

THE PERFORMANCE OF CENTRIFUGAL PUMPS WHEN PUMPING ULTRA VISCIOUS PASTE SLURRIES

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This paper demonstrates that it is possible to pump very viscous, high yield stress slurries with limited head and efficiency de-rating using centrifugal pumps, provided that positive suction conditions are maintained at all times.

Talk Outline



- Background
- Rheology
- Kaolin material properties
- millMAX 6" x 4"
- Pump test rig and procedure
- Clear water test data
- Kaolin paste test data
- Pump performance
- Summary of findings
- Acknowledgements

Background



- Measure centrifugal pump performance when pumping ultra viscous paste slurry
 - kaolin paste slurry
 - Yield Stress Range: 580 Pa to 1 120 Pa
- FLSmidth Krebs millMAX centrifugal pump

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Rheology

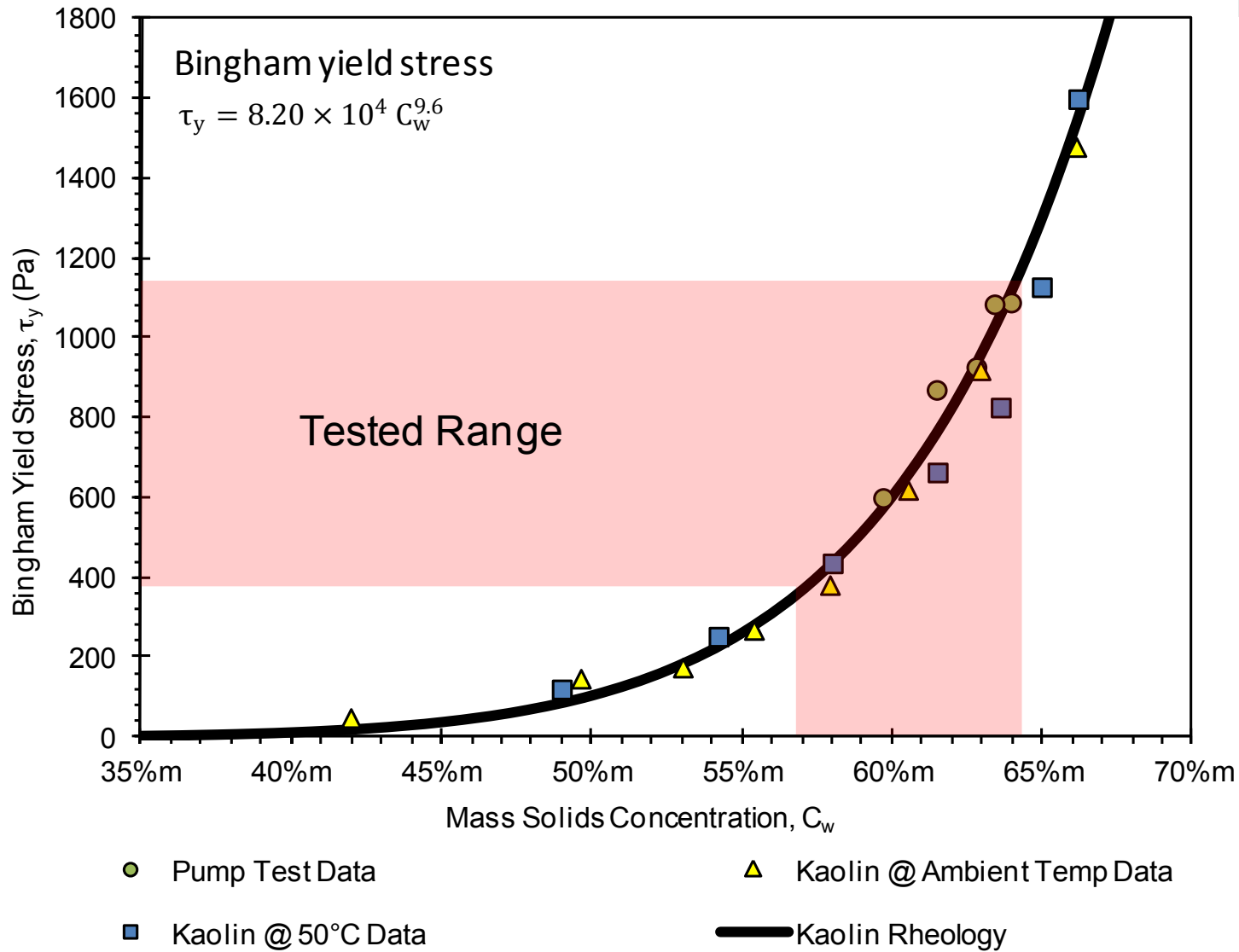
- Anton Paar RheoLAB QC
 - Rotational Bob, Stationary Cup
 - Temperature control bath
- Herschel–Bulkley model

- Bingham plastic: $n = 1$

$$\tau_0 = \tau_y + K\gamma^n$$

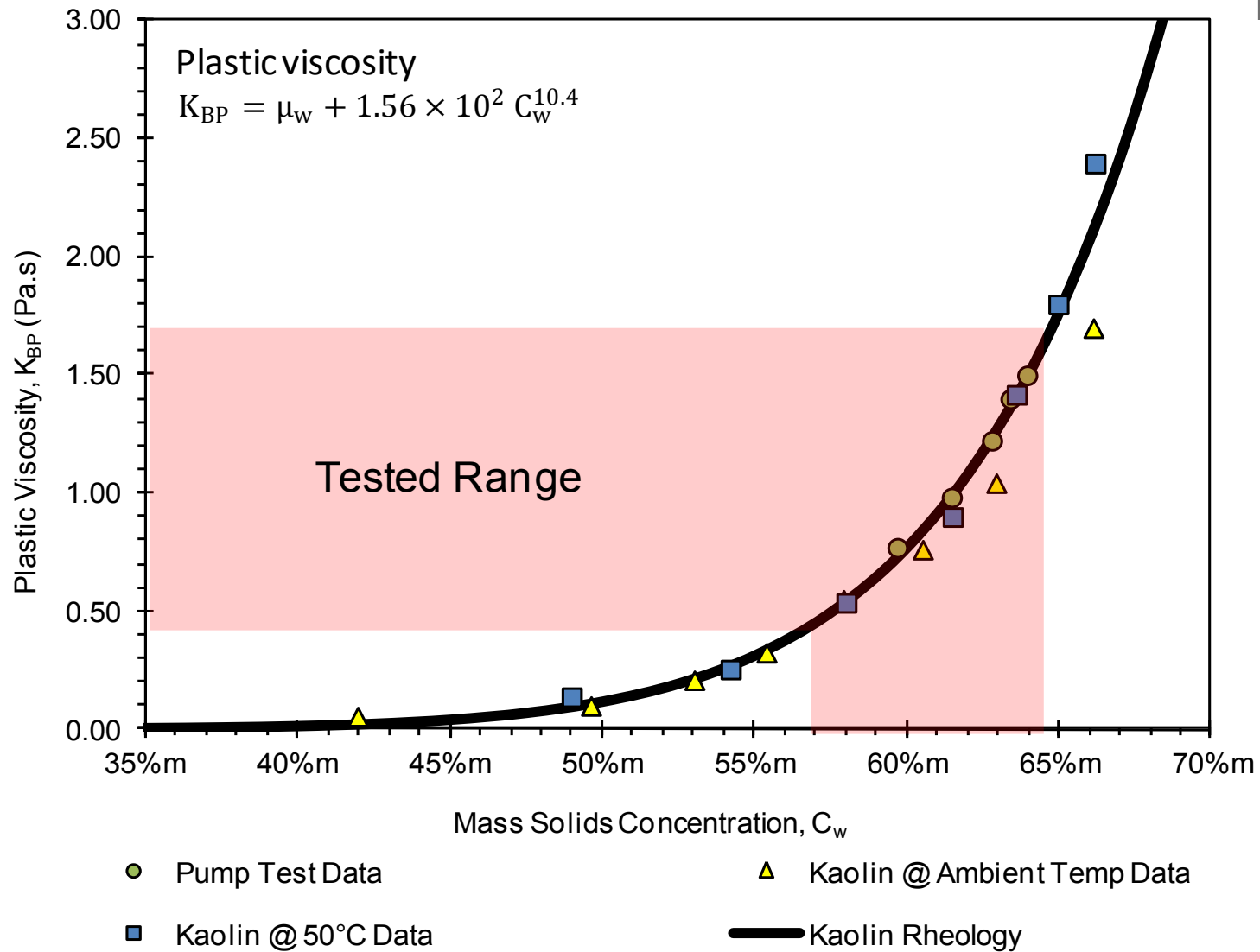
$$\tau_0 = \tau_y + K_{BP}\gamma$$

Kaolin Rheology



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Kaolin Rheology



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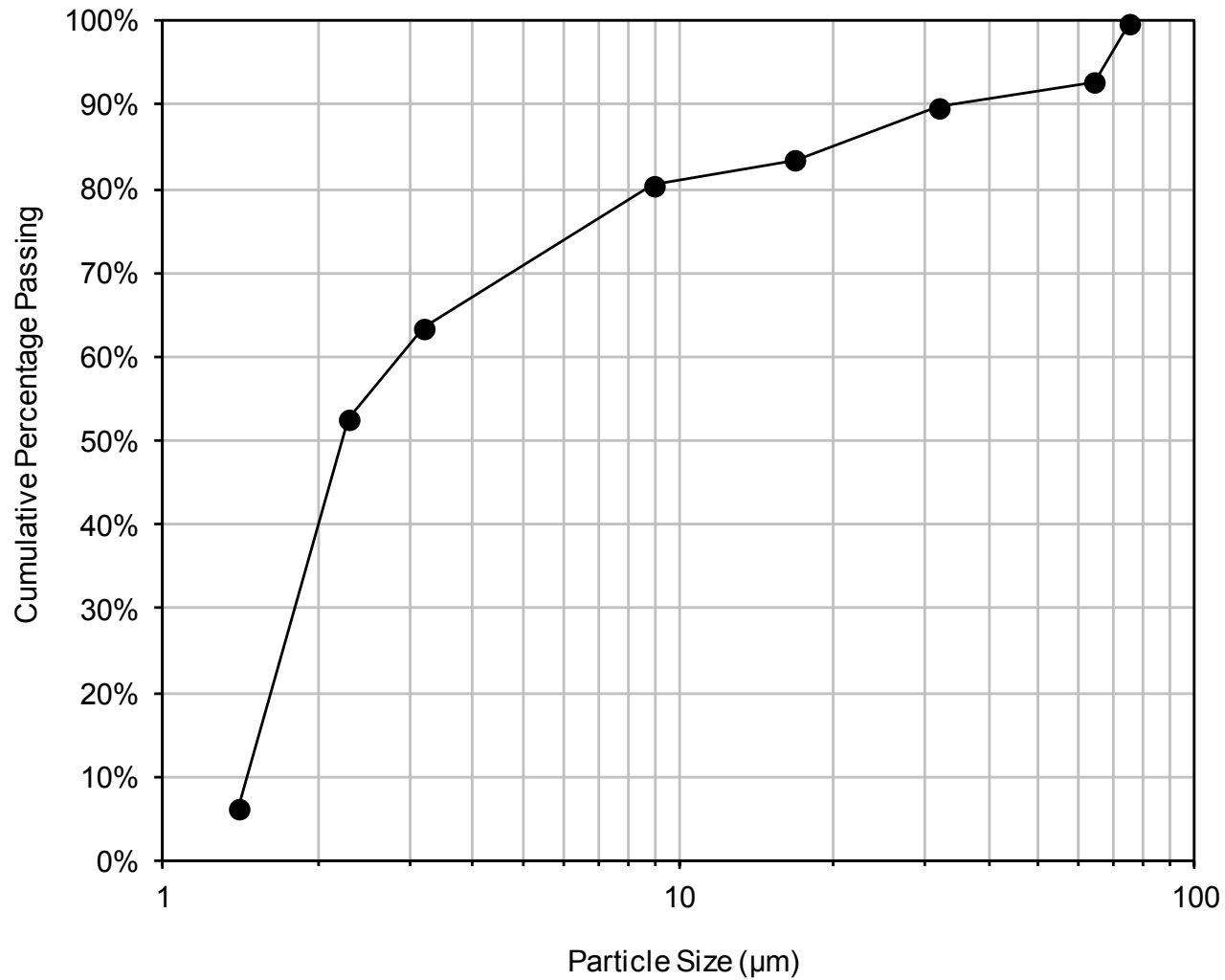
Kaolin Material Properties



- Solids Density: 2.6 t/m³
- d₉₀ Particle size: 34.5 μm
- d₅₀ Particle size: 2.2 μm

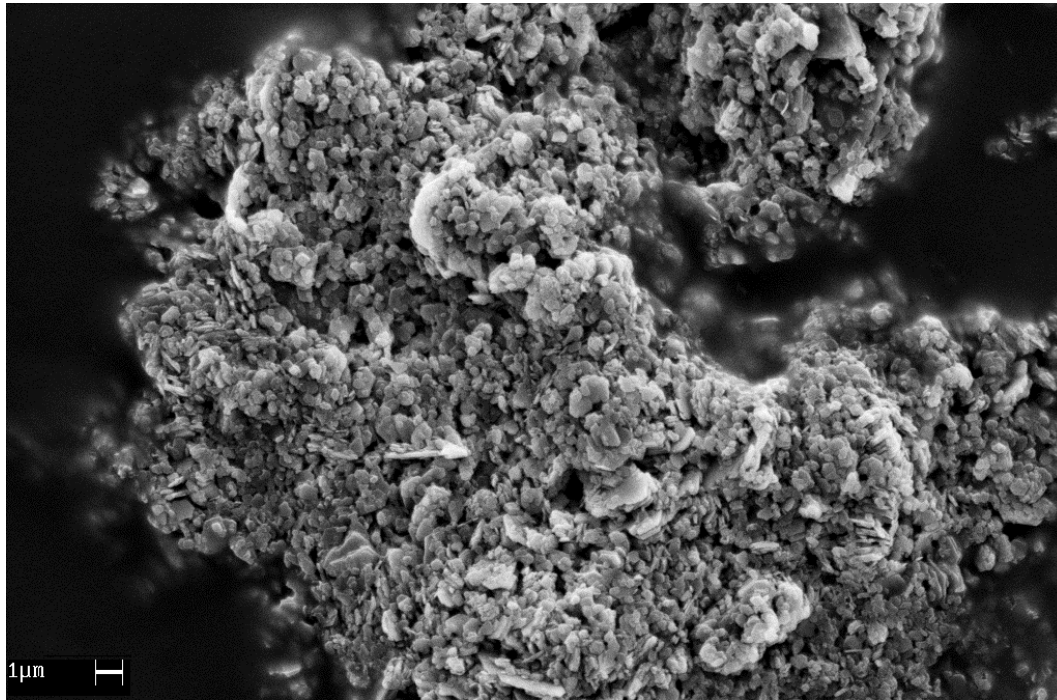
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Kaolin Material Properties



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Kaolin Material Properties



Kaolin Material Properties

- Paste Kaolin: Yield Stress = 1120 Pa



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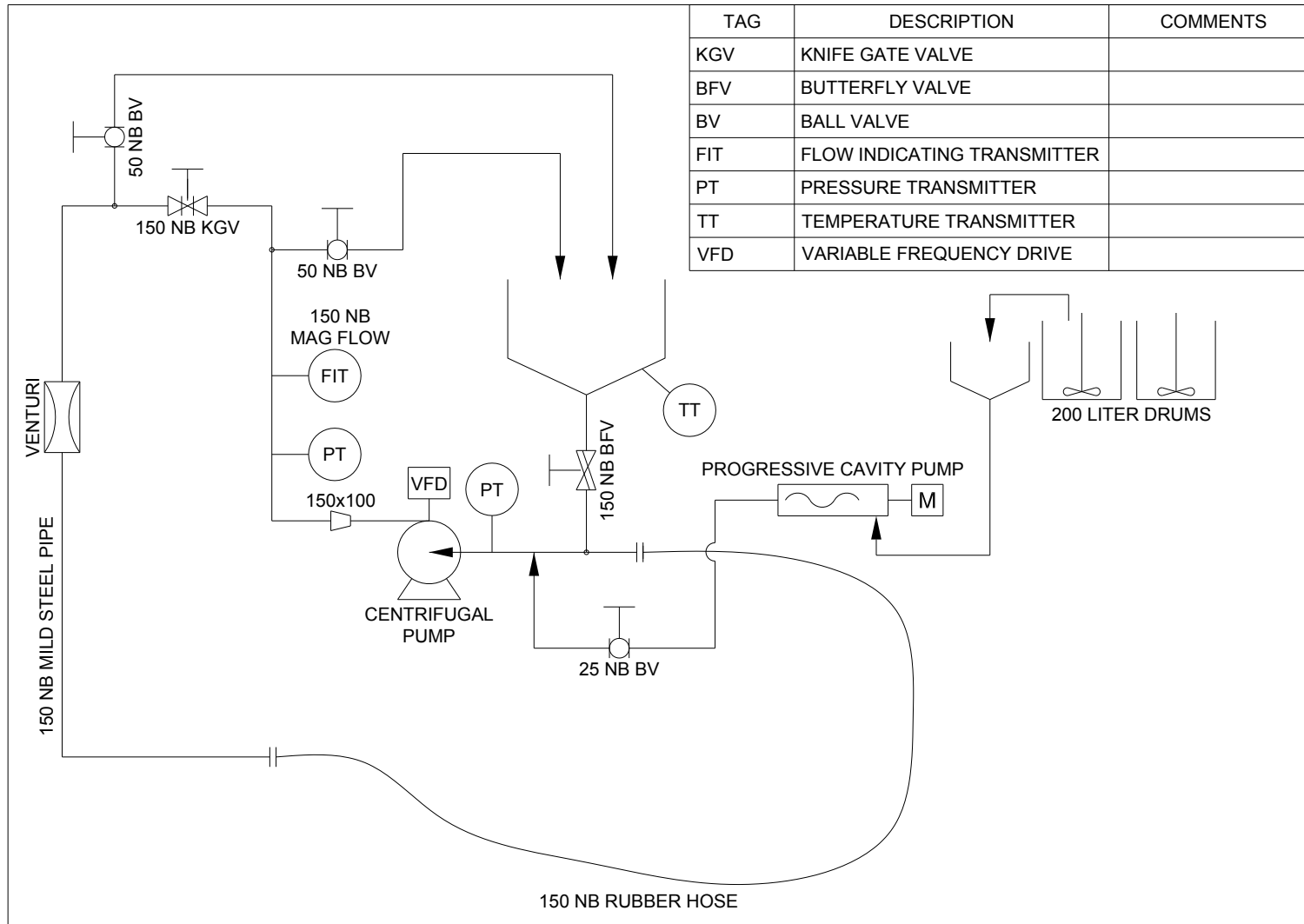
millMAX Pump

Attribute	millMAX Pump
Suction Size	100 NB
Discharge Size	150 NB
Impeller Size	400 mm
Impeller Tipe	Closed
Number of Vanes	4
Max. Solids Passing	45 mm



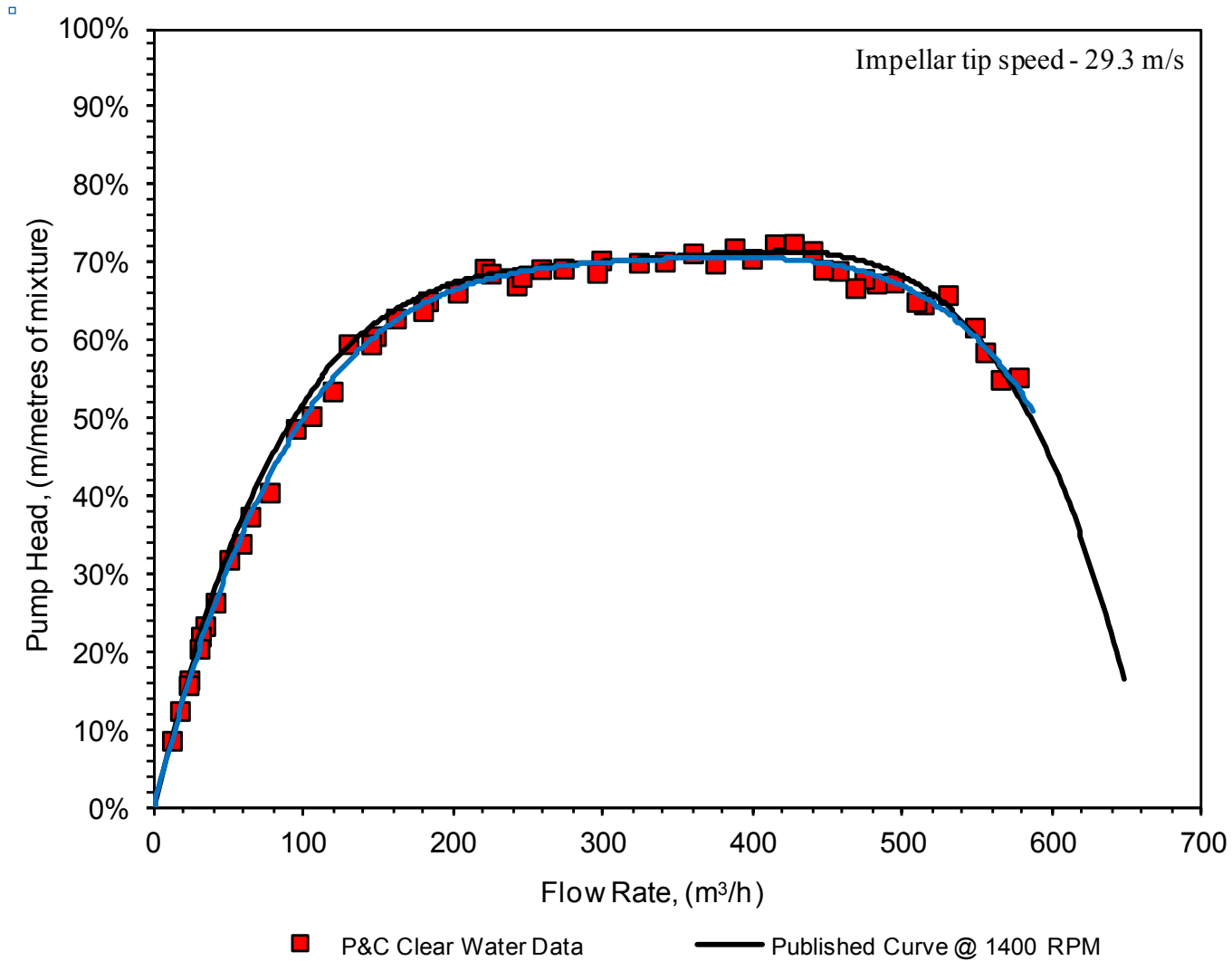
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Pump Test Rig



TAG	DESCRIPTION	COMMENTS
KGV	KNIFE GATE VALVE	
BFV	BUTTERFLY VALVE	
BV	BALL VALVE	
FIT	FLOW INDICATING TRANSMITTER	
PT	PRESSURE TRANSMITTER	
TT	TEMPERATURE TRANSMITTER	
VFD	VARIABLE FREQUENCY DRIVE	

Clear Water Test Data – Efficiency

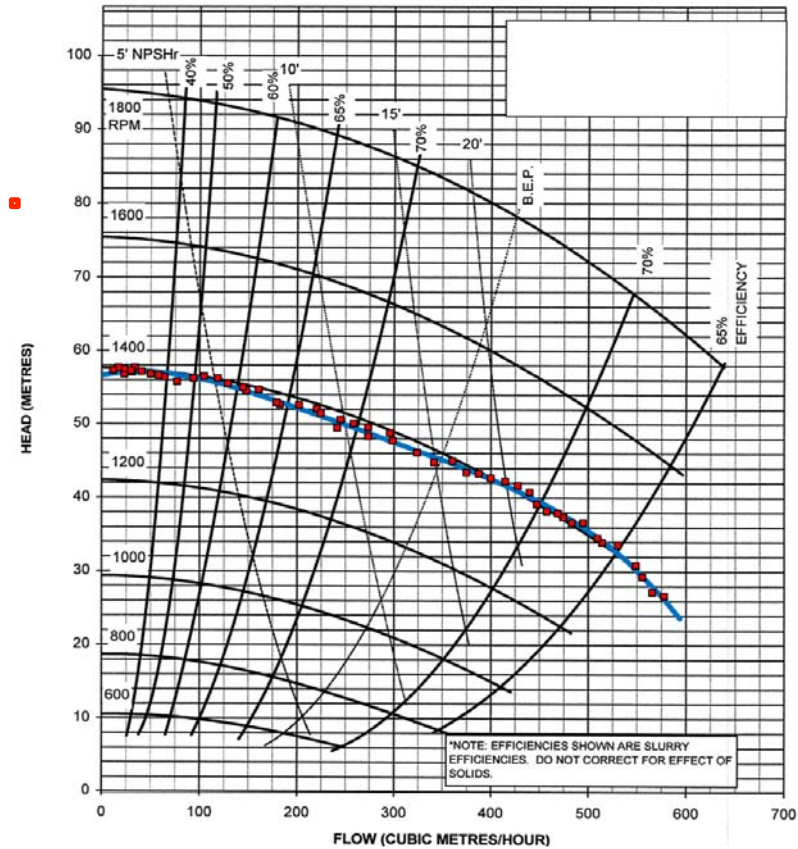


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Clear Water Test Data – Head

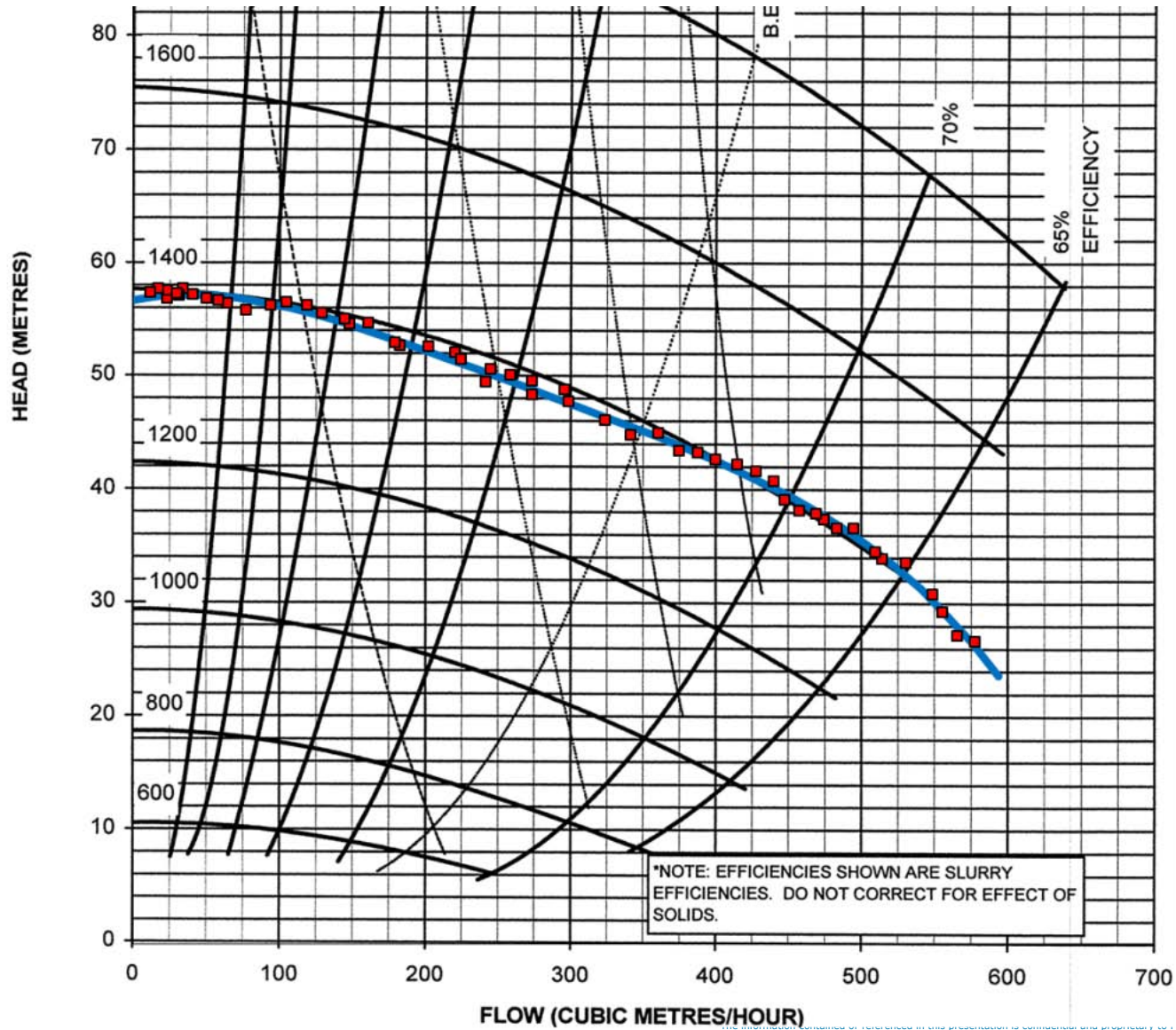


Krebs millMAX™ Pump		PERFORMANCE CURVE			
		DWG. # PCI50-447-SI		REV. 3 01/18/02	
PUMP SIZE 6' x 4' [150mm x 100mm]	POWER FRAME	IMPELLER PART NO. MMI50-447-00001			
		16" Ø [400mm]	4 VANE	CLOSED	1.75" [45mm] Ø MAX SOLIDS
*CURVE FOR CLEAR WATER PERFORMANCE: CORRECTIONS ARE TO BE MADE FOR SPECIFIC GRAVITY & VISCOSITY OF SLURRY. THE PUMP SPEED SHOULD BE CORRECTED FOR THE EFFECT OF SOLIDS IN THE SLURRY. REFER TO KREBS ENGINEERS FOR DETAILS.					

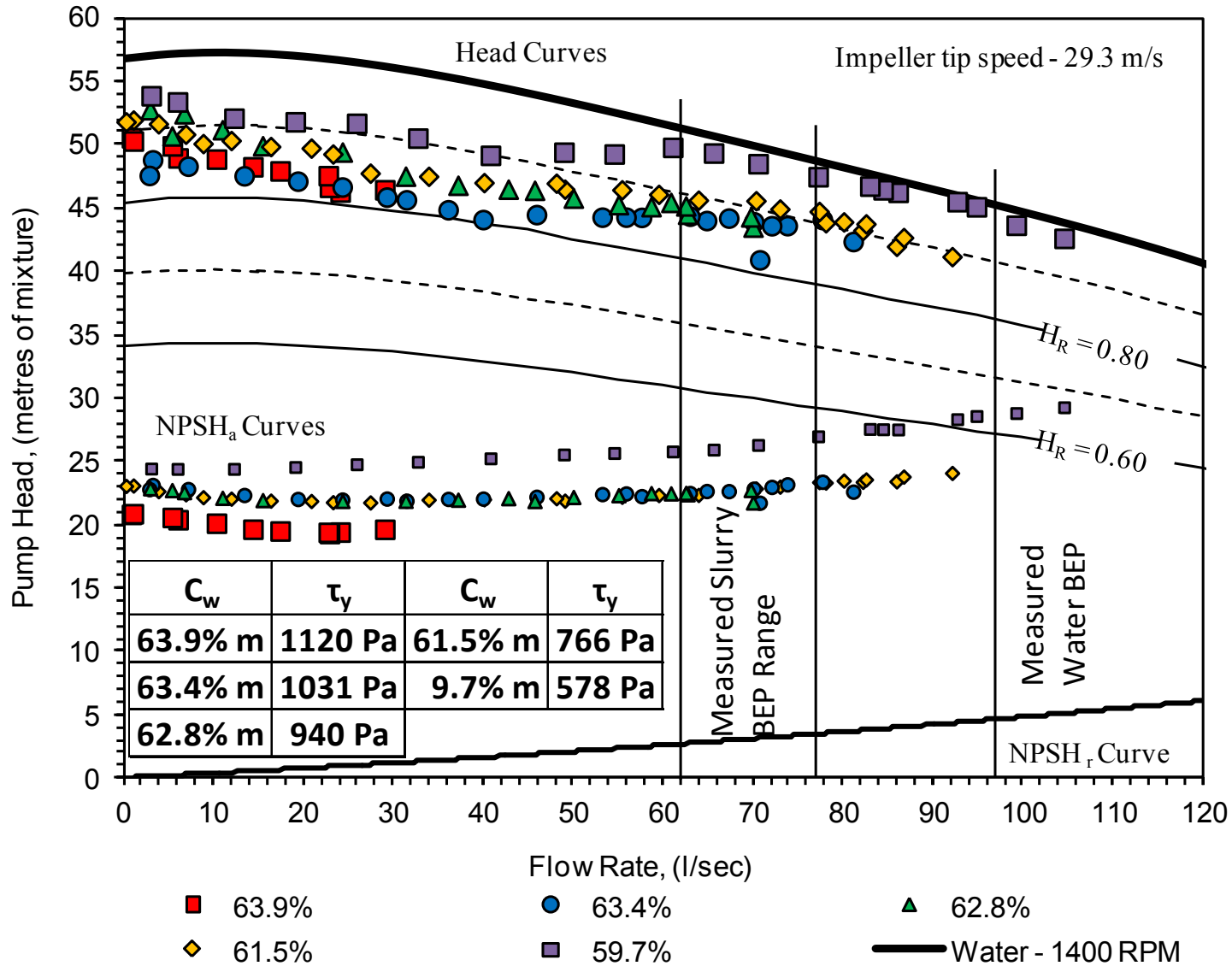


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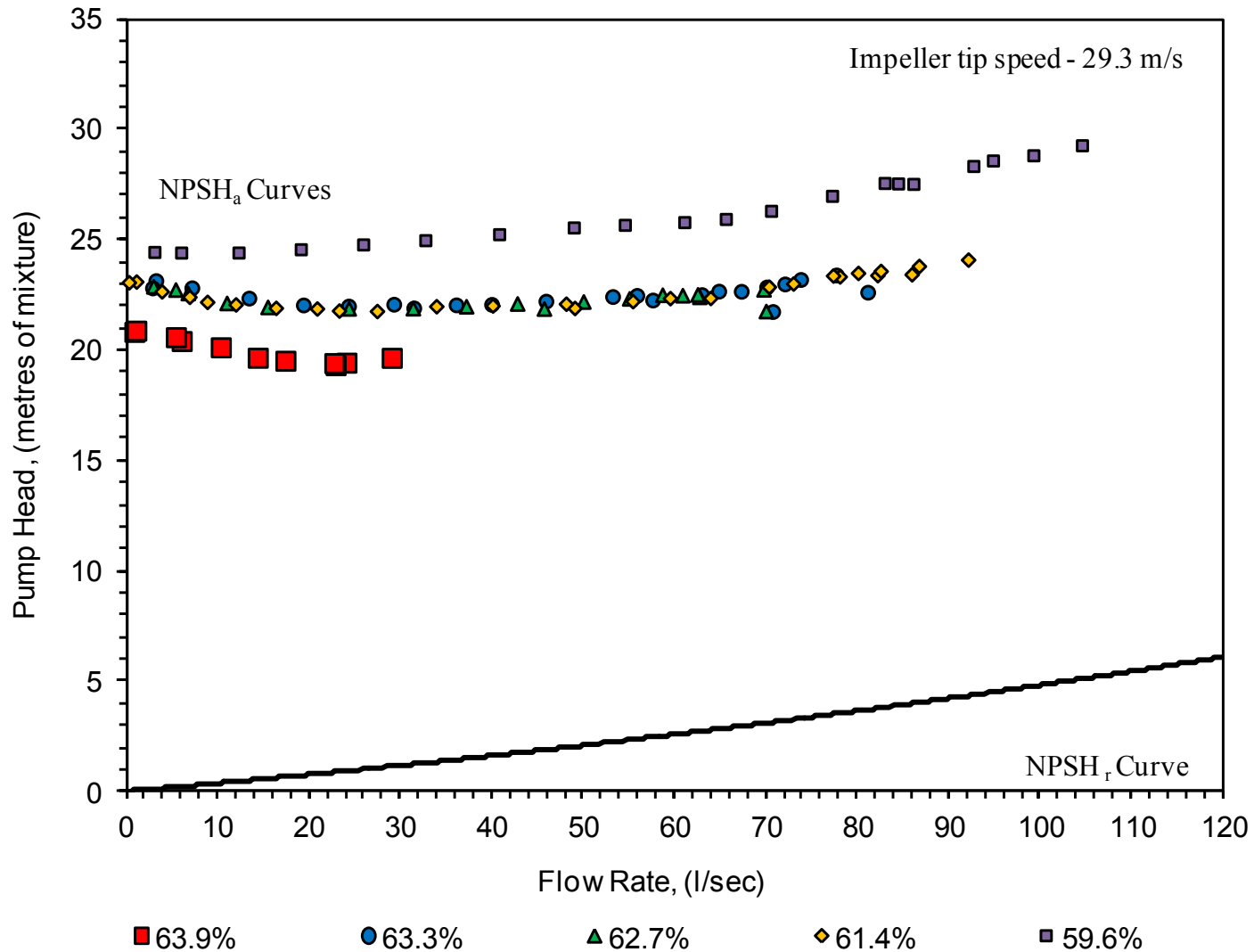
Clear Water Test Data – Head



Kaolin Test Data – Head

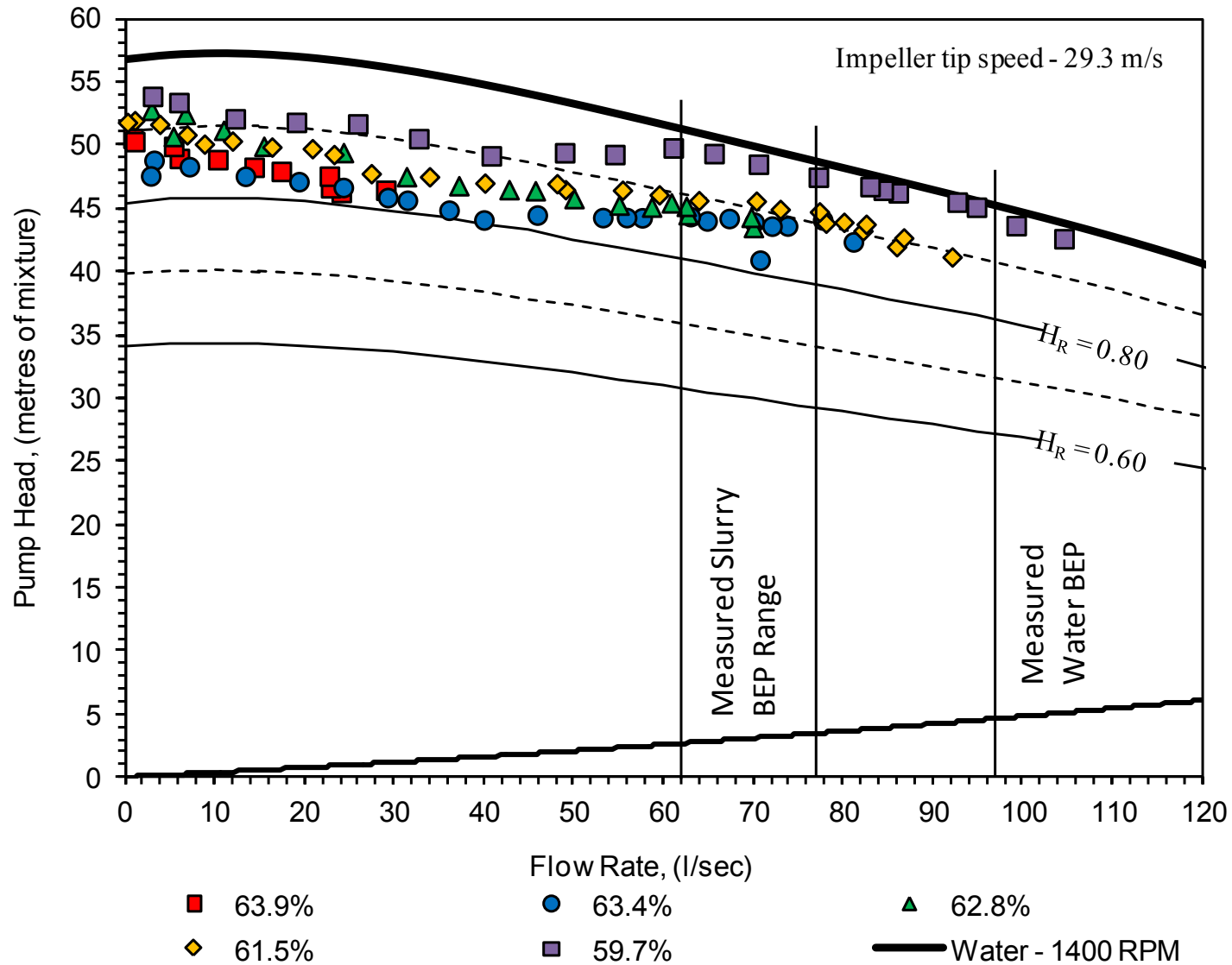


Kaolin Test Data – Head



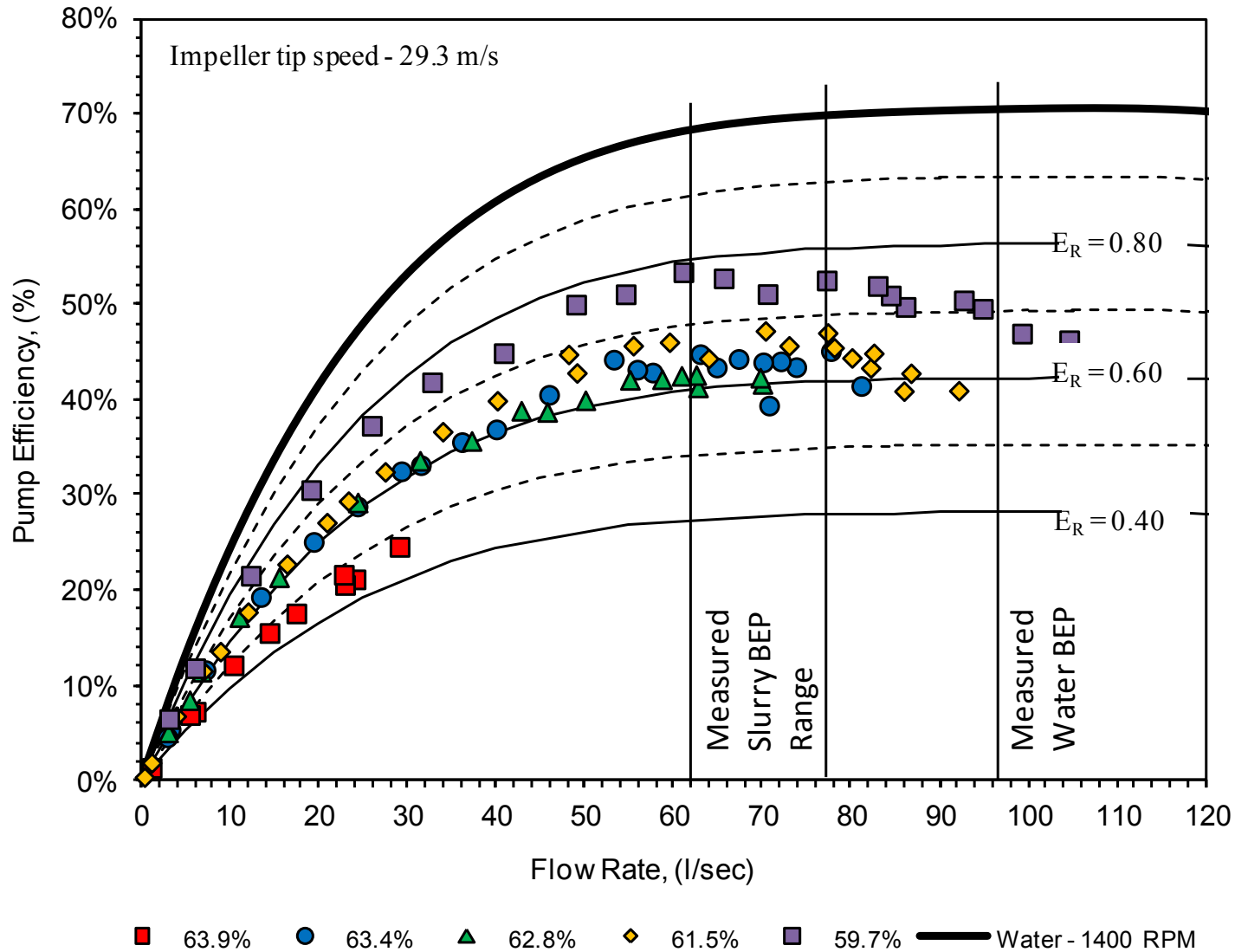
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Kaolin Test Data – Head



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Kaolin Test Data – Efficiency



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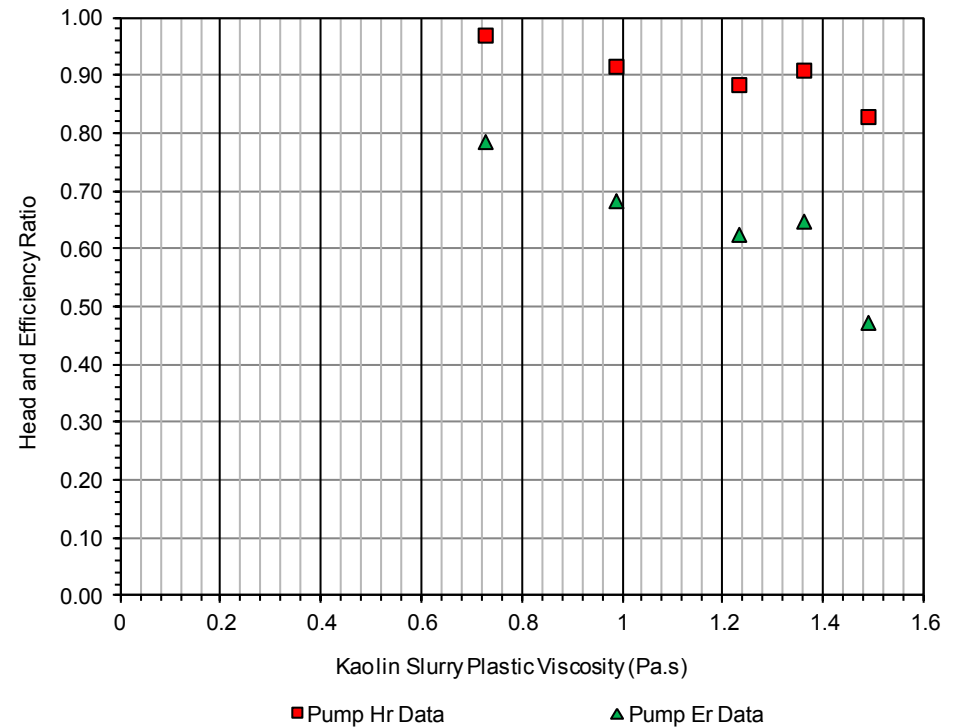
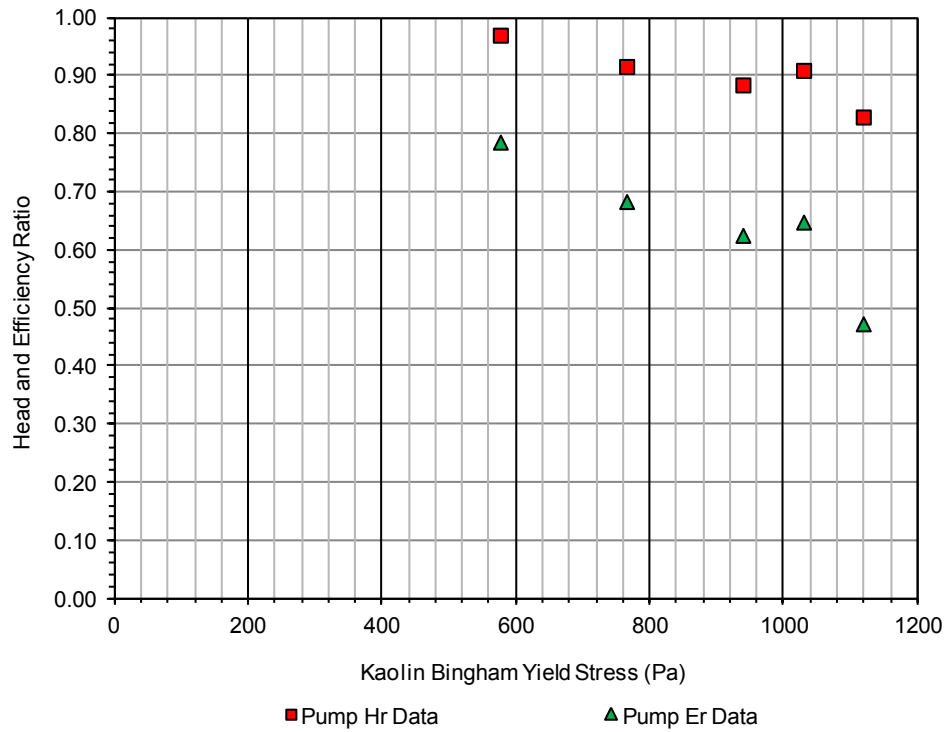
Pump Performance



C_w	K_{BP}	τ_y	Pump H_R data	Pump E_R data
63.9% _m	1.491 Pa.s	1,120 Pa	0.83	0.47
63.4% _m	1.363 Pa.s	1,031 Pa	0.91	0.65
62.8% _m	1.234 Pa.s	940 Pa	0.88	0.62
61.5% _m	0.989 Pa.s	766 Pa	0.91	0.68
59.7% _m	0.728 Pa.s	578 Pa	0.97	0.78

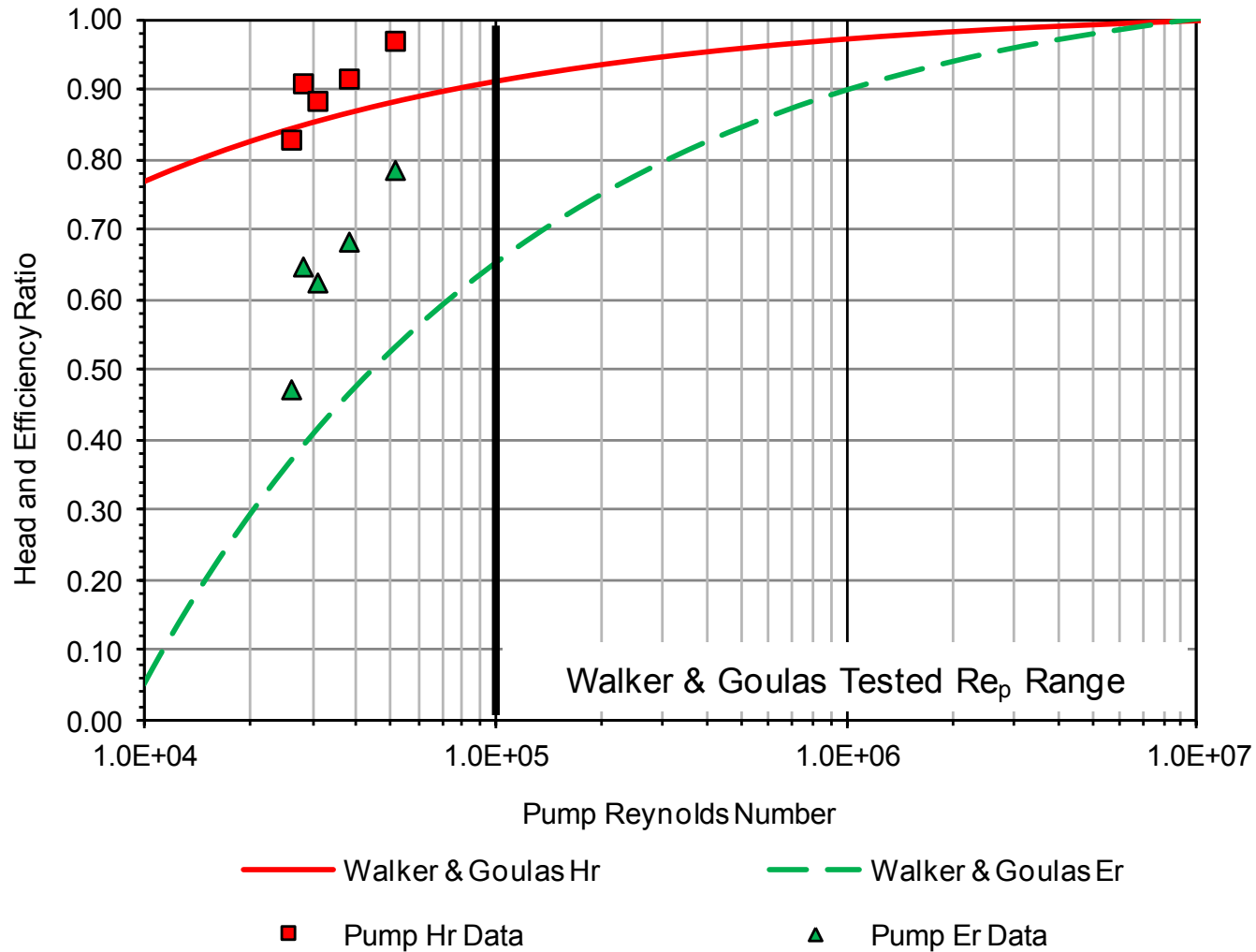
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Pump Performance



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Comparison with Walker & Goulas



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Summary of Findings



- Centrifugal pumps can pump very viscous high yield stress slurries
 - if sufficient $NPSH_a$ is provided
- The slurry head curves derate more at the low flow rate than at high flow rates
- The pump's BEP shifts to the left of the water performance curve
- The pump head and efficiency ratios are calculated at the pump BEP for slurry
- The pump head and efficiency performance decreases as the Bingham yield stress and plastic viscosity increases,
- Theoretical method provided by Walker and Goulas remains a very useful design tool
 - over predicts efficiency derating by more than 20% based on the measured data
 - provide a conservative lower bound for head derating estimates

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This paper demonstrates that it is possible to pump very viscous, high yield stress slurries with limited head and efficiency de-rating using centrifugal pumps, PROVIDED THAT POSITIVE SUCTION CONDITIONS ARE MAINTAINED AT ALL TIMES.

millMAX: PATENTED ON-LINE ADJUSTABLE WEAR RING BENEFITS

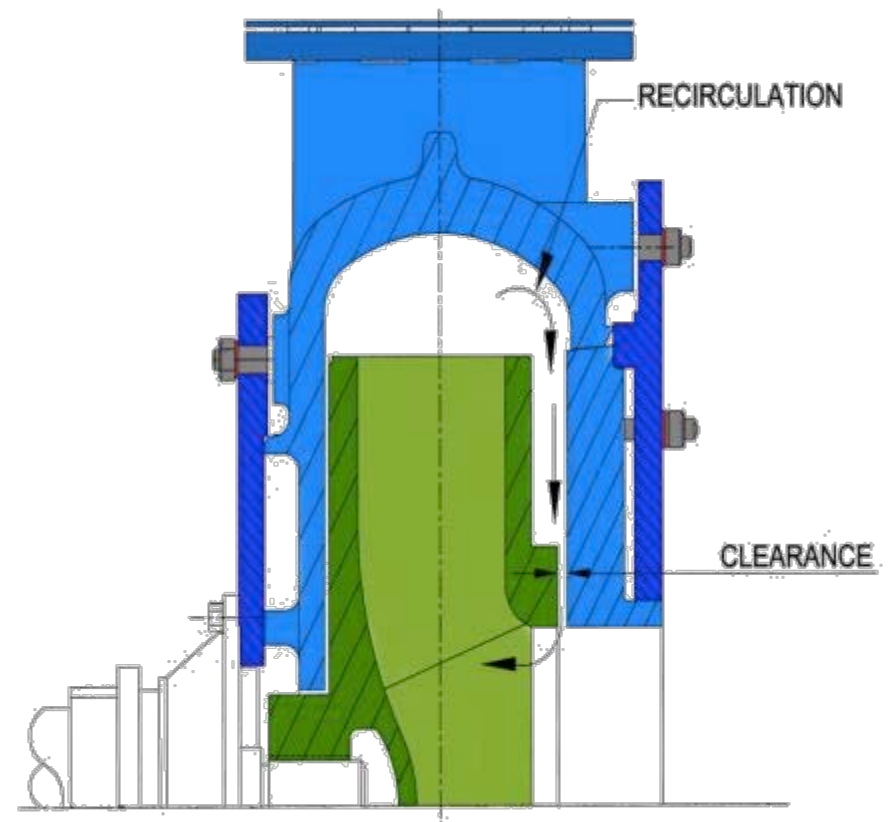


One Source

CONVENTIONAL FLOW RECIRCULATION

Based on Clearance Versus Pump
Speed

CLEARANCE		1400 RPM	1700 RPM
.300 mm	0.012"	3.52%	4.03%
.432 mm	0.017"	6.06%	6.65%
.508 mm	0.020"	7.92%	8.62%
.737 mm	0.029"	13.20%	13.90%
1.000 mm	0.040"	18.70%	19.60%

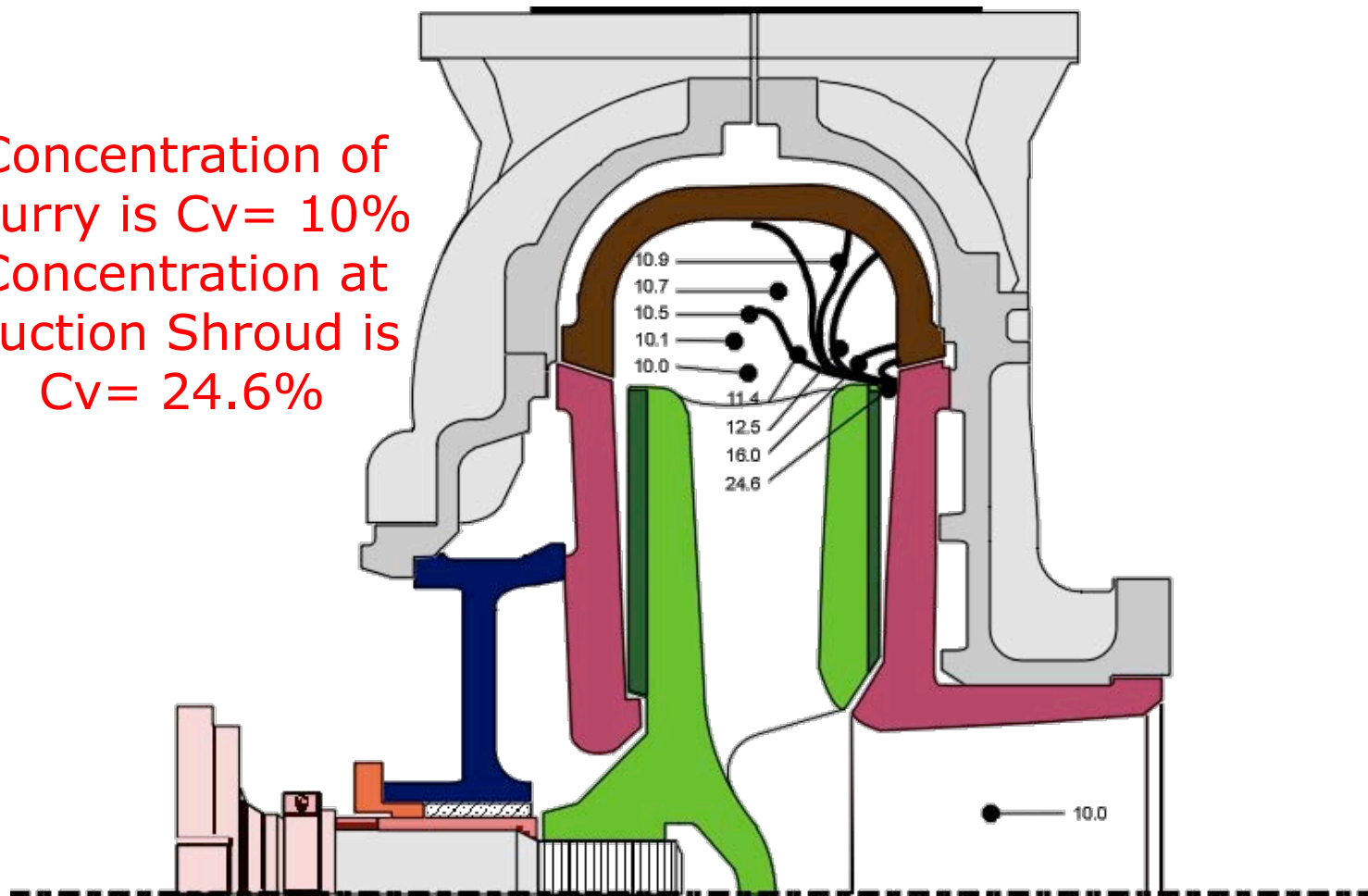


Ref: R.J. Stepanoff – Centrifugal and Axial Flow Pumps

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SOLIDS CONCENTRATION IS HIGHEST AT IMPELLER SHROUDS

Concentration of
Slurry is $C_v = 10\%$
Concentration at
Suction Shroud is
 $C_v = 24.6\%$

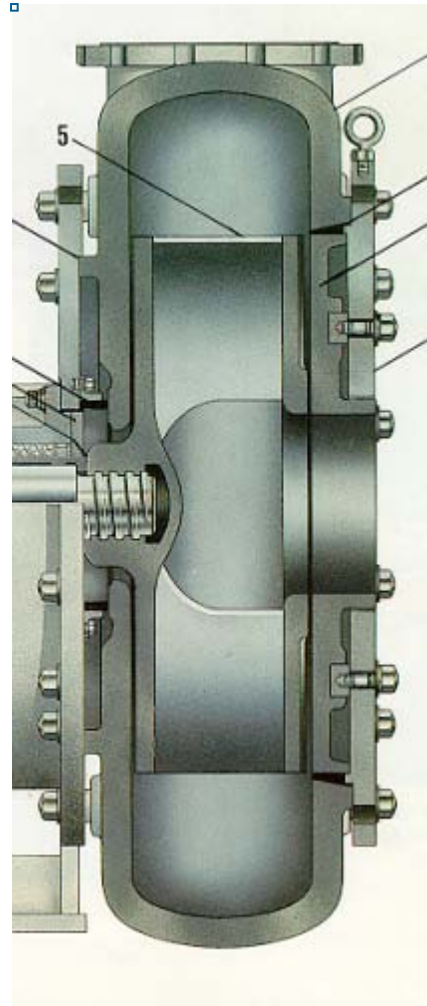


Reference: University of Kentucky Hydraulics Laboratory

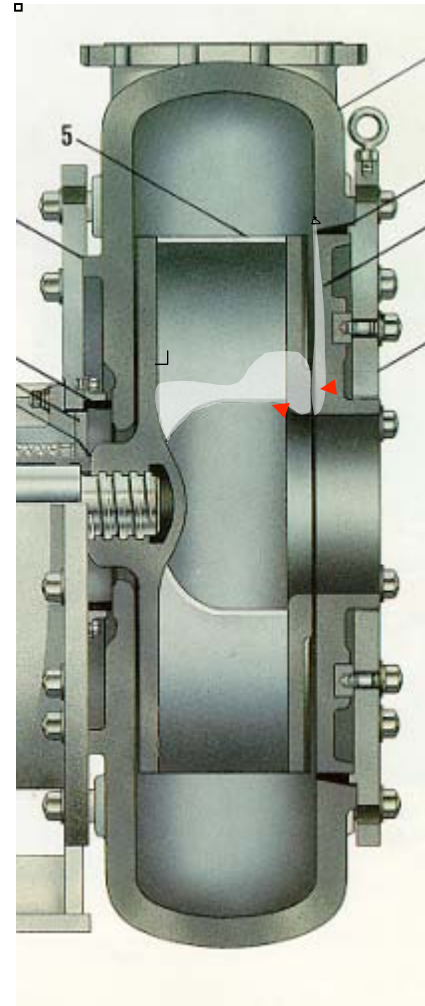
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SUCTION SIDE WEAR PATTERN

BEFORE



AFTER

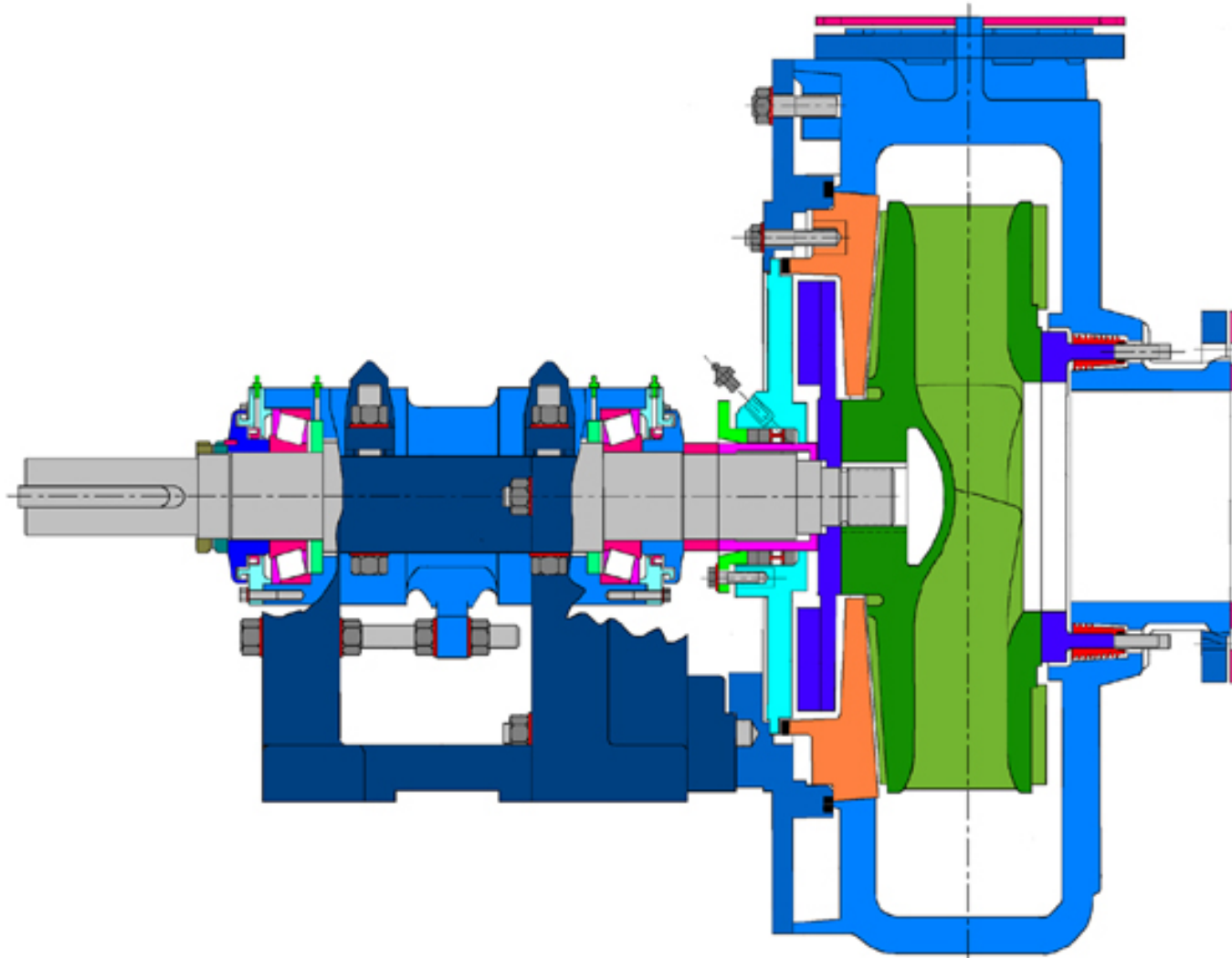


Suction-Side
Wear Zones

Solids Quickly
Erode Running
Clearances

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millMAX PATENTED SOLUTION



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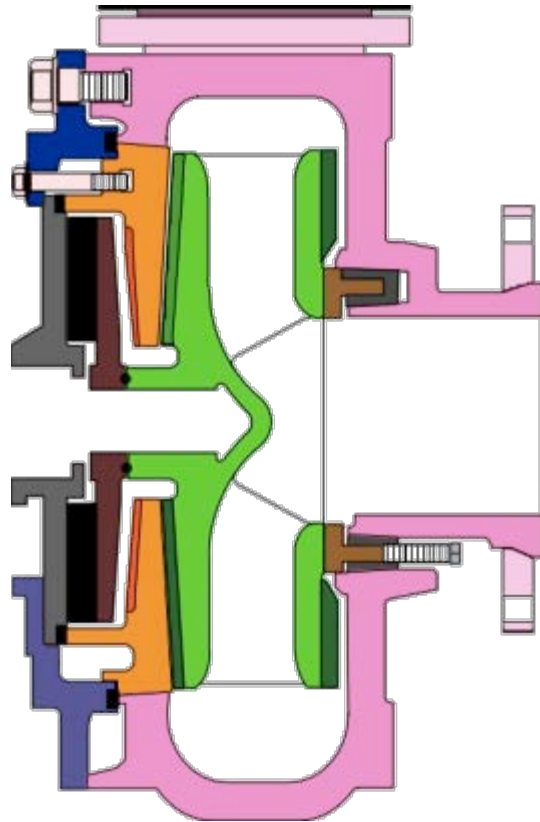
EXTERNAL WEAR ADJUSTMENT SCREW



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SETTING CLEARANCES

Adjustments Can be Done Throughout the Service Life of the Parts:



- **While the pump is **running**.**
- **Without disconnecting the drive.**
- **Without moving the impeller and shaft assembly.**
- **Without disturbing guards or v-belt drive.**

KREBS millMAX RESULTS



Wear Life Increases 1^{1/2} to 3 Times



millMAX Impeller after
1700-2000 hours



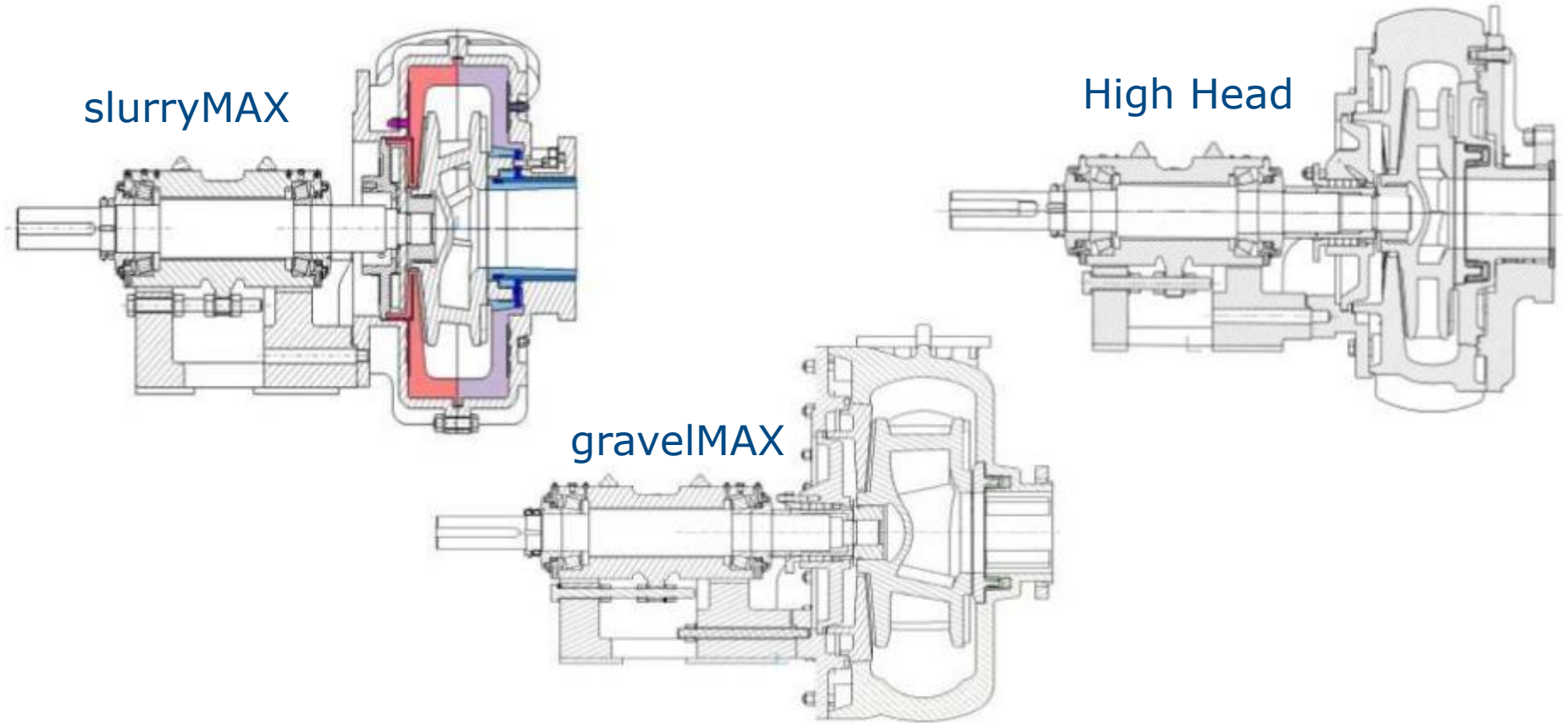
GIW at 550-750 hours

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millMAX™ Patented Solution



Integrated in the slurryMAX, High Head and gravelMAX designs



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Acknowledgements



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