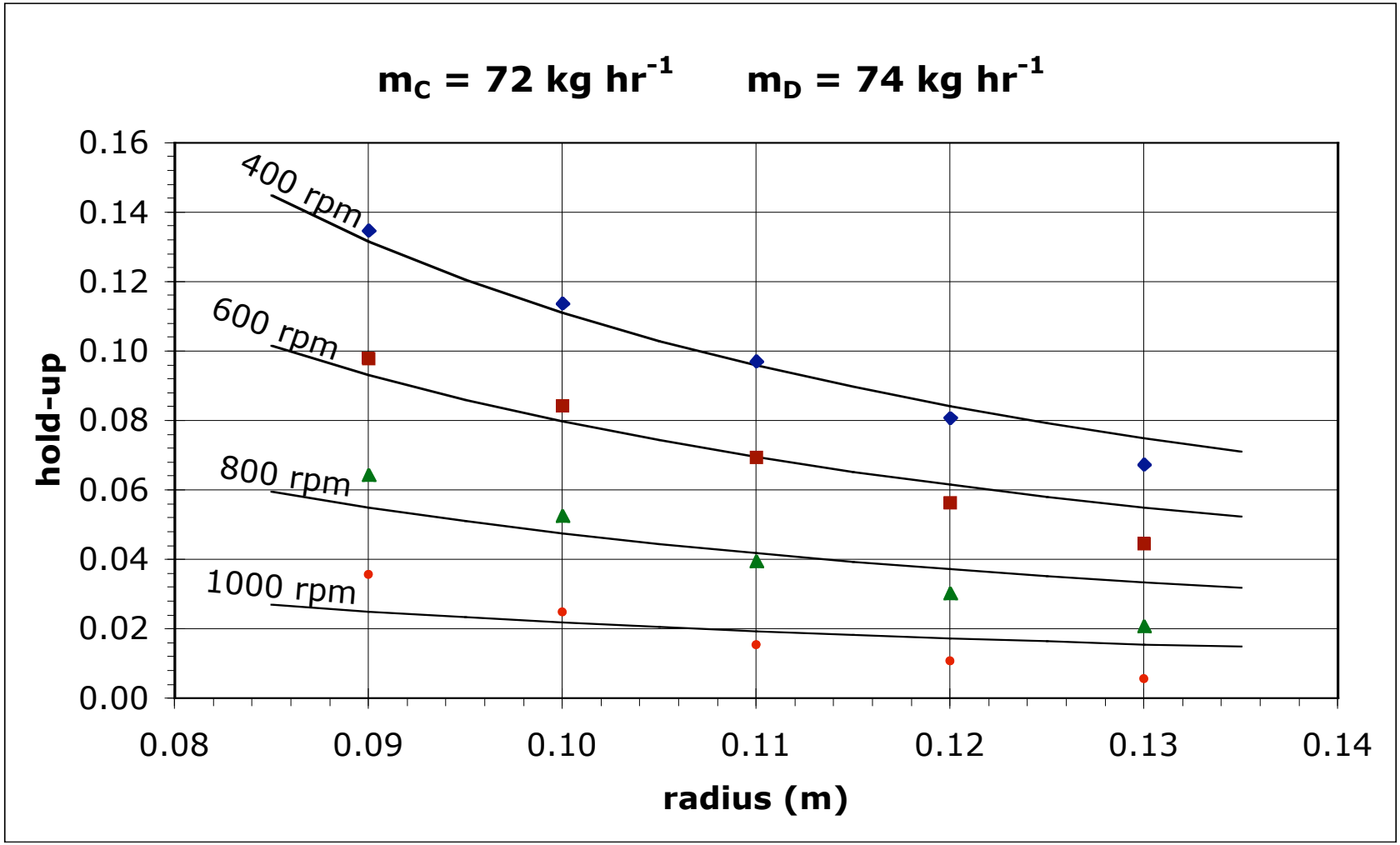
 in the range 0.148 - 0.198 for 600 - 1000 rpm

Results



 in the range 0.133 - 0.192 for 400 - 1000 rpm

Results

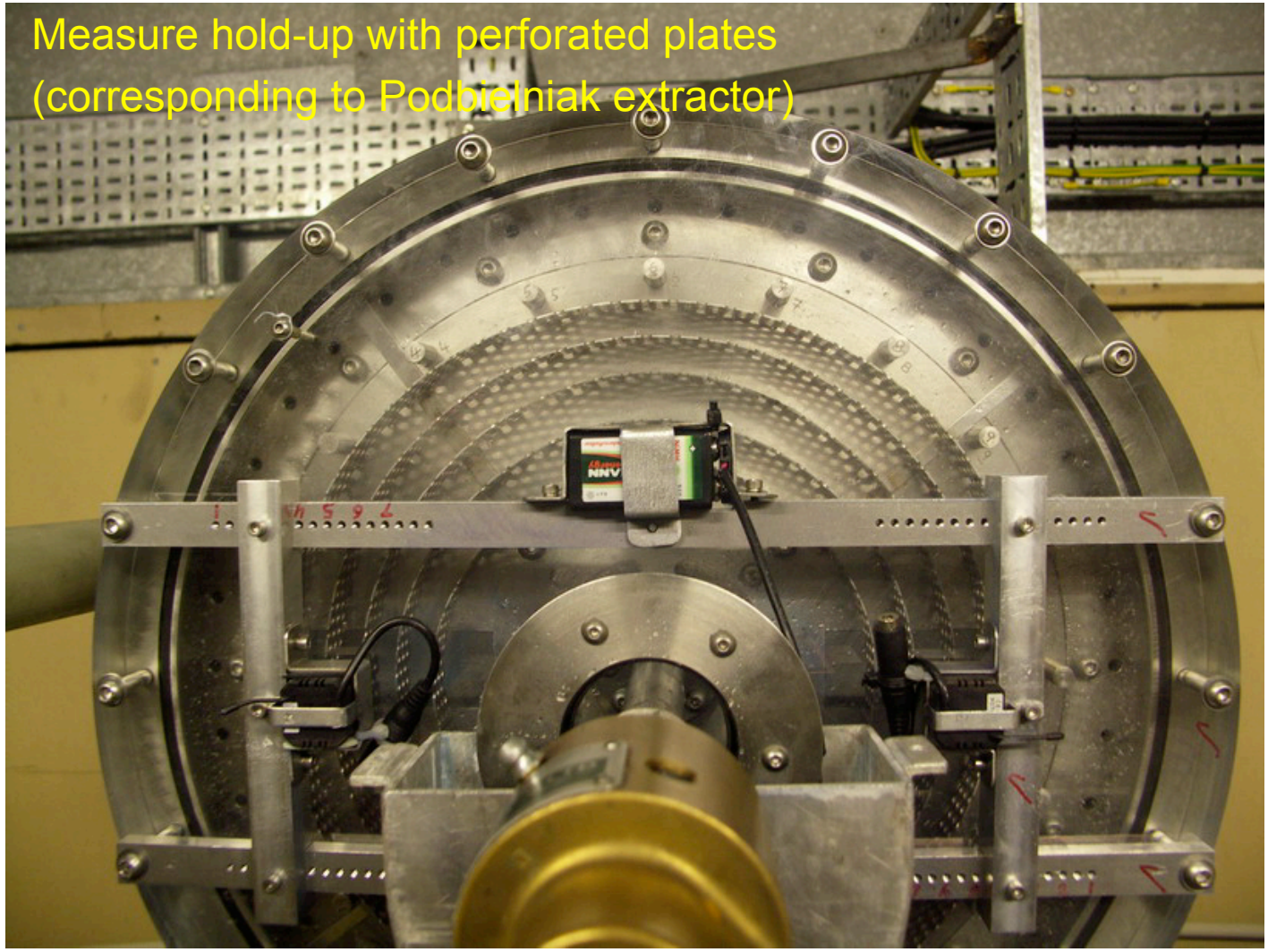


 in the range 0.069 - 0.191 for 400 - 1000 rpm

Conclusions and Future Work

- The hold-up has been measured accurately in a rotating packed bed using a matched refractive index method.
- The hold-up and slip velocity follow expected trends with rotational speed and phase flow rates.
- Initial processing of results shows that drops travel through the packing at up to 20% of their terminal velocity.

Future Work


Measure hold-up with perforated plates
(corresponding to Podbielniak extractor)