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Technical Planning of Ventilation System to Support Development W Undercut in 2021 at PT. Freeport Indonesia Underground Mining

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Abstract

Ventilation is an attempt to drain clean air into the mine and remove dirty air out of the mine. The main components of a mine ventilation system are intake, working, and exhaust. Intake is a tunnel and wells system where air flows from the surface into the mine. The purpose of the ventilation system in an underground mine is to provide and drain clean air into the mine for breathing and comfort of mine workers. Based on the Ventilation Design Criteria used by PTFI, the minimum airflow level required for every mine worker is 0.033 m3 / s / worker. Based on PTFI Ventilation Design Criteria, the minimum level in diluting smoke of heavy equipment diesel engine is 5 m3 / min or 0.08 m3 / s / kW. PT Freeport Indonesia is currently developing new underground mines namely Grasberg Block Caving (GBC) and Deep Mill Level Zone (DMLZ) which will be mined using the block caving method.

1. Introduction

Mine ventilation is the application of the principle of fluid mechanics which enters airflow into the mine pit, as the main tool responsible for air circulation both in number and direction throughout the mine [1]. Meanwhile, according to Malcolm McPherson, ventilation in underground mines will provide sufficient airflow both in quantity and quality to reduce bad air contamination to better conditions in all mining areas [2]. In the planning of development W Undercut, ventilation planning is also needed. This is because the development engineer's plans cannot be worked out if the air is insufficient. Therefore, for development planning, both short-term or long- term ventilation planning, will be followed for the same period. To provide a sufficient quantity of fresh air then drain and divide the fresh air to the desired levels through Drift or Raise using a fan and ventilation control system. So, it will create safe and comfortable working conditions for mine workers.

DMLZ ventilation system is currently operated and evolved under the continuous mine development process. The current supply of intake air is for intake access from Intake # 1 raise from DOZ, Intake # 2 raise from DOZ, Intake # 4 raise from DOZ, DMLZ spur, and conveyor access. Whereas for exhaust air use the Exhaust main fan on NED # 3 as DMLZ main fan # 1 and the fan on NED # 4 as DMLZ main fan # 2 and NED # 5 as DMLZ main fan # 3. Besides, there are also some auxiliary fans to help in draining clean air towards active headings and regulating the direction of dirty airflow to the surface.

The purpose of this research is to analyze the number of air requirements for the development of W Undercut, analyze Resistance and Head Loss to model the ventilation system in W Undercut using Ventilation software.

2. Literature review

2.1. The air need for human

Every work activity carried out by humans requires different air requirements. The respiratory rate will be different for each human activity. The harder the work done, the greater of respiratory rate. [3]. This respiratory rate is related to the amount of oxygen in the work environment. Lack of oxygen will disrupt

the respiratory rate. The physiological effects of this oxygen deprivation vary, among others, if the oxygen content is 17%, the respiratory rate will increase, 15% will feel dizzy, 13% will lose consciousness, and the most severe is convulsions to death if the oxygen content is 6% [4].

2.2. Resistance series of mine ventilation

There are two types of resistance calculations in Airflow Systems used in underground mining, namely:

2.2.1. Series ventilation

R_{eq} = Equivalent resistance of a series network is the sum of all resistances of each airway. So the general equation: Eq (1)

$$R_{ser} = R_1 + R_2 + R_3 + \cdots$$

Note:

Rser = series circuit

R_1, R_2, R_3, = series 1 and so on

2.2.2. Parallel ventilation.

In mine ventilation, this practice is called partition and branching. There are two forms of separation, including natural separation which occurs when air quantity is divided between parallel branches by itself without regulation. And controlled separation occurs when the specified quantity of air is drained through each of the parallel branches by regulation. According to Kirchhoff's first law, a general equation can be written as follows: Eq (2)

$$Q_{tot} = Q_1 + Q_2 + Q_3 + \cdots$$

Note:

Q_{tot} = total air debit

Q_1, Q_2, Q_3 = air debit at the branching

So when the airways are arranged in parallel type, the total amount of airflow is the sum of air flowing through individual airways. According to Kirchhoff's second law, it shows that the head losses for parallel airways are the same. Eq (3)

$$HL = H_1 = H_2 = H_3 = \cdots$$

Note:

HL = Total Head Loss

H_1, H_2, H_3, …. = Head loss in branching

When the airways and others are arranged in parallel type, the resistance equation can be calculated by Eq (4)

$$\frac{1}{\sqrt{R_{par}}} = \frac{1}{\sqrt{R_1}} + \frac{1}{\sqrt{R_2}} + \ldots + \frac{1}{\sqrt{R_n}}$$

Note :

R_{par} = parallel air resistance

R_1, R_2, R_n = resistance in branching

2.3. Mining airways resistance

Air pressure and the quantity of airflow are related to find the resistance value. The resistance of ventilation is the value of resistance experienced by the flow of ventilation air inside the underground mine [5]. As long as the airways have not changed (has a fixed roughness, length, area, and perimeter), the resistance in the airways is constant. So, the correlation between air pressure and the quantity of airflow is formulated with the equation R: Resistance (Ns^2 / m^8) P = Pressure (Pa) and Q = Air Quantity (cfm or m^3 / s) Eq (5)

$$R = \frac{P}{Q^2}$$

2.4. Calculation of air quantity

After getting the value of the air velocity and the surface area of the tunnel drift, it can be calculated the air quantity that passes through the tunnel. To measure the air quantity passing through the tunnel, it can be calculated by the equation Q = air quantity (m^3 / s), V = air velocity (m / s), and A = area (m^2). Eq (6)

$$Q = V.A$$

2.5. Head loss calculation

Head loss is the loss of air debit that occurs due to velocity (Hv), friction (Hf), and bends or channel size changes (Hx). Head loss is the sum of friction loss and shock loss, then: Eq (7)

$$HL = Hf + Hx$$

Head Velocity

Although it is not a head loss, technically it can be considered as a loss. Head velocity is a function of airflow velocity, which Hv = velocity head, V = velocity of flow (fps), g = acceleration of gravity (ft / dt^2) Eq (8)

$$Hv = (V^2) / (2g)$$

Friction loss

It is a function of the velocity of airflow, the roughness, configuration, characteristics, and dimensions of the tunnel. The equation of fluid mechanics (Darcy-Weisbach) for calculating friction loss under circular conditions is [9]

$$Hl = f (L/D) x (V2/2g)$$

Which Hl is the head loss (ft) of the fluid, L is the length (ft), D is the diameter (ft), V is the velocity (fsp) and f is the coefficient of friction. For friction loss in mine ventilation (known as the Atkinson formula), which R = Resistance (Ns^2 / m^8), L = length of airways (ft or m), Per = Perimeter of channels (ft or m), K = Friction Factor (kg / m^3), A = area (ft^2 or m^2)

Shock loss

Shock loss occurs as a result of changes in flow direction in the channel or cross-sectional area of the air channel and addition to friction losses. Although the quantity is only about 10% - 30% of the total head loss in mine ventilation, it must still be considered. Which Hx = Shock loss, X = shock loss factor [5] .Eq (11)

$$Hx = X\,Hv$$

Length equivalent (Leq) is a representation of shock loss due to bends, branches, widening or narrowing, and so on. The value of the equivalent length can be seen in table 1.

Table 1. Equivalent length values [7]

No	Airways Type	Le	
		(ft)	(m)
1	Turns, Sharp angles, Rounded	3	1
2	Turns, Sharp angles, Tapered	150	45
3	Turns, Angle 90^0, Rounded	1	1
4	Turns, Angle 90^0, Tapered	70	20
5	Turns, Blunt angle, Rounded	1	1
6	Turns, Blunt angle, Tapered	15	5
7	Airway inlet	20	6
8	Airways outlet	65	20
9	Narrow path gradually	1	1
10	Narrow path directly	10	3
11	Extend path gradually	1	1
12	Extend path directly	20	6

13	Straight splitting	30	10
14	90^0 splitting	200	60
15	Straight junction	60	20
16	90^0 Junction	30	10

3. Methodology

This research was conducted in several stages, namely literature study, data collection, and data processing. Research data were processed using ventilation software. For more details, the research flowchart can be seen in the figure below (figure 1)

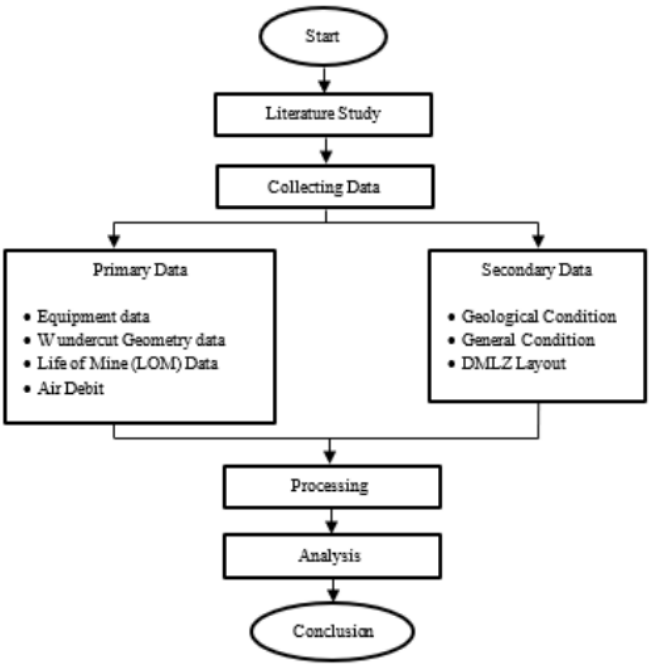


Figure 1. Research flowchart

4. Result and discussion

4.1. Auxiliary fan

There are several types of auxiliary fans that PT Freeport Indonesia has, but for W Undercut itself according to the concept of Preliminary Ventilation Requirements DMLZ W Undercut PTFI only will use Auxiliary Fan Spendrup 125-0800-1800, 150 HP to flow the air from the Intake Raise to Drift. One of the advantages of having an auxiliary fan is to help the main fan so that it generates additional total flow compared to only using the main fan [8]. Each fan flows air to two drifts. The auxiliary fan installed on this raise serves to appeal air because the air cannot flow according to the air quantity air that is expected.

Table 2. Calculation of auxiliary fan

Fan	Quantity	Pressure	Power
Auxiliary Fan 150 HP	43 m^3/s	1,145 Pa	150 HP

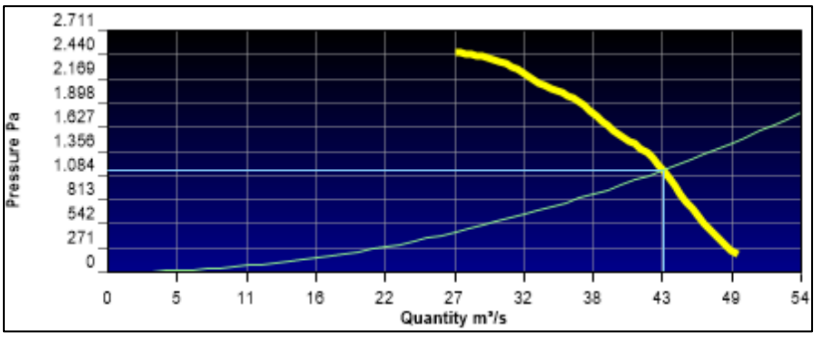


Figure 2. Auxiliary fan data 150 HP

4.2. Airflow budget

Airflow Budget can be calculated based on the number of equipment used plus the number of workers and also based on segments calculated by decreasing PTFI's Multi-Criteria Flow Requirements. Calculation of airflow budget is very important in planning ventilation systems to analyze and provide airflow budget for equipment and people who work in development activities and others. To determine air requirements further based on equipment and workers as well as air requirements in development activities can be seen in table 3 and 4 below

Table 3. Air requirements by equipment and workers [9]

No	Description	Type	Quantity	Opt. Factor (%)	Power (kW)	Air Flow m³/s PTFI
1	Drill	Axera 6 jumbo drill	2	50	111	8,9
		Axera 7 jumbo drill	2	50	111	8,9
		Cabolter DL 43I-7	2	50	110	8,8
2	Utility	Jaxon maxijet 0400	2	30	140	6,7
		A-64 Boom Truck	1	50	129	5,2
4	Loader	CAT R1700	3	80	263	50,5
5	Worker	Operator	21			0,63
		TOTAL				

Note: Air requirements for equipment based on PTFI Ventilation Design Criteria are converted from kW to HP (House Power)

Table 4. Air requirements based on development faces

W Undercut	Faces active		Total faces	*Airflow per faces,* m³/s	Total *Airflow,* m³/s
	North	South			
Development	6	6	12	15	180
TOTAL					180

Note: Preliminary Ventilation Requirements DMLZ W Undercut 12 Faces = 6 Intake Fans Running, airflow per faces = 15 m³/s.

Air requirements for W Undercut level based on equipment and workers for development ± 90 m3 / s and air requirements based on faces that have been conceptualized in the Preliminary Ventilation Requirements DMLZ W PTFI Undercut for each active development face 15 m3 / s, with a calculation of 6 faces in the north and 6 faces in the south so that air requirements in the north are 90 m3 / s and in the south 90 m3 / s with a total of 180 m3 / s. To create safe working conditions, the results of the calculation of the highest air requirements are used, based on the face. To find out the geometry of the design of W Undercut can be seen in table 5.

Table 5. W undercut geometry (preliminary ventilation DMLZ W undercut PTFI)

Description	W Undercut
SVD	Standard F Width 5.5 m x 5.0 m Height
DD	Standard D Width 4.4 m x 4.0 m Height
Intake Raise	4 m
Exhaust	4 m
Pillar distance	30 m

4.3. Resistance and losses in airways

In planning a mine ventilation system in terms of quantity, it is necessary to analyze airflow resistance in the airways and ventilation control system that causes a decrease in air debit. An analysis is carried out on the vent bag on active faces. 6 faces are active in the development, and it needs to be analyzed to get a picture of the amount of resistance and head loss caused by friction factor and shockloss. Table 6 shows the resistance in ventilation control in PT Freeport Indonesia. While table 7 shows the analysis of resistance and head loss in a 52- inch vent bag.

Table 6. Resistance in ventilation control in PT. Freeport Indonesia [9]

Description	Resistance (Ns^2/m^8)
Equipment Door (Each, Site)	1,5
Equipment Door (Each, PHX)	10
Shotcrete Bulkhead	100
Brattice Bulkhead	5
Slatted Curtain	0,15

Table 7. Resistance in vent bag (air density 0.89 kg/m^3)

Location	Airflow (m^3/s)	Head Loss (Pa)	Resistance (Ns^2/m^8)
Apex 5 E	15	403,84	1,795
Apex 6 E	15	400,03	1,778
DD 31 W	15	403,84	1,795
DD 31 E	15	403,84	1,795
DD 32 W	15	402,57	1,789
DD 32 E	15	402,57	1,789

5. Conclusion

Based on the analysis of total air needs, it can be calculated that for the development segment, the total air needs per segment is 15 m3 / s per face. It is derived from the decrease in Multi-Criteria Flow Requirements, PTFI. There are six active faces so that the total of air needs for active development in W Undercut is 180 m3 / s.

From the analysis of Head Loss and Resistance in Vent Bag size of 52 inches at the Undercut Drill Drift level and at the Apex Drift level, it shows that the Head Loss values in all vent bags are average of 402.78 Pa and the average resistance value is 1.79 Ns2 / m8.

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