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Energy efficient overland conveyor development using large idler rollers

Results of research carried out as MRIWA Project M10549

at Big Roller Overland Conveyor Company

by

Shawn Ryan, Tiago Cousseau, Yusuf Badat, and Jayne O'Shea

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Distributed by: MRIWA

1 Adelaide Terrace

Perth WA 6000

to which all enquiries should be addressed

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Hon David Michael MLA

CHIEF EXECUTIVE OFFICER, MINERALS RESEARCH INSTITUTE OF WESTERN AUSTRALIA

Nicole Roocke

EXECUTIVE DIRECTOR, GLENROWAN ENTERPRISES PTY LTD TRADING AS BIG ROLLER OVERLAND CONVEYOR COMPANY

Shawn Ryan

LEAD INVESTIGATOR

Shawn Ryan

AUTHORS:

Shawn Ryan, Tiago Cousseau, Yusuf Badat, Jayne O'Shea

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CONTACT

Minerals Research Institute of Western Australia

1 Adelaide Terrace

Perth WA 6000

+61 8 6180 4340

mail@mriwa.wa.gov.au

https://www.mriwa.wa.gov.au/

1 Executive Summary

1.1 Overview

Decarbonising the transport of iron ore is a critical mandate under the Safeguard Mechanism established by the Clean Energy Regulator, which requires facilities emitting over 100,000 tonnes of CO_2-e per annum to reduce emissions in line with Australia's target of a 43% reduction in emissions by 2030. In the 2023/24 financial year, 28% of all facilities requiring Australian Carbon Credit Unit (ACCU) surrender statements for greater than 30% baseline exceedance were Rio Tinto iron ore operations (Clean Energy Regulator, 2026 (a)). These exceedances were driven by increased diesel consumption from higher haulage "work indexes" as mines mature.

With truck electrification and low-carbon fuels still facing technical and supply barriers and commercialisation delays, energy-efficient conveyor belt infrastructure offers an alternative pathway to reduce carbon emissions and the associated carbon intensity of ore transport toward international best-practice benchmarks.

1.2 Project Summary

This project supported the early-stage development of a supply chain for energy-efficient conveyor technology through a combination of:

1. **Validation:** Completing independent third-party engineering validation of rollers and relocatable ground modules.
2. **Production:** Executing the first commercial run of 50 large-diameter (508 mm) composite nylon idler rollers.
3. **Demonstration:** Proving the viability of relocatable ground modules patented by Big Roller Overland Conveyor Company (BR OLCC).
4. **Empirical Testing:** Generating a technical dataset on Indentation Rolling Resistance (IRR) performance and roller performance (including Rim Drag) at the TUNRA Bulk Solids test facility.

1.3 Energy Efficiency

Indentation Rolling Resistance (IRR) accounts for up to 60% of conveyor energy loss (Hager M. Hintz A., 1993). While industry has traditionally focused on belt compounds as a mechanism for continuous improvement of conveyor performance, this project successfully quantified the efficiency gains of increasing roller diameter beyond the standard range of sizes of between 152 mm and 219 mm, commonly used in Pilbara Iron Ore facilities.

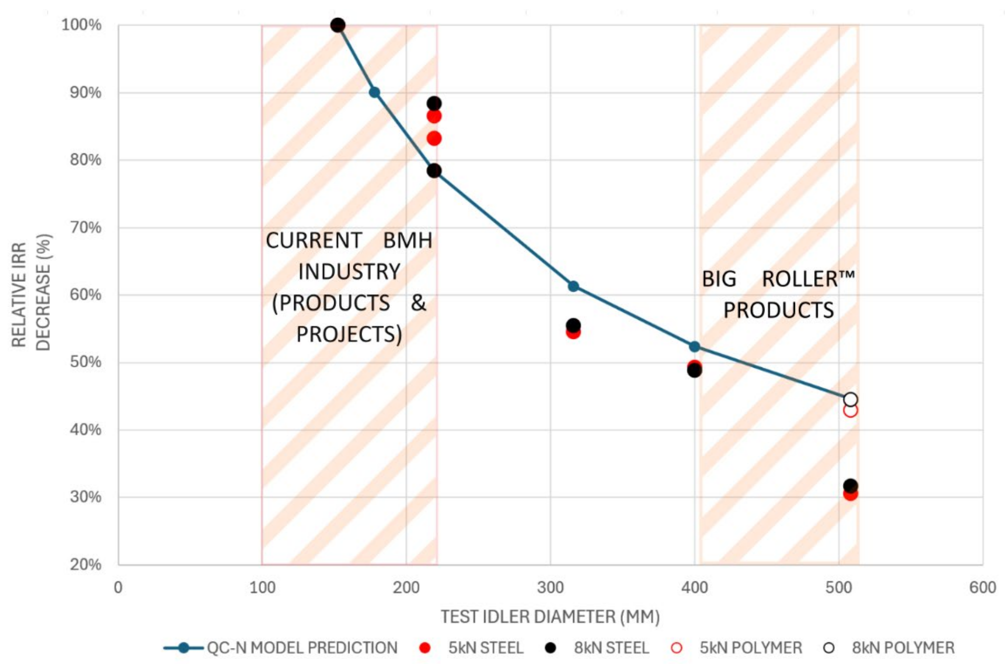
Testing conducted to AS 1334.13 (Type II) on a Contitech Eco Plus belt revealed:

1. **Significant Reductions:** Relative to the standard Pilbara Ports 152 mm diameter steel idler roller, increasing roller diameter to 508 mm reduced IRR by 68% for steel rollers and 57% for nylon rollers. This compares favourably to the 12% IRR reduction

achievable by increasing from 152 mm to the largest steel idler rollers currently in common use in the Pilbara at 219 mm diameter (for BHP South Flank OLCs).

2. **Weight Advantage:** The 508 mm nylon roller weighed less than 25 kg. This compares to 55 kg for an equivalent commercial steel roller and 80 kg for the steel test roller used in this study. This weight advantage offers a pathway to overcoming the historical weight barriers of large-diameter idlers, while maintaining strength and other positive performance attributes associated with nylon and other composite material rollers.
3. **Performance Trends:** Force of IRR (F_{IRR}) consistently decreased as roller diameter and temperature increased, while remaining largely independent of sag ratio.

Figure 1: *Relative F_{IRR} decrease as function of idler diameter at 20°C, 1% sag, 5 kN and 5 m/s.*



1.4 Commercial Developments

Ground Modules: BR OLCC's ground modules and idlers were engineered to meet standard Pilbara operating conditions, including throughputs up to 40 Mtpa and belt speeds up to 6.4 m/s. The modular system for roller installation (incorporating sleepers, legs, and stringers) was validated for high-accuracy installation and relocation.

Rollers: 508 mm nylon shell rollers were manufactured by Tribotech Pty Ltd and successfully type-tested to standards for balance (ISO 21940), noise (Tundra Bulk Solids internal standard), Rim Drag and Breakaway Force, Total Indicated Run-out (TIR) and Maximum Indicated Slope (MIS), Dust and Water Ingress and Resistance to housing press out (SANS 1313-3).

Infrastructure: Other Big Roller™ design suite idler products were developed in parallel with this project and include both offset idlers for overland Run-of-Mine (ROM) conveyors and inline idlers for plant and wharf applications.

Figure 2: *First commercial production run of 508 mm rollers packed for transport to TUNRA Bulk Solids.*

Figure 3: *First commercial production run of ground modules with 508 mm rollers integrated.*

1.5 Conclusion

The adoption of large diameter rollers in conveying systems could provide an energy demand reduction comparable to that achieved through over 30 years of rubber compound developments to reduce IRR. Applied together, these technologies offer a compounding efficiency gain that could significantly advance progress towards achieving carbon reduction targets for ore transportation through the use of belt conveying. With potentially 800 km of new conveying projects and existing retrofit required in WA alone, the potential impact of BR OLCC's designs is substantial.

This project successfully achieved Technology Readiness Level (TRL) 6, moving the Big Roller™ design suite products, relocatable ground modules and offset and inline idlers, from laboratory validation to the threshold of site field trials (TRL 7-9) and delivered commercial samples for future automated construction equipment development.

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Terms, Abbreviations and Acronyms

ACCU	Australian Carbon Credit Unit
ASTM	American Society for Testing and Materials
BR OLCC	Big Roller Overland Conveyor Company
Big Roller™	Design Services Suite offered by BR OLCC
CAPEX	Capital Expenditure
CEMA	Conveyor Equipment Manufacturers Association
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DNV	Det Norske Veritas
DXF	Drawing Exchange Format
ESG	Environment Social, Governance
HDPE	High Density Polyethylene
HME	Heavy Mining Equipment
ISO	International Standards Organisation
ITP	Inspection and Test Plans
IRR	Indentation Rolling Resistance
LF	Load Factor
LV	Light Vehicle
MDR	Manufacturer’s Data Reports

METS	Mining Equipment Technology and Service
MIS	Maximum Indicated Slope
Mtpa	Million Tonnes Per Annum
OH&S	Occupational Health and Safety
OPEX	Operating Expenditure
SANS	South African National Standard
TBS	TUNRA Bulk Solids
TIR	Total Indicated Run-out
TRL	Technology Readiness Level
UC	Utilisation Check
UTFPR	Federal Technological University of Paraná

2 Introduction

2.1 Overview: The Decarbonisation Mandate for the Pilbara

The decarbonisation of the Pilbara iron ore sector is governed by a legislative mandate under the reformed Safeguard Mechanism, which commenced on 1 July 2023. This framework aligns Australia's highest-emitting industrial facilities with the nation's updated Nationally Determined Contribution under the Paris Agreement (United Nations Framework Convention on Climate Change, 2015). By legislating a proportional share of the national target to reduce greenhouse gas emissions by 43% below 2005 levels by 2030, the mechanism applies a compounding 4.9% annual reduction to operational emissions baselines. This rapid trajectory toward 2030 explains the widening gap between current "business-as-usual" diesel consumption and the international best-practice benchmark now used by state and federal regulators to assess project viability. (Department of Climate Change, Energy, the Environment and Water, 2024)

The Safeguard Mechanism applies to existing facilities that emit more than 100,000 tonnes of carbon dioxide equivalent (CO_2-e) per annum. In 2023-24 there were 219 facilities covered, including 22 WA-based iron ore facilities[*] (approximately 10% of the total number) (Clean Energy Regulator, 2026 (b)). Across every sector in the Safeguard Mechanism program, facilities are required to submit Australian Carbon Credit Unit (ACCU) surrender statements to the regulator if they exceed their assessed baseline emissions in a given financial year by more than 30%. In the 2023/24 financial year, 18 facilities nationally were required to issue such surrender statements, with five of these facilities (28%) operated by Rio Tinto, including the Brockman 2, Brockman 4, Hope Downs 1, Marandoo and Paraburdoo Mines (Clean Energy Regulator, 2026 (a)).

In each of the relevant Surrender Statements for these facilities, operator Rio Tinto states "Increased diesel consumption at [the specified facility] was primarily due to a higher work index. As mining operations mature and expand further from processing facilities, mobile equipment must travel greater distances to move material, therefore consuming more diesel." Rio Tinto also provides progress updates on their measures to mitigate expanding diesel consumption including "Mobile fleet electrification is expected to significantly reduce diesel use in the Pilbara, though many of the required technologies are not yet technically viable" and "Alternative fuels, such as low-carbon fuels / renewable diesel, are being explored to complement electrification." (Clean Energy Regulator, 2026 (a))

In the most recent approval of a new iron ore mine proposal (the Hancock Iron Mulga Downs proposal) the Western Australian Environmental Protection Agency states "The proponent has benchmarked the proposal against comparable iron ore operations in the Pilbara and demonstrated that its emissions intensity of 0.0070 t CO_2-e per tonne of iron ore is comparable to, or lower than, other identified operations. Although this intensity is higher than the Safeguard Mechanism's iron ore default (0.00476 t CO_2-e per tonne of iron ore) and

[*] Appendix 4

best-practice benchmark (0.00188 t CO_2-e per tonne of iron ore), these emission intensities reflect the performance of Australia's most efficient iron ore operations." (Environmental Protection Agency , February 2026).

Iron ore default and best practice emissions intensity benchmarks are legislated as Production Variables (Department of Climate Change, Energy, the Environment and Water, 2024) within the Safeguard Mechanism to incentivise low emissions production.

This clearly shows that pathways to reduce carbon emissions and lower the existing and future carbon intensity of transported iron ore are important considerations for miners, mine developers, State and Federal Environmental Protection Agencies and the Clean Energy Regulator.

With Pilbara iron ore mining delivering export earnings of $128.1 billion in 2024 (Department of Treasury and Finance, Government of Western Australia, 2025) maintaining that key contribution to the economy while delivering on emissions reduction targets will require a proactive and expedited approach to incorporating mitigation actions into work practices.

As of March 2026, iron ore mining and processing in the Pilbara is characterised by high operational output (Table 1). It is important to note that "nameplate capacity" (the designed maximum output) often differs from actual annual production guidance, which accounts for factors including mine sequencing, maintenance, port constraints and market demand.

Table 1: *Nameplate production capacity for Pilbara-based iron ore miners (sourced from various company ASX announcements and EPA approvals).*

Company / Project	Nameplate / System Capacity (Mtpa)	Notes
Rio Tinto	345 – 360 (Rio Tinto, 2025)	Represents total Pilbara system capacity.
BHP (WAIO)	~280 – 305 (BHP, 2025 (b))	Based on system capability.
Fortescue	~195 – 205 (Fortescue, 2025 (a))	Operations include the Chichester, Solomon, and Eliwana hubs + Iron Bridge.
Hancock Iron Ore (Roy Hill & Atlas Iron)	64 - 74 (Australian Resources and Investment, 2025)	Roy Hill remains the primary asset; expansion potential exists.
Mineral Resources	35 – 50 (Mineral Resources, 2025)	Includes Onslow Iron (35 Mtpa nameplate) and upgraded capacity.
CITIC Pacific (Sino Iron)	~24 – 27 (Citic Pacific Mining, 2024)	Magnetite concentrate production; largest magnetite operation in Australia.

2.2 Bulk Material Movements – Ore Transportation

Engineering decisions made at the project design stage, particularly on the best way to transport ore and the associated plant layouts required for this, flow through to the mine and port operators in the production phase of a facility's operational life. Choices and trade-offs are made between truck haulage (off road, on road, class, road train configuration, diesel, electric battery, fuel cell, hybrid), conveying (rope, trough, pipe, bucket and sandwich belt), rail (conventional, Railveyor, Bulk Ore Shuttle System) and hybrid (Virta Rail-Running Conveyor™) ore transport variants.

There has been a tendency in mine development to favour diesel truck haulage over fixed infrastructure assets such as conveyors and rail, often driven by the flexibility and lower initial Capital Expenditure (CAPEX) that truck-based solutions offer. With the recent push to electrify mining equipment fleets however, a paradigm shift is changing what constitutes an optimal haulage solution from independently operable assets (like diesel trucks) towards inflexible and high capital intensity integrated infrastructure systems.

2.2.1 Pilbara Iron Ore Heavy Mining Equipment Fleet

There are over a thousand haul trucks currently in service in Pilbara Heavy Mining Equipment (HME) fleets, dominated by Rio Tinto's 430 trucks (Table 2).

Haul trucks typically have a service life on the order of 20 years, with approximately two major rebuilds (gearbox and motor) occurring during that time. Each of these rebuilds presents an opportunity to undertake conversion to an all-electric drivetrain. Once a decision is made on the type of rebuild being pursued, this can have a 6-to-7-year ongoing operational impact.

In addition to strategic decisions on electrification or alternative fuel use for haul trucks, each company also needs to make similar decisions for drills, excavators, front end loaders, bulldozers, water carts and other ancillary mining equipment in the HME fleet. Relevant companies are also progressing the supply of renewable energy for rail networks and port infrastructure electrification programs. This fleet renewal program represents a substantial challenge for the WA iron ore industry, with significant complexity in both conversion processes and the associated electrical network and charging infrastructure required.

BHP (BHP, 2025 (a)) and Rio Tinto (Rio Tinto, 2023 (a)) are reporting delays with electrification developments and required technology commercialisation, pushing back target deployment dates and expectations of widespread market adoption beyond the mid 2030's.

Table 2: *Extent of HME fleet in Pilbara (sourced from company ASX announcements and EPA submissions).*

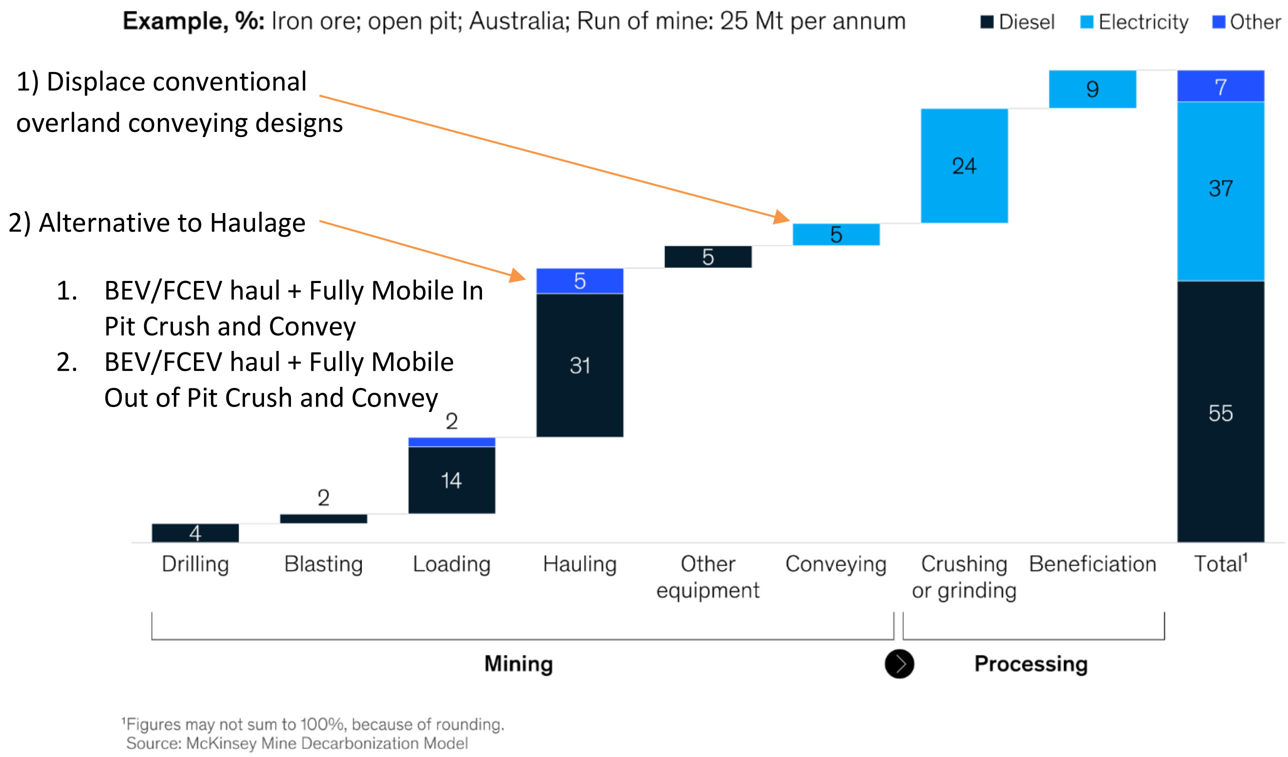
Company	HME Truck types and class	Quantity
RioTinto (RIo Tinto, 2023 (b))	Various, Multiclass	430
BHP (BHP, 2022 (a))	Various, Multiclass	~80
	Various, Ultra class	220
Fortescue (Fortescue, 2023)	Various Multiclass	190
	Liebherr, Multiclass	120
Roy Hill (Hancock Iron, n.d.)	Caterpillar 793F 218-255T class	54
	Hitachi EH5000, Ultra class	24
	Hitachi EH4000, 218-255T class	18
Total		**1136**

2.2.2 Conveying as an Alternative Approach

McKinsey's Mine Decarbonisation Model (McKinsey, 2021) estimates that approximately 41% of the energy used in a 25 Million tonne per annum (Mtpa) iron ore mine is consumed in haulage and conveying (Figure 4).

The development of improved energy-efficient conveyor designs offers immediate benefit with respect to efficiencies on the 5% of energy used by existing conveyor systems, but this benefit could be further magnified by expansion of improved energy-efficient conveyor systems as commercial-ready alternatives to displace the energy currently used in conventional haulage solutions (31% diesel and 5% other energy source).

Figure 4: *McKinsey Decarbonisation Model – 25 Mtpa iron ore mine energy consumption estimates.*



2.3 Conveyor Efficiency

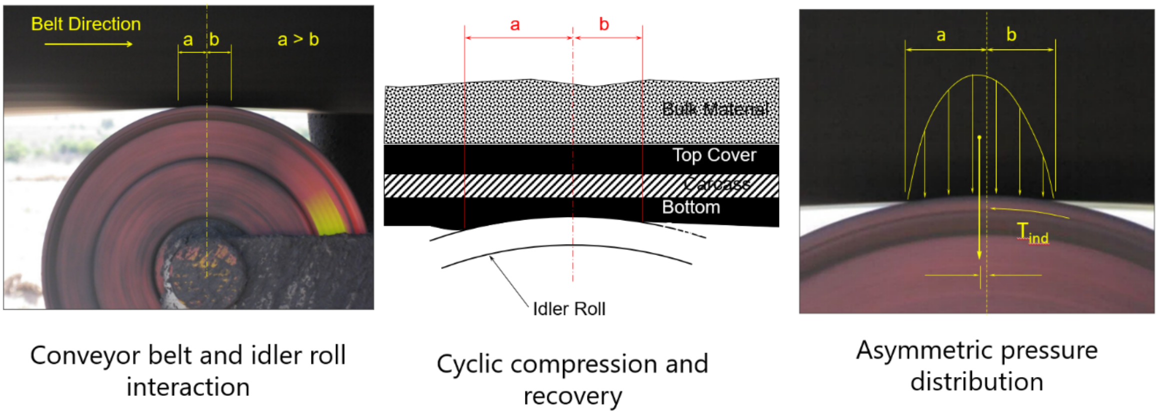
For conventional belt conveyor designers in the bulk materials handling industry, increasing the diameter of idler rollers offers fundamental performance advantages. Larger rollers benefit from reduced Indentation Rolling Resistance (IRR) and Rim Drag, two key factors that directly drive conveyor energy efficiency and operational savings. Because of this value proposition, rapid advancements in composite material science and the increasing availability of advanced on-site handling equipment are proving transformative.

By overcoming the prohibitive weight and installation penalties of traditional steel rollers, composite materials are making it practical to deploy massively scaled, large-diameter idler rollers on long conveying systems. Consequently, identifying the optimal crossover point between "bigger is fundamentally better" and "just how big is practically possible" has become a valuable engineering optimum to identify. As the industry pushes these boundaries, empirical verification of system viability is becoming increasingly important to inform the design of new best practice in conveyor design (Conveyor Equipment Manufacturers Association (CEMA), 2020).

2.3.1 Indentation Rolling Resistance

In loose bulk material belt conveying, IRR is a drag force on the conveyor system generated as the belt travels over each idler. This force arises due to the viscoelastic contact between the conveyor belt and an idler roll forming an asymmetric pressure distribution that opposes the direction of movement. For conventional systems, this drag force resistance can account for up to 60% of the total power demand (Hager M. Hintz A., 1993) that needs to be delivered by the installed drive capacity (gearbox, motor and electrical systems).

Figure 5: *IRR development due to asymmetric pressure distribution across contact length between belt and roller shell* **(Wheeler, 2016)**.



Research into IRR management over the past two decades has primarily been focused on optimising conveyor pulley cover rubber compounds (O'Shea, The influence of viscoelastic property measurements on the predicted rolling resistance of belt conveyors, 2014). For example, energy reductions offered for belt compounds such as Contitech's Eco Plus (15%) and Eco Extreme (30%) when compared to a standard conveyor belt (Contitech, 2022) are often cited as a current action plan item in Environmental, Social and Governance (ESG) reporting (Fortescue, 2025 (b)).

Idler roller diameters however are also known to influence the IRR of belt conveying systems, with indentation depth and contact stress both reducing with increasing roller diameter across the commercially available range of diameters between 127 and 219 mm (Nordell, L.K., Vol. 16 (1996) No. 3,). Above this current commercial size range however, this effect and its impact on demand power have largely been neglected in research, with no publicly available empirical datasets quantifying the continuation of the relationship for rollers larger than 219 mm diameter.

Proof of concept research was previously undertaken by BR OLCC at the IRR test facility located at TUNRA Bulk Solids (TBS), the only test facility of its kind in the world (TUNRA Bulk Solids, 2023), evaluating the performance of steel rollers of 152, 178, 316 and 400 mm diameter (the maximum capacity of the test apparatus at the time).

This preliminary testing was nominally consistent with the hypothesis that IRR continues to decrease at higher diameters, but limitations of the test apparatus with the two larger rollers (316 and 400 mm diameter) prevented the results from complying with AS 1334.13 "Methods of testing conveyor and elevator belting Determination of indentation rolling resistance of conveyor belting" (Standards Australia, 2017) (O'Shea, The Effect of Large Diameter Idler Rollers on the Indentation Rolling Resistance of Belt Conveying Systems., 2023).

To overcome these limitations, the TBS test rig was modified for this study to deliver full test compliance under AS 1334.13 for rollers up to 610 mm (24”). This modified facility is now available to support further work relevant to the wider bulk materials movement industry.

In 2024 AS 1333 "Conveyor belting of elastomeric and steel cord construction" (Standards Australia, 2024) was revised to include IRR testing to AS 1334.13 (Standards Australia, 2017) for the energy efficiency performance qualifications relevant to conveyor designers. The 2024 update included two tests. Type I testing allows for comparative testing between different compounds on standard belt constructions to determine an energy efficiency rating for belt cover compounds. Type II testing allows for specific evaluation of the impact of idler diameter, as well as evaluation of the varied belt constructions of different manufacturers. Each test allows the designer to quantitatively benchmark the design variables of belt manufacture compounds, belt construction and roller diameter.

2.3.2 Rim Drag

Rim Drag represents friction loss and is comprised of three components: labyrinth seal viscous drag, ball and roller bearing friction, and lip seal resistance (Wheeler, 2016). Grease lubricant makeup has proven to be influential in bearing friction. Research undertaken at TBS (Cousseau T O. J., 2025) expanded the dataset of Wheeler (2016) to incorporate larger-diameter roller parameters, lower speed of rotation, and higher loads. This information was used to determine the lubricant selections used in the roller bearings manufactured in this project.

2.4 Design Integration and Benchmark Evaluation

The Big Roller™ design suite products, including relocatable ground modules (green fields) and offset and inline idler frames (green fields and brownfields retrofit), have been developed specifically with the WA iron ore market in mind, and engineered to handle heavy-duty use parameters including 40 Mtpa capacities and 6.4 m/s belt speeds. The technology is readily applicable to iron ore mining nationally and internationally, as well as to other bulk commodities including bauxite, nickel, and copper that can utilise conveying for transfer of material.

Internal benchmark evaluation and comparison of larger conveyor idler rollers against traditional 178 mm diameter rollers for a 13.5 km conveyor system[†] indicates Big Roller™ product designs could deliver the following relative project savings:

- **Reduce steel use by 750 tonnes (~50%)**: Assumes base case of 110 kg per linear metre for traditional 9 m modules, achievable through the structurally optimised framework of the standardised 1500 mm ground module.
- **Remove 10,000 carry rollers**: Achieved by shifting from a standard 2.5 m span, 3-roll carry idler to the Big Roller 4-roll carry configuration (dual offset centre rolls and

[†] Study is Commercial-in-Confidence. Available on request under commercial terms.

central wing rolls). This configuration safely extends idler pitches up to 6.75 m for wing rolls and 3.375 m average (5.65 m / 1.1 m alternating) for centre rolls, better equalising loads experienced by all rollers.

- **Cut fabrication and installation time by 33%**: Increasing the idler station spans to 6.75 m significantly reduces total components and steel quantities required in manufacturing. Through maximising offsite assembly, adoption of automated construction methods and reduction of component installation quantities this delivers substantial construction schedule savings. Structural modelling demonstrates these extended spans safely withstand design mechanical loads, including flooded belt scenarios.
- **Reduced construction plant and equipment:** Improved construction methods replace requirements for equipment and plant including 80 t crane, Franna crane, Manitou telehandler/ all-terrain forklift, 9 t flatbed, 9 t flatbed with Hiab with a single custom installation machine and Manitou telehandler/ all-terrain forklift – both of which can be electric powered. Light Vehicles (LV) are required for crew, but with reduced crew fewer LVs are required.
- **Reduce onsite crew size and cribbing by 50%:** Through reduced installation quantities, automated construction methods and less plant and equipment operators (Crane & Franna operators, riggers, dogman, truck drivers).
- **Reduced land clearing and laydown footprint requirements:** Using a pick-and-place construction approach enables offsite staging with direct to site stringing of the conveyor components, reducing the overall size of the laydown footprint requirement on site and its associated land clearing.
- **Eliminate 300 to 400 trailer movements to site:** By optimising both transported weight, volumes and component design geometries to maximise trailer packaging layout efficiency.
- **Lower installed power demand by up to 1.5 MW and save 9,750 MWh/year of electricity**: Driven by the mechanical efficiency of the large 508 mm rollers, which rotate significantly fewer times per metre of belt travel compared to standard 178 mm rollers.
- **Cut 12,500 tonnes/year of CO_2 emissions**: Based on renewable energy vs diesel Komatsu 930E-5 scenario.

The benefits evaluated in this study are predicted to be scalable and pro-rated across both shorter and longer installations. However, it is important to note that as idler spans and operational loads increase, the roller shell wall thickness must also be increased to maintain flexural rigidity and minimise shell deflection, leading to consequent increase in component weight. Engineering studies indicate that under extreme configurations, this may require a maximum shell wall thickness of 15 mm, resulting in a corresponding individual roller mass of 25 kg.

Benchmark evaluation suggests there would be substantial efficiencies and savings in using larger-diameter roller systems. This makes it important to confirm the manufacture and performance characteristics of these larger rollers and ground modules to support their deployment.

2.5 Project Overview

This project supported the early-stage development of a supply chain for energy-efficient conveyor technology through a combination of:

1. **Validation:** Completing independent third-party engineering validation of rollers exceeding standard commercial diameters, and of relocatable ground modules containing these large-diameter rollers.
2. **Production:** Executing the first commercial run of 50 large-diameter (508 mm) composite nylon idler rollers.
3. **Demonstration:** Proving the viability of Big Roller Overland Conveyor Company's (BR OLCC) patented relocatable ground modules.
4. **Empirical Testing:** Generating a technical dataset on Indentation Rolling Resistance (IRR) performance and roller performance (including Rim Drag) at TUNRA Bulk Solids.

Specifically, BR OLCC hypothesised that a large diameter composite roller of 508 mm, suited to a 1500 mm belt width, 3 roll, 45 degree wing angle carry idler configuration, can deliver significantly improved energy efficiency through reduced IRR and Rim Drag, while still having the mechanical strength and physical properties required to perform under both existing and more arduous operating conditions (e.g., increased idler span and loads) (Ryan S., 2023).

This project aimed to extend the previous understanding:

- of roller behaviour through application of Type II tests to produce relevant empirical datasets for various idler diameters and materials (steel and nylon) with a common belt construction and carry cover rubber compound
- through third-party validation of Rim Drag forces, to validate bearing lubricant selections in commercially manufactured rollers.

Thus, BR OLCC aimed to demonstrate:

1. that larger diameter rollers up to 508 mm would offer reduced IRR and Rim Drag, delivering improved energy efficiency; and
2. the production viability and performance of such rollers.

2.6 Research Impact

WA iron ore and bauxite miners are adopting "hub and spoke" models to develop remote orebodies, extending the utilisation of existing ore handling plants. (Fortescue, 2022; RIo Tinto, 2023 (b); BHP, 2022 (b); Pilbara Ports, 2025; Worsley Alumina / South 32, 2025; ALCOA, 2025). Based on publicly disclosed information from the relevant companies, nearly 300 km of conveyors are required to meet stated commitments over the next 20 years (Table 3), with internal estimates that this figure could double with the addition of truck haulage displacement. The potential retrofit market for existing brownfields conveyors is also well over 200 km (Table 4).

When viewed in a national and global context the potential impact of this research in enabling carbon emissions reductions from the WA mining sector could be substantial.

2.7 Potential Future Benefit to WA

Applied to this future use scenario, Big Roller™ design suite patented products, relocatable ground modules and proprietary offset and inline idlers, could:

- help WA, Australia and mining companies reduce their respective carbon footprints and move towards industry emissions benchmarks, by making ore transportation more energy efficient
- create and support approximately 25 new skilled jobs. Fifteen will be based in the Perth metro area and local surrounds and 10 located in the Pilbara region during construction periods on each project. Many more jobs will be supported within the supply chain facilitating fabrication and supply contracts
- reduce land clearing required for construction laydown and future solar/wind farms due to smaller power capacity requirements
- provide a market-ready solution with low adoption and integration risks and negative marginal abatement costs; and
- provide a large export opportunity, with designs maximising weight and volume efficiencies allowing for intermodal containerised freight, or alternatively via Intellectual Property licensing arrangements, depending on the economic circumstances for each project.

Table 3: *Potential and current projects with ore haulage requirements in WA sourced from company ASX announcements and EPA submissions.*

Company / Entity	Orebody / Project	Approx distance (km)‡
FMG Eliwana	Flying Fish (Diesel Road Train Haul)	26 (survey dynamics)
Rio Tinto	HD2/BHT (Diesel Truck Haul)	26 (ICN, (a))
Rio Tinto	Western Hill (Diesel Truck Haul)	6 (Rio Tinto, 2021)
Rio Tinto	Greater Nammuldi / Silvergrass West	5 (Rio Tinto, 2021)
Rio Tinto	Lens G & Diesel	15 (Rio Tinto, 2021)
Rio Tinto	Endeavour	10 (Rio Tinto, 2021)
Rio Tinto	BS3	10 (Rio Tinto, 2021)
Rio Tinto	Vivash / Atlantis	20 (Rio Tinto, 2021)
Rio Tinto	Homestead	10 (Rio Tinto, 2021)
Rio Tinto	Angelo River	17
Rio Tinto	Gudai-Darri W21/32	10
Rio Tinto	Gudai-Darri W88	10
BHP Yandi	Ministers North	13 (ICN, (b))
BHP Jimblebar	JimbleBar east	6.5 (KPMG, 2023)
BHP Jimblebar	Carramallu	6.5
BHP MAC	PacksaddleW	10.1 (BHP, 2022 (b))
BHP MAC	Tandanya	11.7 (BHP, 2022 (b))
BHP MAC	Mudlark Well	31.2 (BHP, 2022 (b))
BHP MAC	SE Corner	16.5 (BHP, 2022 (b))
BHP MAC	Gurinbiddy	17.4 (BHP, 2022 (b))
BHP MAC	PackSaddle E	15 (BHP, 2022 (b))
Pilbara Port Authority	Point Lumsden	3
South32 / Worsley	Bauxite Transport Corridor	13 - 15 (Worsley, 2025)
Alcoa	Myara North (proposed Diesel Truck Haul)	16 - 20 (Alcoa, 2025)
Alcoa	Holyoake (Conveyor proposed)	20 (Alcoa, 2025)

‡ indicative based on deposit locations relative to existing hubs using citations and Department of Energy, Mines, Industry Regulation and Safety. (2026). *Minedex* [Web Mapping Service]. Government of Western Australia, Data WA. https://catalogue.data.wa.gov.au/dataset/minedex-dmirs-001

Table 4: *Existing WA iron ore mine facilities with haulage by overland conveyor distances estimated from satellite imagery. Inclusion of ports and stockyards increases this estimate.*

Company	Project / Deposit	Estimated distance	First Ore Dates
Rio Tinto	Paraburdoo Channar Western Range	 10 km + 10 km 3 flights – 17 km	 1991 2025
	Hope Downs 1	4.2 km	2009
	Yandicoogina	1.4 km 2.4 km 4.3 km 4.5 km	1998
	Nammuldi Silvergrass BS1	2.9 km 8.8 km 8 km	2014 2017 2026
	WTS1	11.8 km	2015
	WTS2	10 km	2021
	WADCD	10 km	2021
BHP	Jimblebar (CR1/CR3) (Wheelara Hill)	6 km	2013
	Jimblebar Ext	6.2 km	2016
	Newman Western Ridge	13 km	2026
	MAC Deposit E (RGP3)	8 km	2008
	South Flank	14 km + 2 km 10 km	2021
FMG	Cloudbreak Christmas Creek Hall Hub	4.3 km 6.3 km 13.5 km	2008 2009 2024
	Solomon Hub (Firetail / Kings Valley / Valley of Queens / Zion)	3.84 km 1.25 km 1.07 km 10 km	2013 2014 2014 2013/4
	Eliwana	4 km	2021
Hancock Iron	Roy Hill	Wharf belt - 3.6 km ROM 2 – 5 km ROM 3 – 5 km ROM 4 – 5 km	2015 2019 2021 2023

3 Scope of Works

3.1 Pre-Works

In pre-works, the following testing regime was established, output from which informed project design and procurement scope.

Newcastle Institute for Energy and Resources:

- SANS 1313-3 (South African Bureau of Standards, 2012) Bearing and friction torque testing, grease selection and analysis

Universidade Tecnológica Federal do Paraná:

- Modified ASTM G65 Abrasion Test – competitor benchmarking of wear characteristics for roller materials including Tribotech Weartech Nylon.

3.2 Roller Design and Manufacture

50 rollers were designed and manufactured by Tribotech Pty Ltd to the requirements stated in **Appendix 1 – Drawing List & Key Drawings (Drawing 0001-M-0001)** and **Appendix 2 - Idler Roller Datasheet**. Scoping the project in this way enabled a small production run that could enable tooling up and prove out the manufacturing methods and processes for a viable supply chain.

3.3 Roller Testing

Following upgrades of test equipment to accommodate the 508 mm diameter roller envelope, 16 rollers (1x IRR, 9 x destructive, 6x non-destructive tests) were used in a program of testing and verification to determine compliance with the standards listed below at the TBS facilities.

3.3.1 Energy Efficiency

Energy efficiency testing was performed to the below standard for 219 mm and 508 mm diameter steel rollers, and 508 mm diameter nylon rollers.

- AS 1333 (Standards Australia, 2024) Type II IRR testing to AS 1334.13 (Standards Australia, 2017) (1x replicate).

3.3.2 Industry Standard Roller Testing

Industry product certification / type testing was performed to the following standards.

- ISO 21940 (International Standards Organisation, 2019) Balance testing (6x non-destructive replicates)
- TBS Self Noise (6x non-destructive replicates)
- SANS 1313-3 (South African Bureau of Standards, 2012)

- Rim Drag and Breakaway Force, Temperature (6x non-destructive replicates)
- TIR and MIS. (6x non-destructive replicates)
- Dust Ingress (3x destructive replicates)
- Water Ingress (3x destructive replicates)
- Resistance to housing press out (3x destructive replicates).

3.4 Ground Modules - Design and Manufacturing

Ground Module design accommodating 508 mm rollers for a 1500 mm wide belt was developed, engineered and manufactured for use in internal benchmarking studies. For General Arrangement Drawings refer to **Appendix 1 – Drawing List & Key Drawings** and for the Basis of Design refer to **Appendix 2 - Idler Roller Datasheet (Extract)** and **Appendix 3 – Ground Module Design Input**.

Design compliance with Australian Standards (specifically AS 3600 for concrete, AS 4100 for steel, and AS 4600 for cold-formed steel) and typical Pilbara-based client design criteria was independently validated by Strake Engineering (Strake Engineering, 2025).[§]

The design and manufacture techniques incorporated a tolerance and surveying schema to enable the future development of automated construction methodologies and equipment. Two commercial demonstration ground module units were progressed through manufacture for the purpose of manual construction and assembly verification.

3.5 Construction and Commercial Demonstration

Commercial demonstration and assembly verification of the 1500 mm Low-Level Modules, alongside the offset and inline idler frames fully integrated with the 508 mm rollers, establishes that the Big Roller™ design suite has successfully achieved Technology Readiness Level (TRL) 6. Executing this physical assembly in a field trial setting validates the structural engineering, precision manufacturing tolerances and construction methodologies. On this basis, operational field trials and full-scale commercial deployments can be undertaken with a high degree of confidence in the system's viability.

[§] Verification data can be made available under commercial terms with BR OLCC.

4 Methodology

4.1 Roller Design and Manufacture

All roller design and manufacture activities were performed by Tribotech to its internal management process in accordance with their ISO 9001 accreditation and with respect to the design datasheet (BR-DSH-0001) requirements. It included development of the following records:

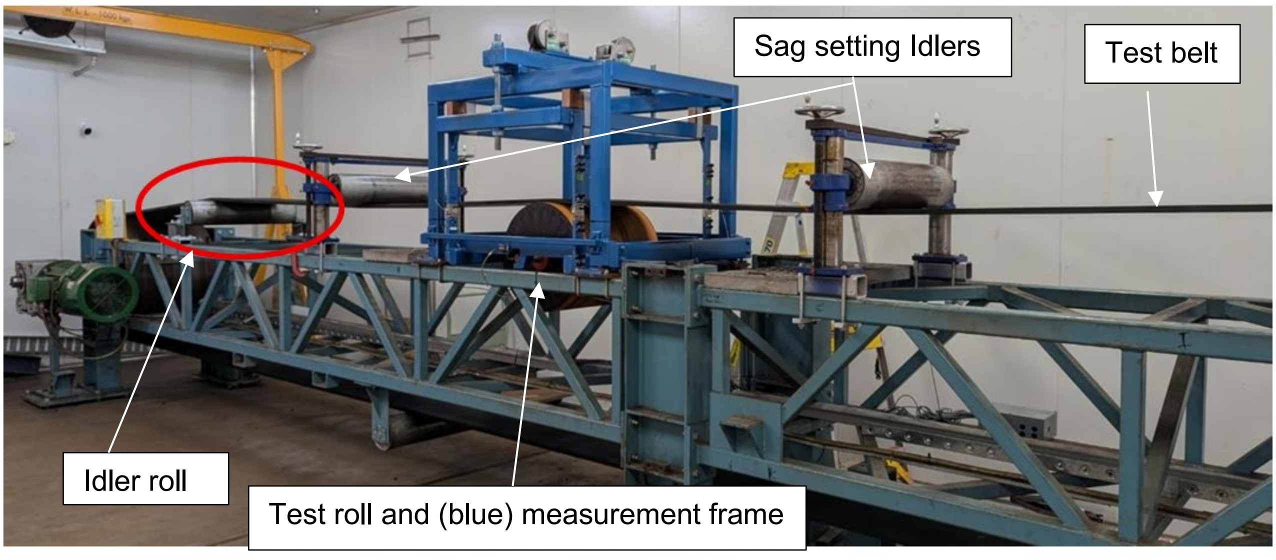
- Design calculations, including FEA
- Manufacturing Drawings
- Inspection and Test Plans
- Manufacturers Data Report.

4.2 Energy Efficiency Testing

All testing was conducted on the large indentation rolling resistance test facility operated by TBS at the University of Newcastle, Australia. The conveyor belt was installed and tested in accordance with AS 1334.13 (Standards Australia, 2017), except for the alignment of the idler rolls and pulleys. Section 5.2 of AS 1334.13 requires the drive pulley, take-up pulley, idler rolls, and test idler roll to support the belt within ±0.5 mm in the horizontal plane.

Because the 508 mm test idler roll exceeded the original design geometry of the test facility, the top of the roll could not be aligned with the drive and take-up pulleys. To accommodate this, the apparatus was modified, with the idler rolls adjacent to the pulleys (circled in red in *Figure 6* below) lifted so that the top of these idlers were in line with the top of the 508 mm test roll in the horizontal plane. For internal consistency, this same adjusted alignment was applied for the 219 mm test rolls.

Figure 6: *Indentation rolling resistance test facility at the University of Newcastle.*

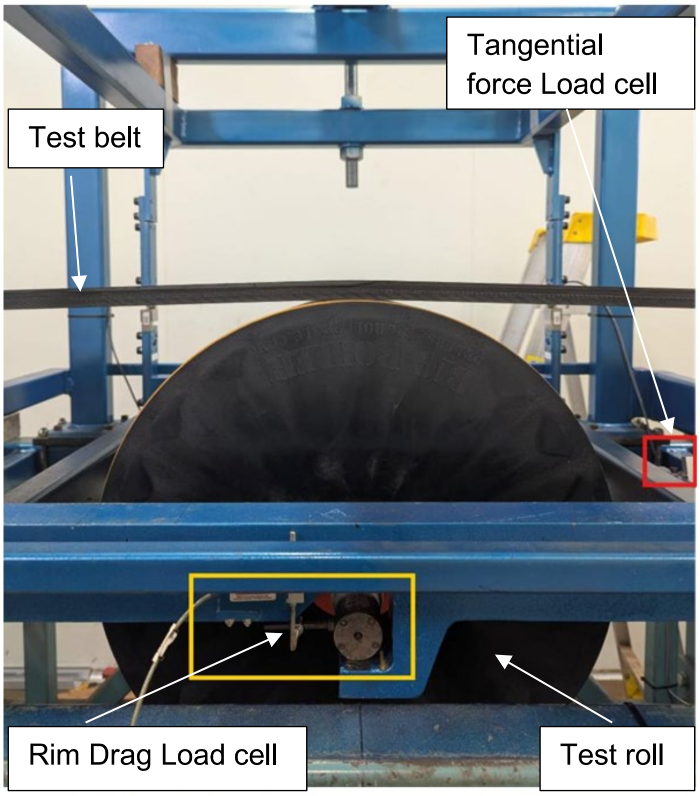


The conveyor belt was acclimatised to each new test temperature for a minimum of 16 hours prior to commencing a new round of measurements.

The vertical load applied to the belt is generated by two hold-down rolls and the tail-end pulley. The hold-down rolls are positioned equidistant from the test idler roll and are lowered onto the belt until the belt deflects to achieve the nominated sag ratio. The resulting vertical load per belt width (F_V) transmitted to the test idler roll is controlled by adjusting the tail-pulley position to change the belt tension.

Figure 7 below shows a close-up of the test frame configured with the 508 mm nylon idler roll, with the hold-down rolls positioned to induce an equivalent sag ratio of 1%. The load cell used to measure the tangential force (F_T) is highlighted in red, and the load cell used to measure the rotating resistance (Rim Drag force - F_{RD}) is shown in yellow. The horizontal force (F_H) is obtained by subtracting the Rim Drag force from the tangential force.

Figure 7: *Test facility set up with the 508 mm diameter test nylon idler roll.*



4.2.1 Belt Flexure Resistance Correction

To obtain IRR force (F_{IRR}), the belt flexure component (A) of the horizontal force (F_H) is first determined and removed. The magnitude of the belt flexure force (A) is obtained by fitting Equation (1) to the measured horizontal force (F_H) versus belt load per unit width (F_V) using a least-squares regression:

$$F_H = A + B{F_V}^c \qquad (1)$$

Where:

A = component of belt flexure force (N/m)

B = coefficient ([N/m]$^{1/3}$)

F_V = vertical load per belt width (N/m)

C = 4/3 (1).

Once the parameters in Equation (1) are determined, IRR is calculated using Equation (2)

$$F_{IRR} = F_H - A \text{ or } F_{IRR} = BF_V{}^c \qquad (2)$$

Where:

F_{IRR} = IRR force (N/m)

Details of the tested belt construction are given in Table 5 and the IRR testing parameters and operating conditions are provided in

Table *6*.

Table 5: *Belt construction.*

Parameter	Value
Manufacturer	Continental
Belt Type	ST 1000
Pulley Cover Thickness	8 mm
Carry Cover Thickness	8 mm
Top and Bottom Cover Compound	Eco Plus
Belt Width	440 mm

Table 6: *Testing details.*

Test Parameter	Value
Pulley cover temperatures	0°C, 20°C and 40°C
Simulated Belt Sag	0.5%, 0.75%, 1.0% and 1.25%
Idler roll diameters	219 mm, 508 mm (Steel), 508 mm (nylon)
Belt speeds tested	2, 4, 5, 6, 8 m/s
Simulated vertical loads	2-3, 4, 5, 6, 8-9 kN/m

4.3 Industry Standard Roller Testing

The following industry standard roller test procedures were performed on the 508 mm diameter Tribotech rollers.

4.3.1 Rim Drag

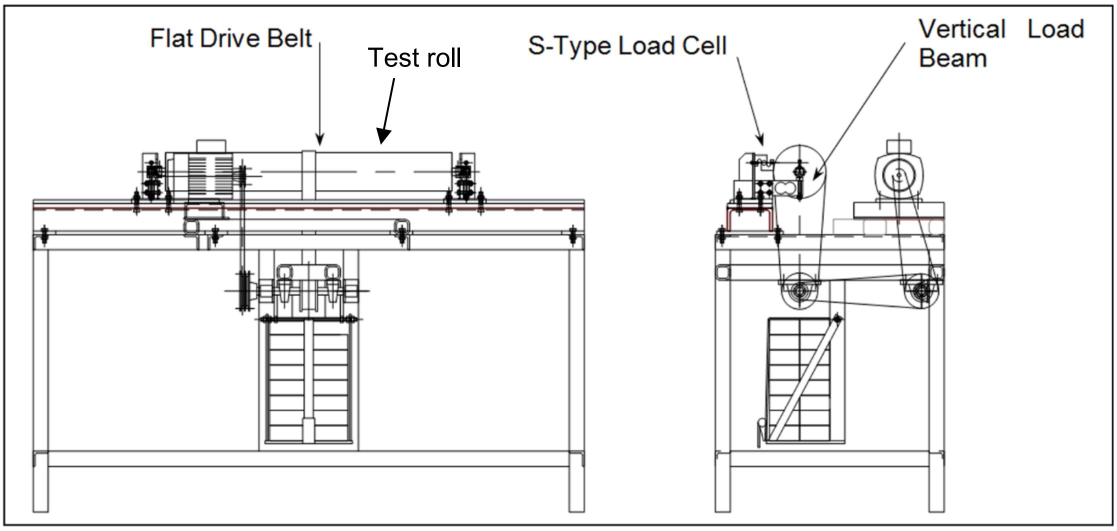
Figure 8 presents a schematic of the apparatus specifically designed to measure Rim Drag (roll resistance) and breakaway force for conveyor idler rolls. The apparatus can test conveyor idler rolls up to 1250 mm in length and 520 mm in diameter.

Collars are attached to the shaft ends, allowing the conveyor idler roll to rest on knife-edge supports. The vertical force acting on each shaft end can be measured independently, while the roll is free to rotate as the shaft experiences torque generated by Rim Drag. This shaft torque is gauged and converted into a Rim Drag value.

A flat belt drive applies both a vertical load and a driving torque to the conveyor idler roll through a variable-speed drive. The roll is ramped up to the required rotational speed, which may be used to simulate the starting characteristics of a conveyor. Rim Drag is continuously monitored by measuring the resisting force about the knife-edge supports.

The applied load is variable in both magnitude and position, enabling simulation of service conditions. Prior to testing, all load cells are calibrated. The total vertical load acting on the conveyor idler roll is achieved using weights positioned directly beneath the drive belt, while the distribution of load between supports is controlled by adjusting the roll's longitudinal position.

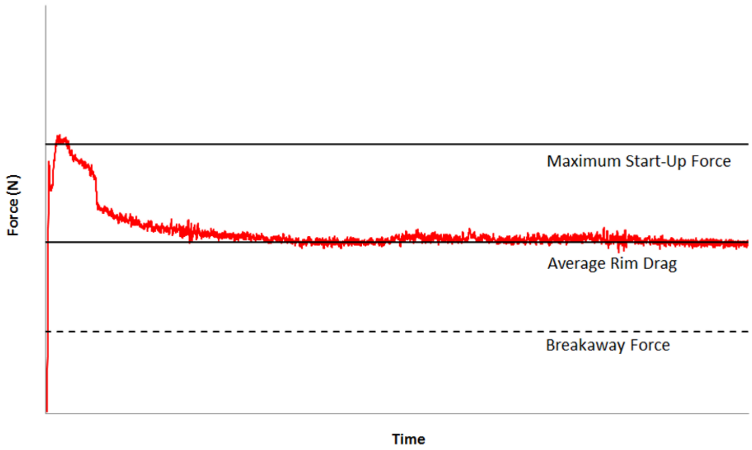
Figure 8: *Conveyor idler roll Rim Drag and breakaway force measurement apparatus schematic front (l) and side (r) views.*



4.3.2 Maximum Start-Up Force

This test records the maximum Rim Drag observed during a standard Rim Drag test, specifically over the initial stages of operation. During this period, the conveyor idler roll components transition from ambient temperature to their operational steady-state temperature. For a comparison of Rim Drag, breakaway force, and maximum start-up force, refer to *Figure 9*. Note: Force axis is not quantified due to various bearing arrangements having different force limits, and Time axis typically represents 1 to 2 hours but can go up to 4 hours.

Figure 9: *Example results highlighting difference between key conveyor idler roll performance characteristics.*



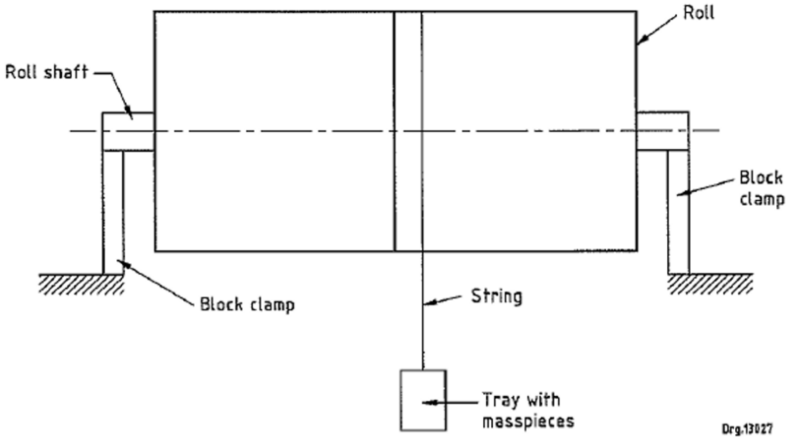
4.3.3 Breakaway Force

The breakaway force is defined as the force required to overcome the static friction in the conveyor idler roll's bearings and seals, i.e., the force necessary to initiate rotation of the idler roll. Testing is conducted both before and immediately after a Rim Drag test.

- **Cold breakaway**: the breakaway force required to induce idler rotation when the internals are at ambient temperature.
- **Warm breakaway**: the breakaway force required to induce idler rotation once the idler internals have reached their operational steady-state temperature.

Roll rotation is initiated by applying mass to a pre-weighed tray suspended on a string wound around the roll shown in *Figure 10*. The total applied mass required to induce rotation is recorded as the breakaway mass.

Figure 10: *Schematic arrangement of test to assess breakaway mass.*



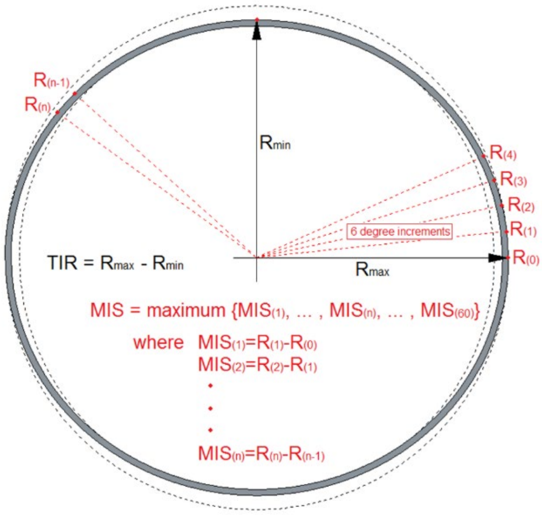
4.3.4 TIR (Total Indicated Run-out) and MIS (Maximum Indicated Slope)

The Total Indicated Run-out (TIR) is defined as the difference between the largest and smallest radius measured around the circumference of the conveyor idler roll shell at a specific point along its axis. In practical terms, TIR quantifies the out-of-roundness or concentricity of the idler shell. Measurements are taken at three points along the length of the conveyor idler roll. This test is prescribed in DIN 22112-3 (DIN, 1996) and SANS 1313-3 (South African Bureau of Standards, 2012).

The Maximum Indicated Slope (MIS) is a measure of the rate of change in shell radius over one full revolution of the idler roll. It is determined by recording the radius around the circumference of the idler roll shell at six-degree intervals along its axis. The differences between consecutive measurements are calculated and the largest difference is reported as the MIS. As with TIR, MIS is determined at three points along the idler roll during the same test procedure.

The schematic procedure for calculating TIR and MIS is shown in *Figure 11*. Both measurements are performed using the same apparatus employed for Rim Drag testing in accordance with the requirements of SANS 1313-3 (South African Bureau of Standards, 2012) and DIN 22112 3 (DIN, 1996).

Figure 11: *Diagrammatic representation of TIR and MIS.*



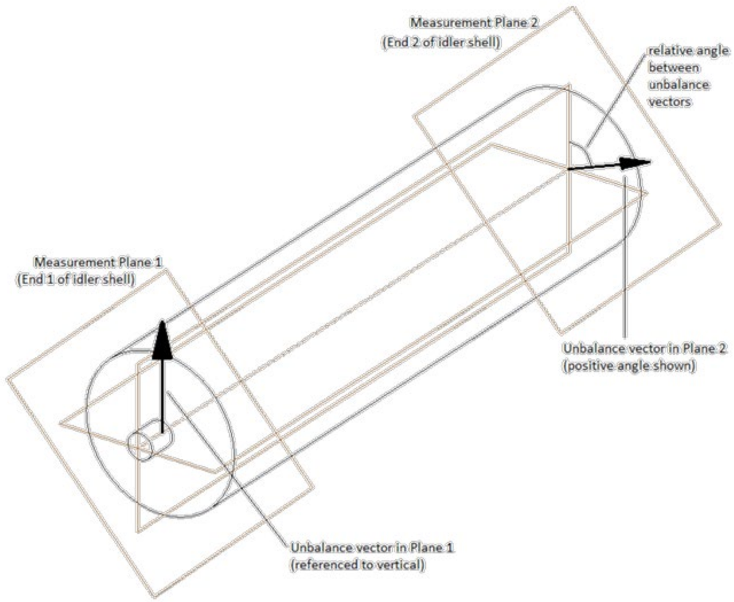
4.3.5 Balance Grade Determination

The conveyor idler rolls are tested in a rig designed to measure the out-of-balance mass of rotating machinery. Each idler is rotated at the standard test speed of 650 rpm (equivalent to 5.2 m/s for a 152 mm diameter idler roll), and the out-of-balance mass is determined in both measurement planes (i.e., each end face of the idler).

Figure 12 provides a schematic representation of dynamic unbalance in an idler roll. The measurement planes are located at each end of the idler roll shell, and the relative angle between the two unbalance vectors is also recorded.

The unbalance mass is determined after establishing the radius at which the mass acts. With this information, the dynamic unbalance is calculated, which then allows the balance grade of the idler to be determined. All measurements and calculations are carried out in accordance with ISO 21940-1 (International Standards Organisation, 2019).

__Figure 12:__ Diagrammatic representation of dynamic unbalance in a conveyor idler roll.



4.3.6 Self Noise

The self-noise test is conducted using the same frame as the Rim Drag apparatus. The idler under test is mounted on knife-edge supports and allowed to rotate at various speeds. A sound level meter is positioned 500 mm from the near face of the idler, aligned with the idler shaft axis.

Before testing, the sound meter reference level is verified. Background noise levels are then recorded by operating the test rig without an idler, at belt speeds from 3 m/s to 6 m/s in 1 m/s increments.

The idler's self-noise levels are subsequently measured following the TBS standard procedure, which involves running the idler continuously through the same belt speed range (3 – 6 m/s in 1 m/s steps). Without stopping the rig, the sequence is reversed until the idler comes to rest and remains stationary for one minute. The test is then repeated with the idler reversed so that the far face is positioned closest to the sound level meter.

4.3.7 Water Ingress

Water ingress testing is conducted in accordance with SANS 1313-3 (South African Bureau of Standards, 2012) using the TBS facility (see *Figure 22*). The idlers are mounted horizontally in a water bath, with the water level set to the centreline of the shaft (i.e. half of the idler submerged). Four immersion levels (L1 to L4) were applied at the BR OLCC's request to evaluate sealing performance at specific locations.

- L1 – Composite housing to roll shell interface
- L2 – Composite housing to rock-shield interface
- L3 – Rock-shield seal to lip seal interface
- L4 – Rock-shield to shaft interface.

During testing, the roll is rotated at 1 m/s for a continuous period of 96 hours. Each idler is weighed before the start of the test and at the end of every 24-hour interval, with mass recorded to the nearest gram. In accordance with the standard, the roll is externally dried prior to weighing.

Although not a strict requirement of SANS 1313-3 (South African Bureau of Standards, 2012), TBS recommended internal inspections after 10 days of storage under controlled environmental conditions to provide additional insight into sealing performance and moisture ingress.

Compliance with SANS 1313-3 (South African Bureau of Standards, 2012) Section 5.10.5 requires that seals shall limit the ingress of dust and water into the bearing and shall have no loss of lubricant from the bearings.

4.3.8 Dust Ingress

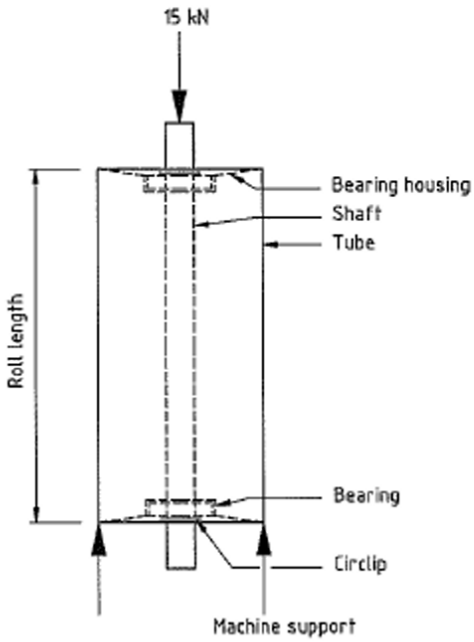
Dust ingress testing is conducted using the rig shown in *Figure 23*. The idler under test is mounted horizontally in a chamber where fine magnesium oxide powder is circulated. The roll is rotated for 96 hours at a speed of 1 m/s. The idler is weighed before the start of the test and again at the end, with all weights recorded to the nearest gram. In line with SANS 1313-3 (South African Bureau of Standards, 2012), the idler roll is externally cleaned before weighing, after which it is inspected to assess the extent of dust penetration into the seal and bearing arrangement.

While not strictly required by the standard, optional internal inspections following a storage period in controlled environmental conditions are strongly recommended by TBS to best understand the test results. Compliance with SANS 1313-3 (South African Bureau of Standards, 2012) Section 5.10.5 requires that seals shall limit the ingress of dust and water into the bearing and shall have no loss of lubricant from the bearings.

4.3.9 Resistance to Pressing Out

Resistance to pressing out is assessed in accordance with Section 7.8 of SANS 1313-3 (South African Bureau of Standards, 2012). A load of 15 kN is applied axially to the shaft (see Figure 13) and compliance with Section 5.5 of the Standard is verified. Both ends of the idler roll are tested to ensure conformity. This test verifies the mechanical integrity of the shaft and composite housing fit, ensuring that the shaft cannot be dislocated under axial load during operation.

Figure 13: *Test apparatus for resistance to pressing out.*



4.4 Ground Modules

4.4.1 Design

The Big Roller™ designs were third-party validated by Strake Engineering. Strake's engineering calculation report (Strake Engineering, 2025) specifically addresses the structural integrity of the primary structural steel and concrete pad footings of the Ground Modules designed for:

- 1500 mm wide belt
- 2500 kg/m³ ore density
- 0.424 m² cross sectional area
- during operational and non-operational conditions
- in non-cyclonic regions.

Additionally, the precast pad footings are designed to be lifted using either forklift pockets or cast-in lift points (such as Swiftlift 2FA120 anchors). Precast pad footing assumes a lifting arrangement of two off slings at 60° minimum and a Dynamic Amplification Factor (DAF) of no more than 1.35.

For General Arrangement Drawings refer to **Appendix 1 – Drawing List & Key Drawings**.

Figure 14: *CAD render of Ground module.*

Design and structural checks were performed to AS 3600 Concrete Structures (Standards Australia, 2018 (a)), AS 4100 Steel Structures (Standards Australia, 2020) and AS 4600 Cold-Formed Steel Structures (Standards Australia, 2018 (b)) along with a major iron ore producer's standard design criteria for structures (BHP). Each arrangement was assessed using Space Gass and Strand7. Utilisation Checks (UC) and Load Factors (LF) are critical components of the AS 4100 design process. UC assess how much a structural member is utilised compared to its capacity, while LF is a measure of how much the design actions can be increased before the point of failure is reached. These checks are essential for ensuring that structural members are designed to be safe and efficient.

4.4.2 Manufacture

Manufacture was performed in accordance with the relevant Australian Standards to comply with design and drawings. The following supply chain was used.

Table 7: *Ground module vendors.*

Component	Vendor
Concrete Sleepers	Geoquest Australia
Structural Steel	BendPro
Stringers	Boyds Metal Industries
Cladding	Fielders (Lysaght / Bluescope)
Survey	RM Surveys
Machining	H-E Parts

A proprietary tolerance schema was developed in conjunction with RM Surveys and integrated idler slots for carry and return idlers were machined by mining solutions provider

H-E Parts in a single pass set up on an Okuma gantry milling machining centre. This approach allowed for a 2 mm to 3 mm machining allowance on the idler roller shaft slots, which were machined post-galvanising to ensure precise tolerances (±0.1 mm), followed by the application of Tectyl 846 surface protection to the bare steel slots, with verification surveys undertaken to validate the manufacturing accuracy achieved.

5 Results and Findings

This section presents the outcomes of the engineering design, physical manufacturing, and structural validation phases of the project. While detailed proprietary testing datasets and proprietary manufacturing records remain commercial-in-confidence[**], a comprehensive summary of the system's compliance against key structural, operational, and industry-standard performance criteria is provided below to validate its TRL 6 achievement

5.1 Roller Design and Manufacture

The roller design and physical manufacturing phase successfully validated the parameters outlined in the Big Roller™ engineering datasheet (BR-DSH-0001).

A small-batch production run of 50 units of the 508 mm diameter rollers was successfully manufactured and verified. The physical manufacturing process proved that the use of advanced composite materials, specifically a rotary cast nylon (Weartech™) shell and injection-moulded nylon bearing housings (incorporating 30% glass fibres), could successfully overcome the weight limitations traditionally associated with large-diameter rollers.

Key design and manufacturing findings include:

- Mechanical Capacity: The engineered assemblies, using NSK 6309 C3 ZZ bearings, were validated to achieve a dynamic 'C' rating of 55.3 kN and an L10 bearing and grease life exceeding 65,000 continuous hours.
- Operational Suitability: The design is verified to safely handle extreme heavy-duty Pilbara operating conditions, accommodating belt speeds up to 6.4 m/s, capacities up to 40 Mtpa, and ambient temperatures up to 50°C.
- Mass and Handling: The manufactured 508 mm rollers successfully maintained an individual component mass of strictly under 25 kg, satisfying strict OH&S manual handling limits.
- Quality Assurance: All rollers were manufactured in compliance with ISO 9001 quality standards and successfully passed strict Inspection and Test Plans (ITPs).

Comprehensive Manufacturer’s Data Reports (MDRs) and detailed proprietary design records are retained as commercial-in-confidence; however, they are available to industry stakeholders and project partners under commercial terms.

[**] Test results are available on commercial terms from both Contitech Australia (stephan.hoette@continental.com) for IRR and for all other matters via orders@bigrollerolc.com.

5.2 Energy Efficiency Testing

A total of 936 individual measurements were completed across the full combination of test temperatures (3), sag ratios (4), vertical loads (5), belt speeds (5) and idler roll types (3) - including repeat measurements at 5 kN and 5 m/s. (TUNRA Bulk Solids, 2025 (b)).

All results, together with fitted curves are available in the form of tables and figures and the Australian Standard Type II energy efficiency rating certificates. Noting their commercial-in-confidence nature, results are presented here in general terms only. This section summarises the key trends observed.

Note that considering the excessive vibration of the apparatus in evaluation of the 508 mm steel roller, reported results for that test configuration should be interpreted with caution.

5.2.1 Effect of Idler Diameter

Figure 15 below shows the percentage reduction in F_{IRR} relative to a 152 mm steel idler roll at 20°C, 5 m/s and 1% sag for both 5 kN and 8 kN loads. The markers represent the measured data, while the continuous curves show predictions from the QC-N model (Qiu, 2011). Data for 152, 219, 316 and 400 mm diameter steel rollers were obtained from previous studies (TUNRA Bulk Solids, 2023).

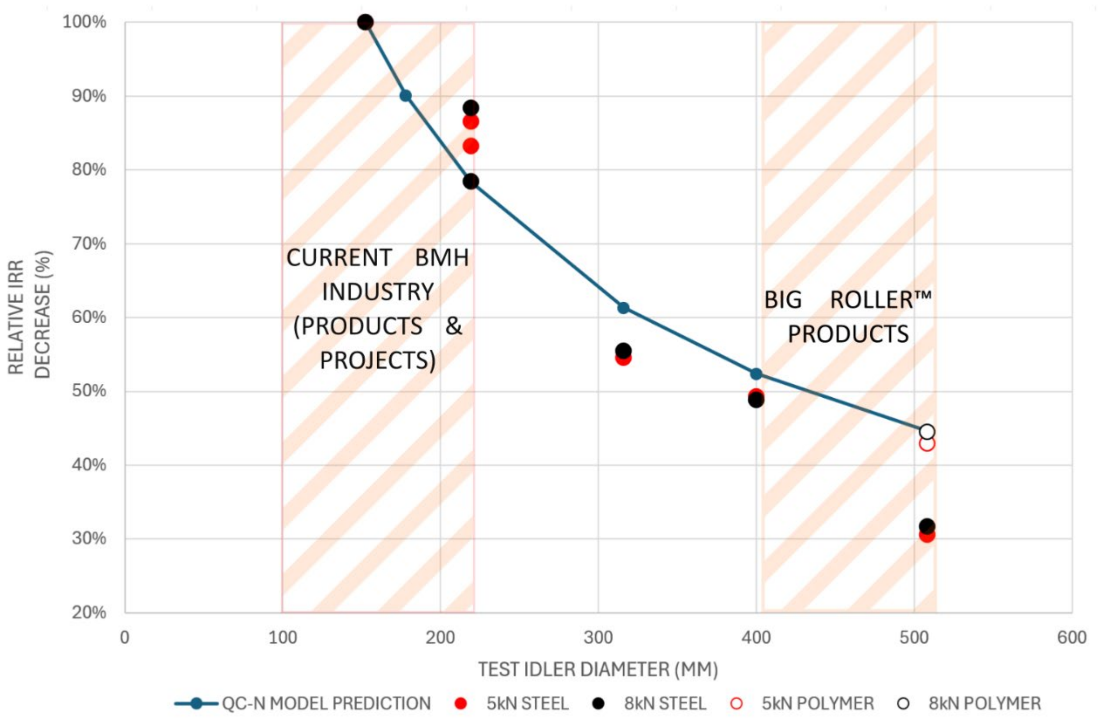
The results demonstrate a substantial reduction in F_{IRR} with increasing idler diameter. Relative to the 152 mm steel roller baseline, the 219 mm steel roller achieved a 12% reduction, while the 508 mm steel roller delivered a 68% reduction in IRR.

While following the same general trend, large-diameter nylon rollers exhibit a smaller reduction than equivalent diameter steel rollers, with the 508 mm nylon roller delivering only a 57% reduction in IRR relative to the base (152 mm steel) case.

The lower relative performance of nylon rollers in comparison to steel is widely (if anecdotally) reported, but the causal mechanism remains to be understood. The different behaviours may be influenced by the different material viscoelastic properties and idler shell deflection, which alters the belt–roll contact area and consequent frictional energy losses. At the time of writing, a research program by TUNRA is ongoing to investigate this phenomenon.

It is worth noting however that the 508 mm nylon roller tested was less than 25 kg, compared to commercial 508 mm steel roller designs typically exceeding 55 kg. This establishes a practical advantage to nylon rollers from material handling, and particularly Occupational Health and Safety (OH&S), perspectives.

Figure 15: *Relative F_{IRR} decrease as function of idler diameter at 20°C, 1% sag, 5 kN and 5 m/s.*



5.2.2 Effect of Temperature, Sag and Idler Material

The results show several general trends consistent with typical IRR behaviour:

- F_{IRR} decreases as idler diameter increases.
- F_{IRR} decreases as temperature increases.
- F_{IRR} shows no consistent or strong dependence on sag ratio within the range tested.
- Slightly lower F_{IRR} values were observed for steel rolls compared to nylon rolls of the same diameter.

5.2.3 Effect of Vertical Force

Across diameter test regimes the general trends observed for the belt compound tested include:

- F_{IRR} increases as belt speed increases.
- F_{IRR} increases as vertical load increases.
- F_{IRR} decreases as idler diameter increases.
- F_{IRR} decreases as temperature increases.

5.3 Industry Standard Roller Testing

Detailed test results (TUNRA Bulk Solids, 2025 (a)) are commercial in confidence. General commentary only will be provided on test compliance.

5.3.1 Rim Drag

Rim Drag tests were conducted on six rollers at an equivalent belt speed of 5.0 m/s (188 rpm) with an applied vertical load of 25 kg, at an ambient temperature of 15 – 20 °C. Each test was undertaken for 1 – 2 hours in both rotational directions. These conditions represent standard operating practice, though with a modified speed. The German standard DIN 22112 3 (DIN, 1996) and the South African standard SANS 1313-3 (South African Bureau of Standards, 2012) specify rotational speeds of 650 rpm and 750 rpm, respectively, corresponding to belt speeds of approximately 5 m/s for idlers of 130 – 150 mm diameter. However, a 508 mm diameter roll operating at 650 rpm corresponds to a belt speed of 17.3 m/s, which does not reflect typical conveyor operating conditions.

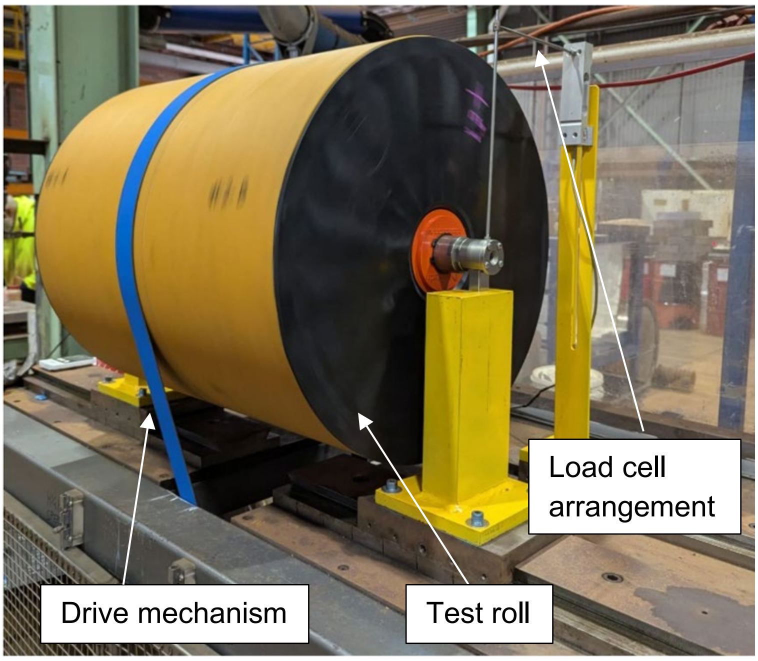
For each roll, the Rim Drag values measured in clockwise and anticlockwise directions were averaged. According to SANS 1313-3 (South African Bureau of Standards, 2012), the maximum Rim Drag force for rolls with 150 mm < d < 180 mm is 2.7 N at 650 rpm (see).

Table 8: *Extract of Table 11 from SANS 1313-2. Maximum friction force.*

Table 11 — Running friction force

1	2
Nominal diameter of roll mm	**Maximum friction force** N
100 125 150 to 180	3,0 2,8 2,7

Figure 16: *Large diameter idler in the Rim Drag apparatus: Friction measurement.*



5.3.2 Maximum Start-Up Force

Maximum start-up force tests were conducted on six rollers. The maximum start-up force cannot exceed 1.5 times the corresponding Rim Drag value to comply with the standard.

5.3.3 Breakaway Force

Breakaway tests were conducted on six rollers. To achieve compliance with SANS 1313-3 (South African Bureau of Standards, 2012), the breakaway mass cannot exceed 250 g (2.5 N).

5.3.4 TIR and MIS

TIR (Total Indicated Run-out) and MIS (Maximum Indicated Slope) testing was conducted on six rollers at three locations along the length of each roll: near both ends and at the centre.

Excessive TIR can result in vibration and misalignment, potentially affecting the trough angle of the conveyor. Elevated MIS values are typically associated with increased idler noise levels. According to SANS 1313-3 (South African Bureau of Standards, 2012), for compliance TIR cannot exceed 0.7 mm for rolls of this size (diameter > 133 mm and nominal face length < 570 mm).

No compliance value for MIS is specified in the Standard.

Table 9: *Extract from Table 10 from SANS 1313-2. Maximum TIR values.*

Dimensions in millimetres

1	2	3
Nominal length of face	Total indicated run-out (TIR)	
	D < 133	D > 133
≤ 570	0,5	0,7
570 ≤ 994	0,7	0,9
994 ≤ 1 378	1,3	1,7
1 378 ≤ 2 518	1,9	2,3

Figure 17 is a polar plot of the measured deviations used for TIR/MIS evaluation. The black curve shows the mean measured cycle of the roller surface, representing its average deviation over one revolution. The two dashed circles indicate the minimum and maximum measured radii, and the dashed blue line connecting them represents the Total Indicated Runout (TIR). The red chord identifies the steepest 6° slope, used as the Maximum Instantaneous Slope (MIS) reference. Surrounding these, the shaded yellow annulus corresponds to the tolerance band defined in SANS 1313-3 (South African Bureau of Standards, 2012), providing a visual benchmark for compliance against the standard.

Figure 17: *Polar plot of roll RD#2 at end B indicating the deviation used for TIR/MIS evaluation.*

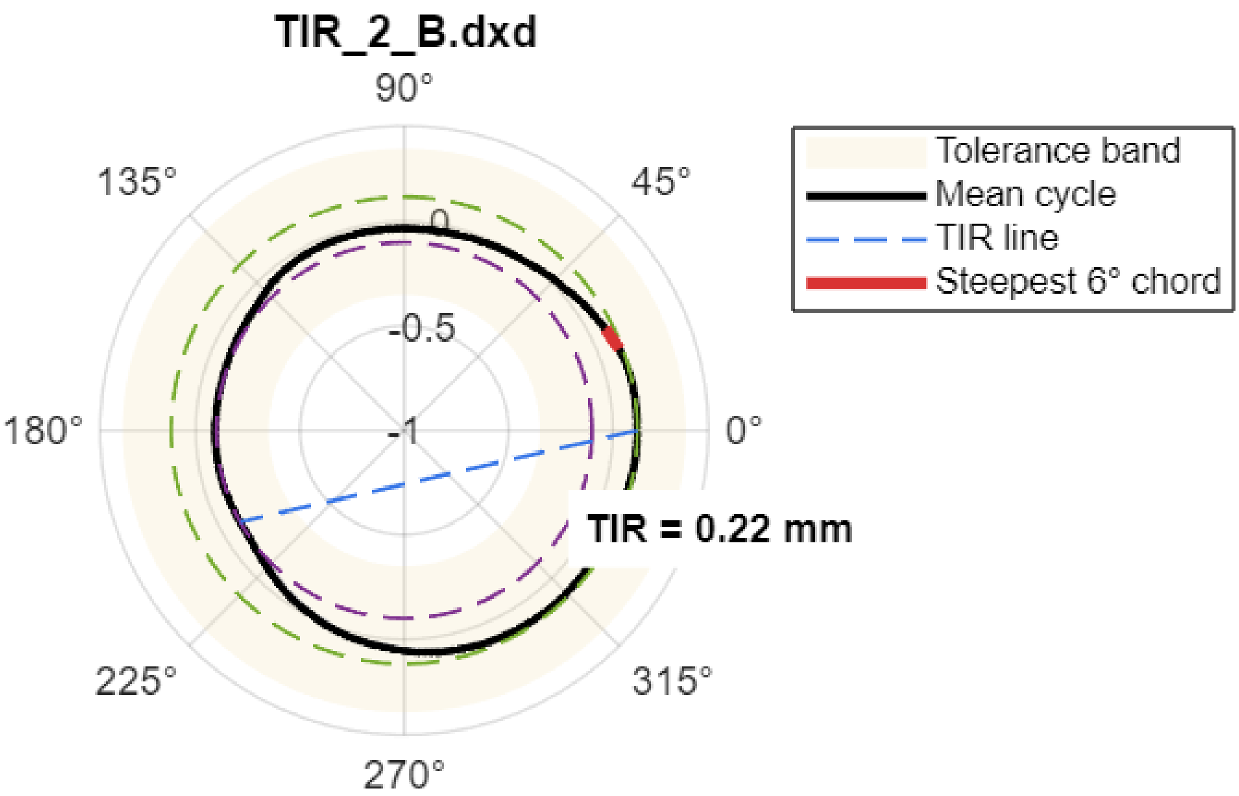
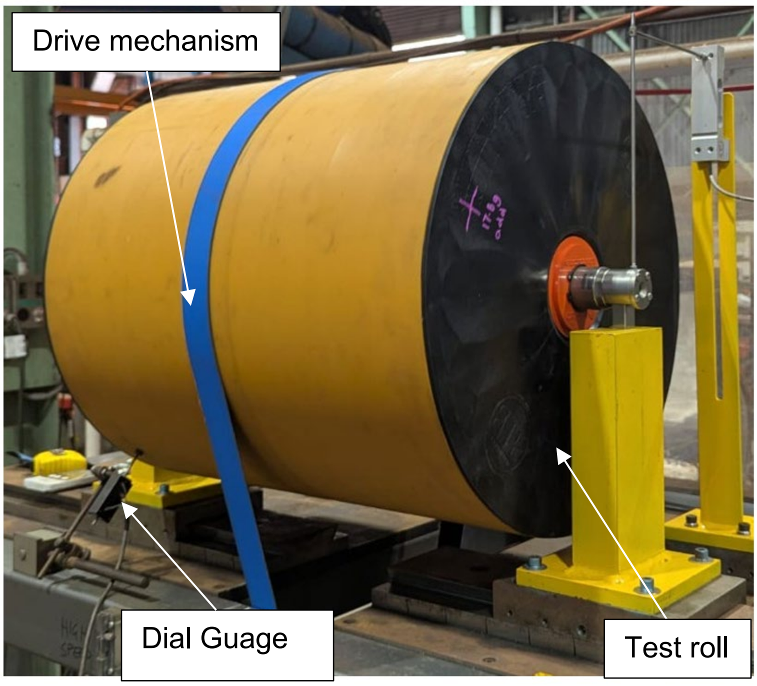


Figure 18: *Large diameter idler under TIR/MIS measurement.*



5.3.5 Balance Grade Determination

Out-of-balance mass determination was conducted on six rollers that had not been pre-balanced in manufacture.

Two methods were applied in calculating the balance grade:

- **CAD Model Method**: The rotating and non-rotating masses were derived from the supplied CAD model using material density.
- **Measured Method**: The rotating mass was calculated by subtracting the measured total mass of the roller from the non-rotating mass (shaft, bearing inner ring, circlips, and rock shield), which was derived from the supplied CAD model using material density.

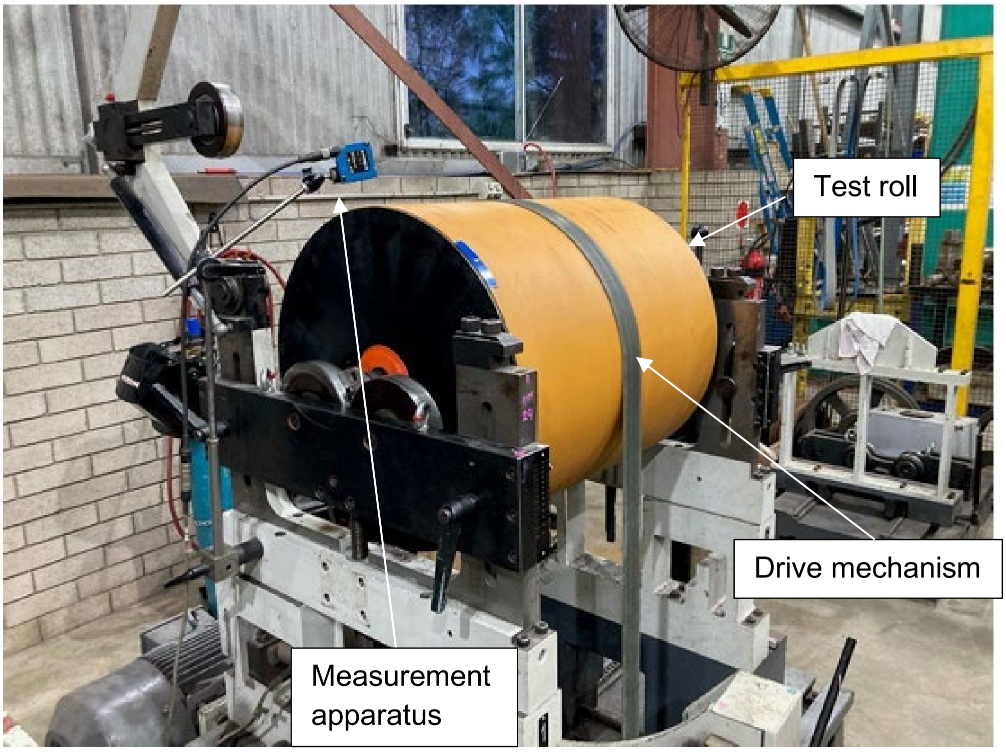
In both methods, the distances between bearings (522 mm) and the roll shell diameter (508 mm) were obtained from the CAD model, while the roll length was measured directly (569.3 mm). The permissible mass at the shell radius per correction plane for each method was determined for the balance grade indicated based on Method 1 and Method 2 and presented in Table 10 below.

Table 10: *Balance grades for different operating speeds and methods. Permissible mass in grams at the shell radius per correction plane.*

Method	Speed	G6.3	G16	G40	G100
1. CAD Model	150 rpm (4 m/s)	13.24	33.63	84.07	210.17
2. Measured	150 rpm (4 m/s)	10.76	27.32	68.29	170.73
1. CAD Model	200 rpm (5.3 m/s)	9.93	25.22	63.05	157.62
2. Measured	200 rpm (5.3 m/s)	8.07	20.49	51.22	128.05
1. CAD Model	250 rpm (6.6 m/s)	7.94	20.18	50.44	126.10
2. Measured	250 rpm (6.6 m/s)	6.45	16.39	40.97	102.44
1. CAD Model	300 rpm (8 m/s)	6.62	16.81	42.03	105.08
2. Measured	300 rpm (8 m/s)	5.38	13.66	34.15	85.36

Conveyor idler rolls are typically manufactured to G40 balance grade, which is considered the acceptable level of residual unbalance to ensure satisfactory performance. Figure 19 shows the apparatus used to measure the balance grade of the idler.

Figure 19: *Large idler diameter roller in the dynamic unbalance apparatus.*



5.3.6 Self-noise

Self-noise testing was conducted on six rollers. Figure 20 shows the measured sound pressure level with the test roll engaged compared to the background noise, which represents the sound pressure of the test rig without a roll plus ambient environmental noise.

No compliance level is specified for this test. Although there is no standard for self-noise testing, the TBS procedure is applied consistently, allowing results to be compared across different idlers.

Figure 20: *Example noise measurement.*

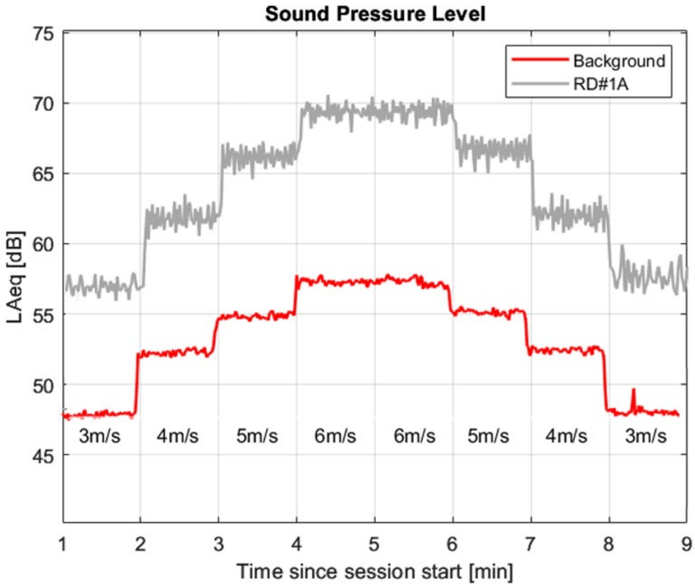
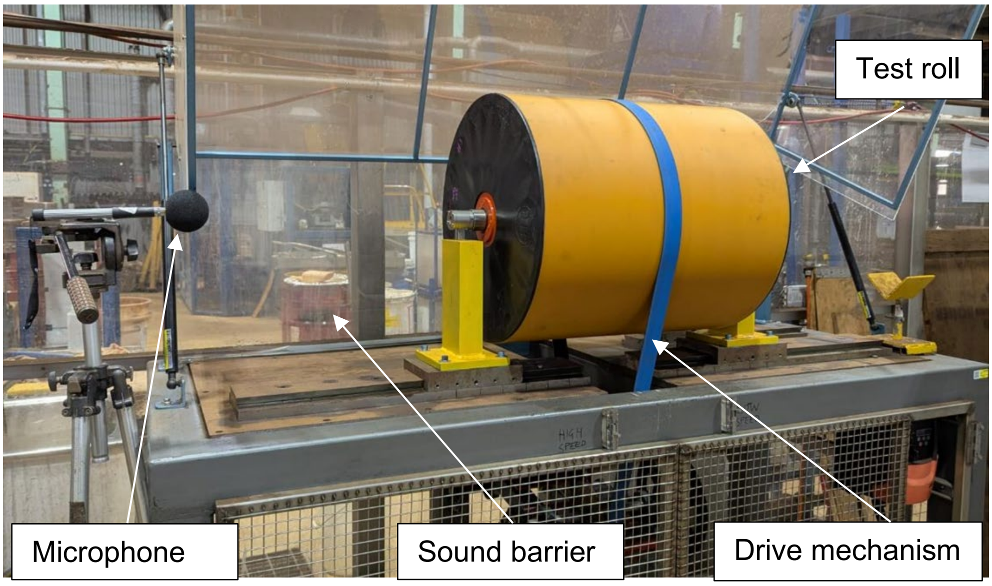


Figure 21: *Large idler diameter roller in the self noise apparatus.*

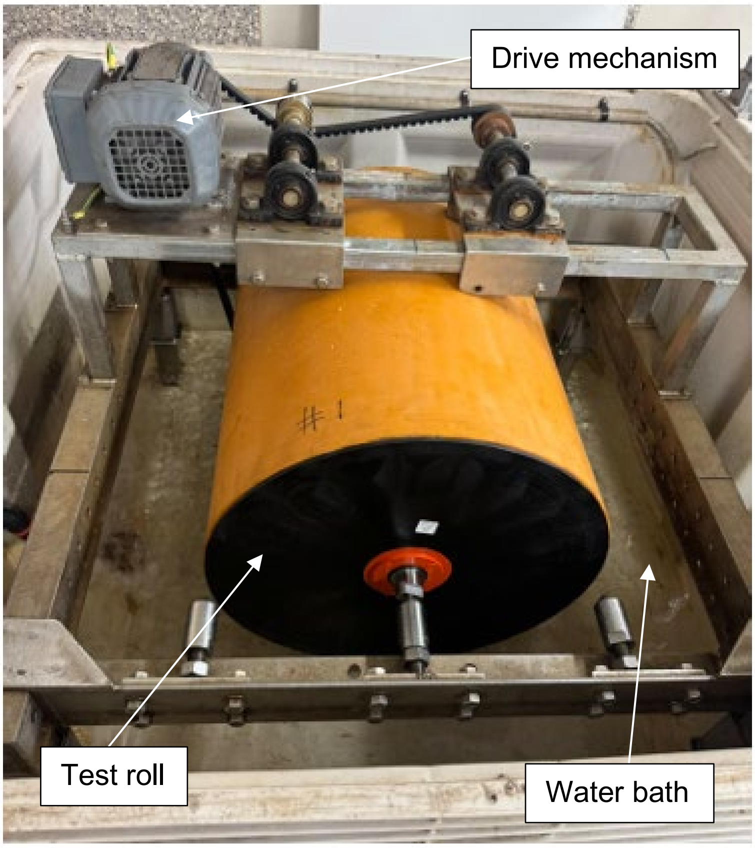


5.3.7 Water Ingress

Water ingress testing was conducted on three rollers at multiple immersion levels to evaluate sealing performance at key locations: between the composite housing and roll shell (L1), rock-shield (L2), contact seal (L3), and rock-shield and shaft (L4).

Following completion of the 96-hour test, the idlers were stored in a controlled environment for 10 days. Each end of the idlers was then inspected using a multi-step procedure, sequentially removing sealing layers up to the bearings to evaluate water ingress, grease condition, and any corrosion.

Figure 22: *SANS water ingress test facility modified for large diameter roll.*

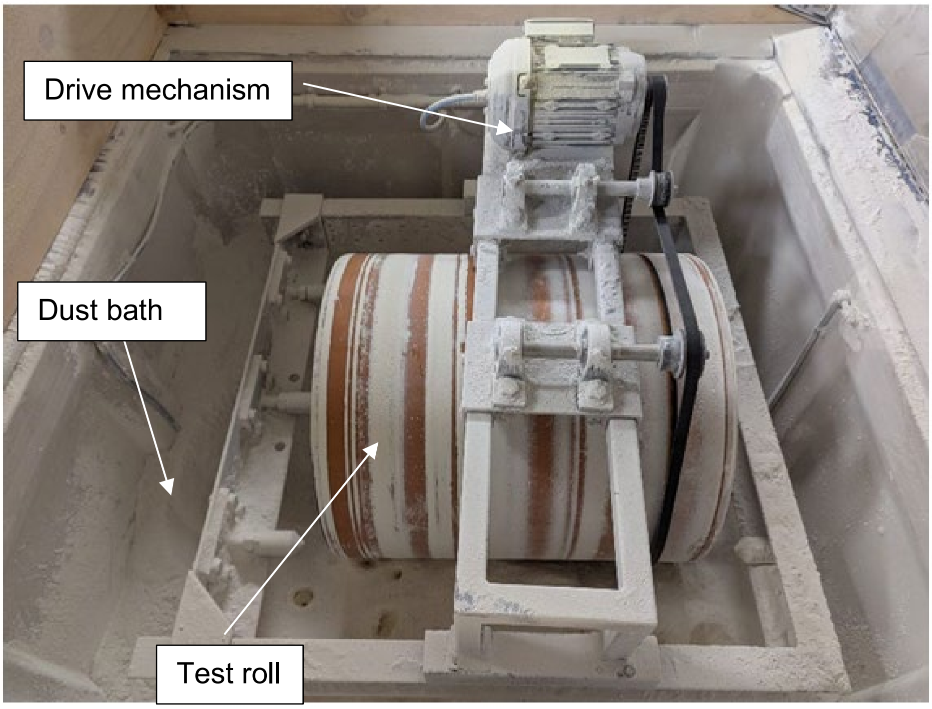


5.3.8 Dust Ingress

Dust ingress testing was conducted on three rollers. The rolls were rotated for a period of 96 hours at a belt speed of approximately 1 m/s. Each roll was weighed prior to the start of the test and again at the conclusion. Compliance with SANS 1313-3 (South African Bureau of Standards, 2012) Section 5.10.5 requires that a seal shall limit the ingress of dust and water into the bearing and shall prevent loss of lubricant from the bearings.

Following testing, the rolls were inspected using the multi-step procedure outlined for the water ingress tests.

__Figure 23:__ SANS dust ingress test facility modified for large diameter roll.



5.3.9 Resistance to Pressing Out

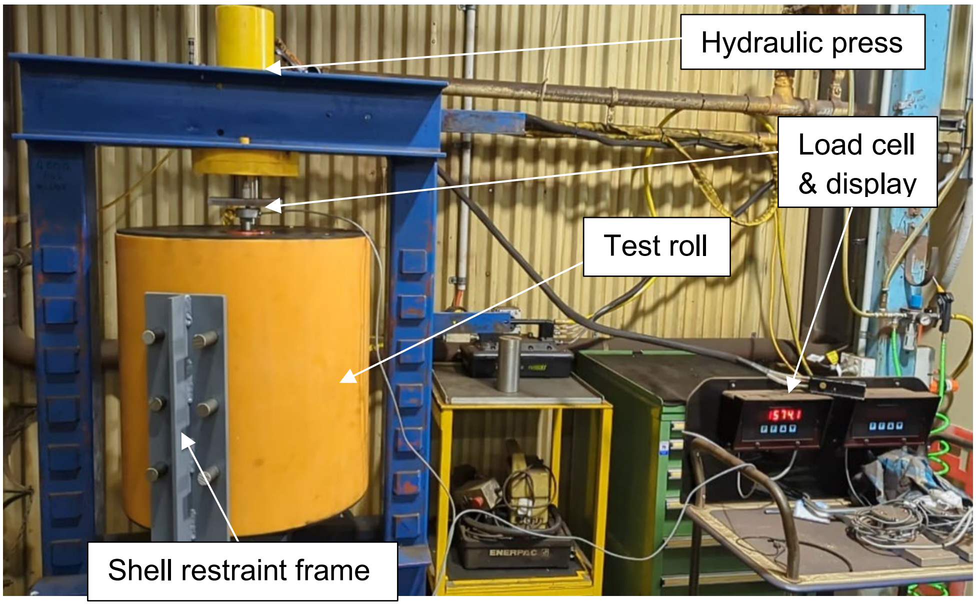
Resistance to pressing out testing was conducted on three rollers. The idler roll is secured on a support frame by six rods crossing the roll shell. A hydraulic press applies an axial load of 15 kN to the shaft at one end. A load cell, connected to a display readout unit, measures the applied force. The test is then repeated at the opposite end of the roll.

Section 5.5 of SANS 1313-3 (South African Bureau of Standards, 2012) specifies the compliance requirements for resistance to pressing out, in accordance with the procedure outlined in Section 7.8 of the Standard.

"The individual components of the idler roll shall be so constructed and assembled that, when a roll is tested in accordance with [this section of the Standard], neither the shaft nor the composite housing (or both) can be separated from the roll body. When a roll is tested in both directions in accordance with [this section of the Standard] under a load of 15 kN applied axially to the shaft, there shall be no visible signs of weld rupturing or material tearing."

Each idler roll was inspected for damage to the shaft and composite housing following the application of the 15 kN force. No discernible damage was observed, and neither the shaft nor the composite housing separated from the roll body. These observations were consistent when the test was repeated at the opposite end of each roll. No visible rupture or material tearing was noted for any of the idlers tested.

Figure 24: *Test apparatus for resistance to pressing out with customised shell restraint frame.*



5.4 Ground Module

The independent engineering review confirm that the designs withstand the evaluated load combinations safely, verifying field readiness.

For ground module general arrangement drawings refer to **Appendix 1 – Drawing List & Key Drawings**.

5.4.1 Design

The key design outcomes of third-party independent reviews as detailed in section 4.4.1 (Strake Engineering, 2025) were:

- All structural components, including members, welds, bolts, and footings, passed utilisation checks (UC) where load factors (LF) ≥ 1.0 for operational and non-operational conditions. The following lists the critical UCs from the design:
  - Members = 0.89 ≤ 1.0
  - Steelwork buckling = 0.84 ≤ 1.0
  - Stringer = 0.74≤ 1.0
  - Connections = 0.67 ≤ 1.0
  - Pad Footing = 0.98 ≤ 1.0
- The 300 mm thick precast pad footing with SL81 top and bottom mesh was deemed sufficient for:
  - Bearing and sliding, achieving Factors of Safety ≥1.5, with no uplift occurring
  - Self-lifting with Dynamic Amplification Factor (DAF) = 1.35 and slings at 60°.

The above results verify that the 1500 mm Low-Level Module design complies with the relevant Australian Standards and is structurally adequate for its intended conditions.

5.4.2 Manufacturing

All components were manufactured compliant to individual Inspection and Test Plans (ITPs) and relevant Australian Standards. Figure 25 shows the completed assembly.

Machining of roller mounting slots to the tolerance schema requirements, as a proof of design and manufacturing concept, was undertaken with verification survey performed by RM Survey. Survey results indicated that the tolerance schema was achieved and the modules are suitable for the next phase of semi-automated construction equipment development.

Figure 25: *First commercial production run of ground modules with 508 mm rollers integrated.*

6 Discussion

6.1 Roller Design and Manufacture

The proof-of-concept roller manufacturing with an initial 50-unit batch production run was successful. Roller testing by TBS identified several potential proprietary product design improvements and the potential for manufacturing process improvements. These opportunities for further improvement in the larger roller design and manufacturing will be enacted in the future to further industrialise and automate processes with increased future manufacturing volumes.

6.2 Energy Efficiency Friction Factor

The energy efficiency friction factor, EE, described in section 7.12 of AS 1333 is given by equation (3). The parameter has units of N/kN and represents the IRR force per unit vertical load on the belt.

$$EE = \frac{F_{IRR}}{\mathrm{F_V}} \qquad (3)$$

Where:

F_{IRR} = IRR force per unit width of belt (N/m)

F_{V} = vertical load per unit width of belt (kN/m).

Energy efficiency friction factors determined at 5 kN, 5 m/s and 1% sag are summarised in Table 11 below. Parameters presented have been normalised relative to the base case of a 219 mm steel idler roller at 0°C.

Table 11: *Eco Plus energy efficiency friction factors at 5 kN/m and 5 m/s.*

F_{V} (kN/m)	Temperature (°C)	EE (N/kN)		
		Idler Ø219 mm Steel	Idler Ø508 mm Nylon	Idler Ø508 mm Steel
5	0	100%	46%	40%
	20	78%	39%	27%
	40	69%	39%	24%

The results show a substantial improvement in energy efficiency for the larger diameter rolls, which consistently exhibited lower EE values across all temperatures.

6.2.1 Simulation Software Utilisation

BR OLCC has undertaken discussions with the major dynamic and static conveyor simulation software providers used by the Western Australian iron ore industry and confirmed that their software is able to model a 508 mm idler roller configuration using the results of this project. This software assessment included:

- Beltstat (Conveyor Dynamics, 2026)
- Sidewinder (AC-Tek (Virta), 2026)
- Belt Analyst, Dynamic Analyst (Overland Conveyor Company (VIrta), 2026)
- Delta T (Helix Technologies, 2026)
- DSI ExConTec (Dos Santos International, 2026).

6.3 Industry Standard Roller Testing

Australian Standards do not currently cover idler roller type testing and the Australian industry relies heavily on SANS 1313 and various DIN standards. With existing standards, testing requirements for larger diameter rollers are in many cases not contemplated and therefore not well defined.

BR OLCC recommends that Standards Australia push for the adoption and evolution of SANS 1313 (South African Bureau of Standards, 2012) as an ISO standard to ensure standardised testing requirements across the industry. A Technical Steering committee should be established to ensure the adoption involves a structured process that ensures coherence and alignment between other national standards and local Australian industry requirements.

BR OLCC is also aware that the Conveyor Equipment Manufacturers Association (CEMA) has an idler technical committee focused on updating Chapter Five of Belt Conveyor for Bulk Materials 8th Edition. It has offered to assist in this by providing its research into large and composite idlers but is unable to engage due to the constraint of CEMA being a membership body that requires members to have an American presence.

6.3.1 Rim Drag and Maximum Start-up Force

There is no maximum value in SANS 1313-3 (South African Bureau of Standards, 2012) attributed for idler rollers above 180 mm diameter. This needs to be resolved for industry standardisation.

When evaluating rotational resistance, it is important not to consider Rim Drag values in isolation but in conjunction with sealing effectiveness. Some idlers are deliberately designed to prioritise low rolling resistance at the expense of sealing, typically achieving Rim Drag values of 0.5 - 1.0 N. Conversely, idlers with robust sealing systems - designed to prevent dust and water ingress - commonly exhibit Rim Drag values in the range of 2 – 5 N.

Therefore, the interpretation of rotational resistance performance should account for the design intent of the idler, the effectiveness of the seals, and the measured resistance values.

It is worth noting that bearing designation selections are contemplated during design which also influence Rim Drag and maximum start-up force. Various Pilbara miners specify L_{10} bearing life ranges between 65,000 and 75,000 hours, typically using the SKF calculation method (SKF, 2008).

Table 12: *SKF L_{10} bearing design catalogue extract.*

$$L_{10} = \left(\frac{C}{P}\right)^p$$

You can use SKF Product select to perform this calculation.

If the speed is constant, it is often preferable to calculate the life expressed in operating hours using

$$L_{10h} = \frac{10^6}{60\,n} L_{10}$$

where

L_{10}	basic rating life (at 90% reliability) [millions of revolutions]
L_{10h}	basic rating life (at 90% reliability) [operating hours]
C	basic dynamic load rating [kN]
P	equivalent dynamic bearing load [kN]
n	rotational speed [r/min]
p	exponent of the life equation = 3 for ball bearings = 10/3 for roller bearings

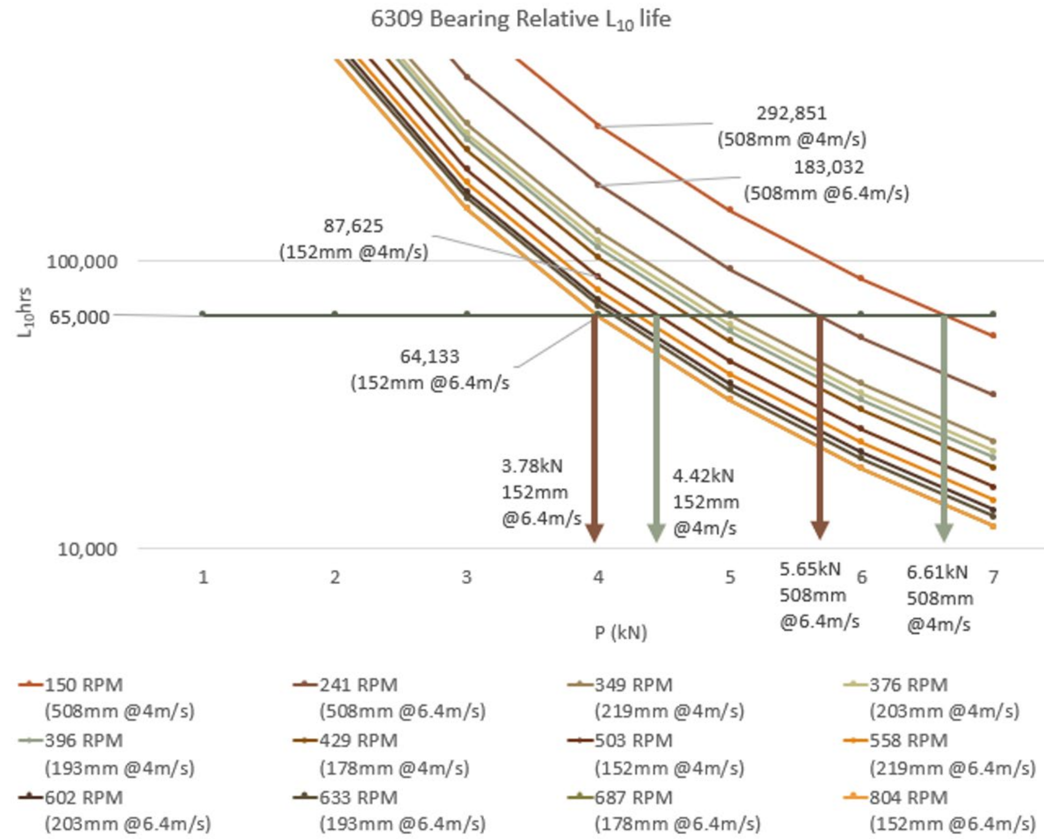
Rearranging the formulae to maintain constant life or constant load constraints, to compare the impact of roller diameter, results in the below formulae.

$$\text{Constant load: } L_{10h} \propto \frac{Dia_1}{Dia_2}$$

$$\text{Constant life: P} \propto \sqrt[3]{\left(\frac{Dia_1}{Dia_2}\right)}$$

This is expressed in Figure 26, where rotation speed curves (cycles) are mapped against load and $L_{10\text{ hrs}}$.

Figure 26: Relative L_{10} bearing life.



The impact presented for comparing 508 mm rollers at constant life of 65,000 hours and 4 kN are:

$$\text{Constant load: } L_{10h} \sim 3.34x(152\ mm) - 2.32x\ (219\ mm)$$

$$\text{Constant life: } P = \sim 1.50x\ (152\ mm) - 1.32x(219\ mm)$$

This implies that for larger rollers either:

- bearing designations and associated sealing arrangements can be reduced for the same conveyor design parameters (belt speed and load / idler span); or alternatively
- for the same bearing designation and associated sealing arrangements, the load / idler span can be increased, thus requiring fewer rollers per unit distance.

Both options lower cumulative conveyor Rim Drag and maximum start-up force.

6.3.2 Breakaway Force

Breakaway force testing is adequate for comparative testing between smaller and larger diameter rollers.

6.3.3 TIR and MIS

Various Pilbara miners have tighter internal compliance standards for TIR than is required for SANS 1313 (South African Bureau of Standards, 2012), for example:

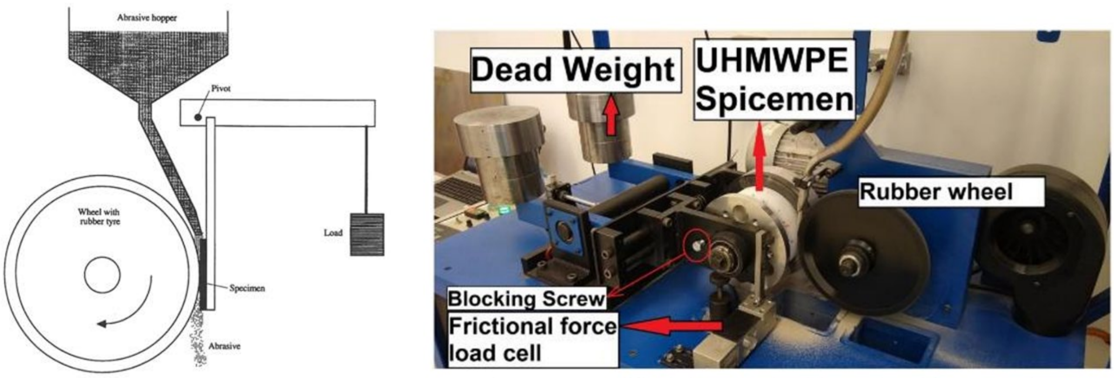
- *0.1 mm for Composite idler rollers less than 750 mm long; and*
- *0.2 mm for Composite idler rollers greater than 750 mm long*.

Therefore, there is a large variation between the industry testing standards and commercial requirements for composite rollers. MIS requirements are currently not explicitly indicated in various Pilbara miner specifications.

In practice, the rate of wear for a shell material and changes to the diameter across the roller face width, known in the industry as an hourglass profile, across a roller’s life have a much greater influence on the noise generation, vibration, parasitic friction loss and poor belt tracking that ultimately result, than do the as-new roller TIR and MIS. Therefore, MIS and TIR are best considered at both start and end of life of a roller, with end of life MIS and TIR being highly dependent on the wearing properties of the shell materials.

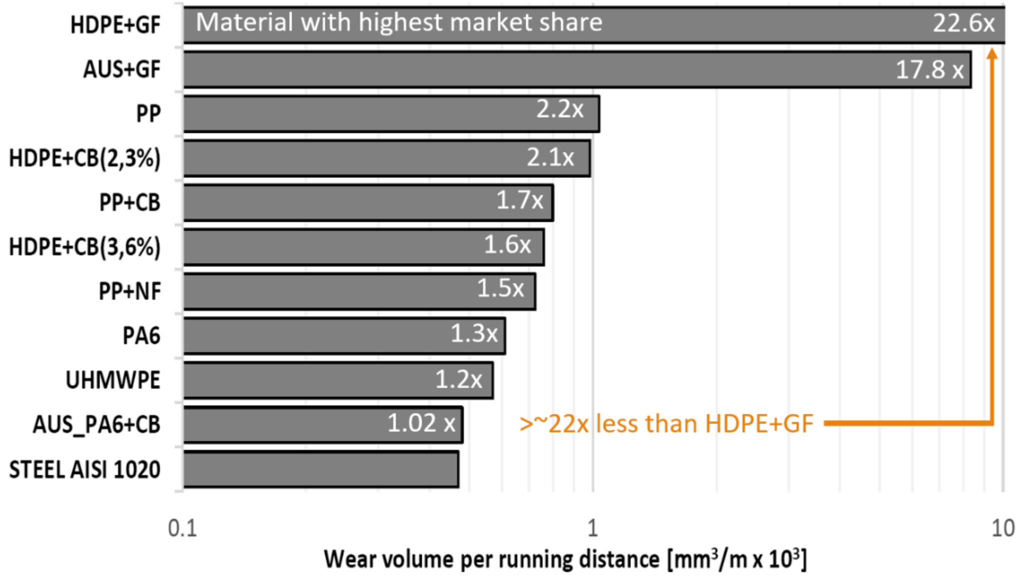
Previous work at Federal Technological University of Paraná (UTFPR) has identified a test method, modified ASTM G65, that is able to replicate field observations of wear characteristics for various transported materials (Cousseau T P. D., 2023). The primary difference in the modified version is that it allows for the testing of rotating idler roll segments rather than fixed ones.

Figure 27: *ASTM G65 dry-sand rubber wheel apparatus and modified rubber wheel in operation.*



Testing of Tribotech’s WearTech™ nylon material has confirmed that it offers superior wear characteristics with greater than 22 times that of high-density polyethylene (HDPE) including 76% glass fibre.

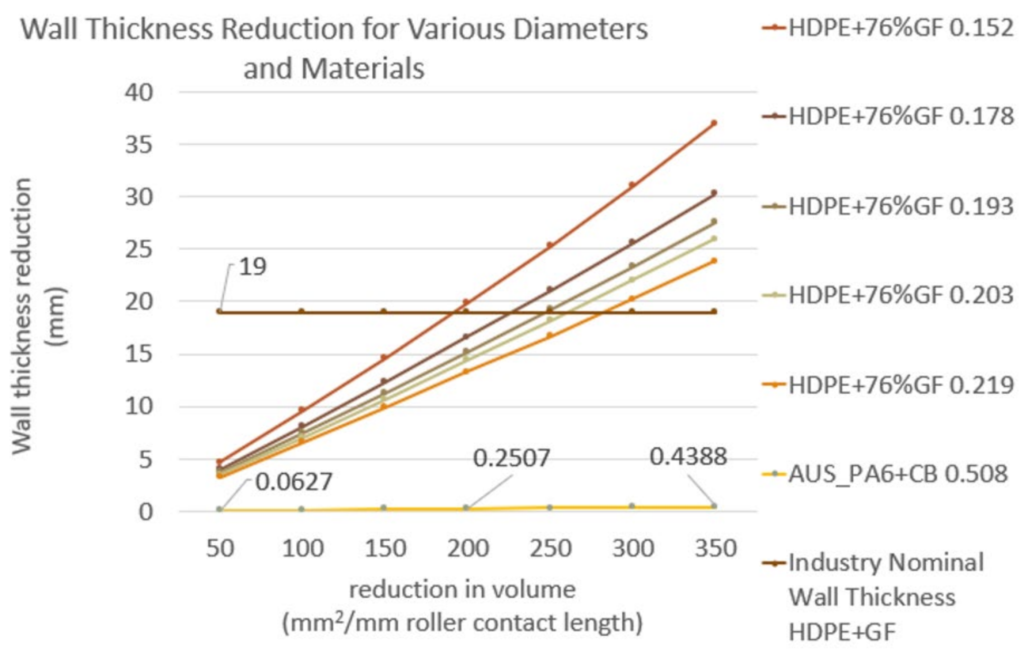
Figure 28: *Modified ASTM G65 - impacted by radius of samples tested.*



Additional unpublished proof of concept work by UTPFR has indicated that larger roller diameters have an additional positive influence on wear rate volume loss. Further work to quantify this effect is required.

The impact on roller shell wall thickness can be calculated using an area of annulus formula to provide a comparison on a per unit face width basis and the above wear volume loss rates for the various materials. Equivalent reduction in volume comparisons are made between HDPE+76% glass fibres and WearTech™.

__Figure 29:__ Wall thickness projections for various roller diameters with HDPE and Weartech™ shell materials.



As expected, wall thickness reduction by wear is less significant at larger diameters and for more wear-resistant materials. Using the above example, it is predicted that the TIR will be maintained within SANS 1313 (South African Bureau of Standards, 2012) limits with a 508 mm Weartech™ roller while all diameters of HDPE will have exceeded the common industry pipe wall thickness.

To establish and then maintain acceptable TIR and MIS throughout the lifespan of a roller, the conveyor designer must consider the impact of wear. A good analogy for the approach to be taken is the Maximum Allowable Operating Pressure and corrosion allowance calculations used in piping system design, whereby the designer allows for the strength and flexural rigidity requirements of the shell in the minimum wall thickness and then allows for the expected abrasion wear for the materials selected on top of this.

6.3.4 Balance Grade Determination

Test results were attained with “as manufactured” rollers to understand the requirements for balancing within the manufacturing process. Generally, the rollers complied with the requirements of ISO 21940 G40 balance quality G grade and will be able to achieve ISO 21940 G16 with balancing through addition of balance weights performed as part of the future manufacturing process.

Balance grade must be specified and tested not only at the initial design speed of the belt, but also at maximum design speed, if there are any indications that a future upgrade will “sweat the asset” with higher production, generally achieved through higher belt velocities.

6.3.5 Self-noise

The TBS self-noise testing is an indicator of potential field performance. Various Pilbara miners have requirements for noise of idlers which are different to the self-noise testing. An example is provided below:

Noise generated by standard idlers, with conveyors running at design/operating speed, both loaded and unloaded, shall not exceed a sound pressure level of 80 dB(A) at one metre. There shall be no tonality in the 1/3 octave spectrum, as defined in WA Environmental Protection (Noise) Regulations 1997, and all testing/noise measurements shall be executed in accordance with AS1081.2 1990 Section 6.0. Sound pressure levels shall not exceed 72 dB(A) at 1 m for low noise idlers in addition to the above.

Field conditions at commissioning can also be substantially different to those experienced throughout the equipment's life due to conditions such as shell wear, carry back adhesion, belt pulley cover de-waxing and bearing / sealing wear and integrity. With every conveyor being unique a standardised laboratory test is unable to be performed for type testing.

6.3.6 Water and Dust Ingress

Water ingress testing is effective at determining lip and bearing seal ingress resistance and dust ingress testing has the additional benefit of testing the effectiveness of external labyrinth arrangements. However, in overland / long conveying the bearing and sealing arrangements are often designed to reduce Rim Drag with bearings generally being specified as ball bearing designation with C3 clearance and ZZ (Shielded), trading sealing integrity for lower Rim Drag friction.

Testing is performed at nominal temperatures of the laboratory room and therefore does not contemplate the design temperature range effects of internal volume gas egress at higher temperatures, and the subsequent rebalancing at lower temperatures that normally arises in roller designs with breathing action (Curry, 2015). This aspect must be considered by designers when specifying roller sealing arrangements.

6.3.7 Resistance to Pressing Out

Resistance to press out testing is an effective method to confirm the bonding / fit design between the shell and bearing housing. However, this measure does not consider the stiffness and deflections of the bearing housing and the resulting shaft position. For laterally loaded roller shells, such as wing rollers, this may result in the shell being displaced laterally relative to the fixed frame bracket position, which can cause interference if the movement exceeds the distances between shaft bracket mounts.

6.4 Ground Module

Ground module designs are typically unique to each conveyor and operator's specific requirements. BR OLCC intended to develop a standardised 1500 mm belt width system that could support a production range of 20 to 40 Mtpa resulting from primary gyratory crushers (60-89 and 70-89 frames), screening and jaw crushers (C160 - C200) and sizers seen at Run of Mine crushing stations located in the Pilbara.

In terms of structural performance, finite element analysis (FEA) of the ground module supports demonstrated robust and reliable behaviour under load. While the models identified localised overstress at rigid load applications and significant geometry changes, the engineering assessment confirms this is an acceptable known phenomenon. The models prove that these small volumes of overstress safely dissipate via welds and local plasticisation (yielding) without causing structural failure.

The module foundations also provide significant stability and installation benefits. The design uses highly optimised 300 mm thick precast concrete pad footings reinforced with SL81 mesh top and bottom. These footings successfully resist bearing and longitudinal sliding, with no uplift occurring under extreme forces. Furthermore, to facilitate rapid and efficient construction, the footings are structurally verified for safe dynamic self-lifting with a DAF of 1.35, assuming a two-sling arrangement at a minimum 60° angle.

A dimensional tolerance schema on idler slot positions for a traditional plant idler requires manufacture to a fabrication tolerance of ±2 mm and for an extremely well manufactured overland idler a tolerance of ±0.5 mm. BR OLCC's proprietary tolerance schema greatly exceeds this. The structural plates are designed with a 2 mm to 3 mm machining allowance on the idler roller shaft slots. These slots are then machined post-galvanising to an exceptional accuracy of ±0.1 mm, before being treated with Tectyl 846 surface protection. When combined with automated installation and high accuracy survey on site the idler skew loss (Michael Carr, 2019) should be further reduced. Adopting the Big Roller™ tolerance schema for roller slots allows the initial installation and later post operational re-survey.

BR OLCC's proprietary design has integrated the energy efficiency and operational benefits of using larger diameter, composite nylon rollers while maintaining the practicality of OH&S weight limits and use of belt-friendly materials.

Finally, BR OLCC's proprietary design integrates the energy efficiency and operational benefits of utilising larger 508 mm diameter composite nylon rollers. These rollers utilise a rotary cast nylon shell (Weartech™) and injection-moulded nylon bearing housings. This advanced material selection maintains the practicality of strict OH&S limits by keeping the individual roller mass under 25 kg, ensuring safe manual handling and the use of belt-friendly materials.

7 Conclusions

7.1 General

The project achieved the following outcomes:

1. Closed the knowledge gap on what is required in design, materials selection and manufacturing methods to produce commercial idler rollers at 508 mm diameters for both existing and more arduous operating conditions.
2. Developed empirical datasets on primary conveyor losses (indentation rolling resistance, Rim Drag) using commercial roller products.
3. Supported the knowledge transfer of new energy efficiency testing standards and energy efficiency ratings for conveyor belt compounds and designs in accordance with AS 1333 (Standards Australia, 2024).

The project achieved the following deliverable outputs:

1. 50 commercial idler roller product samples at 508 mm diameter.
2. Two ground (low-level) module commercial demonstration products, alongside physical assemblies of the proprietary offset and inline idler frames.
3. Validation and verification reports for each relevant industry standard test.
4. IRR test results report for three roller diameters, three temperatures, four belt sag ratios, five belt speeds, and five vertical loads.
5. Delivery of a technical conference paper presenting IRR and Rim Drag results (15th ICBMH)
6. Final Technical Report.

Importantly, physical specimens of the ground modules and idler designs were validated, manufactured, and physically assembled. This commercial demonstration and assembly verification establishes to industry and relevant stakeholders that the Big Roller™ designed products have successfully completed TRL 6. Through this commercial demonstration, the industry can confidently engage in the next phase of commercialisation, which includes operational field trials and the development of automated construction equipment for ground module installation.

7.2 Roller Design and Manufacture

50 units of 508 mm rollers were manufactured in a small batch production run in accordance with the design datasheet (BR-DSH-0001). The design successfully proved that a massive 508 mm composite roller could be structurally engineered to satisfy strict OH&S manual handling limits (maintaining a mass of strictly under 25 kg) while delivering an exceptional L10 bearing and grease life exceeding 65,000 hours.

With future increases in manufacturing volumes, Tribotech will be able to implement proposed modifications to their proprietary design and manufacturing processes to further advance the roller product (including the planned integration of additives to achieve fire resistance for underground applications).

7.3 Energy Efficiency Testing

IRR testing was performed on the ST1000 steel cord conveyor belt with Eco Plus top and bottom covers using the large IRR test facility operated by TBS.

The results demonstrated several consistent trends regarding energy performance and the viscoelastic behaviour of the rubber belt:

- Impact of roller diameter and material: Increasing the idler diameter drastically lowered overall energy efficiency friction factors. Under standard comparison conditions (20°C, 5 m/s, 1% sag), shifting from a baseline 152 mm steel roll to a 508 mm roll reduced IRR by approximately 68% for steel and 57% for nylon variants.
- The nylon vs. steel trade-off: While the 508 mm steel roll achieved the greatest absolute IRR reduction due to its rigid shell stiffness and resulting smaller contact area, its extreme weight makes it prohibitive for safe field handling. This validates the design necessity of the composite nylon roller, which achieves a 57% IRR reduction while successfully maintaining a compliant individual mass of under 25 kg.
- Influence of operational variables: Consistent with the known viscoelastic properties of rubber, IRR increased proportionately with higher belt speeds and heavier vertical loads. Conversely, IRR decreased as temperatures rose, reflecting a reduction in the belt's viscoelastic energy losses at higher operating temperatures.

Overall, the test results indicate that the use of larger-diameter idler rolls can provide substantial reductions in indentation rolling resistance, with corresponding improvements in conveyor energy efficiency. These outcomes support optimisation of idler selection and conveyor power requirements.

7.4 Industry Standard Roller Testing

Standard industry testing on a sample of idlers was undertaken for:

- ISO 21940 (International Standards Organisation, 2019) Balance testing (6x non-destructive replicates)
- TBS Self Noise (6x non-destructive replicates)
- SANS 1313-3 (South African Bureau of Standards, 2012)
  - Rim Drag and Breakaway Force, Temperature (6x non-destructive replicates)
  - TIR and MIS. (6x non-destructive replicates)
  - Dust Ingress (3x destructive replicates)
  - Water Ingress (3x destructive replicates)
  - Resistance to housing press out (3x destructive replicates).

Test results are available on commercial terms from BR OLCC.

7.5 Ground Module

7.5.1 Ground Modules and Idlers

A BR OLCC patented ground module product (specifically the standardised 1500 mm low level module) was designed, had independent structural and civil engineering review by Strake Engineering and was manufactured by various supply chain partners.

The modularised design of BR OLCC's ground module included precast concrete sleepers, structural steel module legs with integrated idlers, bracing, cold formed stringers and cladding. It incorporates unique proprietary features to ensure high-accuracy roller slot position tolerance for installation accuracy and construction automation capabilities for both initial installation and relocation after transportation. Specifically, the design provided a 2 mm to 3 mm machining allowance on the idler roller shaft slots. This allowed the slots to be machined post-galvanising to strict ±0.1 mm tolerances, ensuring highly accurate alignment before being treated with Tectyl 846 surface protection.

7.5.2 Design

The 1500 mm Big Roller™ ground module design is structurally adequate for the intended operational and non-operational conditions as outlined in datasheet BR-DSH-0001, which includes heavy-duty capacities of up to 40 Mtpa, a maximum belt speed of 6.4 m/s, and ore densities of up to 2500 kg/m³.

The design meets all applicable engineering and safety standards, including AS 3600 (Concrete), AS 4100 (Steel), and AS 4600 (Cold-Formed Steel), and is fit for use. The independent review confirmed that all structural components safely passed UC (where LF ≥ 1.0) under extreme conditions. The critical maximum UC were recorded as: Pad Footing = 0.98, Members = 0.89, Steelwork buckling = 0.84, Stringers = 0.74, and Connections = 0.67.

7.5.3 Manufacture

Supply chain partners capabilities were evaluated and engaged to manufacture equipment to the requirements of the design, drawings, Australian Standards and inspection and test plans specific to each component.

7.6 Summary

Adoption of larger idler roller diameters could have a substantial impact on conveying energy efficiency. The individual impact can be as much or greater than that of improving rubber compounds, which have been refined over the last 30 years. For example, energy reductions offered for belt compounds such as Contitech's Eco Plus (15%) and Eco Extreme (30%) when compared to a standard conveyor belt (Contitech, 2022) are often cited as a current action plan item in ESG reporting (Fortescue, 2025 (b)). As can be seen in the results of testing here, the combination of 508 mm roller diameters and low rolling resistance belts has a compounding impact on conveyor energy efficiency.

TRL 6 was achieved for the Big Roller™ design suite products (relocatable ground modules, idlers and rollers). Commercial demonstration and assembly verification proved the structural viability of integrating 508 mm rollers. BR OLCC's commercialisation objective is to have products to suit conventional ground module designs for both greenfield and brownfield retrofit applications. This project has enabled the future progression of customer-focused site field trials (TRL 7-9) and ground module automated construction equipment development.

8 Recommendations for Further Work

Several specific recommendations and options for further work to enable expanded research and commercialisation pathways are outlined.

8.1 Roller Developments

Further work is recommended on the roller development on several fronts, including:

- Examination of the impact of roller design, including face width, wall thickness and roller shell material properties in IRR testing and confirmation of the driving mechanisms of the observed disparity between steel and composite rollers to inform future designs.
- Expansion of the BR OLCC product range to incorporate 406 mm (16”) diameter shell designs to enable larger wall thicknesses while still achieving weight requirement constraints.
- Undertake further testing of IRR with different manufacturers and their respective belt compound offerings to establish Energy Efficiency rating comparisons.
- Expand studies into shell material abrasion wear loss and influence from roller diameter with existing ASTM G65 test rig at TBS to be upgraded to the modified method and accommodate various roller diameters.
- Development of fire resistant anti-static compliant rollers in accordance with the test regime and Quality Management Systems requirements set out in TRG-6308 (NSW Department of Primary Industries and Regional Development, 2024) to expand the scope of the BR OLCC and Tribotech products, enabling their use in explosive atmosphere environments and underground mining. Tests include:
    - Products of combustion – toxicity testing
    - Combustion propagation characteristics (gallery test)
    - Ignitability and maximum surface temperature of idler subject to friction
    - Ignitability and flame propagation characteristics (finger burn test)
    - Oxygen index
    - Electrical resistance.
- Homogenisation of Testing Standards within an ISO/AS standard that contemplates and accommodates testing requirements of larger roller diameters.

8.2 Field Trials of Rollers

BR OLCC ’s next phase of commercialisation will involve the deployment of rollers in the field under operational conditions for a period of at least 12 months to progress through TRL 7 and 8. This may involve one or more of:

- The retrofit of idlers to existing brownfields conveyor facilities.

- The development of a Metro-located closed-circuit test facility where a 100 to 150 m long test conveyor can offer the ability to test various idler configurations and ore types to a high statistical confidence.
- A project to develop a standalone crush and convey circuit that is offline and independent from the main circuits in the Pilbara at an operating mine. This circuit would be used as an alternative to and concurrent with existing diesel truck haulage, using this as a backup and to reduce the production-critical nature of online trials.

BR OLCC is actively seeking participants to work with both locally and abroad to enable this to progress.

8.3 First of a Kind (FOAK) Conveyor Projects

The subsequent phase of commercialisation will involve the deployment of rollers in the field either in idlers or integrated ground modules under operational conditions for an entire conveyor to progress through TRL 9. BR OLCC is actively seeking partners to work with both locally and abroad to enable this to happen.

8.4 Automated Conveyor Ground Module Construction

Using the ground modules developed under this program of work, it is recommended to engage with the identified equipment manufacturers, surveyors and machine control experts to scope, develop, build and test the automated field construction equipment.

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Image Credits: TUNRA Bulk Solids, BR OLCC

Appendix 1 – Drawing List & Key Drawings

DRAWING LIST

BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM)

Title	Project	Discipline	Sequential number
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CONCRETE GENERAL NOTES	0000	-C-	0001
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CONCRETE BORED PIER ARRANGEMENT AND DETAILS	0000	-C-	0002
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CONVEYOR OVERPASS FOUNDATIONS DETAILS	0000	-C-	0003
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CONVEYOR OVERPASS FOUNDATIONS DETAILS	0000	-C-	0004
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS STRUCTURAL GENERAL NOTES	0000	-S-	0001
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W INLINE RETURNS PLAN SECTION AND ELEVATION	0000	-S-	0002
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W INLINE RETURNS DETAILS SHEEET 1 OF 2	0000	-S-	0003

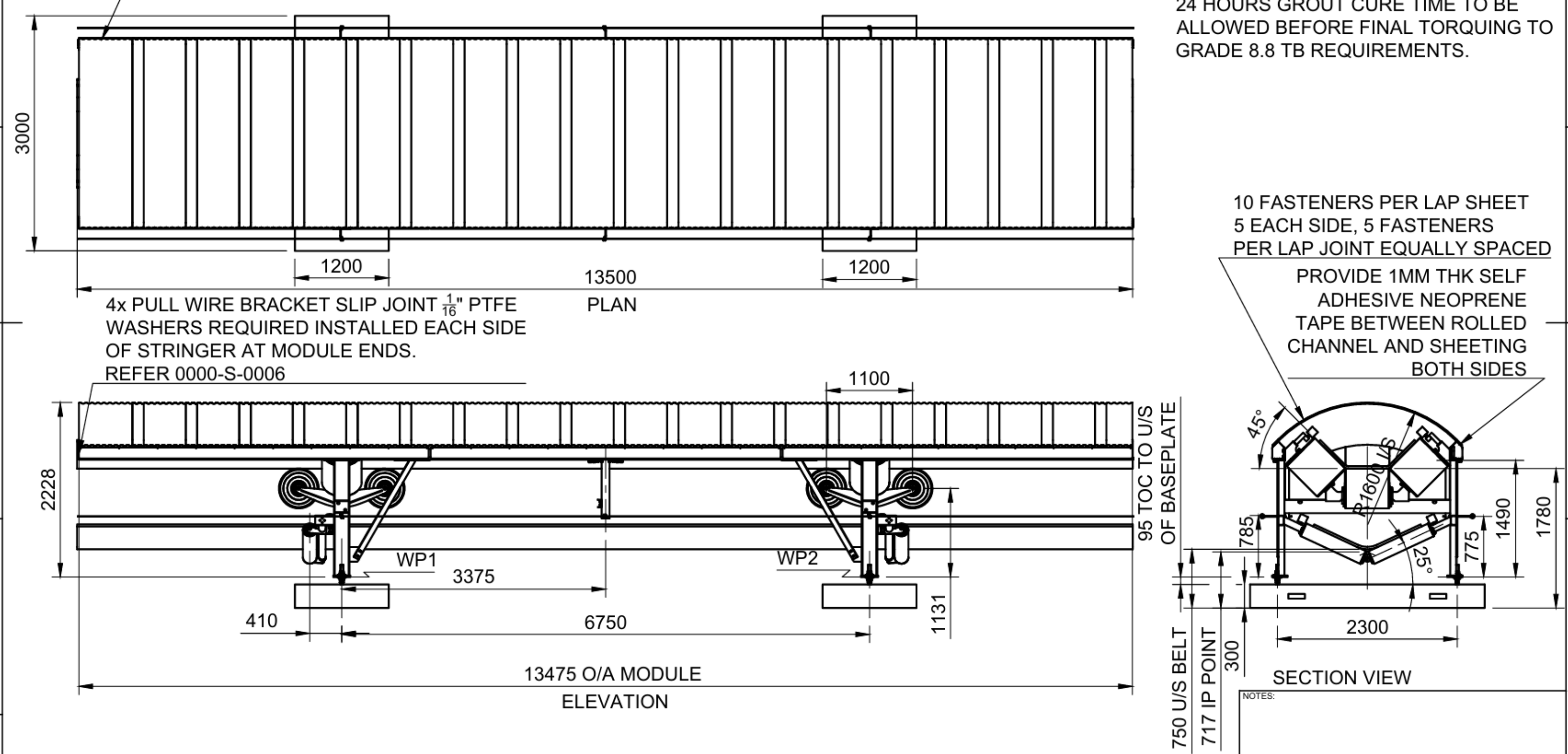
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W INLINE RETURNS DETAILS SHEEET 2 OF 2	0000	-S-	0004
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE STRINGER DETAILS	0000	-S-	0005
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS PULL WIRE BRACKETS PLAN SECTION, ELEVATION AND DETAILS	0000	-S-	0006
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CONVEYOR OVERPASS PLAN SECTION AND ELEVATION	0000	-S-	0007
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W OFFSET RETURNS PLAN SECTION AND ELEVATION	0000	-S-	0008
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W OFFSET RETURNS DETAILS SHEEET 1 OF 2	0000	-S-	0009
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W OFFSET RETURNS DETAILS SHEEET 2 OF 2	0000	-S-	0010
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS BANKED LOW LEVEL MODULE C/W INLINE RETURNS PLAN SECTION AND ELEVATION	0000	-S-	0011
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS BANKED LOW LEVEL MODULE C/W INLINE RETURNS DETAILS SHEEET 1 OF 2	0000	-S-	0012
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS BANKED LOW LEVEL MODULE C/W INLINE RETURNS DETAILS SHEEET 2 OF 2	0000	-S-	0013

BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS LOW LEVEL MODULE C/W OFFSET RETURNS PLAN SECTION AND ELEVATION	0000	-S-	0014
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS BANKED LOW LEVEL MODULE C/W OFFSET RETURNS DETAILS SHEEET 1 OF 2	0000	-S-	0015
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) BIG ROLLER™ PROTOTYPE (RATING 270KG / LM) STANDARD DRAWINGS BANKED LOW LEVEL MODULE C/W OFFSET RETURNS DETAILS SHEEET 2 OF 2	0000	-S-	0016
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS MECHANICAL GENERAL NOTES	0000	-M-	0001
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS PULL WIRE SWITCH PLAN SECTION AND ELEVATION	0000	-M-	0002
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS PULL WIRE ANCHOR PLAN SECTION AND ELEVATION	0000	-M-	0003
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS BELT DRIFT SWITCH PLAN ELEVATION AND DETAILS	0000	-M-	0004
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS FIBRE OPTIC SWITCH PLAN ELEVATION AND DETAILS	0000	-M-	0005
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS CARRY AND RETURN GUIDE ROLLERS DETAILS	0000	-M-	0006

BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS MODULE SURVEY WORKPOINTS ELEVATION DETAILS	0000	-M-	0007
BIG ROLLER™ PROTOTYPE (RATING 270 KG / LM) STANDARD DRAWINGS MODULE SURVEY WORKPOINTS SECTION DETAILS	0000	-M-	0008

- COLORBOND CUSTOM BLUE ORB 0.6 BMT COLOUR PALE EUCALYPT.
- SHEETING TO BE CREST FASTENED TO STRINGERS LAP JOINED ACCORDING TO LYSAGHT INSTRUCTIONS.
- MINIMUM FASTENER SIZE CTEKS 12-14X50 HGS GALVANISED HEXAGONAL HEAD SELF TAPPING 'TEK' SCREW WITH EPDM SEALING WASHER CTEKS MINIMUM COATING SYSTEM TO MEET CLASS 3 OR CLASS 4 AS3566.
- SIDE LAP FASTENING MUST BE CMBT 15-15x20 HWFS GALVANISED CTEKS MINIMUM COATING SYSTEM TO MEET CLASS 3 OR CLASS 4 AS3566.

NOTES:
1. FOR STEELWORK GENERAL NOTES REFER TO DRAWING 0000-S-0001.
2. ALL SWARF, FILINGS AND DEBRIS TO BE CLEARED FROM STRINGERS PRIOR TO CABLE INSTALLATION.
3. ANCHOR BOLT NUTS TO BE SNUG TIGHT POST SURVEY. SPACER VOID TO BE FILLED WITH EPIREZ 5137 GROUT. 24 HOURS GROUT CURE TIME TO BE ALLOWED BEFORE FINAL TORQUING TO GRADE 8.8 TB REQUIREMENTS.



NOTES:

REV.	DATE	DESCRIPTION	BY	APPROVED
0	24/9/25	ISSUED FOR CONSTRUCTION	SR	
B	30/7/25	ISSUED FOR APROVAL	SKR	PC
A	26/2/25	ISSUED FOR REVIEW	SKR	NA

GLENROWAN ENTERPRISES PTY LTD
TRADING AS BIG ROLLER OVERLAND CONVEYOR COMPANY
ACN 48 606 206 848
MUNDARING 6073
WESTERN AUSTRALIA
ORDERS@BIGROLLEROLC.COM

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES
LINEAR:
ANGULAR:

FINISH: NA

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING | REVISION 0

TITLE: BIG ROLLER™ PROTOTYPE (RATING 270KG / LM)
STANDARD DRAWINGS
LOW LEVEL MODULE C/W INLINE RETURNS
PLAN SECTION AND ELEVATION

	NAME	SIGNATURE	DATE
DESIGN	SHAWN RYAN	SRY	24/9/25
CHK'D	TRISTIAN IRIKS		25/9/25
APPV'D	PAUL CONI		25/9/25

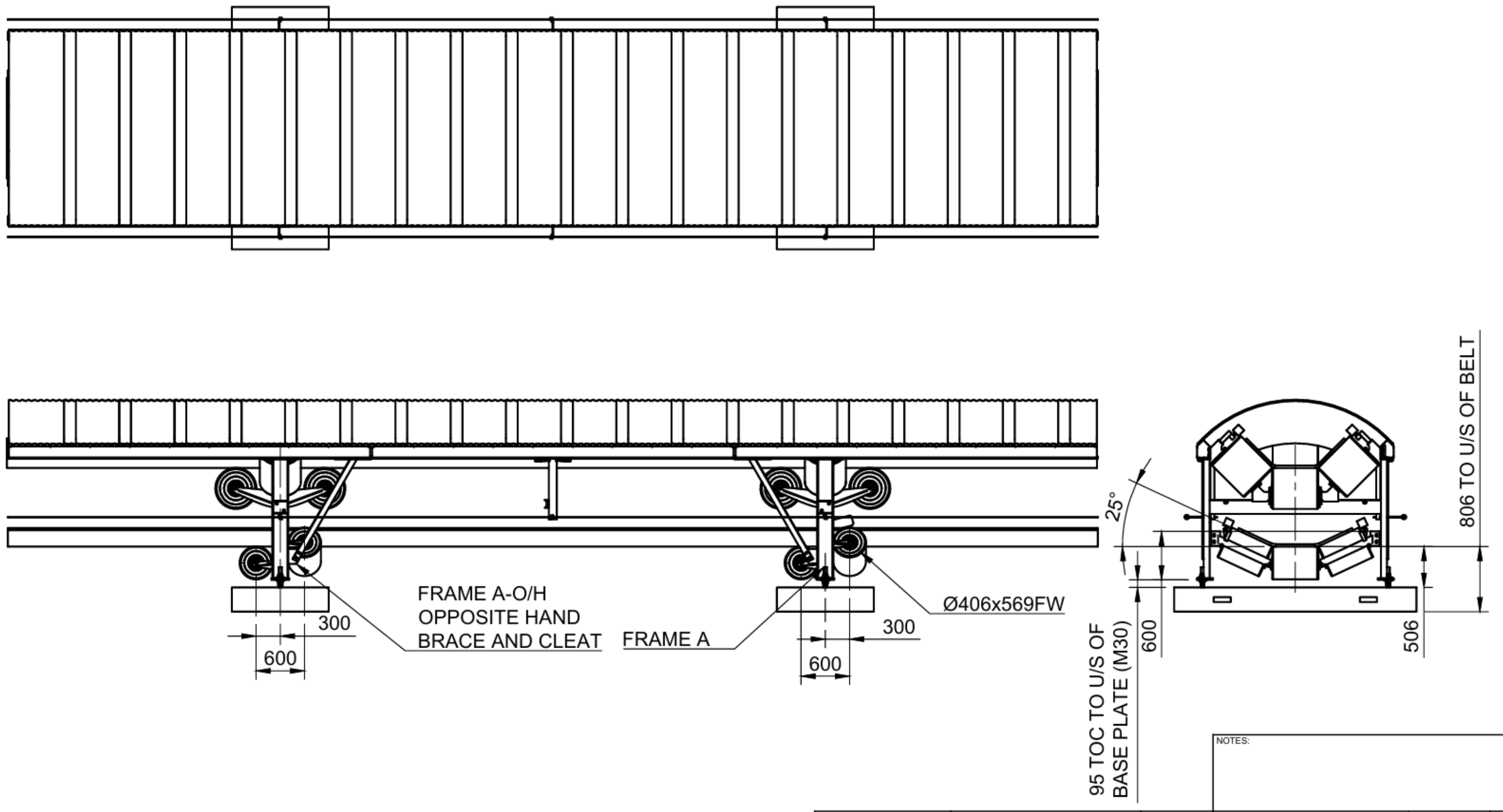
MATERIAL: NA

WEIGHT: NA

DWG NO. 0000 -S- 0002 | A3

SCALE: 1:100 | SHEET 1/1

NOTES:
REFER DRAWING 0000-S-0002 FOR DIMENSIONS AND DETAILS U.N.O.



NOTES:

REV.	DATE	DESCRIPTION	BY	APPROVED
0	13/10/25	ISSUED FOR CONSTRUCTION	SKR	
B	22/8/25	ISSUED FOR APPROVAL	SKR	
A	30/7/25	ISSUED FOR REVIEW	SKR	

GLENROWAN ENTERPRISES PTY LTD
TRADING AS BIG ROLLER OVERLAND CONVEYOR COMPANY
ACN 48 606 206 848
MUNDARING 6073
WESTERN AUSTRALIA
ORDERS@BIGROLLEROLC.COM

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES
LINEAR: +/- 2MM
ANGULAR: +/-1 DEG

FINISH: NA

DEBUR AND BREAK SHARP EDGES

	NAME	SIGNATURE	DATE
DESIGN	SHAWN RYAN		13/10/25
CHK'D	TRISTIAN IRIKS		
APPV'D	PAUL CONI		

MATERIAL: NA

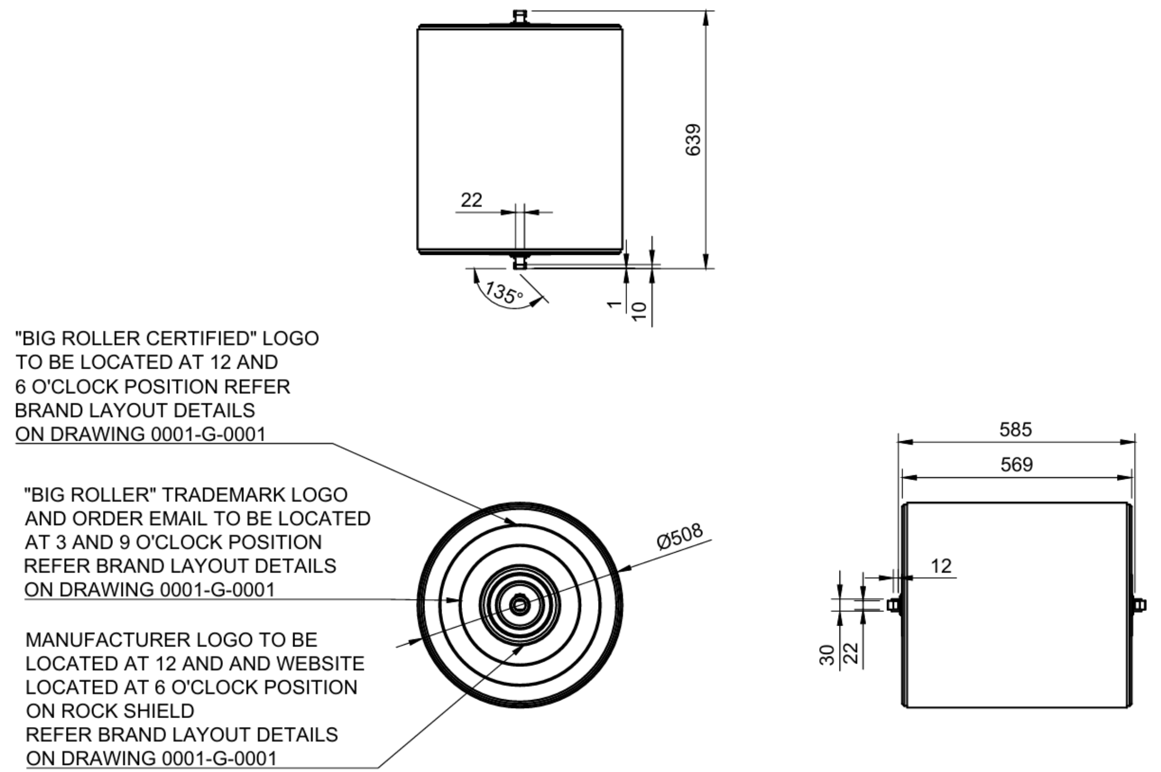
WEIGHT: NA

DO NOT SCALE DRAWING | REVISION 0

TITLE: BIG ROLLER™ PROTOTYPE (RATING 270KG / LM)
STANDARD DRAWINGS
LOW LEVEL MODULE C/W OFFSET RETURNS
PLAN SECTION AND ELEVATION

DWG NO. 0000-S-0008 | A3

SCALE: 1:50 | SHEET 1/1



NOTES:
REFER DATASHEET BR-DSH-0001

REV.	DATE	DESCRIPTION	BY	APPROVED
0	1/08/24	ISSUED FOR ORDER	SXR	SXR

GLENROWAN ENTERPRISES PTY LTD
TRADING AS BIG ROLLER OVERLAND CONVEYOR COMPANY
ACN 48 606 206 848
MUNDARING 6073
WESTERN AUSTRALIA
ORDERS@BIGROLLEROLC.COM

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: REFER PART DRAWING
TOLERANCES
LINEAR: REFER PART DRAWING
ANGULAR: REFER PART DRAWING

FINISH:
MANUFACTURERS STANDARD

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING — REVISION 0

TITLE: BIG ROLLER IDLER ROLLER PROTOTYPE (RATING 270KG / LM)
569 X 508 MM
1500 BELT WIDTH
GENERAL ARRANGEMENT

	NAME	SIGNATURE	DATE
DESIGN	SXR		23/2/2023
CHK'D	SXR		1/8/2024
APPV'D	SXR		1/8/2024

MATERIAL:
REFER DATASHEET BR-DSH-0001

WEIGHT: MAX 20KG

DWG NO. 0001-M-0002 — A3

SCALE: 1:10 — SHEET 1/1

Appendix 2 - Idler Roller Datasheet (Extract)

BIG ROLLER™ WWW.BIGROLLEROLC.COM		**Equipment Data Sheet**	Big Roller™ idler roller
		Project:	MRIWA
		Document Number:	BR-DSH-0001
		Revision	0
Item	**Description**	**units**	**Data**
3.0 Conveyor Design Parameters (Refer Notes 1.1 through 1.3)			
3.01	Annual operation	hours	6,500
3.02	**Material**		Primary Crushed Iron Ore
3.03	Material Bulk Density Range	t/m^3	1.4 - 2.4
3.04	Material Bulk Density L_{10} Life Calculations	t/m^3	1.8
3.05	Material Bulk Density Structural Calculations	t/m^3	2.4
3.06	Maximum Particle Size	mm	350
3.07	Surcharge Angle Range	degrees	10 – 30
3.08	Surcharge angle L_{10}	degrees	20
3.09	Angle of Repose (Flooded Belt)	degrees	40
3.10	Minimum Edge Clearance (50% max PSD)	mm	175
3.11	Lump factor		1.3
3.12	Dynamic factor (Carry)		1
3.13	Dynamic factor (Return)		1.2
3.14	**Belt**		TBC
3.15	Rating		ST4000
3.16	Belt Width	mm	1500

3.17	Belt Mass	kg/m	82		
3.18	Thickness	mm	32		
3.19	Carry Cover Thickness	mm	15		
3.20	Pulley Cover Thickness	mm	8		
3.21	Speed [Min / Nominal / Max]	m/s	3.2	4.0	6.4
3.22	Capacity [Min / Nominal / Max]	Mtpa	20	25	40
3.23	Head Pulley Tension (T1)	kN	900		
3.24	Tail Pulley Tension (T2)	kN	300		
3.25	Minimum Take-up Tension	kN	175		
3.26	Belt Sag - running	% of idler spacing	1		
3.27	Belt Sag - E-stop	% of idler spacing	3		
3.28	Convex curve - min radius	m	2,500		
3.29	**Ground Module Idler Station**				
3.30	Carry Design		4 Roll		
3.31	Carry Configuration		Dual Offset Centre Rolls, Central Wing Rolls		
3.32	Carry Trough Angle	degrees	45		
3.33	Return Rolls		2 Roll		
3.34	Return Configuration		Vee inline		
3.35	Return Trough Angle	degrees	25		
3.36	Carry Wing Roll Span	m	6.75		
3.37	Carry Centre Roll Spans	m	5.65 / 1.1 alternating		
3.38	Return Roller Spans	m	6.75 or 5.95/7.55 alt		
3.39	Idler wing roll projections Drift = 5% allowance	mm	75		
3.40	Clearance to guide rolls	mm	25		

3.41	Cut off bar (height above edge of roller)	mm	117
3.42	Minimum clearance between offset roller and frame	mm	75
3.43	Max Vertical Design Misalignment Carry	mm	3
3.44	Max Vertical Design Misalignment Return	mm	6
3.45	FEA Roller Design Load Distribution Profiles		Hertzian Pressure & Uniformly Distributed

Appendix 3 – Ground Module Design Input

Design Inputs

The following inputs are used to derive design loads:

Structural Importance Level	2
Design Life	25 years
Annual Probability of Exceedance	Wind: 1/200 Earthquake: 1/250
Structure Height	2.6m
Wind	
Region	A0
Terrain Category	2
Shielding Multiplier, Ms	1
Topographic Multiplier, Mt	1
Working Wind Speed	25 m/s (ULS)
Earthquake	
Hazard Design Factor	0.12
Site Class	D
Structure Ductility μ/Sp	2.6
Loose ore density	2500 kg/m^3
Encrustation/Build-up density	2700 kg/m^3
Material load	Normal Operation: 0.280 m^2 Flooded Belt: 0.474 m^2
Belt mass	81 kg/m
Maximum belt tension	900 kN (carry) 300 kN (return)
Idler mass (carry and return)	20 kg
Idler/Belt friction coefficient	0.35
Services (LV and communications)	60 kg/m
Steel Grades	
Hot rolled sections	Grade 300+
Hollow sections	Grade C350
Light gauge/Cold formed sections	Zincalume G450 1.5 BMT Correction (1.9BMT)
Sheeting	Lysaght Custom Blue Orb 0.6 BMT

Appendix 4 – WA Iron Ore Facilities Captured Under the Safeguard Mechanism in 2023/24

Has an overland conveyor	Facility name	Responsible emitter	State/ Territory of operation	ERC	Baseline emissions number	Covered emissions	ACCUs surrendered	SMCs surrendered	Net emissions number	Net position number	SMCs Issued	Cumulative MYMP net emissions number	Cumulative MYMP net position number	Notes
Y	**ARC01 Mining Area C - MNG Facility**	BHP IRON ORE PTY LTD	WA	0.951	694,935	512,387	-	-	512,387	-182,548	-	-	-	-
Y	**Brockman 2 / Nammuldi Mines**	Hamersley Iron Pty. Limited	WA	0.951	185,088	312,410	127,322	-	185,088	-	-	-	-	As the facility surrendered 30% or more of its baseline, the required written explanation as to why more carbon abatement did not occur at the facility can be found on the baselines and emissions data page.
Y	**Brockman 4 Mine**	Hamersley Iron Pty. Limited	WA	0.951	142,158	236,261	94,103	-	142,158	-	-	-	-	As the facility surrendered 30% or more of its baseline, the required written explanation as to why more carbon abatement did not occur at the facility can be found on the baselines and emissions data page.
Y	**Christmas Creek Mine**	CHICHESTER METALS PTY LTD	WA	0.951	351,986	372,251	-	-	372,251	20,265	-	372,251	20,265	Please refer to the Multi-year monitoring period reported emissions data table for more information.
Y	**Cloudbreak Mine**	CHICHESTER METALS PTY LTD	WA	0.951	267,459	295,132	8,411	19,262	267,459	-	-	-	-	-
Y	**Eliwana Mine**	FMG SOLOMON PTY LTD	WA	0.951	135,777	164,894	-	-	164,894	29,117	-	164,894	29,117	Please refer to the Multi-year monitoring period reported emissions data table for more information.
Y	**Gudai-Darri Mine**	Mount Bruce Mining Pty Ltd	WA	0.951	604,067	129,676	-	-	129,676	-474,391	474,391	-	-	-
Y	**Hope Downs 1 Mine**	Hamersley HMS Pty Ltd	WA	0.951	126,313	166,842	40,529	-	126,313	-	-	-	-	As the facility surrendered 30% or more of its baseline, the required written explanation as to why more carbon abatement did not occur at the facility can be found on the baselines and emissions data page.
N	**Hope Downs 4 Mine**	Hamersley HMS Pty Ltd	WA	0.951	100,000	119,586	19,586	-	100,000	-	-	-	-	-

Y	**Jimblebar Mine**	BHP IRON ORE PTY LTD	WA	0.951	302,155	310,615	8,460	-	302,155	-	-	-	-	-
N	**Marandoo Mine**	Hamersley Iron Pty. Limited	WA	0.951	109,985	156,177	46,192	-	109,985	-	-	-	-	As the facility surrendered 30% or more of its baseline, the required written explanation as to why more carbon abatement did not occur at the facility can be found on the baselines and emissions data page.
N	**Mesa A Mine**	Robe River Mining Co. Pty. Ltd.	WA	0.951	100,000	60,255	-	-	60,255	-39,745	-	-	-	The facility is an eligible facility under 58B.
N	**Mesa J / K Mine**	Robe River Mining Co. Pty. Ltd.	WA	0.951	104,837	65,868	-	-	65,868	-38,969	-	-	-	The facility is an eligible facility under 58B.
Y	**Newman Operations**	BHP IRON ORE PTY LTD	WA	0.951	304,376	316,238	11,862	-	304,376	-	-	-	-	-
Y	**Paraburdoo Mine**	Hamersley Iron Pty. Limited	WA	0.951	100,000	163,892	63,892	-	100,000	-	-	-	-	As the facility surrendered 30% or more of its baseline, the required written explanation as to why more carbon abatement did not occur at the facility can be found on the baselines and emissions data page.
Y	**Roy Hill Mine**	Roy Hill Holdings Pty Ltd	WA	0.951	470,949	516,539	45,590	-	470,949	-	-	-	-	-
Y	**Sino Iron Project – Cape Preston**	CITIC Pacific Mining Management Pty Ltd	WA	0.951	1,091,911	1,111,621	19,710	-	1,091,911	-	-	-	-	-
Y	**Solomon Mine**	FMG SOLOMON PTY LTD	WA	0.951	390,033	452,137	42,926	19,178	390,033	-	-	-	-	-
Y	**Tom Price Mine / WTS**	Hamersley Iron Pty. Limited	WA	0.951	161,334	183,325	21,991	-	161,334	-	-	-	-	-
Y	**West Angelas Mine**	Robe River Mining Co. Pty. Ltd.	WA	0.951	208,498	265,099	56,601	-	208,498	-	-	-	-	-
N	**YAN01 Yandi/Marillana**	BHP IRON ORE PTY LTD	WA	0.951	100,000	107,160	7,160	-	100,000	-	-	-	-	-

	Creek Mine - MNG Facility													
Y	**Yandicoogina Mine**	Hamersley Iron - Yandi Pty Limited	WA	0.951	141,890	151,438	9,548	-	141,890	-	-	-	-	-
WA Iron Ore Sector Totals					**6,193,751**	**6,169,803**	**623,883**	**38,440**	**5,507,480**	**- 686,271**	**474,391**	**537,145**	**49,382**	