Appendix 5-E

Brucejack Gold Mine Project: Brucejack Lake Tailings
System Design

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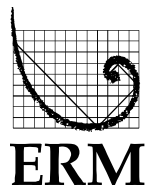
Pretium Resources Inc.

BRUCEJACK GOLD MINE PROJECT
Brucejack Lake Tailings System Design

PRETIVM

May 2013

BRUCEJACK GOLD MINE PROJECT
BRUCEJACK LAKE TAILINGS SYSTEM DESIGN

May 2013
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Prepared for:

PRETIVM

Pretium Resources Inc.

Prepared by:

Rescan™
Engineers and Scientists

Rescan™ Environmental Services Ltd.
Vancouver, British Columbia

Executive Summary

Rescan
Engineers and Scientists

Executive Summary

Subaqueous tailings placement is to be employed at the Brucejack Gold Mine Project. Tailings will be placed at the bottom of 85 m deep Brucejack Lake about 50% of the time and used for paste backfill about 50% of the time. When placed in the lake, the tailings at 65% solids w/w will first report to an agitated slurry mixing tank and be diluted to 35% w/w with water and discharged.

Much of the pipeline alignment may be subject to the risk impact by avalanches. Accordingly, the pipeline overland will need to be trenched and backfilled in most locations to protect the pipe. The pipeline will also have a continuous downward slope from the mill building to the lake shore to permit the line to drain during shutdowns.

The diluted slurry will be pumped through a 10" HDPE DR6.3 pipe overland some 525 m and underwater on the lake bed 445 m. At the lake shore the pipe will wye (split) into two parallel pipes, one of which will discharge at a depth of 80 m, near the bottom of the lake, and the other at a depth of 60 m. Prior to tailings discharge, a small quantity of coarse sand or gravel will be placed at the terminus of each of the outfalls. Through operations, tailings solids will accumulate over the discharge point further covering it and act as a filter intercepting the majority of fine tailings particles in a manner similar to a sand filter. This feature will reduce the likelihood of suspended solids entering the upper layers of the lake's water column and subsequently discharged into Brucejack Creek, potentially in violation of strict receiving water quality regulations. This concept has been demonstrated to be effective in earlier Rescan designs at Minahasa in Indonesia and at CMP in Chile. The approach has recently been adopted at a project in the US.

There will be a constant flow through the pipeline at all times to keep the deposit at the end of the outfall fluidized. When the thickened tailings are used in the backfill plant, water will be discharged to keep a pathway in the mound covering the discharge point fluidized.

The present design has been undertaken at a feasibility study level of detail. For detailed design, a complete bathymetric survey of the lake should be undertaken as well as a detailed survey along the subaqueous pipeline alignment. In addition, the rheology of the tailings slurry at concentrations and strain rates pertinent to the pipeline flow should be determined with a concentric cylinder viscometer. Finally, and if possible, bench scale tests of the mixing of near paste tailings slurry and water should be undertaken.

Acknowledgements

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1. Introduction

1. Introduction

The Brucejack Gold Mine Project is a proposed underground gold and silver mining operation that is expected to produce about 14.5 Mt of ore over the mine lifespan. The site is located in the mountains of north-western BC, about 950 km northwest of Vancouver, at Brucejack Lake. It is above the tree line at an elevation of approximately 1,400 masl and is surrounded by glaciers and ice fields to the north, south, and east. The mill operations will be above ground and housed in one building. About one half of the thickened flotation plant tailings are to be used as paste backfill and about one half will be stored more than 40 m below the surface of Brucejack Lake.

This report presents the feasibility level design of the tailings placement system in the lake and highlights additional information that is required for detailed design.

The tailings placement system receives the thickened tailings at a maximum design throughput of 124 tph of solids at a concentration of 65% w/w. The relatively high concentration of the tailings thickener underflow is intended to provide a desirable feed to the paste backfill plant. The present design has an upstream battery limit at the upstream flange on an agitated mixing tank.

The near-paste slurry is diluted in an agitated mixing tank to 35% w/w. The diluted slurry is then pumped down the pipeline to the bottom of the lake through a deposit of sediment at the outfall terminus. The estimated final footprint of the tailings deposit in the lake is shown in Appendix 1, drawing 194150-24-98-06.

The system has been designed to be flexible and accommodate a range of slurry concentrations. It should be noted that a simpler system could be implemented if the flow from the inlet of the thickener which is at 27% w/w were to be directly discharged, bypassing the agitated mixing tank.

It is anticipated that water that is discharged in the Brucejack Lake outlet must meet end-of-pipe water quality criteria under the Metal Mining Effluent Regulations (MMER) of the *Fisheries Act*. The authorized discharge limits for total suspended solids (TSS) is 15 mg/L on a monthly mean basis to a maximum of 30 mg/L for any individual grab sample. To mitigate concerns that discharging tailings to the lake will increase the TSS at the outlet, the tailings will be discharged through the accumulated, previously discharged tailings that will act as a sand filter and trap particulates. This will minimize suspended solids concentrations in the upper layers of the lake and at the outlet.

Brucejack Lake is not a fish habitat and is naturally depauperate in vegetation. There are no species of conservation concern in the lake that would be affected by the tailings disposal.

2. Background

2. Background

2.1 LAKE DETAILS

Brucejack Lake has a surface area of about 841,000 m^2 and a volume of 28.5 Mm^3. The maximum depth is 85 m confined to a relatively small area. The bathymetry or topography of the lake bed is shown in Figure 2.1-1.

Water flows into the lake from multiple sources and the flow rate varies during the course of the year. Brucejack Lake discharges into Brucejack Creek on the west end of the lake. The highest flow rate is during the freshet which occurs around June or July each year.

Twice per year the lake turns over due to seasonal heating or cooling which causes the lake surface temperature to pass through 4℃, the temperature of maximum density of fresh water. In the fall when the air temperature drops, surface water cools and becomes denser than the water below it causing the surface water to sink and displace the water below it resulting in vertical mixing.

In the spring, the water immediately under the ice is at the freezing point. The temperature increases with depth toward the densest water near the bottom of the lake which will be close to 4℃. As the ice melts and the top layers warm toward 4℃, vertical convection once again occurs mixing the lake in the vertical. Figure 2.1-2 shows the different temperature profiles throughout the year.

There is concern that during lake turn over, fine sediment being discharged on the lake bottom could be transported upward toward the surface resulting in elevated suspended solids concentrations in the surface layer and at the outlet.

2.2 AVALANCHES

The project is located in the mountains surrounded by several avalanche zones. The zones are shown by the red dashed lines in the plant and profile drawing in Appendix 1, drawing 1042-E-006-01. Extra caution must be taken in ensuring the location of the pipeline is properly protected. The original avalanche study was preliminary and will be updated during detailed design to better define the area subject to the risk of impact by avalanches.
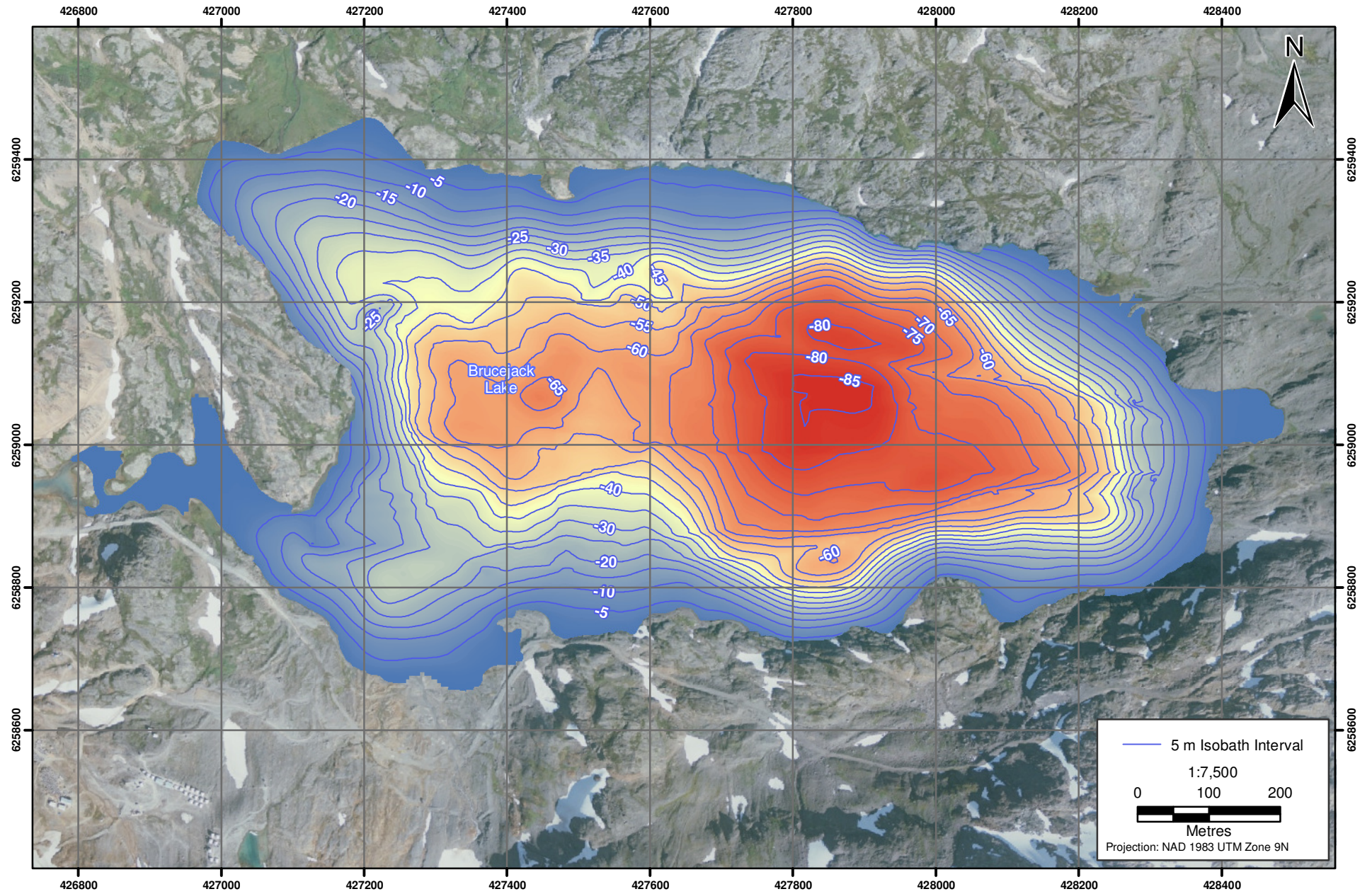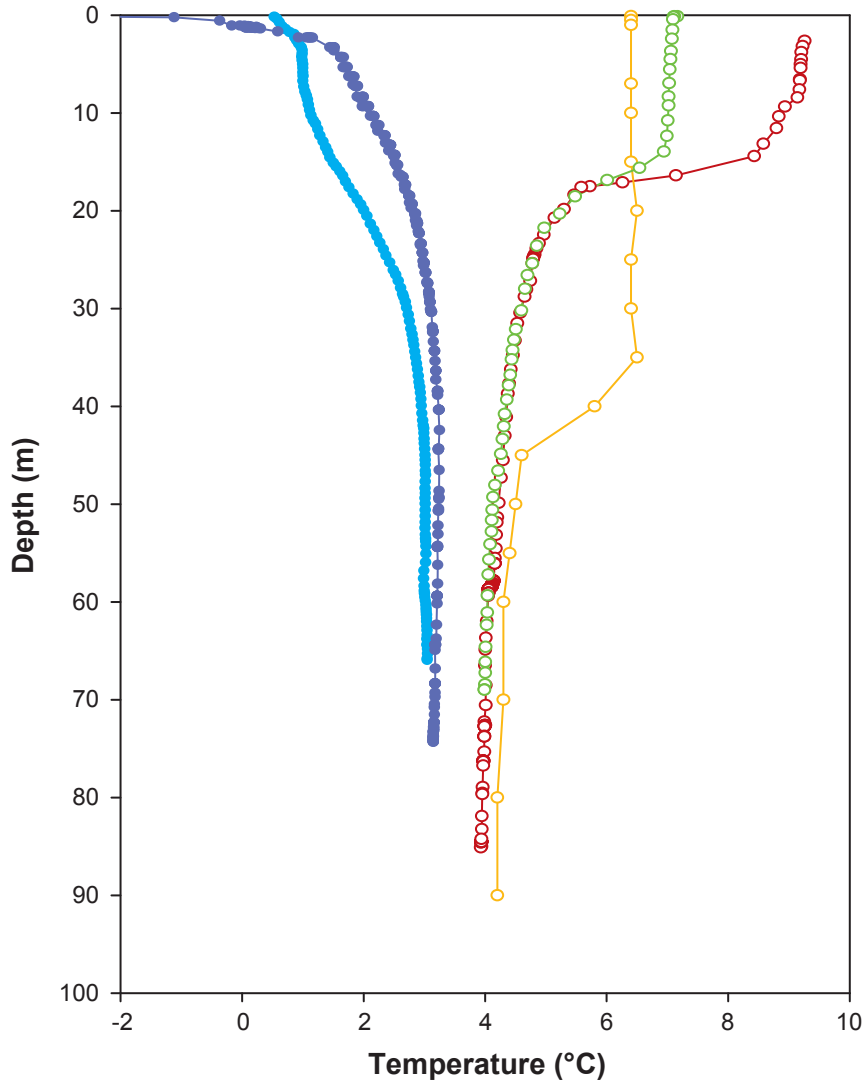
Brucejack Lake Bathymetry 2012

Figure 2.1-1

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Notes: Data collected with a CTD (RBR XR-420), with the exception of Aug 2011, collected with YSI.
        There was no insitu conductivity data collected in 2011.
        Ice/snow depth in July and December 2012 was 120 cm and 75 cm, respectively.

Temperature Profiles in Brucejack Lake, 2010 to 2012

Figure 2.1-2

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3. Design Criteria

3.   Design Criteria

3.1   PARTICLE SIZE DISTRIBUTION

The tailings particle size distribution is fine with a median particle size less than 25 μm. The particle size distribution provided by Tetra Tech is shown below in Table 3.1-1.

Table 3.1-1. Particle Size Distribution for Tailings

Screen Size		Sample Weights			
		Grams	Weight %	Cumulative Weight %	
Micron	U.S. Mesh	Retained	Retained	Passing	Retained
212	70	1.4	0.28	99.72	0.28
150	100	5.9	1.19	98.53	1.47
106	140	27.65	5.57	92.96	7.04
75	200	60.29	12.15	80.80	19.20
53	270	50.71	10.22	70.58	29.42
45	325	21.13	4.26	66.32	33.68
38	400	22.24	4.48	61.84	38.16
25	500	31.47	6.34	55.50	44.50
-25	-500	275.33	55.50		
		496.12	**100%**		
Product size passing 90% (P_{90})		96 Microns			
Product size passing 80% (P_{80})		73 Microns			

Source: Pocock Industrial Inc. (2012)

3.2   RHEOLOGY

The prediction of pipeline pressure drop (or head loss) as a function of pipeline volumetric flow and diameter requires knowledge of the dependence of apparent slurry viscosity on strain rate (the rheology). For a Newtonian fluid such as water, the viscosity is constant with strain rate. The tailings slurry rheology on the other hand, is approximated to be that of a Bingham plastic: a non-Newtonian fluid characterized by a yield stress and a plastic viscosity (or coefficient of rigidity). These two fluid properties also change with solids concentration so that Newtonian behaviour is approached for low concentrations of the tailings slurry as the yield stress value approaches zero. Apparent viscosity measurements were taken at reference shear rates and varying percent solids in the tailings. The results are shown in Table 3.2-1; note the strong dependence of yield stress on concentration.

The apparent viscosity increases as the solids concentration increases at any given shear rate. The shear rate is directly proportional to the velocity in the pipe; therefore, lowering solids concentration and increasing velocity will lower the apparent viscosity of the slurry. Rheological properties (apparent viscosity measurements) were not available for concentrations less than 57% w/w solids. Accordingly, apparent viscosities were estimated by curve fitting the available data and extrapolating to lower concentrations. Plate 3.2-1 shows the data and curve fits for four shear rates and their extrapolation. The figure shows that small changes in solids concentration have a significant impact on the viscosity.

Table 3.2-1. Tailings Slurry Rheology Showing Measured Apparent Viscosities and Calculated Coefficients of Rigidity and Yield Stresses

Solids Concentration (%)	Coefficient of Rigidity (Pa·s)	Yield Value (Pa)	Apparent Viscosity (Pa·s) at Shear Rates (sec^{-1})							
			5	25	50	100	200	400	600	800
70.3	0.091	103.7	8.674	3.265	2.144	1.408	0.924	0.607	0.474	0.398
67.6	0.059	60.9	5.657	2.003	1.281	0.819	0.524	0.335	0.258	0.214
63.1	0.028	26.1	2.977	0.948	0.579	0.354	0.216	0.132	0.099	0.081
57.0	0.016	10.8	1.527	0.434	0.253	0.147	0.086	0.050	0.036	0.029

Source: Pocock Industrial Inc. (2012)
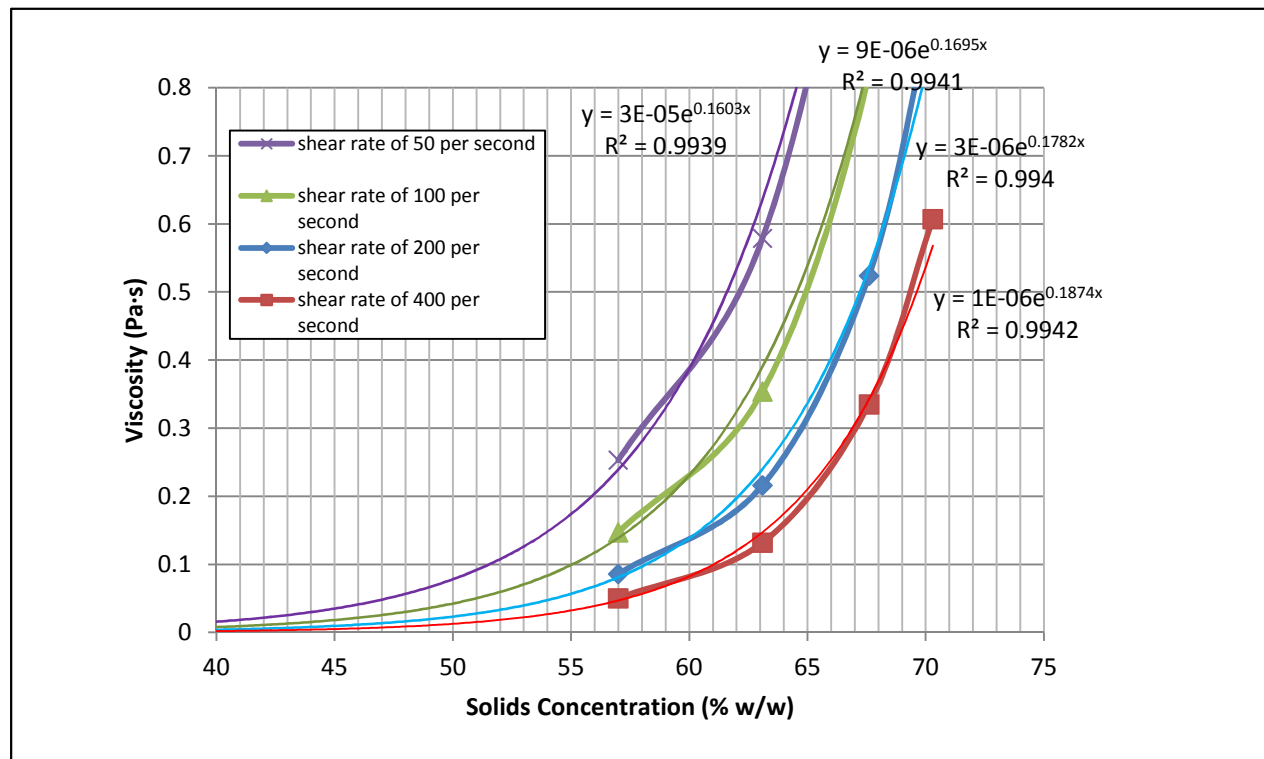
Plate 3.2-1. Apparent viscosity versus slurry solids concentration at four shear rates for 10" DR6.3 pipe.

Based on our experience, it was assumed that at concentrations below 35%, the present tailings slurry would exhibit Newtonian behaviour, (that is, zero yield stress) so that the viscosity would be constant, regardless of shear rate. Table 3.2-2 shows the apparent viscosities adopted.

It should be reiterated that all actual laboratory measurements of viscosity were made for relatively high solids concentrations pertinent to conditioning the slurry for a paste backfill plant. On the other hand, the present design is for a slurry pipeline that will be operating in turbulent mode at relatively low concentration. The estimated values of slurry viscosity at low concentrations shown in Table 3.2-2 need to be verified by measurement with a concentric cylinder viscometer prior to detailed design. The hydraulic and mixing calculations both depend on viscosity and could contain significant error if the estimates in the table are incorrect. For example, Table 3.2-3 shows the dependence of frictional head loss on viscosity in 1,100 m long, 10" DR7.3 pipeline.

Table 3.2-2. Estimated Apparent Viscosities for Lower Solids Concentrations

Shear Rate (sec^{-1})	50	100	200
Solids %	Apparent Viscosity (Pa·s)		
57	*0.253*	*0.147*	*0.086*
55	0.202	0.120	0.070
50	0.091	0.055	0.033
45	0.041	0.025	0.015
40	0.018	0.011	0.006
35	0.005	0.005	0.005
30	0.004	0.004	0.004
25	0.003	0.003	0.003
0	0.0015	0.0015	0.0015

Note: Apparent viscosities at 57% w/w (italicized) are from experimental values.

Table 3.2-3. Viscosity Effects on Head Loss for 1,100 m 10" DR7.3 Pipeline for Slurry Concentration of 40% w/w Solids at a Flow of 231 m^3/h

Viscosity (Pa·s)	Friction Factor	Hydraulic Head (m)
0.010	0.0203	28.0
0.012	0.0212	29.2
0.057	0.0310	42.7
0.100	0.0361	49.8

Actual viscosity measurements at lower solids concentrations are required to verify if the assumed slurry rheology is an adequate approximation. Differing viscosity values could significantly affect the design of the system, as evidenced by the range of head loss from 28.0 to 49.8 m (and thus pump head requirements) in Table 3.2-3.

3.3   SOLIDS CONCENTRATION AND FLOW RATE

Table 3.3-1 shows the values provided for the tailings thickener underflow solids throughputs and concentrations.

Table 3.3-1. Tailings Thickener Underflow Characteristics

Quantity	Units	Value
Solids throughput (maximum)	metric tonnes per hour	112
Solids throughput (design)	metric tonnes per hour	124
Solids throughput (minimum)	metric tonnes per hour	0
Underflow solids concentration	% w/w	40% to 65%

The thickened slurry will be diluted with water in an agitated mixtank resulting in a maximum concentration of 35% w/w solids at 124 tph. This will ensure efficient operation of the agitator, pump, and pipeline while keeping the deposit at the lake bed fluidized. Total flow in the outfall will be 278 m^3/h (velocity of 3.0 m/s). As described later in this report, the volumetric flow rate will be maintained constant by adding dilution water to the tailings flow as needed.

The system is also capable of handling lower throughputs and solids concentrations from the thickener than expected. This is illustrated in Plate 3.3-1 with the red line showing the anticipated operating throughput and concentrations and the blue line showing the minimum.
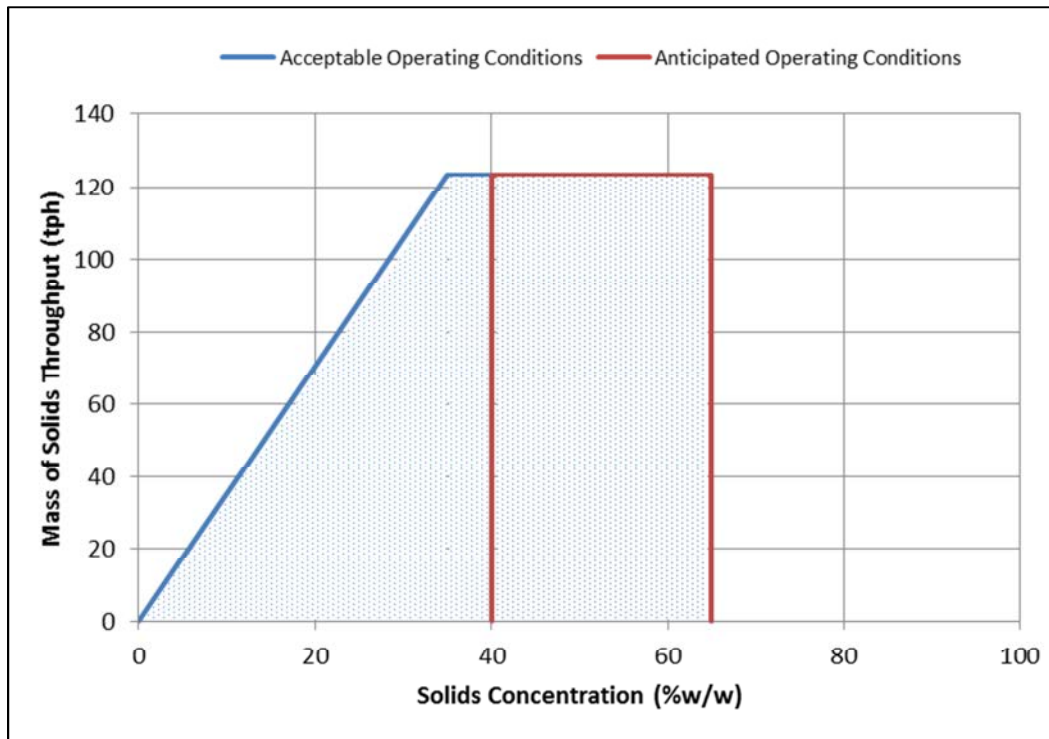
Plate 3.3-1. Operating range for tailings discharge system.

3.4   BATTERY LIMITS

Rescan is responsible for design of the system from the slurry mixing tank to the discharge on the lake bed. The battery limit for the design is at the inlet nozzles on the mixing tank and includes the valve that controls the flow of dilution water into the mixing tank. The battery limits are shown on the process flow diagram (PFD) in Appendix 1, drawing 1042-E-006-02.

4. System Description

4.   System Description

A specialized system has been developed in an effort to prevent the discharge of water from Brucejack Lake with total suspended solids concentrations exceeding regulated values. The subaqueous tailings placement system is intended to discharge in the deepest area of Brucejack Lake in a manner which ensures that the outfall terminus is rapidly buried and that continuing discharge leads to a progressively thickening deposit. This deposit will function as a fluidized media filter to minimize turbidity and suspended solids concentration in the lake water and particularly in the surface layers. As for any outfall system, the depth of discharge and the density stratification of the overlying water column are key design inputs. Seasonal variations in stratification may have some effect on the spatial distribution of TSS in Brucejack Lake.

Tailings will be deposited into Brucejack Lake by diluting the tailings thickener underflow slurry with lake water (or process water) in an agitated mixing tank and pumping the slurry through a pipeline that runs from the mill, overland to the lake and then follows the lake bottom to the discharge point. The process flow diagram is shown in Appendix 1, drawing 1042-E-006-2. The solids concentration is 27% w/w at the inlet of the thickener. If the thickener could be bypassed, there would be no need for a mixing tank as the pipeline could be designed to accommodate 27% w/w solids.

At the lake shore the pipe will wye (split) into two parallel pipes, one of which will discharge at a depth of 80 m, near the bottom of the lake, and the other at a depth of 60 m. Prior to tailings discharge, a small quantity of coarse sand or gravel will be placed at the terminus of each of the outfalls. Through operations, tailings solids will accumulate over the discharge point further covering it and act as a filter intercepting the majority of fine tailings particles in a manner similar to a sand filter. This concept has been demonstrated to be effective in earlier Rescan designs at Minahasa in Indonesia and at CMP in Chile. The approach has recently been adopted at a project in the US.

The most conservative approach to maintaining favourable hydrodynamic conditions, that is, a fluidized deposit, is to ensure that turbulent flow is always present in the pipeline and therefore also at the discharge point. Furthermore, turbulent rather than laminar conditions are preferable in a slurry pipeline.

The velocity in the pipeline will be kept relatively constant and far above the deposition velocity to ensure steady and reliable pipeline flow conditions.

Turbulent conditions (Reynolds' number > 2,400) are achieved with adequately:

- o   high velocity;
- o   large pipe diameter; and
- o   low viscosity.

This requirement along with the need to "choke" the dense flow underwater to prevent slack flow leads to the selection of a pipeline internal diameter of 181 mm with a minimum flow velocity of 3 m/s.

Approximately one-half of the time, thickened tailings will be directed to the paste backfill plant and no slurry will flow to the discharge system. During this operating mode, water will be pumped through the pipeline to maintain a fluidized deposit over the end of the discharge pipe. In fact, there will be a near-constant flow through the tailings discharge pipeline even if no solids or slurry are being discharged. This approach will also help minimize the risk of freezing in the pipeline.

The increasing thickness of the deposit of tailings over the end of the pipeline will cause an increase in the pressure required at the pump with time. If the pump head rises to 45 m above the initial head at commissioning, discharge flow will be diverted to the shorter pipeline that discharges at 60 m depth by manually switching the valves located on the lake shore. A new filtering deposit will then develop at the outlet of the secondary pipeline. The primary pipeline can then be cut off (or replaced) to have a shorter discharge at 40 m depth so that if the pressure builds in the system once again due to the mound at the 60 m outfall, the operating pipeline can again be switched. The timing and switching, if necessary, will be determined after several years of operation. Additionally, in the event of an unforeseen circumstance that would render the primary pipeline unusable, operations can be switched to the secondary pipeline.

4.1   PIPE ROUTE OVERLAND

The mixing tank and discharge pump will be located in the mill building. The pipeline alignment and profile is shown in in Appendix 1, drawing 1042-E-006-01. The pipeline will run from inside the mill building to the lake shore at slopes between 1.4%, and 10%. The overland pipeline route will be approximately 525 m long and split into two pipelines at the lakeshore before entering the lake. There will be manual isolation valves located in a heated enclosure at about 512 m on land to manually switch between the two pipelines. The primary pipeline will discharge at a depth of 80 m with a total length of 970 m, or about 445 m underwater. The secondary pipeline will discharge at a depth of 60 m with a total length of 864 m or about 339 m underwater.

The pipeline is designed to be continuously sloping downward from the mill building to its discharge points in the lake. This configuration is desirable to promote complete drainage in the event that no water is available to maintain pipeline flow. Ideally, the slope would be constant to eliminate areas where air could be trapped on start-up. The maximum slope of 10% upstream of flatter sections is chosen to prevent a settled solid bed from sliding into the flatter section on emergency shutdown. Such an occurrence could cause a pipeline blockage. The pipeline overland will need to be contained in a trench with grating for protection or trenched and backfilled in most sections. There are two road crossings at which the pipeline will be installed in a culvert. The route is close to an avalanche risk area near the lake and must be properly protected and supported. The pipeline is insulated but not heat traced to protect against freezing (site temperatures down to -34°C). Heat tracing is not required as the velocity in the pipeline will be sufficient to prevent freezing the lines.

4.2   PIPE ROUTE UNDER WATER

The subaqueous pipelines (or outfalls) extend from the isolation valves and wye on shore to the two discharge depths. At this time the alignment has been selected to traverse the underwater slope in depths less than about 30 m (above the 1,335 m elevation contour). This alignment may need to be re-examined after the detailed route bathymetric survey is undertaken.

The outfalls will be laid on the lakebed and stabilized with rock bolts and/or concrete ballast weights. Such stabilization is necessary in marine and river applications to resist the horizontal forces imposed by waves and currents. In Brucejack Lake nominal ballasting is required to prevent the pipe from floating (HDPE is slightly buoyant) when discharging clear water and in the event that a significant volume of air enters the outfall as a result of air valve malfunction. Air in the outfall is discussed in more detail in Section 4.7.

Concrete ballast weights (or collars) are precast, each in two pieces and bolted together clamping the pipe between them. The outfalls, complete with the attached weights, are launched and sunk as one piece. In some installations, extra ballast is added after the pipeline is sunk to the bottom.

In general, rock bolting would be preferable to attached ballast weights on a steep slope to ensure against down slope displacement. Rock bolting underwater, however, requires diving operations. In our opinion it would be prudent to avoid diving operations at this relatively remote site above 1,400 m altitude for reasons of both safety and cost.

Pipeline stabilization, therefore, will be accomplished by concrete counter buoyancy weights. There are limitations, based on pipe stress, on the amount of weight that can be bolted onto a pipe prior to sinking, often less than 50% of the air filled pipe buoyancy. Therefore, if it is required to stabilize against a large slug of air entering the outfall, additional ballast must be added to the outfall. The preferred approach is installation and maintenance of air valves.

4.3   MIXING

The tailings thickener underflow slurry will be approximately 65% w/w solids. This concentration is suited for input to the paste backfill plant but would present problems for operation of both the tailings slurry pipeline and the deposition method. It is desirable to maintain turbulent flow in the pipeline and for the anticipated flows this will not be possible at 65 % solids. Further, the planned deposition scheme, beneath a deposit of tailings, relies upon fluidization of the deposit favouring a low apparent viscosity slurry. Finally, it is desirable that the slurry density in the pipeline be maintained reasonably constant. A mixing stage has, therefore, been incorporated into the system to effect the required dilution and homogenization.

The mixing tank is designed to:

- o   dilute the 65% w/w thickened tailings from the thickener underflow to a lower concentration (35% w/w);
- o   ensure that air is purged from the slurry;
- o   provide a liquid level by which the dilution water flow can be controlled; and
- o   minimize solids settling at the bottom of the tank.

Mixing calculations were based on Paul et al. (2004). Three options were considered: a pump box or tank with jet mixing, in-line mixing, and a mechanically agitated mixing tank.

Pump Box or Tank with Jet Mixing

The high apparent viscosity of the tailings thickener underflow slurry precludes mixing with water in a simple pump box. A tank with jet mixing involves a downward-facing, centrally mounted pipe inlet through which a fluid is delivered to the tank at high velocities. The principle behind this type of mixing arrangement is that the momentum and turbulence of the jet can be used to provide the recirculating flow and turbulence at the tank floor that is required for solids suspension and mixing. For the current application, water would need to be added to the slurry jet.

This type of mixing arrangement is typically NOT recommended for solids suspension applications in larger tanks since the requirements to keep solids mixed away from the jet can result in very high jet velocities at the pipe discharge to the tank. Such high velocities can lead to cavitation and unacceptable wear rates. This type of mixing arrangement suffers from a lack of flexibility to accommodate changes in the system as it is highly dependent on the flow rates and compositions of the input streams. As such, this method is not recommended.

In-line Pipeline Mixing — Includes Tee Mixers and Static Mixers

The advantage of these types of mixers is that there are no moving parts and they are relatively easy and inexpensive to operate. The disadvantage is that they tend to have very stringent design requirements and offer little system flexibility. In particular, tee mixers may be inappropriate for use with a high solids concentration (and high apparent viscosity) slurry. Due to the limitations of this arrangement it is not recommended that a tee mixer alone be relied upon to achieve full homogenization of the two fluids.

Agitated Tank with an Impeller

This is usually the preferred method for mixing of solid suspensions due to its capability to handle a wide range of input concentrations and the ability to control the agitator rotation speeds as required. Operated in the turbulent regime, these systems provide thorough and reliable mixing although the rotating mechanical equipment requires monitoring and maintenance (some of which is scheduled for shut-downs). Another advantage of agitated tanks is that there are well-developed design procedures available for them because of their common use. Since this arrangement offers the most flexibility and capability to accommodate changes in flows and concentrations, it has been selected as the primary mixing method for the present application. A tee mixer will also be installed at the entry to the tank to aid in initiating the mixing process.

4.3.1   Mixing Tank Sizing Based on De-aeration

The sizing of the tank diameter is based on the free liquid surface area required for de-aeration of the tailings slurry for a minimum air bubble size of 500 microns (0.5 mm).

Bubble rise velocity is inversely proportional to the liquid viscosity which is, in turn, dependent on the slurry solids concentration. Accordingly, the required tank diameter is a function of the solids concentration of the tailings slurry. Bubble rise velocities and minimum tank sizes are shown in Table 4.3-1. More dilute slurries permit application of a smaller diameter tank.

Table 4.3-1. Minimum Required Tank Diameter for Different Solids Concentrations

Solids Concentration (wt%)	Mixture Apparent Viscosity (Pa·s)	Mixture Density (kg/m³)	Volumetric Flow (m³/s)	Bubble Rise Velocity for 0.5 mm Bubble (m/s)	Minimum Tank Diameter (m)
27	0.0035	1,204	0.1056	0.047	1.63
35	0.005	1,281	0.0765	0.035	1.67
40	0.018	1,335	0.0643	0.010	2.85

The properties of the 35% w/w solids concentration slurry are also attractive for overall system hydraulics and for the de-aeration function. A 2 m diameter tank is selected assuming that solids concentrations will be maintained by dilution below about 35%.

4.3.2   Impeller Selection

The mixing requirement for dilution of thickened tailings is complex. It can roughly be split up into two operations: the break-up of the thickened tailings paste and mixing in of the dilution water to reduce its viscosity and, once the viscosity has been reduced, the need to keep any settling solids suspended or, preferably, uniformly distributed within the tank. This is also to be done while allowing for de-aeration and preventing any air-entrainment from occurring at the surface.

There are two main aspects of an impeller that determine its selection for a particular process objective: the shear induced by the impeller and the axial flow induced by the impeller. Although all impellers impart some amount of both shear and flow, most are designed to accomplish one better than the other. The process objectives that would require high shear, such as drop or paste breakup, call for a different impeller versus the process objectives that would require high axial flow, such as solids suspension. There are, however, some impellers that can accomplish reasonable levels of both. The process of dilution of the thickened tailings paste would require a balance of high shear for break-up of the paste as well as a high flow requirement to keep the liberated solids suspended within the tank.

The tank geometry and impeller shape recommended for mixing of viscous fluids (e.g., 65% w/w thickened tailings) are very different from those recommended for the suspension of solids. In the present application there is a substantial change in the rheology and apparent viscosity of the slurry as it is diluted from 65% w/w to 35% w/w (its apparent viscosity decreases by a factor of almost 100). This rheological transformation somewhat complicates selection of an impeller and its positioning within the tank. A preliminary impeller selection and layout for a 2 m tank is two 4-bladed 45° pitched blade turbines (PBTs) with diameters of 0.711 m each. PBTs are a mixed flow, general purpose impeller. They have the ability to provide high levels of shear while still providing substantial flow. The impellers will operate at 100 RPM and will be powered by a 5 HP motor.

This is shown in drawing 1042-E-006-03 in Appendix 1.

4.3.3   Inlet / Outlet and Baffle Geometry

Tailings and water will enter a tee mixer before flowing together to the tank as shown in drawing 1042-E-006-03 in Appendix 1.

The inlet location should not interfere with the mixing process so it will be located high in the tank but below the liquid surface to prevent air entrainment.

The discharge outlet will be located diametrically opposite from the mixed tailings /water inlet.

Four vertical baffles with a width of 0.17 m are located at 90° intervals on the inner tank circumference. The baffle wall clearance is 0.03 m. Baffles are a necessary part of the tank for solids suspension because they serve to convert the rotational flow created by the impeller to vertical flow which aids in suspending solids. Drawing 1042-E-006-03 in Appendix 1 shows the dimensions for the mixing tank and impeller.

Given the uncommon mixing process, it is suggested that mixing tests with pilot plant thickened tailings samples be performed at the detailed engineering stage, if possible, to optimize the impeller selection and tank geometry.

4.4   DISCHARGE PUMP

The tailings placement system is designed to handle a range of solids throughputs, concentrations and deposit thickness which in turn impose a range of head requirements on the discharge pump (between 0 and 50 m of head). The discharge head required depends both on slurry bulk density, which affects the subaqueous static head, and on apparent viscosity, which affects frictional losses. Note that, as described in Section 3.2, the apparent viscosity at concentrations less than 57% w/w solids was extrapolated from measurements at higher concentrations. Calculated head losses and pump selection may change after viscosities determined in the laboratory are available for this lower concentration range. Required pump head also depends on the length of the pipeline; significant changes to the pipeline routing will impact the head requirements. Table 4.4-1 shows the elevation, static heads, frictional head loss and maximum

head loss assumed at the outfall terminus when discharging beneath a deposit of tailings solids. A velocity of 3.0 m/s is maintained in all cases by the addition of water at low solids throughputs resulting in lower solids concentrations at lower throughputs. If there is no deposit over the end of the outfall, the pump head required is drastically reduced to the range of 4.0 to 13.8 m.

If additional water is added so that the velocity in the pipeline is increased to 3.5 m/s, the frictional losses increase and the density decreases. The reduction in density difference between the slurry and lake water reduces the underwater static head. Both factors cause an increase in the total required head.

Table 4.4-1. Discharge Head Requirements for Different Throughputs at 3.0 m/s in a 10″ DR 6.3 Pipe at a Discharge Depth of 80 m, Total Pipeline Length 970 m

Throughput (tph)	Solids Conc. (%w/w)	Elevation Head Overland (m)	Static Head Underwater (m)	Frictional Head Loss (m)	Total Head Loss - No Terminus Deposit (m)	Terminus Deposit Head Loss (m)	Total Head Required - With Deposit (m)
0	0	-20.5	0	34.3	13.8	40	53.8
50	16	-20.5	-8.1	35.5	6.9	40	46.9
112	32	-20.5	-16.1	40.6	4.0	40	44
123.5	35	-20.5	-17.4	45.4	7.5	40	47.5

Table 4.4-2 shows that a small change in velocity (from 3 to 3.5 m/s) at a given throughput (112 tph) significantly changes the required pump head. Diluting from 32 to 28% w/w (compare Table 4.4-1 with Table 4.4-2) increases the head by 14 m.

Table 4.4-2. Discharge Head Requirement for 3.5 m/s in a 10″ DR 6.3 Pipe at a Discharge Depth of 80 m, Total Pipeline Length 970 m

Throughput (tph)	Solids Conc. (%w/w)	Elevation Head Overland (m)	Static Head Underwater (m)	Frictional Head Loss (m)	Total Head Loss - No Terminus Deposit (m)	Terminus Deposit Head Loss (m)	Total Head Required - With Deposit (m)
112	28	-20.5	-14.2	52.7	18	40	58

It is the intention to maintain the normal operating velocity at 3.0 m/s except during commissioning and in the earliest weeks of operation when the terminus deposit will not yet have accumulated and the associated backpressure will be absent. Additional water will be added to increase the pipeline velocity and head loss under these conditions to ensure that the pump remains within its approved operating range.

4.5   DEPOSIT OVER THE PIPELINE TERMINUS

As previously stated, the deposit at the pipeline terminus will thicken over time and bury the deepest section of the outfall. This will impose increasing backpressure at the end of the outfall. The rationale for the deposit is to filter the slurry being discharged and prevent transport of the tailings solids toward the upper layers of the lake. The deposit, or mound, remains generally fluidized. From experience in other projects, it has been found that the head loss imposed by the fluidized deposit was approximately one metre for each metre of deposit thickness.

Episodic slope failures of the deposit may be accompanied by a decrease in head loss as the deposit thickness and geometry are altered.

Drawing 194150-24-98-06 in Appendix 1 shows the area on the lake bottom that the tailings would occupy at the end of the project life, 22 years, under the assumptions that 9.524 Mt of tailings are deposited during the project life (Keogh 2013, pers. comm.) and that the density of the tailings deposit increases with accumulation and consolidation. (Tailings dry unit weight estimates were taken from the lab report completed by Golder, 2013). The overall footprint of the tailings at the end of 22 years occupies most of the lake bottom, to a depth of approximately 48 m at its edge and a depth of 38.4 m at the apex of the deposition cone.

4.6   CONTROL PHILOSOPHY

A radar level transmitter will maintain a set level in the slurry mixing tank by transmitting a signal to actuate the water control valve.

Water will be sourced from the process water tank and supplied to the control valve at a minimum pressure of 60 kPa. Maximum required water flow will be approximately 300 m^3/h through the valve. Most of the flow to the process water tank is overflow from the tailings and concentrate thickeners but some make-up water will be required and will be supplied from Brucejack Lake.

Water flow to the mixing tank will vary based on the concentration and solids throughput of slurry reporting to the tank. The final concentration of the solids in the mixing tank will also vary with solids throughput but the solids concentration will not exceed 35% w/w.

A flow meter will be located downstream of the discharge pump. The flow meter signal will be transmitted to the discharge pump VFD which will maintain a constant velocity of 3.0 m/s in the pipeline by adjusting the speed of the pump motor. When the tailings slurry flow rate into the mixing tank decreases, supply to the discharge pump will be maintained by addition of water to the mixing tank. (See the process flow diagram, drawing 1042-E-006-02 in Appendix 1 showing the basic control).

Before the deposit at the pipeline terminus develops, there will be much lower head requirements on the discharge pump. The pump would need to operate at unacceptably low speeds (less than 500 RPM for example) to match the low head requirement. Operating below recommended speeds could possibly damage the pump or the motor. When this condition arises, the pump will be programmed to operate at the minimum allowable pump speed which will increase the velocity in the pipeline, overriding the flow meter control. The water control valve will automatically respond to the situation and continue to maintain level in the mixing tank. When the speed of the pump increases beyond a specified speed (depending on the pump chosen), the flow meter will be engaged again to control the velocity in the pipeline to 3.0 m/s.

When the tailings are sent to the paste backfill plant, which will occur roughly one-half of the mill operating time, the slurry inlet valve to the slurry mixing tank will be closed and the pipeline will maintain the flow through the pipeline with water only. When clear water is flowing into the tank and being discharged, there is no need for the agitator and it can be shut down. The agitator motor can be controlled by a position switch on the slurry inlet valve with a time delay to turn off or turn to standby when the inlet valve is closed.

4.7   AIR VALVES

In the absence of reliable air valve operation, the outfall must be ballasted to offset the buoyancy of an air-filled pipe. A slug of air approximately 525 m long at atmospheric pressure would enter the outfall if all the air initially present in the overland pipeline were to be forced into the outfall by advancing liquid. For the current alignment, the air slug would compress as it filled the pipe from the surface to a depth of approximately 22 m (some 165 m from shore). This condition would introduce

buoyancy requiring ballast offset but also impose an additional back pressure on the pumping system equivalent to 22 m of water head (220 kPa).

The slug would continue to shorten as it was driven deeper. Just before being discharged from the end of the outfall at 80 m depth, the slug would be approximately 58 m long and be pressurized to 800 kPa. Pipe weights are typically spaced at 5 m intervals to avoid excess bending stresses on the pipe, so that full buoyancy offset would be required along the entire length of the outfalls. Such heavy ballasting can seriously complicate outfall installation resulting in much higher installation costs.

When the system is started, the overland pipeline will be filled with air. The pump must have a programmed start-up sequence that will slowly increase the pump speed and flow rate before the flow meter will engage to control the discharge velocity flow to 3.0 m/s. If the pump is started too quickly, air in the pipe could be forced down the length of the outfall and discharge at the terminus, resulting in a dramatic increase in suspended solids in the lake due to aerating the filter mound and transporting tailings solids toward the lake surface. In addition, as described earlier, the discharge of large volumes of air could float the outfall, imposing unsustainable bending stresses in the pipe.

Gradual start-up will help ensure that the air is released at the valves. Air valves are positioned along the pipeline profile at the optimum points to allow air to be purged during filling: at the pump discharge, and in heated enclosures at the transition between 3% and 10% slope at station 0+111 m and at the lake shore at station 0+512 m. The brochure for the recommended air/vacuum valves is shown in Appendix 2. This model is specifically designed to maintain a separation between the slurry and the valve seat so that solids do not contact the valve seat.

In the event of sudden shut-down, the slurry would continue to flow down the pipeline and could create a vacuum. The air/vacuum valves will open when the pipeline is partially full at their locations and will allow air in to fill the volume of the pipe that has been emptied of slurry, thus preventing a vacuum condition.

5. Equipment and Installation

5. Equipment and Installation

Table 5-1 is an abbreviated and preliminary list of the equipment and services required and the approximate costs (±30%). It should be noted that the largest cost item is installation of the outfall pipelines in the lake; this will also be the most uncertain cost until bids are received from installation contractors.

Costs are FOB manufacturer and do not include transporting material to the site.

Table 5-1. Preliminary Costs

Item	Quantity	Units	Unit Price	Item Cost
10" DR 6.3 HDPE pipe	1,500	m	$76.30	$114,450
Pipeline overland (weld, trench, backfill)	500	m	$100	$50,000
Flanges, backup rings, bolts	20	ea	$200	$4,000
Pipeline installation (subaqueous, includes ballast weights)	1	lot	$600,000	$600,000
Discharge pumps	2	ea	$65,000	$130,000
Tank	1	ea	$20,000	$20,000
Agitator (w/ motor)	1	ea	$13,000	$13,000
Water control valve	1	ea	$15,000	$15,000
Isolation valves	6	ea	$4,000	$24,000
Flow meter	1	ea	$15,000	$15,000
Level transmitter	1	ea	$5,000	$5,000
Air/vacuum valves	3	ea	$10,000	$30,000
Heated enclosure	2	ea	$5,000	$10,000
Engineering/construction supervision	1	lot	$300,000	$300,000
Total				**$1,330,450**

5.1 PIPELINE

The pipeline will be constructed from HDPE 4710 pipe and will be 10″ (or 250 mm) DR 6.3. The inside diameter is 181 mm and the wall thickness is 43 mm. The pipe thickness is more than adequate for the anticipated operating pressures but provides added strength for the installation procedure in the lake as well as a generous wear allowance.

Inside the mill building, the piping into and out of the mixing tank will be steel. The tank outlet and pump suction and discharge lines will also be steel with an ID controlled transition to HDPE pipe downstream of the flow meter. The pipe will again transition from HDPE to steel for the valves in the heated enclosure on the shore and back to HDPE for the pipelines into the lake. This is shown in Appendix 1, drawing 1042-E-006-03 and 04.

In addition to hydraulic considerations, the pipeline must be designed to prevent freezing and be protected from external loads. Ambient winter air temperature can reach -34°C.The overland section of the pipeline will be insulated with 2″ thick polyurethane foam, trenched and backfilled, but heat tracing will not be required as the pipeline is self-draining, with a continuous downward slope to

prevent accumulation of water during shut-downs. Burial will also contribute to reducing heat flux to the atmosphere.

External forces can be imposed by avalanches, thermal expansion, and accidental vehicle impact. Installing the pipe in a trench protects it from avalanche induced forces and vehicles, and also greatly reduces temperature variances experienced by the pipe. Thermal expansion is controlled by constraining the pipe laterally with the backfill. Pipe wall stresses will vary in the absence of thermally induced strain.

The pipeline will be welded by thermal fusion with a small number of mechanical flanges (consisting of flange adaptors and backup rings) where required at connections to valves and pumps. The internal beads will be removed from the HDPE pipe to prevent excessive wear at the welds.

Installation overland is routine, but the submerged pipeline portions (the outfalls) require specialized procedures. The pipeline will be welded into a single section and weights attached with a blind flange at the end. It will then be launched and floated over its final alignment in the lake. Water will then be pumped into the outfall from the shore end displacing the air.

It will be desirable to provide the maximum practical buoyancy offset to resist discharged air in the unlikely event of failure of the air valves. In shallow areas, the pipe can be stabilized with rock anchors. In deeper areas additional concrete saddle weights or mattress pads will be placed over the outfalls. The initial installation estimate is based on few location details, and, due to remoteness of the site, cannot be estimated with much certainty at this time.

5.2   MIXING EQUIPMENT

The slurry mixing tank will be 2 m in diameter by 3 m tall. The level in the tank will be maintained at 2 m and two PBT impellers on a single shaft will be used for mixing. The agitator will not operate when the slurry inlet valve is closed and only water is flowing through the pipeline. This configuration will be confirmed during detailed design.

5.3   PUMPS

The discharge pumps will need to sustain a flow rate of 278 m^3/h. There will be two discharge pumps operating as 100% standby for when there is maintenance required on one of the pumps. The preliminary pump selection is Goulds model 5500 B3 slurry pump but will be verified during the detailed design. See Appendix 3 for pump information.

5.4   VALVES

The inlet water control valve will be an actuated vee-ball valve.

Isolation valves will be required for maintenance purposes and for switching from the primary to the secondary pipeline: on the tailings slurry inlet to the tank, on either side of the pumps and on each pipeline downstream of the wye in the heated enclosure.

The recommended air/vacuum valves are shown in Appendix 2. The air/vacuum valves located outside of the mill building will need to be located in heated enclosures. These valves are imperative in preventing possible damage to the pipeline and should not be able to be by-passed without a proper procedure.

Complete valve specification will be undertaken at a later date during detailed design.

5.5 INSTRUMENTATION

The magnetic flow meter and the radar level transmitter are essential to the control of the system. Both of these technologies are used for slurries and can accommodate changing densities. Additional instrumentation details, including specification of alarms will be developed in the detailed design stage.

6. System Operations

6. System Operations

6.1 NORMAL OPERATION

During normal operation, the inlet water control valve will maintain the level in the mixing tank by adding dilution water; the flow rate and solids concentration from the underflow is not controlled. The maximum concentration is 35% w/w solids in the mixing tank based on the design flow rate. The discharge pump VFD will be controlled by a signal from the flow meter to maintain the velocity in the pipeline at 3.0 m/s constantly (corresponding to a flow rate of 278 m^3/h).

The thickened underflow will be sent to the paste back-fill plant about half of the operating time. When this occurs, the slurry inlet valve will close causing the water control valve to open further and allow more water into the tank to keep the tank level constant. The pump will still be controlled by the flow meter to maintain the same velocity. The VFD will automatically adjust the pump speed to maintain the constant flow in response to the <u>higher</u> head requirement of clear water discharged to the lake (see Table 4.4-1). The agitator motor will shut off based on the position switch on the inlet slurry valve.

There are two discharge pumps but only one pump will operate at a time. The pumps should be switched at convenient times, for example when switching from back-fill to the tailings placement system. The operating pump should be flushed with water before starting the standby pump. The isolation valves on the pump to be operated must be opened and the isolation valve upstream of the pump being decommissioned must be closed before following the start-up pump procedure.

6.2 START-UP

The following procedure is recommended for starting the tailings placement system:

1. All three combination air vacuum valves are first checked for proper operation and to ensure that isolation valves are open.

2. The slurry mixing tank is filled with water to the normal liquid level by opening the water control valve.

3. The agitator is turned on.

4. All isolation valves on the pumps are checked to ensure that they are open.

5. The pump should be started up slowly following a programmed start-up sequence. The pump will start at a low flow rate and minimum speed (about 500 RPM) and slowly increase the flow rate for the minimum pump speed.

6. When the speed and flow rate match the minimum acceptable speed and flow rates programmed, the flow meter will initiate control of the pump to maintain the programmed velocity. This action allows thickened slurry to be pumped in from the thickener underflow to the slurry mixing tank.

7. The slurry inlet valve is opened and the pipeline will operate at a steady flow rate.

If the required pump head drops after the flow meter is engaged and the pump speed is reduced to the minimum speed (for example due to changes in density), again the flow meter would be overridden and additional water added until the programmed pump speed and flow rate are met.

6.3   SHUTDOWN

In the rare cases when a shutdown is required, the following procedure is recommended:

1. Close the slurry inlet valve.

2. Flush the pump and pipeline by operating with only water flowing in the system for at least 10 minutes.

3. The pump should start the shutdown sequence. The flow meter will disengage from controlling the pump speed and the speed will slowly be turned down until it stops.

4. The agitator is stopped.

5. The water control valve is closed.

6. Depending on the reason for the shutdown, the pump isolation valves may require closing.

The shutdown procedure for an extended maintenance shutdown will require that a small flow of water be trickled down the pipe to keep the deposit at the end of the outfall fluidized and prevent the pipe from freezing. When possible, extended shutdowns should be scheduled in the summer. There will be a back-up pump installed at the lake shore that is capable of pumping lake water from the lakeshore up to the mill building. This will be only be used when the water from the main mill source is not available.

6.4   SWITCHING OUTFALLS

The primary discharge pipeline will be used until the deposit at the outfall builds up and the pressure is equal to about 45 m of head. The pump head can be calculated in the PLC and shown in the control room. The PLC will be programmed to warn the operators in the control room to switch the pipeline when the head reaches 45 m total. To switch the pipelines, the inlet slurry valve would close and only water would be added to the mixing tank. The pump would discharge water for roughly 10 minutes to flush the pipeline of any solids that could have accumulated. The volume of the tank would be replaced more than once in that time so that the tank should be relatively free of solids as well. The pipelines would be manually switched by swinging the isolation valves and allowing flow to the secondary pipeline. The system would not require the pump being shut down, but the pump would require a much lower head as the pipeline length would decrease and the deposit would have to build back up at the terminus.

The system is designed to offer operational flexibility. Once the secondary pipeline is operating, the primary pipeline could be shortened by cutting the pipeline to discharge at a depth of 40 m. It would then be ready to be used once the secondary pipeline has the mound fully developed and the pump head reaches 45 m. The same procedure would be used: flush the line, swing the isolation valves, and re-start the primary pipeline.

6.5   OPERATIONAL LESSONS

Information permitting refinement of the design will be available after the system has operated for some time. The effects of lake turn-over will be monitored and any increase in turbidity above the lake discharge criteria will inform the mitigation strategy for maintaining TSS concentrations below discharge criteria. From previous experience with the design and operation of subaqueous tailings placement systems we feel that is it probable that, for most of the year, fine tailings solids should be excluded from the surface layer of the lake and thus not adversely affect TSS concentrations in Brucejack Creek. This conclusion is based on the depth of tailings discharge in the lake, the density stratification, isolation from wind mixing due to ice cover most of the year and the system configuration which discharges tailings through the deposit (which acts like a sand filter).

Overturn events, however, have the potential to partially vertically mix the lake and transport fine tailings particles to the surface layer. After the first year or two of operation, the timing and duration of lake turnover will be better understood and more predictable. Overturn events of the lake could be planned for and the tailings could be used in the paste backfill plant during this time.

Additionally, development of the terminus deposit and its associated head loss over the firsts two years will permit an estimate of an advantageous time at which to switch to the shorter outfall.

7. Summary

7.   Summary

Thickened tailings from the Brucejack Gold Mine are to be discharged into and stored in Brucejack Lake about 50% of the time when not used for paste backfill. To aid compliance with anticipated environmental regulations, the tailings are to be discharged at 80 m depth to prevent elevated concentrations of suspended solids from being discharged into Brucejack Creek. To maintain favourable deposition conditions at 80 m depth, the pipeline will need to be operated in the turbulent regime. This requires the tailings to be diluted to 35% w/w and the pipeline to be operated at a velocity of 3.0 m/s. A deposit of tailings will form at the outfall outlet and will eventually cover the end of the pipeline. This will act as a sand filter and will prevent fines from entering the upper layers of the lake.

The major components of the system are:

o   An agitated slurry mixing tank with dilution water addition to reduce the tailings concentration from 65% w/w to 35% w/w. Tank level will control the addition of dilution water.

o   Two centrifugal slurry pumps — a duty pump and a 100% stand by pump.

o   A 525 m long overland 10″ DR6.3 HDPE pipeline to the lake shore. This section may be exposed to avalanches and will be trenched and backfilled.

o   Two subaqueous pipelines (also 10″ DR6.3 HDPE) of 445 m and 339 m length the first extending to 80 m depth and the latter to 60 m depth. The twin outfall configuration has been selected to provide system redundancy and flexibility. As the solids deposit is built up at 80 m depth over time, the operating pipeline can be switched from discharge at 80 m to discharge at 60 m depth.

The overland pipeline is designed to have a constant downward slope to ensure that it is self-draining in the event of a shut down.

Air/vacuum valves will be installed at critical points to prevent the possibility of air entering the underwater section of the pipeline. A large air bubble entering the underwater section could potentially float sections of the pipeline and must be avoided. The valves will primarily function during start-up and shut-down of the pipeline.

The underwater pipeline sections will require concrete collar ballast weights to stabilize the pipeline on the lake bottom. Rock anchors will be used at the shallower sections. A preliminary estimate for the cost of the system is approximately $1.33 M CAD (+/-30%). Of this, the pipeline procurement and installation form the majority of the cost at $0.76 M CAD.

For detailed design the following should be undertaken:

o   Determination of tailings slurry rheology at concentrations below 57% w/w.

o   Bench scale mixing tests.

o   Details of the lake bed bathymetry along the pipe line alignments.

o   Confirmation of pipeline route.

o   Confirmation of system hydraulic behaviour if measured slurry rheology differs from that assumed.

References

References

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Paul, E. L., V. A. Atiemo-Obeng, and S. M. Kresta (Editors). 2004. *Handbook of Industrial Mixing: Science and Practice*. Wiley.

Personal Communication

Keogh, Colm, AMC Consultants. Brucejack Pastefill Requirements & Waste Disposal Volumes. Personal Communication: May 2, 2013.

Appendix 1
Drawings

Rescan™
Engineers and Scientists

Plan Layout

Pit

Primary Discharge Pipeline

Primary Discharge at −80m (1286.4m)

Toe of Fill

Secondary Discharge at −60m (1306.4m)

Brucejack Lake

WL 1366.36

Excess Cut Material

54°42'

Secondary Discharge Pipeline

Concrete Weights

Bathymetry from Frontier Services
October 2012

Air Valve in Heated Enclosure

Air Valve, Y Splitter, Manual Valves in Heated Enclosure

Mill Building

Air Valve

EL. 1409.0m

NORTH PORTAL

POWER TRANSMISSION LINE

SOUTH PORTAL

Poles

CAMP

EL. 1385.0m

SCALE

WASTE ROCK

ORE

HELIPAD

FUEL STORAGE

EL. 1371.5m

Access Road

BRUCEJACK AREA AVALANCHE HAZARD ZONE

BRUCEJACK AREA AVALANCHE HAZARD ZONE

Source: Tetratech
- 20-BASE.dwg (20Mar.2013)
- 20-BASE-Overall Location Plan Only.dwg (19Feb.2013)
- 20-GRADINGS.dwg (20Mar.2013)
- 100000-10-001.dwg (19Feb.2013)
- 100000-10-002.dwg (19Feb.2013)
- 100000-10-003.dwg (19Feb.2013)
- 100000-10-BASE.dwg (19Feb.2013)
- 10000020501 − MILL SITE − TAILINGS LINE.dwg (20Mar.2013)

Profile

Mill Building

1385.0m

Access Road Crossing

Air Valve, Y Splitter, Manual Valves in Heated Enclosure

0+863.7m

0+970.0m

Brucejack Lake

Slurry From Process Plant

W. L.=1366.4m(0m)

Slope

1.4%   3.0%

10.0%

1.0%

Concrete Weights

Primary and Secondary Discharge Pipeline

16.6%

9.4%

29.4%

33.9%

Secondary Discharge @ −60m (1306.4m)

Primary Discharge @ −80m (1286.4m)

18.7%

ELEVATION

0+002.4m Air Valve

0+111.0m Air Valve in heated Enclosure

0+512.4m

DISTANCE

NOTES:

1. All Pipelines 10"⌀ (273mm) DR 6.3 HDPE.

2. Cut and fill along pipeline alignment to ensure continuous positive slope and gravity drainage at shut down.

3. Any high point must have an air valve installed.

4. Submerged portion of pipeline to be ballasted and laid on the lake bottom.

Figure 1

PROCESS WATER

TAILINGS
FROM FLOTATION

THICKENER

	t/Hr	S.G.	m³/HR	% solids
Solids	124	2.680	46	—
Water	333	1.000	333	—
Slurry	457	1.204	379	27

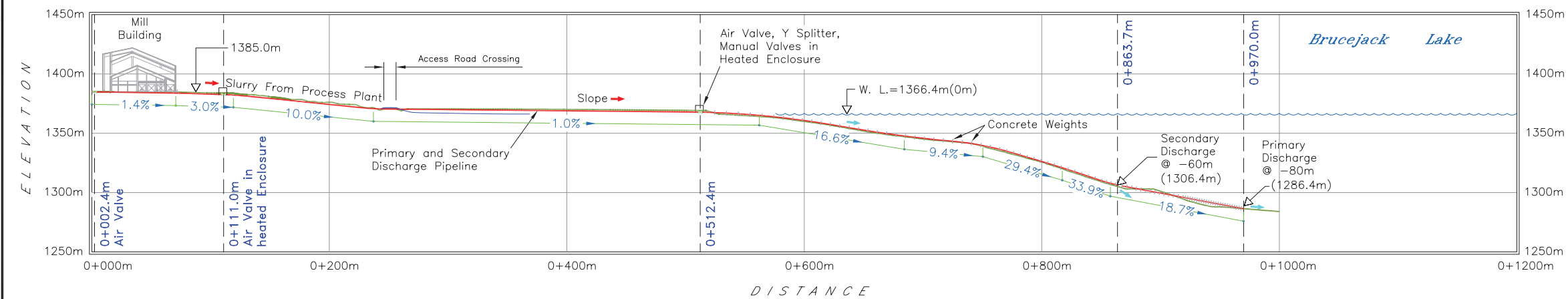|	t/Hr	S.G.	m³/HR	% solids
Solids	0	2.680	0	—
Water	266	1.000	266	—
Slurry	—	—	—	—

	t/Hr	S.G.	m³/HR	% solids
Solids	0	2.680	0	—
Water	101	1.000	101	—
Slurry	—	—	—	—

EXCESS THICKENER OVERFLOW

	t/Hr	S.G.	m³/HR	% solids
Solids	0	2.680	0	—
Water	165	1.000	165	—
Slurry	—	—	—	—

LC

M

SLURRY MIXING TANK

FE

M

Duty

Standby

Note 1

SLURRY DISCHARGE PUMPS

BY OTHERS   BY RESCAN

SLURRY
TO BRUCEJACK LAKE

SLURRY
TO BRUCEJACK LAKE

	t/Hr	S.G.	m³/HR	% solids
Solids	124	2.680	46	—
Water	232	1.000	232	—
Slurry	356	1.280	278	35

SLURRY
TO PASTE BACKFILL

UNDERFLOW PUMP

	t/Hr	S.G.	m³/HR	% solids
Solids	124	2.680	46	—
Water	67	1.000	67	—
Slurry	191	1.690	113	65

LINE SYMBOLS

→ PROCESS WATER

→ TAILINGS

- - - ELECTRIC SIGNAL

NOTES:

1. Standby pump.

2. Rates shown are the design rates and include an additional 10% added to expected operating conditions.

Figure 2

Slurry Discharge Pumps

Duty

Reducer

Standby

Reducer

Min. (Typ)

A

Min. (Typ)

0.17 m

Baffles

Impeler

ROTATION

Slurry Mixing Tank

8" Actuated Ball Valve

Tailings   Water

TOP VIEW

B

Knife Gate Valves (Note 1)

Air Valve

Steel   HDPE DR6.3

1m

ID Controlled Transition Fitting

Flow Meter

Slurry Discharge Pumps

Duty   Standby

Knife Gate Valves (Note 1)

Air Valve

Steel   HDPE DR6.3

1m

ID Controlled Transition Fitting

Reducer

Tee

Flow Meter

VIEW A-A

8" Actuated Ball Valve

Motor

Water

Tailings

3m

2m

Ø2m

Slurry Mixing Tank

VIEW B-B

Knife Gate Valves (Note 1)

Slurry Discharge Pumps

Standby   Duty

Figure 3

TOP VIEW

- HDPE DR6.3 — Steel — Steel — HDPE DR6.3
- Air Valve
- ID Controlled Transition Fitting
- Slurry
- TO BRUCEJACK LAKE
- ID Controlled Transition Fitting
- Knife Gate Valves (Note 1)
- ID Controlled Transition Fitting
- Steel
- HDPE DR6.3
- Min. (Typ)
- 10" HDPE DR6.3 Pipes
- 4m
- TO BRUCEJACK LAKE
- Heatec Enclosure

ELEVATION

- Air Valve
- Knife Gate Valves (Note 1)
- ID Controlled Transition Fittings
- 10" HDPE DR6.3 Pipes
- Reducer
- Tee
- Slurry
- TO BRUCEJACK LAKE
- ID Controlled Transition Fitting
- HDPE DR6.3 — Steel — Steel — HDPE DR6.3
- Heatec Enclosure

NOTES:

1. Install Knife Gate Valve as close as possible to custom made Y.

Figure 4

Rev | Date | Description | Check | Appro | Notes

Bathymetry from Frontier Services
October 2012

Brucejack Lake

WL 1366.36

1356.4
1346.4
1336.4
1326.4
1316.4

Toe of Fill

Excess Cut Material

BRUCEJACK AREA AVALANCHE HAZARD ZONE

Access Road

BRUCEJACK AREA
AVALANCHE HAZARD
ZONE

Mill Building

NORTH PORTAL

SOUTH PORTAL

EL. 1385.0m

SCALE

WASTE ROCK

HELIPAD

FUEL STORAGE

EL. 1371.5m

ORE

POWER TRANSMISSION LINE

Poles

CAMP

Source: Tetratech
• 20-BASE.dwg (20Mar.2013)
• 20-BASE-Overall Location Plan Only.dwg (19Feb.2013)
• 20-GRADINGS.dwg (20Mar.2013)
• 100000-10-001.dwg (19Feb.2013)
• 100000-10-002.dwg (19Feb.2013)
• 100000-10-003.dwg (19Feb.2013)
• 100000-10-BASE.dwg (19Feb.2013)
• 10000020501 - MILL SITE - TAILINGS LINE.dwg (20Mar.2013)

Figure 4b

Rev	Date	Description	Check	Appro	Notes

PRETIVM

Rescan™ Rescan Environmental Services Ltd.
Vancouver   CANADA

Brucejack Lake Prefeasibility Study
Foot Print of 3% Deposition
At the End of Year 22 (Apex of Cone -38.4 m)

Scale:none if fitted to 11"x17"
NONE

	Designed	PEG, RJB		MAY	2013
	Drawn	PKL		MAY	2013
	Approved				

CAD No.194150-24-1to6

Dwg No. 194150-24-98 -06- 00

DO NOT SCALE DRAWING

5/04/2013- 11:40am

Appendix 2
Air/Vacuum Valve Details

Rescan
Engineers and Scientists

D-023 PN 16

Combination Air Valve for Wastewater PATENTED

Description

The D-023 Combination Air Valve combines an air & vacuum orifice and an air release orifice in a single body. The valve is specially designed to operate with liquids carrying solid particles such as wastewater and effluents. The combination air valve discharges air (gases) during the filling or charging of the system, admits air into the system while it is being emptied of liquid and releases accumulated air (gases) from the system while it is under pressure and operating. The valve's unique design enables the separation of the liquid from the sealing mechanism and assures optimum working conditions.

Applications

- Pump stations for sewage, waste water & water treatment plants.
- Wastewater, effluent water and sea water supply lines.

Operation

The air & vacuum component discharges air at high flow rates during the filling of the system and admits air into the system at high flow rates during its drainage and at water column separation. High velocity air will not blow the float shut. Water will lift the float which seals the valve.

At any time during system operation, should internal pressure of the system fall below atmospheric pressure, air will enter the system. The smooth discharge of air reduces pressure surges and other destructive phenomena.

The intake of air in response to negative pressure protects the system from destructive vacuum conditions and prevents damage caused by water column separation. Air entry is essential to efficiently drain the system.

The automatic air release component releases entrapped air in pressurized systems.

Without air valves, pockets of accumulated and entrained air may cause the following hydraulic disturbances:

- Restriction of effective flow due to a throttling effect as would a partially closed valve. In extreme cases this will cause complete flow stoppage.
- Obstruction of efficient hydraulic transmission due to air flow disturbances.
- Accelerate cavitation damages.
- Pressure transients and surges.
- Corrosion in pipes, fittings and accessories.
- Danger of high-energy bursts of compressed air.
- Inaccuracies in flow metering.

As the system starts to fill, the combination wastewater valve functions according to the following stages:

1. Entrapped air/gas is discharged by the valve
2. When the liquid level reaches the valve's lower portion, the lower float is lifted, pushing the sealing mechanism to its sealing position.
3. The entrapped air is confined in a pocket between the liquid and the sealing mechanism. The air pressure is equal to the system pressure.
4. Increases in system pressure compress the trapped air in the upper section of the conical chamber. The conical shape assures the height of the air gap. This enables separation of the liquid from the sealing mechanism.
5. Entrapped air (gas), accumulating at peaks and along the system, rises to the top of the valve, and displaces the liquid in the valve's body.
6. When the liquid level is lowered to a point where the float is no longer buoyant, the float drops, unsealing the rolling seal. The air release orifice opens and allows part of the air that accumulated in the upper portion of the valve to be released to the atmosphere.
7. Liquid enters the valve. The float rises, pushing the rolling seal to its sealing position. The remaining air gap prevents the wastewater from fouling the mechanism.

When internal pressure falls below atmospheric pressure (negative pressure):

1. The floats will immediately drop down, opening the air & vacuum and air release orifices.
2. Air will enter the system.

Main Features

- Working pressure range: 0.2 - 16 bar.
- Testing pressure: 25 bar.
- Maximum working temperature: 60° C.
- Maximum intermittent temperature: 90° C.
- The unique design of the valve prevents contact between the wastewater and the sealing mechanism by creating an air gap at the top of the valve. These features are achieved by:
- **The conical body shape and the external lever:** designed to maintain the maximum distance between the liquid and the sealing mechanism and still obtain minimum body length.
- **Spring loaded joint between the stem and the upper float:** vibrations of the lower float will not unseal the automatic valve. Release of air will occur only after enough air accumulates.
- **Funnel-shaped lower body:** designed to ensure that residue wastewater matter will fall back into the system and be carried away by the main pipe.
- All inner metal parts made of Stainless Steel.

- Unique design of external lever prevents contact between the wastewater and the sealing mechanism, prevents clogging by floating solids and ensures drip-tight sealing.
- The D-023's orifice plug-disc linkage assembly is external, keeping the levers and pins outside the air valve body and its corrosive atmosphere.
- 1" ball valve releases trapped pressure and drains the valve body prior to maintenance.
- Discharge outlet enables removal of excess fluids
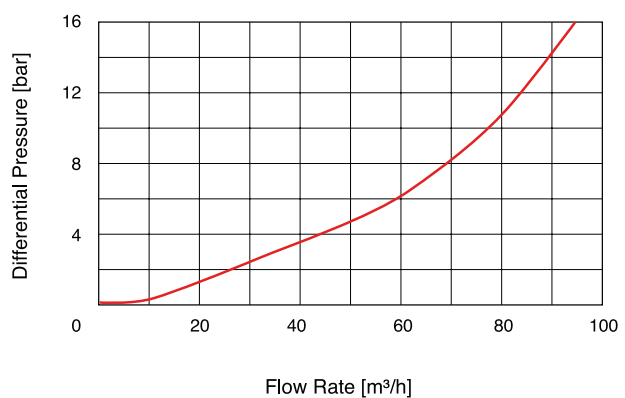
Valve Selection

- Size range availability: 3" - 8".
- Valves manufactured with flange ends to meet any requested standard.
- Standard metal body, also available with a ST ST body.
- Valve body coating: fusion bonded epoxy coating according to the standard DIN 30677-2.
 - Additional coatings available upon request.
- Optional Accessories
• With a One-way, Out-only attachment, allows for air discharge only, prevents air intake.
• With a Vacuum Breaker, In-only attachment, allows for air intake only, prevents air discharge.
• With a Non-Slam discharge-throttling attachment, allows for free air intake, throttles air discharge - Model D-023 NS.
- For best suitability, it is recommended to send the fluid chemical properties along with the valve request.

Upon ordering, please specify: model, size, working pressure, threads standard and type of liquid.

AIR & VACUUM FLOW RATE

Differential Pressure [bar] vs Flow Rate [m³/h]
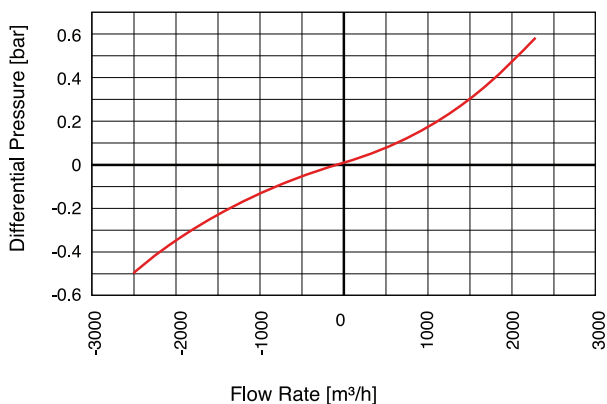
AUTOMATIC AIR RELEASE FLOW RATE

Differential Pressure [bar] vs Flow Rate [m³/h]

DIMENSIONS AND WEIGHTS

Nominal Size	Dimensions mm		Connection	Weight	Orifice Area mm²	
	A	B	C	Kg.	Auto.	A / V
3" (80 mm)	554	580	3" BSP / NPSM Female	22	15.7	5024
4" (100 mm)	554	580	3" BSP / NPSM Female	23	15.7	5024
6" (150 mm)	554	580	3" BSP / NPSM Female	24.5	15.7	5024
8" (200 mm)	554	580	3" BSP / NPSM Female	27.5	15.7	5024

D-023

A.R.I.

PARTS LIST AND SPECIFICATION

No.	Part	Material
1.	Cover	Ductile Iron ASTM A-536-60-40-18 / ST ST ASTM A744 CF8M
2.	Disk Arm Assy.	ST ST SAE 316 + E.P.D.M.
3.	Orifice (Ductile Body only)	Bronze B 62
4.	O-Ring	BUNA-N
5.	Rivet	ST ST SAE 304
6.	Air & Vacuum Disc	Reinforced Nylon / ST ST ASTM A744 CF8M
7.	Air & Vacuum Disc Seal	E.P.D.M.
8.	Air Release Disc Seal	E.P.D.M.
9.	Bolt (Screw)	ST ST SAE 304
10.	Air Release Disc	Reinforced Nylon
11.	Air Release Disc Cover	Reinforced Nylon
12.	Pin	ST ST SAE 304
13.	Rod Adaptor	Polypropylene
14.	Domed Nut	ST ST SAE 304
15.	Stopper	Polypropylene
16.	Spring	ST ST SAE 316
17.	Float Assy.	Polycarbonate + ST ST 316 / ST ST
18.	Body 3"	Steel Din St.37 / ST ST SAE 316 / Steel A216 WCB / ST ST ASTM A744 CF8M
	4" - 8"	Steel Din St.37 / ST ST SAE 316
19.	Bolt	ST ST SAE 304
20.	Washer	ST ST SAE 304
21.	Bolt, Nut & Washer	ST ST SAE 316
22.	Ball Valve 1"	Brass, Chrome Coated / ST ST
23.	Plug	Polypropylene
24.	Bushing	Acetal
25.	Domed Nut	ST ST SAE 316
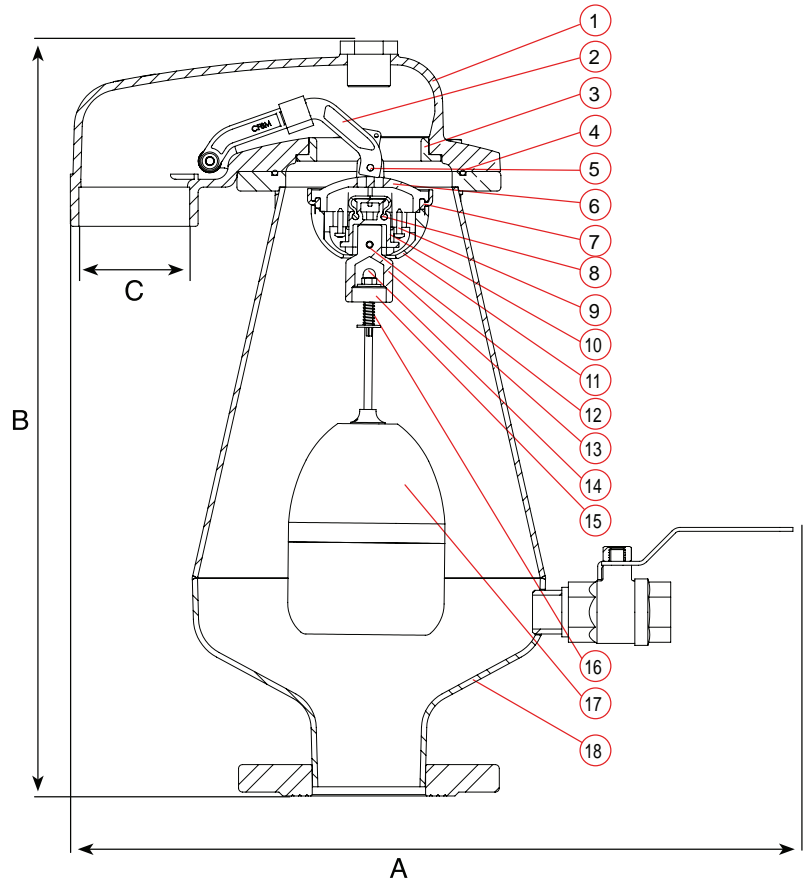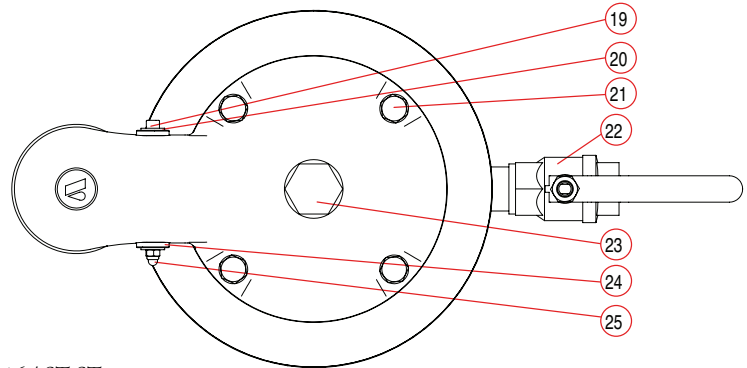
Appendix 3
Goulds Pump
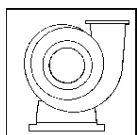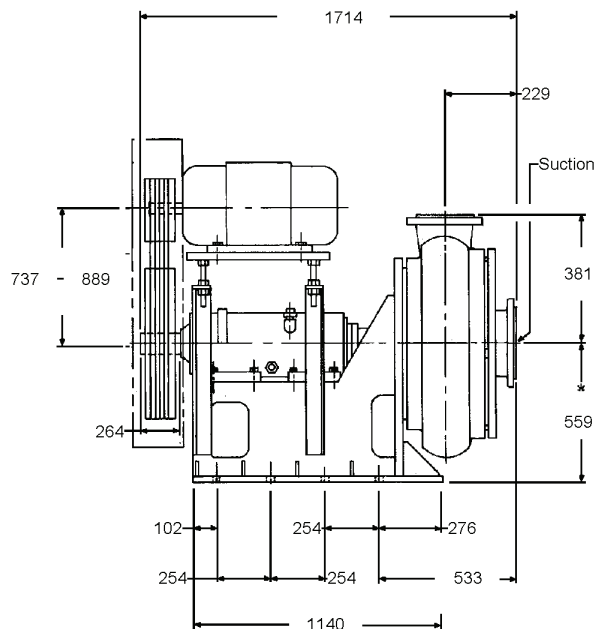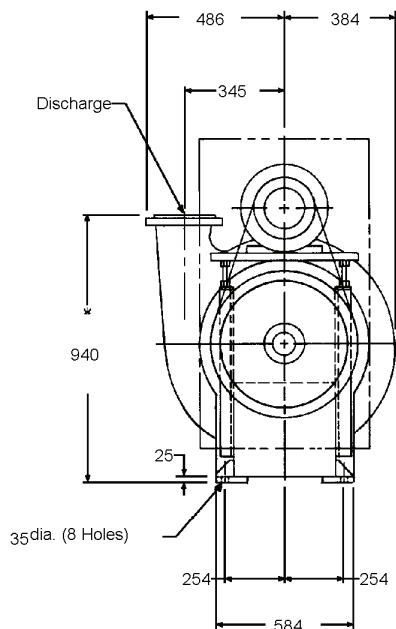
Discharge position 0° (Vertical Up)

Pump Specification

SUCT.FLANGE SIZE *8"*	DRILLING *ANSI 125#*	FACING *RF*	FINISH *SMOOTH*		
DISCH.FLANGE SIZE *6"*	DRILLING *ANSI 125#*	FACING *RF*	FINISH *SMOOTH*		
PUMP ROTATION (LOOKING AT PUMP FROM MOTOR)		*CW*			
TYPE OF LUBRICATION *FLOOD OIL*			COOLED *NO*		
TYPE OF STUFFING BOX *N/A*			COOLED *NO*		
TYPE OF SEALING *PACKING*					

Weights and Measurements

PUMP	*1,408 kg*
MOTOR	*653 kg*
BASEPLATE	*1,580 kg*
TOTAL	*3,641 kg*
GR.VOLUME w/BOX	*4.341 m³*
GR.WEIGHT w/BOX	*3,989 kg*

Motor Specification

MOTOR BY *PUMP MFG*	MOUNT BY *PUMP MFG*	MFG. *WEG*			
FRAME *444T*	POWER *150.0 hp*	RPM *1800*			
PHASE *3*	FREQUENCY *60 HZ*	VOLTS *575*			
INSULATION *F*	S.F. *1.15*				
ENCLOSURE *TEFC - PREMIUM EFFICIENCY*					

Notes and References

- MTR DIMENSIONS ARE APPROXIMATE
- ADJUSTMENT:76 mm DOWN TO INSTALL BELTS.
* Tolerance is -+6.4 mm
- ADJUSTMENT:102 mm UP TO TAKE-UP BELTS.
- FLANGE SLOTS OFF CENTER LINE.

Auxiliary Specification

V-BELT MNT BY *PUMP MFG*	V-BELT TYPE *WOOD'S SINGLE SPEED*
GUARD BY *PUMP MFG*	GUARD MATL *STEEL (OVERHEAD)*
BASEPLATE *OVERHEAD BASE - MOUNT TYPE M*	
PACKING *GRAPHITE POLYMER*	

Customer: CAC INDUSTRIAL EQUIPMENT
Serial No:
Customer P.O. No:
Item No: ITEM 001
End User: bbb
Service:

All dimensions are in mm.
Drawing is not to scale
Weights (kg) are approximate

DRAWING NO KB13-03-14 02/ITEM 001
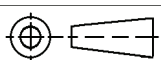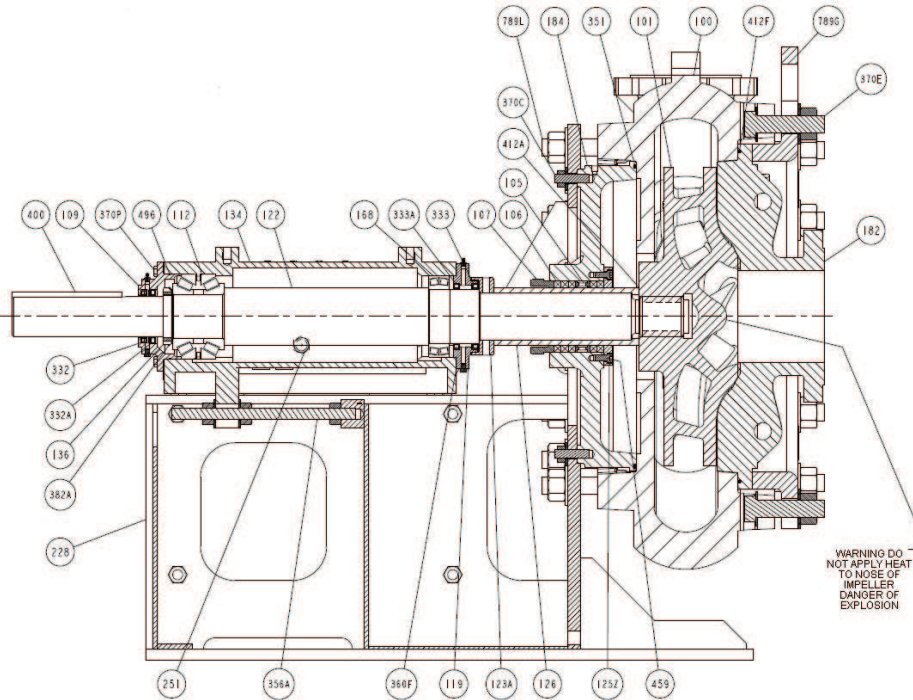
WARNING DO NOT APPLY HEAT TO NOSE OF IMPELLER DANGER OF EXPLOSION

* Recommended spare parts

\# Items not illustrated

BILL OF MATERIAL

ITEM	QTY			PART NAME	MATERIAL		ASTM#
100	1	*		CASING	28% CHR.CI	HC600	A532
101	1			IMPELLER			
105	1	*		LANTERN RING/ASSY (1 PIECE/	TEFLON-15%		
106Z	1	*		PACKING SET			
107	1	*		ASSY,GLAND	CAST IRON	CI	A48
112C	1		#	BEARING (OUTBOARD)			
113A	1			BREATHER (TOP CENTER OF B			
119B	1	*	#	COVER,END (INBOARD)			
119C	1	*	#	COVER,END (OUTBOARD)			
122	1			ASSY,SHAFT			
123Z	1	*	#	ASSY,KNOCKOFF	CARBON STEEL		A519
125Z	1			ASSY,SBOX BUSHING (MAY NO	HARDWEAR 500 AB RESIST		
126	1	*		SLEEVE,SHAFT	IR-CHRM ALLOY		A743
134C	1	*	#	HOUSING,BEARING	CAST IRON	CI	A48
136	1			LOCKNUT,BEARING			
168C	1		#	BEARING (INBOARD)			
182	1			COVER,SUCTION	28% CHR.CI	HC600	A532
184	1			COVER,STUFFING BOX	DUCTILE IRON A538 GR 80-55-06		A536
228	1	*		FRAME,BEARING	CARBON STEEL		
232C	1	*	#	V-BELT DRIVE			
240	1	*	#	MOUNT,MOTOR	CARBON STEEL		
319	2	*	#	GUAGE,OIL VIEW			
332				SEAL,OIL (OTBD/OUTSIDE)			
333				SEAL,OIL (INBD/OUTSIDE)			
351	1	*		GASKET/O-RING (CSG-SBOX C	BUNA-N		
351Z	1	*	#	GASKET SET			
353	2	*		STUD,FULL THREAD (GLAND-S	303SS		A582-91
355	2	*	#	NUT,HEX (GLAND-SBOX CVR)	303SS		A582-91
356A	1	*		STUD,FULL THREAD (IMPELLE	303SS		A582-91
360F	1		#	GASKET (INBD END CVR)	VELLUMOID		D-1170
382	1		#	LOCKWASHER,BRG			
400	1			KEY,COUPLING	CARBON STEEL		A108
402Z	4	*	#	CLAMP,BRG HOUSING	CARBON STEEL		A576
412A	1	*		GASKET (SLV-IMPLR) OR (SLV-	HYDROID VEG FBR		D1170
412F	1	*		O-RING OR GASKET (CSG-SUC	BUNA-N		
415	3	*	#	NUT,HEX HVY (IMPELLER ADJU	ZINC COATING		A153-82
496	1	*		O-RING (OTBD END COVER-BR	BUNA-N		
500	1	*	#	V-BELT GUARD/ASSY (HDWE M			
528J	2	*	#	WASHER,USS PLAIN (GLAND-S	303SS		A582-91
788Y	6	*	#	SCREW,HHC (INBD END COVE	CARBON STEEL		A307
788Z	8	*	#	SCREW,HHC (OTBD END COVE	CARBON STEEL		A307
789G	2	*		CLAMP,SUCTION COVER	CARBON STEEL		

PACKING ARRANGEMENT

DYNAMIC SEAL

BREATHER / BEARING HOUSING

OIL LEVEL

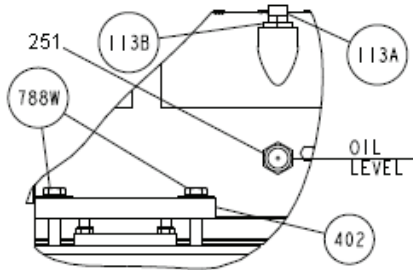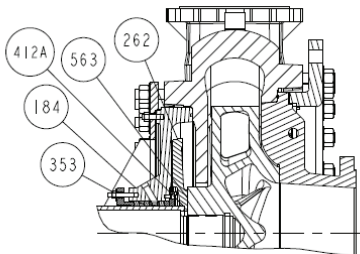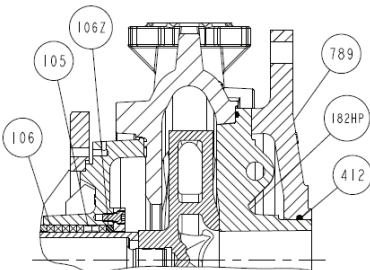### PACKING FLUSH ARRANGEMENT
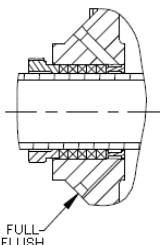
FULL FLUSH

Customer: CAC INDUSTRIAL EQUIPMENT
Serial No:
Customer P.O. No:
Item No: ITEM 001
End User: bbb
Service:

Copyright 2013 ITT Corp

DRAWING NO KB13-03-14 02/ITEM 001

Model: 5500	Size: 6x8-19	Group: B3	60Hz	RPM: 1134	Stages: 1

Job/Inq.No. :
Purchaser :   CAC INDUSTRIAL EQUIPMENT
End User: bbb   Issued by :   Kevin Bushnell
Item/Equip.No. :   ITEM 001   Quotation No. : KB13-03-14 02   Date :   03/18/2013
Service :
Order No. :   Certified By :   Rev. :   0

Operating Conditions

Pump Performance

Liquid:	Tailings	Published Efficiency:	62.5 %	Suction Specific Speed:	9,558 m³/hr,m
Temp.:	21.1 deg C	Rated Pump Efficiency:	62.5 %	Min. Hydraulic Flow:	124.60 m³/hr
S.G./Visc.:	1.300/1.000 cp	Rated Total Power:	104.8 hp	Min. Thermal Flow:	N/A
Flow:	278.00 m³/hr	Non-Overloading Power:	153.3 hp		
TDH:	50.00 m	Imp. Dia. First 1 Stg(s):	483 mm		
NPSHa:	0.00 m	NPSHr:	2.78 m		
Solid size:		Shut off Head:	50.70 m		
% Susp. Solids (by wtg):		Vapor Press:		Max. Solids Size:	63.50 mm

Notes: 1. Power and efficiency losses are not reflected on the curve below.
2. Elevated temperature effects on performance are not included.
3. Non Overloading power does not reflect v-belt losses.