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BELT ROAD SEGREGATION AND ESCAPEWAYS - COMPLIANCE OR RISK MANAGEMENT?

Martin Olsen

ABSTRACT: Segregation of conveyor roadways is a ventilation practice that is being increasingly applied in Australia. It is largely driven by the legislated requirements in Queensland pertaining to separation of escape ways from the mine. This legal requirement was based on a recommendation from the Moura No. 2 Wardens Inquiry into the mine disaster that claimed 11 lives. The report recommended "the introduction of a requirement for all underground mines to have one intake airway that is completely segregated from other parallel intake airways so as to provide two separate means of egress from the mine via an intake airway". This recommendation seeks to assist mineworkers to escape from a mine after a fire by providing them with an airway that is free from smoke or contaminants. The concept of an airway being "completely segregated" is an ideal that is challenging to implement in practice when considering the effect of leakage. The practice of belt segregation is concerned with the potential for fires in the belt roadway although there are numerous other potential fire sources in underground coal mines. A review of segregation practices has been conducted applying ventilation engineering principles. Four different scenarios have been analysed with regard to the effectiveness of the segregation stoppings in preventing potential fire contaminants migrating to other parts of the mine. The results show that in some cases the benefits of segregation to a person evacuating a mine in the event of a fire range from beneficial to detrimental. This is influenced by many factors including the location of that individual in that particular mine. There is room for improvement in the design and implementation of escape ways in underground coal mines. Escape ways need to be planned and designated with regard to the potential sources of fire, pressure differentials between escape ways and the operational practicalities of maintaining the pressure differential between them.

INTRODUCTION

The term "segregation" is used widely in the Australian underground coal industry today but this term cannot be found in any legislation relating to underground coal mining. The intent of this paper is to identify the origins, reason and purpose for segregation and also to assess its practical effectiveness. It is worth noting that this paper is focused on the modelling of contaminants from fires on main conveyors and that there are other types of mine fires or "reasonably foreseeable events" that can cause the intakes of a mine to become contaminated. The reason for this is in response to the industry practice of belt road segregation as means of mitigating the risks to underground personnel in the event of a belt fire.

Maintaining separated intake escapeways is a legal requirement in Queensland and one that is often complied with by segregation of the main belt road from the main travel road. Mines inspectors ensure compliance with the legislation by enforcing the segregation of the belt road at individual sites by issuing directives to bring the segregation into compliance. For the mining operation the segregation of the belt road is often a nuisance as it limits access to the belt road. It can be a headache for the ventilation officer to control and maintain as there is often operational requirements to breach the segregation stoppings for access purposes.

Mining operation invest considerable amounts of time and money in the installation and maintenance of these ventilation control devices. It is important that they are serving a purpose and reducing the risk to underground personnel. If they are not, then they are a waste of time and money and are providing a false sense of security to underground personnel and management at the mine.

HISTORY IN AUSTRALIA

The legal requirement for belt segregation started in the Queensland coal mining legislation in the 1970s. The Queensland Coal Mining Act 1925-1981 General Rules for Underground Coal Mines (Queensland Government 1981) rr. 4.2 stated:

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"(1) In an underground coal mine other than a mine existing at 1st July, 1978, provisioning shall be made for an intake airway other than a roadway containing a belt conveyor. This requirement shall apply to any part of such mine other than a panel or sub-panel where the method of working limits the number of roadways to less than three: Provided that in the initial development of a new mine the belt conveyor roadway may serve as the only intake airway for such time as is reasonably required to provide a second intake roadway.

(2) All belt conveyor roadways shall be segregated from other intake airways and from return airways".

This rule was very specific about what was required and when it was required.

The current legislation in Queensland does not call for belt segregation. Section 296 of the Coal Mining Safety and Health Regulation 2001(Queensland Government, 2001) calls for two intake escapeways to be established that are separated in a way to prevent any reasonably foreseeable event happening in one of the escapeways affecting the ability of persons to escape through the other escapeway. In Schedule 4 - Ventilation control devices and design criteria, the stoppings used for establishing separation are specified as being of substantial construction with no overpressure rating. This section of the regulations came about in response to a recommendation on p67 of the Wardens Inquiry Report for the Moura No. 2 Mine Explosion, which called for: "the introduction of a requirement for all underground mines to have one intake airway that is completely segregated from other parallel intake airways so as to provide two separate means of egress from the mine via an intake airway".

Despite the change in legal requirement the practice of belt segregation is often used to achieve the requirement for two intake escapeways.

It is also worth noting that s296 of the CMS and HR 2001 is part of Division 4 of Part 9 which deals with mine design and that it is an obligation of the Site Senior Executive and not the Ventilation Officer to ensure that this is in place. The Ventilation Officer is however usually tasked with the responsibility of ensuring this is compliant. This responsibility is often begrudgingly accepted, as it is a constraint that is in some cases a hindrance to the ventilation of the mine. It is not surprising then that the separation of escapeways is not planned and modeled to the same extent as the ventilation of production panels.

The Queensland Mines Inspectorate issued a Safety Bulletin titled, "Lessons of mine segregation must be applied" (Taylor, 2008). This Safety Bulletin explains the legislated requirements and the origin of these requirements. It also warns operations that non-compliance with this requirement will result in a directive to suspend operations being issued under section 167 of the Coal Mining Safety and Health Act 1999 (Queensland Government, 1999).

In NSW there is no requirement for two escapeways in intake air. Some mines have implemented a separate escapeway in intake air to part of the mine. The legal requirement for escapeways or means of egress is in cl 45 of the NSW Coal Mine Health and Safety Regulation 2006 (NSW Government, 2006)

(b) (iv) at least 2 means of egress from each production area or other part of the mine to the surface part of the mine so that, in the event of any roadway becoming impassable, another is always available,

INTERNATIONAL PRACTICE

USA

The United Sates has very prescriptive requirements on segregation of conveyor roadways. The principle that is applied is that no air from a conveyor roadway is allowed to ventilate a working face. Leakage through ventilation control devices is included in this requirement and results in the practice of ensuring the pressure in the conveyor roadway is always less that the pressure in the travel road. This is achieved in practice by the routine placement of regulators in the conveyor roadway and overcasts where necessary to dump conveyor roadway air to the return airway.

These requirements come from § 75.350 of the Title 30 Code of Federal Regulations (30 CFR) (Federal Government of USA, 2008), which include the following:

(a) The belt air course must not be used as a return air course; and except as provided in paragraph (b) of this section, the belt air course must not be used to provide air to working sections or to areas where mechanized mining equipment is being installed or removed.

(1) The belt air course must be separated with permanent ventilation controls from return air courses and from other intake air courses except as provided in paragraph (c) of this section.

The double fatality at the Aracoma Alma No. 1 Mine in 2006 after a conveyor fire filled the primary escapeway of a working section with thick smoke increased the focus placed on this section of the 30 CFR by MSHA.

South Africa

In South Africa the Regulations under section 98 of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996) call for two means of egress from the mine (Government of South Africa, 1996). There is no requirement for the provision of two separate intake airways or for the segregation of belt roadways from intake air. The safety systems for dealing with mine fires rely on:

- Emergency lifelines
- Establishing refuge chambers with borehole to the surface and small fan for fresh air supply
- Capacity to ream out refuge chamber boreholes for evacuation of personnel

United Kingdom

The UK contains similar legislative requirements to those required under the Queensland legislation but contains some more clarity on when the requirements are applicable. The Mines (Safety of Exit) Regulations 1988 Regulation 9 (Government of the United Kindom, 1998) states the following:

Intake airways
9. The manager shall ensure that, apart from those persons who are going to or leaving their place of work at the beginning or end of a shift, not more than 50 persons are employed below ground in any part of the mine unless;
(a) there are two separate intake airways into that part of the mine which are connected only in such a way that in the event of a fire, transmission of the products of combustion from one airway to the other is prevented so far as is reasonably practicable; or
(b) there is one intake airway which is constructed of suitable fire resistant materials and is free, so far as is reasonably practicable, from the risk of fire.

In addition to this regulation there is a requirement for at least two means of egress to the surface, ie. an intake and a return.

DIFFERENT SCHOOLS OF THOUGHT

From looking at the different segregation practices used locally and around the world several different concepts emerge. These may not be immediately clear so they are listed below:

1. No segregation of intake roadways
2. Segregation of the belt to prevent belt fire contaminants entering intake roadways
3. Segregation of the belt to prevent belt fire contaminants entering working faces
4. Provision of a separated intake airway for use as an escapeway

These four different approaches all have advantages and disadvantages and different levels of complexity with regard to implementation.

It is important to understand what is trying to be achieved before an appropriate arrangement can be adopted. Too often, it seems, segregation stoppings are installed purely from a compliance standpoint with little understanding or interest in the purpose or effectiveness.

MINE SCENARIOS

For the purpose of analysis of belt segregation four different mine layouts were used to model the effectiveness of the segregation. The first scenario, called Case 0 is a conceptual model and does not represent the workings of an actual mine. This was used so that any ventilation layouts and analysis results could be published without concern for confidentiality. The other three scenarios, called Case 1, Case 2 and Case 3 are based on the ventilation models from actual longwall coal mines in Queensland, Australia. For the purposes of confidentiality only the analysis results are published.

Methodology

Pressures

Pressure gradient plots were generated for each scenario. These display the relative static pressure in the mine roadway from the surface intake to the longwall and along the return back to the main fans. The belt road pressure gradient was also plotted. The pressure gradients of any additional separated intake roadways were also plotted.

Contaminant test

A 100 ppm contamination was placed into the model inside the belt portal and then modeled to see where the contaminant would migrate throughout the mine. This test was applied to each of the scenarios and the results recorded. The models were then modified with all the segregation stoppings in the mine removed and the same 100 ppm contamination test reapplied. This allowed the two results for the same mine to be compared. One set of results with segregation stoppings in place and one with the segregation stopping removed. This was used so the effectiveness of the segregation stoppings of the scenario could be measured. It is important to note that the numerical value of the contamination concentration in the results table in only relevant with respect to the 100 ppm contaminant that was used for the test. It is primarily for comparison between models and between segregation and no segregation. For example, a 20 ppm contamination in a primary escapeway may appear to be acceptable until you consider that if the contamination at the belt portal was 1000 ppm then the concentration in the escapeway would be 200 ppm. Table 1 displays the model results for each scenario with the segregation stoppings in place and also with the segregation stoppings removed.

Table 1 - Contamination test - Modelled segregation stopping effectiveness

	Modeled Number of Segregation Stoppings	Modeled Contaminant Concentration (ppm)					
		Belt Portal	LW face	Mains	Dev 1	Dev 2	Primary Escapeway Maximum
Case 0	157	100	14	76	16	14	18 or 4*
	0	100	31	28	30	27	33 or27*
Case 1	203	100	7	30	25	0	31
	0	100	17	22	21	1	22
Case 2	106	100	53	15	1	1	6
	0	100	53	1	7	0	31
Case 3	64	100	21	44	29	44	26
	0	100	22	26	24	25	29

* Depending on which heading is classified the Primary Escapeway

The purpose of this test is to measure the effectiveness of segregation stoppings to reduce the spread of contaminants to other parts of the mine. No consideration has been given to the dynamic nature of a fire, the buoyancy and pressure differentials that are possible from an active fire.

Case 0

The ventilation layout for Case 0 is shown in Figure 1. This fictitious mine consists of seven heading mains, 3 headings with flanking returns and a segregated belt road in the middle heading. As the mine does not exist there is not a designated primary escapeway. There are two results for the contaminant test for the primary escapeway shown in Table 1 depending on which set of intake roadways is adopted as the primary escapeway. The results show that with the 157 segregation stoppings in place the contaminant is directed predominantly into the mains development area with a concentration of 76 ppm. The other three panels (including LW) modeled a contamination around 15 ppm. The greatest benefit modelled with this arrangement of segregation was the contaminant concentration of 4 ppm adjacent to the 76 ppm in the mains. The 4 ppm result came from the single intake airway to the left of the middle heading belt road in Figure 1.

The reason for the relatively low level of contamination can be seen in the pressure gradient plot for Case 0 in Figure 2. The heading that returned the result of 4 ppm is referred to in Figure 2 as "Primary". This heading for the most part sat at a higher static pressure than the surrounding roads particularly the belt road where the contaminant was concentrated. This resulted in leakage paths flowing away from this "Primary" heading. The instances where the static pressure in this roadway drops below the belt road is due to the placement of segregated belt underpasses that were put into the model to allow for transport movements (operational requirement) and balancing of the intake airway pressures. It is this balancing that has caused the drop in static pressure to below that of the belt road in some instances. This could be mitigated in practice by the installation of machine doors at the segregated underpasses. The results in Table 1 also show that by removing all segregation from the model all inbye areas of the mine received similar contaminant concentrations of around 30 ppm. This includes all working faces and escapeways.

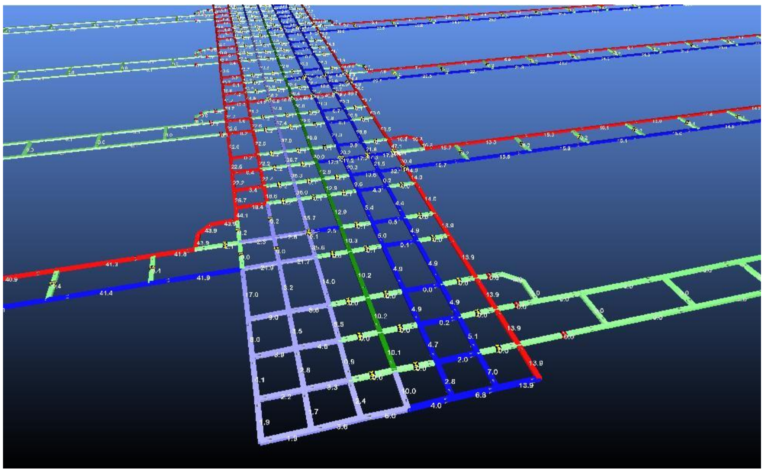

Figure 1 - Case 0 – ventilation layout

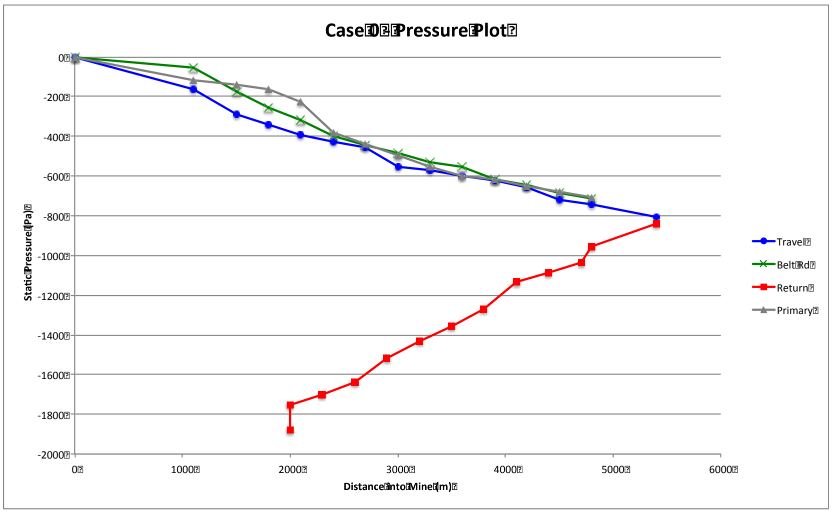

Figure 2 - Case 0 – pressure plot

Case 1

Case 1 is based on a longwall mine in the Bowen Basin in Queensland, Australia. The trunk conveyor of the mine is segregated on both sides from the surrounding intakes with 203 segregation stoppings. The primary escapeway of the mine is the main travel road. The contaminant test in Table 1 shows some very interesting and unexpected results. The highest contaminant results with the segregation stoppings in place were 31 ppm in the primary escapeway, 30 ppm in the mains development panel and 25 ppm in one of the gateroads. Without the segregation stoppings in place the most significant result was the reduction of contaminant in the primary escapeway by 30% down to 22 ppm. The longwall result increased from 7 ppm to 17 ppm without the segregation stoppings in place and the mains development and one of the gateroads both had reductions in the level of contaminant. As expected, the contaminant was more spread out and diluted without the segregation stoppings and more concentrated in particular areas.

The pressure gradient plot for Case 1 in Figure 3 shows the belt road at a higher pressure than the primary escapeway most of the time. The first 1000 m the primary escapeway and the belt are in separate drifts so the leakage would be almost non-existent. The time where the primary escapeway sits above the belt road in static pressure around the 2000 m mark is due to a significant reduction in the number of main headings which causes the static pressure of primary escapeway to peak in this area. It is possible to see that the general pressure gradient trend of the segregated belt road is flatter than that of the primary escapeway causing the belt road to be at a higher static pressure than the primary escapeway. This results in the leakage of contaminant into the primary escapeway in the event of a belt fire. This scenario had 17 vehicle doors positioned along the trunk belt system. This highlights the need for vehicle and personnel access to the belt road and subsequent issues with quality of stoppings and leakage.

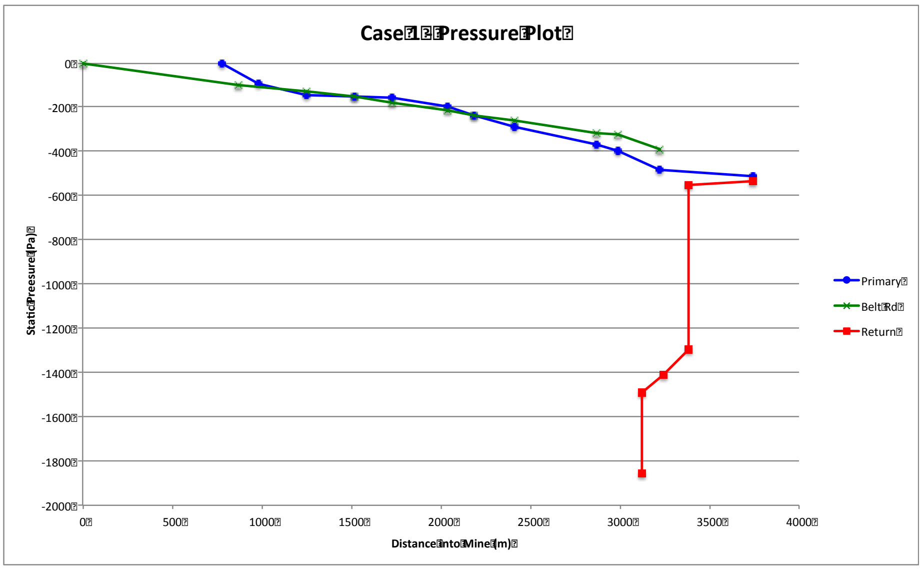

Figure 3 - Case 1 – pressure plot

Case 2

Case 2 is based on a longwall mine in the Bowen Basin in Queensland, Australia. The trunk conveyor of the mine is generally segregated on both sides from the surrounding intakes with 106 segregation stoppings. The primary escapeway of the mine is the main travel road. This scenario involved the most elaborate layout for segregation of the belt road of all the scenarios analysed. Table 1 shows that the contaminant result for the longwall face is 53 ppm regardless of whether the segregation stoppings are in place or not. The mains development panel showed a reduction of 15 ppm to 1 ppm with the removal of the segregation stoppings and another development panel showed a rise from 1 ppm to 7 ppm. The primary escapeway however showed a significant increase from 6 ppm to 31 ppm with the removal of the segregation stoppings. The pressure gradient plot for Case 2 shown in Figure 4 shows the extent that this particular operation has gone to get the pressure in the belt road to below the pressure in the primary escapeway (travel road).

The step in the pressure gradient for the belt road at the 2000 m mark is due to the placement of a regulator and an air dump in the belt road. This does a good job to reduce the pressure of the belt road and largely prevents leakage of the contaminant into the primary escapeway. The infrequent instances when the belt road has a higher static pressure than the adjacent primary escapeway results in the low result of 6 ppm. The air dump directs air out of the belt road into adjacent intake roadways. It is this air that is directed to the longwall and this is the reason for the 53 ppm result for the longwall face.

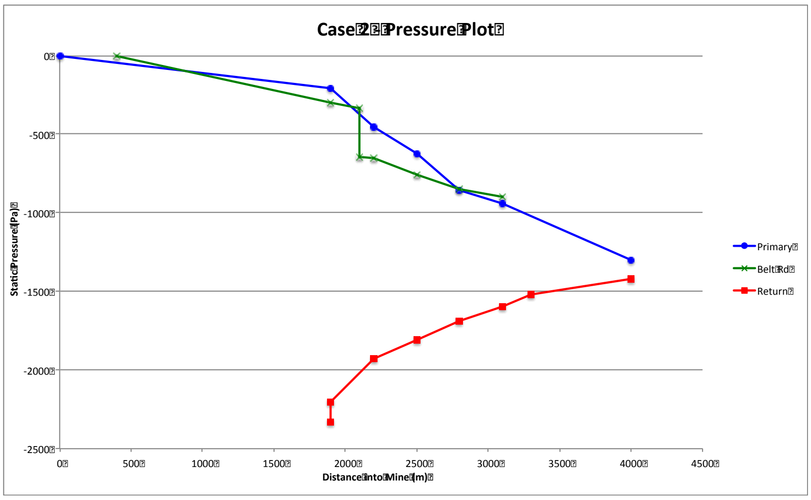

Figure 4 - Case 2 – pressure plot

Case 3

Case 3 is based on a longwall mine in the Bowen Basin in Queensland, Australia. The trunk conveyor of the mine is generally segregated on both sides from the surrounding intakes with 64 segregation stoppings. The primary escapeway of the mine is a roadway separate from the main travel road and on the other side of the trunk conveyor. This scenario initially showed the most promise for having a simple design and maintaining a primary escapeway at a pressure above the adjacent belt road. The pressure gradient plot in Figure 5 shows that this is not the case. The belt road is generally at a greater static pressure than the adjacent primary escapeway. This is reflected in the results in Table 1 with arguable better results achieved with the segregation stoppings removed from the model. The primary escapeway showed an increase in contaminant concentration from 26 ppm to 29 ppm with the segregation stoppings removed.

There are two ways this scenario could be dramatically improved. The primary escapeway loses significant pressure early in the mains due to a segregated belt underpass. This allows air to travel from the primary escapeway to the travel road. This could be easily corrected with the installation of a vehicle door. Additionally there is a 200 Pa pressure drop in the belt road around the 2500 m mark. This is due to a high resistance Ventilation Control Device (VCD) located in the belt road. This VCD would have very likely been installed to achieve compliance with belt segregation. The result is an increase in the static pressure of the belt road and the increased level of contamination of the primary escapeway in the event of a belt fire. In fact the primary escapeway suffers less contamination if this VCD is removed from the model. This is a good example of where compliance does not necessarily result in lower risk.

CONCLUSIONS

A line of stoppings will not prevent contaminants from a belt fire entering a primary escapeway if the belt road is at a higher static pressure than the primary escapeway. For the examples analysed, segregation of the belt road from all other roadways usually resulted in the belt road being at a higher pressure than surrounding intake airways.

Consideration needs to be given to the static pressure differential between separated escapeways. The only way to ensure that a contaminant does not enter the primary escapeway is to ventilate the mine such that the primary escapeway is generally at a higher pressure than the surround roadways. Ideally the primary escapeway should have the highest static pressure of any adjacent roadways.

Consideration should be given to establishing primary escapeways that are not the main travel road in the mine. This will allow for the following:

- Provide a primary escapeway for the full length of the main headings free from contaminants in the event of a fire in the belt road or travel road
- To better meet the requirements of s298 of the Qld CMS and H Reg 2001 for primary escapeways. Specifically "As far as practicable, free from the risk of fire"
- Ease of access to the belt road and less issues with damaged stoppings or leaking vehicle doors
- Improve early detection of heatings and small fires(ie. via smell)

Consideration should be given to putting more focus on reducing the level of risk to personnel than just being compliant. There are several examples from the modelling conducted where compliance is achieved but a more hazardous result is also achieved.

Based on the modelling work conducted the following observations have been made:

- In the event of a belt fire, segregation of the conveyor roadway will result in the smoke generated by the fire being concentrated in particular areas of the mine. This will usually be the mains but may be elsewhere, eg. Case 2 where the contaminant showed up greatest at the longwall face

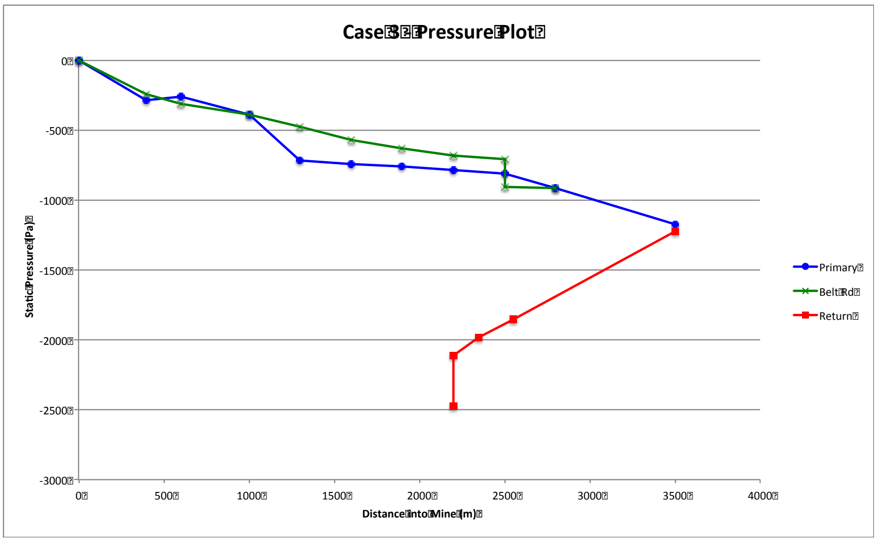

Figure 5 - Case 3 – pressure plot

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