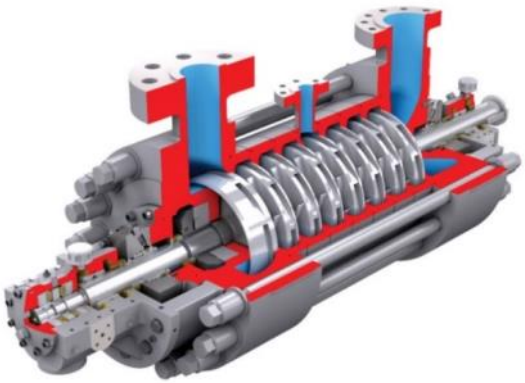
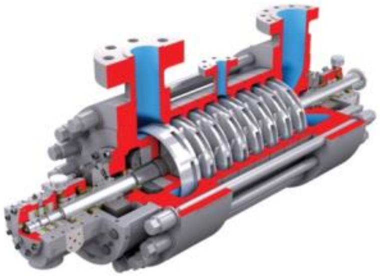
THE DEVELOPMENT AND OPERATION OF A NEW HIGH PRESSURE SLURRY PUMP FOR OIL SANDS INCORPORATING THE MILLMAX SUCTION RECIRCULATION CONTROL SYSTEM

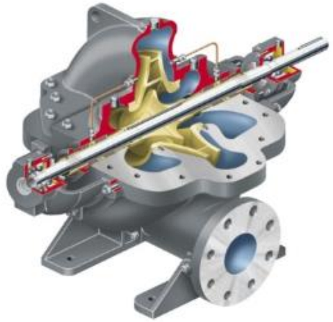
- **Dan Wolfe, Syncrude Canada Ltd.**
- **Luis Echeverri, FLSmidth Krebs Inc.**



Presenters

Dan Wolfe	Mechanical Engineer in R&D at Syncrude since 2007, with previous experience in the downstream oil & gas industry. Focus on reliability improvement of equipment including ground engaging tools, crushers, slurry pumps and piping.
Luis Echeverri	Hydraulic Design Engineer at FLSmidth Krebs since 2011. Responsible for hydraulic design and development of centrifugal slurry pumps millMAX™ and mechanical design of pressure resisting components for high pressure pumps.





CONTENTS

Slurry Pumps at Syncrude

- 108 large slurry pumps in severe duty
  - Hydrotransport and Tailings
  - 500-5500HP
  - 10-100 tonne pump assembly weight
- ~50 lighter duty slurry pumps
  - Froth, PSV middlings, dredge duty

Why So Many Pumps?

Our Process Requires It

- Aqueous extraction process requires mixing with warm water (extraction and tailings)
- Hydrotransport requires mixing with warm water 3-4km from extraction plant

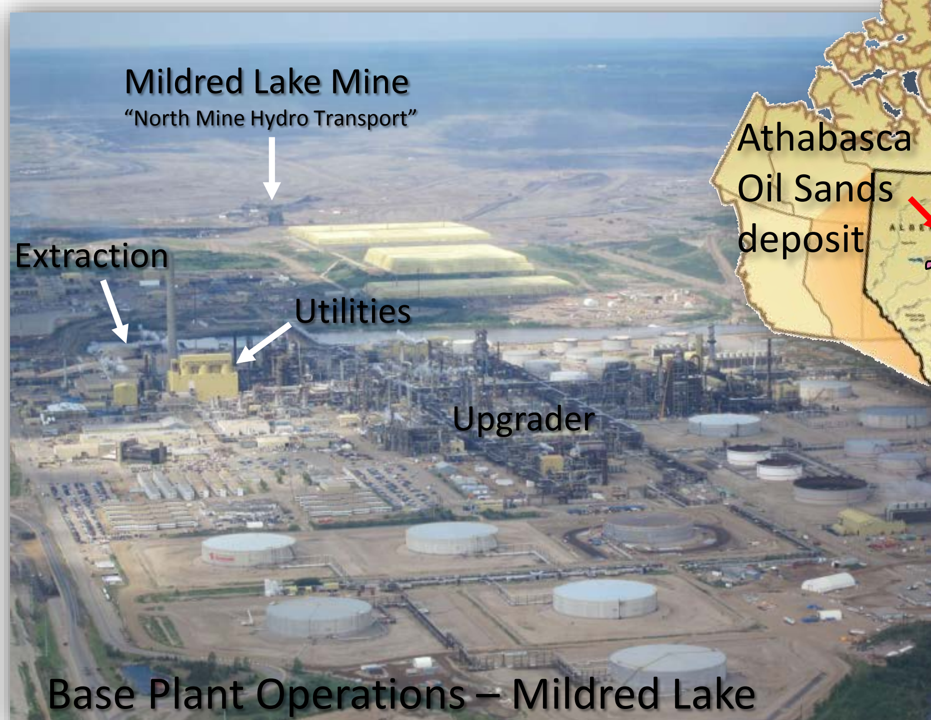
Cost-Effective Mode of Material Transport

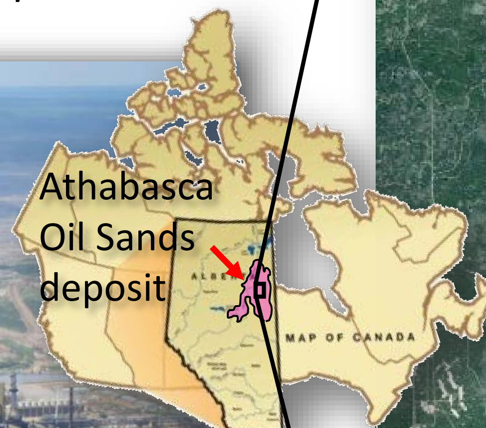
- Similar cost to conveying (4-6 cents/t-km), but less than ¼ the cost of trucking (>20 cents/t-km)
- We pump 7-800kt of solids daily, over a distance of 6-15km

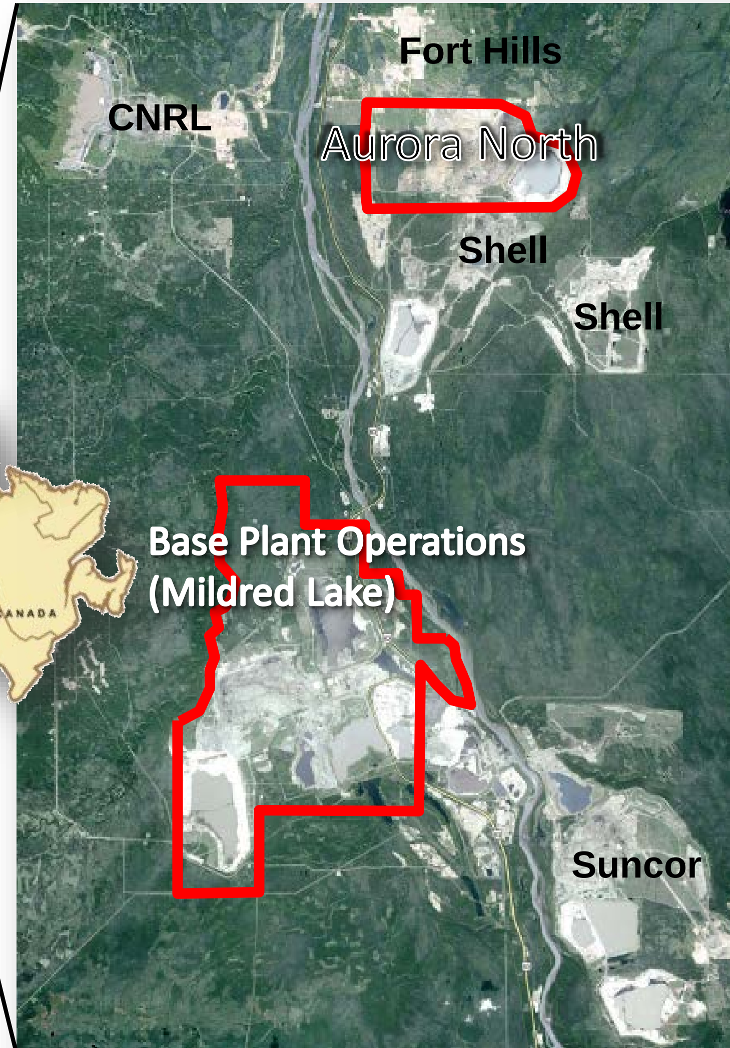
Surface mining locations
in the Athabasca Oilsands

Syncrude Base Plant & Mildred Lake Mine are located just outside *Fort McMurray, Alberta* near the center of the Athabasca oil sand deposit

- *Name plate capacity: 350,000 bpd of oil*
- *14% of Canada's domestic consumption*

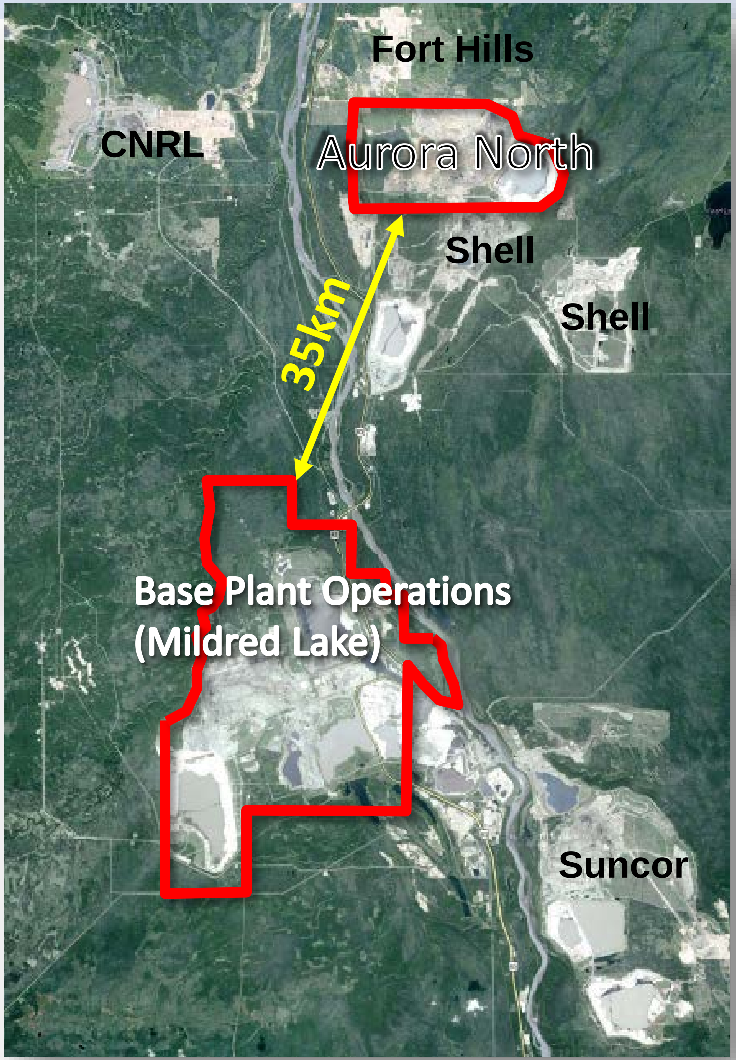






Aurora North Mine

Surface mining locations
in the Athabasca Oilsands



- Remote operation
- ~35 km north from Base Plant
- Operating since 1999
- Mines & processes ~120 Mt/yr oilsand
  - *Warm water extraction process*
  - *Relies on Hydrotransport (HT) technology for pipeline conditioning and oil sand delivery to separation vessels* (PSV's).

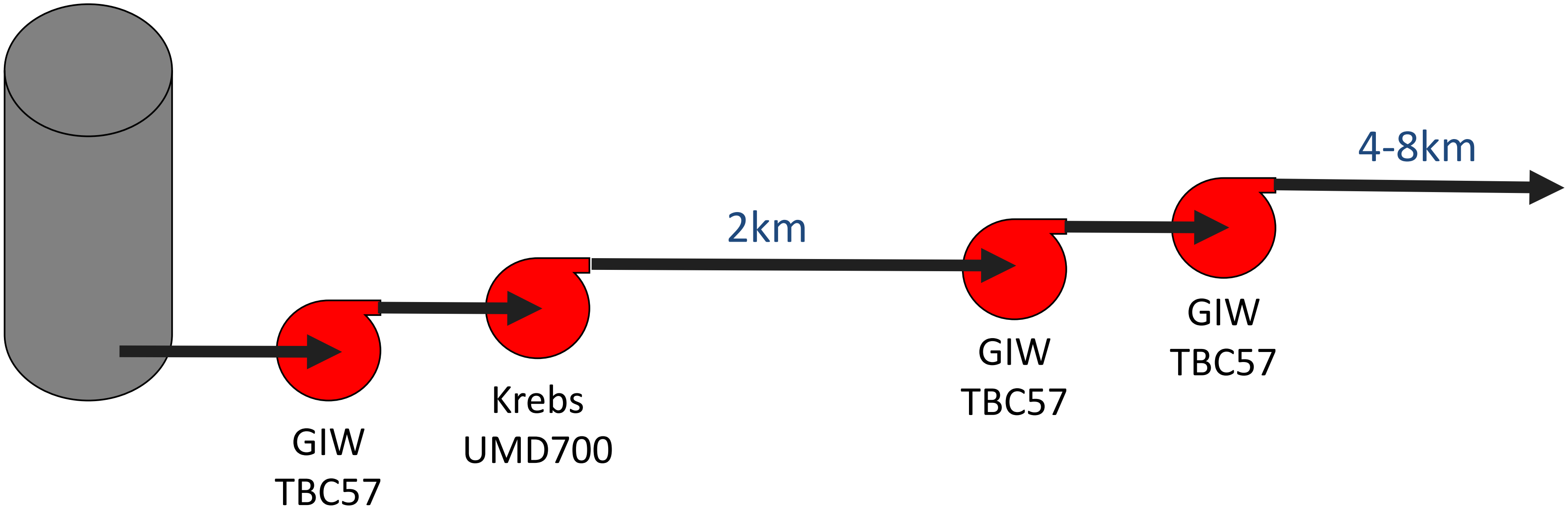
- *Every year, Aurora North moves more than 3 billion t-km of slurry by Hydrotransport…*

Aurora North Tailings

- 3 Tailings Lines
  - ***2 Operating, 1 Standby*** (Available for maintenance)
  - Nominal pipeline solids feed rate 8250 tph per train
- Tailings Pipeline
  - 4-5 pumps in series on each Tailings line
  - 30” nominal diameter
  - 5-11km distance to pour points

Aurora Tailings Line 2

- 4 pumps in series
- Head varies from 20-80m per stage (average 35-45m)

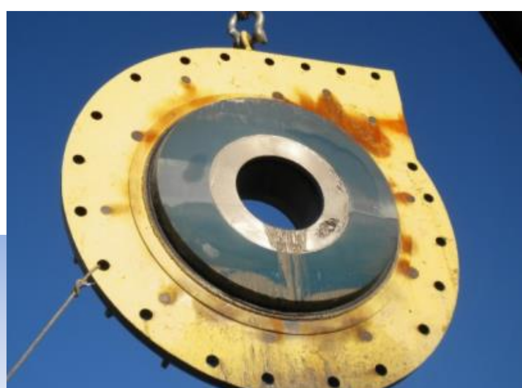


Tailings Pump Wear Mode

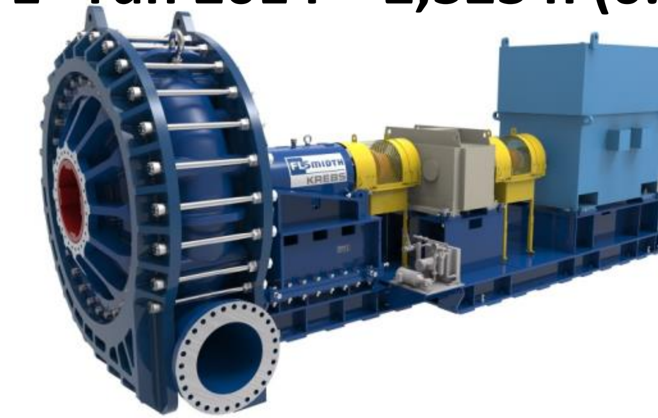
- Suction liner gouging, impeller recirculation wear dominate
- 2000 hour life span at 35-40m head (less with high d50 sand)

DESIGN CONCEPT

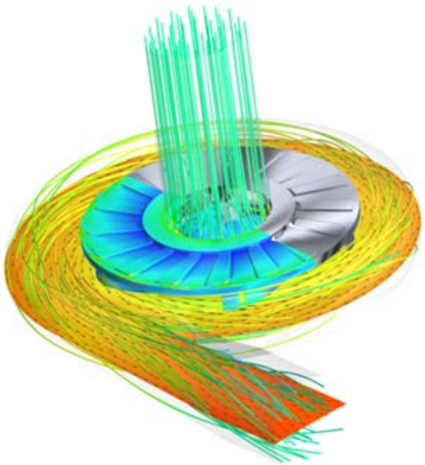
Copper tailings
millMAX 20x18-46
1.5-2.0 yr



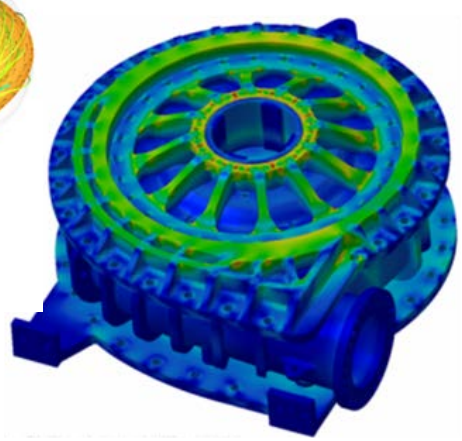
Oil Sand Tailings, Syncrude
millMAX UMD 28x26-71
1^{st} run 2014 – 2,323 h (0.26 yr)



New High Pressure Pump for Oil Sands



Hydraulic Design



Mechanical design

Max 533 psi (3.67 Mpa)

Test 800 psi (5.51 Mpa)

(2012)

Pressure test

Performance test

(2013)

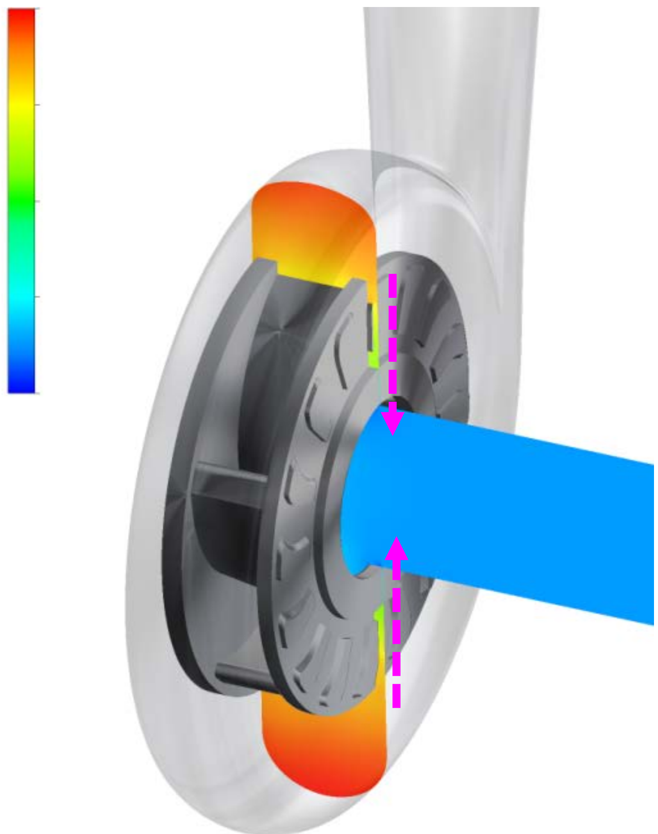
Installation & first run in Syncrude

(2014)

Suction Side Recirculation
and
millMAX™ Solution

Suction-side Recirculation Problem

Pressure
[CFD]

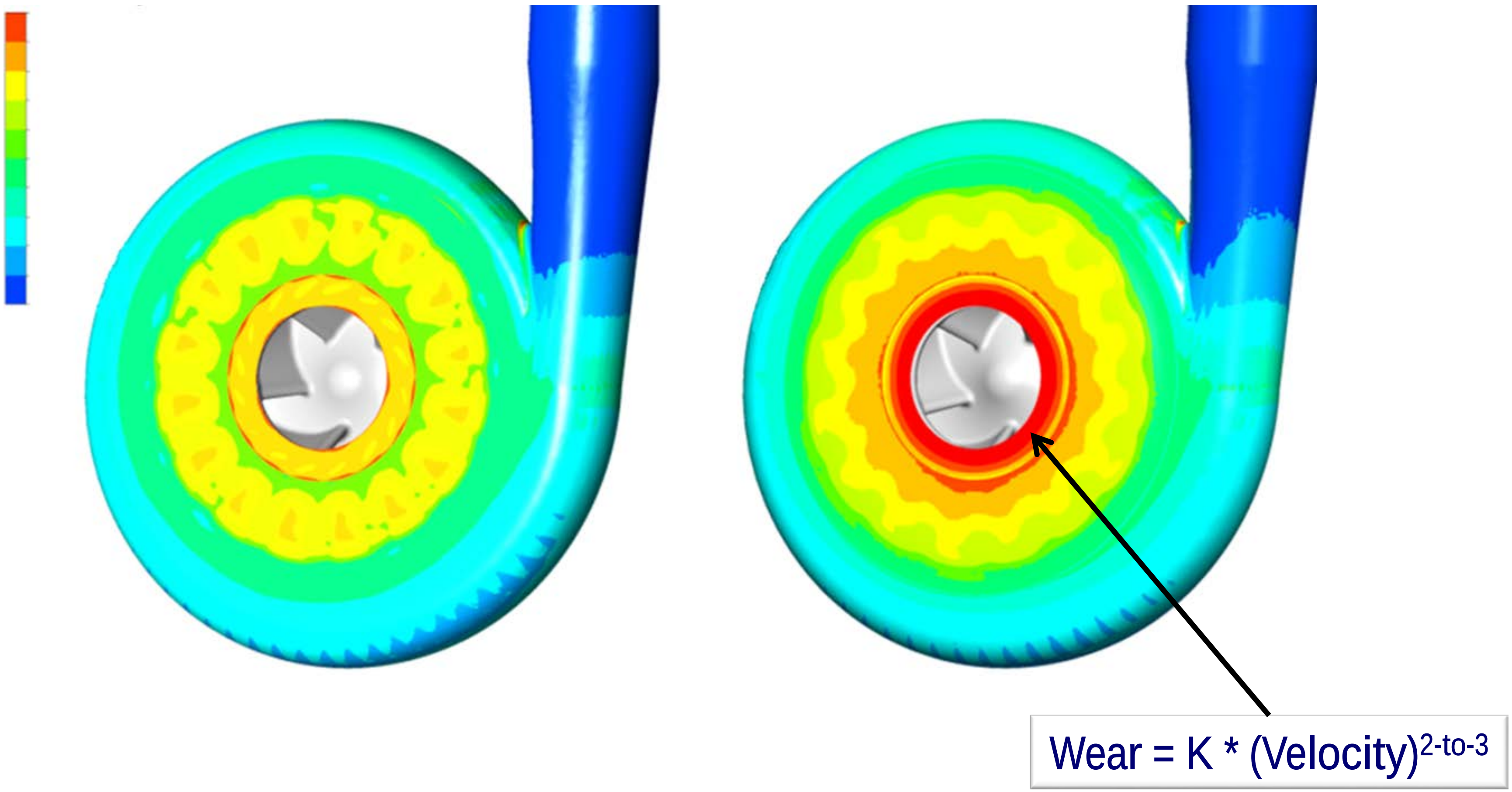


- Performance losses
- Wear increases (vicious cycle)

Trapped solids in impeller clearance

Suction-side Recirculation Problem

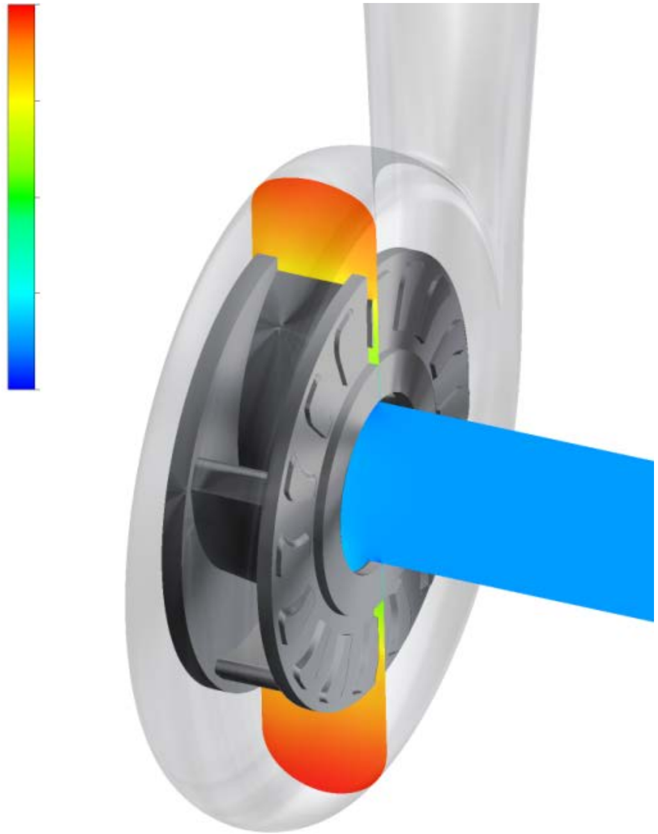
2-mm front clearance 50-mm front clearance



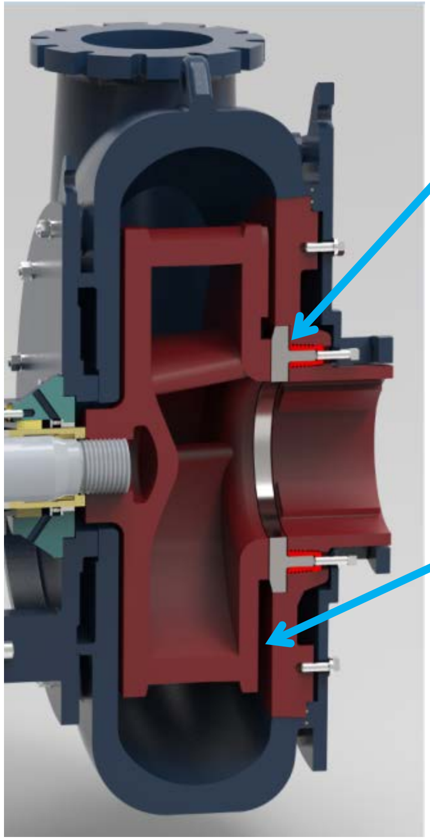
You know your pump has recirculation wear if …

millMAX™ Patented Solution

Pressure [CFD]



Adjustable wear ring

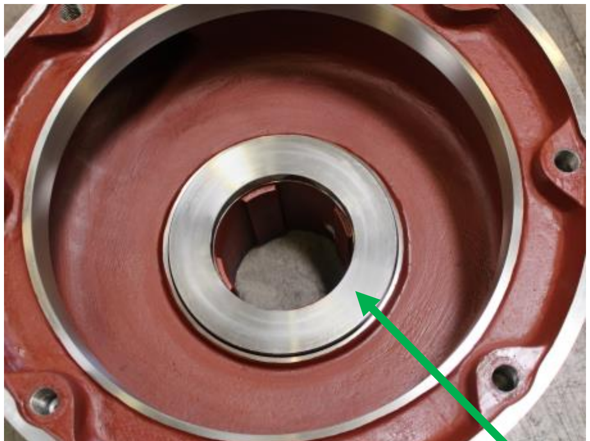


Tight clearance at wear ring prevents suction side recirculation.

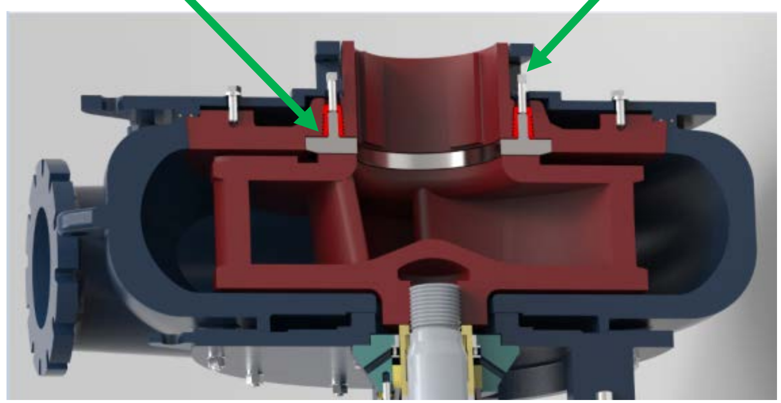
Wide clearance at expelling vanes prevents large solids from being crushed.

millMAX™ Patented Solution

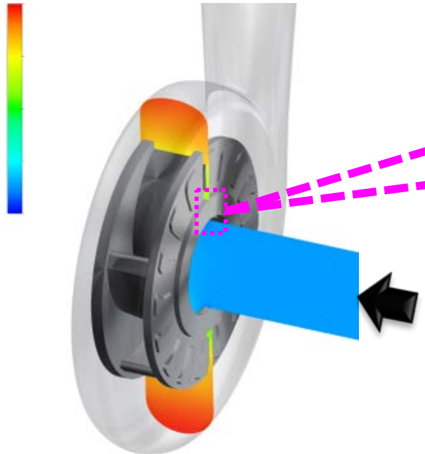
WEAR RING



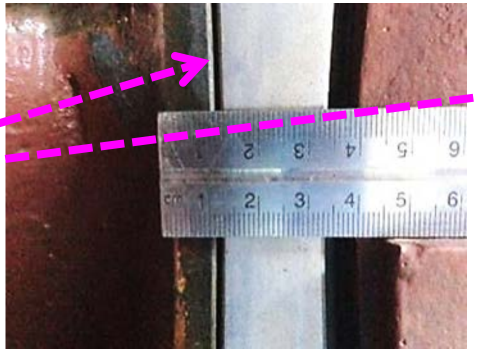
EXTERNAL ADJUSTMENT



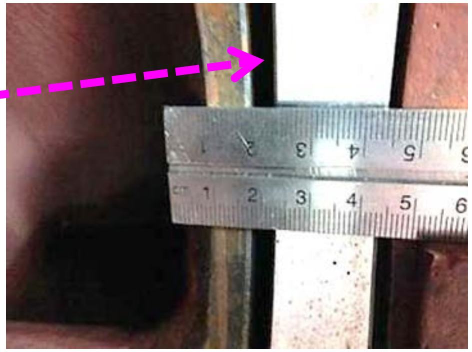
Recirculation Effect on Performance



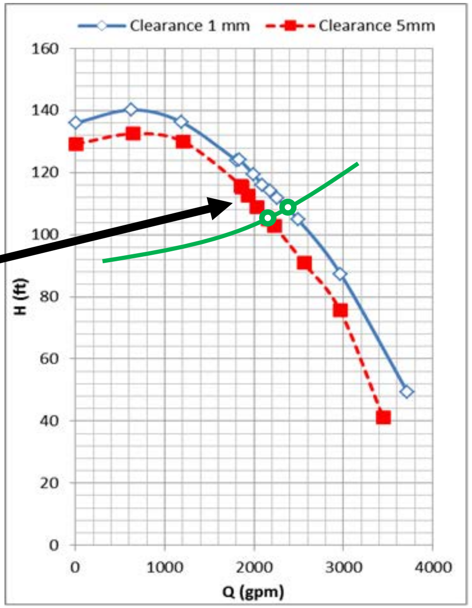
1-mm clearance



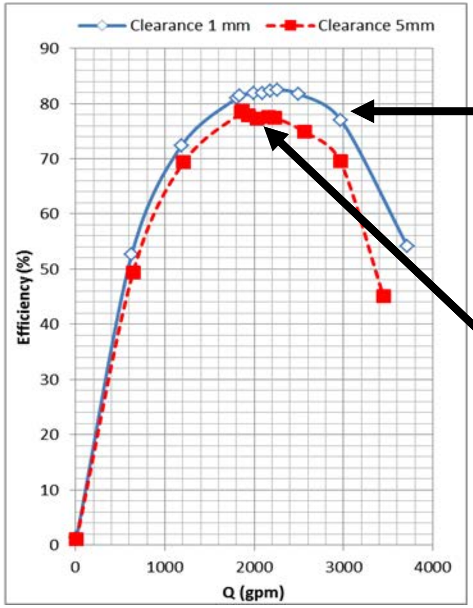
5-mm clearance



Suction Flow



-8% Head at BEP



-4% Efficiency

-11% flow BEP

Recirculation Effect on Wear

Copper Mill Discharge, millMAX UMD 28x26-65

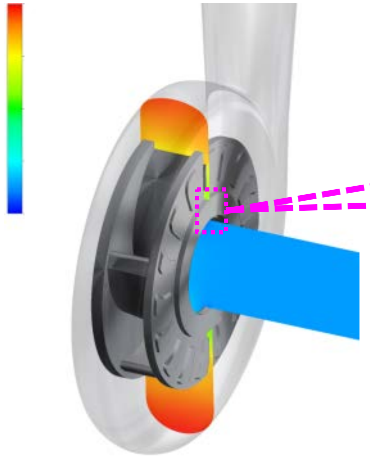
Wear ring not adjusted
42 d / 1,008 h

Wear ring adjusted weekly
41 d / 984 h

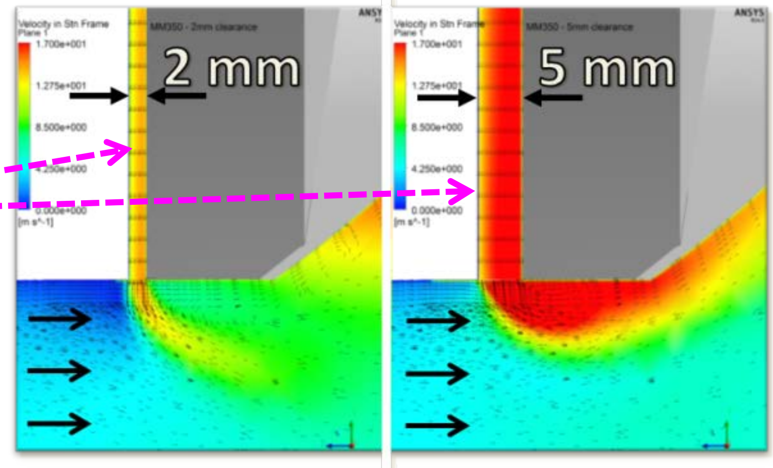
- **Recirculation increases wear rate significantly.**
- **Adjusting the wear ring consistently is extremely effective to minimize wear.**

Recirculation Effect on Wear

Pressure [CFD]



Velocity [CFD]



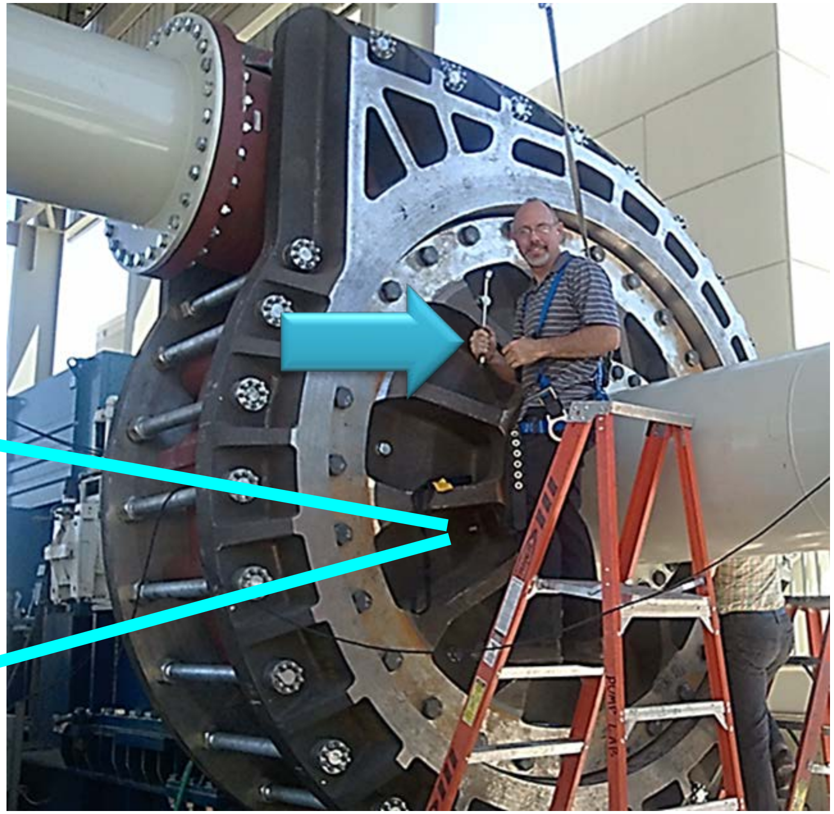
"Eye opener"
Wear = K * (Velocity)$^{2\text{-to-}3}$

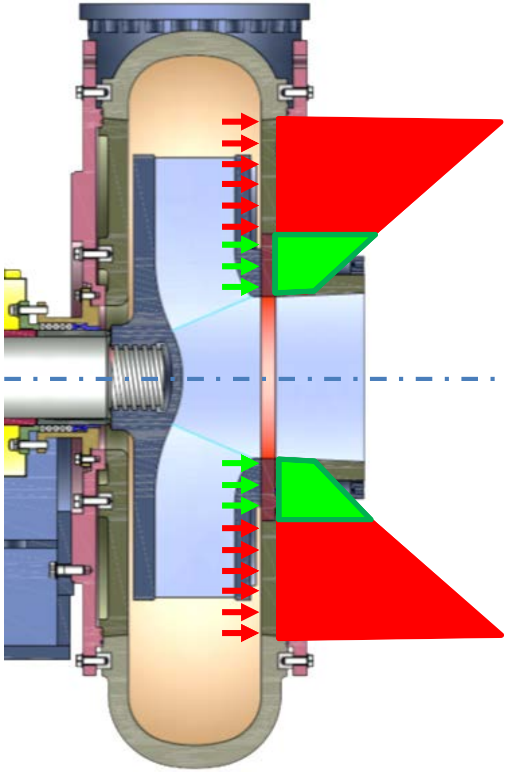
Impeller eye enlarged
e.g. ID14" → ID19.5"

Impeller
front shroud

Leading edge of
pumping vanes

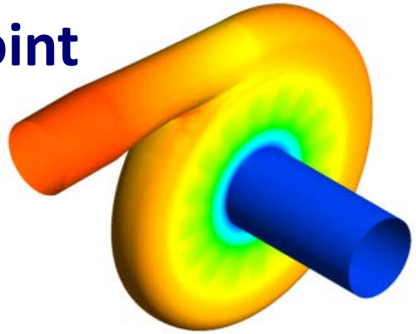
millMAX™ Suction-side Recirculation Seal





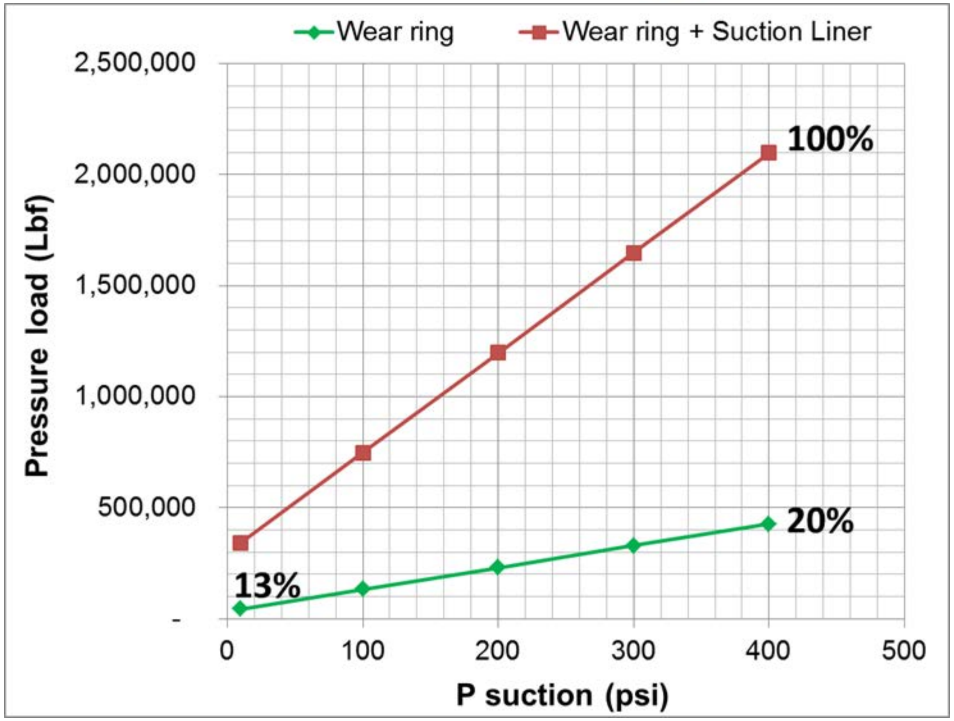
millMAX™ Mechanical Advantage

Best efficiency point
174 ft / 53 m
1.4 s.g.



Suction Liner	3,503 in²	(79%)
Wear ring	961 in²	(21%)
Total	4,464 in²	(100%)

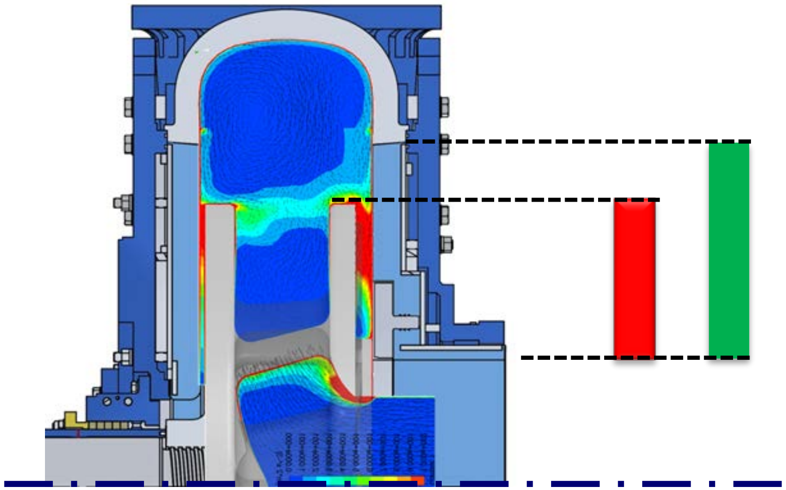
- Wear Ring adjusts against a relatively small cross sectional area (e.g. 20 % Side liner wall), allowing safe and easy adjustment even at high pressures.

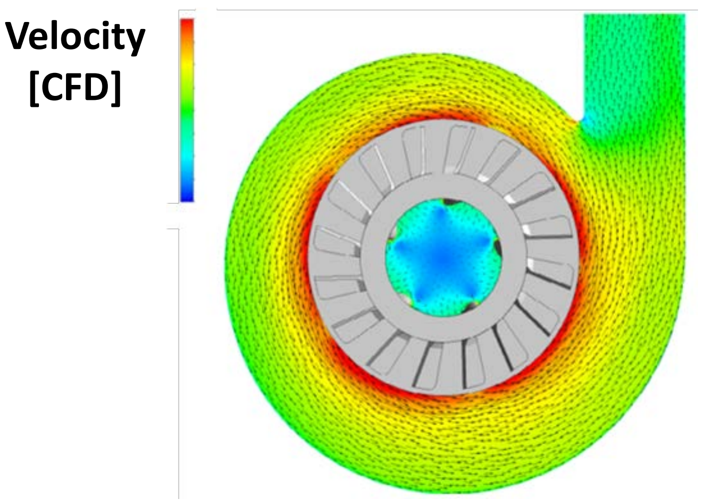


- UMD-STYLE SIDE LINERS OVERSIZED IN OUTER DIAMETER.

- CASING WITH LARGE CLEARANCES.

UMD Patented Features

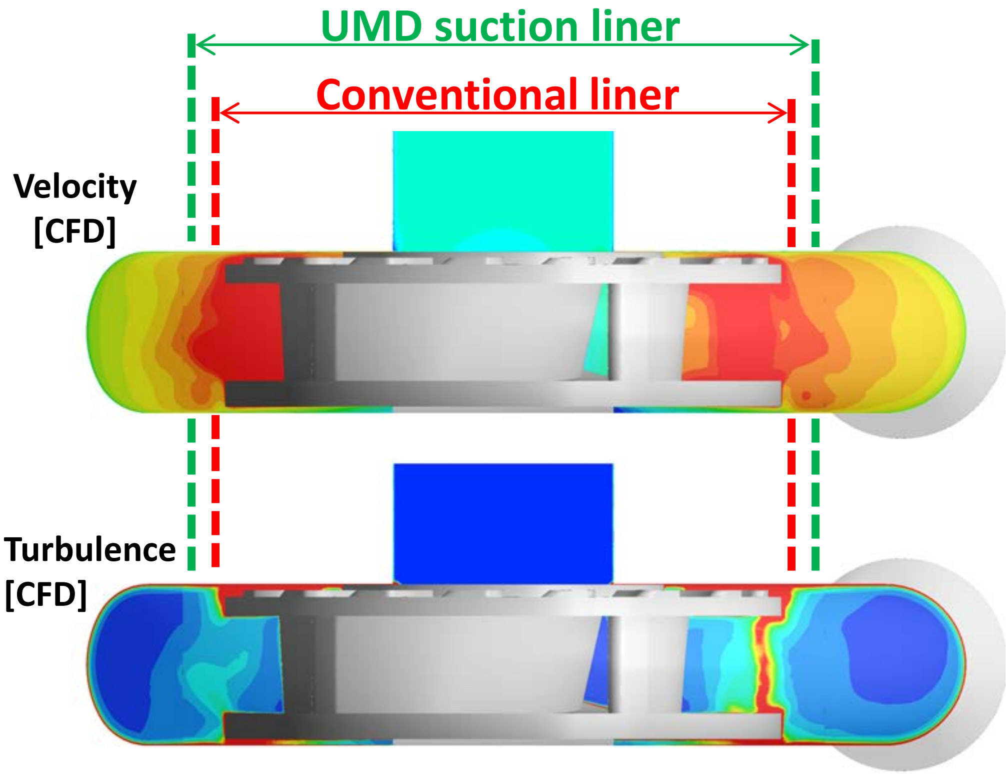




- Side liners with oversized outer diameter protect casing from high velocity and turbulence at periphery of the impeller.

- Large casing clearances reduce velocity and turbulence near the walls increasing service life.

Patented UMD-style Side Liners



Region around impeller outer diameter displays high velocity and turbulence, resulting in high wear rates on the side wall or suction liner.

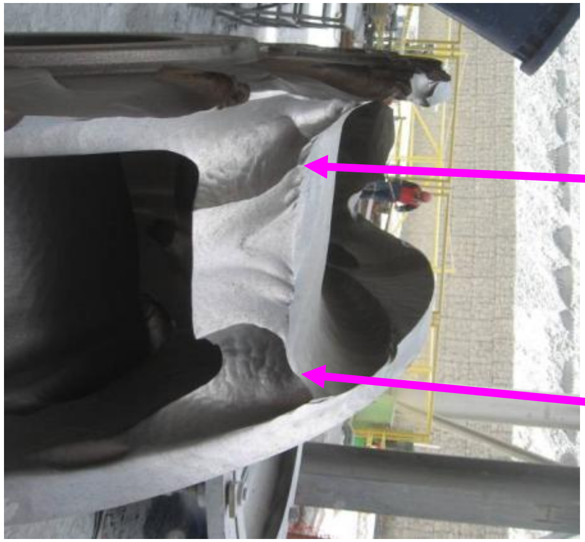
Conventional suction liner

UMD suction liner with enlarged OD

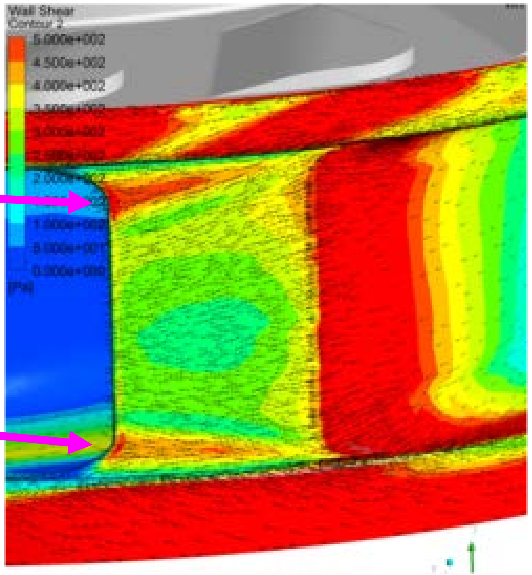
UMD-700 Impeller and Casing

IMPELLER DESIGN

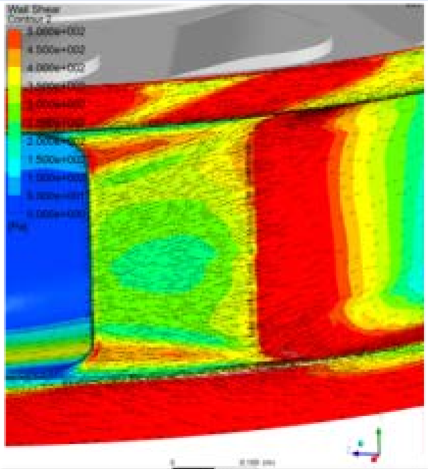
Impeller – Trailing Edge

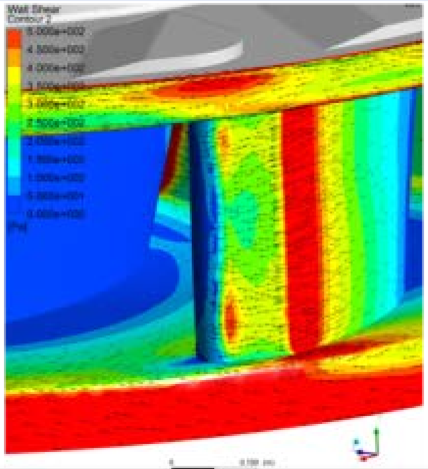


(2011)



Impeller – Trailing Edge



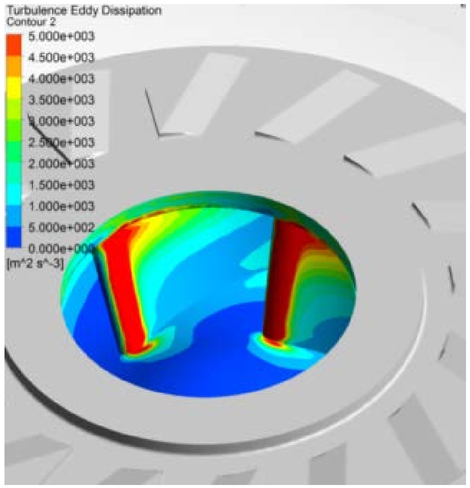


Inspection
6-wk
(2011)

Inspection
6-wk
(2012)

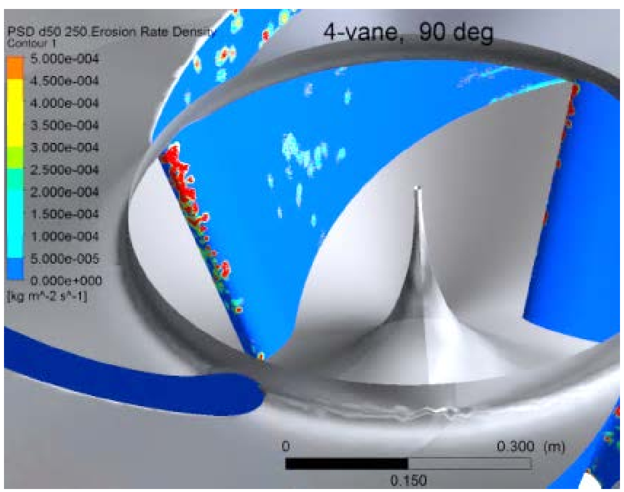
Impeller – Leading Edge

Turbulence [CFD]



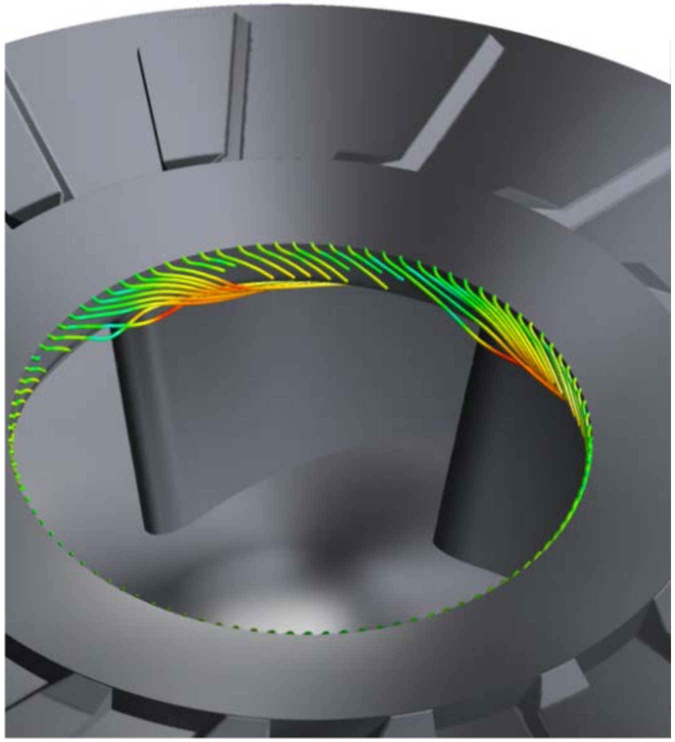
Wear ring not adjusted

Wear [CFD]

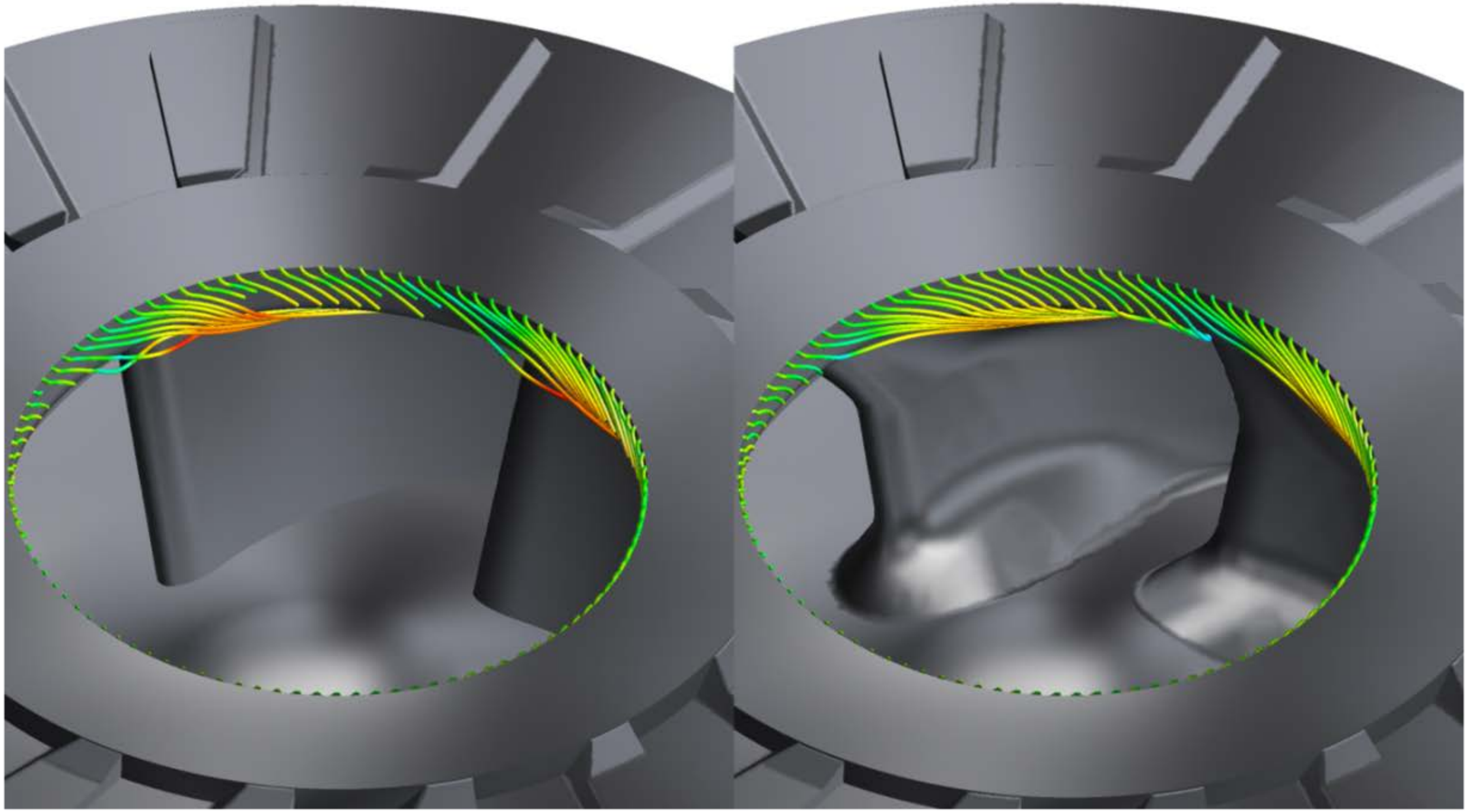


Wear ring adjusted

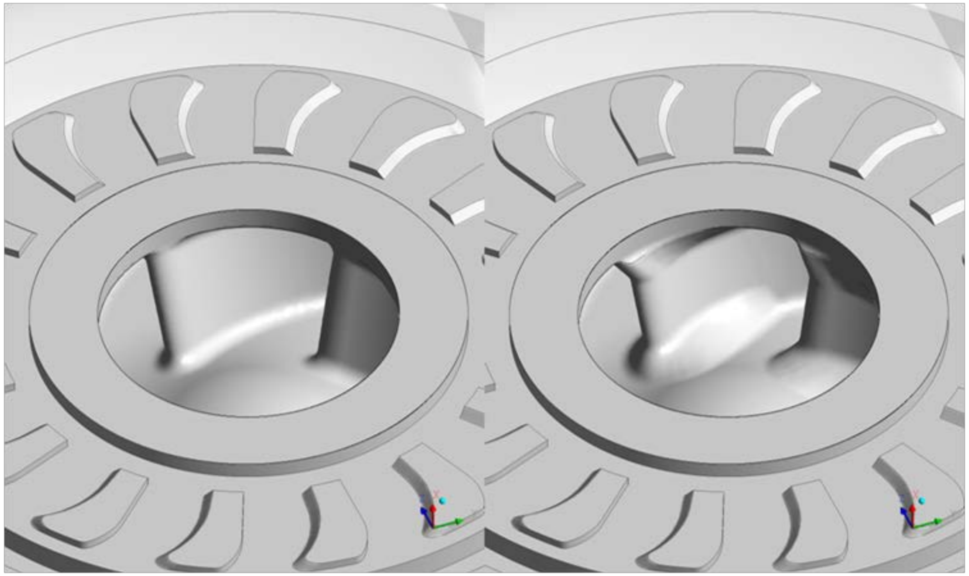
Impeller – Leading Edge

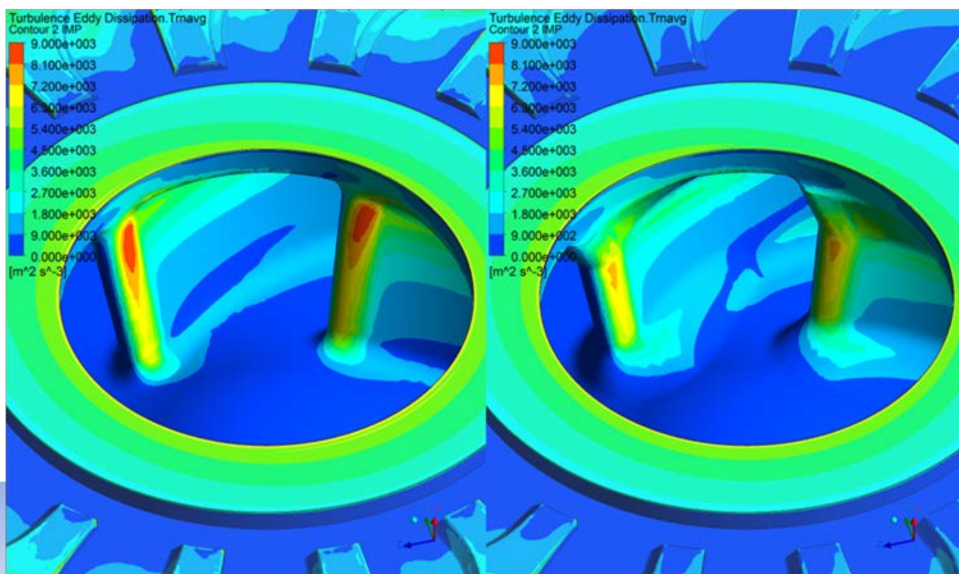


Low Vorticity Entrance Impeller (Pat. Pending)
The "Supertanker"



Standard impeller | "Supertanker" impeller | 1st "Supertanker" 28x26-65





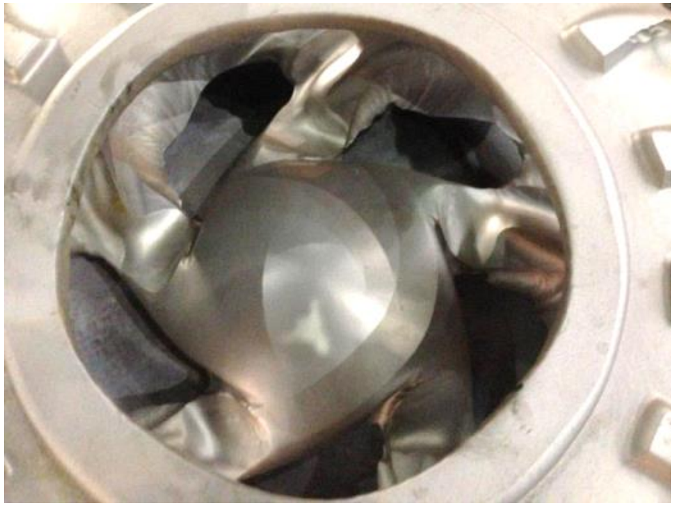
(2015-6)
Years after UM700hp development

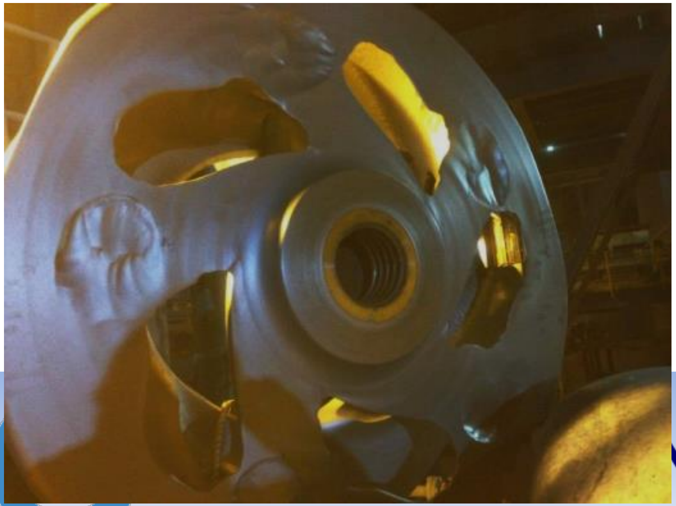
Gold mill discharge, millMAX UMD 28x26-65

Standard	"Supertanker"
2,850 h (17 wk)	3,020 h (18 wk)

Impeller – Back Shroud Holes

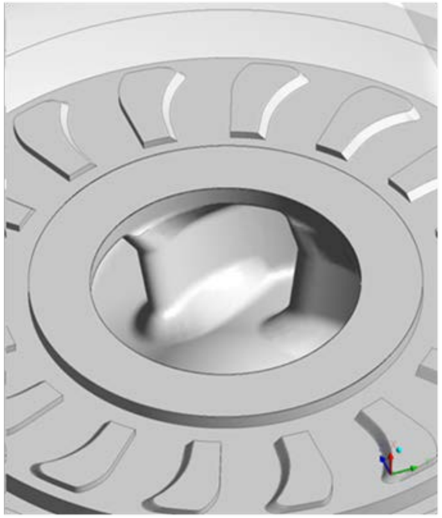
High suction velocity (overflow)





Large solid particles

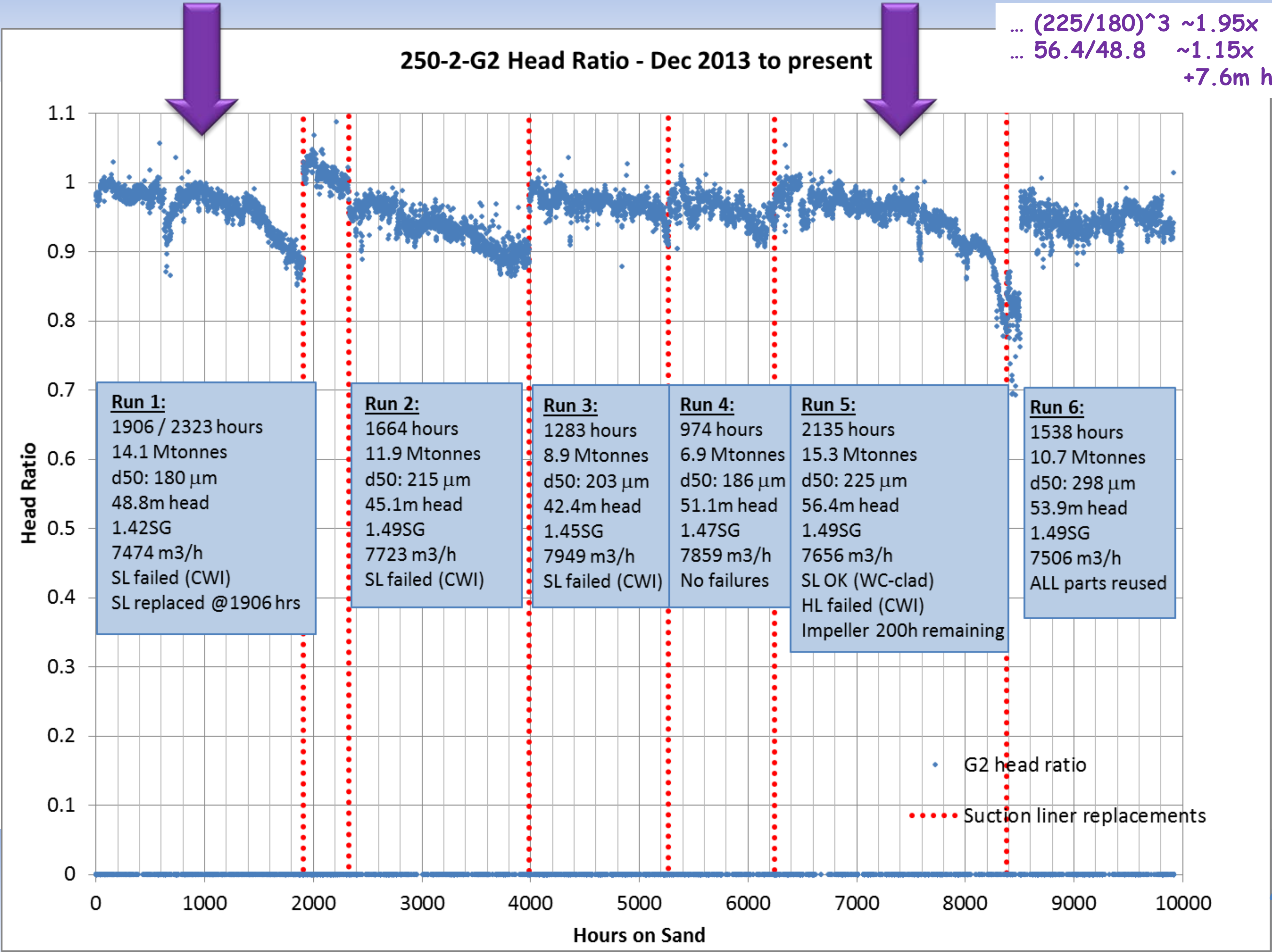
"Supertanker" impeller



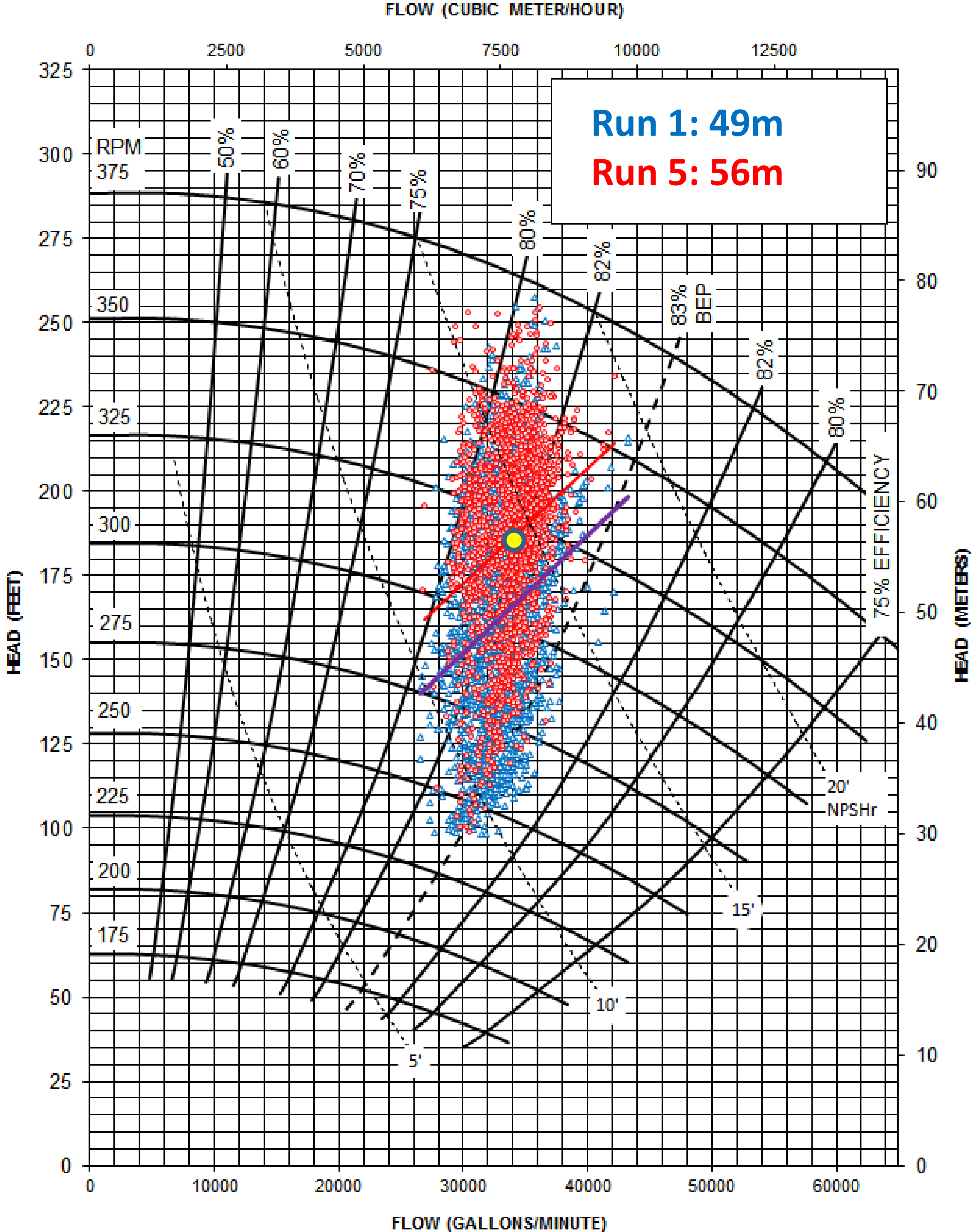
Copper mill discharge, millMAX UMD 26x22-60

Standard	"Supertanker"
2,000 h (12 wk)	2,350 h (14 wk)

OPERATION
- FLOW, HEAD
- HR



… (225/180)^3 ~1.95x
… 56.4/48.8 ~1.15x
+7.6m head

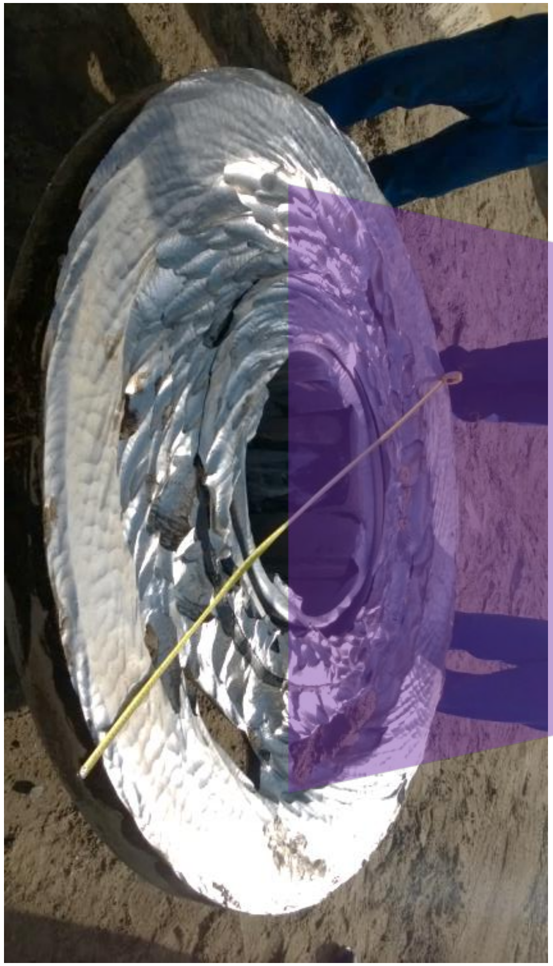


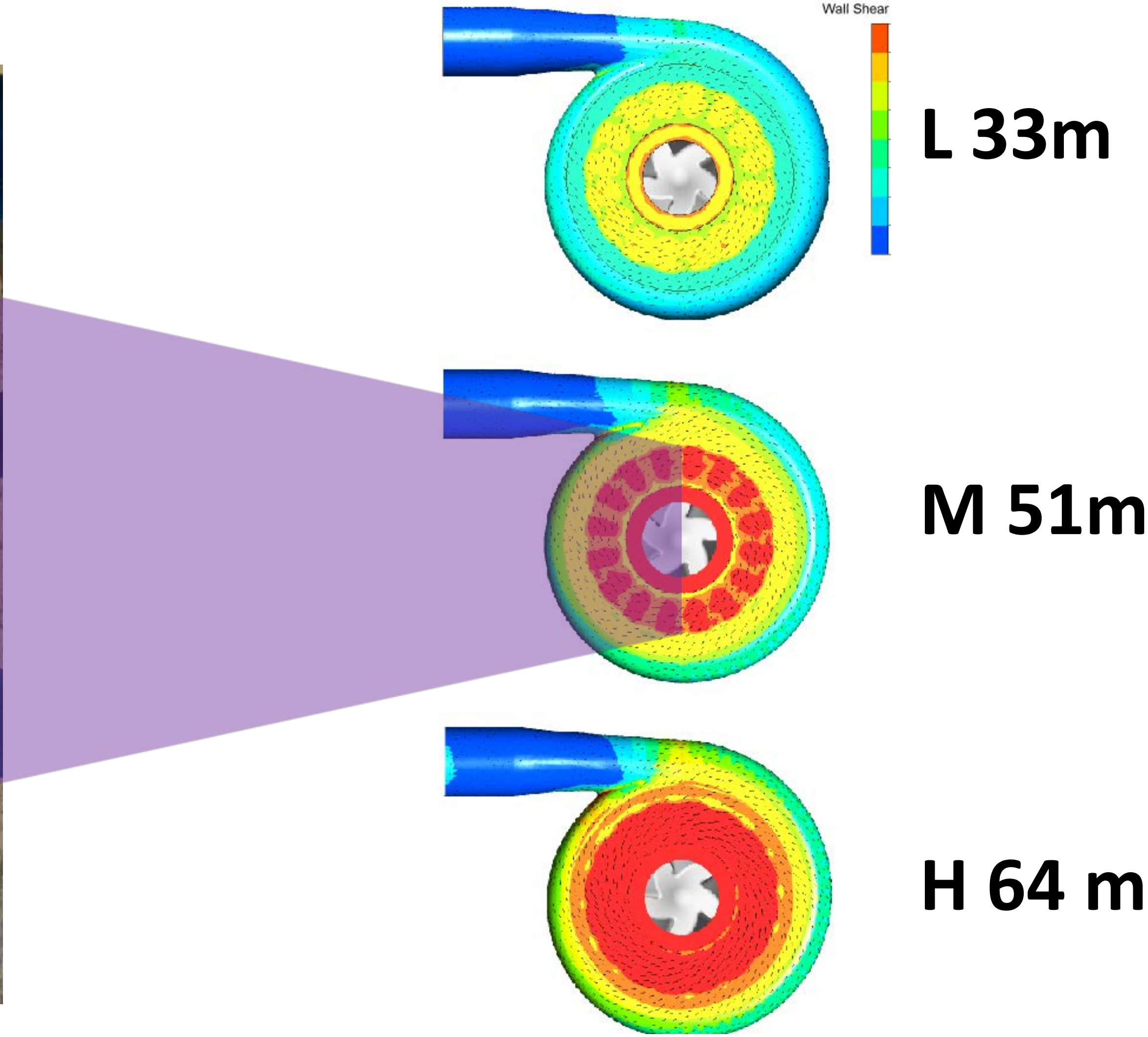
FLOW (CUBIC METER/HOUR)
0
2500
5000
7500
10000
12500
Run 1: 49m
Run 5: 56m
RPM
375
350
325
300
275
250
225
200
175
50%
60%
70%
75%
80%
82%
83% BEP
82%
80%
75% EFFICIENCY
20' NPSHr
15'
10'
5'
HEAD (FEET)
325
300
275
250
225
200
175
150
125
100
75
50
25
0
HEAD (METERS)
90
80
70
60
50
40
30
20
10
0
FLOW (GALLONS/MINUTE)
0
10000
20000
30000
40000
50000
60000

Wear patterns

- Wear ring and Suction liner
- Tungsten carbide laser cladding

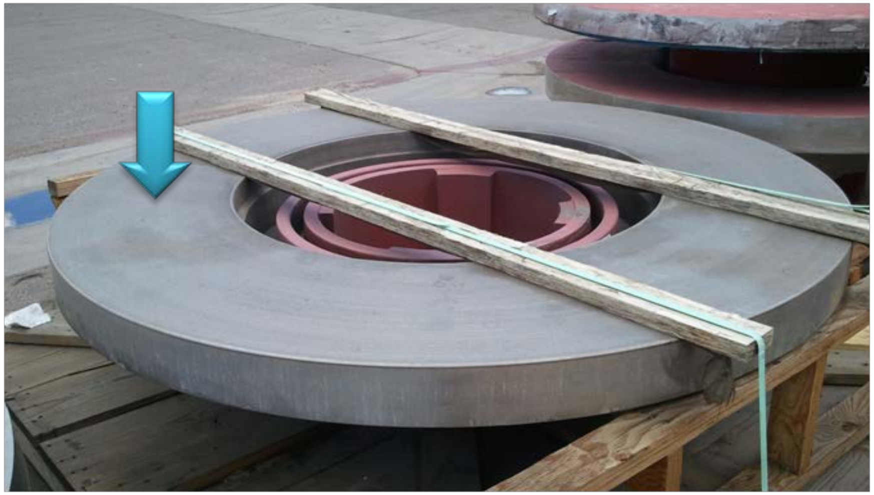
Run #1 – 1,906 h - avg. 49 m slurry





Tungsten Carbide Laser Cladding

Wear ring



Suction liner

Impeller (wear ring facing surface only)

Tungsten Carbide Laser Cladding

Run #1
1,906 h

Run #2
1,664 h

Run #5
2,135 h

Wear patterns

- Impeller and particle size

Run #1

750 h	2,323 h
	
	

Run#1 2,323 h

d50 180 micron

Run#5 2,135 h

d50 225 micron

– **Larger solids impact back shroud due to high inertial forces.**

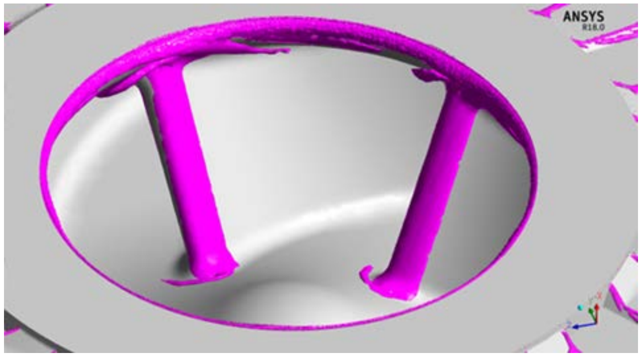
– **Larger solids impact increased in high vorticity areas.**

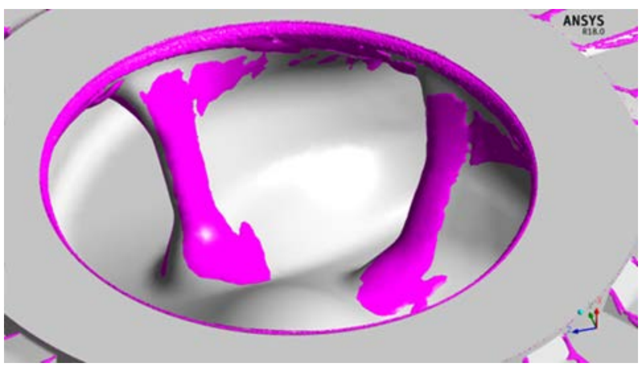
Impeller - Run #5 2,135 h

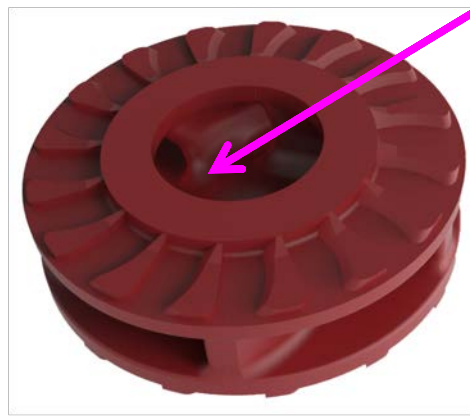
Trailing edge in good condition

Leading edge and back shroud became weak points - The “Supertanker” design will be implemented and is expected to help reducing local wear

Impeller - Run #5 2,135 h







"Supertanker" design expected to reduce wear rate and increase local thickness of back-shroud exactly where failure occurred.

Wear patterns

- Backliner
- Casing

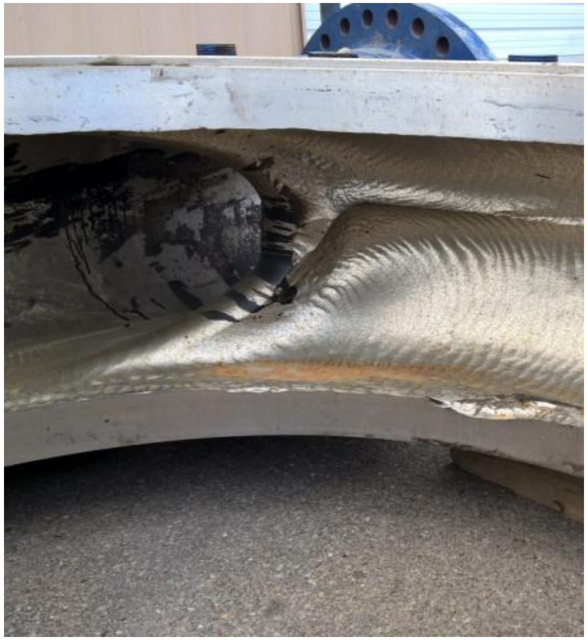
Backliner and Casing – Run #4

Casing

Run1 - 2,323 h

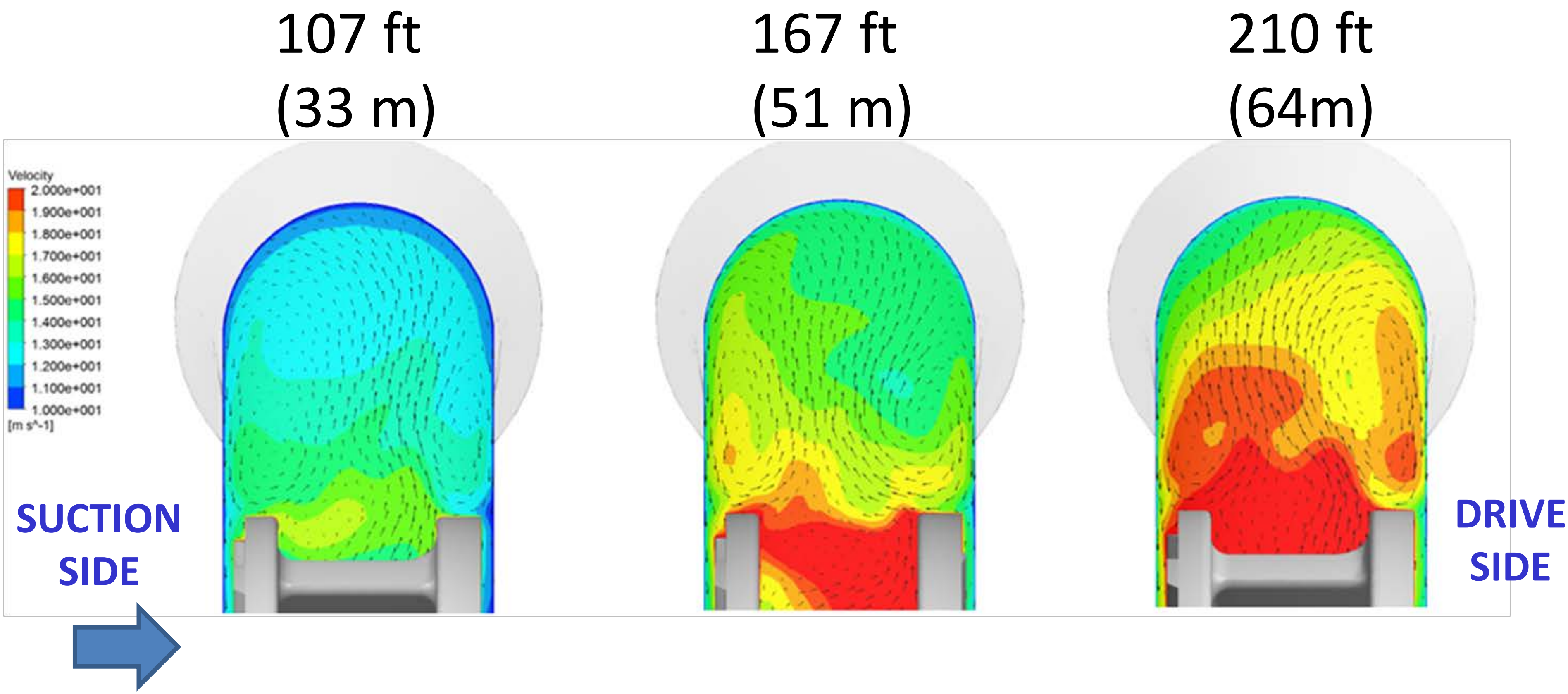
Run4

Run5 - 2,135 h



Backliner and Casing – Run #5

Backliner and Casing



Conclusions

- Wear due to recirculation is the primary failure mode of Tailings pumps at Syncrude's Aurora mine
- Recirculation can be minimized by maintaining a tight gap between the suction liner and impeller
  - Adjusting the wear ring consistently is proven to be extremely effective at reducing recirculation
- millMAX slurry pump has achieved about double the suction liner and impeller life of other Aurora Tailings pumps of similar size
- "Supertanker" impeller design should provide further benefits (results in early 2018)