A Closer Look at Increasing HPGR Efficiency via Reductions in Edge Effect

Brian Knorr – Metso

Victoria Herman – Metso

Devon Whalen – Freeport-McMoRan Inc.

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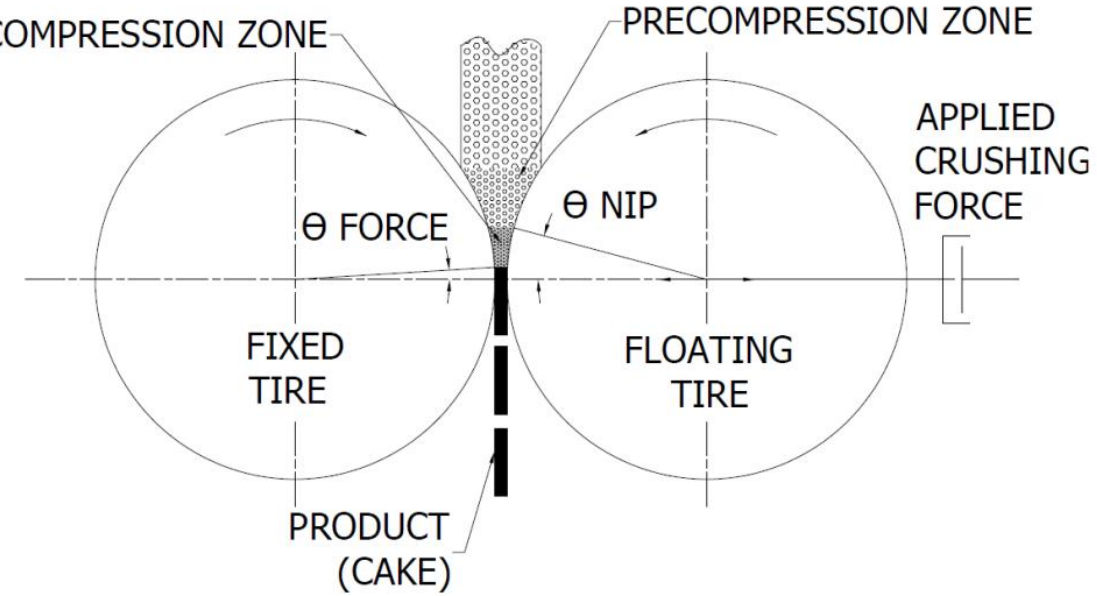
Introduction to HPGRs

HPGR operating principles:

- Two counter-rotating tires (one fixed and one floating)
- Hydraulic cylinders apply pressure to floating tire
- The counter-rotating tires draw in a bed of material
- This bed of material is crushed via inter-particle comminution



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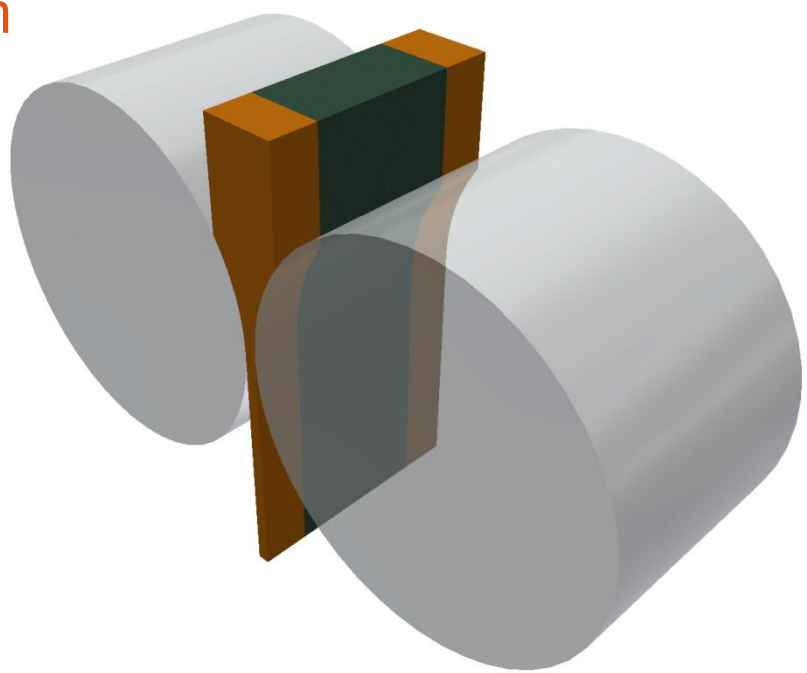
Comparison of HPGR Tire Designs

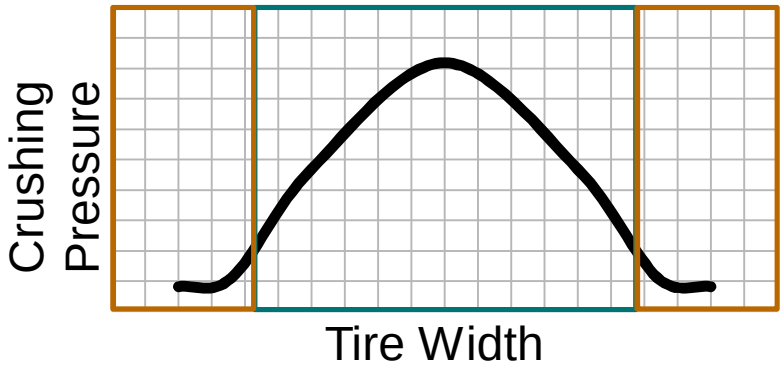
Edge effect in traditional HPGR design

Edge Effect is the impaired comminution performance at the edges of the HPGR tires due to a reduction in crushing pressure.



This results in:

- Coarser product size
- Uneven wear on the tire surface
- Decreased energy efficiency



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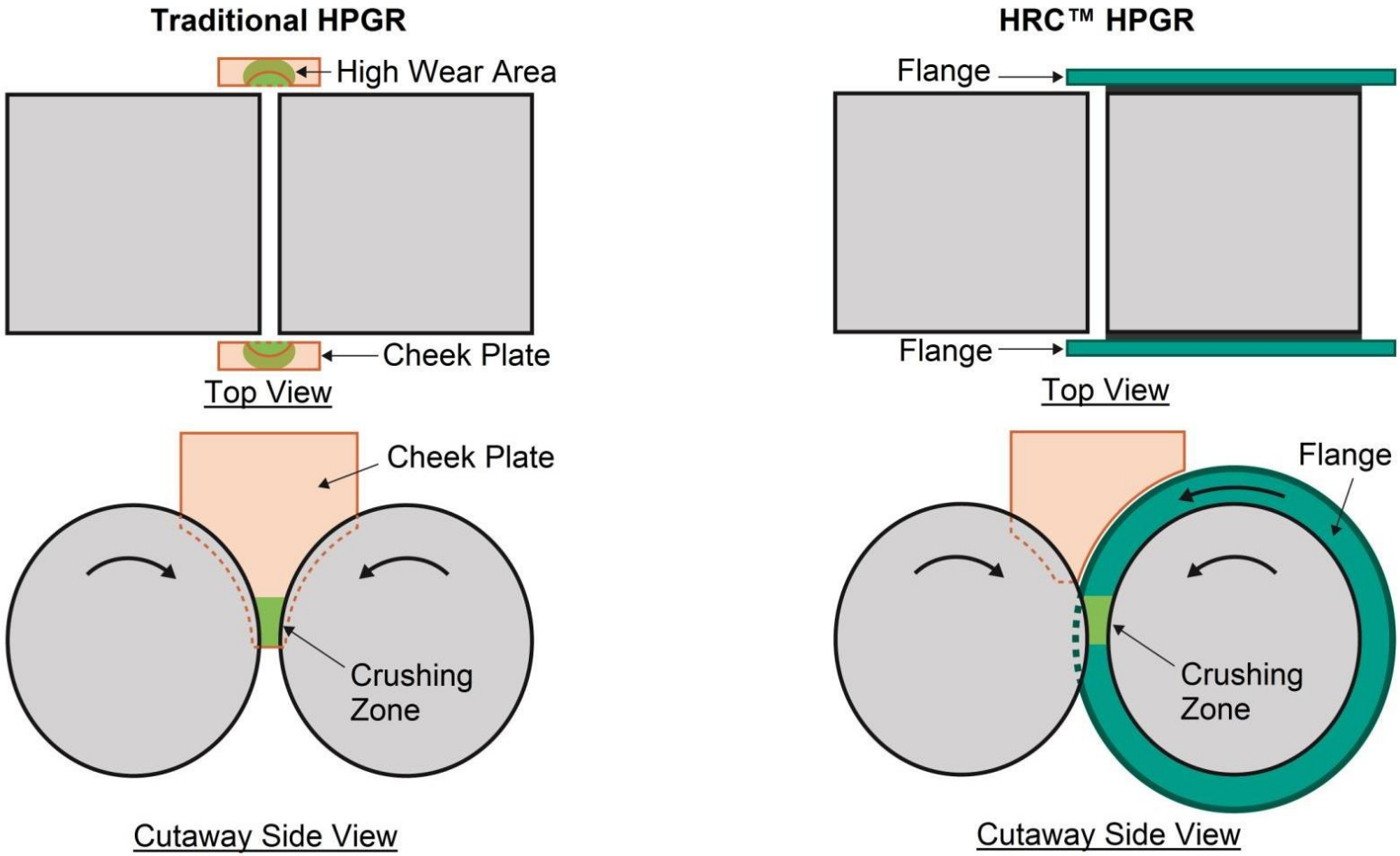
Comparison of HPGR Tire Designs

Traditional HPGR versus Metso's HRC™ HPGR



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Comparison of HPGR Tire Designs

A closer look at the HRC™ HPGR

Proposed advantages of flanges:

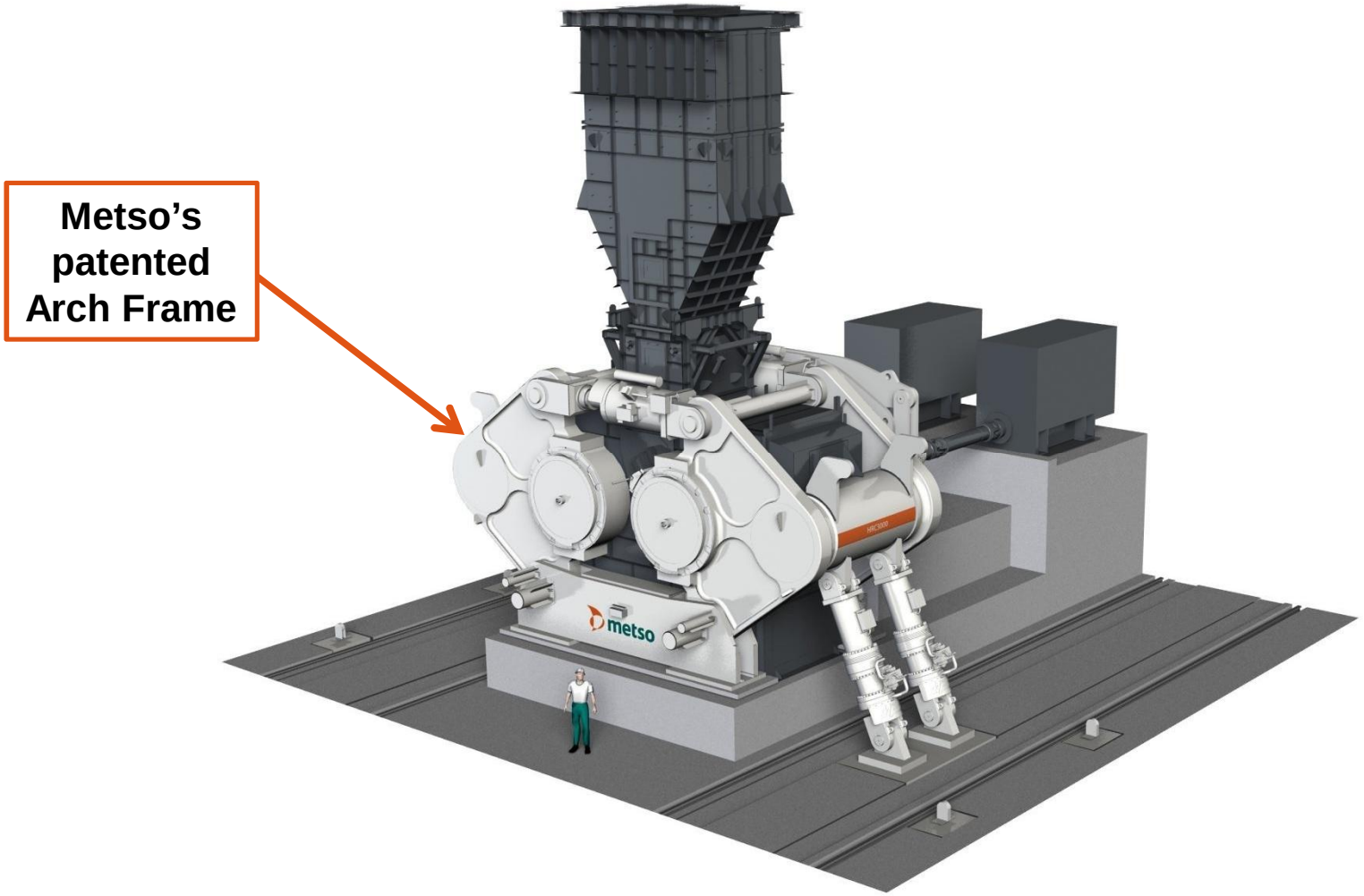
- Moving with the material through the crushing zone
- Higher crushing forces at the tire edge
- Greater total wear surface area utilized at high wear crushing zone

Important to note:

- The patented Arch-frame maintains a parallel relationship between the tires to avoid interference

Comparison of HPGR Tire Designs

A closer look at the HRC™ HPGR



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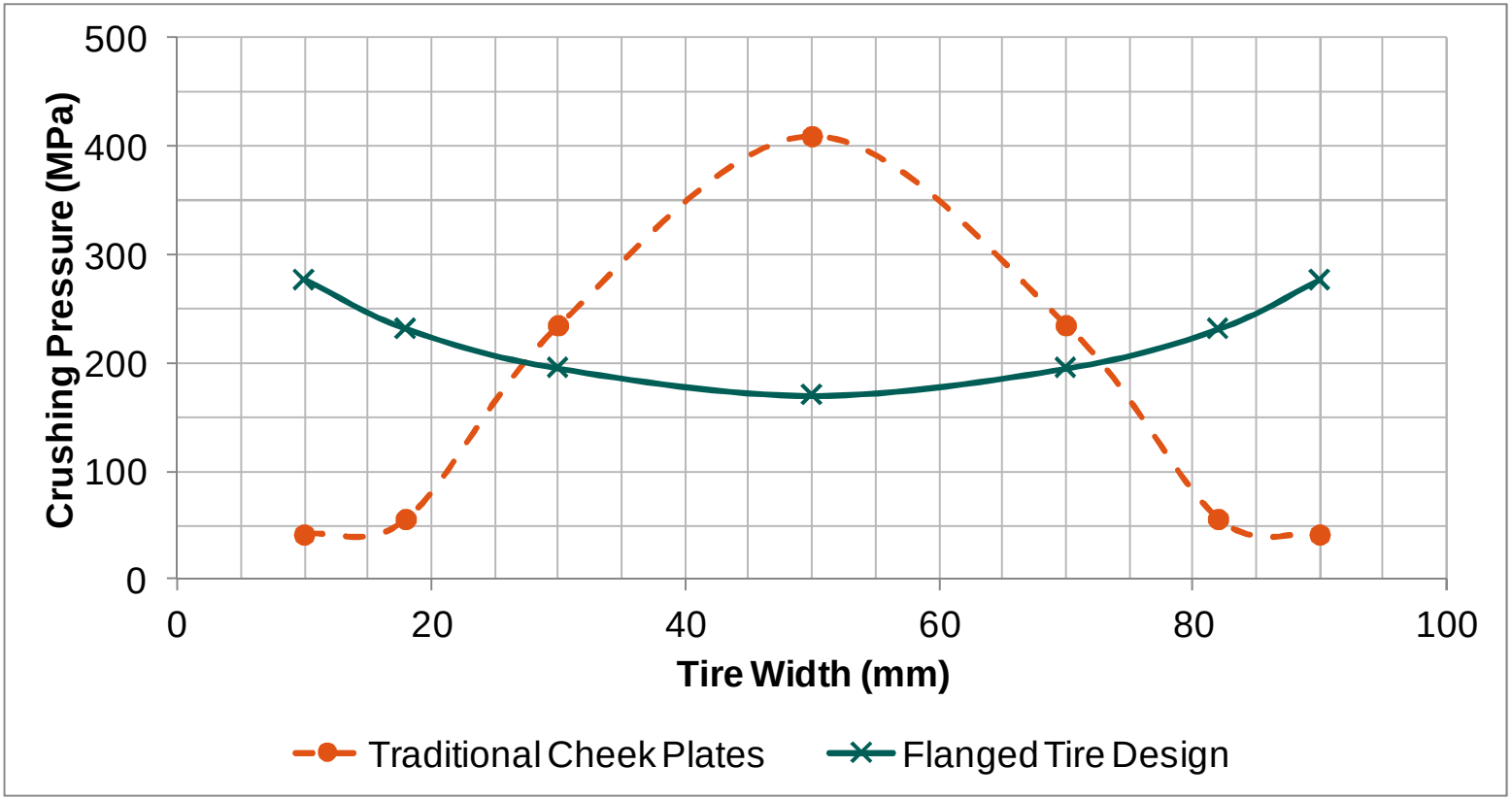
HRC™ High Pressure Grinding Rolls (HPGR)

Measured pressure profile in laboratory HPGR



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Morenci Pilot Plant

Proving grounds for the Metso HRC™ HPGR

A collaborative research & development program between Metso and Freeport-McMoRan.

Major Equipment:

- Metso HRC™ HPGR
- Metso VTM-650-WB Vertimill
- 10’ x 10’ Horizontal Ball Mill

Operating Hours*	Processed Tons *	Process Surveys	Controlled Process Variables
11,950	667,500	114	11

*through December 2013

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Edge effect testing series

A total of twelve (12) tests were completed, varying:

- Presence of flanges or cheek plates
- Relative wear of flanges/cheek plates
- HPGR specific force (N/mm^2)

For each test, the HPGR circuit was surveyed under steady state conditions, including fractional samples of the HRC discharge (edge, center, edge).

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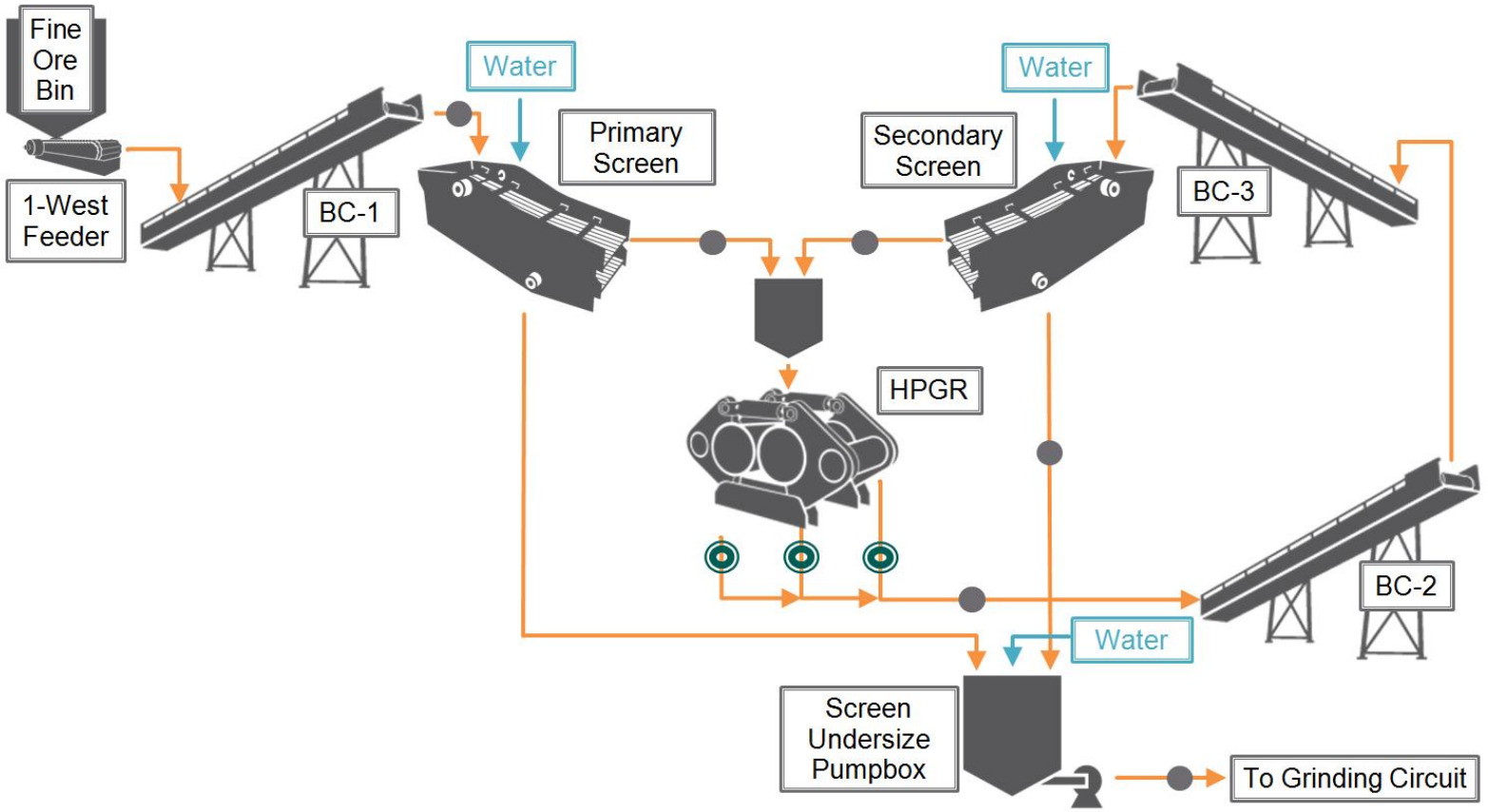
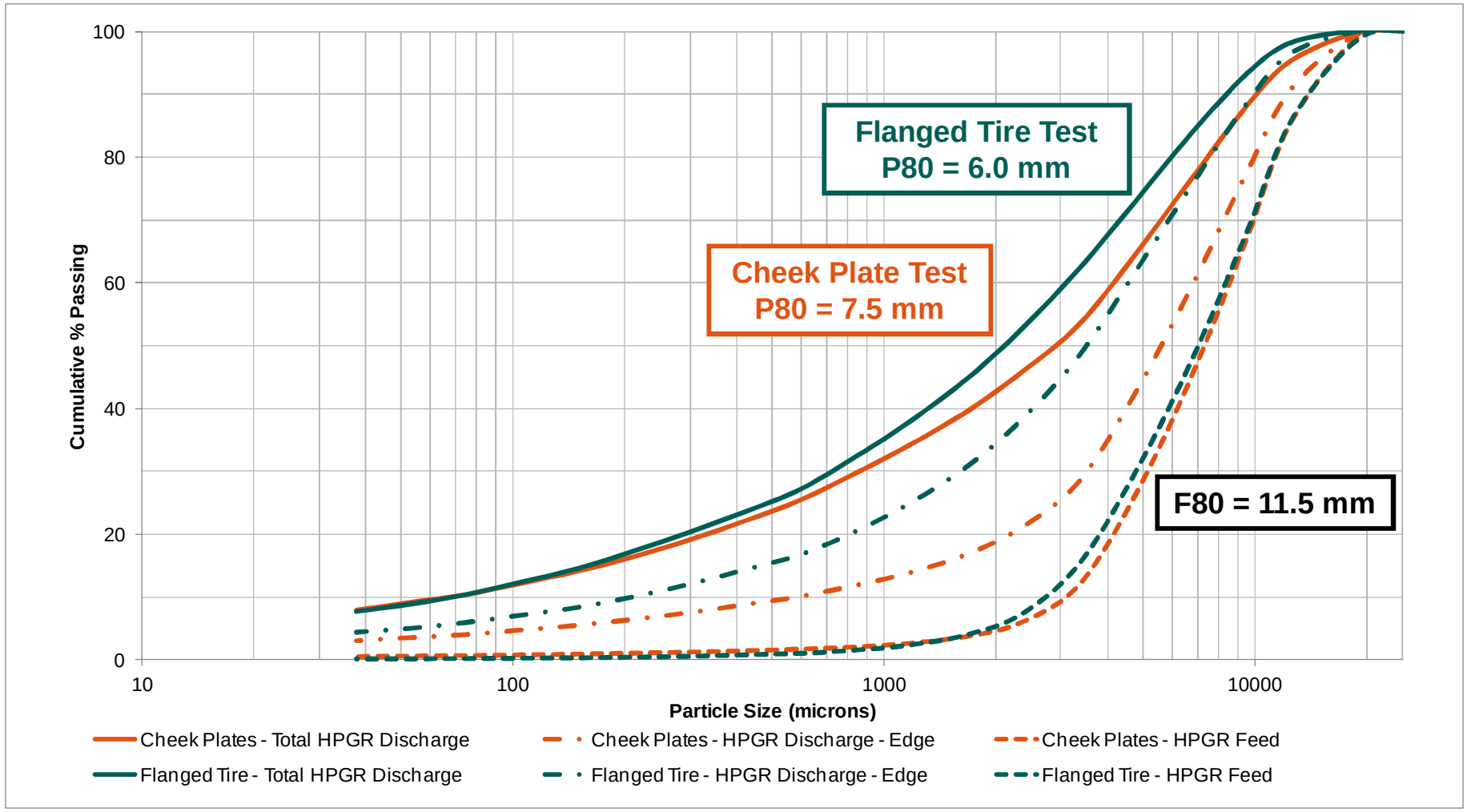
HPGR circuit flowsheet



HRC™ HPGR – Comminution Performance

Diminishing edge effect through design innovations



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HRC™ HPGR – Comminution Performance

Diminishing edge effect through design innovations

One of the most significant findings at the pilot plant was the enhanced comminution performance resulting from the HRC Flanges.

Test number	Test Z2B	Test Z8A	% change
Test description	Cheek plates - new	Flanges - new	
Specific force (N/mm^2)	4.49	4.51	+0.3%
Tire speed (RPM)	23.2	22.3	-3.7%
Plant feed tonnage (dry MTPH)	35.3	42.8	+21%
HPGR throughput (dry MTPH)	57.7	61.7	+6.9%
Specific throughput (t·s/m^3·hr)	216	240	+11%
Net circuit specific energy (kW·hr/tonne)	3.04	2.72	-11%
Circulating load (%)	111%	87%	-22%
HPGR feed F80 (microns)	11,577	11,502	-0.7%
HPGR discharge product P80 (microns)	7,491	6,004	-20%
Circuit product P80 (microns)	1,700	1,697	-0.1%

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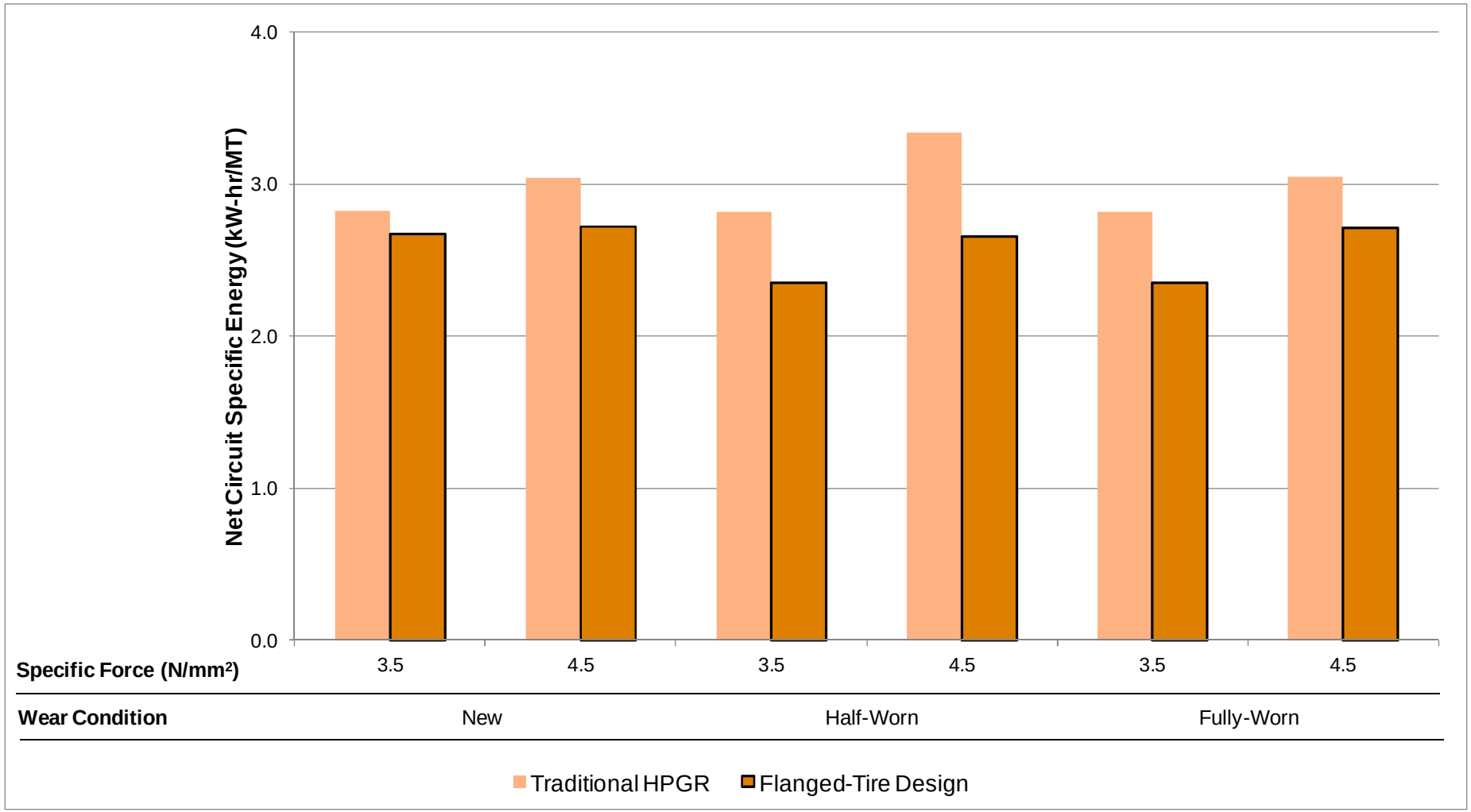
HRC™ HPGR – Circuit Specific Energy

Diminishing edge effect through design innovations



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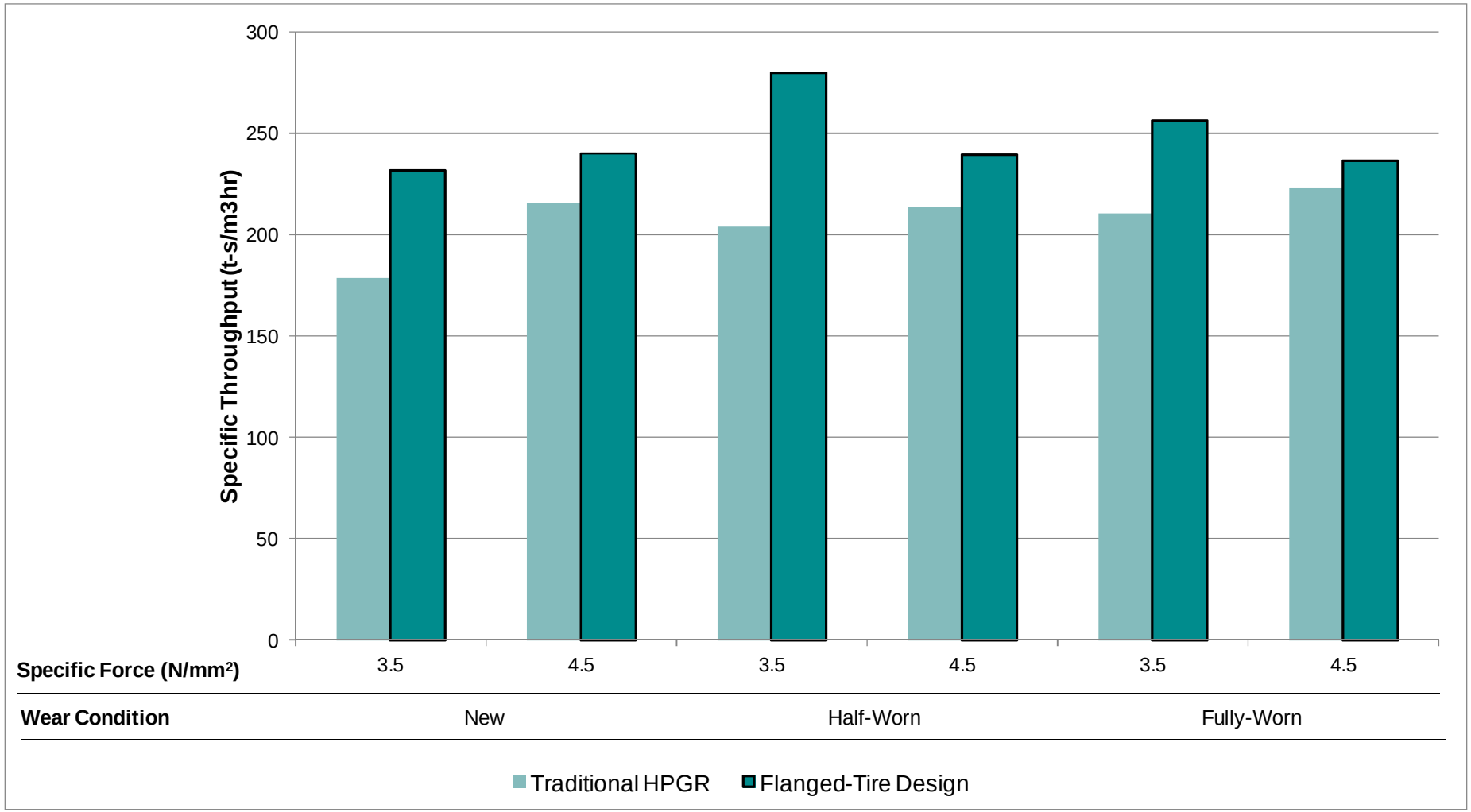
HRC™ HPGR – Specific Throughput

Diminishing edge effect through design innovations



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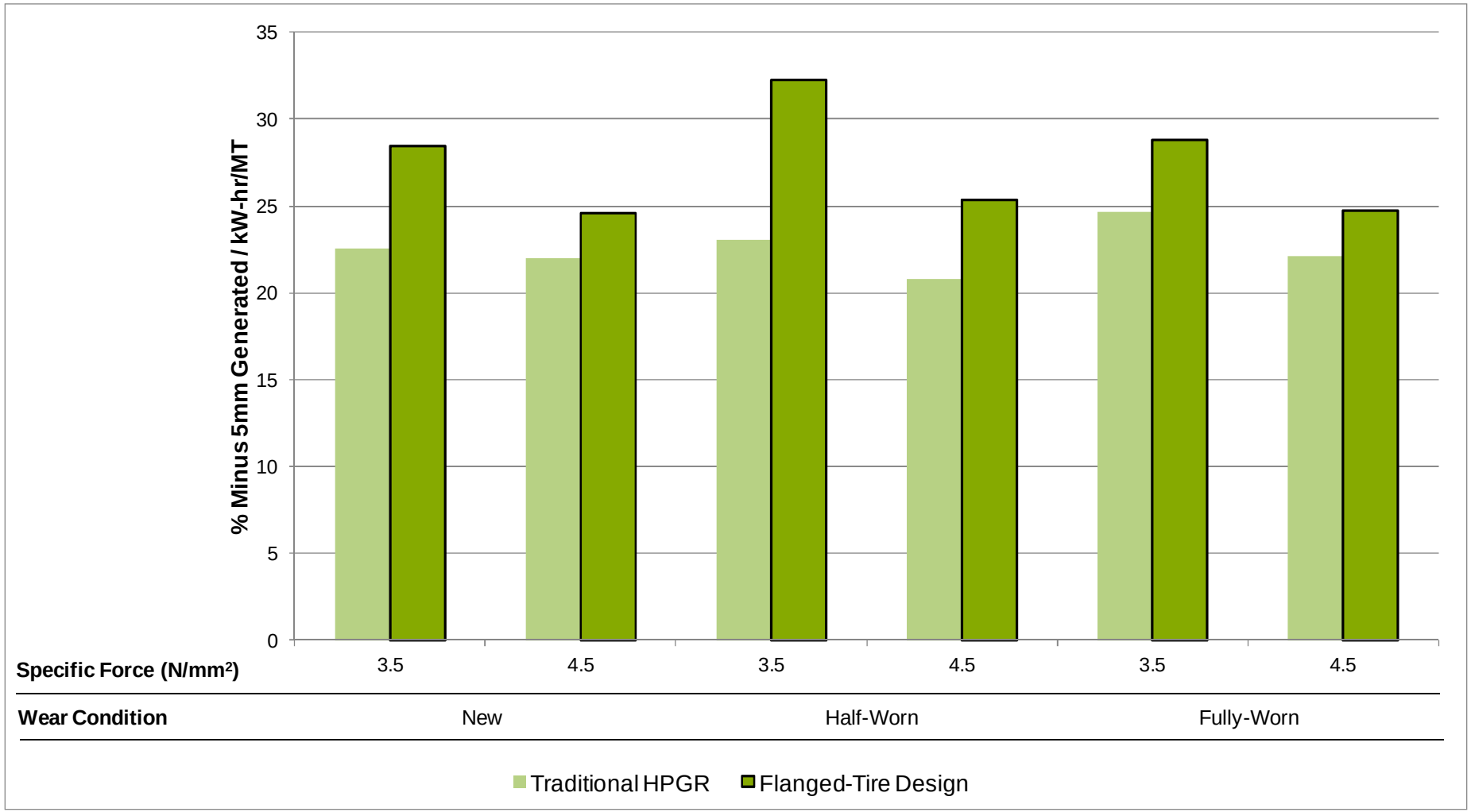
HRC™ HPGR – Comminution Efficiency

Diminishing edge effect through design innovations



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Conclusions from edge effect testing

The presence of flanges has been shown to yield better particle breakage at the edges of the HPGR tire. At the 750mm diameter pilot scale, the flanged tire design has been shown to:

- Reduce specific energy by 13.6%
- Lower circulating load by 24%
- Increase the specific throughput by 19%

These results have significant implications for the design and operation of HPGR circuits.

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Metso HRC™ HPGR

Reducing edge effect through the use of the flanged-tire design

HPGR circuit design and operation implications:

- Increased breakage rates provide higher energy efficiency
- Higher specific throughput increases unit capacity
- Finer product in open circuit applications
  - Open circuit can be applied in a broader range of applications
- Reduced circulating load in closed circuit applications
  - Potential to design auxiliaries (screens, conveyors) for lower recycle rate
  - Alternatively, potential for a smaller aperture on the screens, generating a finer product
- Even crushing force reduces the tire wear
  - Promotes even wear across the width of the tires
  - Allows for innovative carbide stud composition

Freeport-McMoRan's Metcalf Concentrator

Metso HRC™3000 HPGR

In operation since May 2014, the HRC™3000 is capable of processing over 70k STPD of fresh feed through a single unit of operation.

Current observations compared to predictions from flanged-tire pilot plant indicate the benefits scale up to full scale operations:

- Specific Throughput of 275-325 t·s/m^{3}hr
  - Prediction → 276 t·s/m^{3}hr
- Operating Gap of 93-112 mm
  - Prediction → 99 mm tire gap
- Circulating Load of 45-55% with 8mm screen aperture
  - Prediction → 58-85% recycle

Operating Hours*	Processed Tons *
+4,200	+17,000,000

*through January 2015

HRC™3000 HPGR

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Expect results