Promat

Tunnels

Over Track Exhaust Ducts

Tunnel & Underground Structure Fire Protection

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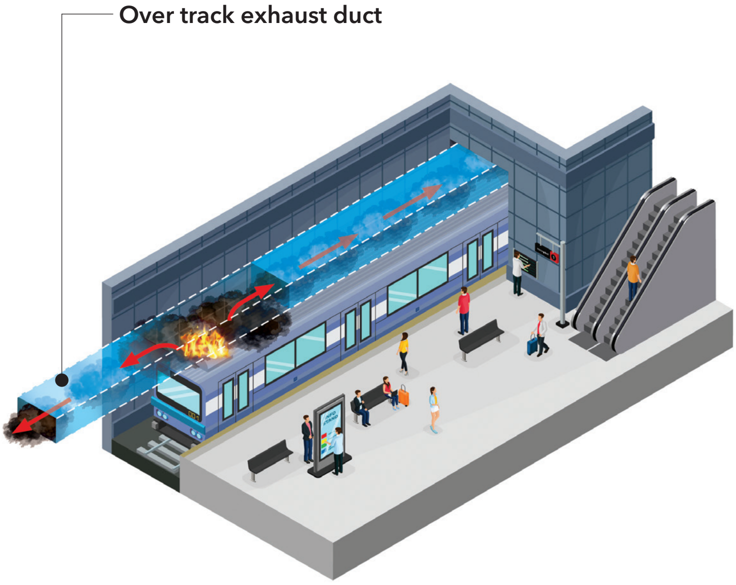
1. Introduction

The risk of fire within underground metro systems has meant the need for tunnel ventilation to control the spread of smoke to ensure safe evacuation of passengers without the risk of smoke inhalation and subsequent life safety.

A common approach in recent years is to drive the "on-fire" train to the nearest station where appropriate fire safety measures are in place for the passengers to evacuate. Over Track Exhaust systems facilitate the safe evacuation of the passengers by exhausting the smoke away from the incident allowing safe evacuation to non-incident areas.

It is therefore critical that the OTE can withstand the effects of fire without collapsing, as collapse of the duct compromises its primary function.

The vast numbers of people moving through these concourses, platforms, underground enclosures and elevated structures cause the danger to life safety to increase significantly.



2. Scope

OTE ducts are used at underground train stations for the extraction of smoke and hot gases in the event of a fire and can also be used as supply ducts for fresh air if required. The OTE ducts are typically designed to extend to the length of the platforms and are placed above the tracks to extract hot air in the event of fire on the train. Due to its function the OTE duct shall provide structural adequacy in its construction, integrity to the resistance of fire spread and tolerance to increased temperatures when assessed in accordance with the standards in Section 3.

The OTE duct has the primary objective of smoke management in the tunnel at the platform track for exhausting smoke and hot gases from fire events inside or outside the train. This will mitigate smoke entering the station and endangering lives. The OTE duct is not intended to be used for station fire. Generally these projects will have a defined interface, which will differentiate the "tunnel" from the station". In certain cases the station design will be more aligned with local standards and building codes, where the tunnel itself may be more performance based or "fire engineered design". For the stations a separate fire safety system is intended for this purpose, in which case the OTE duct remains inactive during a station fire.

The OTE ducts shall be capable of handling hot smoke and be fire resistant with respect to the structural adequacy and integrity requirement of various international standards referred to in the Appendix. Generally, they are designed for the event of a fire in a train standing at a platform in the station, where the OTE duct is exposed externally to flames and heat of the burning train.

The purpose of this document is to offer solutions for the above and to also provide guidance for the evaluation of fire resistance and other required functions for the use of the OTE duct.

3. Fire Resistance Levels

3a. Fire curve

The tunnel designers will determine the fire resistance levels (FRL's) required. Where there is a risk of increased heat being transferred from the duct to other critical areas full insulation criteria shall be used (240/240/240) or (120/120/120). Please refer to section 7a Standards and Norms for more information regarding fire resistance.

Where the designers determine that the requirement is purely to limit the transfer of flames and hot gases, then the FRL can be based on structural adequacy and integrity of the system e.g.; (240/240/-) or (120/120/-). (please refer to Section 7a).

When discussing fire resistance, the following standards are generally referred to within the requirements of this manual. BS476 Part 24, BS EN 1363-1 2012, ISO 6944, AS 1530.4, and ASTM E119 among others. (these all use a similar fire curve originating from ISO 834 – see curve below in figure 1. Commonly known as the standard time temperature curve, cellulosic curve or "the ISO curve".

Please also refer to supplementary standards in Clause 11.

Notwithstanding the previous comments, there may be a requirement to evaluate the system against other international fire curves. An example would be the German RABT ZTV fire curve for rail (see below in 3b).

The purpose of these standards, in the context of this manual, is to measure the ability of an OTE duct system to extract smoke and hot gases from the train below and exhaust them to a safe area without allowing spread of fire to other areas (such as the station for example).

It should be noted that the system relates to a complete ductwork installation and therefore joints, supports and the fire stopping through any other fire compartments, all form an integral part of the approved construction.

3b. Alternative fire curves

In some cases, the system may be required to resist higher fire curves – (for example RABT – train) (see RABT fire curve shown in figure 2 along with other fire curves typically used in road tunnels). Materials and systems are available to meet the design requirements of these fire curves – please contact the Promat tunnel team for details.

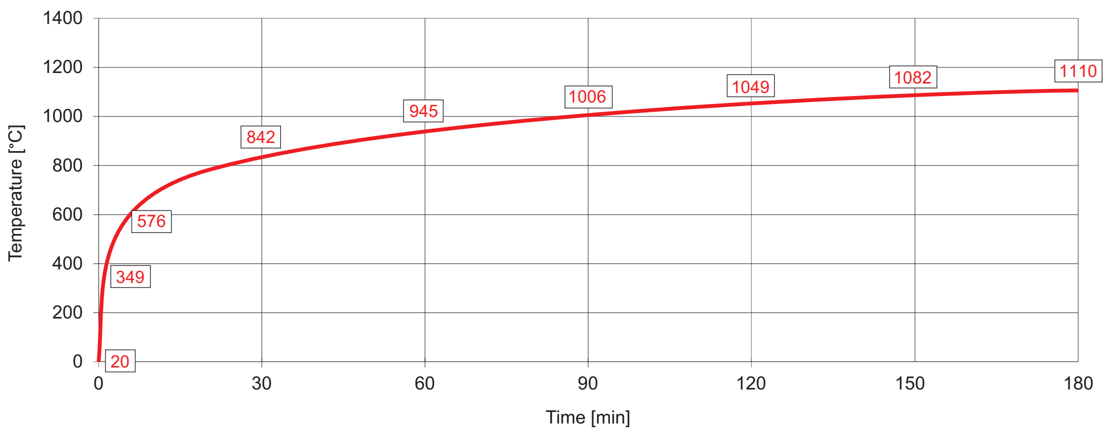


Figure 1: ISO fire curve

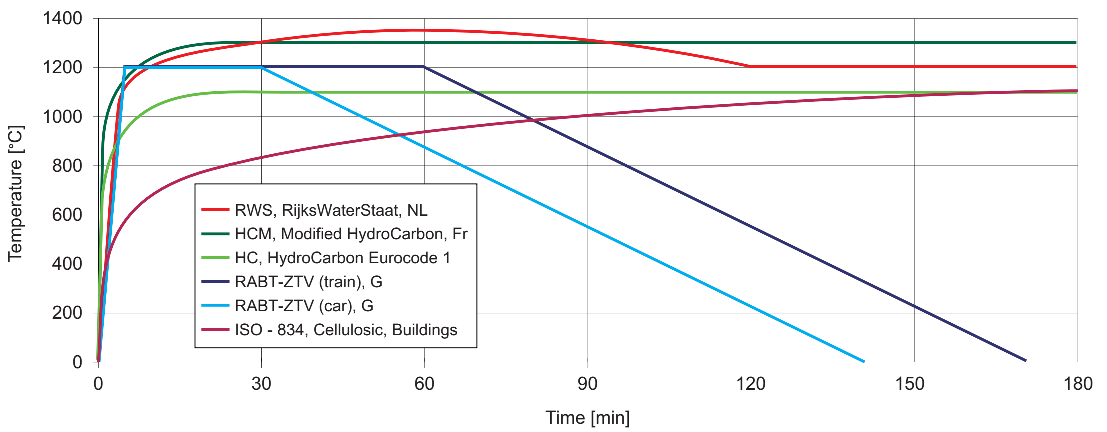


Figure 2: Alternative fire curve

4. Standards and Norms

4a. Fire resistance

Failure Criteria

There are three governing criteria that the selected OTE duct material may be required to achieve when tested against the requirements of various test standards such as BS476, Part 24, ISO 6944: EN 1363 part 1 or AS 1530.4. Below is a general description of the three criteria. For detailed information, please refer to the specific standard.

1.1. Stability or Structural Adequacy: The ability of a duct and the support system to remain intact and fulfil their intended function for a specified period. Stability failure shall be deemed to have occurred, when the duct collapses in such a manner that the duct no longer fulfils its intended function.

1.2. Integrity: The ability of a duct to remain free from cracks, holes or openings in the cladding material in which the fire is present for a specified period. The presence and the formation of cracks, holes or other openings through which flames or hot gases can pass shall constitute integrity failure.

1.3. Insulation the ability of a duct cladding to maintain its function without developing unacceptable temperatures on the unexposed side of the barrier. Given that OTE's typically have extraction dampers to use as extraction devices, typically these OTE ducts will not use Insulation as a failure criterion.

Types of Fire Exposure

It is generally understood that these OTE ducts will be exposed to fire from the outside (the source is typically the train). However, consideration must be given to the temperatures inside the duct if it is extracting hot smoke and gases via the dampers in the duct.

4b. Hose stream

In the event of a fire incident, it may be necessary for the fire and emergency services to enter the tunnel and fight the fire. This may require the system to have evidence showing that the material is resistant to the effects of the hose stream to protect its personnel from being injured if fighting a fire on the train.

While this physical test is normally to evaluate the integrity of the system after a fire, it is reasonable to use this data to show an elevated level of safety for the fire fighters, PROMATECT® H, and DURASTEEL® have data showing resistance to the hose stream test after exposure to fire. Please see figure 3 and reference standard in the Appendix.

4c. Blast

It may be a requirement for this installation to resist a blast. This could be due to terrorist activity or possibly some other unexpected event from the train, in this case Promat has test data on DURASTEEL® ducts to resist the effects of blast. (see figure 4)

4d. Dynamic pressures

With the train traffic comes the piston effect – this occurs as a positive pressure in front of the train and a negative pressure after the train passes. Therefore, the structure needs to show resistance to these positive and negative pressures. Promat has extensive testing for this occurrence. Please see figure 5 showing standard testing on the cladding boards.

Figure 3: Hose stream test

Figure 4: Blast test

Figure 5: Dynamic presurres test

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5. Supporting Systems

The supporting systems used for fire rated ductwork must be capable of bearing the load of the ductwork under fire conditions.

5a. Smaller ducts

For smaller ducts the support system may consist of the hangers and horizontal bearers (see figure 6). Attention must be given to the spacing of the supports and the size of the support components in accordance with the manufacturer's test data and recommendations. The following must not be exceeded.

i. The maximum allowable span of the duct between supports;

ii. The maximum distance of the hangers from the side of the duct;

iii. The maximum allowable stress within the components of the supports for the required fire rating.

iv. Stresses within the support components can be reduced by increasing the size of the components, or reducing the spacing centres of the supports, or applying fire protection to the support systems. The element of building construction to which the support systems are attached must have a fire rating of at least that specified for the duct and be able to support the weight of the duct under fire conditions.

5b. Larger ducts

For larger ducts that are unable to use the design methods of typical steel lined extract ducts, it will be necessary for the main contractor / client to design a suitable structural framework that will allow for the application of the tested cladding materials. Using this method will require stringent evaluation of existing test methods to demonstrate suitability of the materials for the design / performance requirement.

Loads on structural members will need to be evaluated by the structural engineer to evaluate if there is a need to fire rate the individual members.

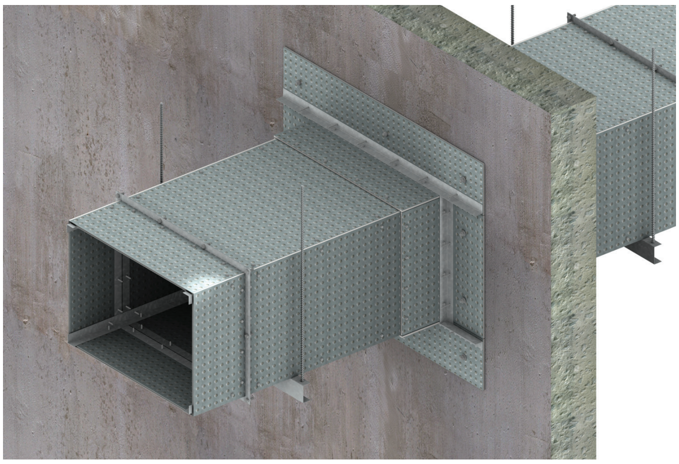

Figure 6: Smaller duct system support

6. Design Options

When discussing OTE ducts within the tunnel it may be necessary to provide different design options due to the specific geometry of the tunnel. Or the volume of air to be moved means that these may be required to be constructed fundamentally different to the test methods used for steel lined extract ducts in normal construction buildings.

Steel lined extract ducts as often used in buildings are generally not suitable for underground stations, because while the steel strength reduces with increasing temperatures, the duct has to remain intact without significant loss of cross-section despite the underpressure inside the duct that is generated by the exhaust fans to create sufficient air flow.

Therefore, the manufacturer is required to demonstrate that the materials and system specified will meet the specification required of the OTE duct. This is normally done in conjunction with the stakeholders which may include the client, the main contractor, the AHJ as well as the installing company.

Note that these ducts have been tested and approved in 1, 2, 3 and 4 sided applications to suit the tunnel geometry.

Normal steel lined ducts have limitations on their spans, however DURASTEEL® OTES's can span large spaces depending on the steel framework used.

Figure 7: 1 sided duct system

Figure 8: 3 sided duct system

7. Trafficability

Depending on the design of the system it may be a requirement for the OTE duct to allow for inspection from within the duct, this will require a trafficable floor to be installed inside the duct on the top part of the horizontal component. This floor should be designed to carry the dead and live load of the maintenance activities. Promat DURASTEEL® is a product which can deal with these types of loads easily and therefore will not require any other type of trafficable flooring within the duct.

Figure 9: People inside the duct

8. Air Leakage

Depending on the design of the system, it may be a requirement to demonstrate limited air leakage.

Figure 10: Air leakage testing

9. Durability

Durability of products is obviously an important issue for the client / owner. The materials used in the construction of these OTE ducts should have a design life of not less than 40 years. Depending on the environment, DURASTEEL® will be able to meet this requirement.

Low heat transfer CHARACTERISTICS

DURASTEEL® low radiation

Radiation levels measured during a test on a single skin 9.5mm Promat DURASTEEL® barrier

Radiation Levels (kW/m²)				
Distance from barrier (m)	**After 30 minutes**	**After 60 minutes**	**After 120 minutes**	**After 240 minutes**
0.5	7.5	12.0	16.0	20.0
1.5	4.6	7.1	9.8	12.5
2.5	2.5	3.9	5.4	6.9

Effects of Thermal Radiation	
Radiation Heat Flux (kW/m²)	**Observed effect**
0.67	Summer sunshine in the UK
1.0	Maximum of indefinite skin exposure
6.4	Pain after 8 seconds skin exposure
10.4	Pain after 3 seconds skin exposure
12.5	Piloted ignition of timber
16.0	Blistering of skin after 5 seconds exposure
29	Spontaneous ignition of timber

10. Certifications

Fire-resisting ductwork should meet the appropriate fire resistance period for the specific application when tested in accordance with the standards discussed in section 3 by a recognized accredited laboratory – e.g. NAMAS/UKAS/NATA. All fire tests should be evaluated against the criteria and procedures in the previously mentioned standards and certification must be provided by a recognized accredited laboratory. Final approval must always be obtained by the Authority Having Jurisdiction (AHJ) prior to commencement of construction.

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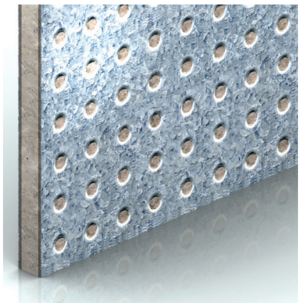
11. Systems and technical data

DURASTEEL®



Promat DURASTEEL® is a composite panel of fibre reinforced cement mechanically bonded to punched steel sheets on both outer surfaces. It is classed as 'non-combustible' to BS 476: Part 4: 1970 and A1 to Clause 10 of BS EN 13501-1:2002.

Promat DURASTEEL® is both highly impact and moisture resistant.

Promat DURASTEEL® has been developed and supported through rigorous testing for use in barriers, door, ceiling and ducts applications, with a wide range of specifications available. Promat DURASTEEL® systems combine lightness, strength, impact, blast resistance and durability with exceptional fire resistance. In addition, Promat DURASTEEL® can also withstand the effects of firefighters' hoses.

Promat DURASTEEL® systems have been used successfully across the industry for many years, including large rail, metro and airport projects, as well as military developments and commercial, pharmaceutical and petrochemical facilities.

Promat has developed DURASTEEL® to provide an effective blast resistant solution to constructions in a wide range of industrial applications, including power generation and anti-terrorist installations.

PROMATECT® H

PROMATECT®-H is a non-combustible matrix engineered mineral board reinforced with selected fibres and fillers. It is formulated without the use of formaldehyde. PROMATECT®-H is off-white in colour and has a smooth finish on one face with a sanded reverse face. The board can be left undecorated or easily finished with paints.

PROMATECT®-H is resistant to effects of moisture and will not physically deteriorate in a damp or humid environment. Whilst its performance characteristics are not degraded by moisture or aging, PROMATECT®-H is not designed for application in areas subject to continual damp or high temperatures.

12. Reference documents

Reference Test standards.

Note, it is not the intention for this document to comply with all the standards referenced below, it is a purely a reference that designers / AHJ's may wish to use.

- BS 476, Part 24: 1987 Fire tests on building materials and structures (method for determination of the fire resistance of ventilation ducts)
- ISO 6944: 1985 Fire resistance tests – Ventilation ducts (similar to BS 476 above)
- AS 1530.4:2014. Methods for fire tests on building materials, component and structures. Section 9. Air Ducts
- BS EN 1363-1 2012, General Requirements
- EN 1366-1:2014. Fire resistance for service installations- Part 1: Ventilation ducts
- ASTM E119 -07 Hose stream test – Section 11
- Factory Mutual
- Lloyds Register
- Underwriters Laboratories (UL)

13. Project references

- London Underground
- Channel Tunnel Rail Link
- Dubai Metro, UAE
- Doha Metro, Qatar
- Mass Rapid Transit, Singapore
- Riyadh Metro, Saudi Arabia
- Kolkata Metro, India
- St. Pauls Thames Link, Ludgate Place
- Waterloo International Rail Terminal
- MTRC WIL West Island Line Building Services for Sai Ying Pun and Hong Kong University Station
- MTRC WIL Building Services for Kenny Town Station
- MTRC WIL Tunnel Ventilation
- MTRC SIL (E) (South Island Line) Building Services for Wong Chuk Hang Depot
- MTRC SIL (E) Tunnel Environmental Control System
- MTRC XRL (Express Railway Link) West Kowloon Terminus Environmental Control System
- MTR Existing Plant room Relocation at Admiralty Station for Shatin Central Link
- MTR SCL (Shatin Central Link) Hung Hom Station

14. Technical Data sheets

Please contact your local Promat office for the technical datasheets.

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→ All data contained herein conforms to and frequently surpasses generally accepted fire protection standards recognised by most professional fire science practitioners and regulatory authorities worldwide. The same general principle is equally applicable to all Promat products and systems. Promat has access to a considerable body of test authentication data and this can be provided on a complimentary basis upon request. It should be noted however that this publication replaces all previous editions in its entirety.

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