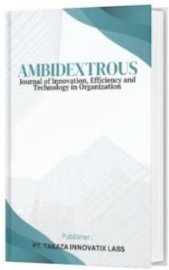
Ambidextrous: Journal of Innovation, Efficiency and Technology in Organization

https://journal.takaza.id/index.php/ambidextrous

Vol. 5, no. 2, 2026 , pp. 138-143
E-ISSN: 3031-7002

E-mail:ambidex@takaza.id



Performance of Primary Fan in the Toguraci Underground Mine

Dea Natasa[1], Peter Eka Rosadi[2]
Program Studi Sarjana Teknik Pertambangan, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia
Corresponding Author e-mail : deanatasa20@gmail.com

Article History:
Received: 11-08-2026
Revised: 13-08-2026
Accepted: 13-08-2026

Keywords: airflow requirements, primary fan performance, fan configuration, underground mine ventilation

Abstract : *The Toguraci Underground Mine, operated by PT Nusa Halmahera Minerals (PT NHM), experienced a temporary production shutdown that resulted in the ventilation system operating below its original design capacity. During this period, Primary Fan T01 was operated at 600 RPM, equivalent to approximately 60% of its maximum rotational speed of 990 RPM. As mining activities resumed under normal operating conditions, an evaluation of primary fan performance was necessary to determine whether the existing ventilation capacity could satisfy underground air requirements and to identify an optimal fan configuration. This study employed a quantitative approach based on field measurements of airflow velocity, air pressure, temperature, relative humidity, and ventilation conditions at Primary Fans T01 and T03 and selected ventilation stations. The measured fan performance was evaluated using fan affinity laws, manufacturer performance curves, underground air requirement calculations, and fan configuration simulations. The results showed that Primary Fan T01 at 600 RPM delivered an actual airflow of 81.20 m³/s, compared with a theoretical airflow of 109.09 m³/s, indicating an airflow deviation of 27.89 m³/s. Under contingency conditions, the combined airflow from Primary Fans T01 and T03 reached 117.46 m³/s, exceeding the required airflow of 104.67 m³/s. However, under normal operating conditions, the required airflow increased to 207.43 m³/s, which could not be satisfied by the existing configuration. Simulation results identified the optimal configuration as one T01 fan unit operating at 900 RPM combined with two T03 fan units, producing an estimated airflow of 208.19 m³/s with a total power demand of 640.74 kW. The findings indicate that optimizing fan rotational speed and the number of operating fan units can satisfy ventilation requirements while improving energy efficiency. Further field verification and investigation of airflow losses in Primary Fan T01 are recommended to ensure the reliability of the proposed configuration.*

How to Cite: First author., Second author., & Third author. (20xx). The title. Ambidextrous Journal of

Innovation Efficiency and Technology in Organizations. 5(2). Pp 138-143 https://doi.org/10.61536/ambidextrous.v5i02.678
https://doi.org/10.61536/ambidextrous.v5i02,.678

Introduction

The ventilation system is a vital component in underground mining activities because it functions to provide fresh air, dilute hazardous gases, and maintain a safe and comfortable working environment (Hartman et al., 2012). The ventilation system implemented in this study is a diagonal ventilation system, namely a system with an intake airway and a return airway at different locations so that air flow can pass through the mine work area more effectively. In this system, the primary fan plays a major role as an air flow driver that distributes air throughout the ventilation network (Hartman et al., 2012). Insufficient air flow can cause a decrease in air quality, an increase in the concentration of hazardous gases, and a decrease in productivity and work safety (Kissell, 2003), so evaluating the performance of the primary fan is important to ensure optimal ventilation system operation.

At the Toguraci underground mine of PT Nusa Halmahera Minerals (PT NHM), the ventilation system experienced a temporary shutdown, preventing it from operating according to its initial design conditions. The primary fan was operated at only about 60% of its maximum capacity (±600 RPM from 990 RPM) to support maintenance activities. When the mine resumed normal operations, adjustments were required to the primary fan's actual performance, particularly regarding the number of underground mining equipment operating simultaneously in one shift, to ensure the air flow generated could meet ventilation needs with the most ideal configuration. Previous studies related to underground mine ventilation, such as the evaluation of the ventilation network at PT Antam Tbk UBPE Pongkor (Rabbani et al., 2022; Yuniarto et al., 2020) and the Bojong Deet Sukabumi gold mine (Rustiyanto et al., 2025), generally focused on optimizing the ventilation network in general. The novelty of this research lies in the evaluation of the primary fan performance specifically on two different types of fan units (variable-speed and fixed-speed) combined with fan affinity law-based configuration simulation for normal post-contingency operating conditions, which has not been widely studied in similar studies in the Toguraci underground mine (Pulu, 2021).

Based on these conditions, this study aims to evaluate the performance of the primary fan based on the results of actual measurements of pressure and air flow, analyze the suitability of ventilation capacity to the air flow requirements of underground mines, calculate air requirements when the mine returns to normal operations, and determine the appropriate primary fan configuration for these conditions.

Method

This research is an applied research with quantitative methods, an approach that emphasizes the systematic and objective collection and analysis of numerical data (Creswell, 2014; Sugiyono, 2019). The parameters analyzed include air flow velocity, air flow rate, air demand, and pressure in the mine ventilation network and primary fans T01 and T03 of the Toguraci underground mine, PT NHM.

Field data collection was conducted on the surface area of primary fans T01 and T03, as well as at four vent stations (VS-01 to VS-04) representing the main ventilation circuit. Static, total, and velocity pressure data on the primary fan were measured using an Alnor AAXD620 manometer connected to a pitot tube, with 18 measurements on each fan (1 point on T01 and 3 points on T03, each with 9 readings). Barometric pressure, relative humidity, dry and wet temperatures were measured using a Kestrel 5500 Weather Meter on T01 and a VelociCalc 9565-P-NB with a hot wire on T03. Air velocity at each vent station was measured using a VelociCalc 9565-NB with a continuous traversing method (McPherson, 1993).

The data obtained was processed through several stages: (1) calculating the average pressure, temperature, and humidity from 18 measurement data; (2) calculating the psychrometric value to obtain the primary fan air flow rate T01 and T03; (3) calculating the primary fan performance and comparing it with the factory performance, and validating it with the results of air volume measurements at the vent station; (4) calculating the underground mine air requirements under actual conditions (contingency) according to the Director General of Mineral and Coal Decree No. 185.K/37.04/DJB/2019 and comparing it with the actual primary fan flow rate; (5) calculating the air requirements under normal operating conditions according to the Minister of Energy and Mineral Resources Decree No. 1827

K/30/MEM/2018; and (6) simulating the primary fan configuration using the fan affinity law approach by considering the fan deviation (loss) factor, in order to obtain the optimum configuration that meets the air requirements under normal conditions.

The primary and secondary data used in this study along with the field equipment used to obtain them are summarized in Table 1.

Table 1. Field Data and Equipment

Data Types	Parameter	Equipment / Resources
Primary Data	Total pressure, static pressure, and velocity at primary fan T01 and T03	Alnor AAXD620 Manometer + Pitot Tube
	Barometric pressure, dry/wet temperature, RH at T01	Kestrel 5500 Weather Meter
	Temperature, RH, air velocity at T03 and each vent station	VelociCalc 9565-P-NB + Hot Wire
Secondary Data	Ventilation network map, factory specifications and fan curves, working front dimensions	PT NHM internal documents

Results and Discussion

At the time of the research, the Toguraci underground mine was in a contingency plan condition so that the primary fan T01 which normally operated at 990 RPM was reduced to 600 RPM to support maintenance activities, while the primary fan T03 only operated 1 of 3 fan units. Based on the factory performance curve (Figure 1), at a blade angle of 56° and a speed of 990 RPM, the primary fan T01 was designed to produce an air flow rate of 180 m3/s. Based on the fan affinity law approach, at 600 RPM a flow rate of 109.09 m3/s should be produced, but the actual measurement results in the field that have been validated with measurements at the vent station only showed 81.2 m3/s, so that a deviation/loss of 27.89 m3/s was indicated. Validation using the results of psychrometric measurements of air velocity at the vent station showed a relatively small difference in the two primary fans (81.24 m3/s compared to 81 m3/s for T01, and 36.22 m3/s compared to 36 m3/s for T03), so that the calculations can be considered representative of actual conditions in the field.

With the actual configuration as shown in Table 1, the combination of primary fans T01 (1×560 kW) and T03 (1×110 kW) produces a total air flow of 117.46 m3/s.

Table 2. Actual Primary Fan Configuration

Parameter	Unit	T01 Performance (1×560 kW)	T03 Performance (1×110 kW)
Rotation Speed	RPM	600	Fixed
Blade Angle	°	56	Fixed
Motor Power	kW	124.66	110
Air Flow	m^3/s	81.2	36.22

Air requirements in contingency conditions are calculated based on the number of diesel equipment, workers, main drive and development areas, and active human metabolism during maintenance activities, as presented in Table 3.

Table 3. Contingency Condition Air Requirements

Parameter	Air Requirements (m^3/s)
Diesel Tools	81.18
Worker	0.934
Main drive area	4.67
Area development	4.08

https://doi.org/10.61536/ambidextrous.v5i02,.678

Human Metabolism	0.178
Total	**91,042**
Total + 15%	**104.67**

The air requirement value under contingency conditions of 104.67 m3/s can still be met by the actual primary fan discharge of 117.46 m3/s, so that the actual configuration does not require adjustment and the decision to reduce the primary fan power by 60% is proven to be correct because it saves power consumption without sacrificing adequate ventilation. However, when the mine returned to normal operations, the number of tools and workers increased significantly so that the air requirement also increased, as shown in Table 4.

Table 4. Normal Air Requirements

Parameter	Air Requirements (m^3/s)
Diesel Tools	169.72
Worker	1.6
Main drive area	4.67
Area development	4.08
Human Metabolism	0.304
Total	**180,374**
Total + 15%	**207.43**

The air requirement under normal conditions of 207.43 m3/s far exceeds the actual ventilation capacity, so that adjustments to the primary fan configuration are required. In addition to the adequacy of air volume, the working environment conditions are also assessed through the thermal work limit (TWL); the measurement results show that VS-03 and VS-04 are in the withdrawal zone (TWL < 78 and < 94), while the virgin rock temperature (VRT) of the Toguraci underground mine of 52°C has exceeded the threshold that requires a mechanical refrigeration system (Van der Walt & Whillier, 1980), so that in addition to adjusting the air volume, additional heat control strategies are also needed in the form of a cooling system (chiller/air cooler) in deeper and hotter work areas.

The primary fan configuration adjustment was carried out through simulation using the fan affinity law approach by considering the deviation/loss value at T01 of 27.89 m3/s, with a target of meeting the air requirement of 207.43 m3/s. Three configuration variations were simulated as presented in Table 5.

Table 5. Simulation Variations of Primary Fan Configuration

Parameter	Unit	Condition A (T01 600 RPM, 560kW×2)	Condition B (T01 900 RPM, 560kW×2)	Condition C (T01 900RPM 560kW×1 + T03 110kW×2)
Rotation Speed	RPM	600	900	900
Blade Angle	°	56	56	56
Air Flow (Q)	m^3/s	162.40	271.49	208.19
Motor Power	kW	249.33	841.47	640.74
Information	-	Does not meet air requirements	Satisfactory, but not ideal	Compliant with lower power (ideal)

Condition A (T01 at 600 RPM, both F-18 and F-19 fans running) only produces 162.4 m3/s and does not meet the air demand. Condition B (T01 at 900 RPM, both fans running) produces 271.49 m3/s with a power requirement of 841.47 kW; this condition meets the air demand but is wasteful of power and therefore not ideal. Condition C, which is a combination of one primary fan T01 unit at 900 RPM with two primary fans T03 units, produces an air flow of 208.19 m3/s with a power requirement of 640.74 kW, meeting the underground mine air demand of 207.43 m3/s with the most efficient power consumption among the three simulated configurations. These results confirm that increasing ventilation

https://doi.org/10.61536/ambidextrous.v5i02.678

capacity does not always require operating all fan units at maximum capacity, but can be achieved through an optimal combination of rotational speed and number of operating fans.

The finding of air flow deviation in primary fan T01 aligns with the results of previous research in the Toguraci underground mine (Pulu, 2021), which also identified a difference between the actual air flow and the plant design flow, indicating that losses in the primary fan system are consistent over time and require attention in routine maintenance. Compared with ventilation optimization approaches in other mines, such as at PT Antam Tbk UBPE Pongkor (Rabbani et al., 2022; Yuniarto et al., 2020), which focused on network and regulator adjustments, this study shows that in the Toguraci case, adjusting the rotational speed and number of operating fans is sufficient to meet air requirements without the need for structural changes to the ventilation network, making it more economical and faster to implement. This implies that fan affinity law-based primary fan performance evaluation can be an effective approach for ventilation planning in underground mines experiencing changing operating conditions, particularly during the transition phase from maintenance to normal production.

Conclusion

Based on actual measurement results, the performance of primary fan T01 at 600 RPM (1×560 kW) and primary fan T03 (1×110 kW) produces a total air flow rate of 117.46 m3/s, with a flow rate deviation of 27.89 m3/s from the theoretical value based on the fan affinity law due to losses in the primary fan T01. The actual ventilation capacity has been able to meet the air flow rate needs of underground mines under contingency conditions of 104.67 m3/s, so the decision to reduce the primary fan power to ±60% of the maximum capacity is the right step because it still meets ventilation needs while saving power consumption. The air flow rate requirement under normal operating conditions is calculated at 207.43 m3/s, much higher than the actual ventilation capacity, so adjustments to the primary fan configuration are required. The simulation results show that the optimum configuration to meet the air requirements under normal conditions is primary fan T01 operated at 900 RPM (1×560 kW) combined with two primary fan T03 units (2×110 kW), which produces an air flow of 208.19 m3/s with a total power requirement of 640.74 kW — meeting ventilation requirements with the most efficient power consumption compared to other alternative configurations.

Further research is recommended to further investigate the exact cause of the airflow deviation in primary fan T01, such as blade condition inspection, ducting leaks, or other airflow obstructions. In addition, considering the virgin rock temperature value of 52°C in the Toguraci underground mine has exceeded the threshold requiring a mechanical refrigeration system, further studies are needed regarding the cooling system (chiller/air cooler) for temperature control. Field verification (actual trials) of the recommended primary fan configuration is also needed to ensure the results of the fan affinity law-based simulation are consistent with real conditions in the field.

Thank-you note

The author would like to thank PT Nusa Halmahera Minerals (PT NHM) for the permission and support of facilities during the research data collection, as well as to the supervising lecturer and field supervisor for the direction and input provided during the research process and preparation of this article.

Bibliography

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2011). ASHRAE handbook: Fundamentals. ASHRAE.

Brake, D. J., & Bates, G. P. (2017). Limiting metabolic rate (thermal work limit) as an index of thermal stress. Applied Occupational and Environmental Hygiene, 17(3), 176–186.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). SAGE Publications.

Direktorat Jenderal Mineral dan Batubara. (2019). Keputusan Direktur Jenderal Mineral dan Batubara Nomor 185.K/37.04/DJB/2019 tentang standar kebutuhan udara pada kegiatan usaha pertambangan mineral dan batubara. Kementerian Energi dan Sumber Daya Mineral.

Hartman, H. L., Mutmansky, J. M., Ramani, R. V., & Wang, Y. J. (2012). Mine ventilation and air conditioning (3rd ed.). John Wiley & Sons.

Kementerian Energi dan Sumber Daya Mineral Republik Indonesia. (2018). Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 1827 K/30/MEM/2018 tentang Pedoman Pelaksanaan Kaidah Teknik Pertambangan yang Baik. KESDM RI.

Kissell, F. N. (2003). Handbook for dust control in mining. National Institute for Occupational Safety and Health (NIOSH).

https://doi.org/10.61536/ambidextrous.v5i02,.678

McPherson, M. J. (1993). Subsurface ventilation and environmental engineering. Chapman & Hall.
Pulu, P. (2021). Kinerja primary fan T1 TOG PT NHM. INTAN Jurnal Penelitian Tambang, 4(2), 126–134.
Rabbani, R., Sriyanti, & Moralista, E. (2022). Kajian perubahan kuantitas udara pada sistem ventilasi area penambangan Kubang Kicau di PT Antam Tbk UBPE Pongkor, Kabupaten Bogor, Provinsi Jawa Barat. Bandung Conference Series: Mining Engineering, 2(2), 505–513.
Rustiyanto, P. A., Razak, S., & Nabella, A. (2025). Analisis jaringan sistem ventilasi tambang bawah tanah pertambangan emas Bojong Deet Sukabumi. Jurnal Pertambangan dan Lingkungan.
Sugiyono. (2019). Metode penelitian kuantitatif, kualitatif, dan R&D. Alfabeta.
Van der Walt, J., & Whillier, A. (1980). Engineering of systems for cooling mines. SME-AIME.
Yuniarto, W. B., Erwin W., R. A., & Sidiq, H. (2020). Optimalisasi fan pada sistem ventilasi tambang bawah tanah area Kubang Kicau PT Aneka Tambang Tbk, UBPE Pongkor, Bogor, Jawa Barat. Prosiding Nasional Rekayasa Teknologi Industri dan Informasi (ReTII), 15, 325–332.

https://doi.org/10.61536/ambidextrous.v5i02.678