Minefill 2020-2021 – Hassani et al (eds)

Review of sandfill reticulation system at northern Ontario mine

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SUMMARY: A mine in northern Ontario Canada has been in operation for several years. The mine produces 1.2 Mtpa of nickel and copper ore. The facility contains a sand plant that has been in operation for 15 years. The current sand plant combines local alluvial sands, classified tailing and reclaim tailings to produce a cemented sandfill that is sent underground via gravity.

The current underground distribution system has been expanded and modified many times throughout the history of the mine and now has a total length of several kilometers. The mine operator has concerns regarding the pressure profile and flow regime of the fill throughout the reticulation system.

This paper will provide an overview and evaluation with regards to the operation of the reticulation system as well as the flow model and layout. It will highlight the pressure trends and indicate where the system can be optimized and modernized.

Keywords: Sandfill, reticulation, pressure, underground

1 INTRODUCTION

A backfill systems reticulation design is crucial to the system's ability to transport the backfill to the desired underground destinations. As such, optimization opportunities exist in most systems to allow more efficient and safer transport underground. High pressure areas in the reticulation system can be of concern to operators and underground personnel and can be minimized through proper design and operation.

The sandfill reticulation system at a mine in northern Ontario Canada is driven by gravity. This requires that, at a minimum, the first borehole operate in slack flow to provide the required head pressure for the remainder of the pipeline. This increases the ability to push material through at the desired flowrate, with some additional height available for upset conditions. The actual reticulation geometry could be improved to allow greater amounts of slack flow from the level piping through the borehole piping.

It is not uncommon to have several boreholes within a reticulation system operating under slack flow conditions, which allows for different areas of the mine to be filled using the available head. For a borehole serving a backfill stope that is relatively close, the borehole may only be a fraction full compared to when the pour site is a further distance away. It is possible that in some instances a borehole may operate in slack flow for some pours and be filled completely for other pours. This is dependent on the geometry of the line, mix design and flowrate contributing to the system pressure.

DOI: 10.1201/9781003205906-33

The intent of this paper is to review the reticulation system and to identify problem areas and balance the geometry of the reticulation system to reduce movement in the line at flexible connections and reduce the overall wear and degradation.

2 UNDERGROUND DISTRIBUTION (RETICULATION) SYSTEM

The underground distribution system (UDS) or reticulation system is a key design consideration for the transportation of cemented backfill underground. Many factors must be taken into consideration when designing a reticulation system such as geometry, pipe size and thickness as well as couplings and instrumentation. A lot of these design consideration are based on the friction loss of the backfill material in the pipeline. To mitigate risk of high-pressure events, robust pressure monitoring is required for any UDS that transports backfill underground. This can be accomplished with pressure instrumentation that can indicate a difference in pressure when it occurs in the line. This will alert the operators that there is a possible leak or a possible blockage. Burst discs or rupture spools should be incorporated into any UDS design to allow the release of pressure from the line. If a line becomes blocked and is not cleared before the cemented material sets, then the line would have to be blasted and replaced. This is time consuming and costly.

The mining method for the northern Ontario mine is cut-and-fill with the use of cemented sandfill in the mined stopes. The mine plan calls for mining underneath the sandfill with the stipulation that a cored sample's strength is at least 1 MPa. The actual cured backfill has a strength much greater than 1 MPa (approaching 2 MPa).

The mine consists of the "upper country", the already mined and filled areas of the mine. Due to the expanse of the system the sandfill travels through these areas before it reaches the operating mining areas. 3370 level (L) is the location of the toe of the boreholes that form the "upper country" and serving the current mining areas. The toe of the boreholes leading to the 3370 L are cased and equipped with a dead leg "Kettle". The majority of the pipe in the distribution system is 5" Schedule 120 induction hardened pipe with external shoulder couplings. The boreholes are DDH holes 3.78 inches in diameter. However, there is frequent use of flexible hoses throughout the distribution network. The use of flex hoses is not ideal for high pressure lines, this was done in the past for cost and layout reasons. Ideally the flex hoses would be replaced with steel pipe.

Free fall in the boreholes is a problem in the upper parts of the mine. The creation of vacuum in the boreholes has been the cause of damage to the reticulation system in the past and results in violent shaking of the line downstream of the borehole toe. In order to remediate this, different apparatii have be used in order to break the vacuum, with more or less success (gate valve, ball valve). Several boreholes are in an advanced stage of degradation, which has led to some big pieces of rock being found in the fill. This will need to be addressed immediately. It is recommended that new cased boreholes be drilled if the current boreholes cannot be repaired to the proper standards.

There are a pressure transducer and a flow meter on each of the two sandfill lines on 3370 L. However, this is the only place where such instruments are located. To better reduce risk the mine should install a greater number of transducers. As well the current pressure transducers could be better positioned at the top of the pipe i.e. 12 o'clock. All of the diverter valves used in the reticulation system are manually operated with no instrumentation present. It is recommended that these valves be modified to be automatic. This would reduce the requirements of the operators.

3 SANDFILL PLANT

The backfill consists of cement, sand and classified tailings that are blended as dry materials by a front-end loader and transported to the mixing tank via a conveyor. The ratio for backfill materials (loader buckets) is two reclaimed tailings, one operation mill classified tailings, and two alluvial sand. These proportions had been used since October 2018. There is no time weighting on the dry material belt and maintaining the correct proportions relies on the loader operator filling the main bin. Once a month, a "belt cut" is manually done in order to validate the feed rate. A tramp screen is in place in order to reject the lumps and oversize material. Typical operations produce 1200-1500 tons per day (tpd) of backfill. This is based on an 8-hour day of pouring. The plant consists of a “twin” system. However, one of them is not operational and has not been used for quite some time.

A three-inch orifice plate is used on top of the boreholes to better control the flow into the reticulation system. The plates must be changed once a week due to rapid wear. There is a “breather” on top of the boreholes, which must be opened more and more as the plate starts to deteriorate.

4 FLOW MODELLING

Three separate iterations of the flow model have been done for the reticulation system. The original geometry data that was provided was remodelled in a standard template with current friction loss estimates. This allowed the model to demonstrate the current state of the system and identify potential problem areas. Two modified flow models were subsequently completed to demonstrate how potential modifications could impact and benefit the system. The two modified flow models use different friction loss data, one from 2012 and the other from 2019.

Table 1 shows the current layout of the reticulation system from surface through the “upper country” to the lower areas of the mine. As a note, the level naming convention at this mine is in feet of elevation and study is metric. The flow model shows that there are several instances

Table 1. Current flow model data.

Node	Vertical distance (m)	Pipe or b/h length (m)	Pressure Loss		Available Head		Pressure	
			Start (kPa)	End (kPa)	Start (kPa)	End (kPa)	Start (kPa)	End (kPa)
1 (Surface)	209	211	7734	7102	21406	17664	0	0
2	3	9	7102	7088	17664	17615	0	0
3	73	91	7088	6814	17615	16305	free fall	6
4	5	55	6814	6727	16305	16223	6	0
5	50	50	6727	6577	16223	15328	0	0
6	5	51	6577	6495	15328	15246	0	0
7	109	119	6495	6138	15246	13287	free fall	270
8	6	237	6138	5758	13287	13177	270	0
9	130	130	5758	5369	13177	10852	0	0
10	3	20	5369	5337	10852	10803	0	0
11	71	71	5337	5294	10803	9536	0	0
12	8	8	5294	5281	9536	9400	0	0
13	146	146	5281	4842	9400	6780	free fall	106
14	5	118	4842	4654	6780	6698	106	0
15	129	129	4654	4267	6698	4394	free fall	23
16	3	5	4267	4260	4394	4334	23	76
17	56	57	4260	4226	4334	3330	76	1046
18	5	31	4226	4175	3330	3242	1046	1083
19	1	610	4175	3200	3242	3221	1083	129
20	9	180	3200	2913	3221	3062	129	0
21	125	899	2913	1474	3062	830	free fall	644
22	-13	196	1474	1161	830	1064	644	96
23	32	32	1161	1077	1064	486	96	591
24	1	145	1077	643	486	461	591	181
25	16	17	643	632	461	175	181	458
26	10	71	632	421	175	0	458	421
End	0	140	421	0	0	0	421	0
	Total	**3827**						

Source: Review of Sandfill Reticulation System at Northern Ontario Mine.

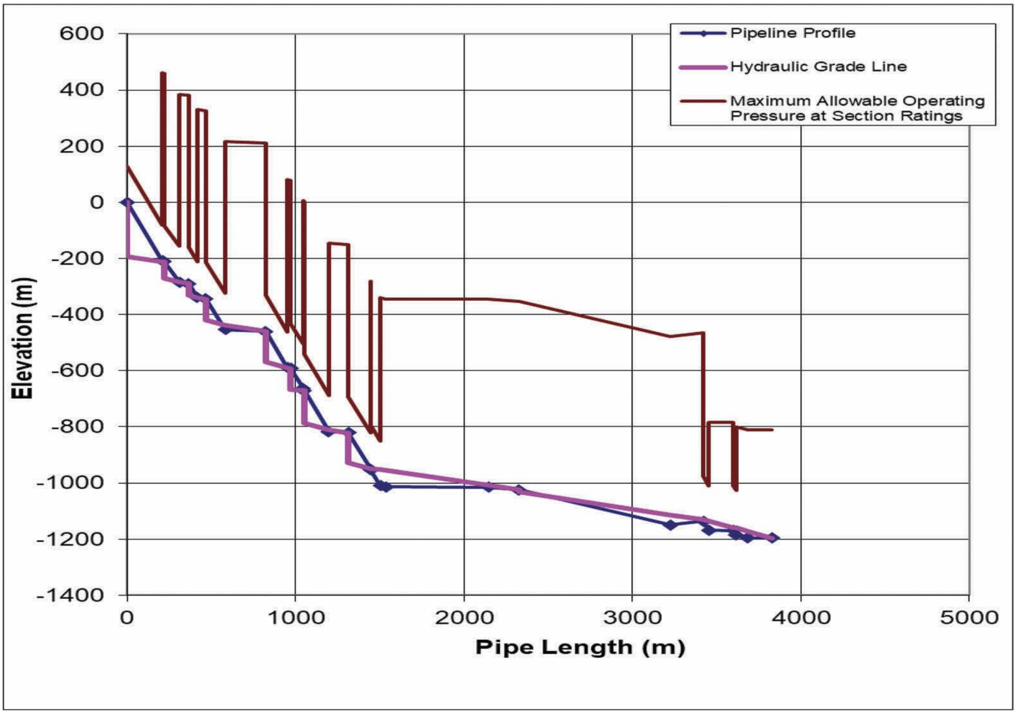

Figure 1. Flow model of the current state of the reticulation system.
Source: Review of Sandfill Reticulation System at Northern Ontario Mine Golder Associates, Canada 2019.

where the pipeline operates in slack flow for substantial portions of the pipeline. This is also graphically represented in Figure 1. This large portion of slack flow is expected since the system has a substantial amount of elevation change through boreholes with little horizontal piping to balance it by adding backpressure through friction losses in the line.

In short, the flow model can be adjusted several different ways to achieve a more stable process. At this stage in the lifecycle of the operation there is a fixed specific recipe and throughput tonnage which leaves modification of the piping as one of the sole options to remedy the issues.

Table 2 shows the same flow model with several lengths of horizontal level piping elongated (edited values highlighted red). These horizontal lengths correspond to locations following boreholes.

By elongating those sections, changes to pipeline pressure as calculated through the system are realized and the result is a reticulation system that regains control of material flow at the bottom of each borehole where a jog occurs. What is also realized is the modification of the impact zone location from the free fall. The goal is to relocate the impact zone into the borehole, shortening the free fall distance and moving the impact away from the downstream piping which alternatively will require significant mechanical restraint.

These horizontal lengths would be added as control loops to the current system, where the operator installs additional piping that extends past the downstream target borehole and loops back to return and hit the borehole.

Table 2. Modified flow model data.

Node	Vertical distance (m)	Pipe or b/h length (m)	Pressure Loss Start (kPa)	Pressure Loss End (kPa)	Available Head Start (kPa)	Available Head End (kPa)	Pressure Start (kPa)	Pressure End (kPa)
1 (Surface)	209	211	10384	9584	21406	17664	free fall	318
2	3	209	9584	9216	17664	17615	318	0
3	73	91	9216	8870	17615	16305	free fall	191
4	5	155	8870	8597	16305	16223	191	0
5	50	50	8597	8407	16223	15328	free fall	201
6	5	161	8407	8124	15328	15246	201	0
7	109	119	8124	7671	15246	13287	free fall	308
8	6	237	7671	7254	13287	13177	308	0
9	130	130	7254	6761	13177	10852	free fall	197
10	3	140	6761	6515	10852	10803	197	0
11	71	71	6515	6482	10803	9536	0	0
12	8	8	6482	6468	9536	9400	0	0
13	146	146	6468	5912	9400	6780	free fall	214
14	5	168	5912	5617	6780	6698	214	0
15	129	129	5617	5127	6698	4394	free fall	733
16	3	5	5127	5119	4394	4334	733	785
17	56	57	5119	5093	4334	3330	785	1763
18	5	131	5093	4863	3330	3242	1763	1620
19	1	610	4863	3791	3242	3221	1620	570
20	9	180	3791	3475	3221	3062	570	413
21	125	899	3475	1894	3062	830	413	1064
22	-13	196	1894	1550	830	1064	1064	485
23	32	32	1550	1444	1064	486	485	959
24	1	145	1444	859	486	461	959	398
25	16	17	859	852	461	175	398	677
26	10	71	852	567	175	0	677	567
End	0	140	567	0	0	0	567	0
	Total	**4507**						

Source: Review of Sandfill Reticulation System at Northern Ontario Mine.

5 RETICULATION SYSTEM DESIGN RECOMMENDATIONS

The original model showed areas in the reticulation system that were in freefall for multiple consecutive boreholes and short sections of 'level pipe' that connected two boreholes.

The redesign focused on eliminating freefall in large sections of the pipeline and minimizing it to select boreholes that would operate in slack flow and have subsequent boreholes filled to maintain order in the system. This results in greatly reducing pressure spikes formed from material exiting completely empty boreholes with no resistance which is hard on the downstream piping and pipe supports to regain control of the mass of backfill. There have been instances, during operation, of flexible piping near borehole bottoms shaking violently during operation due to that phenomenon, this addition of piping would be one solution to that problem.

Other recommendations include locating pressure transmitters away from the bottom of the borehole as the system currently operates. The best practice to ensure the system works at optimum efficiency is to ensure the pipeline is full on the levels when backfilling. This eliminates shocks delivered to instrumentation as material rockets through horizontal piping which can damage the diaphragm.

It is also recommended that two transmitters be located a known distance apart on a straight length of pipe (approx. 300ft) to capture friction loss data of their backfill material

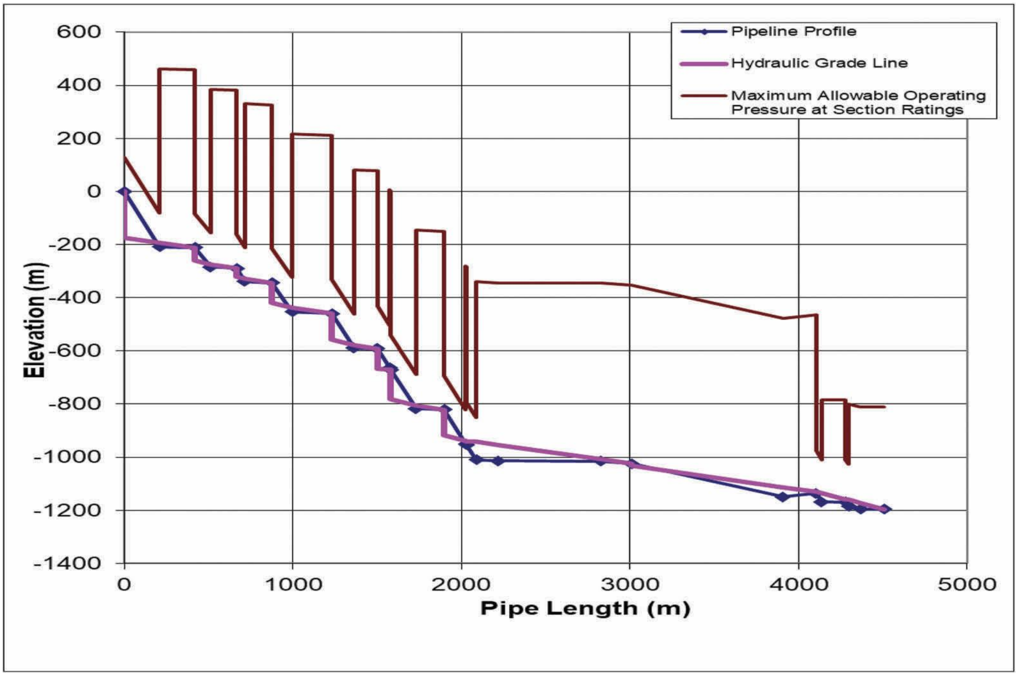

Figure 2. Modified Flow model the reticulation system (2012 Friction Factor).
Source: Review of Sandfill Reticulation System at Northern Ontario Mine Golder Associates, Canada 2019.

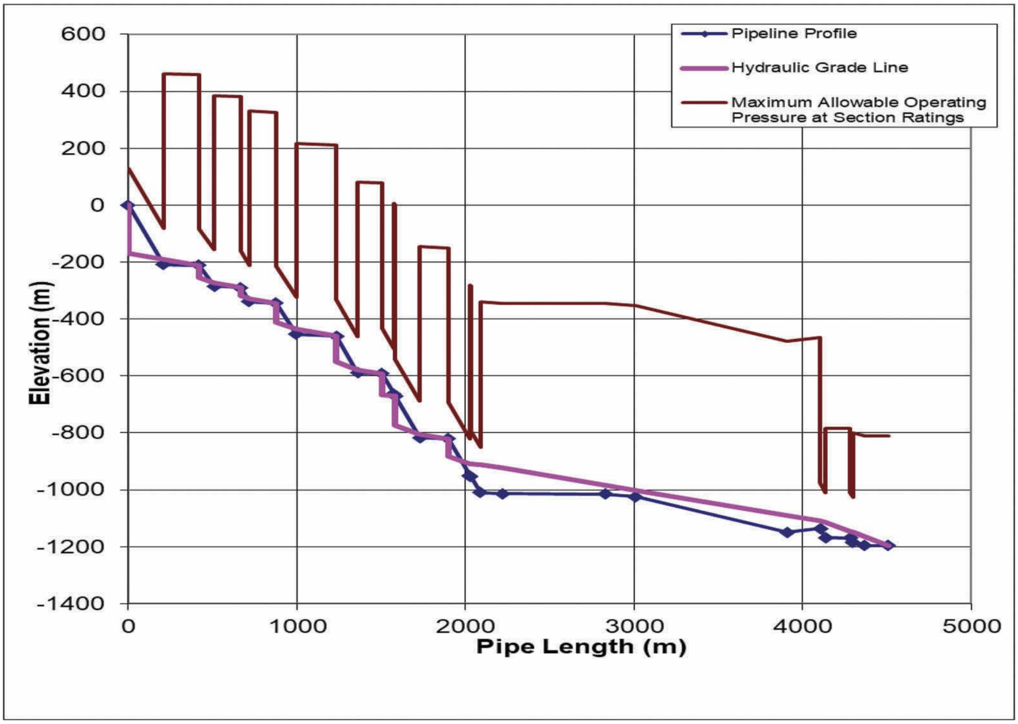

Figure 3. Modified Flow model the reticulation system (2019 Friction Factor).
Source: Review of Sandfill Reticulation System at Northern Ontario Mine Golder Associates, Canada 2019.

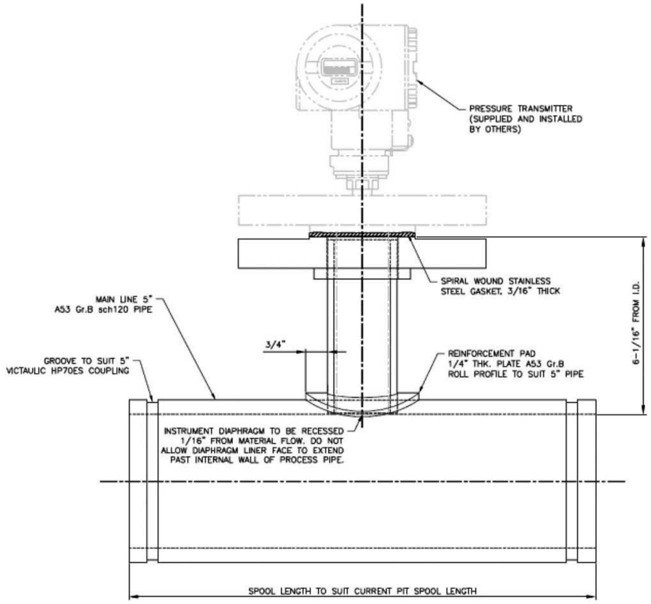

Figure 4. Typical Pressure Monitoring Arrangement.

Source: Review of Sandfill Reticulation System at Northern Ontario Mine Golder Associates, Canada 2019.

which will aid in further tuning of the system to attenuate issues, by inputting real time data into the model.

The use rubber flex hose in the reticulation system can be acceptable, so long as the borehole is sufficiently full, allowing the backfill to exit the borehole in a controlled manner. Operating with a nearly empty borehole causes a lot of movement in the hose and is a potential operation and health and safety risk

Ultimately it is recommended that preliminary efforts be undertaken to elongate the horizontal piping at specific chronic problem areas to demonstrate that the symptoms are attenuated and validate the model and the theory.

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