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Ventilation challenges and opportunities at tunnelling construction operation – Snowy 2.0 Powerhouse Complex Ventilation

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ABSTRACT: The Snowy 2.0 project involves linking two existing dams, Tantangara and Talbingo, through 27 km of tunnels and building a new underground power station. Water will be pumped to the upper dam when there will be surplus renewable energy production, and the energy demand will be low and then released back to the lower dam to generate energy when the electricity demand is high. It will provide power while reusing the water in a closed loop and maximise the efficiency of other energy sources to pump water to the higher dam, which will be stored for later use.

This paper focuses on the ventilation challenges, implementation, legislative requirements and planning on one of the sites, taking upfront designs into the execution phase with development and construction taking place before hand-over for long-term use. Lobs Hole consists of the two main tunnels, the Main Access Tunnel (MAT) and the Emergency Cable Ventilation Tunnel (ECVT), both developed by an 11 mØ Tunnel Boring Machine (TBM) that form the access to the two main powerhouse chambers developed by drill and blast techniques. These chambers, or "Halls", will house the electric power station and turbines and will be two of the largest underground chambers in the world (80 m High x 40 m Wide x 250 m Length).

1 INTRODUCTION

Snowy Hydro Ltd is constructing Snowy 2.0 as the next stage in the Snowy Hydro Scheme's Project. It is a renewable energy Project that will provide on-demand energy and large-scale power storage, the largest in Australia. Snowy 2.0 will provide an additional 2 200 megawatts of generating capacity and approximately 350 000 megawatts hours of large-scale storage to the National Electricity Market. This is enough energy to power three million homes over the course of a week (Snowy Hydro Ltd, 2024).

The Project involves linking two existing dams, Tantangara and Talbingo, through 27 km of tunnels and building a new underground power station 800 m below surface. Water will be pumped to the upper dam in a closed circuit when there is surplus renewable energy production utilising excess solar and wind energy when the demand for energy is low. Water will be released back to the lower dam utilising the hydraulic head between the dams to generate energy when electricity demand is high (Figure 1; Snowy Hydro Ltd, 2024).

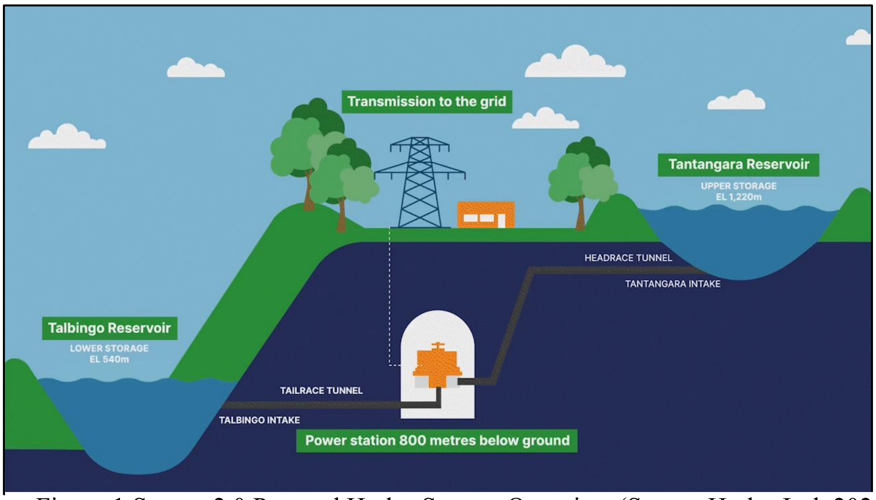

Figure 1 Snowy 2.0 Pumped Hydro System Overview (Snowy Hydro Ltd, 2024)

At the Snowy 2.0, there will be four (4) development sites (Figure 2):

— Talbingo – Tailrace tunnel inlet/outlet
— Lobs Hole – Main Access Tunnel (MAT) and Emergency/Cable/Ventilation Tunnel (ECVT), Tailrace Pressure Shaft and Powerhouse complex
— Marica – Headrace pressure shaft
— Tantangara – Headrace tunnel inlet/outlet.

This paper aims to discuss the challenges and critical solutions employed to change the primary and secondary ventilation circuits at the Lobs Hole site (Figure 2) to adequately ventilate the Transformer and Machine Halls, which will be two of the largest subsurface chambers in the world. The paper will also discuss value-add engineering practices used to conceptualise, design and install ventilation network controls to maintain the legislated level of safety and health for personnel during development and construction.

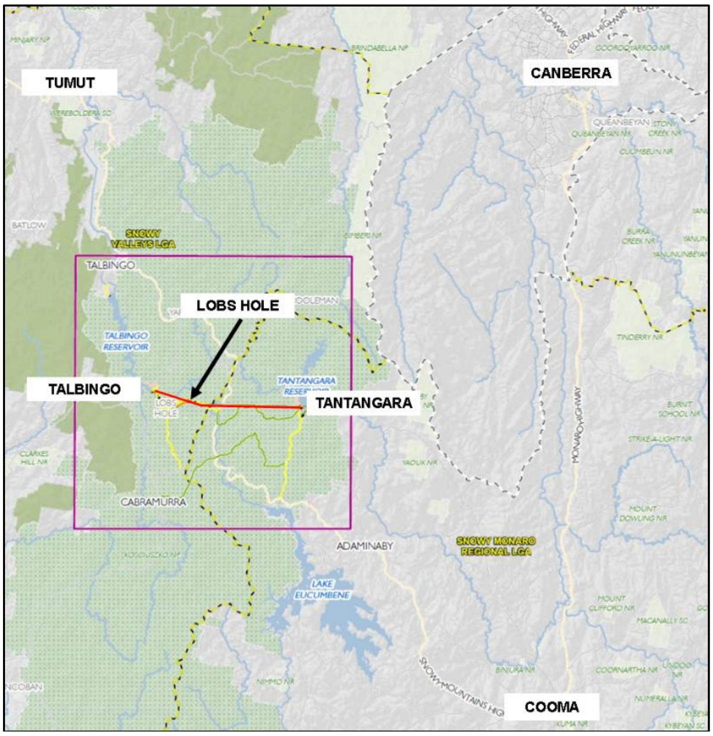

Figure 2. Snowy 2.0 and Lobs Hole Location

2 VENTILATION DESIGN CONSIDERATIONS

Tunnelling guidelines and industry best practice standards for air quality, contaminant dilution and monitoring are discussed in this section. A summary of the ventilation criteria has been provided.

2.1 *Standards*

The Project complies with the SafeWork Australia – Tunnelling Guide and industry-regulated exposure limits, and it is based on the following reference documents:

- SafeWork Australia – Guide for Tunnelling Work (SafeWork Australia, 2013)
- SafeWork Australia – Workplace Exposure Standards (SafeWork Australia, 2024)
- MDG29: Guideline for the management of diesel engine pollutants in underground environments British standard, BS 6164 code of practice for safety in tunnelling in the construction industry (MDG, 2008).

2.2 *Air Quality*

The construction team and ventilation officer must ensure that the air supplied to the ventilation system in the tunnel(s) are obtained from the purest source available (Snowy, 2024; SafeWork Australia, 2013). The recommended minimum standards for sufficient volume, velocity, and quality are:

- 0.3 m/s – with temperature ≤ 25°C wet-bulb
- 0.5 m/s – with temperature ≥ 25°C wet-bulb.
- 2.0 m/s – maximum airflow velocity in work areas together with suitable dust management in place (if in excess, regulated by Risk Assessment).

2.3 *Diesel Equipment and Dilution*

Mine Design Guideline 29 (MDG 29, 2008), 'Management of Diesel Engine Pollutants in Underground Environments', recommends that workers should not be exposed to levels of Diesel Particulate Matter (DPM)—in the form of EC—greater than 0.1 mg/m^3. For gaseous emissions (from operating diesel equipment), the minimum ventilation quantity in each place where a diesel engine operates shall be such that a ventilation quantity of not less than:

- 0.067m^3/s per rated kW of the maximum capacity of the engine (Australian Tunnelling Guidelines), and by Safe Work Australia standard for diesel particulates at <1.0mg/m^3

2.4 *Ventilation System – Monitoring and Testing*

The ventilation management plan (Anon, 2024) should include periodic monitoring and testing of the ventilation system to validate that minimum air velocities and dilution of dust and gases remain within safe limits. This includes developing Trigger Action Response Plans (TARPs) where emissions exceed 50% of the Work Exposure Limit (WEL).

The ventilation management plan should include the following:

- Diesel gas and DPM management plan
- An emergency preparedness management plan
- Specifies the maximum rated diesel engine power that may operate in each tunnel section and how this will be managed
- Radio communication system to alert workers in an emergency
- Welding standard work practices to minimise workers' exposure to welding fumes.

3 THE MAIN FOCUS – VENTILATION REQUIREMENTS AT LOBS HOLE (MAIN ACCESS TUNNELS)

The Lobs Hole site consists of two 11.0 mØ TBM tunnel excavations (MAT and ECVT) concrete segment lined to 9.9 mØ that are ~3.5-4.0 kms each. These tunnels provide connections to the Powerhouse Complex (Transformer and Machine Halls) as shown in Figure 3. Both Halls (red) will be 80 m High x 40 m Wide x 250 m Length and will connect to the penstock (olive) and draft tube tunnels (cyan) to power the turbines. The tunnels established perpendicular off the main TBM tunnels will be an average size of 9 m High x 9 m Wide and will be established by drill and blast techniques.

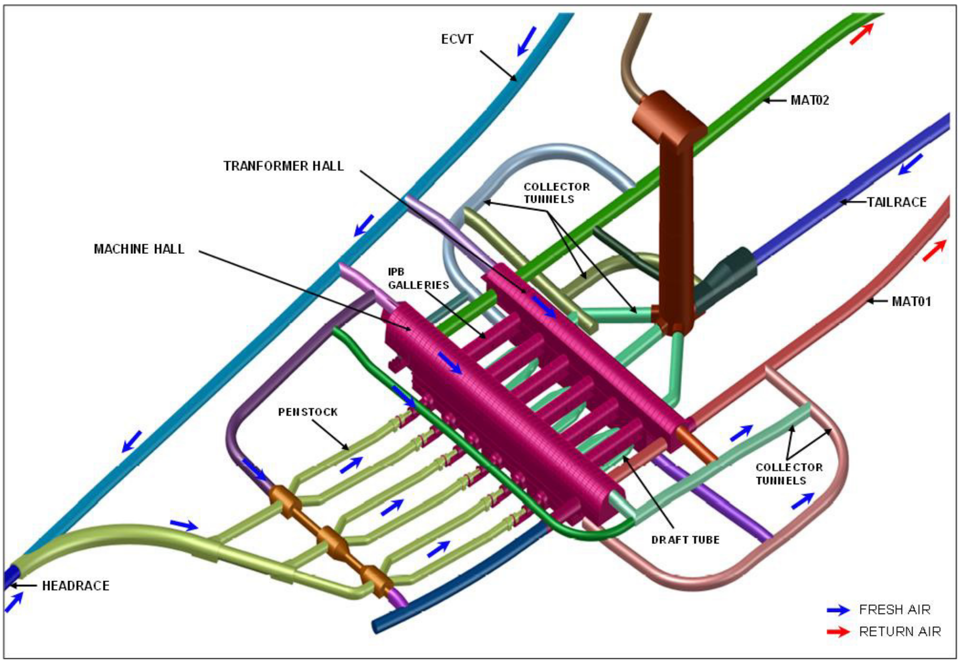

Figure 3 Lobs Hole MAT and ECVT – Powerhouse Complex (isometric view, Fratello and D'Ulisse, 2024)

3.1 *Challenge – Establishing a Primary Ventilation Network During Development*

During the development phase, the ECVT and MAT tunnels will be force-ventilated via two (2) twin-stage 315 kW fans (four fans installed) and one single-stage 500 kW fan from the portals utilising 2.4 mØ and 3.0 mØ ducting. As soon as through-ventilation is established at the Machine and/or Transformer Halls, the ECVT fans will be used as Primary Fans, and the MAT fans will be repurposed as Secondary Development Fans. Air will naturally ventilate to the surface via the MAT tunnel as all ventilation control devices will be commissioned. The ventilation requirement during the development phase is approximately 480 m³/s and will be increased to ~900m³/s to serve the construction phase.

The total airflow of 480 m³/s can serve a total diesel power of 7.2 MW (at 0.067 m³/s per kW) to achieve an average velocity of 1.5 m/s throughout the underground. The total rated power and number of equipment required during the development phase will be 3.26 MW. The fan and ventilation control inventory for underground is indicated in Table 1.

Table 1. Development Phase Infrastructure Requirements

Ventilation Control/Fan	Number of Units
Primary Fans 315 kW	8
Primary Fans 500 kW	1
Auxiliary Fans 55 kW – 160kW	3
Regulated Bulkhead	1
Brattice Wall	1

3.2 *Challenge – Establishing a Primary Ventilation Network During Construction*

The main challenge with establishing minimum ventilation requirements in large, excavated tunnels is that there are no shafts to use as intake or return airways to provide 200 m³/s of fresh air into each of the Machine and Transformer Halls to satisfy the minimum airflow quantity and velocity criteria of 0.3 m/s would be managed on the working floor via strategically placed air-movers. Therefore, it was recommended to use the TBM access tunnels as intake and return in lieu of shafts. Fresh intake air will be supplied via the ECVT tunnel and will be returned via the MAT tunnel creating a primary ventilation circuit (Figure 4).

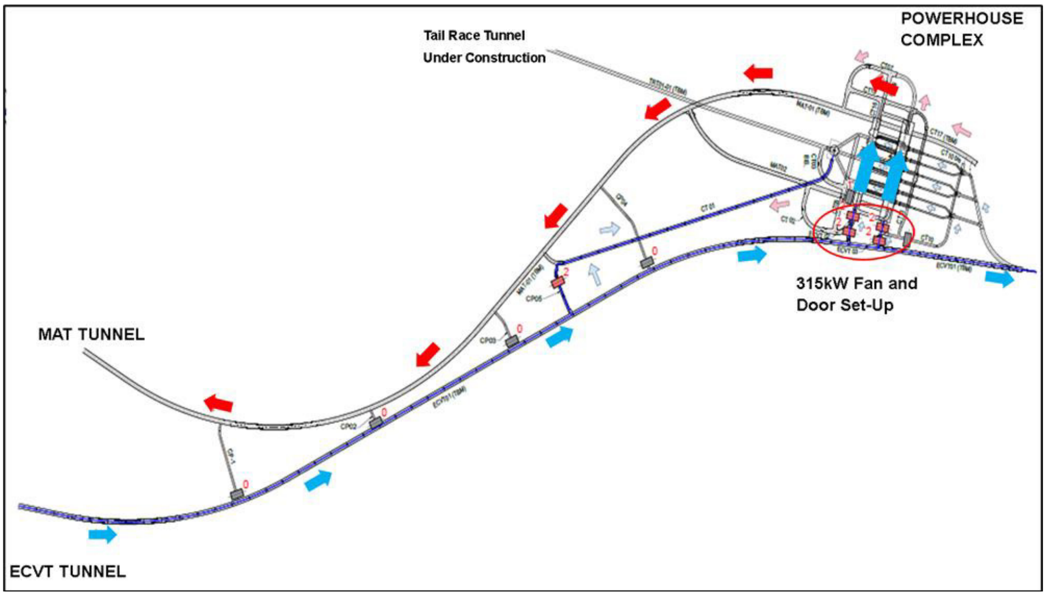

Figure 4. Proposed Primary Ventilation Circuit

This is achieved by installing air lock doors to the access of each hall supported by two single-stage 315 kW fans each (Figure 5). These fans act as the Primary Fans as they are the driving force behind the primary circuit. To minimise contamination, personnel and light vehicles access the complex only via the fresh air intake ECVT. All other heavy vehicles access via the MAT as velocities are expected to reach close to 9.0 m/s towards the surface sections of the MAT.

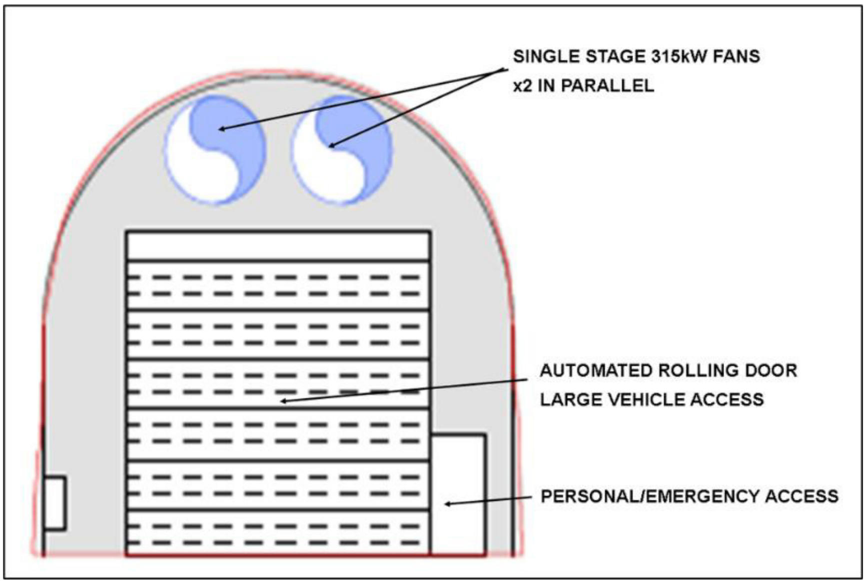

Figure 5. Door/s and Fan Arrangement (Section view, Snowy Hydro Ltd, 2024)

4 VENTILATION OF HALLS DURING DEVELOPMENT AND CONSTRUCTION

Once the primary ventilation circuit is established, the challenge will be to establish a secondary system to adequately ventilate the large halls. Secondary rigid steel ducting teed off from the primary ventilation ducts from the ECVT tunnel will supply air to each of the Halls. Reduced sections of ducts will be installed in each Hall and will be extended vertically down until it reaches each active development level (Figure 6).

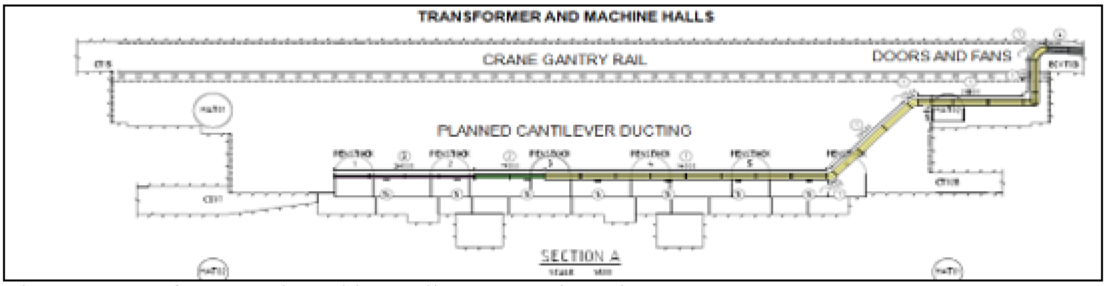

Figure 6. Transformer and Machine Hall Cross Section Views

Ventilation distribution to each Hall will be achieved by using step-down duct sections at strategic locations along the Hall. Modelling and duct calculations were completed to ensure the set-down cantilever duct system is established at the correct locations as indicated in Figure 6. The step-down cantilever duct will comprise flexible ducting to 1.6 mØ, 1.4 mØ and finally 1.2 mØ.

Each section will have two smaller openings to ventilate the development floor as the duct extends. The pressure in the duct is planned be at ~1 500 Pa to 2 000 Pa to ensure equal airflow quantities out of each opening along the length of the steel duct.

With both ducts set up in this configuration in each Hall, the ~200 m³/s can be evenly distributed along the Hall's development floors. The schedule and distribution of works were calculated using diesel fleet loading to create a base to justify predicted contamination dilution rates.

4.1 *Meeting Airflow Requirements*

The quantity at 200 m³/s gives an allowable diesel fleet of 3.0 MW which is ~200% of the planned diesel fleet in a Hall at any one time. Being a large excavation, double the amount of airflow was designed to mitigate dust and heat potential concerns.

Once the ventilation system is set up, the next challenge is achieving the correct velocity to support personnel on the construction floor and meet legislative compliance. With the required quantity in each Hall, the velocity is required to be maintained at no less than 0.3 m/s. This is then achieved via the use of large-scale air movers that will force airflow up to 34 m ahead of its location. Strategically placed fans ensure compliance with regulations and can be easily moved to provide adequate air for active work areas (Figure 7).

Ventilation modelling software was used to evaluate airflow movement, velocity, and heat mapping and to minimise any potential recirculation/re-use of airflow in the Halls. In addition, software is used to ensure air moves from south (ECVT) to north (MAT) through the Halls. This was necessary to identify compliant airflow movement and to ensure the proposed system set-up could meet the optimal working conditions.

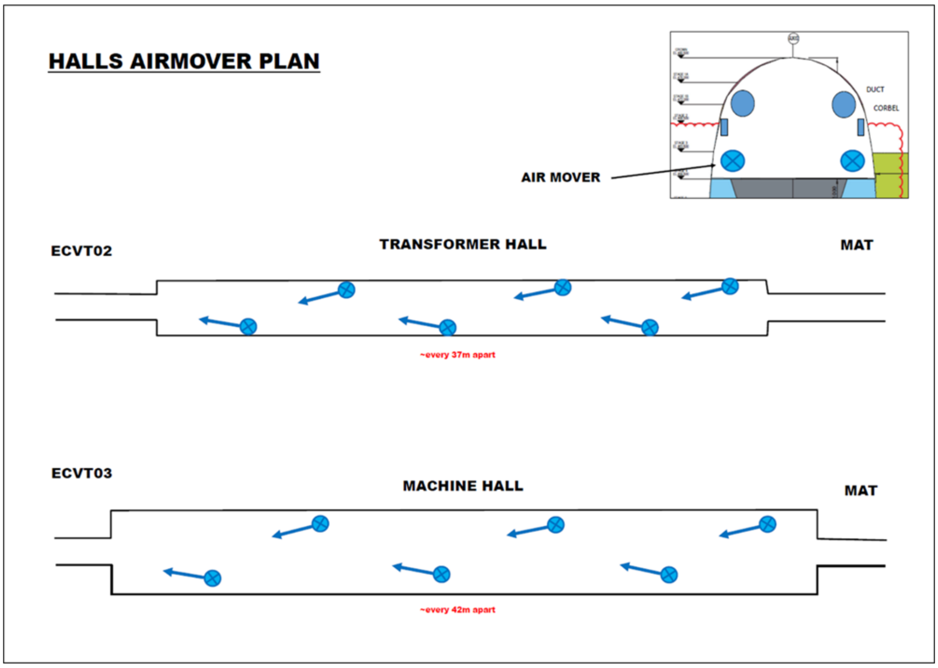

Figure 7. Air Mover Placement in Halls (Top View)

4.2 *Ventilation Controls and System Optimisation*

To achieve the circuit, the main driving force behind the network is the 315 kW force fans from the ECVT portal and the airlock doors at the ECVT side access to each Hall. These are essentially the system's primary fans that deliver the 200 m³/s to the Halls. Figure 5 and Figure 6 shows cross-sectional views of the Transformer and Machine Halls detailing the essential ventilation system requirements and controls to adequately ventilate the halls to acceptable guidelines.

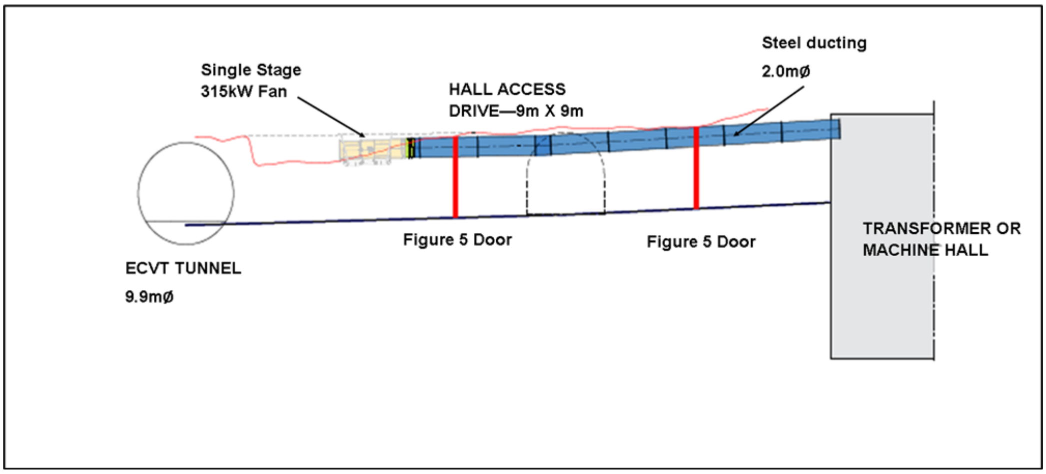

Figure 8. Fan / Door Layout (Snowy Hydro Ltd, 2024)

The pressure ratings for the doors/walls used in this application required an operational design load of ~500 Pa to suit locations with areas up to 100 m² in size. Little to no access will be through these doors as the development profile of the halls have a "drop-off" 20-30 m past them as part of the hall design. All access for personnel and machinery will be via the MAT side. The project was constrained to the extent ventilation controls could be implemented, as nearly all areas required full unrestricted access. Breakthroughs occurred in the halls from the penstock and draft tubes, which made ventilation planning more challenging.

The airlock system for the halls was evaluated for infrastructure movement prior to fabrication and required a temporary engineering design to manage the pressure load of <500 Pa. The doors also needed to be easily installed, maintained and removeable. A set of doors was required at each breakthrough in the halls. They were designed with automation for frequent access and ease of access for large machinery movements (e.g., trucks). These doors were designed to be relocatable, robust in high demand shift changes, operate with high open/close cycles per hour, and withstand easy damage, etc. A robust control system was required to minimise ventilation disruption during operation and provide smooth operation.

5 CONCLUSION

Communication, consultation and engaging all stakeholders were crucial in overcoming the main challenges of increasing airflow and ventilation of two of the largest underground caverns in the world. This ensured the safety and success of the ventilation network and distribution of airflow to the construction work areas. By addressing each stage of ventilation change with development on site and consultants in Torino, Italy, with a systemic and innovative approach, the Lobs Hole site was able to create and implement a primary and secondary ventilation system that supported the project development and construction life and contributed to the overall success of the Snowy 2.0 Project.

By utilising mining, tunnelling and industrial ventilation solutions, the permanent works team were able to successfully identify locations for the ventilation infrastructure with minimal changes as the project progressed, especially with the halls developing deeper.

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