CHAPTER 8

VENTILATION AND AIR-CONDITIONING SYSTEM

8.1 INTRODUCTION

This chapter covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed Metro Rail Project Pune Metropolitan area. It includes the following:

- Station Air-conditioning System
- Ventilation System for station plant rooms (ancillary spaces)
- Station Smoke Management System
- Tunnel Ventilation System

8.2 ALIGNMENT

The proposed alignment has an underground section of about 4.5 km. This would include 5 underground stations and 3 tunnel portals.

The MRTS alignment passes through the heart of the city. The underground section starts from tunnel portal between Hill Range and Shivaji Nagar station and passes through ASI U/G station. The alignment goes to PMC elevated station and starts underground again from tunnel portal between PMC and Budhwar Peth station and passes through Mandai and Swargate U/G Metro Stations. The route terminates in underground dead end. The inter-station distances vary from 675 m to 1604 meters.

8.3 NEED FOR VENTILATION AND AIR CONDITIONING

The underground stations of the Metro Corridor are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from
outside and do not have natural ventilation. It is therefore, essential to provide forced ventilation in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the authority’s staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Escalators, Fare Gates etc. working in the stations;
- Removing heat from air conditioning plant and sub-station and other equipment, if provided inside the underground station.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation, especially when the outdoor air temperature and humidity is high. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions are considered appropriate. In winter months it may not be necessary to cool the ventilating air as the heat generated within the station premises would be sufficient to maintain the comfort requirement.

8.4 EXTERNAL ENVIRONMENT CONDITIONS AND WEATHER DATA

The design weather data from the ASHRAE handbooks have been used to arrive at the design criteria. Based on the feedback and analysis of the VAC system installed at Delhi Metro, it is suggested that 2% criteria would be acceptable on techno economic reasons. The climate pattern in Pune suggests that the summer season is generally between March to June. During the July and February months the weather generally has temperate conditions

The air pollution of Pune throughout the year adds new dimension and there is a critical need for maintaining desired Air – Quality (Environmental control) in public
places like MRT stations. High content of suspended particles, Carbon Mono-
oxide, Sulphur Dioxide etc. discharged in the air from moving traffic, industries,
etc requires consideration of appropriate measures for air -pollution control in
metro stations, while designing the VAC system.

8.5 SUB SOIL TEMPERATURE

The temperature conditions of sub-soil play a vital role in the system design of
the underground stations. It is also expected that water table surrounding the
underground alignment is not very much below the surface level, thereby
facilitating adequate heat exchange between the tunnel structures and soil.

8.6 INTERNAL DESIGN CONDITIONS IN UNDERGROUND STATIONS

With hot and humid ambient conditions of Pune during the summer and monsoon
months, it is essential to maintain appropriate conditions in the underground
stations in order to provide a ‘comfort-like’ and pollution-free environment. The
plant capacity and design of VAC system needs to be optimized for the designed
inside conditions.

The Indian Standards & Codes, which pertain to office-buildings, commercial
centers and other public utility buildings, have no guidelines on temperature
standards to be maintained for the underground mass rapid transit systems as
yet. The standards used for buildings cannot be applied straightforward for the
underground spaces, because the patrons will stay for much shorter durations in
these underground stations.

The comfort of a person depends on rapidity of dissipation of his body heat,
which in turn depends on temperature, humidity and motion of air in contact with
the body. Body heat gets dissipated is given out by the process of evaporation,
convection and conduction. Evaporation prevails at high temperature. Greater
proportion of heat is dissipated by evaporation from the skin, which gets
promoted by low humidity of air. The movement of air determines the rate of
dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The ‘Effective
Temperature’ criterion was used in selecting the comfort conditions in earlier
metro systems, including the north-south section of Kolkata Metro. In this
criterion, comfort is defined as the function of temperature and the air velocity
experienced by a person. More recently a new index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient conditions of the metabolic rate and is evaluated based on the changes to the surrounding ambience of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a subway system where the train headway is expected to be six minutes or less, RWI is the preferred criterion.

8.7 DESIGN PARAMETERS FOR VAC SYSTEM

Based on the reasons stated in the previous sections. The following VAC system design parameters are assumed in the present report.

(1) **Outside ambient conditions:**

This is based upon ASHRAE recommended design conditions for 2% and 1% criteria, as under

<table>
<thead>
<tr>
<th></th>
<th>2% Criteria</th>
<th>1% Criteria</th>
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<tbody>
<tr>
<td>Summer</td>
<td>35.9 DB, 19.6 WB</td>
<td>37.0 DB, 19.6 WB</td>
</tr>
<tr>
<td>Monsoon</td>
<td>28.2 DB, 23.7 WB</td>
<td>28.8 DB, 24.1 WB</td>
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For Pune Metro Underground Corridor it is suggested to use 2% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 2% of the total time.

(2) **Inside design conditions:**

<table>
<thead>
<tr>
<th></th>
<th>Platform areas</th>
<th>25 deg. C at 55 % RH</th>
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<tbody>
<tr>
<td></td>
<td>Concourse</td>
<td>26 deg. C at 60% RH</td>
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</table>

(3) **Tunnel design conditions**

<table>
<thead>
<tr>
<th></th>
<th>Normal conditions</th>
<th>Max. DB 40 deg. C</th>
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<tbody>
<tr>
<td></td>
<td>Congested conditions</td>
<td>Max. DB 45 deg. C</td>
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(4) **Minimum fresh air**

(in station public areas). 10 % or 18 cmh / person
8.8 DESIGN CONCEPTS FOR VAC SYSTEM

There are various VAC design concepts technically feasible in a subway system that can provide and maintain acceptable subway environment conditions under different requirement and constraints. These are: Open type; Closed type; Mid-Tunnel Cooling; Semi Transverse Ventilation; Use of jet fans; use of mid-shafts; platform screen doors etc. An overview of VAC systems in other metros like Jubilee line extension, Bangkok etc. that have similar climatic behavior and ambient conditions have provided valuable information in deciding VAC concept for Pune Metro Underground Corridor. The experience available from the design of VAC system for Delhi Metro also provides key guidelines.

From the experience of DMRC, for such conditions it can be concluded that with open shaft system the piston effects can be sufficient to maintain acceptable conditions inside the tunnel, as long as the ambient DB temperature is below 33°C. When the outside temperature is higher than 33°C the tunnel shafts should be closed to prevent any further exchange of air with atmosphere. The station premises (public areas) can be equipped with separate air-conditioning system during the summer and monsoon months to provide acceptable environment for patrons. There shall be provision of Trackway Exhaust System (TES) by which platform air can be re-circulated. The train cars reject substantial heat inside subway. When the trains dwell at the stations TES would capture a large portion of heat released by the train air conditioners mounted on the roof tops and under gear heat because of braking, before it is mixed with the platform environment.

The train heat generated inside the tunnel sections would be removed by the train piston action. It is envisaged that for the design outside conditions, it may not be necessary to provide forced ventilation using Tunnel Ventilations Fans for normal operating conditions. The two tunnel ventilation shafts would be required at the end of the stations. As the maximum inter station distance in under ground stations is 1057.7m therefore considering the ultimate train headway the mid tunnel ventilation shaft would not be required. These end-shafts at the stations also serve as Blast Relief Shafts i.e. the piston pressure is relieved to the atmosphere before the air-blast reaches the station. All these shafts are connected to the tunnels through dampers. The dampers are kept open when the exchange of air with the atmosphere is permitted (Open system). For the closed system the shaft dampers can be in closed mode and the displaced air is dumped in the adjacent tunnel.
Generally each tunnel ventilation shaft has a fan room in which there are two fully reversible tunnel ventilation fans (TVF) are installed with isolation dampers. These dampers are closed when the fan is not in operation. There is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TV fans, allowing air exchange between tunnels with flows generated by train movements. Dampers are also used to close the connections to tunnels and nozzles when under different operating conditions. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated in more accurate manner with the help of Computer Simulations during the detailed design stage.

8.9 TRACKWAY EXHAUST SYSTEM (TES)

The TES is to be installed in the trainways of each station to directly capture heat rejected by the vehicle propulsion, braking, auxiliary and air conditioning systems as the train dwells in the station. The TES includes both an under platform exhaust (UPE) duct and an Over-trackway (OTE) exhaust duct. The TES uses ducts formed in the under platform void and over the trackway. Exhaust intakes are to be located to coincide with the train-borne heat sources.
8.10 TUNNEL VENTILATION SYSTEMS (TVS)

The TVS is provided in a Subway system essentially to carry out the following functions:

(a) Train Pressure relief during normal operation
(b) Ventilation during maintenance periods, if required
(c) Removal of smoke during emergency conditions
(d) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.
There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:

### 8.10.1 Normal Conditions

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the trackway exhaust system.

During summer and the monsoon seasons, the system will be functioning essentially with the station air conditioning operating. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements. The platform air captured by the trackway exhaust system shall be cooled and recirculated. For less severe (i.e. cool) environmental conditions (or in the event of an AC system failure), station air conditioning will not be used and ventilation shafts will be open to atmosphere (open system) with the trackway exhaust system operating. For cold conditions, the closed system or open system mode may be used, but without any station air conditioning. System heating is achieved by the train heat released into the premises.

### 8.10.2 Congested Conditions

Congested conditions occur when delays cause disruption to the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result, reduced performance of coach air conditioners that may lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a ‘push-pull’ effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust mode. Nozzles or booster (jet) fans will be used to direct air into the desired tunnel, if required.
8.10.3 Emergency Conditions

Emergency conditions are when smoke is generated in the tunnel or station trackway. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the fire fighting purposes. The method of controlling the smoke is the same as for the open system congested mode. The ventilation system is operated in a ‘push-pull’ supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction.

8.11 PRESSURE TRANSIENTS

The movement of trains within the underground system induces unsteady air motion in the tunnels and stations. Together with changes in cross section, this motion of air results in changes in air pressure within trains and for wayside locations. These changes in pressure or ‘pressure transients’ can be a source of passenger discomfort and can also be harmful to the wayside equipment and structures. Two types of transient phenomenon are generally to be examined:

a) Portal Entry and Exit Pressure Transients – As a train enters a portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train. There are three locations of the portal between Hil range and Shivaji Nagar Station, ASI and PMC stations PMC and Budhwar Peth station.

b) Wayside Pressure Transients – As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains. Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

The detailed analysis to assess the effect of pressure transients will have to be done during the design stage. For the portal entry/exits the effect of higher train speed may pose discomfort to the passengers. Although, based on the recent
studies, it is assumed that a design train speed of 85 kmph would not be of major concern. The estimation of Way-side transients during design stage would be necessary to select design mechanical strength of the trackside components and fixtures, e.g. false ceilings, light fittings etc at the platform levels.

8.12 VENTILATION AND AIR CONDITIONING OF ANCILLARY SPACES

Ancillary spaces such as staff room, equipment plantroom, will be mechanically ventilated or air conditioned in accordance with the desired air change rates and temperatures/humidity. All ancillary areas that require 24-hour air conditioning will be provided with fan-coil units (FCU) and standby AC units. During the revenue hours when the main chilled water system is running the FCU will be used for air-conditioning and in non-revenue hours standby AC units will be operated. Return air grilles will be fitted with washable air filters for the recirculation of the air.

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filters, common to a group of ancillary areas. The fresh air units will be located in the VAC plant room and will be time switch controlled with local override. Temperature control will include an alarm setting, which is activated on attaining high temperature.

8.13 STATION SMOKE MANAGEMENT SYSTEM

The Trackway Exhaust and Concourse smoke extract fans will be provided for smoke extract purposes from the public areas and will operate in various modes depending on the location of the fire. The associated supply air-handling units will provide support, to assist in smoke control in the event of a fire in the station. The control of this system in fire mode will be fail-safe. These exhaust fans will be provided with “essential” power supplies, with automatic changeover on loss of supply.

Down stand beams will be provided underneath the ceiling around floor openings for stairs and escalators, so that a smoke reservoir is formed on the ceiling. The smoke will be contained in this reservoir at ceiling level and exhausted to atmosphere. By controlling smoke in this manner, it is possible to maintain a relatively smoke clear layer above human head height and to protect the escape route, giving sufficient time for evacuation. The stations will be designed to accommodate the full smoke exhaust volumes and thus prevent the reservoir
from completely filling with smoke. To provide an additional barrier against smoke migration, the overall smoke management system would be designed to provide a draught of fresh air through entrances and escape routes, to assist in protecting those routes from smoke.

8.13.1 System Components for VAC

The various components and equipment used in the VAC system are described in the following sections:

8.13.2 Station Air Conditioning

The platform and concourse areas will be air-conditioned using supply ‘air handling units’ located in Environmental Control plant rooms throughout the station. Each platform will be served by at least two separate air handling units (AHU’s) with the distribution systems combined along each platform to ensure coverage of all areas in the event of single equipment failure. Based on the initial estimation about 6 units (2 for the concourse each with 18 cum/s and 4 for the platform each having 24 cum/s air-flow) would be needed for the full system capacity.

Concourse Air Handling Unit
These air conditioning systems mix return air with a desired quantity of outside air. The outside air requirement is based on occupancy, with a minimum of 5 liters per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimize the enthalpy reduction needed to be achieved by the cooling coil. This mixture of outside and return air is then filtered by means of suitable filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to diffusers, discharging the air into the serviced space in a controlled way to minimise draughts. Return air to the platform areas is extracted via the trackway exhaust system and either returned to the AHU'S or exhausted as required.

Water-cooled chiller units with screw compressors are recommended to be provided at each station, which are energy efficient. These units can be installed in a chiller plant room at surface level or in the underground premises. Based on the initial concept design, the estimated capacity for a typical station would be around 660 TR, hence three units of 330TR (including one stand-bye) may be required for full system capacity (i.e. design PHPDT traffic requirement). During the detail design stage this estimated capacity might get marginally changed for individual station depending on the heat loads and geometry of the stations. It is recommended that initially 2X330 TR may be installed with the provision in terms of space be kept for the future/stand by addition.

During the detail design stage this estimated capacity might get marginally changed for individual station depending on the heat loads.
In view of the temperate outdoor conditions, alternatively, it is possible to utilize air-cooled chiller units, which can save large amount of water requirement. The air-cooled chillers should be equipped with screw compressors so that they can be operated at a very less load with high efficiency. These units also eliminate requirement of condenser water circuits including pumps, cooling towers and make up water plants, but are less efficient as compared to the water-cooled-units.

**8.13.3 Tunnel Ventilation System**

As described earlier tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room at each end of the station. The fan capacity depends on the inter-station distances and may vary from 60 m$^3$/s to 100 m$^3$/s. The exact capacity will be obtained through the simulation during detailed stage. If necessary, nozzle type structures made up of concrete or steel may also be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively booster fans (jet fans) may be installed to direct the flow in the desired direction. These fans may also be used for emergency ventilation at crossover locations.

The distance between Hil Range and Shivaji Nagar Station is 1604.6 meter and the ramp portion length is 360 m therefore, Tunnel Booster Fans (TBF) may be
required in the ramp portion. The capacity of the TBFs can be obtained from the simulations.

The trackway exhaust system will have two fans of each 30 cum/sec. for each platform. The connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated.

A comprehensive remote control and monitoring system for operation and control of tunnel ventilation system will be installed. The alarm and status signals from the equipment will be transmitted to operations control centers (OCC) through SCADA. The activation command for a group of equipment will be initiated from OCC by the controller. There shall be a mode table defining sequence of equipment operation for each event or scenario.

8.13.4 Space Requirement for VAC System

The station air conditioning and tunnel ventilation equipment plant room are normally located at each end of the concourse for the two level stations. The approximate area for air handling equipment room would be 400 sq. m and for tunnel ventilation fan room would be 600 sq. m. respectively at each end of the station. The tunnel vent shafts of approximately 20 sq. m. area will be constructed at each end of the stations. There shall be supply shaft and exhaust shafts at the stations of similar dimensions. For the underground stations with large inter station distances there may be necessity of constructing mid tunnel shaft. Considering the ultimate headway of 3-minute and the inter-station distances in Pune metro corridor the mid tunnel ventilation shafts are not required.

However, the adjacent station’s end shafts will have fans with higher pressure since thrust required will be more. We can reduce the pressure (and also fan power requirement) if booster fans are used but this is preferred if cut-cover tunnel sections is there. Computer simulation during design stage would tell about the need of mid tunnel cooling dumping. Although increase in in-bound dumping can eliminate this need. Train AC condensers should work at full load till 50°C.
8.14 CONTROL AND MONITORING FACILITIES

For the underground stations the control and monitoring of station services and systems such as station air-conditioning, ventilation to plant rooms, lighting, pumping systems, lifts & Escalators, etc shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel Ventilation as well as Smoke Management system will normally be done through OCC. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network (such as FOTS). There shall be an Auxiliary Power Controller at OCC who will be monitoring these services and systems. The command signals will be initiated at OCC and relayed up to the relevant equipment for operation. The feedback signal is received through SCADA whether the command is implemented or not. The control from OCC is generally performed using ‘Mode Tables’ for each system. This table defines the sequence of the desired equipment that need to be operated based on the event. The abnormal conditions such as train congestion, emergency, fire in subway would be detected by various components and the emergency response thereto will be activated based on the mode tables. In the event that remote control is not possible due to any reason, the local control via SCR would be performed. The OCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

8.15 CODES AND STANDARDS

The concept VAC design is guided by the following codes and standards:

a) SEDH – Subway Environment Design Handbook
c) CIBSE – relevant document
d) NFPA – 130, 2003 edition