

OPTIONAL USE OF JET FANS IN THE GOTTHARD BASE TUNNEL NEAR THE PORTALS TO SUPPORT THE EMERGENCY VENTILATION

D. Portmann, HBI Haerter AG, Zurich, Switzerland
J. Shaha, HBI Haerter AG, Zurich, Switzerland

ABSTRACT

In case of a burning train stopping outside the rescue stations in the Gotthard Base Tunnel (GBT) the emergency ventilation system is used to provide a smoke-free environment in the opposite tube. The present paper discusses the performance of the emergency ventilation system with the simultaneous use of jet fans. In this way it is not a discussion of the superior, general safety concept, but it focuses exclusively on the relevant aspects with regard to a safe escape in case of an incident train stopping near a portal.

Calculations of the air flows in the tunnel system demonstrate that jet fans placed in tunnels near the portals are an efficient means to support the emergency ventilation system.

The use of jet fans near the portals leads to

1. a more uniform level of flow velocity in the open cross-passages along the tunnel
2. increased air flow velocities in the open doors of cross-passages, above the value which is required to prevent smoke from penetrating into the non-incident tube
3. a quicker response of the air flows in the open doors of cross-passages to the ventilation
4. a lower sensitivity of the air flow in the open doors of cross-passages to remaining train traffic.

1 INTRODUCTION

The planned 57 km long Gotthard Base Tunnel (GBT) is one of the main Swiss alpine tunnel projects. It will be a central part of the European high-performance rail network. The main elements of the GBT with regard to ventilation and safety in an emergency are shown in Figure 1. Basically, the tunnel system consists of two single track tubes (twin tube system). The eastern tube is for trains passing from north to south, i.e. from Erstfeld to Bodio. Trains running from south to north use the western tube. Cross-passages connect the two tubes at a regular distance of 325 m. Two cross-overs are located at the basis of the access points in Sedrun and Faido.

Safety considerations have led to the construction of the GBT as a twin tube system with a separation of trains running in different directions. In the rare event that a train catches fire and is unable to leave the tunnel, it will stop at one of the rescue stations in Sedrun and Faido. They are designed for the stop of a burning train and are the main items of the emergency ventilation system of the tunnel. They are equipped with an air supply and exhaust system and allow a safe escape and evacuation of the passengers from the train.

There is a very low probability that a burning train is unable to stop at a rescue station and breaks down somewhere else in the tunnel. In this event the passengers of the incident train use cross-passages to reach the opposite (non-incident) tube. The emergency ventilation of the rescue stations is used to produce a smoke-free area in the non-incident tube. This is achieved by an overpressure in the non-incident tube and an underpressure in the incident tube provided that the cross-overs at Sedrun and Faido are closed. The pressure difference between the two tubes decreases towards the portals. Therefore, the air velocities in the open doors of cross-

passages near the portals are only slightly higher than the required velocities to prevent smoke from penetrating into non-incident tube.

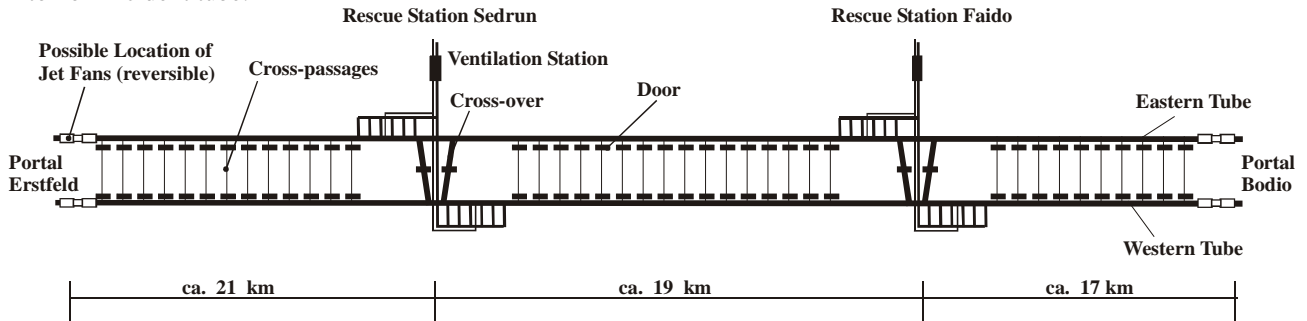


Figure 1: Main elements of the Gotthard Base Tunnel (GBT) with regard to ventilation and safety in an emergency

2 PURPOSE OF THIS STUDY

This paper focuses on the optional use of jet fans at the tunnel portals to support the emergency ventilation system in the eventuality, that a burning passenger train stops outside a rescue station. It concentrates on the following aspects:

- the change of the level of flow velocity in the open cross-passages along the tunnel
- the level of air flow velocities in the open doors of the cross-passages
- the time response of the air flows in the open doors of cross-passages to the emergency ventilation
- the sensitivity of the air flow in the open doors of the cross-passages to remaining train traffic

3 SAFETY IN THE GOTTHARD BASE TUNNEL

For the safety planning of the Gotthard Base Tunnel a number of key principles were defined. The relevant principles concerning the actions to be taken in case of a burning passenger train in the tunnel are listed below ([1]):

- In the event of a fire or other life-threatening incidents on a passenger train, the train shall not be required to travel more than approximately 20 km before either exiting the tunnel or reaching a dedicated place of safety within the tunnel. Drivers shall attempt to take their train to the first available designated place of safety, where passengers shall be taken to a protected area in a safe and orderly manner. There shall be a high probability that all passengers reach the protected area.
- In the event of a passenger train being unable to reach a designated place of safety, the tunnel ventilation system shall be configured to provide an alternative place of safety to which passengers can be evacuated. The possibility of passengers reaching the place of safety shall be as high as reasonably practicable.
- The designated place of safety and, where necessary, the alternative place of safety shall be maintained free of smoke and supplied with sufficient clean air until all passengers are evacuated from the tunnel.

The dedicated places of safety in the Gotthard Base Tunnel are the emergency stations at Sedrun and Faido. They are located in the tunnel such that the distance between a portal and an emergency station or between the emergency stations is approximately 20 km. A quantitative risk analysis ([2]) showed that there is a very high probability for trains to reach an emergency station in an incident. However, the remaining trains have to stop outside the emergency station. In this case the passengers of the train escape to the non-incident tube via the cross-passages between the tunnels. The distance of 325 m between the cross-passages is suited to guarantee self-rescue conditions which are as safe as practicable. Although the eventuality of a burning train stopping outside a rescue station is very unlikely, the safety concept also accounts for this case.

4 THE EMERGENCY VENTILATION SYSTEM IN THE GOTTHARD BASE TUNNEL

In the event that a burning train stops outside a rescue station the ventilation of the rescue stations of Sedrun and Faido is used to supply air (a maximum of $200 \text{ m}^3/\text{s}$ per rescue station) to the non-incident tube and to extract air (a maximum of $250 \text{ m}^3/\text{s}$ per rescue station) from the incident tube. Thereby, an overpressure is achieved in the non-incident tube and an underpressure in the incident tube. Optionally, jet fans at the portals may support the emergency ventilation, with a maximum thrust of 4180 N per portal. Figure 2 depicts the ventilation system.

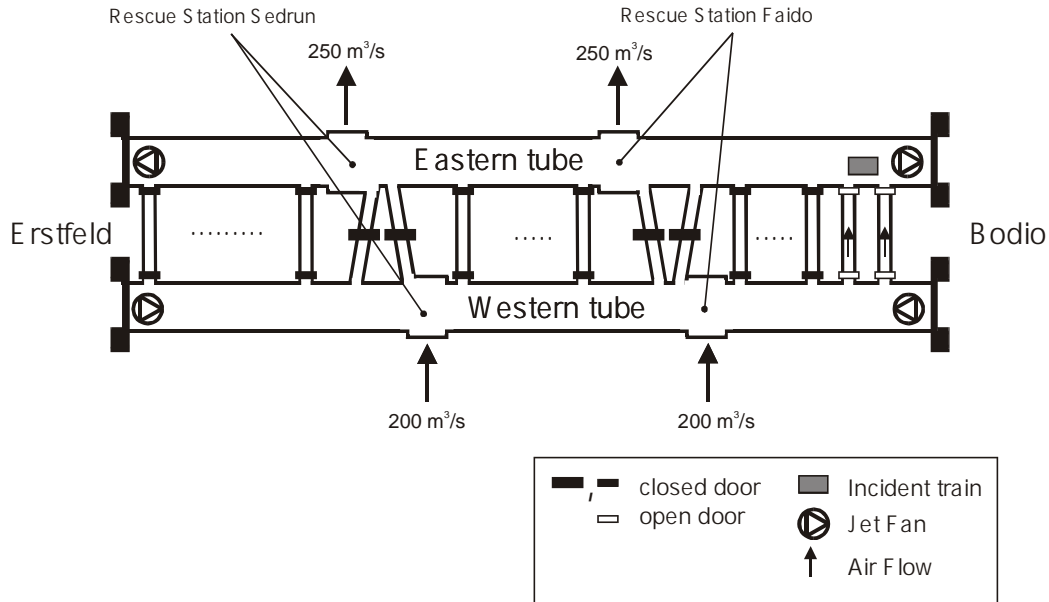


Figure 2: Schematic of the ventilation system in an emergency case (with a burning train near a portal)

5 METHODS

The aerodynamic calculations for this study were conducted with THERMOTUN [3]. The code is based on a 1D model and can be used to perform calculations of transient, compressible flows. It allows to determine the air flows in a tunnel network under realistic operating conditions. The program can account for train traffic, the ventilation regime and the opening and closing of doors.

Initially, a set of calculations under steady state conditions was performed, i.e. no train traffic was modelled. These calculations were used to obtain information on the air velocities in open cross-passages along the tunnel and the response time of the emergency ventilation. In a second set of calculations transient conditions were modelled, i.e. train traffic was accounted for using a realistic emergency scenario. The scenario started with train traffic under normal conditions. At the time corresponding to the alert of the tunnel control centre, changes in the train schedule were made and the emergency ventilation system was started. These calculations under transient conditions were used to study the sensitivity of the air flow in open doors of cross-passages to moving trains.

In the model calculations it was assumed that two adjacent cross-passages were used for the evacuation of the passengers (see also Figure 2). The air velocity in both openings (doors) was calculated. The results of the calculations were represented as arithmetic mean values (see Figure 3 to Figure 5).

6 RESULTS

Results of the calculations for steady state conditions, i.e. where no influence of the train traffic was accounted for, are represented in Figures 3 and 4. Figure 3 depicts the air velocity in the open doors of cross-passages along the tunnel. The data points, which were used to produce the graph, represent the mean air flow velocity in the open doors of two adjacent open cross-passages. The remaining cross-passages are kept closed. The jet fans have a positive influence on the air velocities. It is seen that a flow velocity of 2 m/s , which is required to prevent smoke from penetrating through an open cross-passage into the non-incident tube, is obtained in every case.

However, without the jet fans the air flow velocity in the open cross-passages close to the portals is only slightly above the required 2 m/s. When jet fans are used the air flow velocities in the open cross-passages increase considerably (by a factor of approximately 3.5) and the level of flow velocity in the open cross-passages becomes more uniform along the tunnel. These are consequences of the increased pressure difference between the eastern and western tube, which is obtained with the use of the jet fans.

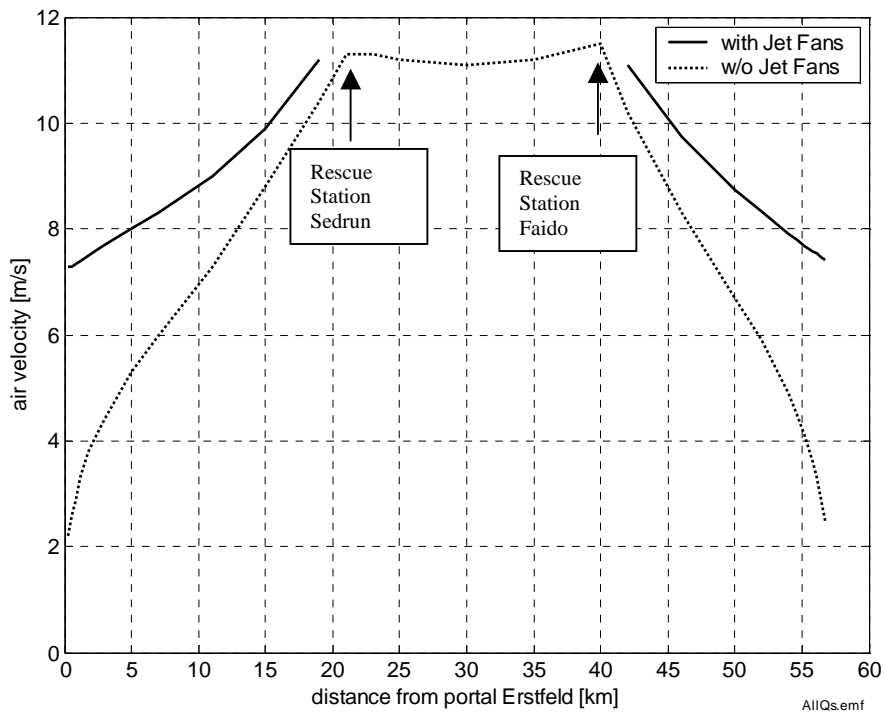


Figure 3: Air velocity in open cross-passages along the tunnel (each data point represents the mean air flow velocity in two adjacent open cross-passages)

Figure 4 represents the time characteristics of the air flow in the open door of a cross-passage near the portal and is used to study the time response of the air flows in the open doors of cross-passages to the emergency ventilation. The data was obtained under the assumption that the ventilation starts simultaneously with the opening of the cross-passage doors. This assumption represents a pessimistic case as the ventilation should be taken into operation before the cross-passage doors are opened. The results show that an air flow velocity of approximately 7 m/s is immediately obtained in the open cross-passage doors provided that jet fans are in operation. Without jet fans, the air flow in the open cross-passage door responds after about 1 min, and reaches a steady airflow of about 2 m/s.

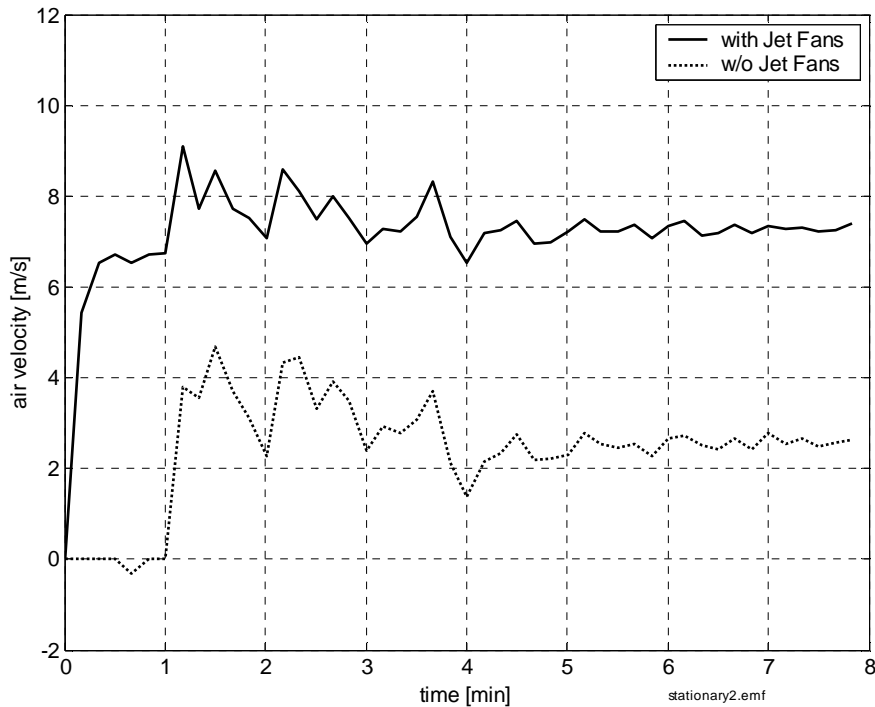


Figure 4: Air velocity in the open doors of cross-passages near the portal under steady state conditions (i.e. no train traffic considered)

Calculations for transient conditions, i.e. where the influence of the train traffic was accounted for, were performed for a realistic scenario where the emergency train stopped near the portal. Figure 5 represents the time characteristics of the air flow in the open doors as averages over the two cross-passages next to the emergency train. The time scale relates to the outbreak of the fire on the incident train. In the given scenario the ventilation system is taken into operation prior to the opening of cross-passage doors. The train movements in the scenario are characterised by the following principles:

- Trains behind the burning train in the incident tube stop and reverse
- Trains in the non-incident tube slow down, stop in the next rescue station and then continue their journey towards the portal

The results for the ventilation without jet fans show that the air flow velocity in the open doors of cross-passages can temporarily fall below 2 m/s. This is due to trains running in the non-incident tube. For velocities below 2 m/s the penetration of smoke through the open cross-passage doors into the non-incident tube cannot be excluded. The benefit of jet fans at the portals manifests itself in a high air velocity obtained right after the opening of the doors ($t = 18$ min) as found in the steady state case (see Figure 4). In addition the sensitivity of the air flows in the open cross-passage doors to the train movements is reduced. The air flow velocity in the open cross-passage doors is always above the required 2 m/s.

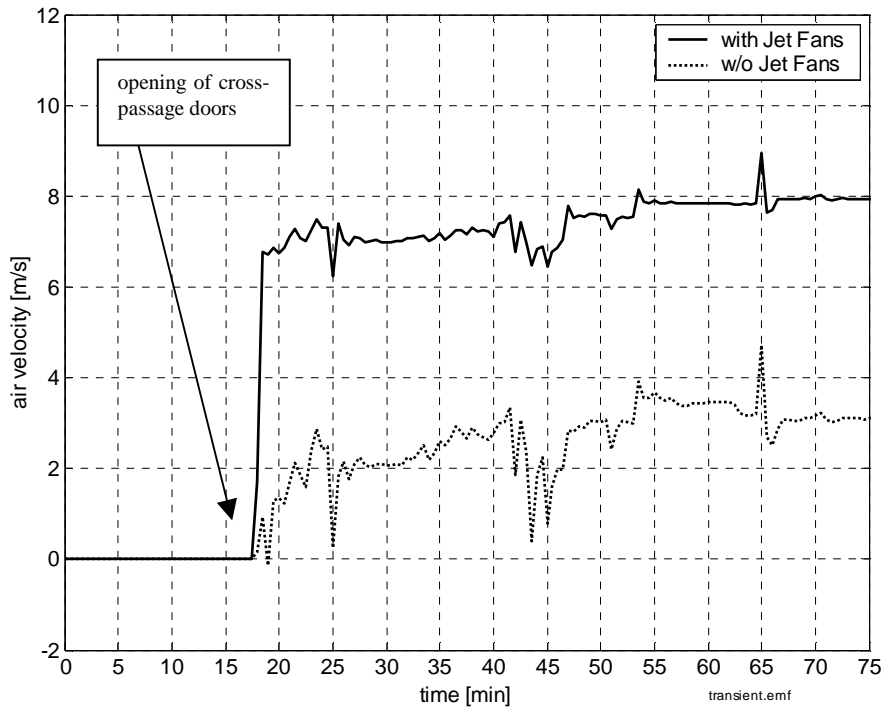


Figure 5: Air velocity in the doors of cross-passages near the portal under transient conditions (i.e. train traffic considered); time scale related to outbreak of fire

7 CONCLUSIONS

The optional use of jet fans at the portals of the Gotthard Base Tunnel can enhance the efficiency of the emergency ventilation system which is used in case of a stop of the burning train outside the rescue station. In particular the jet fans lead to the following improvements:

1. a more uniform level of flow velocity in the open cross-passages along the tunnel
2. increased air flow velocities in the open doors of cross-passages, above the value which is required to prevent smoke from penetrating into the non-incident tube
3. a quicker response of the air flows in the open doors of cross-passages to the ventilation
4. a lower sensitivity of the air flow in the open doors of cross-passages to remaining train traffic.

Where conclusion 1 addresses the system as a whole, conclusions 2 to 4 are mainly relevant for cross-passages near the portals.

This study focuses on the optional use of jet fans at the portal to support the emergency ventilation. It demonstrates that jet fans increase the efficiency of the ventilation, especially near the portal. An optimisation of the number and the power of jet fans has not yet taken place and would have to be addressed at a later stage of the project. However, the issue of using jet fans also has to be discussed with regard to cost and safety. The key question could be expressed as follows: "Are the expenses for jet fans justified with regard to their benefit for the safety of the GBT?" The present paper cannot answer this question, since it addresses only the ventilation aspects. The conclusions drawn from this paper are therefore mainly relevant from the point of view of ventilation.

ACKNOWLEDGMENTS

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