

**APPLYING GOOD PRACTISE TO THE INSTALLATION AND SERVICING
OF PUMPS IN MILL CIRCUITS**

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ABSTRACT

The purpose of this document is to highlight typical problems encountered in various ore grinding plants and mill pump applications, as well as to set out options, recommendations, advantages and benefits offered by Weir Minerals to increase grinding circuit availability and durability and reduce risks in primary and secondary mill circuit pumps.

Information on real cases has been gathered from a number of mineral processing plants in various countries, and shows that small changes to volume and operating and production costs associated with these services have meant significant savings and processing tonnage increases in these circuits.

KEYWORDS

Slurry, Slurry pumps, centrifugal pumps, maintenance, availability, mills, hydrocyclones, grinding, wear, safety, costs, Wet End.

INTRODUCTION

In the mining world, an increase in ore processing has led to the design of larger equipment. In primary and secondary grinding plants, the growth in mill sizes has been accompanied by a similar increase in the size of centrifugal slurry pumps that operate in the pumping circuits of these plants, such as the hydrocyclones feed and transfer circuits.

These larger equipment sizes increase the Capex, construction costs and Opex of these plants, and optimizing plant size thus has a fundamental part to play in project investment. Though the cost per square meter of building these plants can be optimized through construction techniques and technologies, a more prudent approach would be to optimize the amount of equipment required to reach the treatment capacity of a mill plant; that is, to employ the minimal amount of equipment, and eliminate stand-by units, etc.

Maintenance times for these slurry pumps increase along with the size of such equipment, which means that maintenance costs also rise. Moreover, when a plant is not provided with a stand-by pump, the cost of stopping ore processing is significant; that is, the availability of such equipment influences not only maintenance costs, but plant production as well.

A sound plant design not only means processing a given quantity of ore; it should also ensure that the availability of each unit is not impacted by space restrictions or by interference, which makes it difficult to perform maintenance safely and with minimal time loss.



Figure 1 – Grinding plant, Sag Mill and Ball Mills Circuit

DRIVE ARRANGEMENTS

There are a number of different configuration options for pump operations, which are dependent on motor powers and frames and equipment costs.

For on-line assembly, there are two options available; a conventional option with gear box, which may be parallel shaft (see Figure 2), or with shafts at 90° (see Figure 3); and a second option that utilizes a multi-pole motor, which eliminates the need for a gear box (see Figure 4).

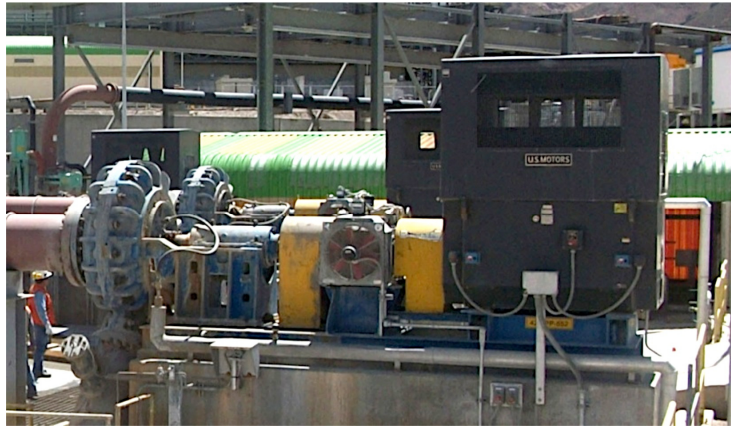


Figure 2 - Warman® pumps, Standard Assembly on Line, Motor – Gear Box – Pump

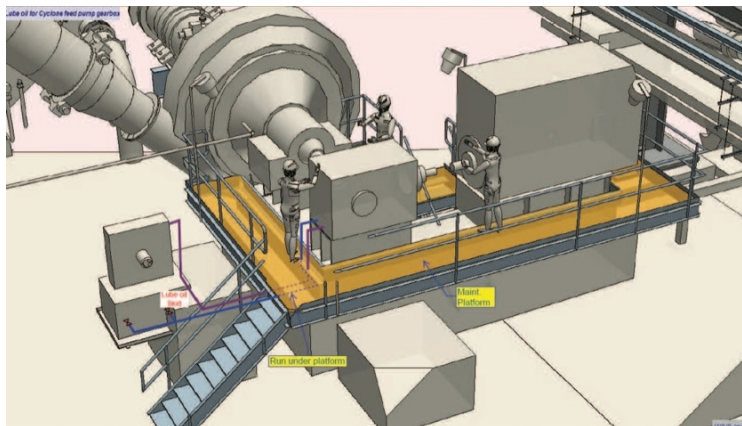


Figure 3 - Warman® pump, Std. Assembly on Line, Motor – 90° Gear Box – Pump

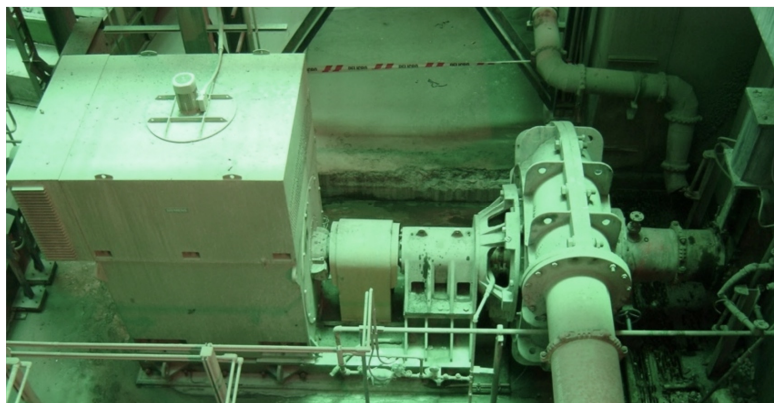


Figure 4 - Warman® pump, Std. Assembly on Line, Motor – Pump

DISCHARGE PUMPS POSITIONS

The discharge on Warman® slurry pumps can be positioned in a number of different locations without the need for the pump to be modified (see Figure 5).

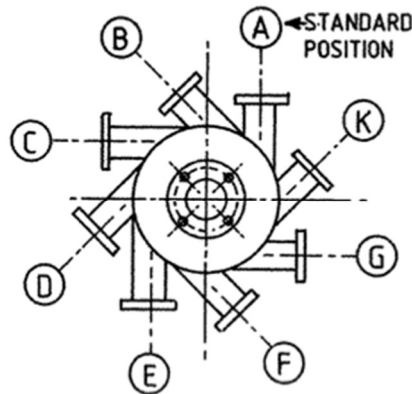


Figure 5 – Discharge pump positions for Warman® pumps

Discharge Position “A” is normally the standard position, but in our experience, for Cyclone feed applications the wear life of the liners decreases in this position due to the effect of gravity on hard particles and ball chips, which can restrict their outflow and result in recirculation inside the pump.

When the discharge is type “G”, the effect of gravity decreases and the life of the pump wear parts are extended.

An unexpected pump shutdown also creates the risk of settling inside the pipeline and inside the pump. For discharge positions “K”, “A”, “B” and C”, drainage is only possible inside the pump as per the bottom level of the inner suction pipeline. This means that if the slurry settles inside the pump, the impeller can be obstructed by the settling solids, Figure 6 and 7.

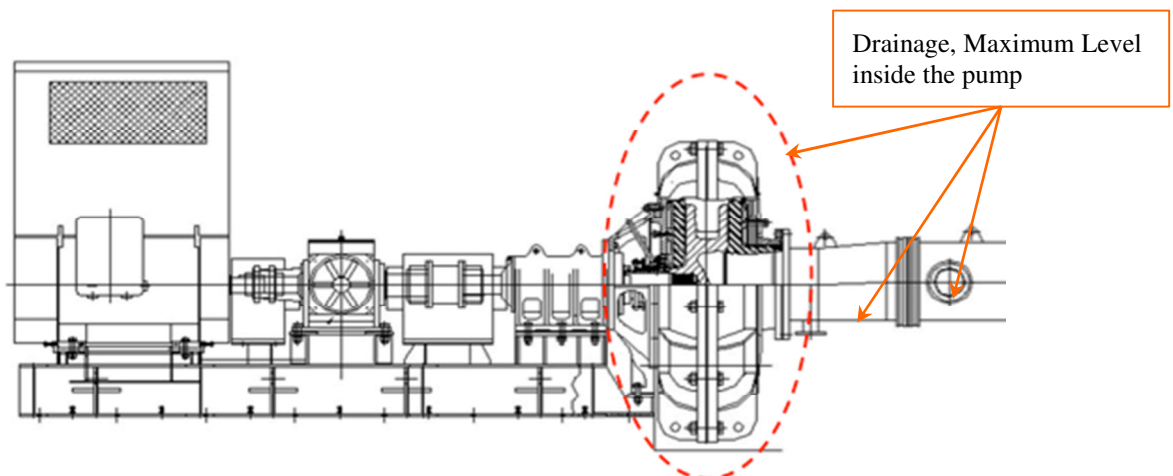


Figure 6 – Discharge pumps positions – Settling

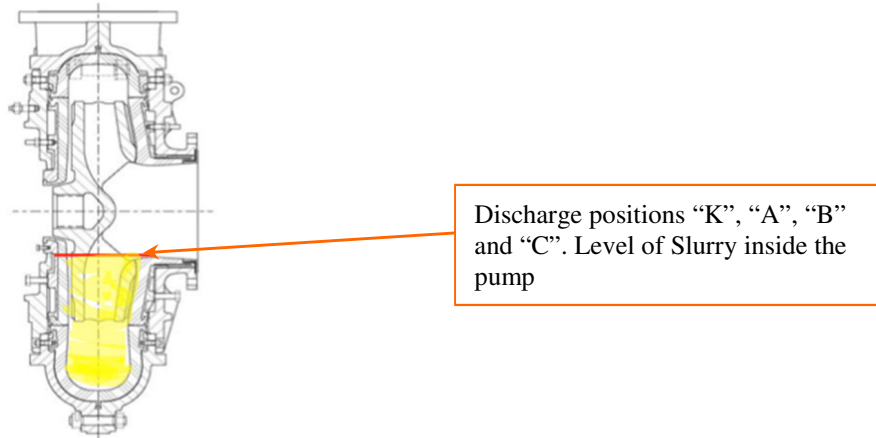


Figure 7 – Discharge pumps orientations – Settling

With position “G” it is possible to drain the pump without blocking the impeller. Position “G” recommended for Mill Circuit Pumps, Figure 8.

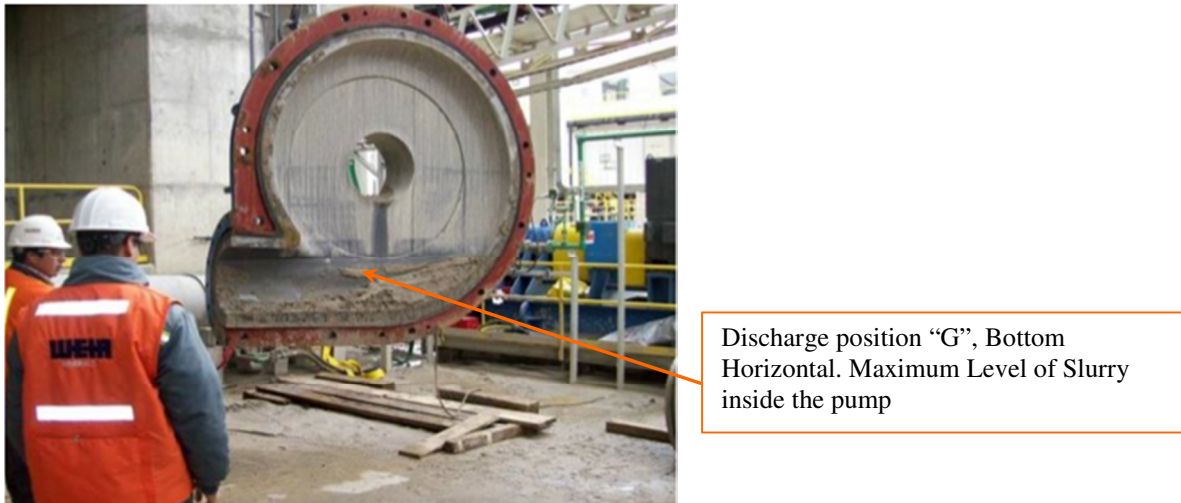


Figure 8 – Discharge pumps positions – Settling

Our recommendation of slurry pump position "G" for mill circuit applications has been implemented in a number of grinding plants, as shown below:

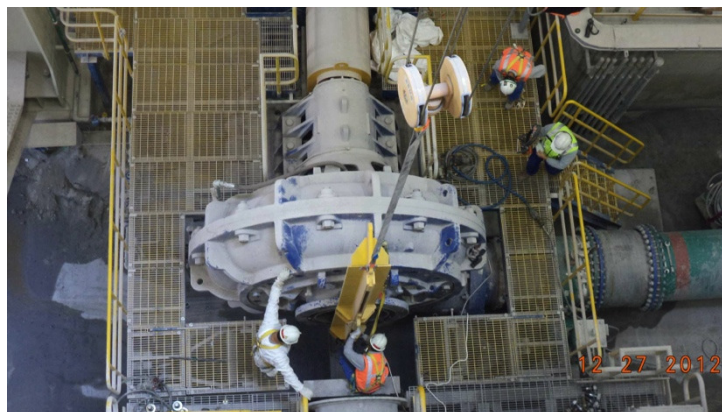


Figure 9 – Discharge positions, Position “G” – Warman® MCR-M 750 pump



Figure 10 – Discharge positions, Position “G” – Warman® MCR® 650 pump



Figure 11 – Discharge positions, Position “G” – Warman® AH® 20x18 pump



Figure 12 – Discharge positions, Position “G” – Warman® MCR® 550 pump



Figure 13 – Discharge positions, Position “G” – Warman® MCR® 650 pump

 WARMAN® Centrifugal Slurry Pumps							
WARMAN® PUMPS							
ITEM	MODEL	DISCHARGE ANGLE	QUANTITY	ARRANGEMENT	ORE	COUNTRY	MOTOR (HP)
1	650 MCR-M200	Position G	4	Motor-pump	Copper	PERU	2,100
2	650 MCR-M200	Position G	2	Motor-Reducer-Pump	Copper	PERU	2,800
3	550 MCR-M180	Position G	1	Motor-Reducer-Pump	Gold	PERU	850
4	450 MCR-TU	Position G	1	Motor-Reducer-Pump	Copper	PERU	500
5	750 MCR-M240	9° of the position G	2	Motor-pump	Copper	PERU	4,000
6	650 MCR-M200	8° of the position G	2	Motor-Pump	Copper	PERU	2,800
7	750 MCR-M240	Position G	2	Motor-Pump	Copper	CHILE	3,000
8	650 MCR-M200	Position G	2	Motor-Reducer-Pump	Copper	CHILE	2,500

Figure 14 – Discharge pump positions, Position “G” Installations

DIRECTION OF PUMP ROTATION

Warman® MC pumps for primary and secondary grinding applications are available for either of the two possible impeller rotation directions: standard or clockwise from the motor side (CW, Clockwise), Figure 15; and reverse or counter clockwise from the motor side (CCW, Counter Clockwise), Figure 16.

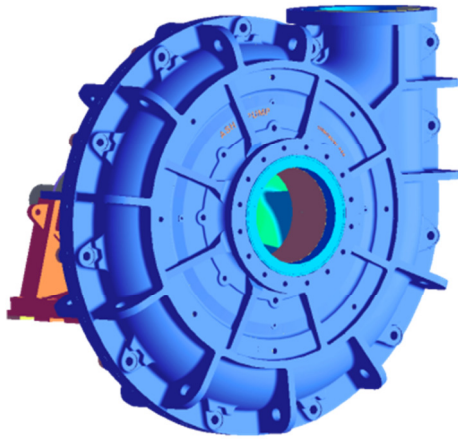


Figure 15 - Warman® Pump,
Standard Rotation

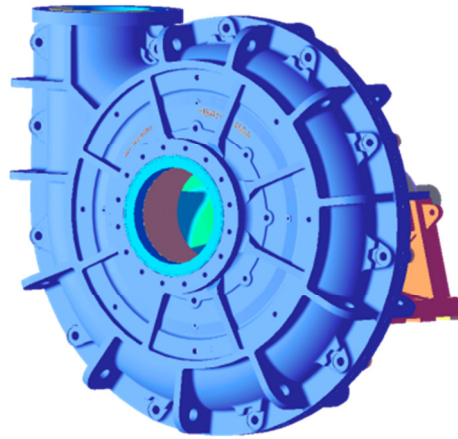


Figure 16 - Warman® Pump,
Reverse Rotation

These two rotation directions offer greater flexibility for pumping system design. Moreover, in cases where pumps are positioned in the opposite way, there is no impediment to the discharge of pumps in position "G" (Figures 17 and 18).

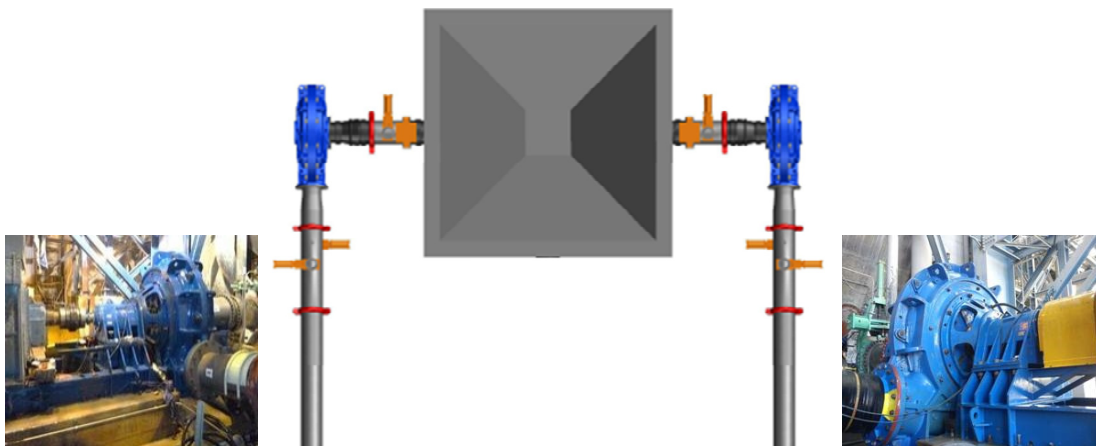


Figure 17 – Discharge Position “G”, Warman® MCR® cyclone feed pumps.

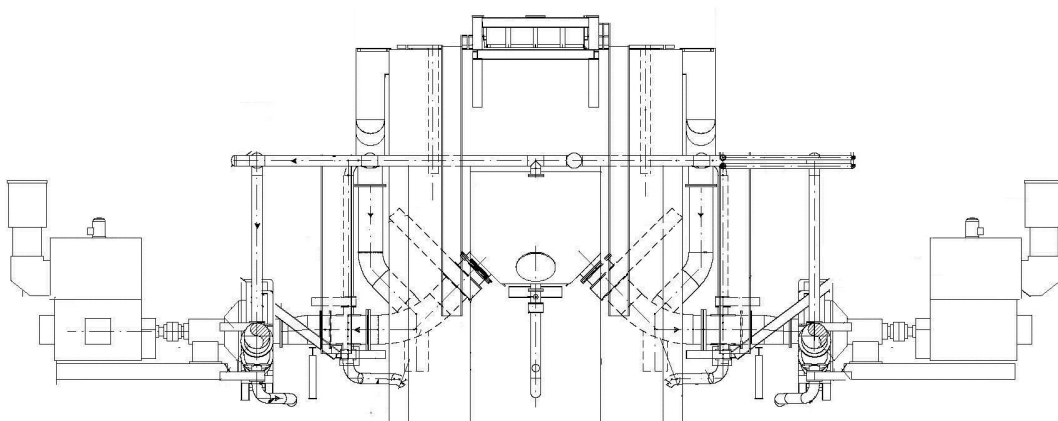


Figure 18 – Discharge Position “G”.

SUCCESS CASES – DISCHARGE LAYOUT EFFECT

At a Concentrator Plant located in Chile at an altitude of 3200 masl, the standard discharge position of the Warman® MCR® 450 pumps that feed the Sag plant cyclone clusters (Figure 19) was "K", 45 degrees (Figures 5 and 20).

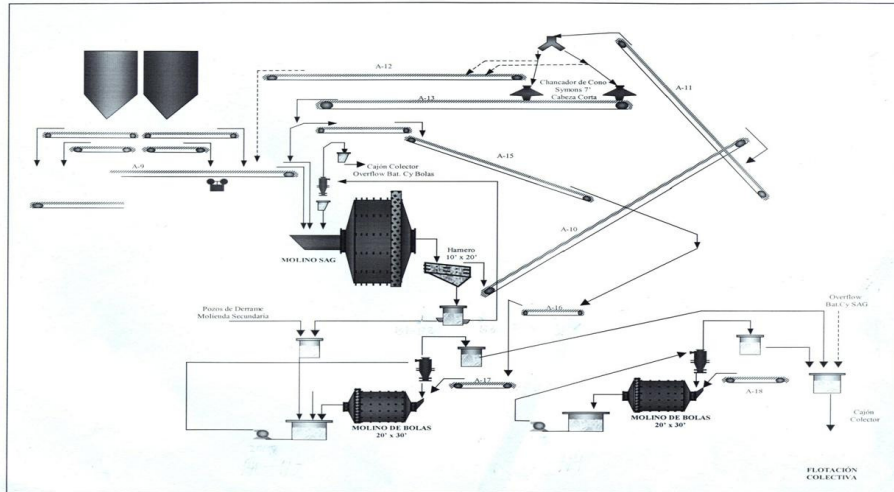


Figure 19 – Flow sheet, Grinding Plant.



Figure 20 – Warman® MCR® 450 pump, Discharge Position “K”.

Changing the 45° discharge, position “K”, to lower horizontal, position “G”, means that the settling of coarse particles and ball chips inside the pump can be avoided. This change led to a 40% increase in wear part life and improved the availability of MCR® 450 pumps. For this case, all that was required was to rotate the pump discharge positions and to change the locations of the three hoses (Figure 21, 22 and 23).

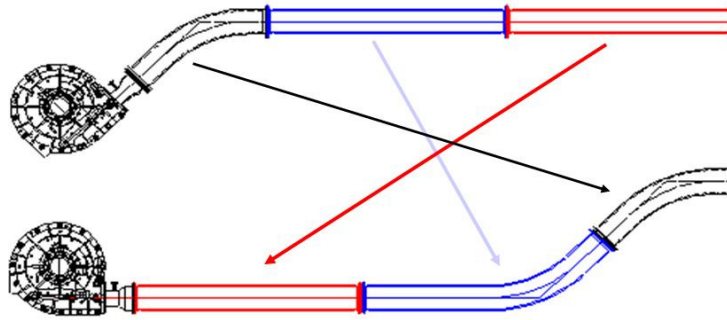


Figure 21 – Layout modification, MCR® 450 pumps

Together with changing the discharge position, a section of suction piping was replaced by an expansion joint to facilitate the maintenance of the MCR® 450 pump (Figure 22).



Figure 22 – Warman® MCR® 450 pump, Suction modification.



Figure 23 – Warman® MCR® 450 pump, Discharge Layout modification.

CYCLONE FEED PUMPS – HOSE & EXPANTION JOINT APPLICATION

For Cyclone feed pump applications, expansion joints are available in diameters of between 10 inches and 48 inches. The general specifications of these joints are an inner tube of Anti-abrasive thick rubber, reinforcement with layers of synthetic fibres, highly traction-resistant wire spiral, and synthetic rubber cover resistant to friction, outdoor conditions and ozone action ageing. Connections may be Victaulic or flanges. In general the working pressures are between 80 psi to 150 psi. Other pressures may be available subject to prior consultation with the manufacturer.

Special requirements for the expansion joints can be requested, such as concentric, eccentric, branches, single or multiple arc joints. Internal arcs or bellows can come filled to obtain a uniform internal diameter to prevent turbulence and wear.

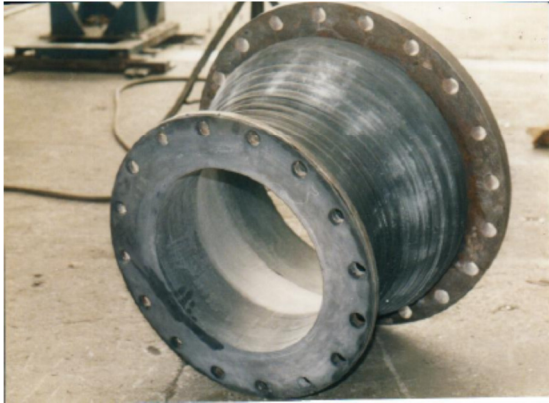


Figure 24 – Expansion Joint



Figure 25 – Triple Arc Expansion Joint



Figure 26 – Expansion Joint, 900 mm Inner Diameter

In addition to the primary advantages offered by expansion joints and hoses, such as absorbing expansions and contractions, and reducing vibration, noise, etc., they facilitate pump maintenance by allowing assembly and disassembly to be conducted more safely and quickly, thus reducing maintenance times and increasing the availability of the equipment. Some examples are shown in Figures 26, 27, 28 and 29.



Figure 27 – Discharge Hose



Figure 28 – Expansion Joint and Hose



Figure 29 – Suction with Expansion Joint and Discharge with Hose

SLURRY PUMPS – SUCTION PIPELINE

As a first recommendation, the pump itself should never be used as an anchorage point for the piping, and the allowable suction and discharge nozzle loads induced by pipelines should not be exceeded. Rather, the pipelines should be anchored in close proximity to the pump and should be connected without transmitting any stresses or strains. Moreover, the pipe diameter should be at least equal to the diameter of the pump nozzle [1].

Slurry piping should be sized so as to achieve the correct range of velocity for the expected pumping conditions; otherwise, low net positive suction head (NPSH) availability, high wear, excess energy consumption, unstable operation, or plugging may result. Suction pipe losses and pipe velocity should be controlled in order to satisfy pump NPSH requirements.

Piping should be arranged to avoid sudden changes in direction and areas where solids can accumulate, which could result in rapid wear and blockages [1].

There are three types of reductions, Figures 30, 31 and 32. Which one to use? The answer: it depends; an eccentric “Flat on Top” reduction (Figure 30) prevents the accumulation of air or the formation of “air pockets” in the upper part of the piping, but this option enables part of the solids to be deposited in the lower part of the piping. An eccentric “Flat on Bottom” reduction (Figure 31) minimizes entrapment and the accumulation of solids in the lower part, but air may remain trapped in the upper part of this reduction. A concentric reduction (Figure 32) enables accumulation of solid deposits in the lower part and air in the upper part of the reduction. In general, this type of reduction is not recommended.

In slurry pumps for primary and secondary mill circuits, eccentric “Flat on Bottom” reductions (Figures 31, 33 and 34) are generally recommended so as to avoid the settling of particles in the suction piping; in circuits of this type the particles present in slurry are larger in size, so the sedimentation speed is greater.

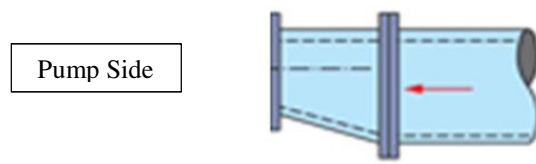


Figure 30 – Suction pipe reducer, Flat on Top

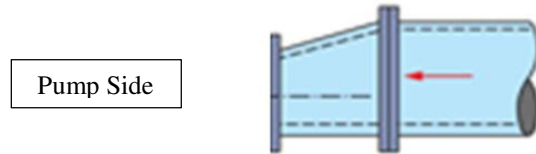


Figure 31 – Suction pipe reducer, Flat on Bottom

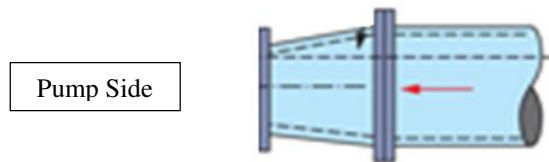


Figure 32 – Suction pipe reducer, concentric type

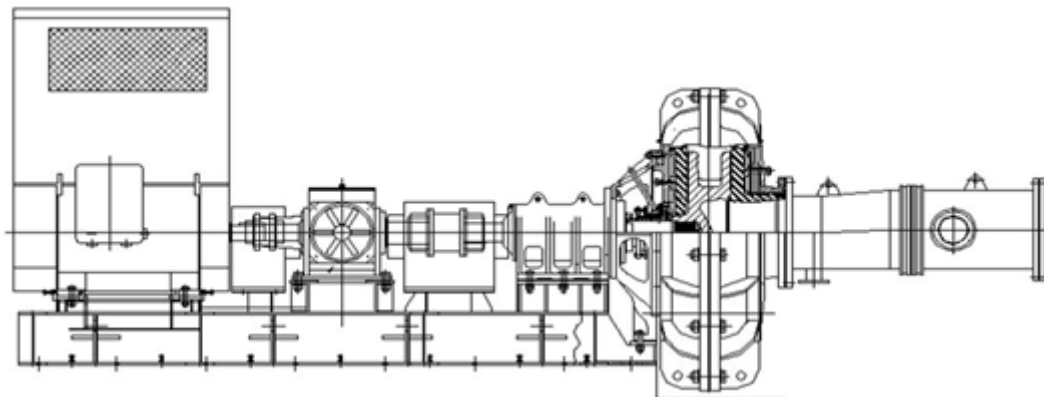


Figure 33 – Suction pipe reducer, Flat on Bottom, Mill Circuit Pump

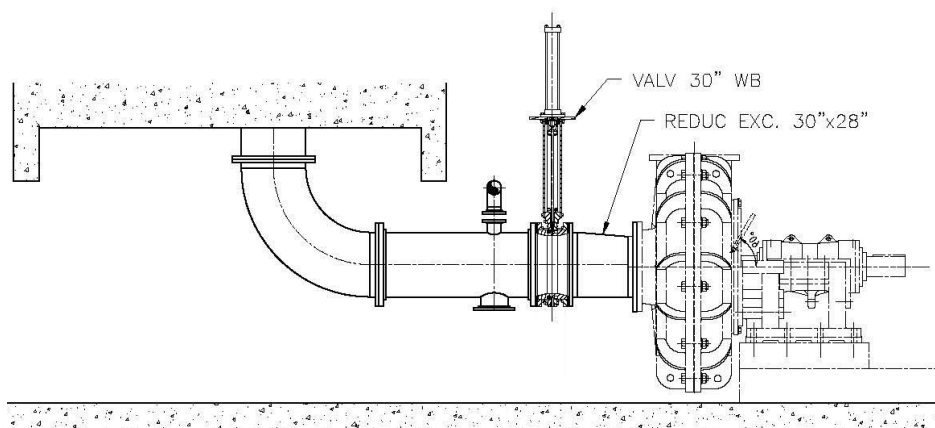


Figure 34 – Suction pipe reducer, Flat on Bottom, Mill Circuit Pump

SLURRY SUCTION SUMP HOPPER

Low level of slurry in the sump or low suction head can result in formation of vortices and an uneven distribution of flow, and may introduce air into the pump, causing a reduction of capacity and efficiency, an increase in vibration, and additional noise. Uneven flow distribution can also increase or decrease power consumption with a change in total developed head [2]. Taller hoppers are preferred to wider flat-bottom vessels [1].

The slurry sump design requires special considerations to prevent uneven flow into the pumps, and to ensure effective transfer of all solids into the pump. Lining or coatings protect the sump, help to decrease sump surface roughness and friction, and aid transfer of settling solids to the pump suction nozzle [1].

The minimum sump level should not be less than two intake pipe diameters above the top of the intake pipe to the pump [1].

The level sensors should be arranged so that the above-mentioned scenario does not occur in the minimum suction level. In addition, care should be taken to ensure that the available NPSH exceeds what is required for the entire operational range of the pump. As an added benefit, when the pump operates with high suction levels, there is an energy saving.

Operating a slurry pump with a poorly designed suction system can negatively affect pump performance, reliability and wear life [3].



Figure 35 – Suction Sump Hopper, MCR® 650 Mill Circuit Pump

SUCTION PIPELINE, MINIMUM MAINTENANCE CLEARANCE REQUIRED

When designing a pumping system, in addition to bearing the above-mentioned in mind, the minimum required spaces for performing maintenance and changing wear components on slurry pumps should be considered, as should the spaces for moving larger components and allowing bridge crane cable and hook access. All disciplines should participate in this analysis, as it is not unusual to find interference from electric pipes, instrumentation pipes, gangways, supports, lighting, etc.

If there is not enough space to perform the activities involved in maintenance, pump availability will be directly affected. Today, processing plants are large in size and are not provided with stand-by equipment. Thus, maintenance times directly affect plant production.

When changing pump wear parts on mill circuit slurry pumps, in addition to analysing the dimensions of these components separately, their special lifting tools should be analysed. Figure 36 shows the activity required for replacing the throatbush and/or impeller; this requires removal of the suction cover with the special tool for assembling and disassembling this piece. To replace the impeller, it should be lifted with the tool for that purpose prior to suction cover removal, as shown in Figure 37.

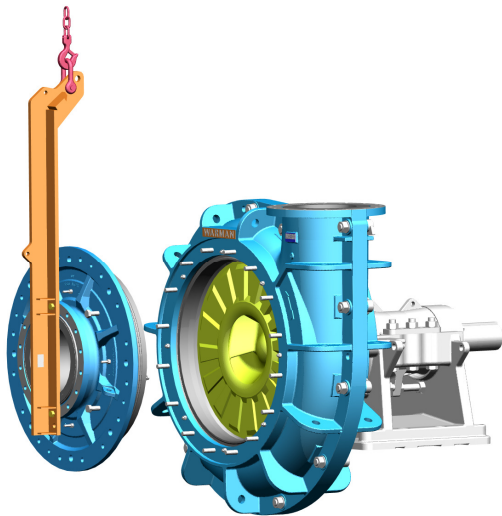


Figure 36 – Assembly / Maintenance, Separate Suction Cover allows access to Throatbush, Impeller and Shaft Sleeve without disturbing discharge piping.

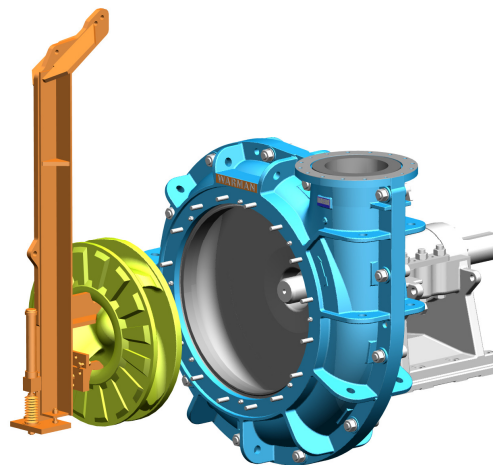


Figure 37 – Assembly / Maintenance

When designing pumping systems, in which two pumps will be placed alongside each other, sufficient space should be provided for performing maintenance and changing components. Figure 38 shows that the rear-positioned pump discharge piping passes very close to the first pump, which makes maintenance work difficult. Moreover, certain structures, supports and auxiliary piping interfere with maintenance activities, as shown in Figures 39 and 40.



Figure 38 – Mill Circuit Pumps, maintenance interferences

Simulations were performed on the pumps shown in Figures 38 and 39 in order to analyse throatbush and impeller replacement activities. Once the suction expansion joint has been disassembled, the suction cover may be removed, even though the space available is not ideal for this purpose (Figure 41). However, it is not possible to remove the impeller, as the lifting tool interferes with the suction piping (Figure 42). To solve this problem, we modify the suction piping in such a way as to enable correct component change. Here is a real example in which serious problems are shown, such as restricted concentrator plant production due to incorrect design.



Figure 39 – Assembly/Maintenance

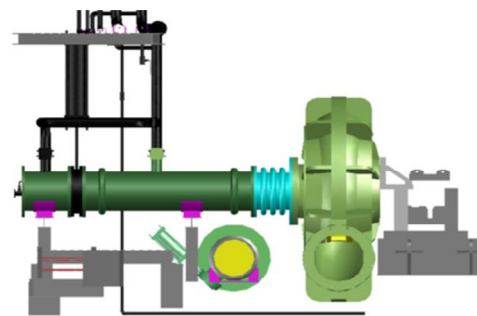


Figure 40 – Assembly/Maintenance

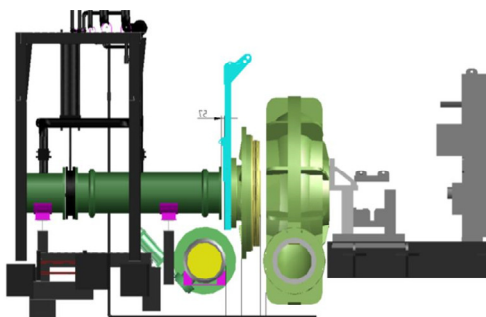


Figure 41 – Maintenance, Throatbush

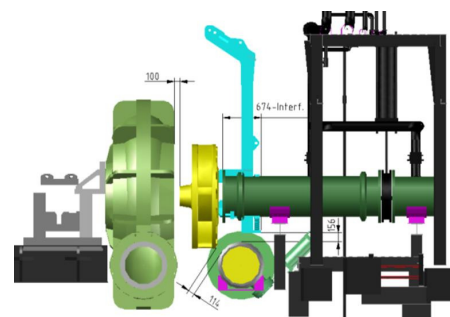


Figure 42 – Maintenance, Impeller

SUCTION HEAD AND DISCHARGE HEAD

The variables required for calculating the total head (TH) calculation include static discharge height (Zd) and suction height (Zs). The TH is a variable that is required to correctly select a slurry pump, as well as their auxiliary equipment such as motor, gear box, VFD, etc. A TH calculation error can affect not only the slurry pump, but also its auxiliary and related equipment. The use of safety factors in calculating the TH is not recommended for compensating approximate values or unknown information; an unrealistic TH calculation affects pump operation, so it is important that accurate values are used for specific operating conditions.

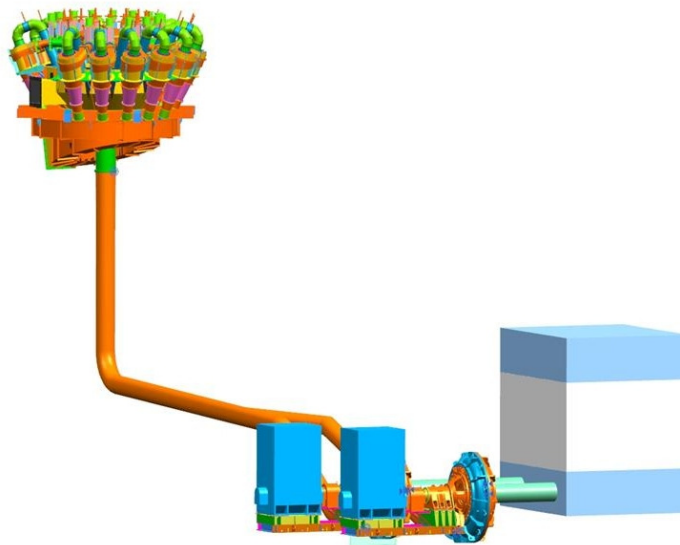


Figure 43 – Feed Cyclone System

In one case, a customer requested assistance to review the performance of cyclone feed pumps, as the required flow could not be pumped at 100% of the motor speed (Figure 43). We reviewed the operating points and the TH calculation, for which a land survey was performed to verify pump suction levels, as well as maximum suction tank height of pumps and hydrocyclones cluster distributor or manifold. When this information was obtained, it was compared with the values utilized in the Calculations Report. The static elevation height used for hydraulic calculations factored in only the Victaulic connector type that connects the hydrocyclone cluster feed pipeline (Figure 44 and 45). The height of the hydrocyclone cluster from the lower point of the Victaulic connector to the horizontal line shaft of the hydrocyclones feed manifold is 5.4 metres, which was not considered in the TH calculations.

With regard to the review of pump suction height, distance between the pump suction shaft line and the liquid level in the suction tank, the TH calculations utilized the maximum suction height value when they should have used the minimum suction height value, which produced an error of approximately 4 metres.

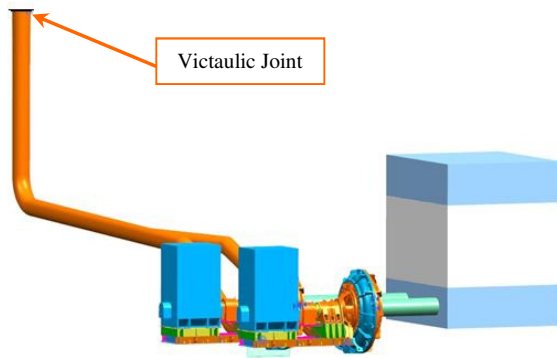


Figure 44 – Feed Cyclones System

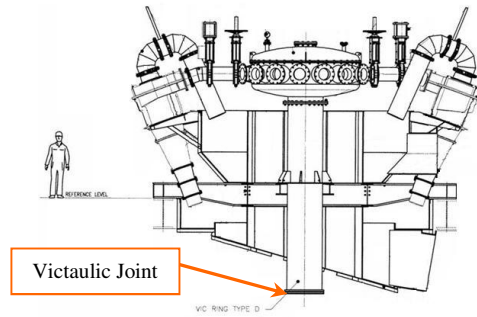


Figure 45 – Hydrocyclones Cluster

Adding together these two differences causes an error of approximately 9.4 metres, which produced a 36% increase in calculating motor power. In this case, with the specified motor power it is not possible to pump the projected flow, and so the power must be increased. In addition, the pump operating speeds should increase by approximately 10%. In this case, the motors are multi-pole, and so an increase in the pump speed could require a change in the quantity of motor poles; that is, replacement of the motor.

WET END QUICK CHANGE

The most routine maintenance performed on slurry pumps is the replacement of their elements in direct contact with the slurry, known as Wet End (Figures 46, 47, 48 and 49). Thus, there is no doubt that a reduction of in-situ maintenance times presents a considerable economic advantage.



Figure 46 – Warman® Pump, Wet End

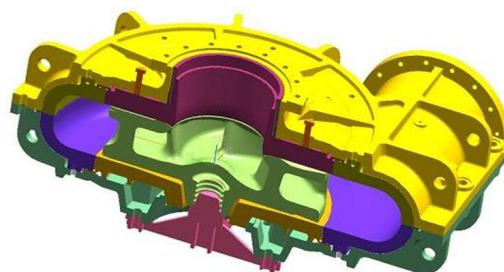


Figure 47 – Warman® Pump Wet End, Cross Section

An additional set of casings and a Wet End pre-prepared with its new components are required for rapid change (Figure 49).



Figure 48 – Warman® Pump Wet End



Figure 49 – Warman® Pump Wet End

Assembling the Wet End of a pump with all its new parts to replace the worn parts (Figures 54 and 55) will reduce maintenance costs and times considerably, if compared with the times involved in standard in-situ parts replacement; added to this is the fact that exposure times of staff who perform maintenance are also reduced (Figure 50 and 51).



Figure 50 – Standard Maintenance



Figure 51 – Standard Maintenance

Once the Wet End is disassembled with its worn parts (Figure 52 and 53), it is transferred to the specified maintenance site for the replacement of worn parts.

Weir Minerals operates large mill pumps which enable rapid Wet End changes. Some of the characteristics, recommendations, and advantages of quick Wet End change in these large pumps:

- Reduction of in-situ maintenance times.
- Reduction of plant stoppage time (when there is no stand-by pump).
- Change in the worn elements is not accounted to plant stoppage.

- There is no need to disconnect pump coupling, and thus no need to align the pump shaft with the gear box or motor shaft.
- It enables replacement of the shaft sleeve without completely dismantling the pump; it is enough to remove the Wet End, disassemble the worn sleeve, assemble the new sleeve, and assemble the Wet End anew.
- Reduction in exposure times of staff that perform in-situ maintenance (Figure 50 and 51).

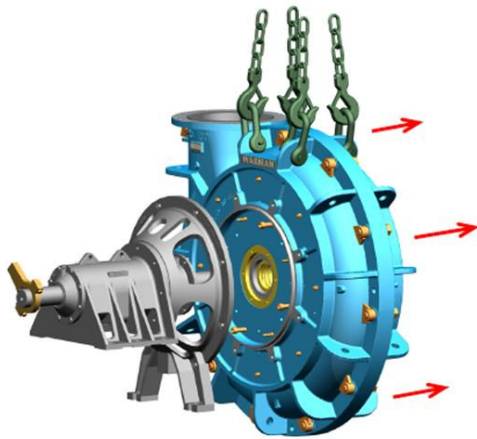


Figure 52 – Wet End Disassembly for Warman® Pump



Figure 53 – Wet End Disassembly for Warman® Pump

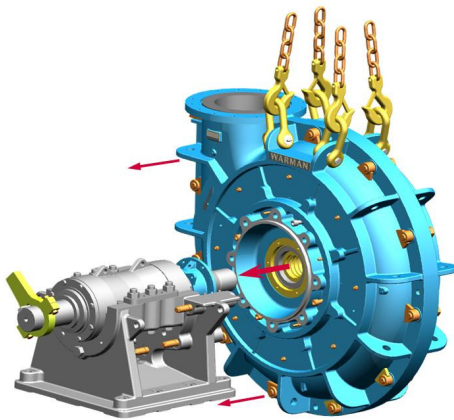


Figure 54 – Warman® Pump, Wet End Assembly



Figure 55 – Warman® Pump, Wet End Assembly

To implement quick Wet End change, the following should be reviewed and implemented:

- Review bridge crane capacity to lift the Wet End.
- Review bridge crane hook accessibility; the hook should reach the centre line shaft of the bearing assembly.
- Incorporate a load viewer screen into the bridge crane so that the operator can see the value of the weight being lifted.
- In the absence thereof, incorporate the speed option under the motion of the bridge crane hook.
- Review Wet End accessibility for transfer.

- Review the suction ducts, the removal of one of these should allow Wet End disassembly and removal (Figure 56).
- Possess a second Wet End as a spare.
- Implementation of tools.
- Chains and shackles for the quadruple leg sling, a minimum of 02 sets: one to be utilized on the Wet End that is running or is due to be replaced, and a second set for the replacement Wet End. In this way, Wet End change times will be optimized. It must be recalled that the length of the chain slings depends on the pump discharge position (Figure 57) which, as with the lengths, differ; thus, these should be identified and the chains should be utilized only for lifting the Wet Ends. [4], [5] [6].
- Pneumatic Tools, 02 sets minimum.
- Special tools.

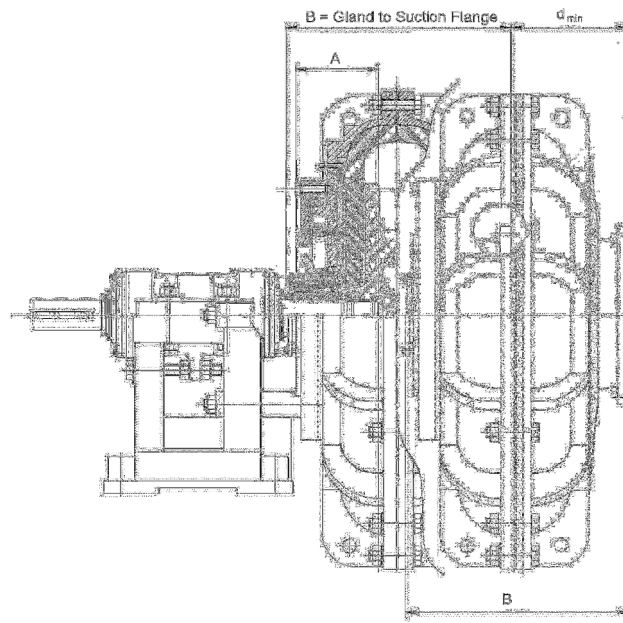


Figure 56 – Warman® Pump, Wet End disassembly and removal

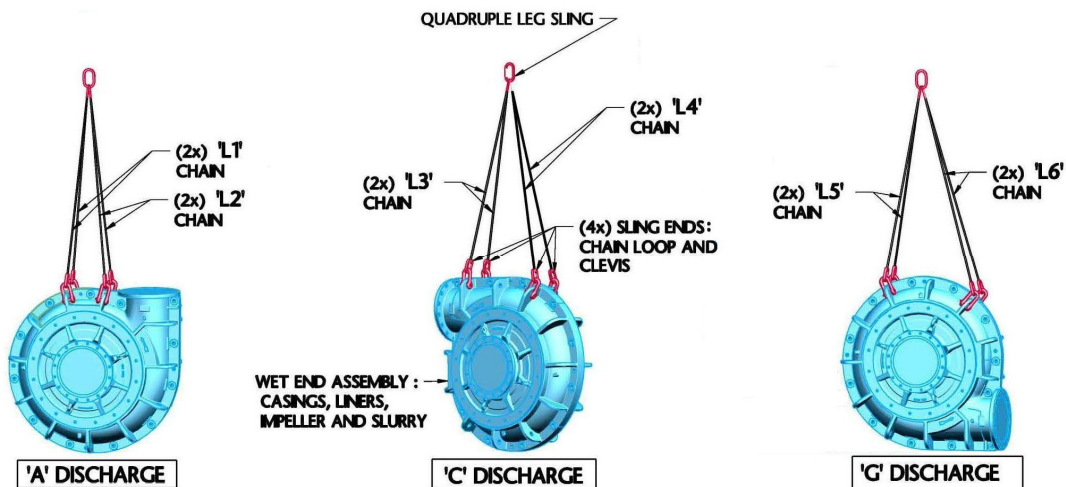


Figure 57 – Warman® Pumps, Sling Lift complete Wet End assembly

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NOMENCLATURE

Capex	CAPital EXpenditures
CW	ClockWise
CCW	Counter ClockWise
masl	metres above sea level
mm	millimetres
NPSH	Net Positive Suction Head
Opex	Operating Expense
Stand by	A state in which a device, piece of equipment, or system is operational and available, but is not in use. Also called standby operation.
TH	Total Head
VFD	Variable Frecuency Drive
Victaulic	Connector type for piping
Zd	Static discharge head
Zs	Suction Head