

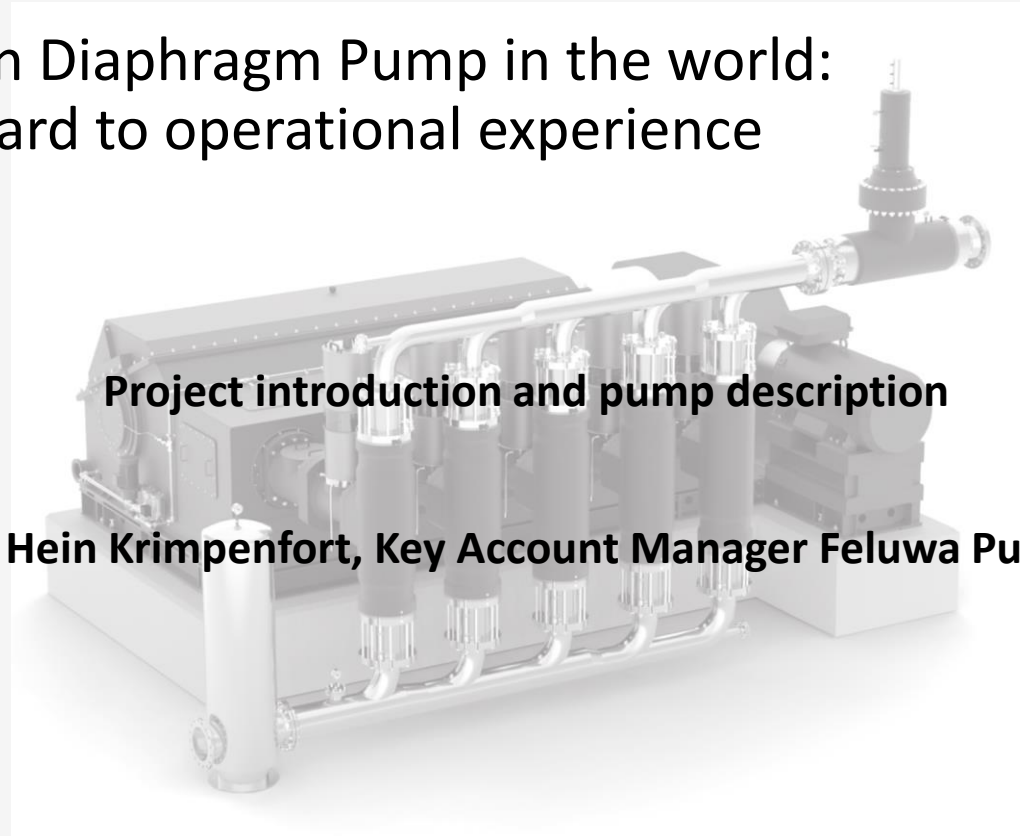
The largest Piston Diaphragm Pump in the world: from drawing board to operational experience

Hein Krimpenfort, FELUWA PUMPS, Germany

Brad Ricks, Brass Engineering, Unites States



The largest Piston Diaphragm Pump in the world:
from drawing board to operational experience



Project introduction and pump description

By Hein Krimpenfort, Key Account Manager Feluwa Pumps

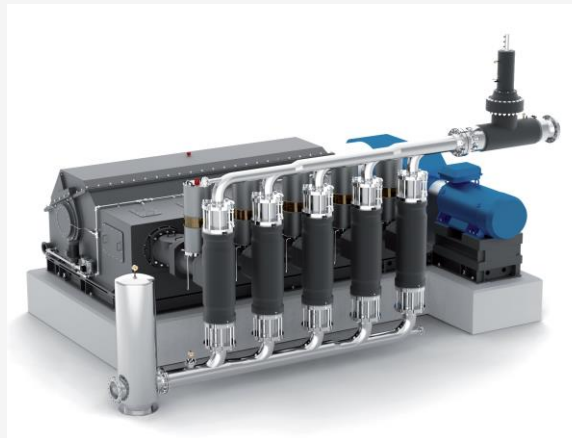
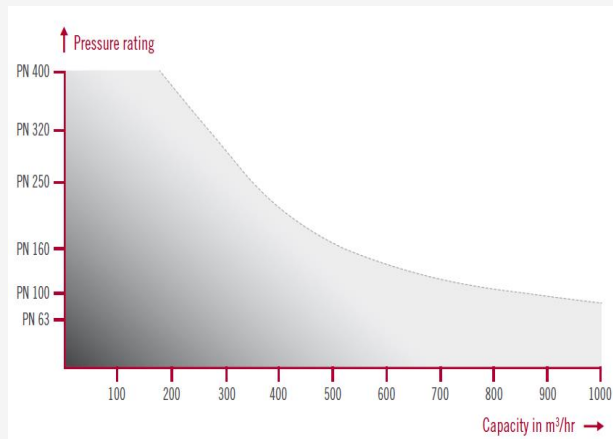
Boleo Key Project Data

- Location : Santa Rosalia, California Sur, Mexico
- Owner : Minera y Metalurgica del Boleo (MMB)
- Type of operation : Copper /Cobalt mine and processing plant
- Capacity : 3.1 MTY
- EPCM contractor : Fluor ICA
- Pipeline engineer : Brass Engineering International, San Ramon, Ca, USA
- Start of construction : 2010
- Start of operation : 2014
- Proven reserve : 70 MT
- Estimated mine life : 22 years



Boleo Pump Data

- Type of pump : Double hose piston diaphragm pump
- Pump configuration : 5 cylinder single acting
- Max. capacity : 1.000 m³/hr (@ 9.000 kPa)
- Max. pressure : 32.000 kPa (@ 200 m³/hr)
- Absorbed power : 3.000 kW (at max. duty)
- Pump manufacturer : Feluwa Pumps, Germany
- Start development : 2008
- First pump supplied : 2011
- In operation : 2014

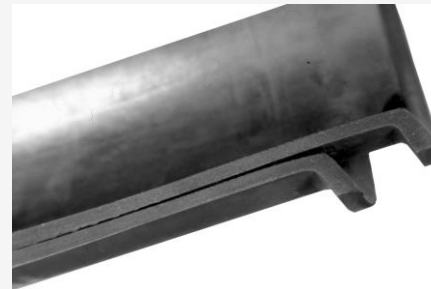
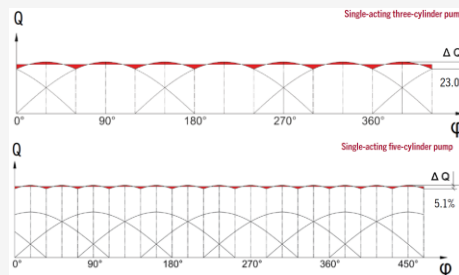


Features of QGK design

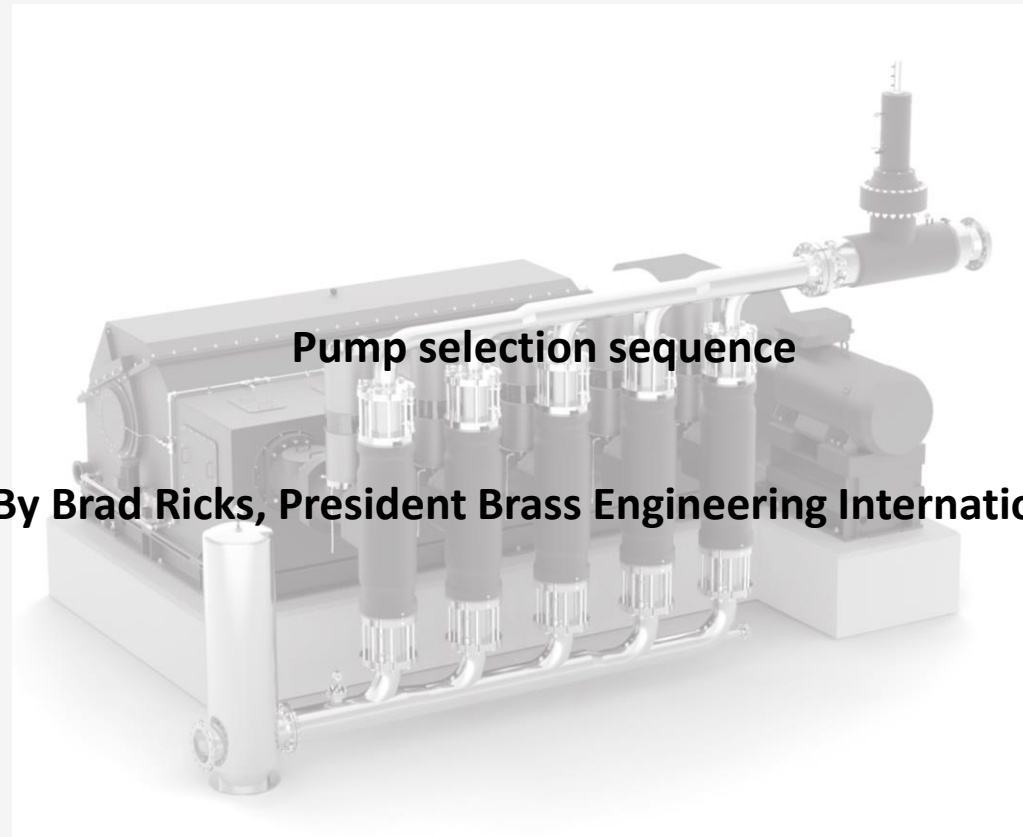
- Pulsations
 - 3 cylinder single acting : 23% peak to peak
 - 2 cylinder double acting : 46% peak to peak
 - 5 cylinder single acting : **5% peak to peak**

- Diaphragm design
 - Double hose : in case of diaphragm damage, pumping can continue

- Valves design
 - Ball valves : only 3 wearing parts (ball, seat, guide)
 - Smaller valves : reduce NPSHr, increased safety during maintenance
 - Quick change : Swing out cassettes enable valve part replacement < 30 min.



The largest Piston Diaphragm Pump in the world: from drawing board to operational experience



Pump selection sequence

By Brad Ricks, President Brass Engineering International

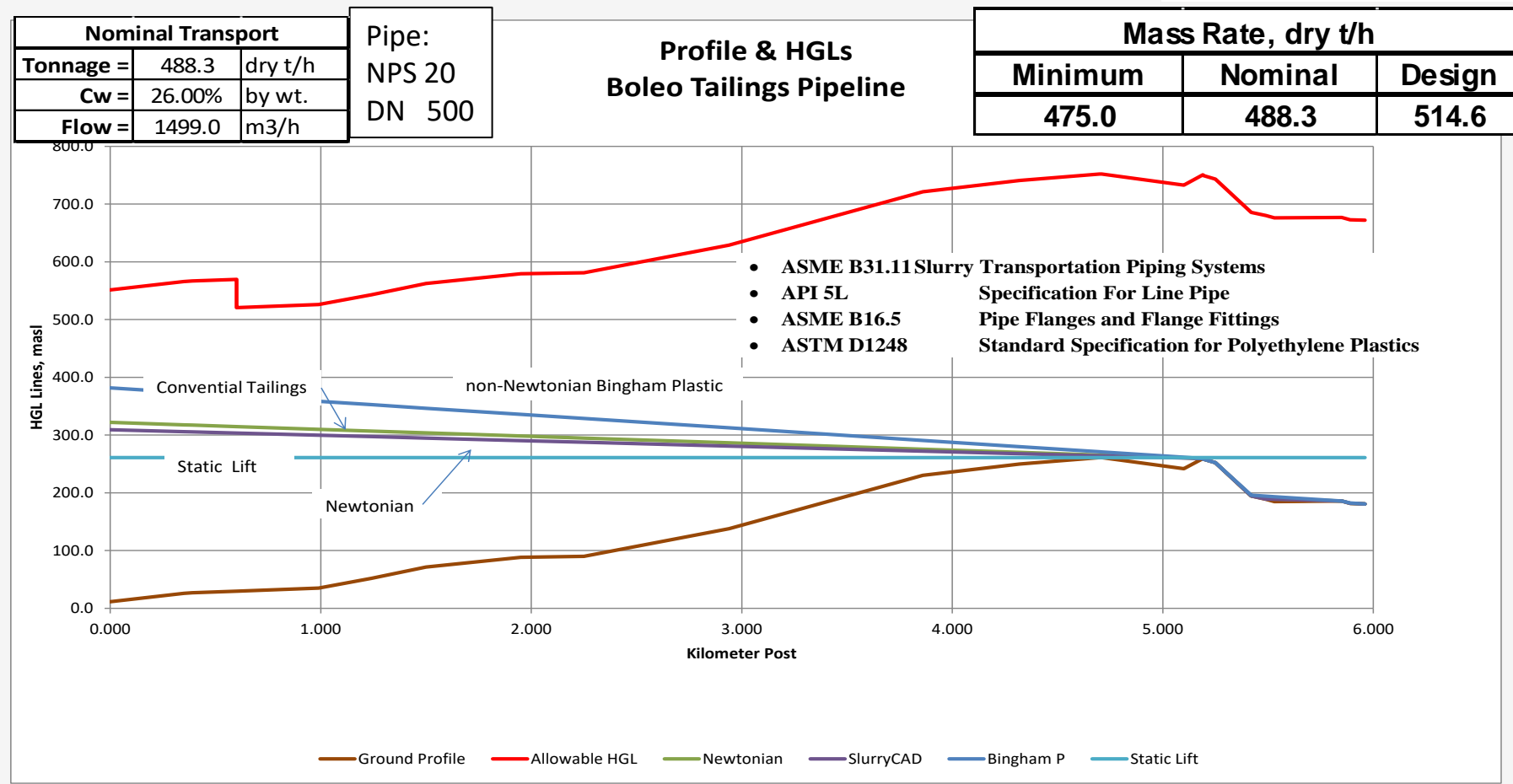
Pump selection sequence

- Specified Capacity Range
- Tailings Pipeline Route
- Tailings Slurry Properties

- Pumping Duty
- Availability
- Costs

Pump selection sequence, pipeline and route

Specified Capacity Range



Slurry data

- Liquid

- Temperature : 36° C (97° F)
- Liquid SG : 1.06
- pH : 5 - 6 (**corrosive**)
- Viscosity : 0.00080 Pa-s

- Solids

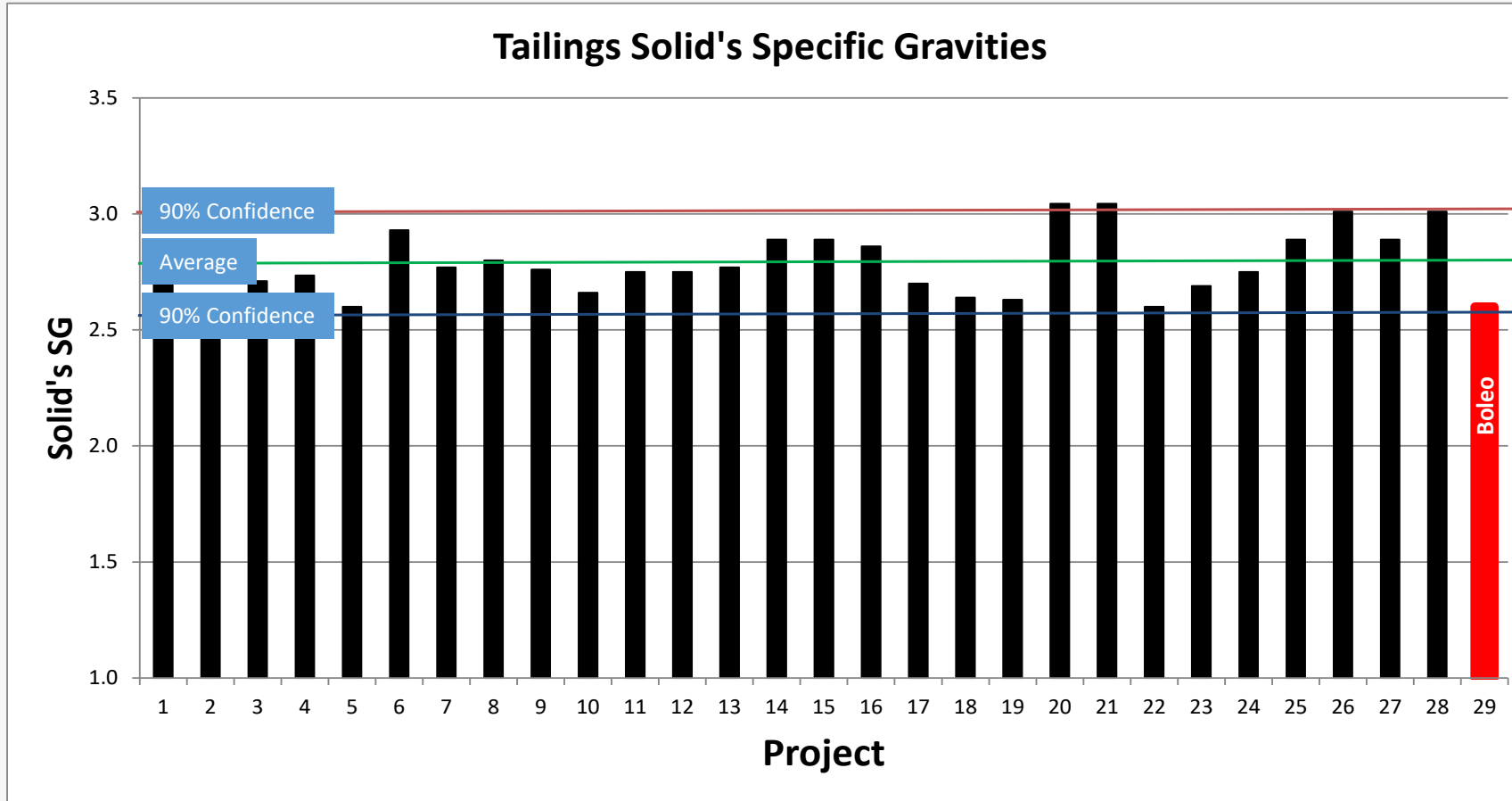
- Solids SG : 2,6 operating data
: 2,06 initial data (light)

- Equilibrium moisture : 0%

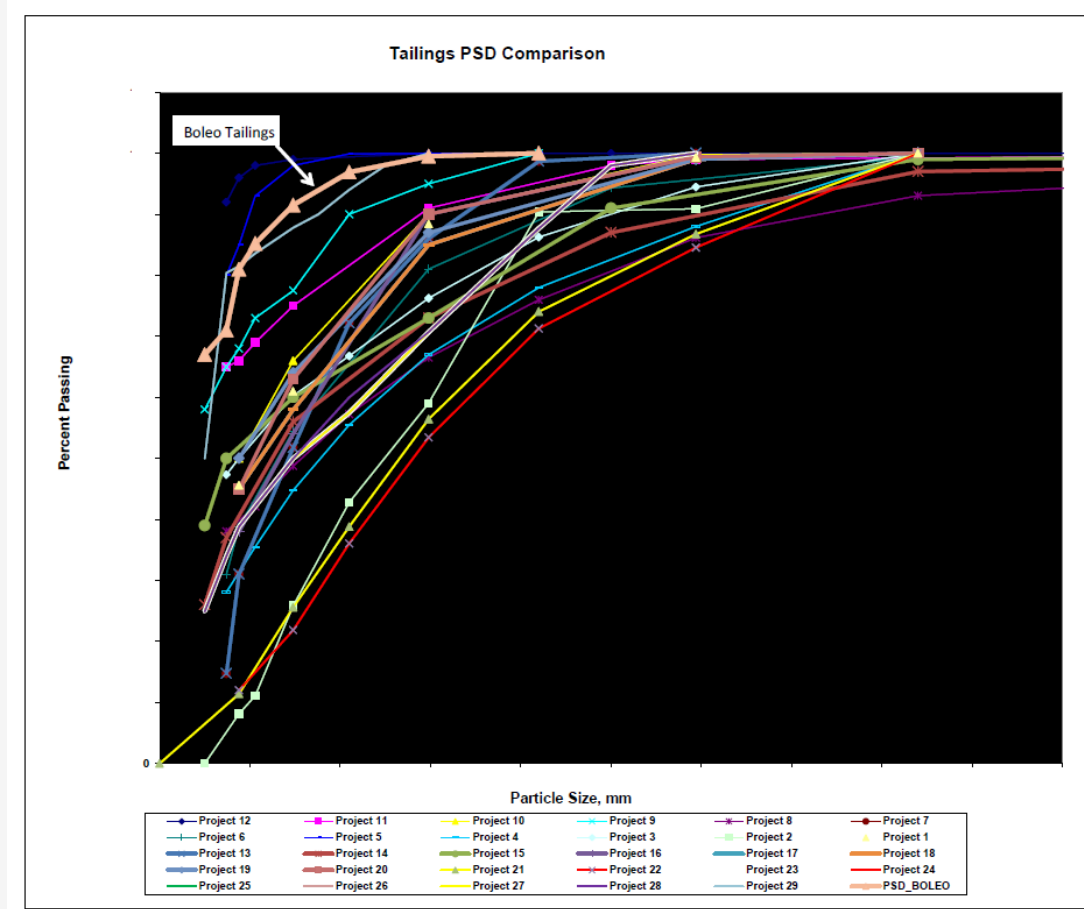
Solid size distribution

Tyler Mesh	Particle Diam (mm)	Percent Passing
65	0.210	100.0
100	0.150	99.5
150	0.110	96.9
200	0.070	91.5
270	0.050	85.2
325	0.040	81.0
400	0.040	71.0
500	0.030	67.0

Solids SG Comparison with other Tailings



Particle Size Distribution, Comparison with other Tailings

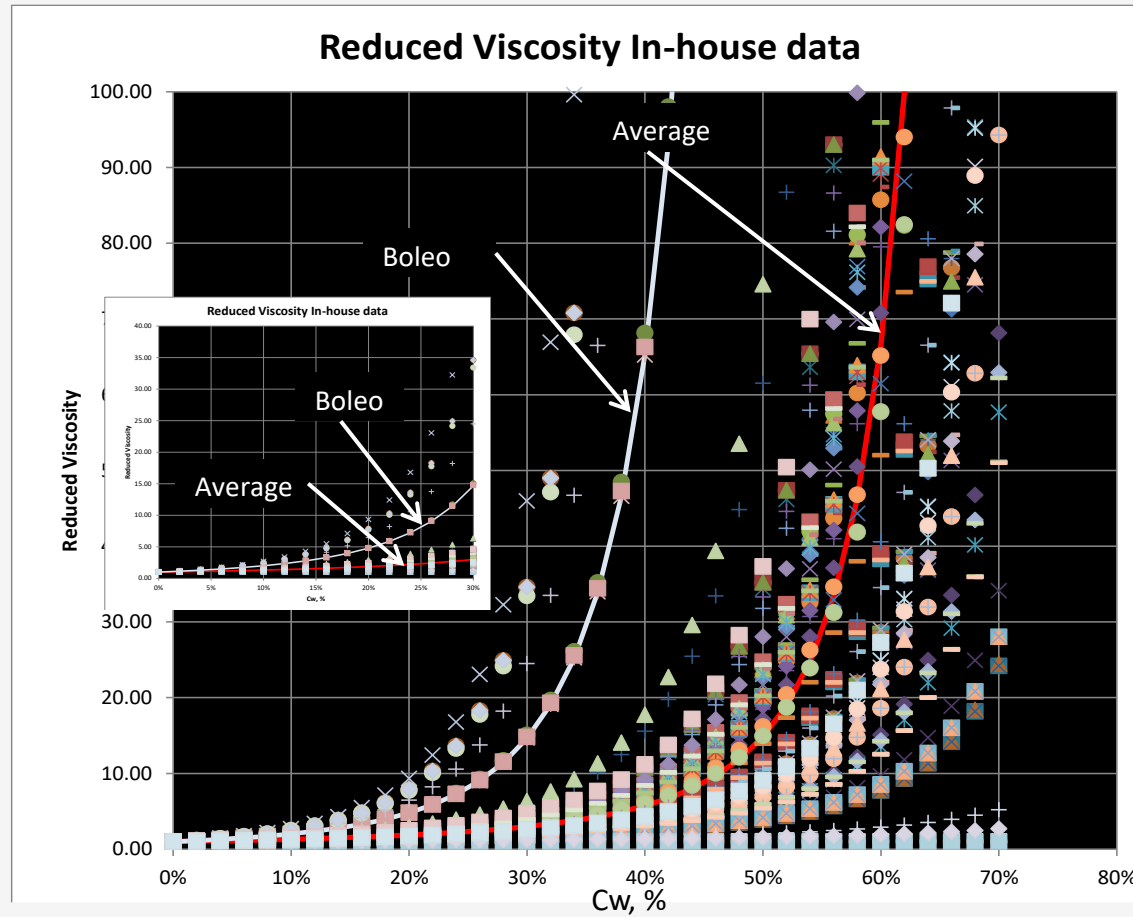


Slurry Data

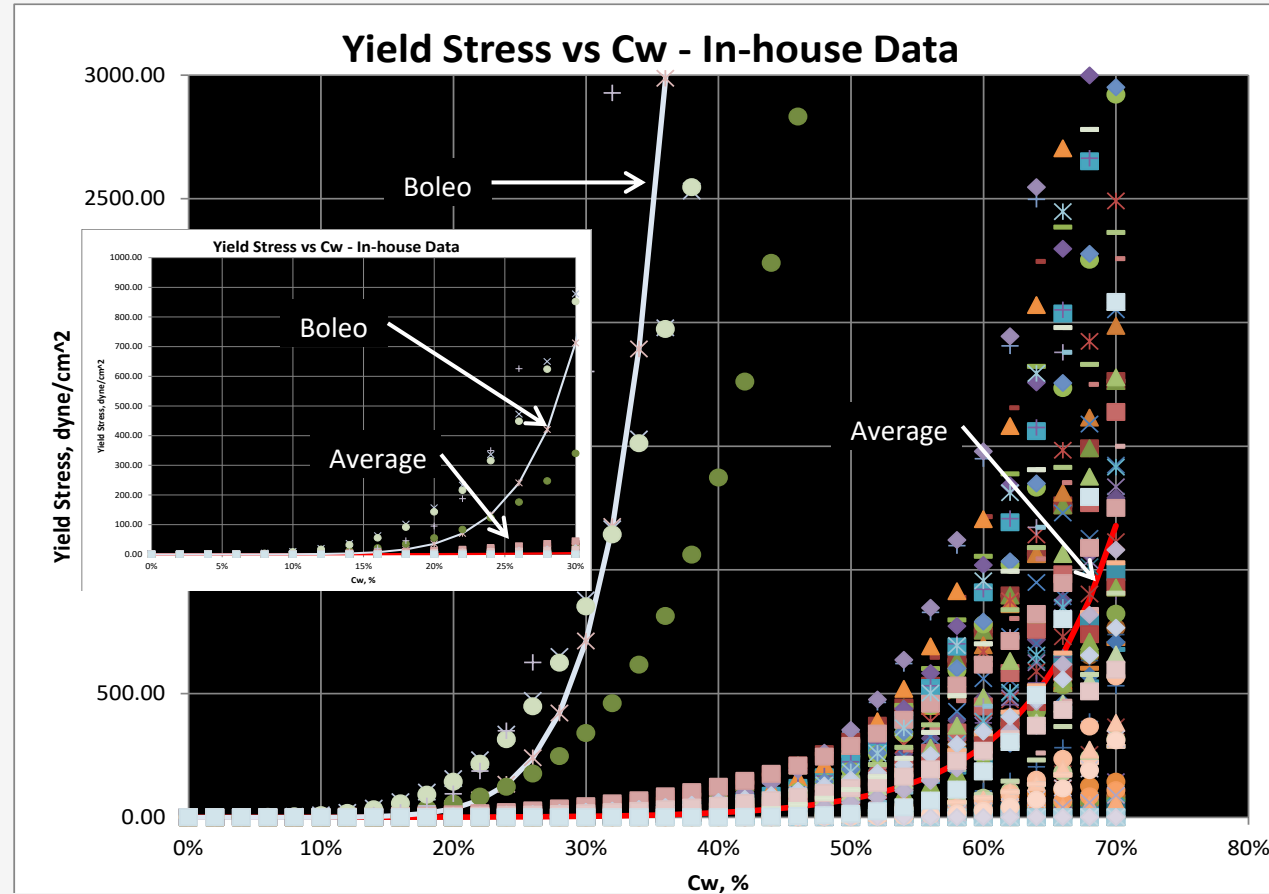
- Slurry

- Cw	: 22 – 28%
- Slurry SG	: 1,219 – 1,271
- Viscosity	: 0,0047 – 0,0092 Pa-sec
- Yield stress	: 7,02 -42,1 Pa

Viscosity, Comparison with other Tailings



Yield Stress, Comparison with other Tailings



Pump Duty

- Nominal Capacity: 488 dry t/h, solids, SG=2,6, Cw=26%, Flow= 1500 m³/h

Operating Conditions

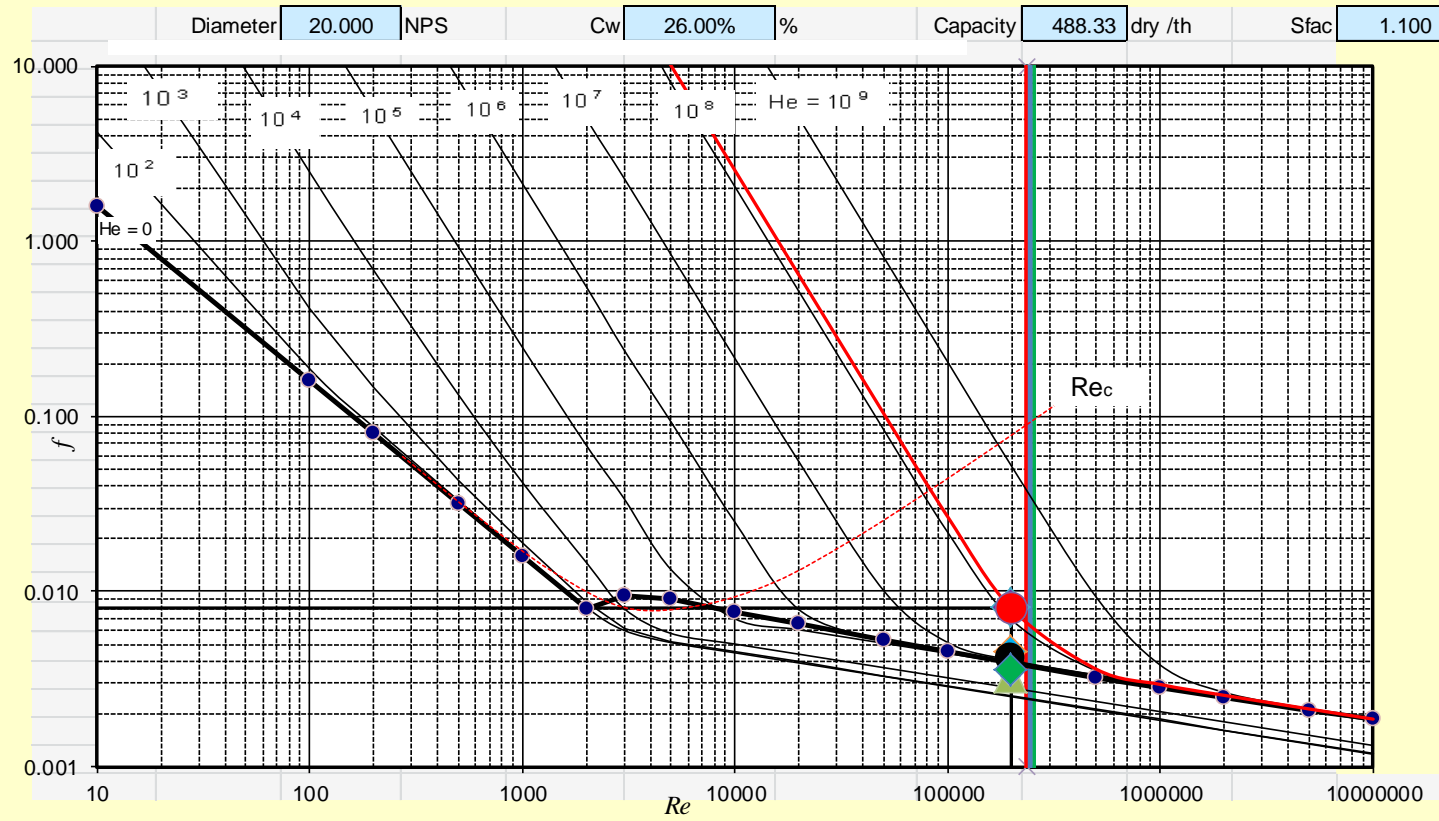
User: blr
Date: 2017-02-04

Operating Conditions

Dry solid throughput	t/d	11720	
Availability	%	100.0%	
Throughput/pipeline	t/h	488.3	
Weight Concentration	%	26.00%	26.0%
Solid/Liquid Volume Ratio		0.143	0.143
Volume Concentration	%	12.5%	12.5%
Slurry Specific Gravity		1.253	1.253
Flowrate Per Pipeline	m ³ /h	1499.0	1499.0
Flowrate Per Pipeline	gpm	6600.2	6600.2
Plastic Viscosity	cP	7.2	7.2
Yield Stress	dyn/cm ²	240.7	240.7

Centrifugal Pump Overall Efficiency	76.6%	2474	kW
PD Pump Overall Efficiency	91.2%	2078	kW

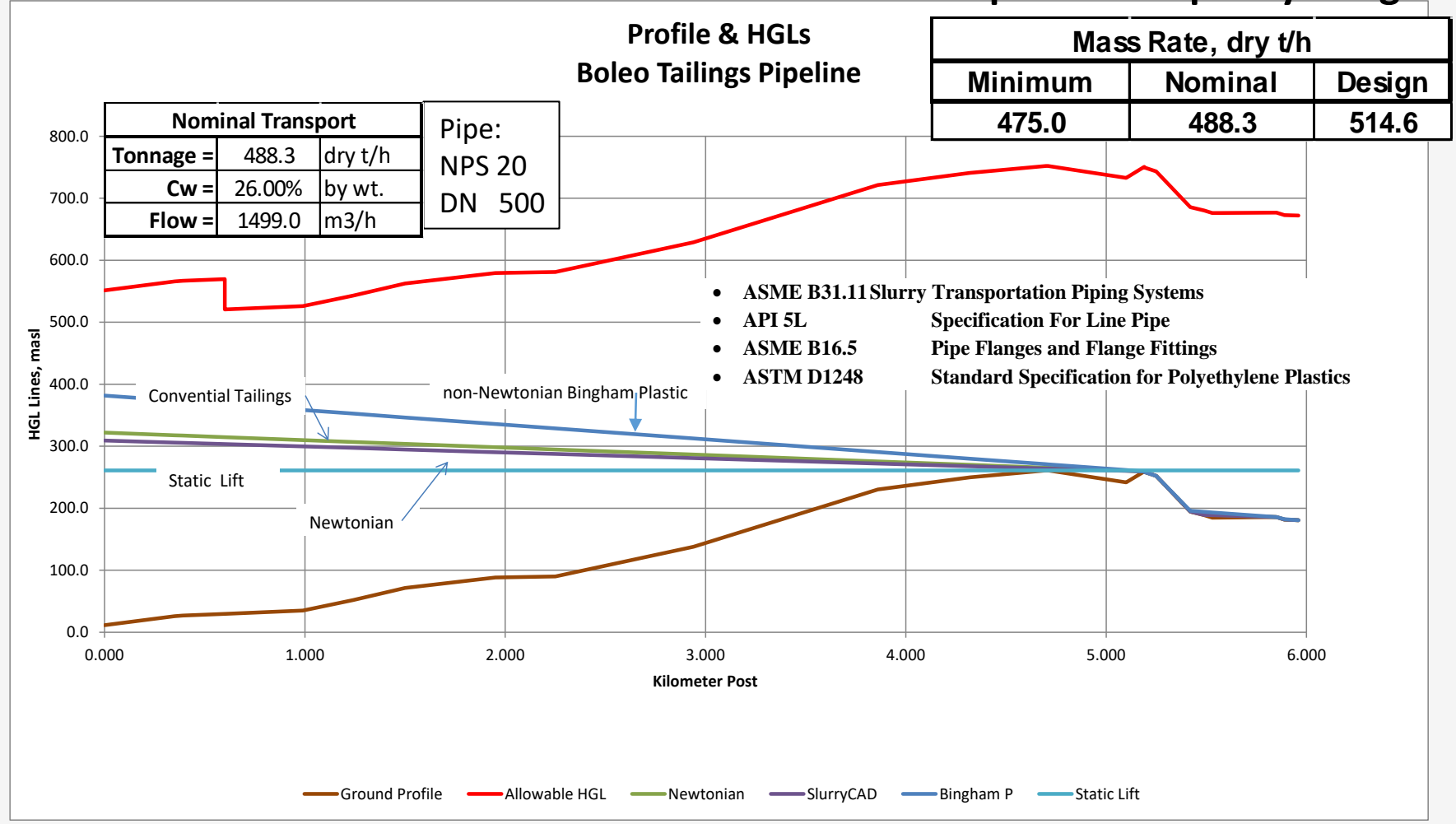
Fluid Type = 3
Fluid Type = Bingham Plastic



Pump Selection Sequence

Pipeline and Route

Specified Capacity Range



Pump Duty

- Design Capacity: 514 dry t/h: solids, SG=2,6, Cw=22%, Flow= 1920 m³/h (low Cw, high flow)

Operating Conditions

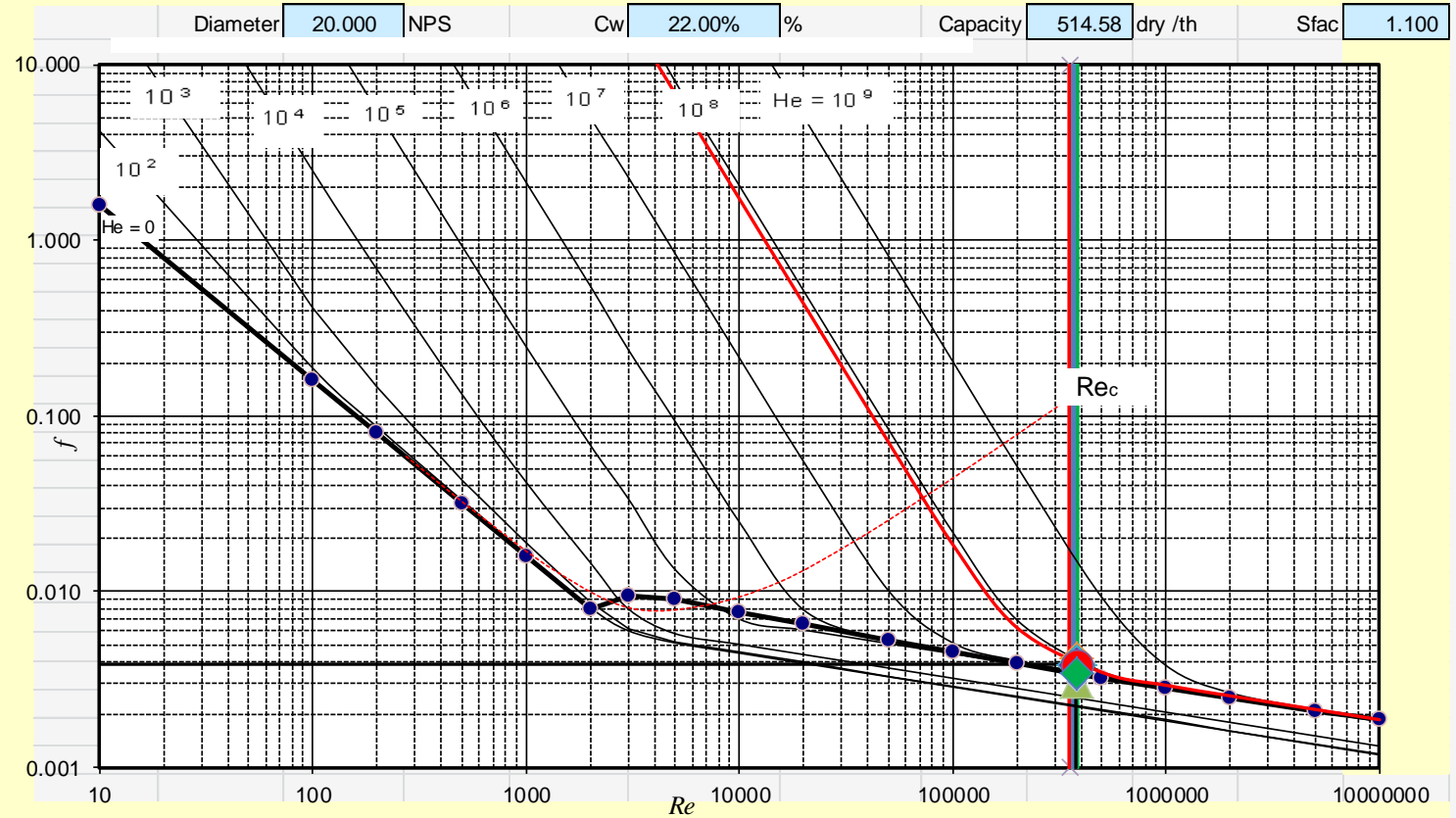
User: blr
Date: 2017-02-04

Operating Conditions

Dry solid throughput	t/d	12350	
Availability	%	100.0%	
Throughput/pipeline	t/h	514.6	
Weight Concentration	%	22.00%	22.0%
Solid/liquid Volume Ratio		0.115	0.115
Volume Concentration	%	10.3%	10.3%
Slurry Specific Gravity		1.219	1.219
Flowrate Per Pipeline	m ³ /h	1919.1	1919.1
Flowrate Per Pipeline	gpm	8449.7	8449.7
Plastic Viscosity	cP	4.7	4.7
Yield Stress	dyn/cm ²	70.2	70.2

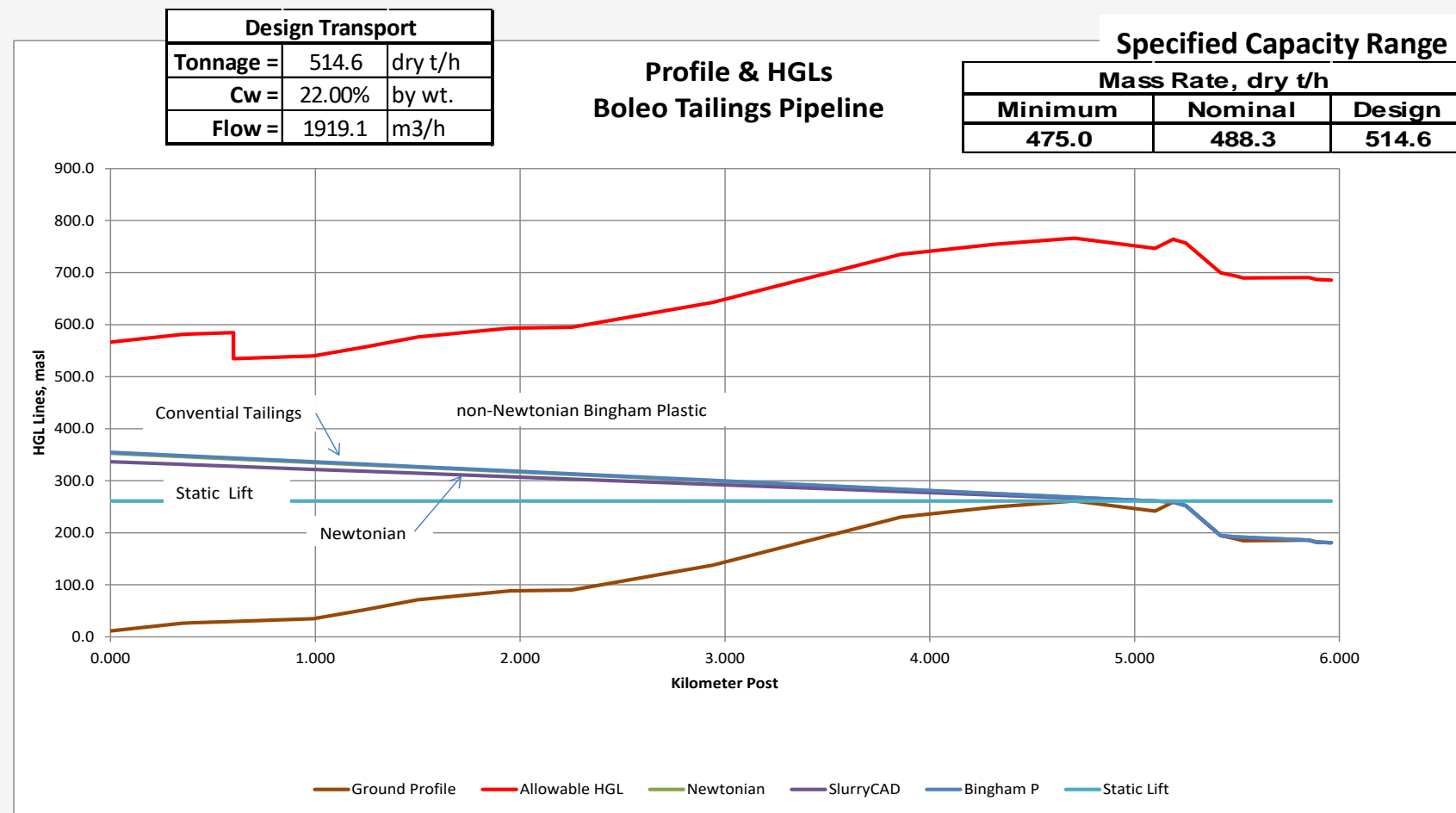
Centrifugal Pump Overall Efficiency	80.9%	2705	kW
PD Pump Overall Efficiency	91.2%	2398	kW

Fluid Type = 3
Fluid Type = Bingham Plastic



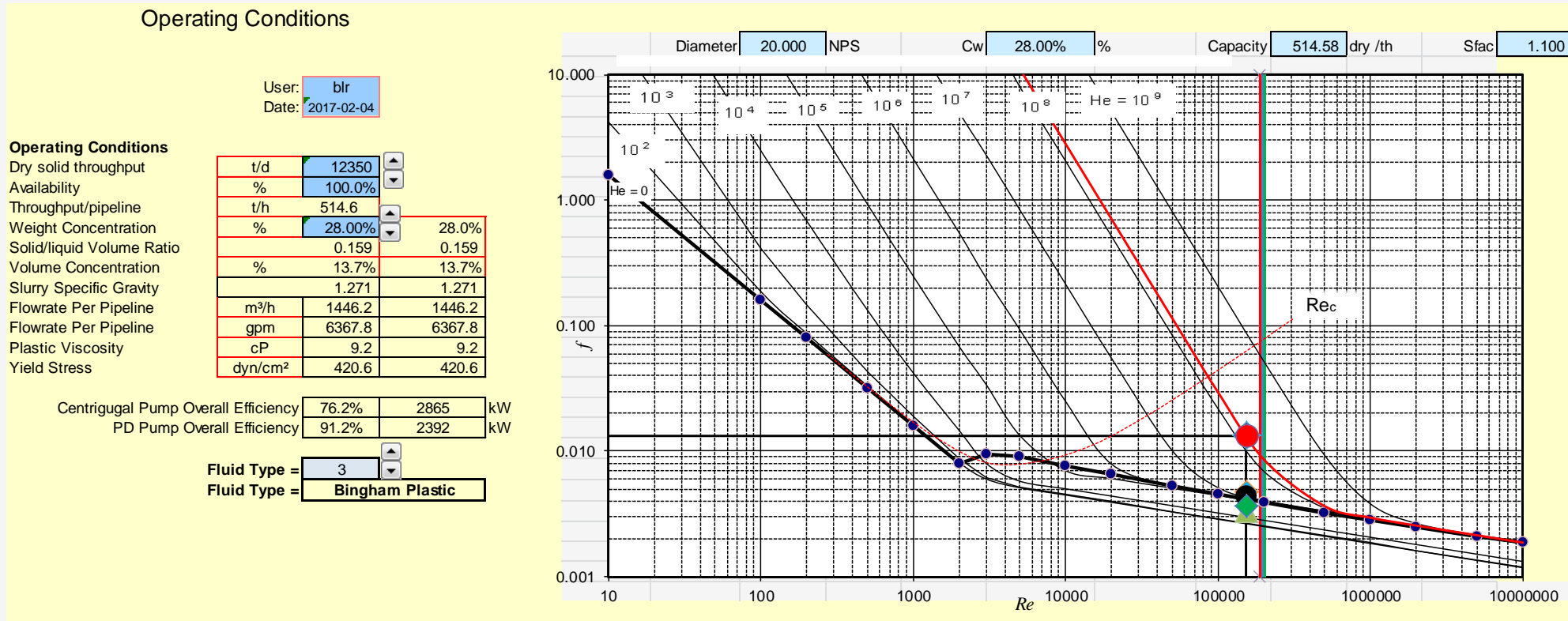
Pump Duty

- Design Capacity: 514 dry t/h: solids, SG=2,6, Cw=22%, Flow= 1920 m³/h (low Cw, high flow)



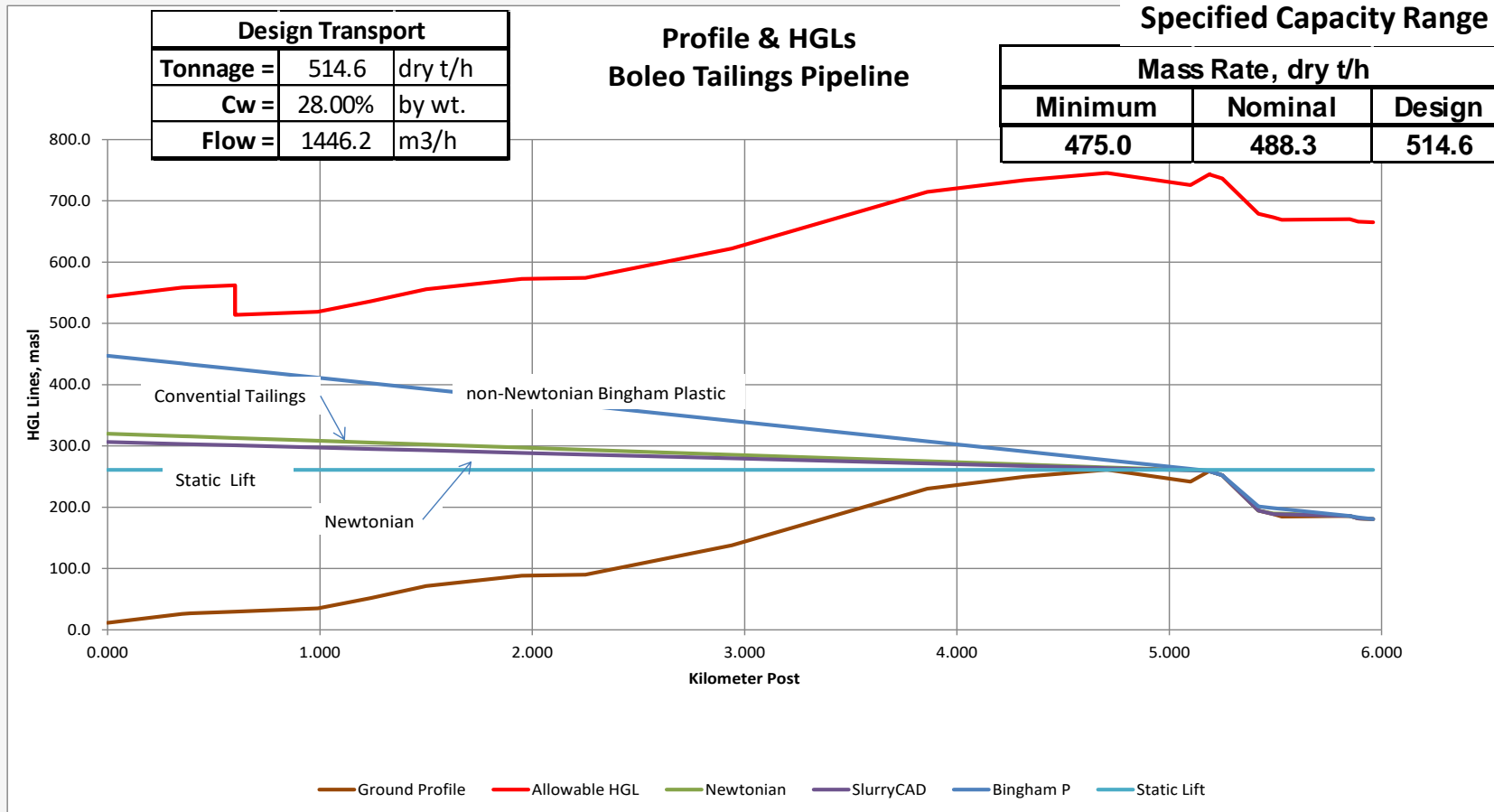
Pump Duty

- Design Capacity: 514 dry t/h: solids, SG=2,6, Cw=28%, Flow= 1450 m³/h (low Cw, high flow)



Pump Duty

- Design Capacity: 514 dry t/h: solids, SG=2,6, Cw=28%, Flow= 1450 m³/h (low Cw, high flow)



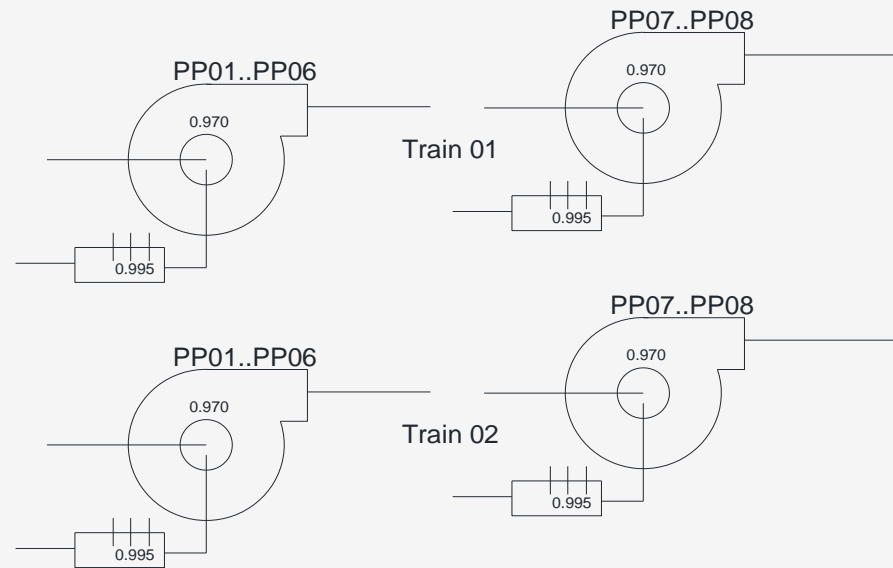
Pump Duty and Description

- Common to both centrifugal and PD pumps
 - Cw : 22 – 28%
 - Flow : 1560 -1950 m³/h
 - TDH : 330 – 440 m
 - Casing pressure : 3,85 – 5,25 MPa
 - Casing pressure : 560 – 760 psig (ANSI Class 400)

- Centrifugal pumps
 - Duty : medium – heavy
 - Tip speed : 33 – 38 m/sec
 - Corrosion resistant lining (High Chrome (28%) and impeller (High Chrome))

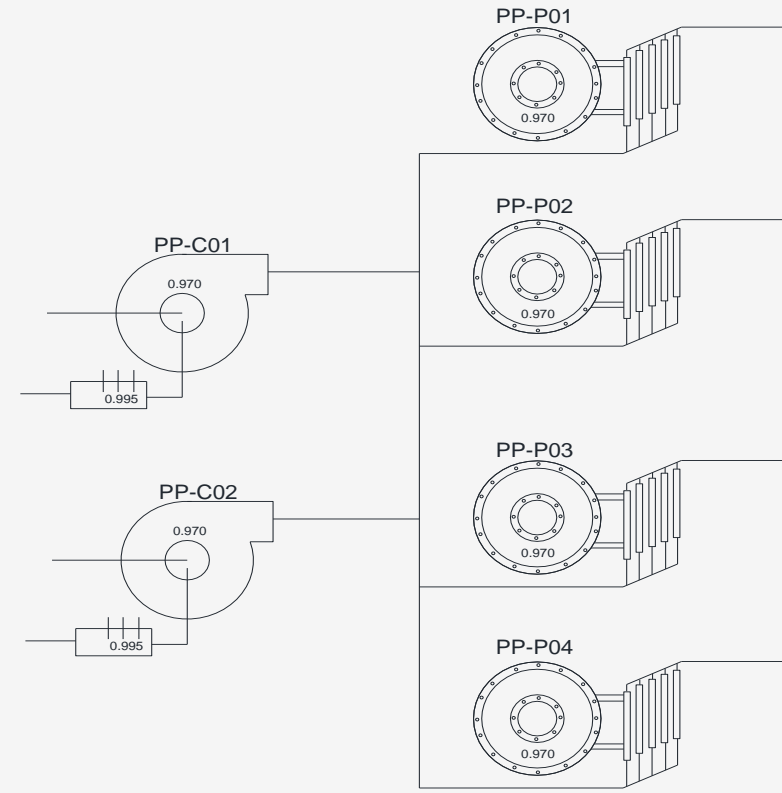
- Positive displacement pumps
 - Corrosion resistant wetted fluid parts (super duplex steel)

Availability Centrifugal Pumps



Centrifugal Pump Station Availability			
Pumping Unit Availability			
Prime Mover	0.970		
Seal Water	0.995		
Pumping Unit	0.96515		
Pump Train Availability			
Pumping Unit	0.96515		
Units in series	8		
Pump Train	0.752937		
Pump Station Availability			
Pump Trains	0.752937		
Trains in Parallel	2		
Availability of at least 1 train	0.93896		
At Least	1	of	2
Uptime	8225	hours	per year
DownTime	535	hours	per year
DownTime	22.3	days	per year
Pump Station Availability			
Pump Trains	0.752937		
Trains in Parallel	3		
Availability of at least 1 train	0.984919		
At Least	1	of	3
Uptime	8628	hours	per year
DownTime	132	hours	per year
DownTime	5.5	days	per year

Availability Piston Diaphragm Pumps



PD Pump Station Availability			
Charge Pump Unit Availability			
Charge Pump			0.970
Seal Water			0.995
Charge Pump Unit			0.96515
Charge Pumps Availability			
Charge Pump Unit			0.96515
Charge Pumps in Parallel			2
Availability of at least 1 unit			0.998785
Prime Movers Availability			
Prime Mover			0.970
Prime Movers in Parallel			4
Availability of at least 3 unit			0.994814
Pump Station Availability: 3 of 4 Pumps)			
Charge Pumps			0.998785
Prime Movers			0.994814
Pump Station Availability			0.993605
At Least	3	of	4
Uptime	8704	hours per year	
DownTime	56	hours per year	
DownTime	2.3	days per year	
Pump Station Availability: 2 of 3 Pumps)			
Charge Pumps			0.994814
Prime Movers			0.997354
Pump Station Availability			0.992181
At Least	2	of	3
Uptime	8692	hours per year	
DownTime	68	hours per year	
DownTime	2.9	days per year	

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Costs

Note: quotes from three different PD Pump manufacturers were received. The FELUWA MULTISAFE Double Hose-Diaphragm Pumps were selected based upon limited amount of fluid end parts exposed to the corrosive slurry (valves and seats).

Other pumps also utilized corrosion resistant metals, but the quantity of these metals were more than required by the Feluwa pumps and consequently more expensive

Initial Cost Comparison

- Piston diaphragm versus centrifugal pumps

PRIME MOVERS				VF Drives			Gland Seal Water Pumps			Charge Pumps		
Description	Number Pumps	Unit Cost	Total Cost	Units	Unit Cost	Total VFDs	Units	Unit Cost	Tot SW Pumps	Units	Unit Cost	Tot C Pumps
Centrifugal	16 (8 + 8)	\$152,000	\$2,432,000	6	\$251,000	\$1,506,000	16	\$20,000	\$320,000	0	\$160,000	\$0
Centrifugal	24 (8 +16)	\$152,000	\$3,648,000	9	\$251,000	\$2,259,000	24	\$20,000	\$480,000	0	\$160,000	\$0
Feluwa (650 m ³ /h)	4 (3 + 1)	\$1,760,000	\$7,040,000	4	\$251,000	\$1,004,000	2	\$5,000	\$10,000	2	\$160,000	\$320,000
Feluwa (780 m ³ /h)	3	\$2,190,000	\$6,570,000	3	\$251,000	\$753,000	2	\$5,000	\$10,000	2	\$160,000	\$320,000

PRIME MOVERS				Backup PD Pump			D Installed Electrical Gear			Total Costs
Description	Number Pumps	Unit Cost	Total Cost	Units	Unit Cost	Tot PD Pumps	D kW	Unit Cost	Total	
Centrifugal	16 (8 + 8)	\$152,000	\$2,432,000	1	\$715,000	\$715,000	200	\$1,400	\$280,000	\$5,253,000
Centrifugal	24 (8 +16)	\$152,000	\$3,648,000	1	\$715,000	\$715,000	300	\$1,400	\$420,000	\$7,522,000
Feluwa (650 m ³ /h)	4 (3 + 1)	\$1,760,000	\$7,040,000	0	n/a	n/a	base	base	\$0	\$8,374,000
Feluwa (780 m ³ /h)	3	\$2,190,000	\$6,570,000	0	n/a	n/a	base	base	\$0	\$7,653,000

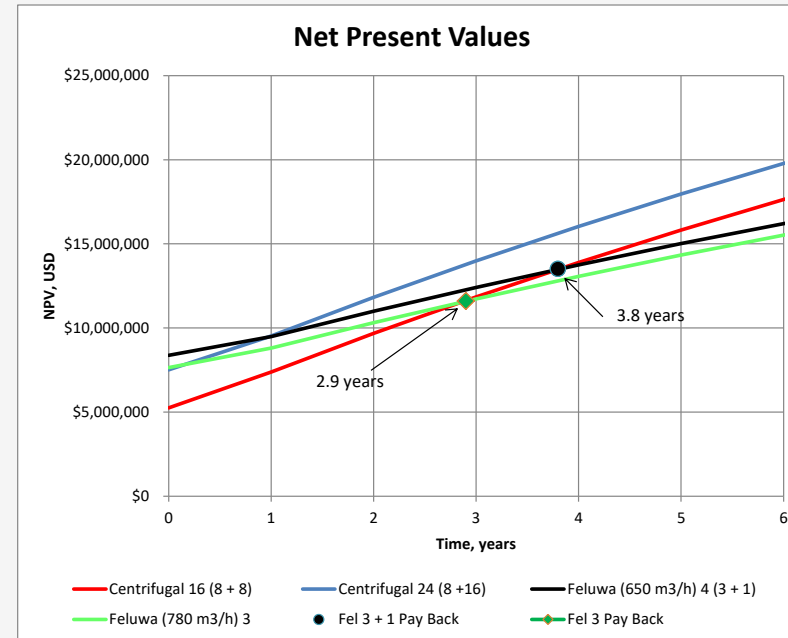
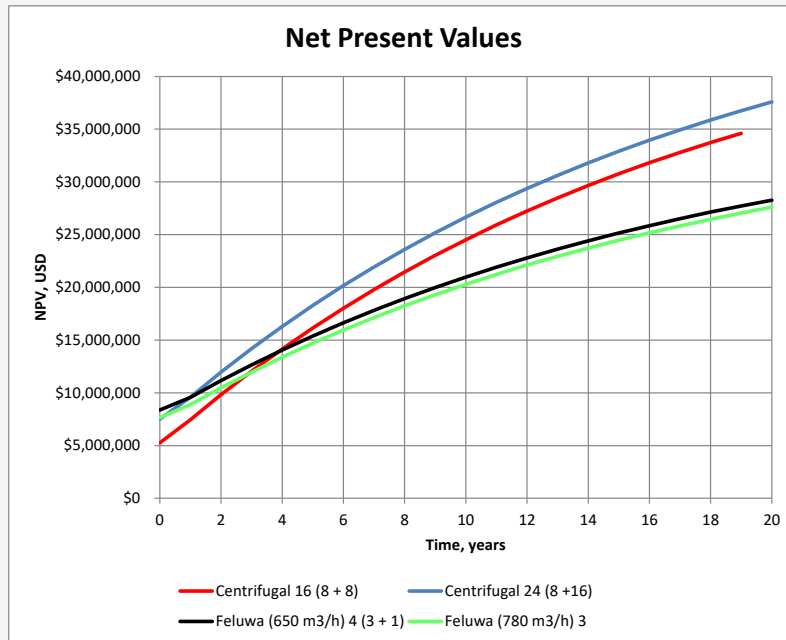
Operating Cost Comparison

- Piston diaphragm versus centrifugal pumps
 - Efficiency : overall efficiency (motor, gear, volumetric)
 - Power costs : 0,088/kwh

Prime Mover Operating Cost Comparison (Nomial Capacity, Cw=26%)						
Description	Number Pumps	Operating Power			Operating Spa Annual costs	Total Annual
		Eff	kW	Annual Costs		
Centrifugal	16 (8 + 8)	0.766	2,561	\$1,974,586	\$760,000	\$2,734,586
Centrifugal	24 (8 +16)	0.766	2,561	\$1,974,586	\$760,000	\$2,734,586
Feluwa (650 m ³ /h)	4 (3 + 1)	0.912	2,152	\$1,658,635	\$131,000	\$1,789,635
Feluwa (780 m ³ /h)	3	0.912	2,152	\$1,658,635	\$131,000	\$1,789,635

NPV Cost Comparison

- Piston diaphragm versus centrifugal pumps
 - Nominal Capacity : 488 ndry t/h
 - Cw : 26%
 - Increment : 1 year
 - Annual discount rate: 6%



Pump Selection Sequence

Pump Selection Summary		
Category	Centrifugal Pump	FELUWA MULISAFE Double Hose Diaphragm Pump
Slurry Dilution		✓
Resartart w/ Plug	requires PD pump	✓
Corrosion Resistance	✓	✓
Efficiencies		✓
Availability		✓
Initial Costs	✓	
NPV Analysis		✓

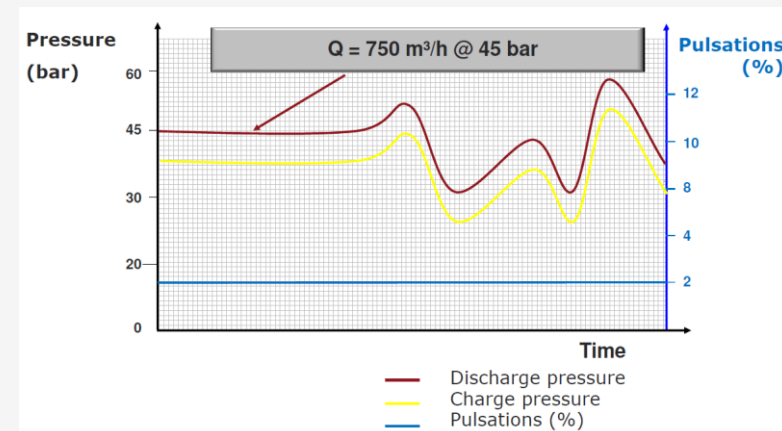
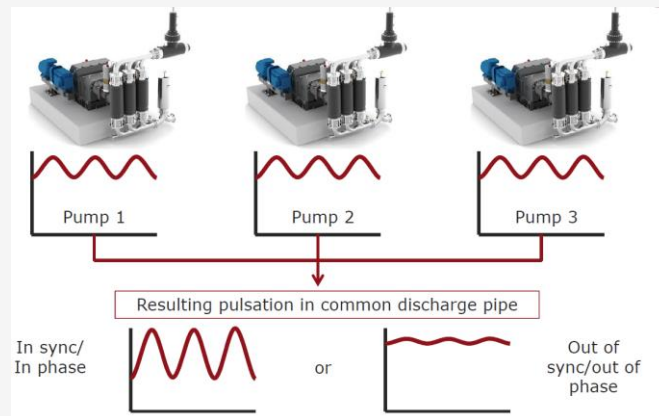
The largest Piston Diaphragm Pump in the world: from drawing board to operational experience



Scope of Supply, Operational Experience and Conclusion
By Hein Krimpenfort, Key Account Manager Feluwa Pumps

Scope of Supply

- 4 pumps
 - Down Flow Technology
 - Capacity : 750 m³/h
 - Pressure : 54 bar (design)
 - Stroke rate : 42 per minute
 - Weight : 150 ton
- 4 motors : ABB
- 4 VFD's : ABB
- Electronic crankshaft connection
- Pulsorber pulsation dampeners with automatic charge pressure adjustment
- 2 year inspection contract



Operational experience

- Development and performance of pump components at Boleo

- Diaphragms

- Material : NBR
- Life time : > 16.000 operating hours

- Valves

- Balls material : Polyurethan
- Seat material : Super duplex stainless steel
- Life time : > 2.500 operating hours

Operational Experience

Utility consumption

Power consumption

- At pump shaft : 1030 kW
- Auxiliary power : 8 kW
- Charge pumps : 55 kW
- Cooling fan : 15 kW

Total power consumption : 1108 kW

Water consumption

- Only gland water for charge pump
- Flushing water in case of extended stops

Air consumption

- None

Impressions: FAT



Impressions: transportation



Impressions: erection



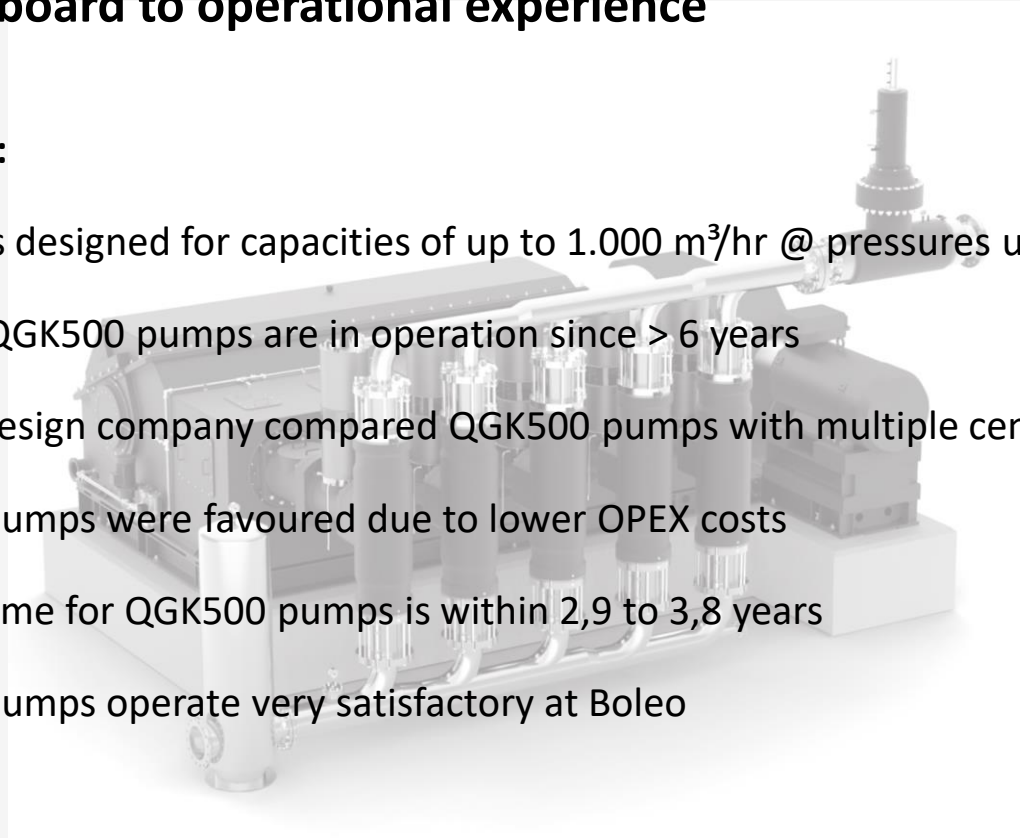
Impressions: operation



The largest Piston Diaphragm Pump in the world: from drawing board to operational experience

Conclusions :

- QGK500 is designed for capacities of up to 1.000 m³/hr @ pressures up to 9.000 kPa
- At Boleo QGK500 pumps are in operation since > 6 years
- Pipeline design company compared QGK500 pumps with multiple centrifugal pumps
- QGK500 pumps were favoured due to lower OPEX costs
- Payback time for QGK500 pumps is within 2,9 to 3,8 years
- QGK500 pumps operate very satisfactory at Boleo



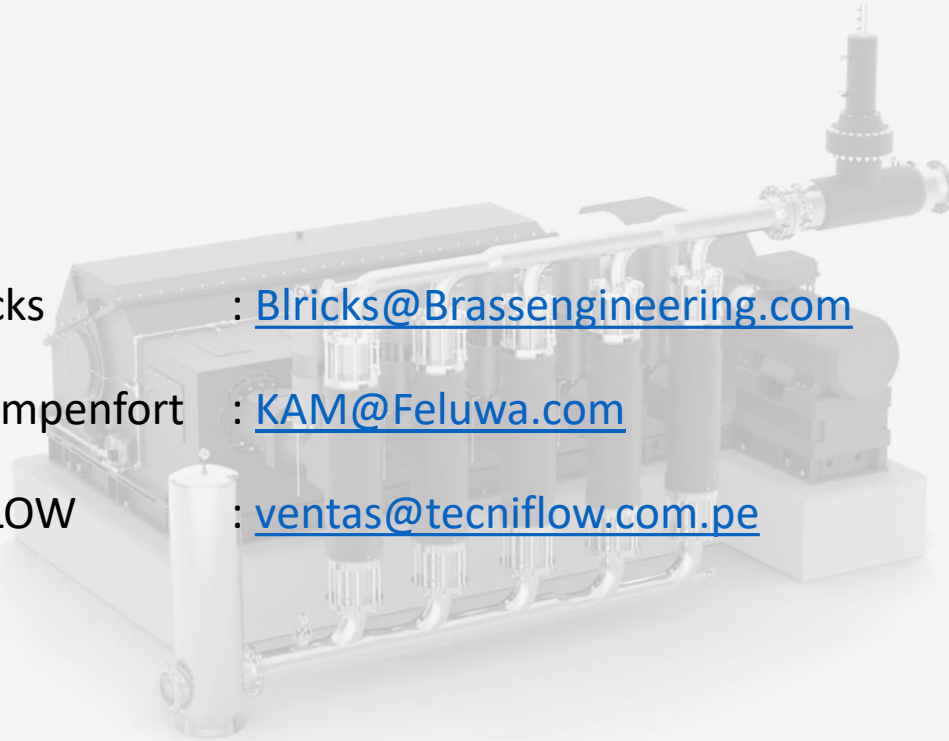
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Contact :

Brad Ricks : Blricks@Brassengineering.com

Hein Krimpenfort : KAM@Feluwa.com

TECNIFLOW : ventas@tecniflow.com.pe





Thank you!

