CRUSHING AND MATERIALS HANDLING AT NGEZI PLATINUM MINES – ZIMBABWE

Livio Talocchino
Procurement Technologies Africa (Pty) Ltd

INTRODUCTION

Ore crushing, storage and materials handling systems are used extensively in the mining and minerals industry. These systems are employed in both underground and surface mining operations and in downstream processing facilities. In this paper an attempt is made by the writer to record the scope of the work completed, lessons learned, and the improvements implemented at the various stages of the design and construction of these systems over a period of seventeen years at four platinum mines and at the concentrator facility at Ngezi in Zimbabwe.

The mineral rights owned by Zimbabwe Platinum Mines (PVT) Limited (Zimplats) on the Ngezi tenements forming part of the Great Dyke in Zimbabwe are located approximately 120 km Southwest of the capital Harare and extend over a distance of some 30 km in a Southerly to Northerly direction with the ore body dipping slightly towards the North.

Mining commenced at Ngezi in the late 90's with an open-cast mining operation in the Southern part of the ore body. As this ore body was depleted mining continued towards the North with the development of underground mines at Portals 1 to 4. Currently Zimplats is in the process of developing a new mine at Portal 6.

Our team under the banner of Exclusive Technical Services (ETS) at the time commenced working on the Ngezi projects in 2002 with the award of a feasibility study to investigate the use of overland conveyors vs trucking for linking several proposed underground mines along the strike owned by the client to a future concentrator. At the time ten portals were envisaged along the thirty-kilometre strike length with a concentrator situated roughly at the centre.

Following the study, work by the project team continued with the design and construction of an in-pit primary crushing and conveying facility at Portal 2. This plant is built at the bottom of the mined-out section of the existing open pit and is fed from the underground mine (decline) developed from the bottom of the open pit. The ore is trucked to surface, crushed and conveyed to an existing ore stockpile (built previously by others) which loads road trains (105t capacity) that transport the ore seventy kilometres to an existing concentrator plant at Selous (SMC).

Immediately after the completion of Portal 2, the team continued working at Ngezi as a part of Sandvik Materials Handling (SMH), this work included the development of the surface crushing and conveying system at Portal 1, the underground and surface primary crushing and materials handling systems at Portals 3 and 4, and the secondary and tertiary crushing and screening facility feeding the Ball Mills at the Ngezi Concentrator.

NGEZI - SITE DATA

PLANT LOCATION

- Country : Zimbabwe
- General Location : ± 160km South West of Harare
- Site Altitude : 1275m above MSL
- Access : Tarred Road to Mine entrances

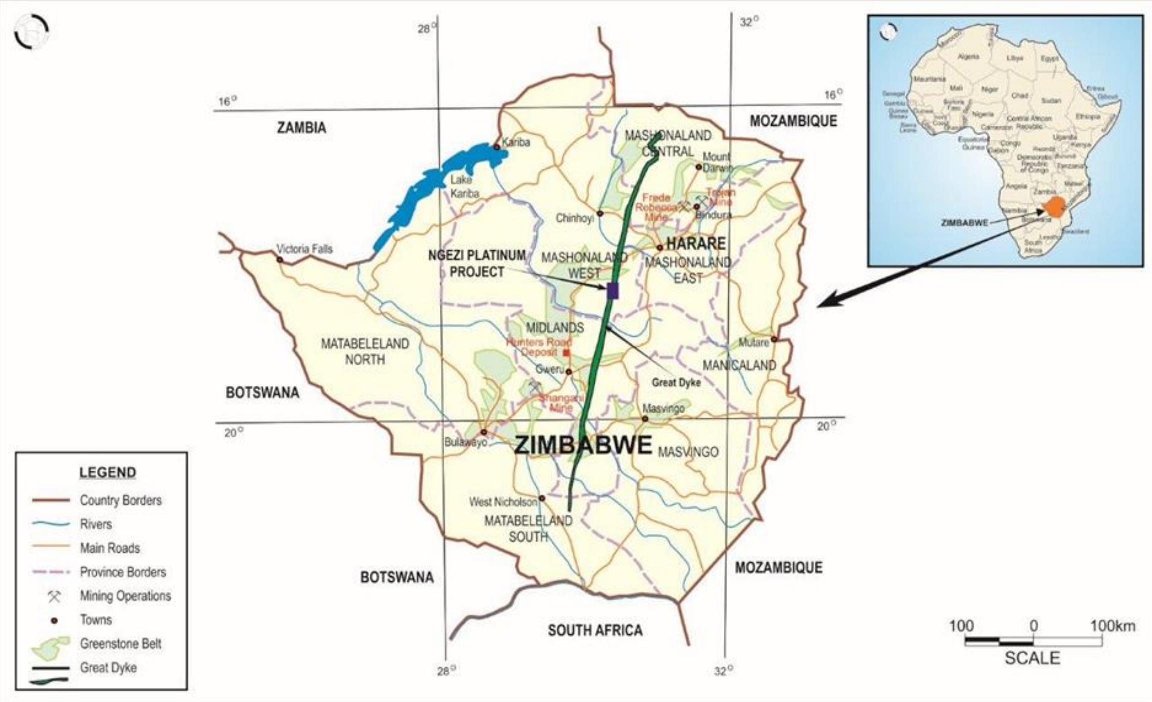

Figure 1. Map of Zimbabwe showing position of Ngezi Platinum Project

NGEZI - ROM ORE CHARACTERISTICS

Results from test work performed on a bulk sample from Portal 2 indicated that the ore was reasonably hard and abrasive, when broken it also tended to be “slabby” and have sharp edges.

- Top size 800mm
- Bulk Density (In Situ) 3.24t/m^3
- Bulk Density (Broken) 1.79 – 1.99t/m^3
- Uniaxial Compressive Strength Max = 300 MPa
- Abrasiveness Index (Pennsylvania) 0.45 – 0.54
- Crushing Work Index (Bond) 17.8 – 19.4 (Max 26.6)
- RoM Moisture Content 5 – 8%

ROM SIZE DISTRIBUTIONS

Table 1. ROM size distributions

Before Crushing Size (mm)	% Retained	Cum % Passing
800	0.00	100
650	4.04	96
500	11.2	88.8
300	29.4	70.6
250	44.2	55.8
150	58.6	41.4
50	66.1	33.9

MINING

Typically the underground mines use a mechanised bord and pillar mining method, the distance between the mines is approximately 3.0 km along strike. Maximum depth at the existing mines is expected to reach +- 350 m below surface.

Access to the underground workings is gained via a box cut and decline system. When conveyors are utilised to bring crushed ore to surface three declines consisting of two mining and one conveyor decline are used. The mining declines fall on dip (West to East) to the sink line (bottom of reserve) with the conveyor decline running below the mining declines.

Thirty tonne trucks are loaded by load haul dump vehicles (LHD's) in the mining sections, the trucks haul the ore to surface crushing tips (Portals 1 and 2) and to underground ore passes or crushing tips (Portals 3 and 4). Tipping at underground ore tips is generally from two sides to increase the availability of the system. A static grizzly over the top of each tip stops oversize RoM ore from entering and a hydraulic rock breaker is employed to break the oversize material.

PORTAL 2 (RUKODZI MINE)

Figure 2. Aerial view of Portal 2 – Rukodzi Mine

Ore transport from underground is by truck to a surface crushing station. The crushing and conveying system is designed for a throughput of 1.0Mtpa.

RUN OF MINE TIPPING/SCALPING/CRUSHING/CONVEYING:

- Hours of operation : 6 300 hours per annum
- Nominal Feed Rate : 160 tph.
- Peak Feed Rate (System Availability) : 275 tph.
- Design Feed Rate : 400 tph.
- Equipment design duty : 24hours/day, 365 days

The crushing station is built in a concrete structure which retains the earth fill for the tip approach ramp, it is open on one side to allow for the exit of the crushed ore sacrificial conveyor. Trucks tip from one side into an 80t steel bin through a static grizzly mounted at the top which has 0.6m square openings, a hydraulic rock breaker mounted on a concrete base alongside the bin breaks the oversize on the grizzly.

Ore is discharged from the bin by apron feeder onto a vibrating grizzly which scalps off the -140mm material and feeds the oversize to a single toggle 30x55 jaw crusher. The crusher product (-150mm) and scalped undersize from the vibrating grizzly discharge onto a 900mm wide sacrificial conveyor, the crushing plant throughput (apron feeder speed) is controlled by a belt scale mounted on the sacrificial conveyor.

A fly-wheel on the high speed side of the drive keeps the conveyor running for approximately 12 seconds to avoid the ore in the crusher chamber, the vibrating grizzly and the undersize chute flooding the conveyor during power trips.

The head chute on this conveyor is designed to contain the surge and provide a controlled withdrawal onto the downstream conveyor. A tramp iron magnet on the head chute protects the subsequent conveyor belts from possible belt damage.

The ore from the sacrificial conveyor is transported by three 750mm wide conveyors in series, the first in the series transports the ore out of the pit and feeds onto a downhill decline conveyor which discharges onto the next conveyor in the series that feeds an existing (upgraded) 1200mm wide conveyor which delivers the ore to the existing road train load out stockpile. The downhill decline conveyor has a brake mounted on the tail pulley to control the regeneration of power by the motor (+- 16kW for 60 sec) when the conveyor is loaded.

Table 2. Portal 2 conveyor data

Portal 2 Conveyor Data	**Width mm**	**Length m**	**Lift m**	**Belt Speed m/s**	**Installed kW**	**Soft Start**	**Add. Equipment**
Sacrificial	900	56	3	2.0	22	VSD	Flywheel, Self Cleaning Tramp Magnet
Pit Transfer	750	454	53	2.2	2 x 75	VSD	Motor Encoders
Downhill Decline Transfer	750	440	- 22 + 13	2.2	45	VSD	Tail Brake
Transfer to Exist.	750	191	21	2.2	55	VSD	Hammer Sampler
Exist. to Stockpile	1200	123	12	2.5	75	Fluid Coupling	Drive upgraded (Speed & kW's)

Portal 2 (Rukodzi) Crusher Station – Civil Construction and Completed Plant

Figure 3. Portal 2 (Rukodzi) Crusher station under construction

Figure 4. Portal 2 (Rukodzi) Crusher station completed

PORTAL 1 (NGWARATI MINE)

Figure 5. Aerial view of Portal 1 (Ngwarati) Mine

Ore transport from underground is by truck to a surface crushing station similar to that at Portal 2. Production from this mine is 1.5Mtpa and the crushing and materials handling system is sized as follows:

▪ Hours of operation	:	6 300 hours per annum
▪ Nominal Feed Rate	:	240 tph.
▪ Peak Feed Rate (System Availability)	:	421 tph.
▪ Design Feed Rate	:	550 tph.
▪ Equipment design duty	:	24hours/day, 365 days

The mine is positioned at the top of a rise and the crushing station is built in a concrete structure excavated into the side of the Northern embankment.

Trucks tip from one side into an 120t steel bin which has static grizzly mounted at the top similar to that at Portal 2 and a hydraulic rock breaker mounted on a concrete base alongside the bin which breaks the oversize on the grizzly. Discharge from the bin is by apron feeder feeding a vibrating grizzly feeder scalping at -180mm and feeding the oversize to a JM1211 single toggle jaw crusher. The crusher product and the vibrating feeder undersize is transported via three conveyors in series to the existing Open Pit/Road Train Stockpile Tip.

The crusher product (-212mm), scalped undersize from the vibrating grizzly and apron feeder dribble discharge onto a 1200mm wide sacrificial conveyor, the crushing plant throughput (apron feeder speed) is controlled by a belt scale mounted on the sacrificial conveyor. A fly-wheel on the high-speed side of the drive keeps this conveyor running for approximately 15 seconds (normal stop = 7 seconds) to avoid the flooding of the conveyor by the ore remaining in the crusher chamber, the vibrating grizzly and the undersize chute during power trips. The head chute on this conveyor also provides for a controlled withdrawal onto the downstream conveyor. A tramp magnet fitted on the head chute protects the downstream conveyors from possible belt damage.

The sacrificial conveyor transfers onto a 1200 mm wide overland conveyor which is 2400 m in length, inclines from the tail for 1400 m to a height of 52 m, it dips 17 m to the head and has two horizontal curves. Existing overland stringer modules and concrete footings (sleepers) from two unused conveyors at SMC mine in Selous were re-located and utilised to build the conveyor.

The head, tail and take-up systems were redesigned to suit the new layout conditions and new drives, pulleys, idlers and belting were procured to suit the new design. The conveyor has a drive station at the head end with 2 x 160kW drives, (VSD) soft starts and a brake on the primary drive. Under a controlled stop condition the VSDs slow the belt down to a stop in approximately 17 seconds, once stopped the brake unit engages to prevent forward movement of the conveyor if the decline portion of the conveyor is loaded. In the event of an emergency stop or loss of power the brake engages and stops the belt in 17 to 20 seconds (un-assisted coasting time with a full belt is about 37 seconds), under this condition the brake is utilised to assist the flywheel on the last conveyor in the series to prevent flooding.

The last conveyor in the series discharges into the existing open pit tip bin, it is 1200 mm wide and has a fly-wheel on the high-speed side of its drive so that it can clear the over-run material from the overland. Samples to determine head grade from the Portal are taken three times per shift by a hammer sampler installed on this conveyor.

Table 3. Portal 1 conveyor data

Portal 1 Conveyor Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Sacrificial	1200	57	3.5	2.5	45	VSD	Flywheel, Self Cleaning Tramp Magnet
Overland	1200	2413	+52 -17	2.5	2 x 160	VSD	Brake
Transfer to Exist. Tip	1200	51	5.4	2.5	45	VSD	Flywheel, Product Sampler

Portal 1 (Ngwarati) Crusher Station and Overland Conveyor

Figure 6. Portal 1 (Ngwarati) Crusher Station

Figure 7. Aerial view of equipment and services common to Portals 1 and 2

Equipment/Services Common to Portals 1 and 2

Dust suppression - Installed at the apron feeder discharge, vibrating grizzly feeder discharge, crusher discharge and conveyor transfers.

Fire detection/suppression - Heat detection and alarms in the sub stations and MCC rooms, fire suppression is by hand held CO2 cannisters. The crushing stations have hand held powder and CO2 cannisters placed on all floor levels, hand held powder cannisters are placed at 50m intervals along the conveyors and close to all drives, take ups and pulleys.

Plant control is by Programmable Logic Controllers (PLCs) installed in the Tip Substations. A Remote I/O unit is located in the transfer tower at the head-end of the Portal 1 overland conveyor and the Portal 2 open pit decline conveyor. A Human Machine Interface (HMI) is located in the crusher area near the apron feeder at both crusher stations to enable operating personnel to monitor the systems.

The PLC software stops and starts the plant under normal operating and emergency conditions. It monitors all onboard safety devices (conveyor pull switches, belt slip/breakage (zero speed) switches, alarm sirens/lights, belt rip detection and blocked chute detection). The PLC also monitors and controls the operation of the tips (bin levels), apron feeders, vibrating grizzlies, jaw crushers, over band magnets, conveyors, belt scales, dust suppression systems and it communicates with other associated plant PLC's.

Level detection devices at the tip bins warn the rock breaker operator of filling conditions and stop the apron feeder from fully emptying to avoid damage on restart from large rocks.

The pull-wire switches on all the conveyors are hard-wired into the PLC to affect a "controlled stop" of the crushing circuit in case of an emergency induced stop.

A "Dupline" intelligent pull key system is employed on the Portal 1 overland conveyor to identify trips on the individual pull keys along the length of the conveyor.

Portal 1 - Ore Tip and Overland Conveyor

Figure 8. Portal 1 Ore tip

Figure 9. Portal 1 Overland conveyor

PORTAL 4 (BIMHA MINE)

Figure 10. Portal 4 (Bimha Mine)

Original Underground Facilities Prior to Mine Re-development

The original underground material handling facilities were designed to handle 2.4Mtpa of ore in order to feed the new concentrator at Ngezi. The flowsheet/design was based on a dynamic simulation study that was undertaken of the overall system which included, mining, ore pass storage, conveying, primary crushing, surface storage at the Portal, overland conveying to and storage at the concentrator, closed circuit secondary/tertiary crushing and screening and ball milling.

The mine layout (mining plan) comprised of three declines (two mining and one conveyor). The mining declines fell on dip at approximately 9 deg. West to East to the sink line with the conveyor decline running below the mining declines. Within the “spine” (area between the mining declines), four 700t capacity (one shift for two mining sections) ore passes equally spaced at approximately 220m apart were constructed. The ore was transported by underground truck from the mining faces and tipped into the ore passes.

Based on the RoM sizing (blasting fragmentation) data from the mine static grizzlies with 400mm square openings were installed at the top of the ore passes and hydraulic rock breakers mounted alongside the ore passes broke the oversize on the grizzlies.

At the bottom of each ore pass the ore was fed by vibrating feeder onto a 1500mm wide sacrificial conveyor and then conveyed up the decline by four 1350mm wide conveyors running in series (405, 404, 403, 413) to a surface crushing facility. Hydraulic radial gates were employed on the ore pass discharge chutes for vibrating feeder maintenance and emergency shut off.

Table 4. Portal 4 underground conveyors to surface crushing data

Portal 4 U/Ground Conveyors to Surface Crushing Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Sacrificial Conveyors	1500	22	3	1.5	37	VSD	Impact Bed, Self Cleaning Tramp Magnet
Decline 405	1350	450	55	2.0	2x200	VSD	Auto T/UP Winch + Load Cell & Anti Run Back Idlers
Decline 404	1350	498	80	2.0	2x200	VSD	Auto T/UP Winch + Load Cell & Anti Run Back Idlers
Decline 403	1350	770	120	2.0	2x315	VSD	Anti Run Back, Belt Pulling Winch, Idlers/Belt Grab
Surface Transfer 413 - to Crusher	1350	164	18.5	2.0	110	VSD	Belt Grab

Belt widths on the decline conveyors were selected based on three times anticipated maximum lump size and a safety factor for belt start under load and the occasional slabs larger than 400mm. To avoid possible spillage from vibrating feeder surges the sacrificial conveyors were run slower and belt width was increased.

Vibrating feeder throughput was controlled by a belt scale mounted on the decline conveyor after the sacrificial conveyor transfer chute. A tramp magnet on the sacrificial conveyor head chute was installed to remove tramp metal and protect the upstream decline belts from damage.

To absorb the impact from the large material and the additional height required above the belt for the passage of material from the down-stream ore passes, heavy duty drop box type transfer chutes were utilised and heavy-duty impact roller beds and skirts mounted on independent steel supports were used to protect the conveyors.

Level monitors in the ore-passes linked to the plant SCADA system controlled the filling and withdrawal sequences of the ore-passes which ensured that the conveying system was utilised to its optimal capacity and that the trucks were not delayed at the tips.

The inclination of the decline conveyors varied from 5° to 9° in accordance with the dip of the reef. Conveyor components (pulleys, drives, idlers, belting) were standardised as much as practical. Steel cord belts were utilised on the decline conveyors and fabric belts on the sacrificial conveyors, all decline conveyors were equipped with sensor guard rip detection systems.

The conveyor design was based on a 2.4 Mtpa operation. Availability and utilisation factors were agreed with the client and incorporated into the designs.

The mining cycle dictated that trucks were capable of tipping into the ore-passes for 15 hours per day (5400 hours per annum) which results in a conveyor capacity of 444 tph (for 200ktpm over 30 days). This together with a cumulative allowance for both utilisation and availability of 5 conveyors running in series (4 U/G and 1 surface) resulted in the theoretical design capacity for the conveyor system of 1,095 tph up to surface crushing.

Conveyor Availability and Utilisation Factors

Table 5. Conveyor availability and utilisation factors

No. of Conv. belts in series	Availability%	Utilisation %	Over-all Utilisation %	Belt capacity required for 200ktpm tph	Belt equipment rating (plus 25%) tph
Sacrificial	97	90	87.3	509	636
405	97	90	76.2	583	729
404	97	90	66.5	668	835
403	97	90	58.1	764	955
413	97	90	50.7	876	1095

Surface Facilities

Ore from the main decline conveyor (403) is delivered from underground onto a surface transfer conveyor (413) that feeds a 100t capacity elevated steel bin, the bin feeds the crusher station and has an overspill arrangement so that it can also discharge onto an emergency stockpile.

Material from the stockpile is fed back into the bin by FEL via a receiving bin and vibrating feeder. Control of feed back onto the transfer conveyor is by VSD on the vibrating feeder and a belt scale on the transfer conveyor.

Ore is withdrawn from the 100t bin by an apron feeder which feeds a vibrating grizzly feeder scalping at -180mm, the oversize is fed to a C140 single toggle jaw crusher.

The crusher is supported on a raised concrete foundation and the crushing station is serviced by a 30t overhead crane. The vibrating grizzly and jaw crusher throughput combined is 1100tph max. and the crusher produces a -212mm product to suit the Ngezi concentrator secondary/tertiary crushing circuit.

The scalped undersize from the vibrating grizzly and crusher product discharges onto a 1200mm wide sacrificial conveyor, a belt scale on this conveyor controls the apron feeder throughput via its hydraulic variable speed drive.

The drive on the sacrificial conveyor has a fly-wheel on the high-speed side which keeps the conveyor running for up to 17 seconds to avoid the flooding of the conveyor by the ore remaining in the crusher chamber, the vibrating grizzly and the undersize chute during power trips. A tramp magnet fitted at the head end of the conveyor protects the downstream conveyors from possible belt damage.

The sacrificial conveyor feeds the ore onto 1,050mm wide conveyor which discharges into an ore storage silo (5,500t capacity), a radial gate on the head chute of this conveyor can divert the feed either into the silo, or onto a 1050mm wide silo by-pass conveyor to form an emergency stockpile (1000t capacity) adjacent to the silo.

Material from the emergency stockpile is fed back by FEL to a 60t bin c/w vibrating feeder and 1200mm wide load-back conveyor onto a 1500mm wide reversable conveyor which can feed either a road train load-out station or a 900mm wide overland conveyor.

The silo has four bottom outlets each equipped with vibrating feeders (fixed throughput) which feed directly onto the reversable conveyor. Two alternate feeders simultaneously feed the conveyor at pre-determined intervals in order to maintain an even draw down of material in the silo to minimise wear. The vibrating feeder discharge chutes can be rotated to suit the direction of the reversable conveyor and radial gates are installed on the silo discharge chutes prior to the vibrating feeders for shut off.

The reversable conveyor is rated at 1400 tph to suit the maximum capacity of 2 vibrating feeders. The overland conveyor starts at Portal 3 (Mupfuti Mine), it passes underneath the reversable conveyor and the load-out station and transports ore from both mines (Portals 3 and 4) to the 15000t concentrator feed silo.

The reversable conveyor operates under load and intermittently when feeding the weigh flask and continuously in the opposite direction when feeding the overland conveyor, the drive is at the head and is fitted with a brake on the high-speed side to stop the conveyor overfeeding the weigh flask.

Load cells mounted on the weigh flask measure the mass and control the starting and stopping of the reversable conveyor when it feeds the weigh flask. The weigh flask has two sets of hydraulic clam shell gates which discharge into 105t road trains (3 x 35t trailers).

The road train load out facility was utilised continuously to transport ore to the Ngezi concentrator prior to the completion of Portal 3, the overland conveyor and the Ngezi concentrator feed silo which were all part of the concentrator 4Mtpa upgrade. The Portal 4 ore is now transported by the overland conveyor which also receives 2.0Mtpa of ore from Portal 3. The road train facility is now only used during breakdowns and maintenance.

Table 6. Portal 4 surface conveyors data

Portal 4 Surface Conveyors Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Sacrificial Conv. 402	1200	64	3	1.5	45	VSD	Brake, Self-Cleaning Tramp Magnet
Silo Feed 401	1050	506	38	2.5	250	VSD	Hyd. Diverter Chute
Silo By-Pass 410	1050	38	0	2.0	15	VSD	Tail Drive & Hyd./Screw T/UP
Stockpile Load Back 412	1200	65	7	1.5	55	VSD	Auto Winch & Load Cell T/UP
Reversable Load Out 411	1500	128	10	1.5	90	VSD	Brake, Rotating Feed Chutes

Underground Mine Re-Development

Due to a geological fault unsafe ground conditions were detected by the mine in 2014 in the existing mining areas at Portal 4 and all mining activities were suspended.

After extensive geotechnical work by Zimplats, Portal 4 mine was re-designed in order to gain access to the remaining ore body not affected by the fault. The design proposed the development of new North and South access ways on strike (two access ways for mining and one for the conveyors) to go around the affected areas in the middle. The conveyor access ways run approximately 900m and 700m on strike and then turn through 90 degrees and run on dip (West to East) to the sink line (bottom of reserve) – see Figure 11

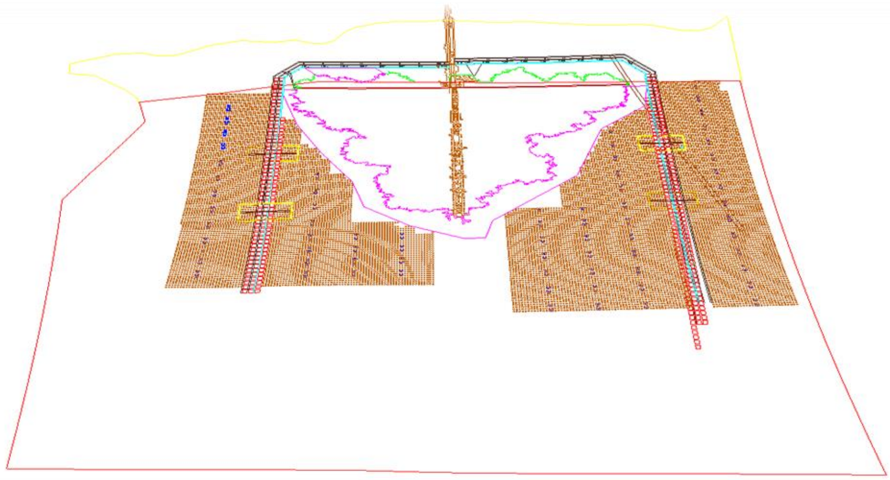

Figure 11. New design for Portal 4 conveyor access routes

The materials handling facilities currently comprise of two ore passes, one in the North section (2000t capacity) and one in the South (1200t capacity) at the head end of each strike conveyor access way. The difference in capacity is dictated by their position on dip relative to the existing decline conveyor. To save on haulage costs the construction of the ore passes was completed early on the project (commenced as soon as mining had moved a safe distance away) so that mined ore could be transported to surface crushing with the existing main decline conveyor.

The uncrushed ore is tipped by underground trucks through a 450mm square static grizzly at the top of each ore pass. Each ore pass is equipped with a hydraulic rock breaker for breaking oversize.

Once the North and South crushing and conveying facilities were completed the main source of feed to the ore passes are the strike conveyors which discharge crushed ore via a dead box through side entry points below the grizzly. The tips are now mostly used during crushing/conveyor maintenance and breakdowns.

The ore pass outlets each have discharge chute, radial shut-off gate, vibrating feeder and a sacrificial conveyor (1500mm wide) that feeds onto the existing decline conveyor (1350mm wide). The decline conveyor belting, pulleys, idlers, chutes and safety equipment have been replaced. The drives and take up were refurbished and the support structures repaired and upgraded as required.

Two underground crushing stations (1 x North and 1 x South) have been built and crushed ore is transported from each by four conveyors in series (sacrificial, 1st dip, diagonal dip and strike) to the ore passes. The conveyor design is based on a 2.2 Mtpa operation for each of the North and South sections, which results in a theoretical conveyor capacity of 408 tph based on a mining cycle of 5400 hours. Crusher station availability and utilisation is ignored as the trucks can tip directly into the ore passes if required.

Conveyor availability and utilisation factors are as per the original underground pre-development design. The conveyor systems are each designed to handle 1000tph to include for catch up when required.

Conveyor Availability and Utilisation Factors

Table 7. Conveyor availability and utilisation factors

No. of Conv. belts in series	Availability%	Utilisation %	Over-all Utilisation %	Belt capacity required for 184ktpm tph	Belt equipment rating (plus 25%) tph
Sacrificial	97	90	87.3	467	584
1st. dip	97	90	76.2	535	669
Diagonal dip	97	90	66.5	614	768
Strike	97	90	58.1	702	878

Each crusher station comprises of an 80t bin, static grizzly with 640mm square openings, hydraulic rock breaker, variable speed apron feeder, vibrating grizzly feeder scalping at -180mm and a C140 single toggle jaw crusher which produces a -212mm product. Based on the simulation of the crushing circuit flowsheet the system throughput was calculated to be 1000tph.

Apron feeder dribble, scalped undersize from the vibrating grizzly and crusher product are collected by a short 1500mm wide sacrificial conveyor. A belt scale mounted on the 1st dip conveyor after the transfer chute controls the apron feeder throughput via its hydraulic variable speed drive. A fly-wheel on the high-speed side of the sacrificial conveyor drive keeps it running for up to 17 seconds to avoid the flooding of the conveyor by the ore remaining in the crusher chamber, the vibrating grizzly and the undersize chute during power trips.

A tramp magnet is fitted at the head end of the sacrificial conveyor to protect the downstream conveyors from possible belt damage. From the sacrificial conveyors three 1350mm wide conveyors running in series (455, 456, 457) in the North and (475, 476, 477) in the South feed the North and South ore passes respectively.

The use of 1350mm wide conveyors was dictated at the design stage when on-reef tips (handling -400mm uncrushed ore) were utilised to load onto the conveyor system. These were subsequently replaced with crushing stations a late stage in the project (after the delivery of the conveyor equipment) by the client who decided to expand the mine footprint by 1.5km in the North. The expanded mine justified the use of crusher stations in terms of cost and avoided mining through a serious fault during the development the future Portal.

Table 8. Portal 4 re-development conveyors data - North

Portal 4 Re-Development Conveyors Data – North	**Width mm**	**Length m**	**Lift m**	**Belt Speed m/s**	**Installed kW**	**Soft Start**	**Add. Equipment**
Sacrificial Conveyor	1500	26	2.5	1.3	22	VSD	Impact Bed, Tramp Magnet
1St. Dip Conveyor 455	1350	655	89.6	2.0	2x185	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Diagonal Dip Conveyor 456	1350	156	25.3	2.0	110	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Strike Conveyor 457	1350	850	1.0	2.0	110	VSD	Auto Winch & Load Cell T/UP, Brake

Table 9. Portal 4 re-development conveyors data - South

Portal 4 Re-Development Conveyors Data – South	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Sacrificial Conveyor	1500	26	2.5	1.3	22	VSD	Impact Bed, Tramp Magnet
1St. Dip Conveyor 475	1350	670	91	2.0	2x185	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Diagonal Dip Conveyor 476	1350	123	12.5	2.0	1x75	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Strike Conveyor 477	1350	681	-19	2.0	75	VSD	Auto Winch & Load Cell T/UP, Brake

PORTAL 4 – (BIMHA) SACRIFICIAL CONVEYOR AND UNDERGROUND CRUSHING STATION

Figure 12. Portal 4 (Bimha Mine) sacrificial conveyor

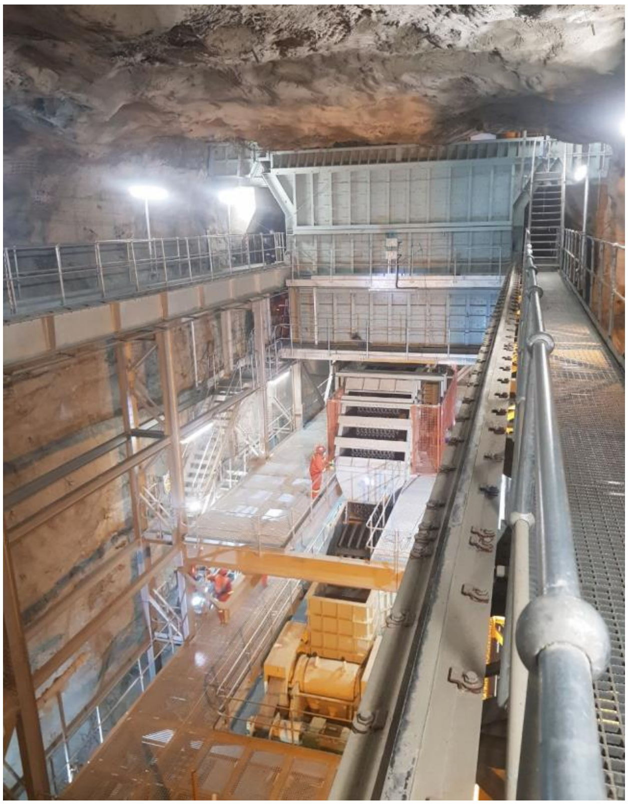

Figure 13. Portal 4 (Bimha Mine) crushing station

PORTAL 3 (MUPFUTI MINE)

Figure 14. Portal 3 (Mupfuti Mine)

Underground Mine

Portal 3 (Mupfuti) was developed to provide 2.0Mtpa of crushed ore to the Ngezi concentrator. The ore is delivered from a 13000t (live capacity) surface stockpile at Portal 3 to a 15,000t storage silo at the concentrator by a 5.8Km long overland conveyor.

The underground mine comprises of a box-cut, two portal entrances (mining and conveyor) and three access declines (two mining and one conveyor), the mining declines fall on dip at between 5 and 9 deg. in accordance with the dip of the reef and the conveyor decline dips below the mining declines. An underground crushing station positioned approximately 450m from the portal entrance and built between the mining declines feeds an 800t capacity ore pass that feeds a 1050mm wide decline conveyor.

The underground rock transport in the plane of the reef is by underground 30t trucks which tip onto a horizontal static grizzly mounted on top of an 85t tipping bin from two sides. The static grizzly has 640mm square openings and a hydraulic rock breaker mounted alongside breaks the oversize rock.

Ore is withdrawn from the bin by an apron feeder which feeds onto a vibrating grizzly feeder. The vibrating grizzly oversize is fed to a C140 single toggle jaw crusher which discharges the crushed ore directly into an 800t storage capacity ore-pass. Undersize from the vibrating grizzly feeder is fed by a discharge chute directly into the ore pass and dribble from the apron feeder is collected on a 7m long x 900mm wide conveyor that also feeds into the ore pass.

The crusher is mounted on concrete beams spanning the ore pass and the top of the ore pass is fully enclosed by a concrete slab. A chamber with a movable trolley for access to the crusher discharge liners is provided between the beams for inspection and maintenance.

Dust suppression (spray nozzles) is utilised on the apron, vibrating grizzly and crusher feed chutes and a dust extraction system (wet scrubber type) extracts from the top of the ore pass. The crusher station is equipped with a 30t overhead crane for initial erection and for maintenance once the crusher is operational. A 5t jib crane is used for rock breaker and static grizzly maintenance.

At the bottom of the ore pass the crushed ore passes through a chute onto a vibrating feeder that feeds a 1500mm wide sacrificial conveyor. The chute has a radial gate for maintenance and emergency shut-off.

The vibrating feeder has a variable speed drive (VSD) for controlling throughput, the VSD is controlled by a belt scale mounted on the decline conveyor after the transfer chute from the sacrificial conveyor. A tramp magnet is mounted above the sacrificial conveyor head pulley to protect the main decline conveyor.

The conveyor design caters for four conveyors in series. A second decline conveyor and crusher station will be added as the mine expands towards the East.

The conveyor design is based on a 2.0 Mtpa operation which results in a theoretical conveyor capacity of 463 tph based on a mining cycle of 5400 hours and includes a crusher station availability and utilisation factor. A cumulative allowance for both utilisation and availability for four conveyors in series and a 25% (catch-up) results in a required design capacity for the conveyor system of 996 tph. The conveyor system is designed for 1100tph.

Conveyor Availability and Utilisation Factors

Table 10. Conveyor availability and utilisation factors

No. of Conv. belts in series	Availability%	Utilisation %	Over-all Utilisation %	Belt capacity required for 168ktpm tph	Belt equipment rating (plus 25%) tph
Sacrificial	97	90	87.3	530	663
Future Decline Conveyor 307	97	90	76.2	608	760
Decline Conveyor 306	97	90	66.5	696	870
Surface Crusher Feed 309	97	90	58.1	797	996

Selection of 1050mm wide decline conveyor belt width was based on the crushed ore size analysis performed at Portal 4 which also produces a -212mm product and generates occasional slabs of 350 x 350 x 150mm.

Table 11. Portal 3 underground conveyor data

Portal 3 Underground Conveyor Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Sacrificial Conveyor	1500	15	2.5	1.1	37	VSD	Impact Bed, Tramp Magnet
Future Decline Conveyor 307	1050	440	35	2.0	2x132	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Decline Conveyor 306	1050	670	94	2.0	3x200	VSD	Auto Winch & Load Cell T/UP, Anti Run Back Idlers, Belt Grab
Surface Crusher Feed 309	1500	187	24	2.0	132	VSD	Impact Beds, Self-Cleaning Tramp Magnet

Surface Facilities

Ore from the decline conveyor (306) is delivered from underground onto a surface crusher feed conveyor (309). This conveyor together with a surface tip, crushing station and radial stockpile were built at an early stage of the project so that trucked RoM ore from underground could be crushed and delivered to the concentrator during the development of the mine and the construction of the underground crushing station.

The surface tip includes a reinforced earth/concrete panel retaining wall, 80t capacity steel tip bin, static grizzly, hydraulic rock breaker and vibrating feeder. The vibrating feeder feeds onto conveyor 309 which was built with an extended tail section and a transfer tower for transferring ore from decline conveyor 306 in the future.

Conveyor 309 has a 1500mm belt width in order to cater for the -400mm ore passing through the surface tip static grizzly and a belt scale mounted after the vibrating feeder discharge chute which controls feeder throughput via its VSD. The vibrating feeder discharge chute is raised above the belt so that underground ore from conveyor 306 can pass underneath. to reduce belt and structural damage by the large RoM ore. Independently supported impact cradles with heavy duty impact idler strings and skirts are employed at the feed points to reduce belt and structural damage by the large RoM ore. Tramp metal is removed by a self-cleaning magnet fitted across the conveyor.

The surface crusher station design is based on the Portal 4 surface unit with minor layout changes. It also consists of a 100t capacity elevated storage bin which feeds the crusher station and an overspill chute to discharge onto an emergency stockpile.

Overspill material from the stockpile is fed back to the crusher station bin by FEL and truck via the surface tip and conveyor 309.

As in Portal 4 ore is withdrawn from the 100t bin by an apron feeder which feeds a vibrating grizzly feeder that scalps at -180mm and feeds the oversize to a C140 single toggle jaw crusher. The vibrating grizzly and jaw crusher throughput combined is 1100tph max. and the crusher produces a -212mm product to suit the Ngezi concentrator secondary/tertiary crushing circuit. The apron feeder fines dribble, vibrating grizzly scalped undersize and the crusher product discharge onto sacrificial conveyor 310 (1200mm wide).

A belt scale on this conveyor controls the apron feeder throughput via its hydraulic variable speed drive. A fly-wheel on the high-speed side of the sacrificial conveyor drive keeps it running for up to 17 seconds to avoid the flooding of the conveyor by the ore remaining in the crusher chamber and the vibrating grizzly undersize chute during power trips. A self-cleaning tramp magnet is fitted at the head end of the conveyor to protect the downstream conveyors from possible belt damage.

The sacrificial conveyor delivers the ore to a diverter chute (operated by motorised hydraulic cylinder) that can feed either a radial slewing stacker conveyor (318) or a cantilevered stacking conveyor (311) that feeds a 13000t live capacity stockpile.

The radial stacking conveyor (318) is 1050mm wide, it pivots about its tail terminal and is supported on two gear driven rail mounted bogeys which provide the slewing motion. It is used to create a 24000t emergency stockpile which keeps the mine in operation when the overland conveyor and the 13000t stockpile are shut down. The radial motion is controlled by a level sensor mounted at the head of the conveyor which signals the machine to move when the pre-set maximum stockpile height is reached, limit switches stop the machine when it reaches its travel limits. Wind speed is monitored by an anemometer and the machine is locked down in the event of high wind speeds. Radial stockpile material is fed back to the to the overland conveyor stockpile by FEL and truck via the surface tip and the crushing station.

Stacking conveyor (311) is 1050mm wide, it deposits ore in the centre of the stockpile and has a 38m cantilevered section. The stockpile has a 13000t live capacity and a 45000t overall capacity, level detectors mounted on the conveyor stop the feed from the up-stream plant when the stockpile is full. A concrete tunnel under the stockpile houses two expanded flow outlet flasks, each flask has two outlets with vibrating feeders that discharge onto a 1200mm wide overland feed conveyor (313), the concrete tunnel is above ground and covered by earth fill, a ramp alongside provides access to the base of the stockpile so that dead material can be “dozed” into the expanded flow outlets. Vibrating feeder throughput (700tph each max.) is controlled by VSD’s on each machine and a belt scale mounted on conveyor 313.

Conveyor 313 is fitted with a self-cleaning magnet at the head pulley prior to feeding onto overland conveyor (317). The overland conveyor is 900mm wide and 5.8km long, it has two horizontal curves (2.1km and 3.5km radius) and a vertical curve that takes it through a cutting along the side of a hill. Two major road crossings (Portal 4 and the management village) and three vehicle cross-overs provide access over the conveyor. Independent stringer modules mounted on concrete sleepers and resting on profiled compacted fill are utilised to follow the ground profile, box gantries and galleries are used on the elevated sections. The conveyor has two drives, dual primary drive units and a single secondary drive unit, the drives are positioned under the conveyor as it rises towards the 15000t silo. Disc brakes mounted on the high-speed side of the primary drives stop the belt in approximately 60 seconds.

The conveyor take-up is positioned at the tail (closest to the 2.1km horizontal curve) so that it stabilises the tensions in the curve. Belt turnovers are provided at both ends of the conveyor to minimise spillage. The conveyor carries crushed ore (1400tph max.) from either the Portal 3 stockpile or the Portal 4 silo and feeds a diverter chute at the top of the 15000t silo that discharges either into the centre of the silo or onto a 1200mm wide silo by-pass conveyor (320) that feeds a 2500t live capacity emergency stockpile which is utilised during silo maintenance.

As well as a “Dupline” intelligent pull key system, belt tracking, under-speed detection and blocked chute detection, safety and condition monitoring systems on the overland conveyor include belt tear detection (embedded loop) and splice and cord condition monitoring. The overland conveyor system including the Portal 3 stockpile, Portal 4 silo discharge, feed into the 15000t silo and the feed to the by-pass stockpile is controlled from the Portal 3 control room.

Table 12. Portal 3 surface conveyor data

Portal 3 Surface Conveyor Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
Surface Crusher Sacrificial Conv. 310	1200	106	10.5	2.0	75	VSD	Brake, Tramp Magnet
Radial Stacking Conveyor 318	1050	50	38	2.5	75	VSD	Rail Mounted Bogeys, Level Detection, Positioners, Anemometer
Cantilevered Stacking Conveyor 311	1050	290	31.3	2.5	200	VSD	Product Sampler, Level Detection
Overland Feed Conveyor 313	1200	173	4.0	2.5	75	VSD	Self-Cleaning Tramp Magnet,
Overland Conveyor 317	900	5800	33	4.0	3x400	VSD	Belt Turn Overs, Anti Run Back Idlers, Belt Grab, Brake
Silo By-Pass Conveyor 320	1200	36	0	2.0	22	VSD	Tail Drive, Fly-Wheel

Portal 3 – (Mupfuti) Underground Crushing Station and Overland Conveyor with Silo By-Pass

Figure 15. Portal 3 (Mupfuti Mine) underground crushing station

Figure 16. Portal 3 (Mupfuti Mine) overland conveyor with silo by-pass

NGEZI CONCENTRATOR MATERIALS HANDLING

Figure 17. Ngezi Concentrator materials handling

Phases 1 and 2

The Ngezi concentrator consists of two 2.0Mtpa modules which require a -13mm mill feed and produce a concentrate that is transported to an existing smelter at SMC. Each module contains a ball mill and a flotation circuit, they have common thickening, filtration, tailings disposal and water recovery facilities. The current plant was built in two phases, phase one comprising of module 1 plus the common facilities with the second milling and flotation module being built in phase two.

The crushing and materials handling facilities were designed as modular 4Mtpa units so that additional units could be added for future expansions. The existing 15000t silo feed (overland conveyor 317) head chute design allows it to divert the feed directly into the silo or onto a transfer conveyor (currently utilised as the silo by-pass) which will discharge into a second 15000t silo (fed by the future North Portals expansion). The layout of the silos and crushing plant feed conveyors allows the feed from both the North or South Portals to be diverted to either silo and to be fed to either of the crushing/screening modules.

As stated above, a 2.0Mtpa concentrator module requiring a -13mm feed to the ball mill was built in phase 1 of the project. The crushing/screening plant module to feed it consisted of a three compartment road train off-loading station receiving ore from Portal 4 and a closed circuit secondary/tertiary crushing and screening plant module comprising: 1 x secondary crusher, 1 x secondary double deck screen, 2 x tertiary crushers (one stand-by), 2 x tertiary single deck screens, a 6000t mill feed storage silo, a variable speed belt feeder and a mill feed conveyor.

In order to cater for the phase 2 and 3 expansions the secondary crushing feed conveyors were sized to handle 8Mtpa. The secondary/tertiary crushing and screening circuits were designed as a 4Mtpa modules, however in phase 1 only the equipment items required to achieve the 2Mtpa throughput were installed. These were added in phase 2 and included 1 x secondary and 1 x tertiary screen which together with the full time use of the existing stand-by tertiary crusher completed the 4Mtpa module. A diverter chute and transfer conveyor were added at the top of the existing 6000t mill silo to feed a new 7000t mill feed silo which feeds the second mill via variable speed belt feeder and a mill feed conveyor.

Current facilities forming part of the concentrator plant include a 15000t concentrator feed silo which has four bottom outlets each equipped with vibrating feeders (variable throughput) which feed directly onto transfer conveyor (122). To maintain an even draw down of material in the silo in order to minimise wear two alternate feeders simultaneously feed the conveyor at pre-determined intervals.

Transfer conveyor 122 is equipped with a belt scale that controls the feed rate of the vibrating feeders and a self-cleaning magnet is mounted across the conveyor to remove tramp metal. The tail end of transfer conveyor 122 extends into the emergency stockpile tunnel and is also fed by the two stockpile vibrating feeders during silo maintenance. The conveyor crosses over the main access road from Selous and feeds onto transfer conveyor 102 on the concentrator plant side.

Should conveyor 122 be shut down conveyor 102 can also be fed at a rate of 2Mtpa from the road train tip by conveyor 101. This tip has three-compartments (capacity 65t each) with three variable speed vibrating feeders installed under each compartment that feed onto tip withdrawal conveyor 101. Conveyor 101 is equipped with a self-cleaning magnet for tramp removal and a belt scale for controlling the feed rate of the vibrating feeders.

Transfer conveyor 102 feeds onto transfer conveyor 103 which in turn feeds secondary crusher feed conveyor 106 which discharges into a 400t secondary crusher feed bin. Conveyor 106 also receives oversize material from the top deck of the secondary screens for recirculation back to the secondary crusher.

A variable speed vibrating feeder withdraws material from the 400t bin and discharges onto crusher feed conveyor 104 which feeds the CS660 secondary cone crusher. Level detection in the crusher bowl controls the feed rate of the vibrating feeder. The secondary crusher delivers a -60mm product at a fresh feed rate of 800tph for Phase 2 (4Mtpa).

The secondary crusher product is fed onto the secondary screens feed conveyor 105 which feeds two secondary screen feed bins via a hydraulically operated diverter chute controlled by level detectors in the bins. Vibrating feeders withdraw material from the bins at a pre-set rate and deliver it to the secondary double deck screens. Oversize from the top deck of the screens reports back to the secondary crusher via the secondary crusher feed conveyor 106. Oversize from the bottom decks is transferred to the tertiary crushers by tertiary crusher feed conveyor 107.

Conveyor 107 feeds a moving diverter chute system (hydraulically controlled by level detectors in the bins) that feeds two 120t bins. The bins discharge onto two retractable belt feeders F 101 & F 102 (variable speed) which feed the CH870 tertiary crushers.

Level detection in the crusher bowl controls the feed rate of the belt feeders into the crushers. In order to protect the crushers metal detectors on the belt feeders warn the plant operator and stop the feeders when tramp metal is detected.

The tertiary crushers discharge onto tertiary screen feed conveyor 113. A fly-wheel on the high-speed side of the conveyor drive keeps it running for up to 10 seconds to avoid the flooding of the conveyor by the ore remaining in the crusher chambers during belt trips/power outages. Conveyor 113 feeds the tertiary screen bins belt feeder system (114 & 115). The system consists of two belt feeders, feed chutes and a centre chute mounted on a common support frame on rails. The system is mounted on top of and feeds three 120t secondary screen feed bins, movement of the system is by hydraulic cylinder controlled by bin level detection and limit switches.

Belt feeders (F103, F104, F105) together with profile chutes withdraw from the bins and feed onto the single deck tertiary screens. The oversize from the tertiary screens (re-circulating load) is added to the oversize from the bottom deck of the secondary screens onto tertiary crusher feed conveyor 107.

The undersize (product) from the secondary screens together with the undersize of the tertiary screens bottom deck is transferred by a series of four conveyors 119, 120, 121 & 126 to two mill feed silos. Conveyor 119 collects -13mm material from the secondary and tertiary screens and feeds onto conveyor 120. It is designed for fitting a moving head in the future in order to feed a second conveyor product stream to future silos.

The current length of conveyor 120 allows it to be fed from two future crushing/screening modules. It feeds onto conveyor 121 which delivers the material to a diverter chute that feeds either into the 1st mill feed silo or onto conveyor 126 which feeds into the 2nd mill feed silo.

The layout of the conveyors as it currently exists also makes allowance for feeding future mill feed silos with conveyors running parallel to conveyors 120, 121 and 126.

The product silos each have two bottom outlets with profile chutes and hydraulic shut off gates. The feed to the mills is via hydraulically driven variable speed belt feeders FEB 121 & FEB 220 and mill feed conveyors 151 & 251.

Belt scales mounted on the mill feed conveyors control the feed from the belt feeders onto the mill feed conveyors. A ball loading facility is provided at the tail end of the mill feed conveyors. Ball discharge is controlled by the belt scales mounted on the mill feed conveyors so that balls can only be loaded with material on the belt to avoid run-back.

A hammer sampler is installed on each mill feed conveyor after the belt scale. No sampling takes place when mill balls are fed onto the mill feed conveyor. Scats from the mills are fed back onto the mill feed conveyors by FEL via a 5t bin and vibrating feeder after the sampler.

Table 13. Concentrator conveyors and belt feeder data

Concentrator Conveyors and Belt Feeders Data	Width mm	Length m	Lift m	Belt Speed m/s	Installed kW	Soft Start	Add. Equipment
15000t Silo Discharge Transfer Conv. 122	1200	246	9.7	2.5	132	VSD	Vert Gravity T/UP, Tramp Magnet
Road Train Off-Loading Conv. 101	1050	147	7.8	1.5	55	VSD	Hor. Gravity T/UP, Tramp Magnet
Transfer Conv. 102	1200	77	13.6	2.5	160	VSD	Vert Gravity T/UP, Tramp Magnet
Transfer Conv. 103	1200	175	5.6	2.5	90	VSD	Hor. Gravity T/UP,
Sec Crusher Bin Feed Conv 106 (Fresh & Recirc.)	1200	218.5	18.9	2.5	200	VSD	Vert Gravity T/UP, Tramp Magnet
Sec Crusher Feed Conv. 104	1500	10.7	0	10	11	VSD	On rails, Winch Moveable, Screw T/UP
Sec Crusher Product Conv 105	900	214.2	25.1	2.0	132	VSD	Vert Gravity T/UP
Tertiary Crusher Bins Feed Conv 107	900	227.3	18.9	2.0	132	VSD	Vert Gravity T/UP, Tramp Magnet
Tertiary Crushers Belt Feeders F101 & F102	1500	14.2	0	0.46	45	VSD	Adjustable Feed Chute, On rails, Winch Moveable, Screw T/UP
Tertiary Crushers Product/ Sec Screen feed Conv 113	900	211.4	25.1	2.5	160	VSD	Vert Gravity T/UP, Drive Fly Wheel
Tertiary Screen Bin Belt Feeder Convs.114 & 115	1500	5.2	0	1.0	11	VSD	On rails & Hyd. Moveable, Drive Fly Wheel
Tertiary Screens Belt Feeders F103,104,105	1500	8.9	0	0.46	45	VSD	Adjustable Feed Chute, Screw T/UP
Sec & Tertiary Crushers Product Conv. 119	900	203.5	8.0	2.0	75	VSD	Future Moving Head Design, Hor. Gravity T/UP
Product Transfer Conv 120	1050	64.1	0	2.5	30	VSD	Product Collection from Current & Future Modules, Hor. Gravity T/UP
1st Mill Silo Feed Conv 121	1050	157.7	36	2.5	160	VSD	Hyd. Diverter Head Chute, Hor. Gravity T/UP
2nd Mill Silo Feed Conv. 126	1200	46.0	4.9	2.5	75	VSD	Enclosed Gallery. Screw T/UP
Mill Silo Discharge Belt Feeders FEB 101 & 220	1500	13.75	0	0.1	22	VSD	Variable Speed Hyd. Drive
Mill Feed Convs. 151 & 251	900	131.7	11.8	1.0	37	VSD	Hor. Gravity T/UP

NGEZI CONCENTRATOR SECONDARY AND TERTIARY CRUSHING AND SCREENING PLANTS

Figure 18. Ngezi Concentrator secondary crushing and screening

Figure 19. Ngezi Concentrator tertiary crushing and screening

LESSONS LEARNED/IMPROVEMENTS

Listed below are some of the lessons learned, improvements implemented and suggested future enhancements for improving the Ngezi materials handling and conveyor system availability and safety in the future:

- **Changes/Improvements made to date:**
  - Static grizzlies with 400mm square openings in place of 550mm square at the ore pass tips to reduce slabs and oversize material.
  - Rock breakers with greater impact energy to maintain throughput into the ore passes due to the smaller grizzly openings.
  - Strain gauge system level detection mounted on the ore pass discharge support steel in place of ultrasonic level detection at the tips which proved unreliable due to dust and moisture.
  - DEM modelling for transfer chute designs (drop box design, material flow)
  - Increased chute plate thicknesses and better liner fixing methods (hardened CSK bolts, dome washers, lock nuts).
  - Work hardening “Cruesabro 8000” (higher manganese content) liners in high wear areas.
  - Heavy duty impact beds with series 40, 159mm dia., 5 roll impact roller strings, mounted on independent support structures to avoid conveyor stringer damage and subsequent belt damage.
  - Static tramp magnets supported on crawl beams with an automated trolley system for tramp removal. Replacing belt over-band magnets which were constantly subject to belt tears due to mining roof bolts.

- Wherever possible underground conveyors are suspended from the hanging wall, ±900mm from underside stringers to the foot wall) to facilitate footwall cleaning of spillage.
- Automatic load-cell controlled take up winches on underground conveyors (minimise tensions in the belt during start up).
- Belt rip detection on all conveyors with loops embedded in the belt and monitoring/tripping systems linked to the plant control SCADA system. Monitoring of cord and splice condition on the overland conveyor.
- Fire retardant anti-static conveyor belting (SANS 971:2013), independent conveyor belt fire testing.
- Anti- roll back idlers and belt break grabs on carry and return at points of maximum tension on elevating conveyors.
- Electrically operated belt pulling winches for conveyor belt replacement on conveyors longer than 30m.
- Cameras installed at RoM tips, transfers and in areas of high risk, reporting to the Plant Control Room and the Emergency Control Centre.
- Use of underground crushing stations in place of RoM ore passes and tips. Conveyor system fed with – 250mm material in place of -400mm. Use of 1050mm conveyor width in place of 1350mm). Less impact damage and wear at ore passes and transfer chutes. Height decrease of transfers and roof height in conveyor access ways. Additional capital costs mitigated by the saving on conveyor and mining capital expense and major reduction in long term maintenance costs and an increase in conveyor system availability.
- Safety systems improvement: Fire retardant low halogen cables with the 11kV cables kept out of conveyor access ways and dry type Mini Sub. Transformers.
- Fire system detection and alarm which sets in motion an escape strategy for personnel in the conveyor declines and ore pass discharge areas and reports via fibre optic cable to the SCADA and an Emergency Control Centre. The fire system on the conveyors has linear heat cable detection and infrared flame detectors in parallel with deluge fire suppression split into individual zones, substations and MCC rooms have automatically actuated clean agent inert gas fire extinguishing systems.
- The "Leaky Feeder" mine radio communication system was upgraded to include man and machine tracking, vehicle collision warning and gas monitoring.
- Sheeting of all conveyors and the overland conveyor stockpile to avoid flooding and down time at the concentrator crushing and screening circuit during the rainy season.

- **Improvement suggestions for the future:**
  - Improve mine blasting patterns to reduce number of large boulders and long slabs arriving at the underground tips which can save on rock breaker energy and grizzly and apron feeder wear.
  - Use of modular/movable crushing stations during mine development (prior to the underground crushing stations being constructed) which can be utilised at the other mines when needed.
  - Use of lower profile crushers at the underground crushing stations to reduce mining excavation heights (cost and time).
  - Use of covered stockpiles with maintenance by-pass outlets in place of silos for the -250mm material. The additional expense is mitigated by the fact that silos generally need to be re-lined more frequently and need to be taken off-line during the re-lining process (3 to 4 weeks) depending on size unless a by-pass facility is incorporated in the system (by-pass stockpile).

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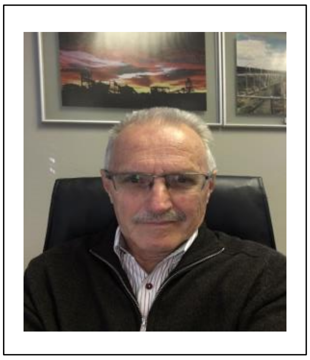
ABOUT THE AUTHOR



LIVIO TALOCCHINO

Livio has over 40 years' experience in project management, engineering and construction. Currently employed by Procurement Technologies Africa, Livio has enjoyed a career spanning many major feasibility studies and projects in the bulk materials handling industry, and has contributed to two published papers: "Cost benefits of continuous elution from activated carbon" and "Plant siting and layout".

Livio Talocchino

Procurement Technologies Africa (Pty) Ltd.

Email: Livio@proctechafrica.com