Chapter 22
Ventilation and Air Conditioning in Tunnels and Underground Stations

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ABSTRACT
This chapter is an overview of the state of the art and advanced principles in the field of ventilation and air conditioning (AC) in tunnels and underground stations. The first part is dedicated to the background which deals with the design objectives that are generally retained for normal and emergency operation of underground rail projects. The second part provides solutions and recommendations of ventilation and AC strategies that can be used in metro and rail projects. Advantages and drawbacks of the proposed solutions are also discussed. The main parameters that can influence the design are introduced in this section. The possibility of using draught relief shaft is detailed. Advantages of Platform Screen doors and heat sink effects are also described. Various cooling technologies of station air conditioning systems are presented. Critical issues when designing longitudinal ventilation system for tunnel emergency situations are also discussed. The last part is a short list of future research directions in the field of cooling / heating production for air conditioning systems.

INTRODUCTION
In order to avoid insertion issues related to dense urban areas, urban rail and metro infrastructures are now-a-days mostly underground. This leads to a particular care to maintain the operation under acceptable environment and safety conditions. Indeed, in normal operating conditions trains and the presence of passengers in the transportation network lead to large amounts of sensible and latent heat released in the underground spaces that may lead to high temperature and humidity levels. Moreover, the underground rail infrastructures are also exposed to a high level of fire risks due to the confined space that increases
the consequences of fire on passengers but also more generally on civil and assets. Ventilation and air conditioning systems are part of the main systems which contribute to the achievement of acceptable environment and safety conditions. The following chapter is dedicated to those systems detailing the state of the art and recent researches and developments.

BACKGROUND

This section gives an overview of the state of the art regarding the main objectives that are currently retained for the design of ventilation and air conditioning system in rail and more particularly metro infrastructures.

BACKGROUND AND OBJECTIVES DURING NORMAL OPERATION

1. Thermodynamic Conditions

In normal operation, ventilation and air conditioning systems are dedicated and designed for various purposes.

One of the first targets is to maintain acceptable hygienic and thermal conditions for the passengers using the metro system.

For hygienic conditions, the aim of the ventilation systems is to provide a fresh air renewal into the underground spaces in order to reduce the level of contaminants and carbon dioxide. The volume of fresh air to be provided is generally expressed as a number of volumes to be renewed in a dedicated time but also as a volume of flow rate per passenger. Various standards already exist depending on the country where the infrastructure is built. One of the most common standards used internationally is the ASHRAE 62-1 (ASHRAE, 2007). In this standard, the volume of fresh air for a transportation waiting area is set to 0.3 L/s/m² or 4.1 L/s/person.

Thermal comfort of passengers is also becoming one of most critical issues when designing Air conditioning and Ventilation systems in tunnels and underground station areas. Indeed, the quantity of heat released in the station is generally at high level due to the presence of passengers, the functioning of various electrical and mechanical systems but also the large quantity of heat released by trains in the tunnels and stations. The thermal comfort in metro system was very often not properly addressed in the 20th century. Now-a-days, passengers are more on more accustomed to air conditioning which also tends to increase the demand of suitable thermal comfort area in the underground stations. Thermal acceptability is a quite a complicated field of research as it depends on various factors such as the origin of the population, the type of activity, the manner to be clothed, the influence of draught, the subjectivity of passengers regarding the thermal comfort sensation etc. Many research works have already been performed such as those provided by Berglund (1979), Fanger (1988) or Goldman (1978). The results of those researches have been largely detailed in the international standard ASHRAE 55 (ASHRAE, 2004). This standard indicates a comfort level between 19°C and 28°C depending on the humidity ratio and the level of clothing insulation. Those values can be increased up to 4°C depending on the air speed. The upper limit for the absolute humidity is also fixed at 0.012. This standards provides interesting information for the design of ventilation and air conditioning systems in underground stations but should also