

TEL-AVIV LIGHT RAIL RED LINE HVAC & TVS SYSTEMS

SEEEI/SACEEI Conference – Eilat 2018

WAM8 07.11.18

David Young - HRVAC

Red Line - HVAC & TVS Systems

Tel-Aviv Light Rail Red-Line - design principles for:

- HVAC: Heating Ventilation and Air-Conditioning of under ground stations
- TVS: Tunnel Ventilation Systems

Project team:

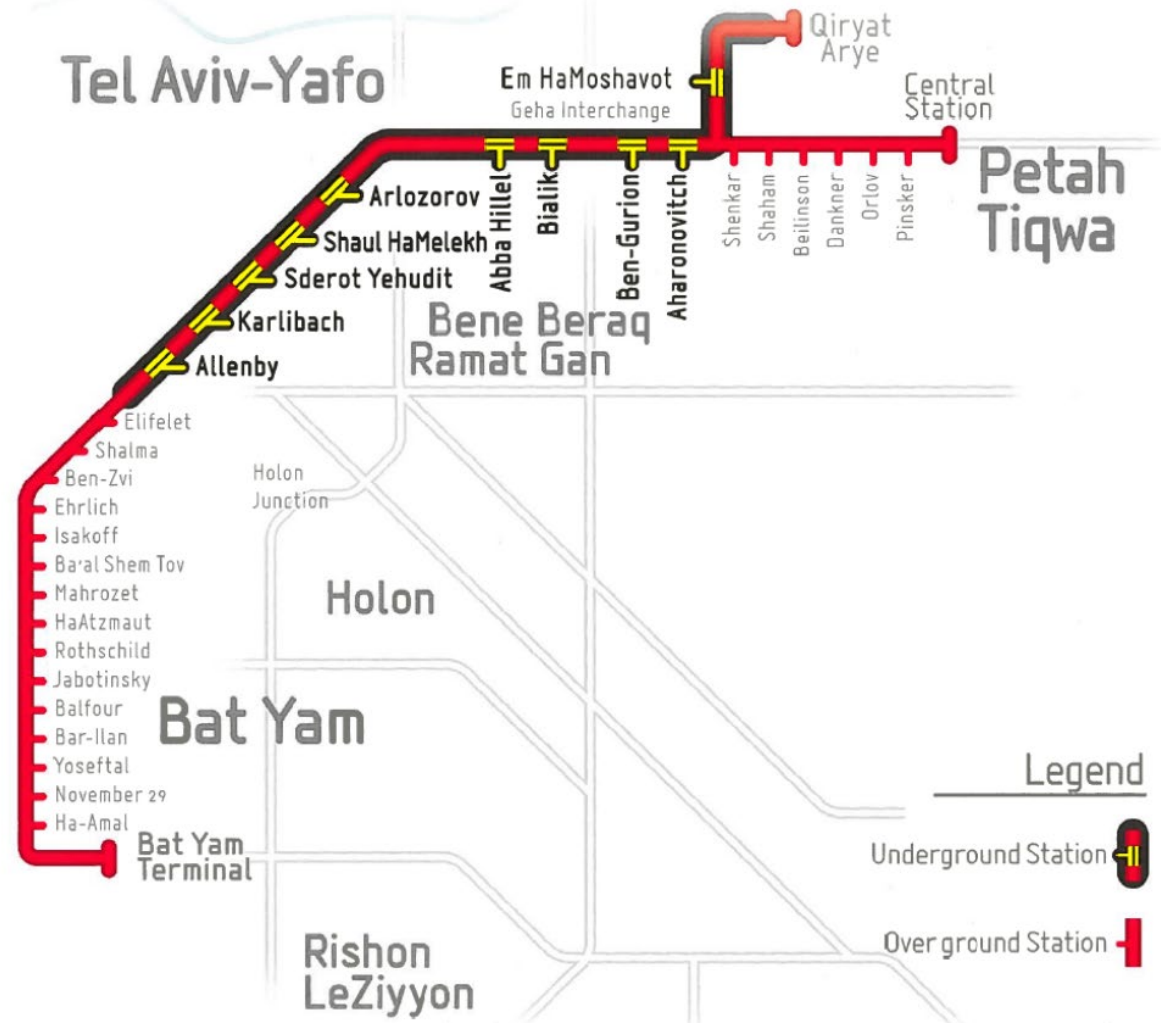
- Client: NTA
- Main designer and architects: IBI/DHV
- Sub-designer: HRVAC
- CFD & SES analysis: Jensen Hughes (US)

Schedule:

- Start of preliminary design: 2011
- HVAC & TVS contract awarded: 2018
- Permit to operate: 2021

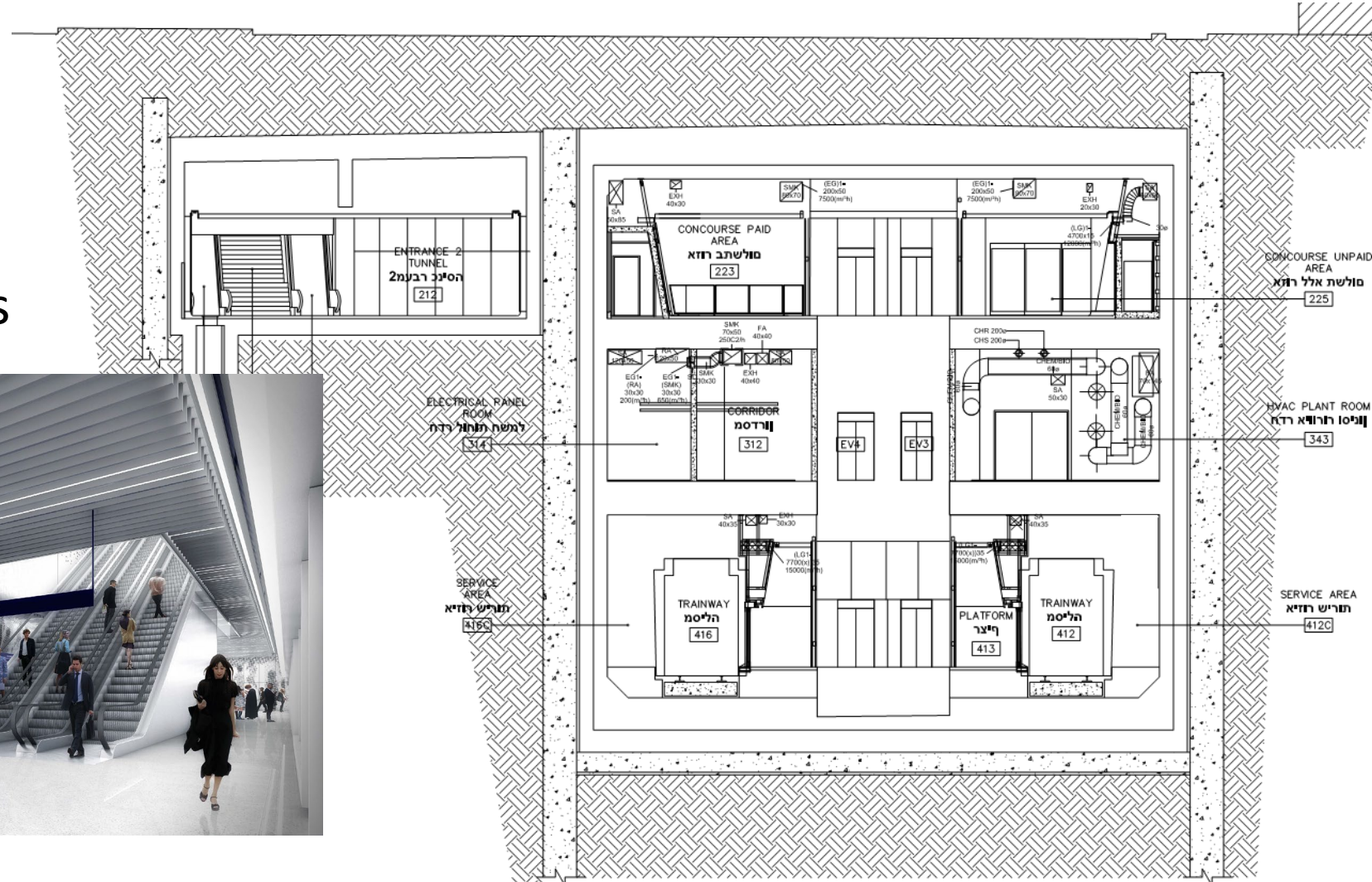
Red Line Configuration

- Total tracks length 24 km
- 23 at grade stops
- 10 underground stations
- 11 km twin bore tunnels

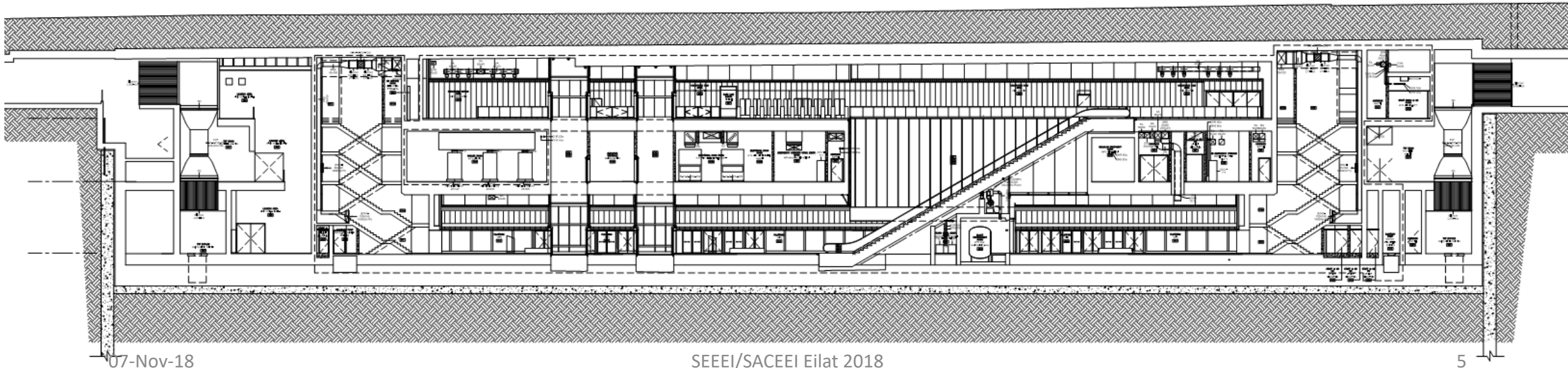


Typical UG Station: Cross-section

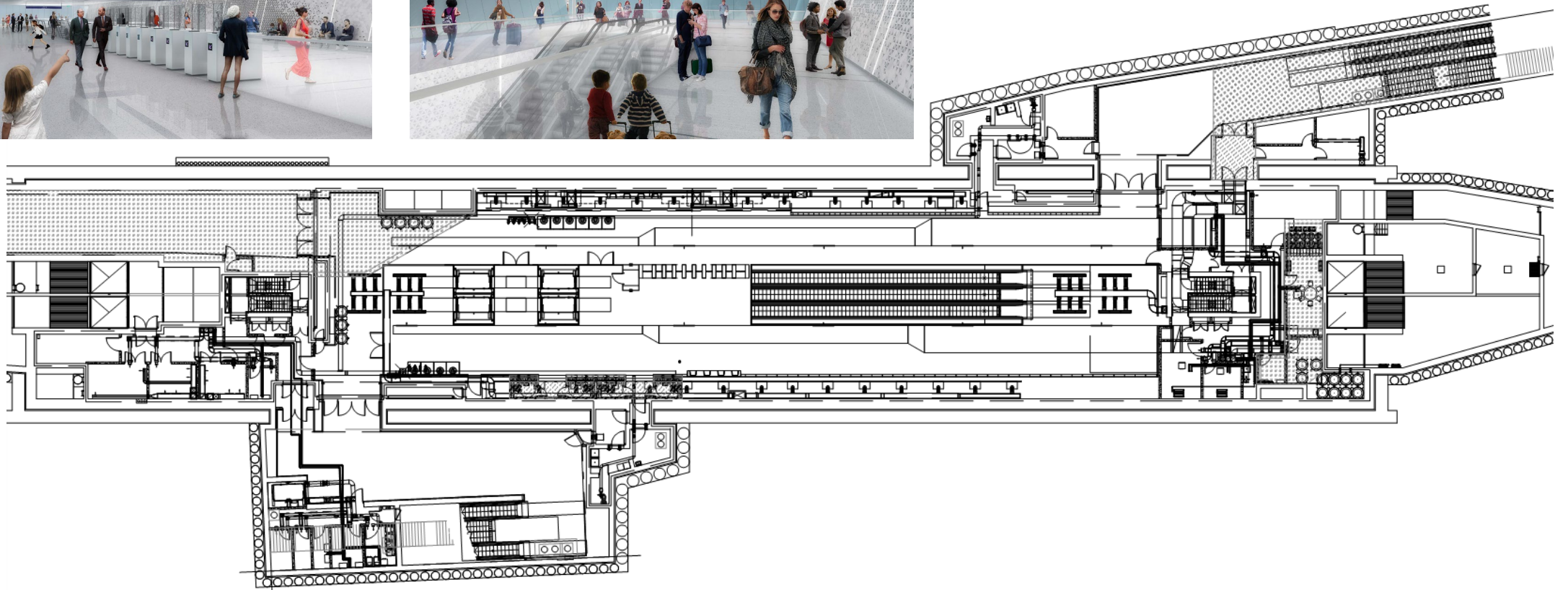
- 3 levels:
 - Concourse level
 - Technical level
 - Platform level
- Platform screen doors



Typical UG Station: Cross-section



Typical UG Station: Concourse level



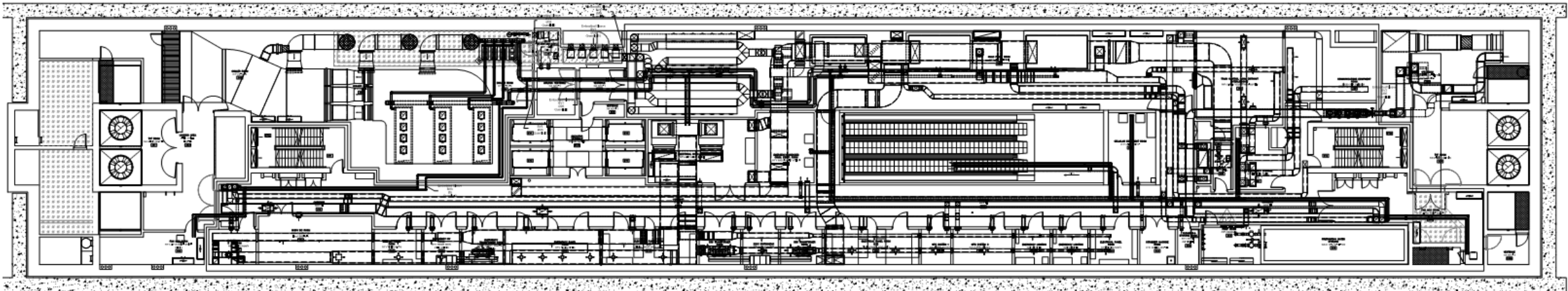
Typical UG Station: Technical level

Chiller Plant

Chem-Bio Filtration

Air Handling Units

CEF Rooms

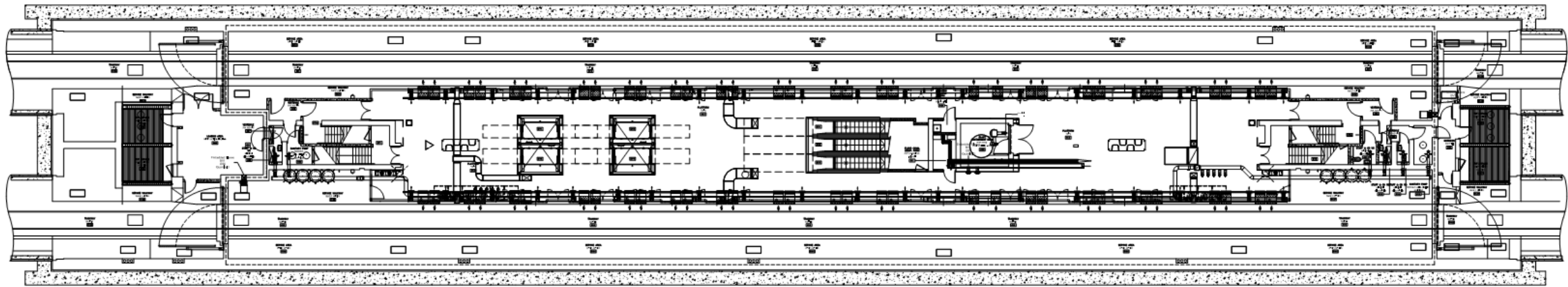


TVF Room

Electrical Rooms

TVF Room

Typical UG Station: Platform level



HVAC Systems: Chiller Plant

UG Station Chiller Plant:

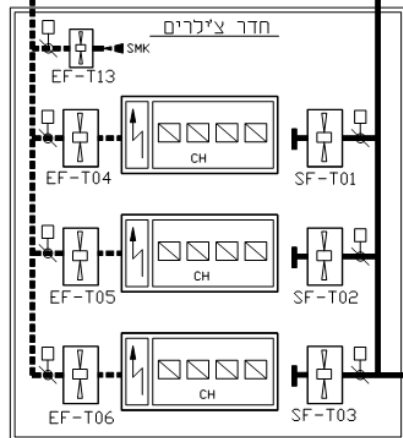
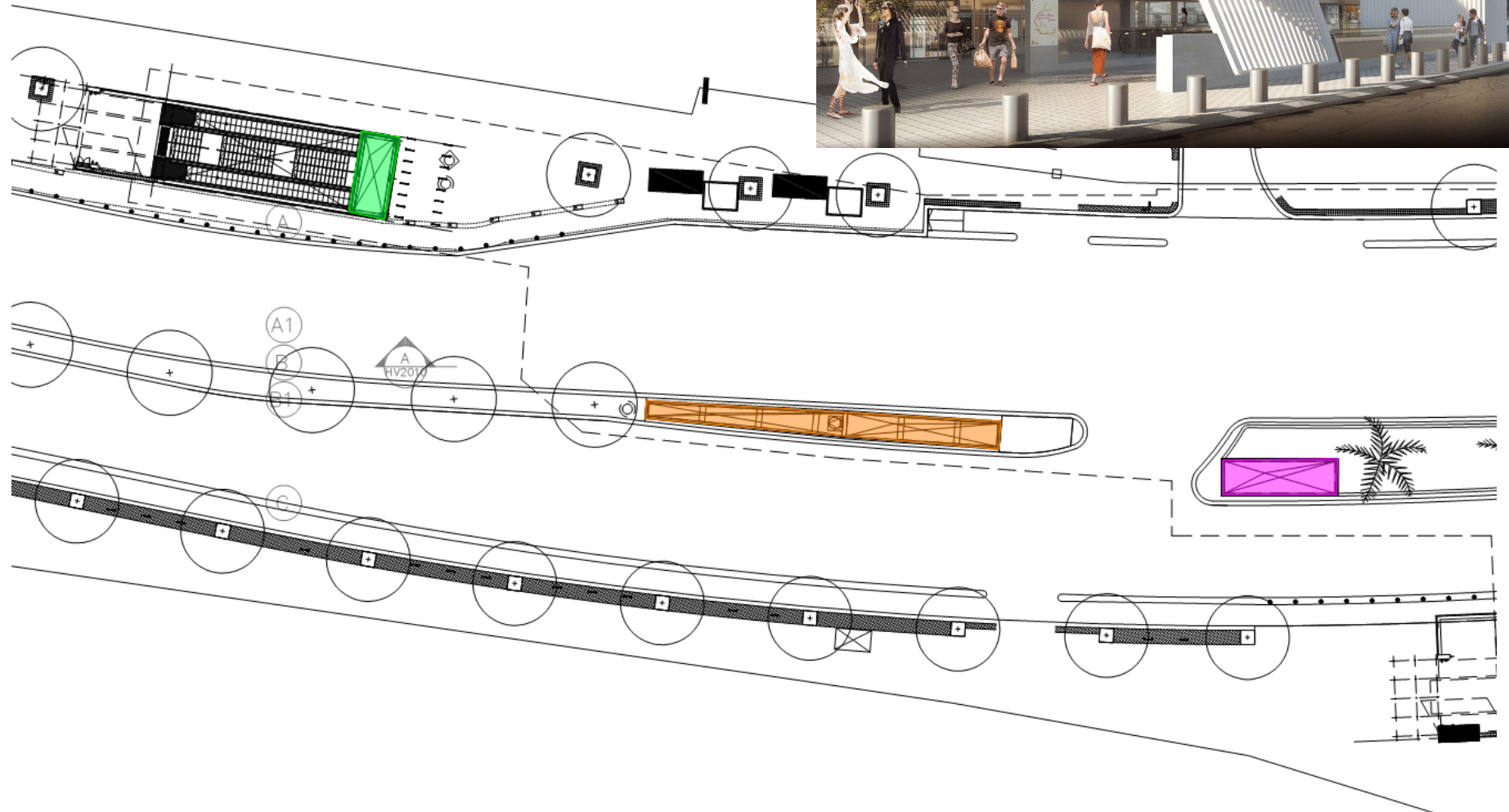
- Cooling loads based on installation of Platform Edge Doors (PED's) and automatic doors at station entrances
- Air-conditioning systems cooled by independent air-cooled chillers installed inside each UG station box for production of chilled water
- Installed capacity: 3 x 80TR
- Ventilation shafts and openings at grade for chiller cooling

HVAC Systems: Chiller Plant



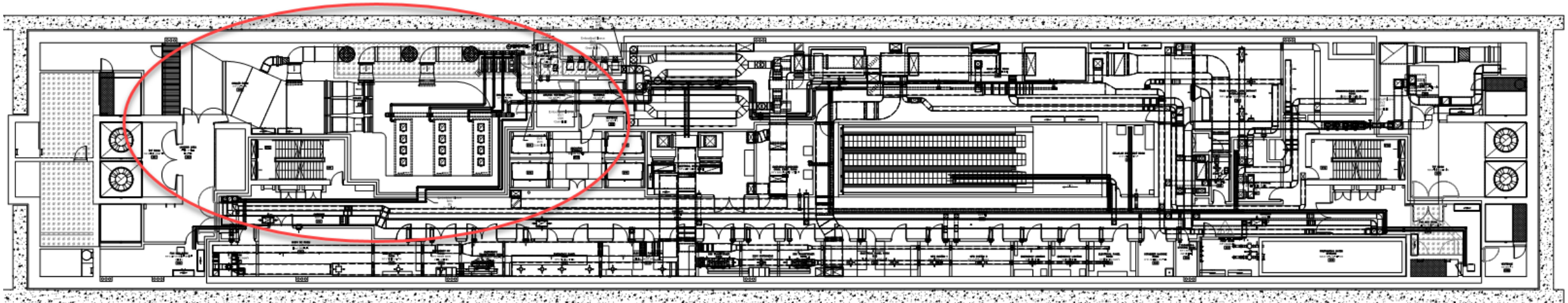
הכנסת אוויר צח
צילרים ותחתנה

פתח פנימי
אוויר כחדר צילרים

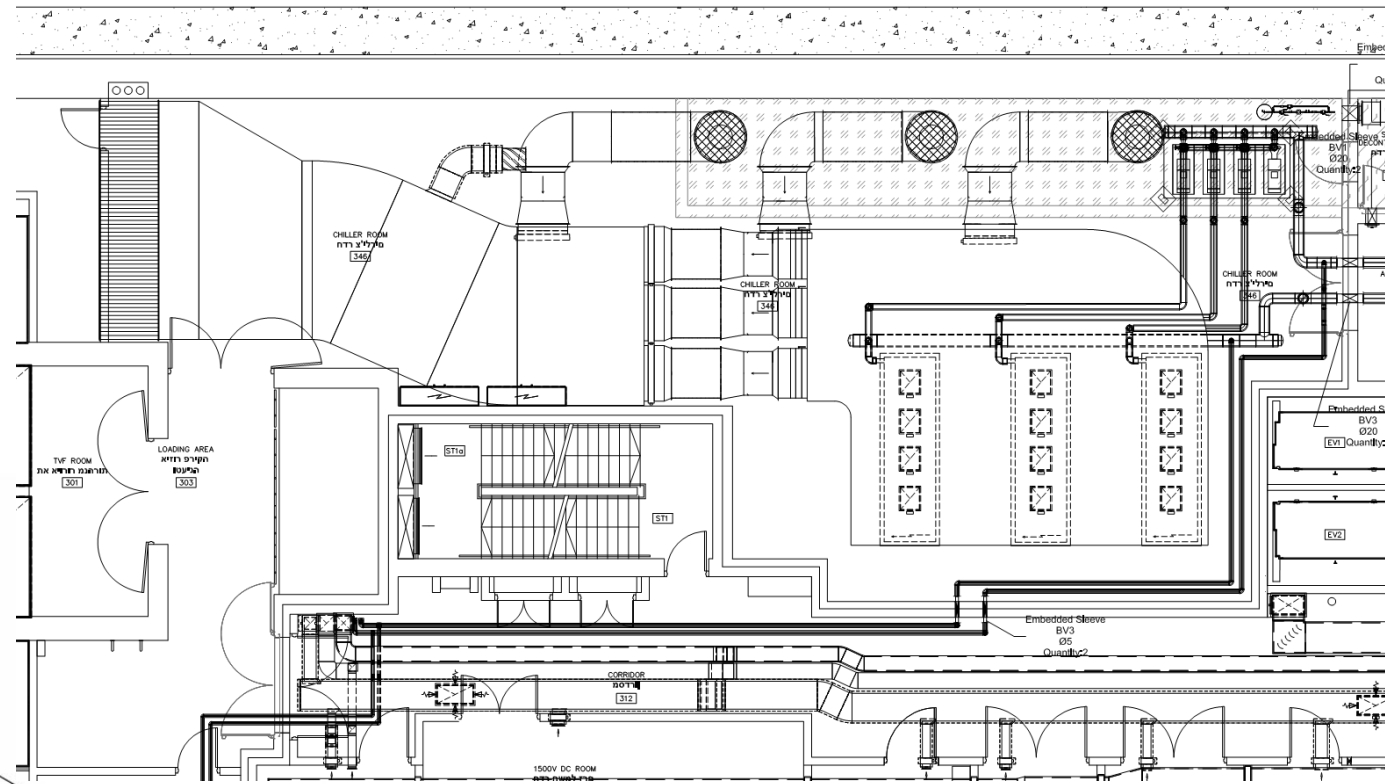
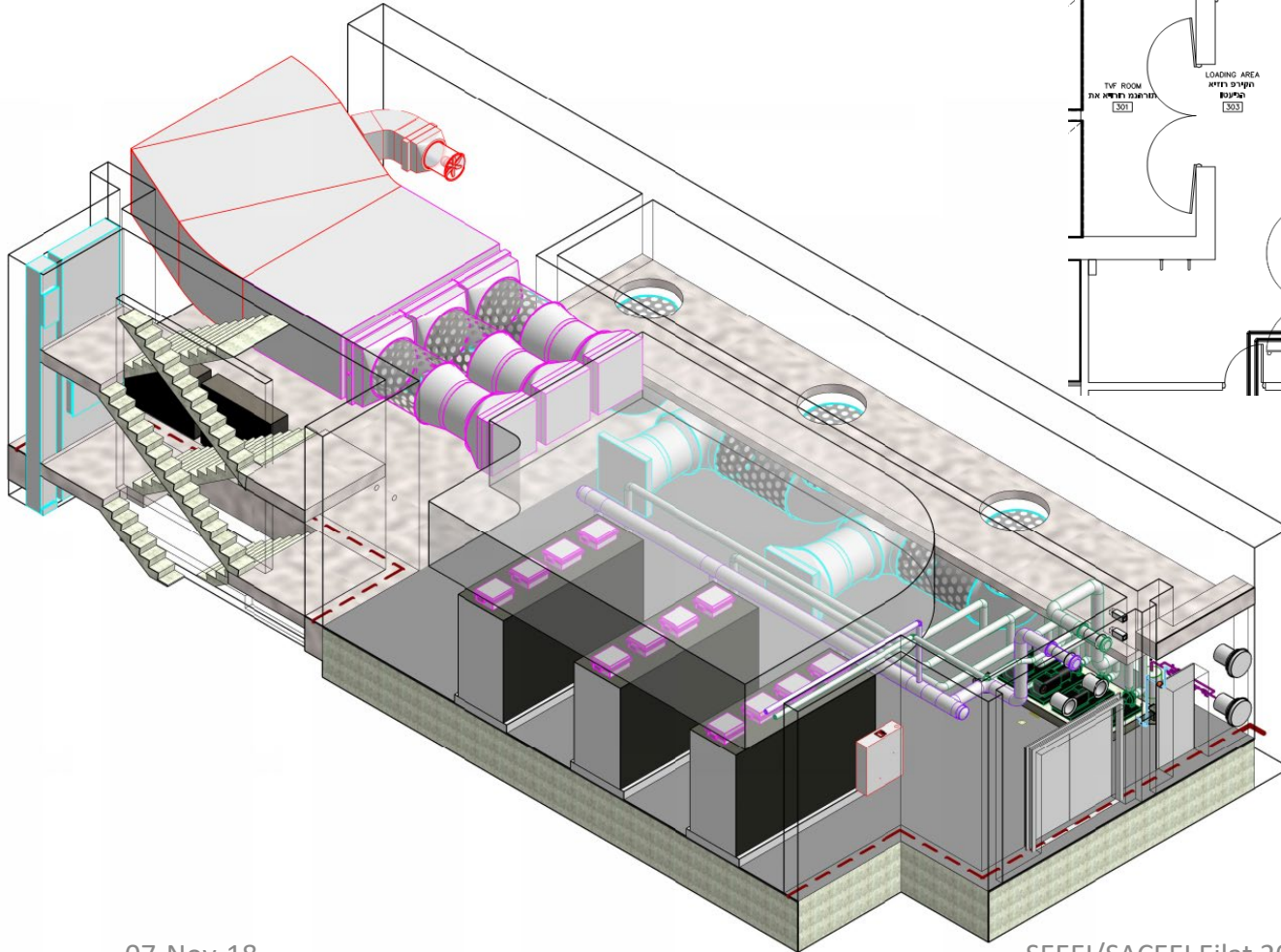


HVAC Systems: Chiller Plant

Technical Level – Chiller Room



HVAC Systems: Chiller Plant



Technical Level – Chiller Room

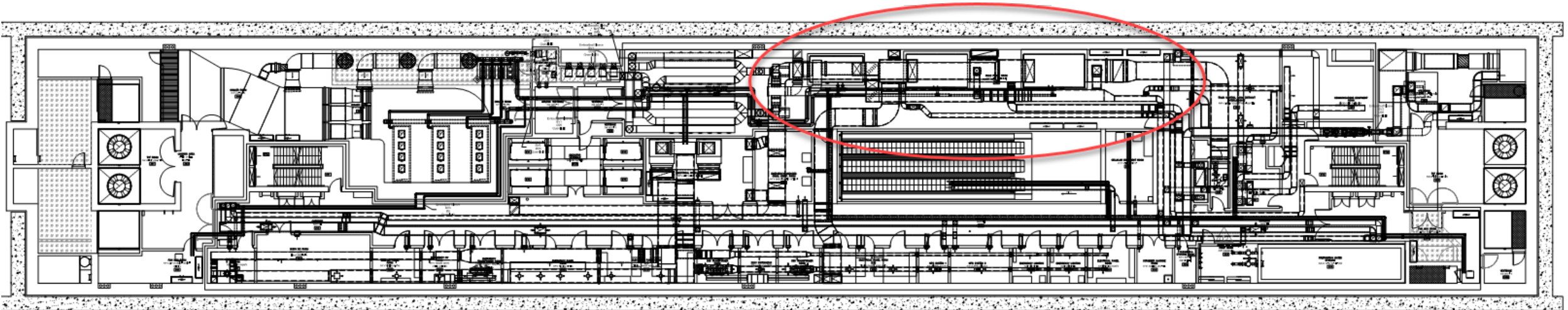
HVAC Systems: Air-Handling Systems

UG Station Air-Conditioning:

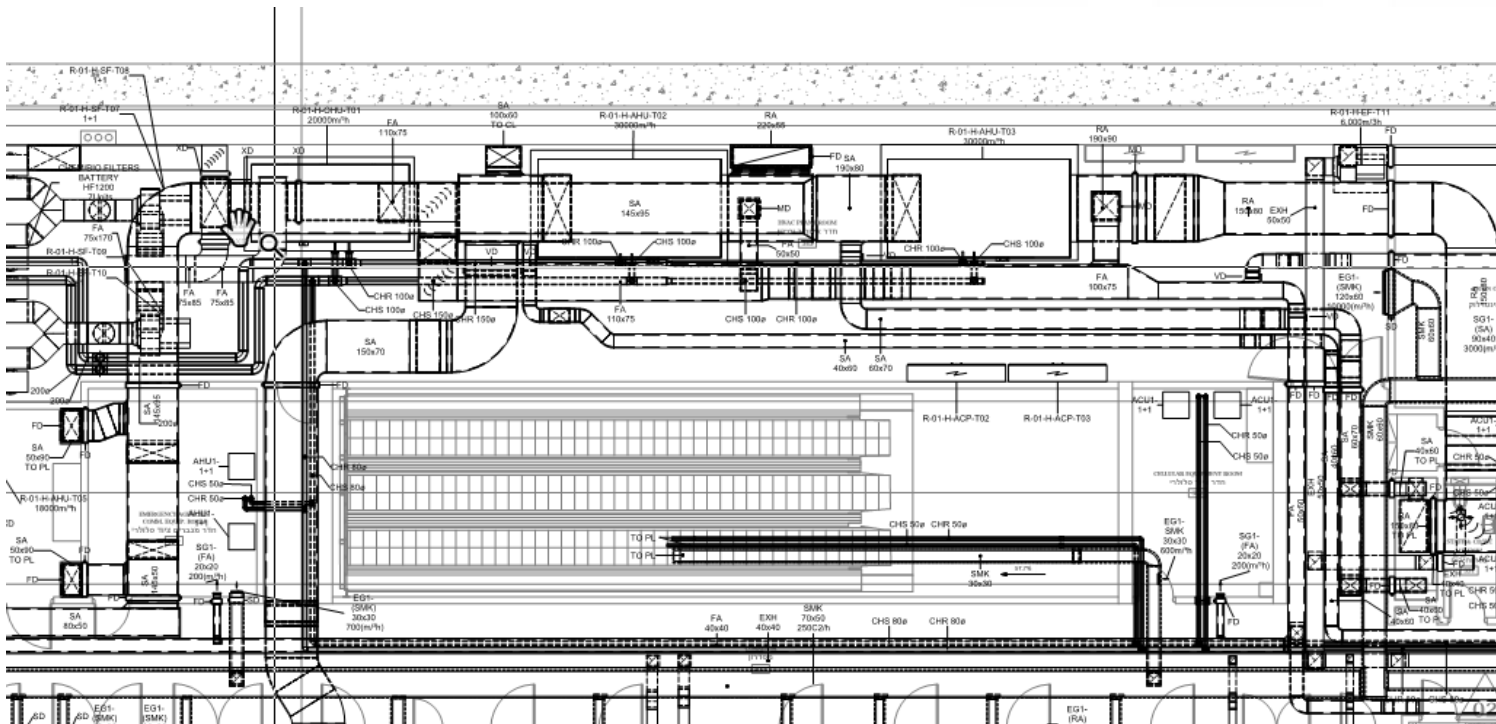
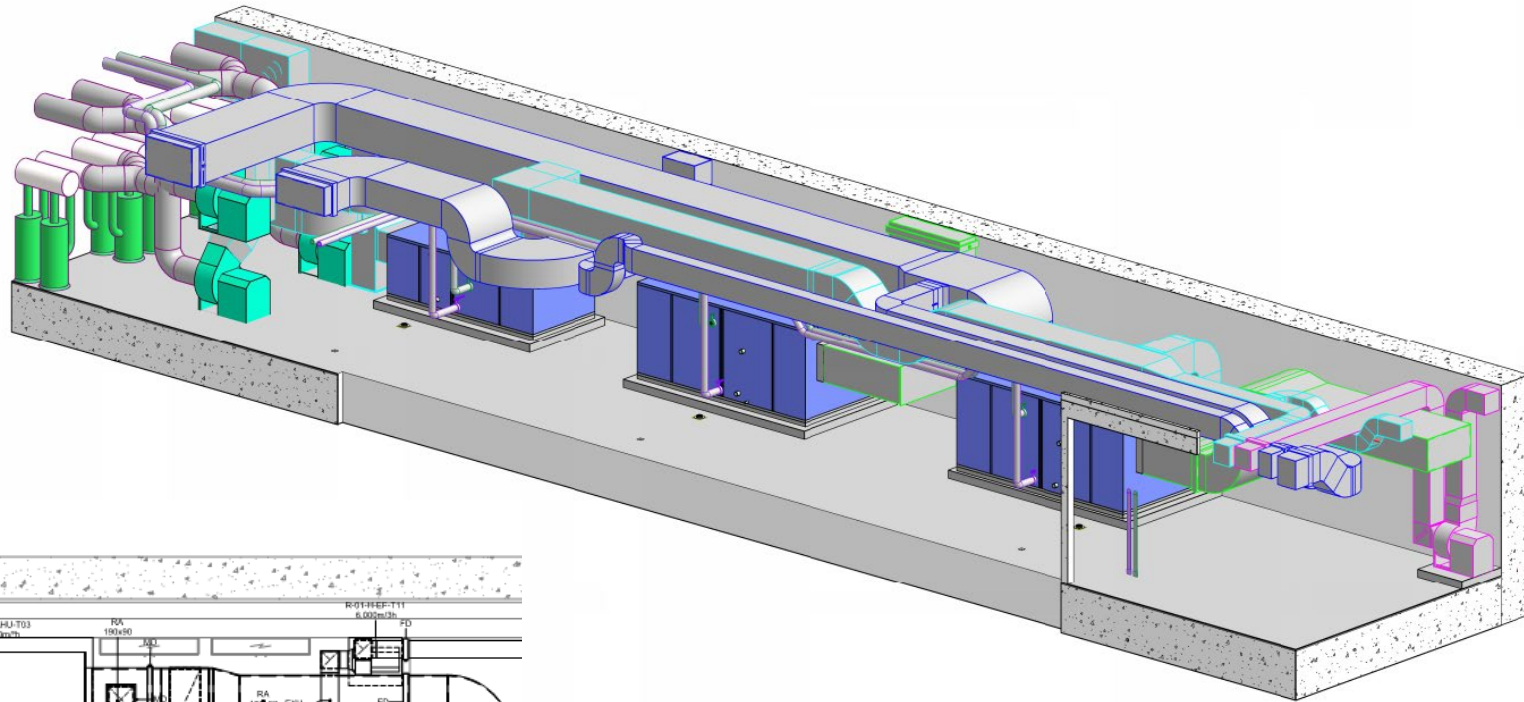
- Concourse and platform levels served by 2 Air Handling Units (AHU's):
2 x 30,000 m³/h
- Staff rooms equipped with Fan Coil Units (FCU)
- Pre-treated Outside air Handling Unit (OHU) with activated carbon filter:
1 x 20,000 m³/h
- Transformers and Electrical rooms served by 2 central AHU's
- Controls and communications rooms served by individual FCU's & ACU's
with N+1 back-up
- General exhaust for toilets and technical rooms
- Mechanical smoke exhaust systems from technical rooms

HVAC Systems: Air-Handling Systems

Technical Level – AHU Room



HVAC Systems: Air-Handling Systems

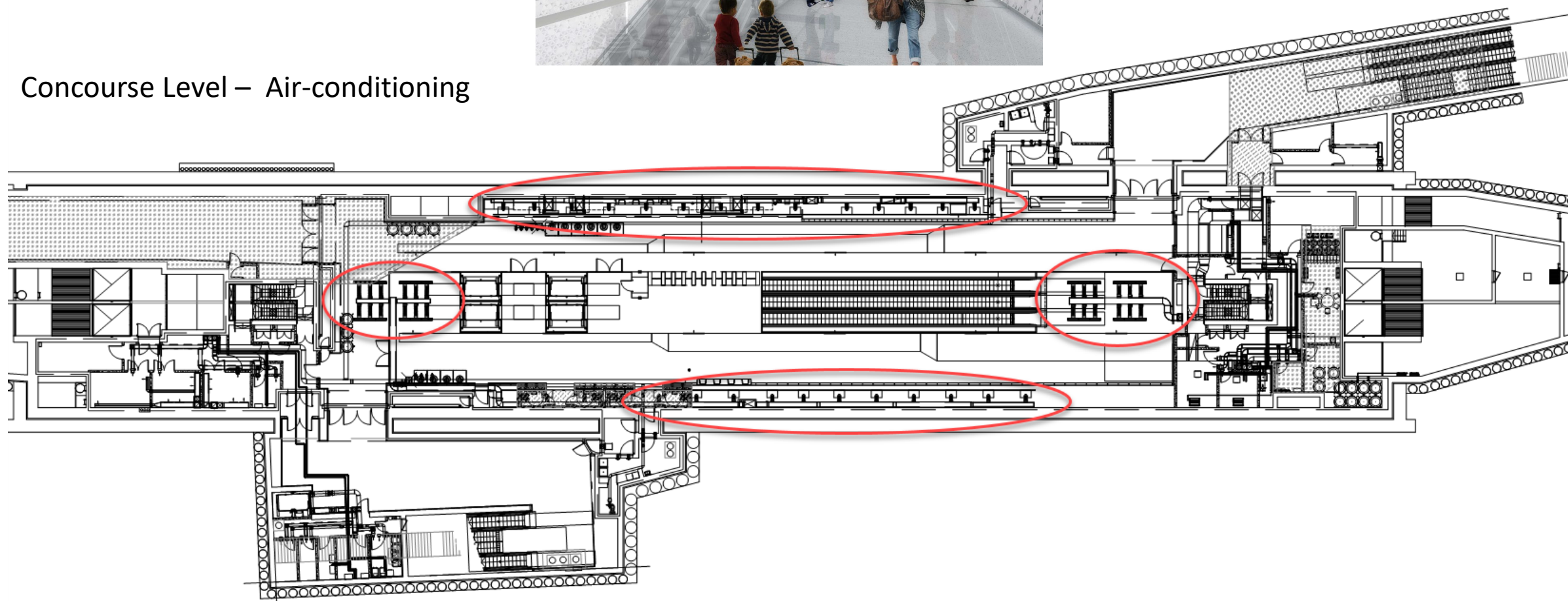


Technical Level – AHU Room

HVAC Systems: Air-Handling Systems

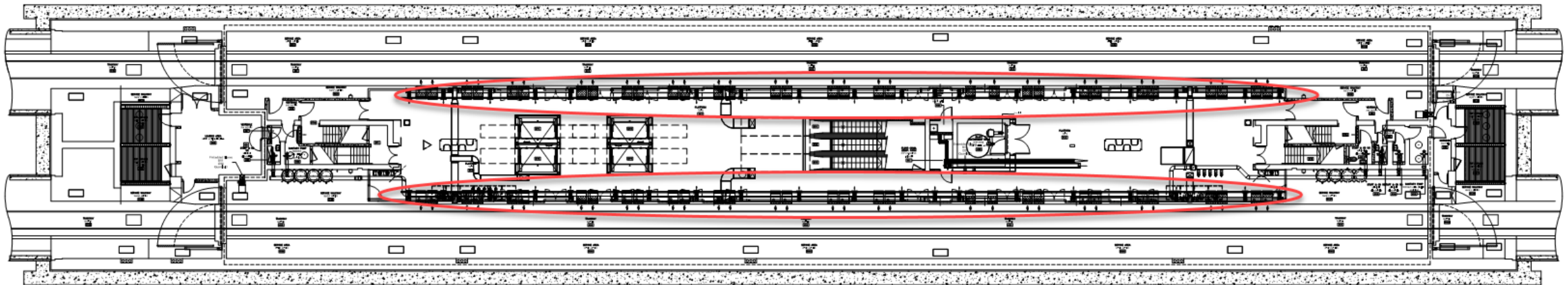


Concourse Level – Air-conditioning



HVAC Systems: Air-Handling Systems

Platform Level – Air-conditioning

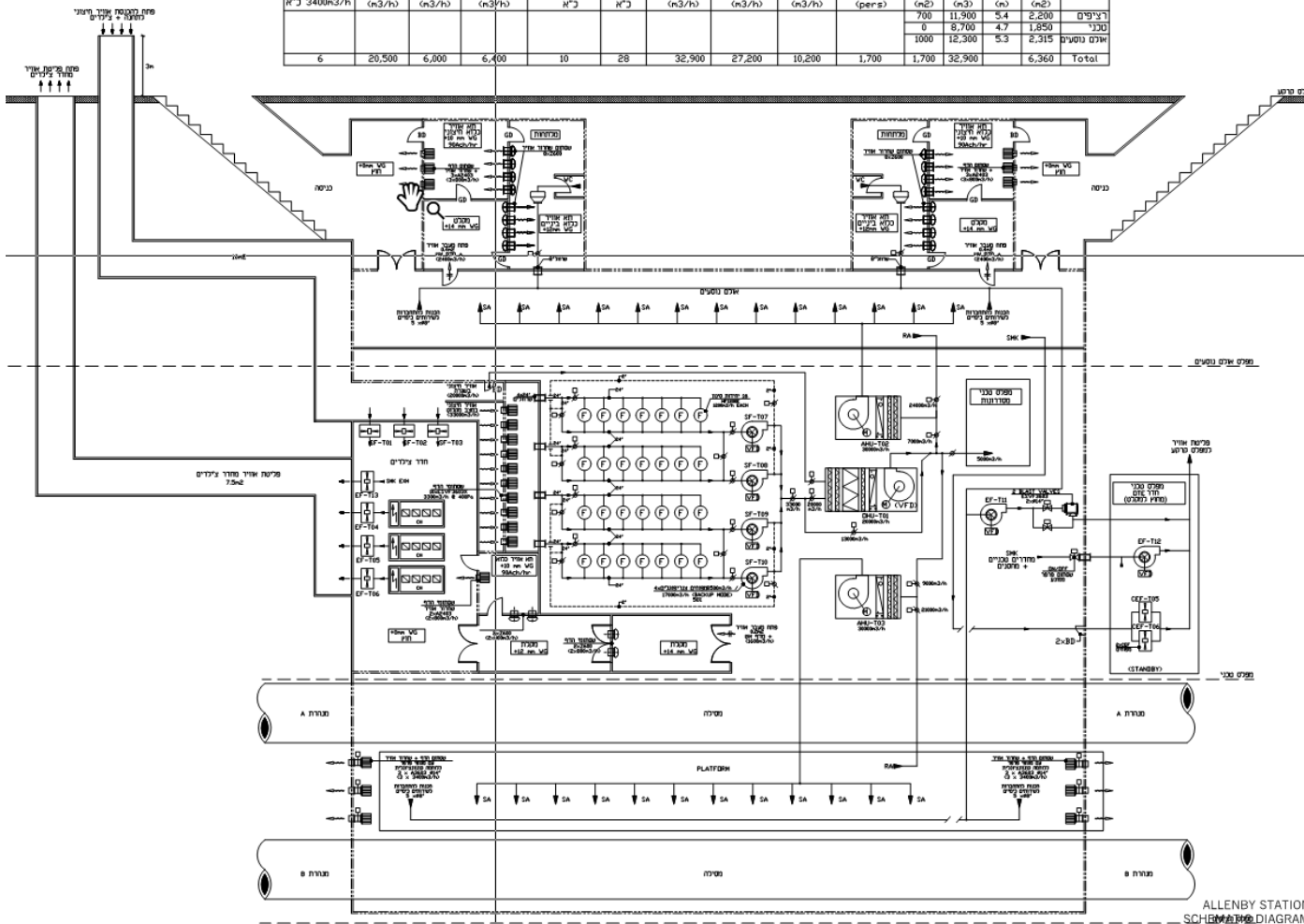


HVAC Systems: Chem-Bio Filtration System

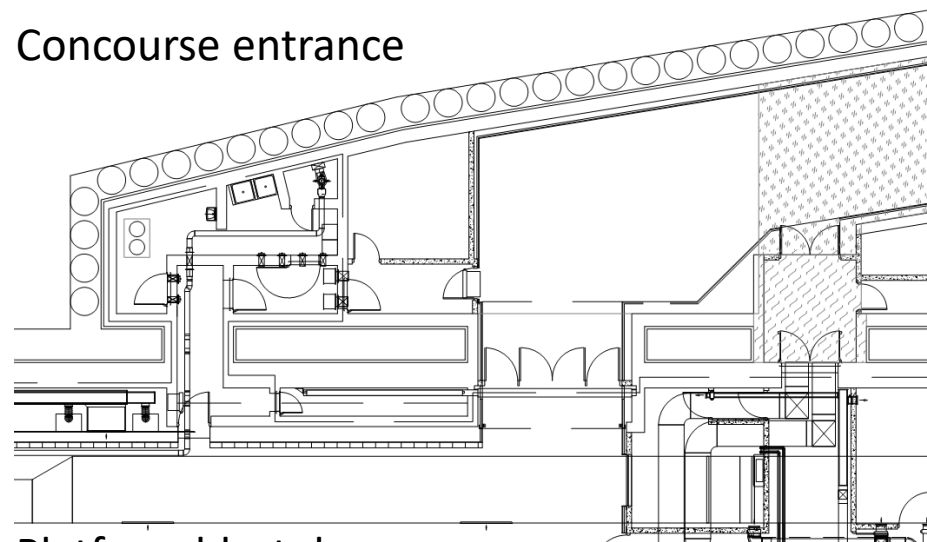
UG Station Civil Defense (CD) Ventilation and Filtration Systems:

- Fresh air intake protected by blast valves
- Chem/bio filters and auxiliary fans for 2,000 persons
- Decontamination air-lock pressurization equipped with over-pressure blast valves
- Chillers located outside shelter boundary (not blast protected) however provided with full back-up power from central generator plant

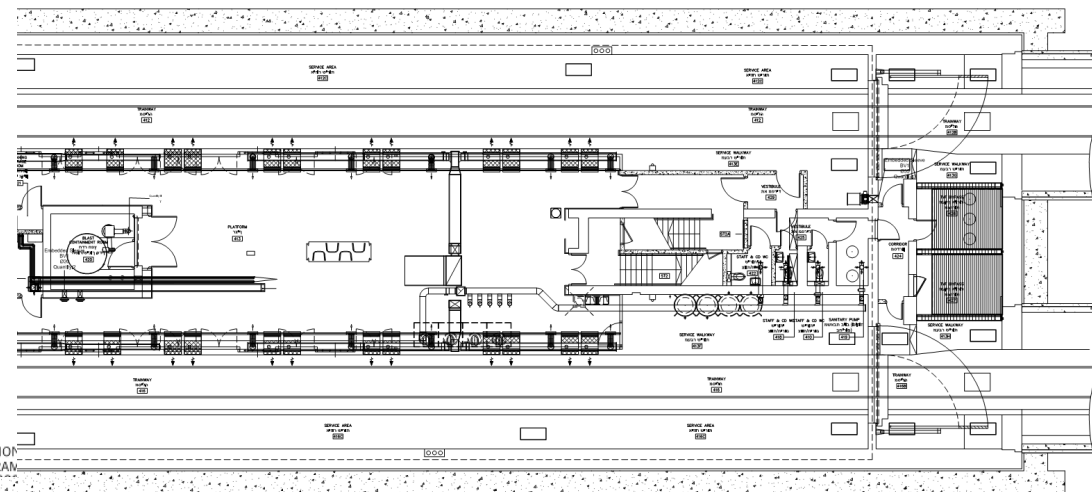
HVAC Systems: Chem-Bio Filtration System

[illegible]

Concourse entrance

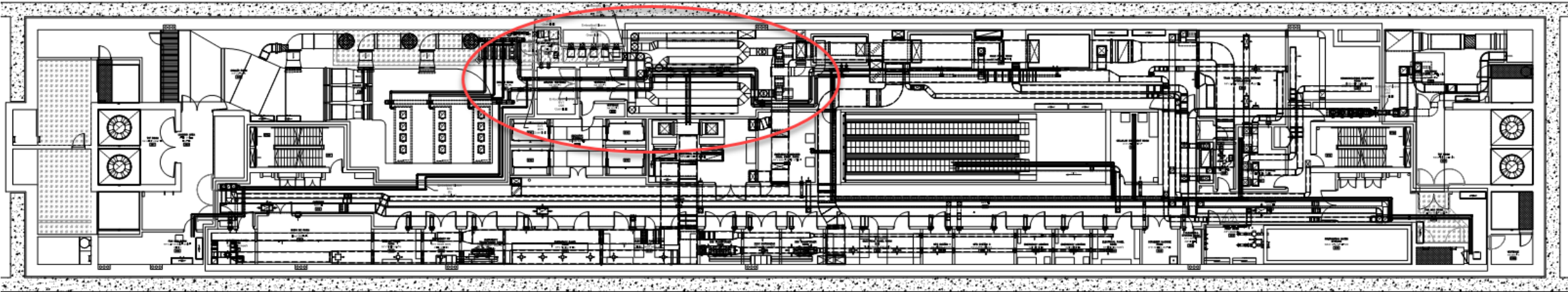


Platform blast doors



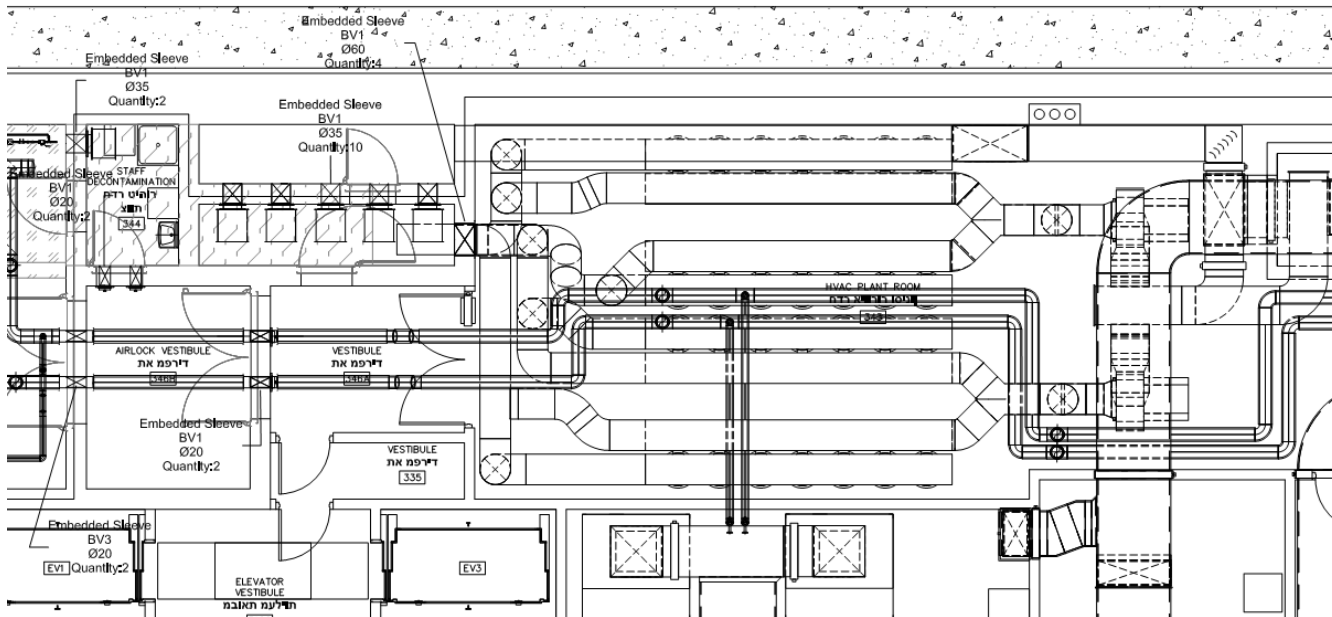
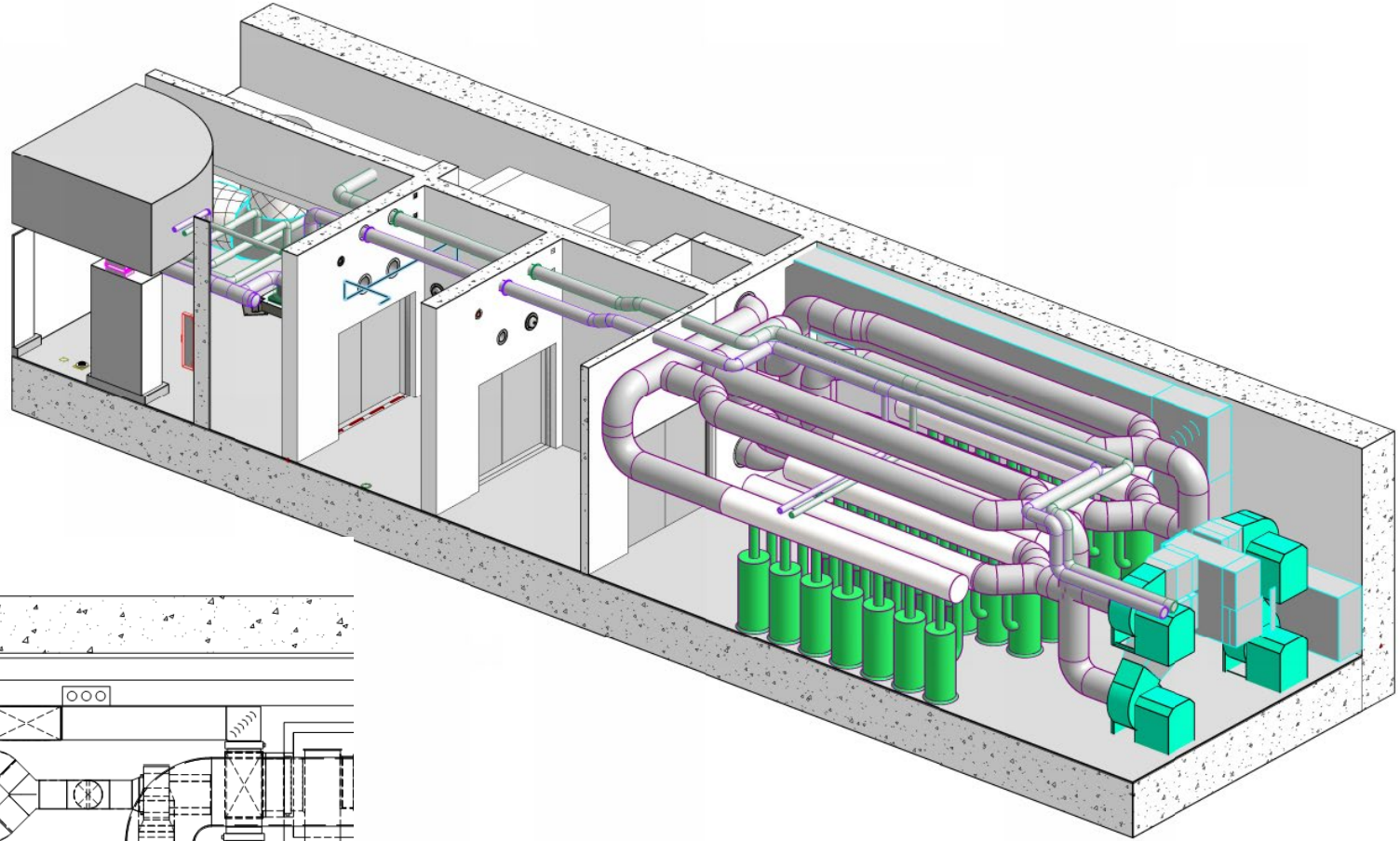
HVAC Systems: Chem-Bio Filtration System

Technical Level – Chem-Bio Filters Room



HVAC Systems: Chem-Bio Filtration System

Technical Level – Chem-Bio Filters Room



מפת התמצאות
(without scale)



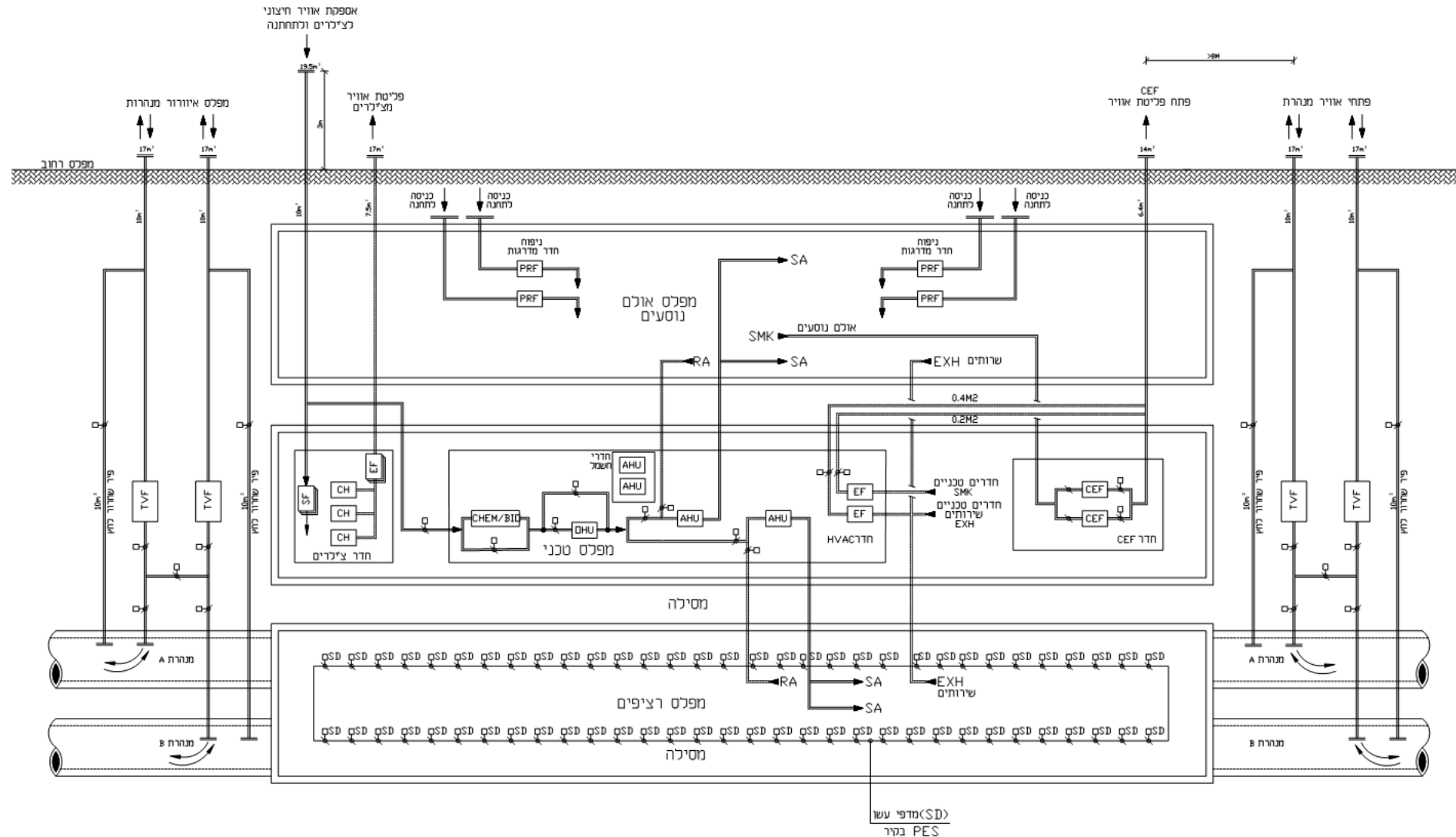
Tunnel Ventilation System (TVS)

TVS functions:

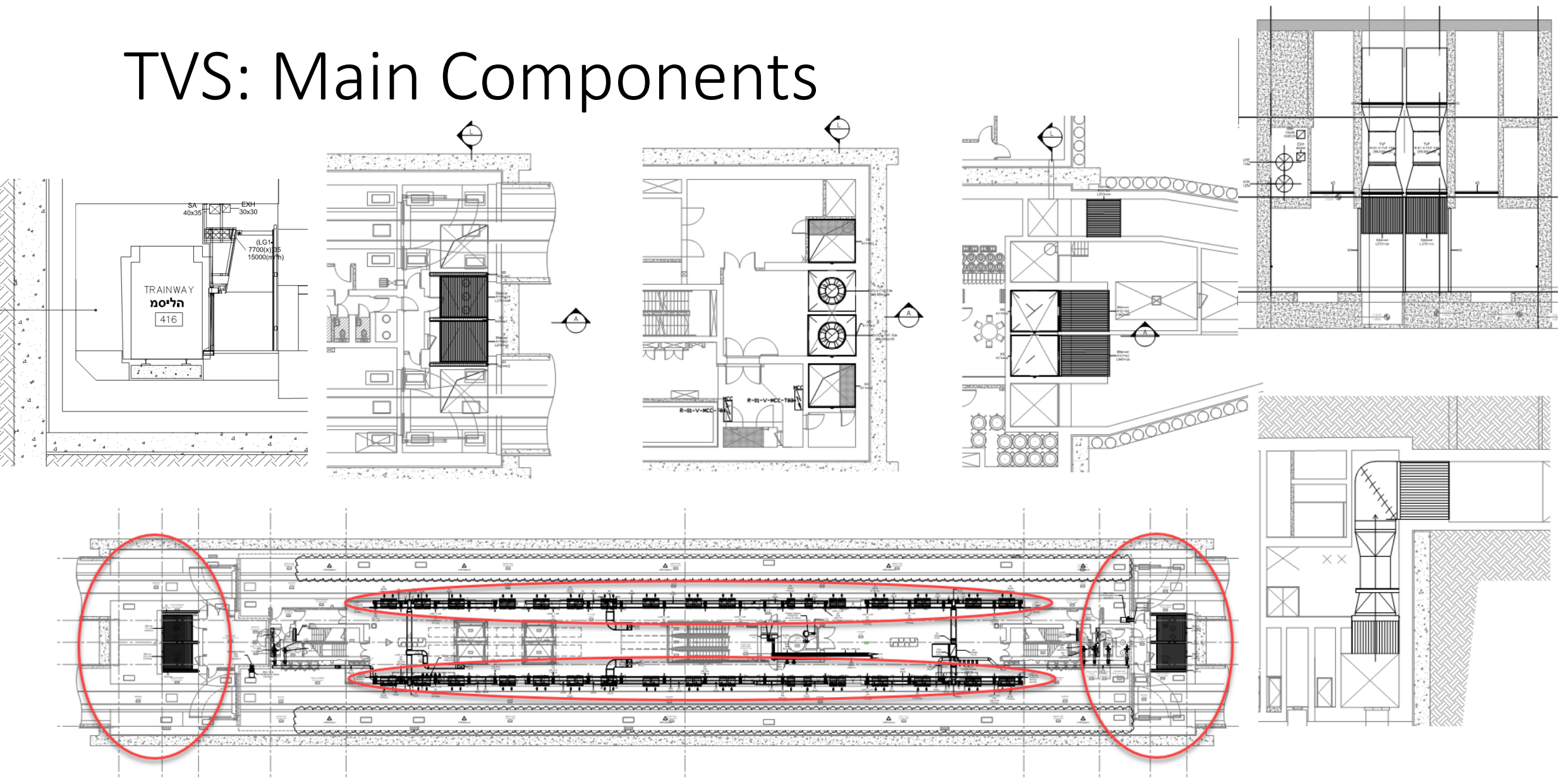
- Natural ventilation during normal operation induced by train “piston effect” to limit the temperature rise inside the tunnels due to heat dissipation from trains operation: less than 40°C (with 45°C max. peaks)
- Forced ventilation in case of congested operation where trains are stopped inside the tunnels between stations.
- Mechanical smoke control in the event of a train fire in the tunnels which ensures smoke exhaust from incident tunnel and pressurization of non-incident tunnel to allow safe egress via tunnel cross-passages.

TVS: Main Components

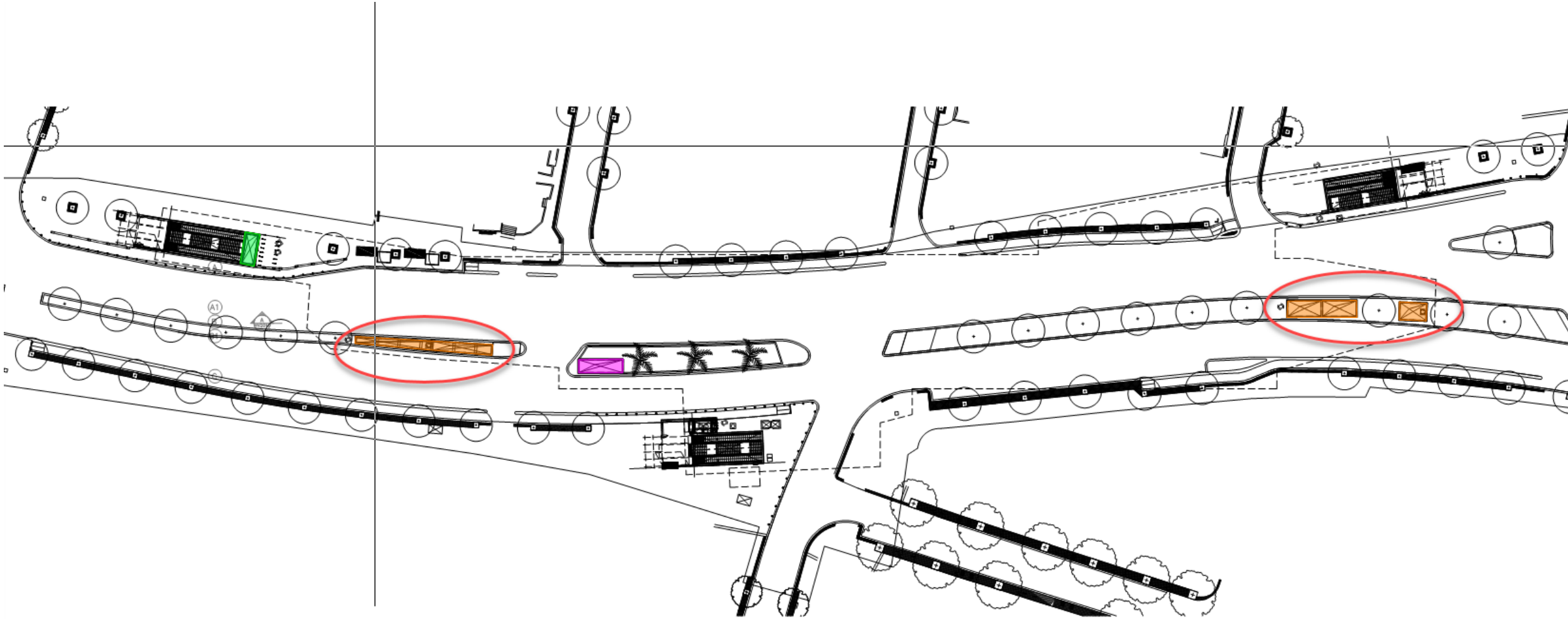
- Tunnel Ventilation Fan (TVF): 4 x 80 m³/s
- Draft relief (DR): 4 x 10m² each with dampers
- Platform smoke vents above PES
- Concourse smoke exhaust
- Emergency Stairs pressurization fans (PRF)



TVS: Main Components



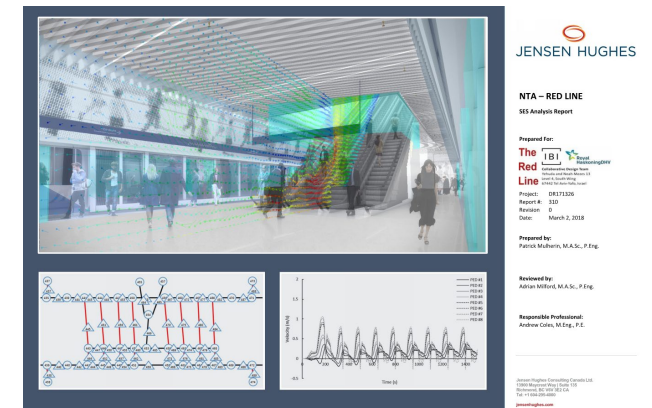
TVS: Ventilation openings “at grade”



TVS: Design

TVS design is based on “1D” & “3D” computational analyses performed by specialist US consultant Jensen Hughes:

- SES (Subway Environmental Simulation) “1D” analysis:
 - Tunnel climate analysis: short term and long term
 - To define boundary conditions for CFD “3D” analysis
- CFD (Computational Fluid Dynamics) “3D” analysis:
 - Smoke control simulation in UG station: track fire (17.6MW), platform and concourse fires (1MW)
 - Special tunnel sections



TVS: SES Analysis

SES analysis criteria:

- Tunnels geometry and characteristics (ground thermal properties)
- Climate: annual temperature fluctuation
- Train configuration, heat rejection and route scheduling

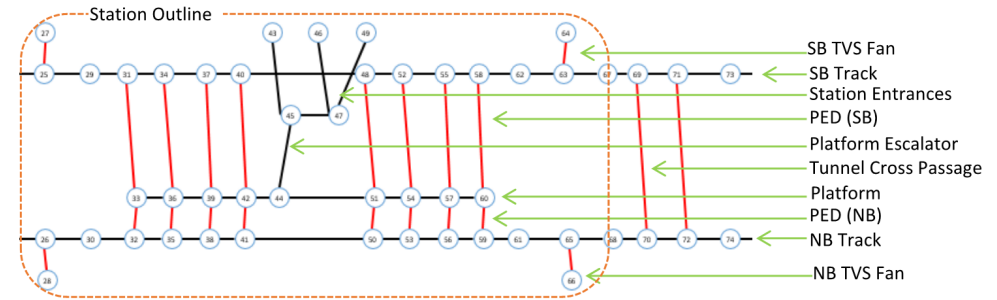


Figure 4-1: Example node diagram for a three-entrance station with station TVS fan shafts and Platform Edge Doors.

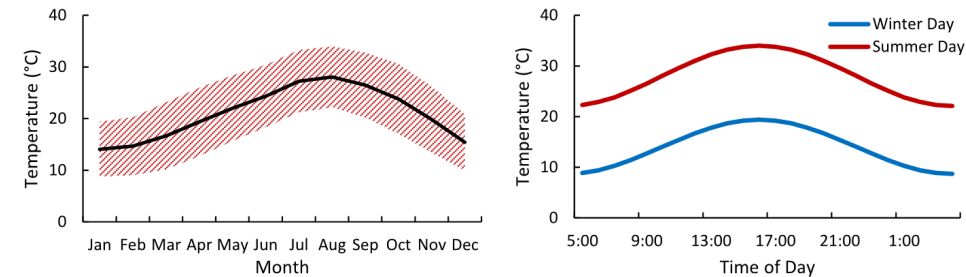


Figure 3-2: Annual temperature fluctuation (left) and daily temperature fluctuation (right).

Table 3-2: Tunnel and ground thermal properties.

Parameter	Value
Tunnel wall concrete thickness	0.65 m
Concrete thermal conductivity	0.8 W/m K
Concrete thermal diffusivity	$4.167(10^{-7}) \text{ m}^2/\text{s}$
Rock thermal conductivity	2.26 W/m K
Rock thermal diffusivity	$1.223(10^{-6}) \text{ m}^2/\text{s}$
Temperature of ground water	25.4 °C
Percent of tunnel wetted wall surface	0%

Table 3-7: Modelled headways for underground portion.

Period	Elifelet → Shenkar	Elifelet → Depot	Shared Underground Section	
	Frequency: (t/hr)	Frequency: (t/hr)	Frequency: (t/hr)	Headway: (min.)
5:30 - 6:00	3	3	6	10.0
6:00 - 7:00	8	4	12	5.0
7:00 - 9:00	16*	8*	24	2.5
9:00 - 15:00	8	8	16	3.8
15:00 - 19:00	10	10	20	3.0
19:00 - 22:00	5	5	10	6.0
22:00 - 1:00	3	3	6	10.0
Daily Average	8	7	15	4.0

TVS: SES Analysis

SES results:

- Long term: tunnel wall average temperature after 30 years less than 30°C
- Normal operation: air temperature throughout the tunnel system only exceeds 40°C at 2 locations during dwell for less than 12 seconds (peak of 43.8°C)

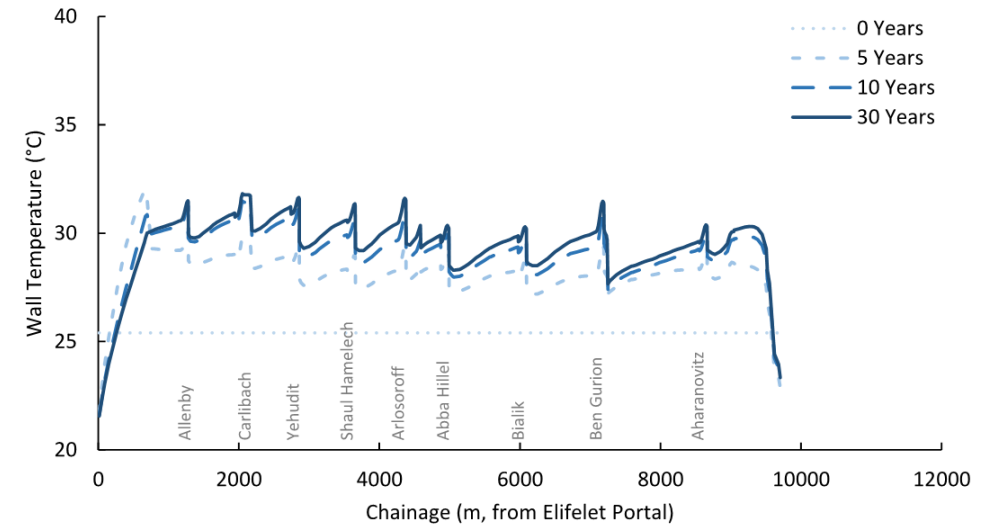


Figure 5-3: Finite difference model results for NB tunnel wall temperature development over time (Without OTE).

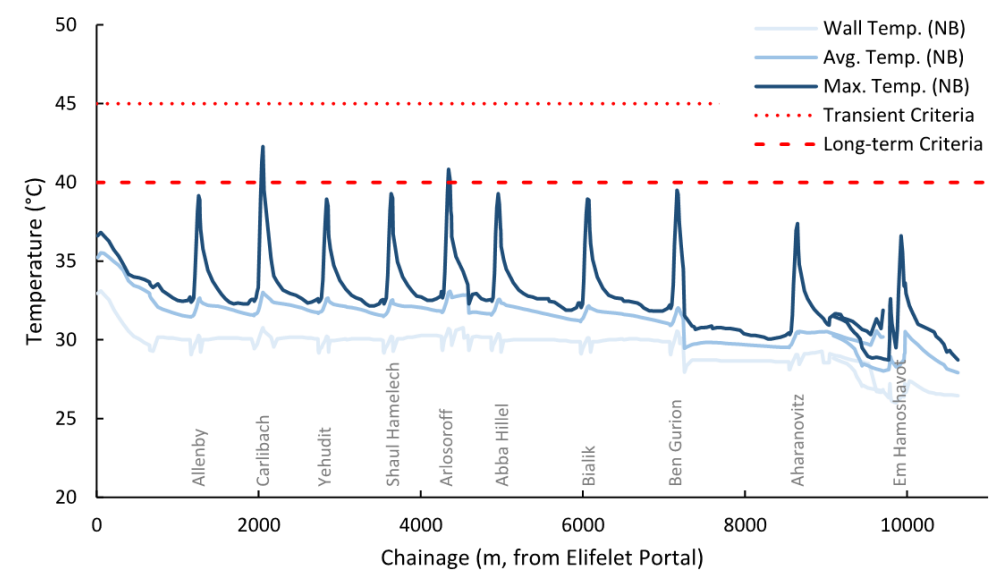


Figure 5-6: SES model results for NB tunnel air temperature during summer peak hours (34 °C ambient temperature – without OTE).

TVS: SES Analysis

SES results:

- Congested operation: TVF can be operated at reduced capacity to maintain design temperature criteria of 40°C, but must be operated within 2 minutes of train stopping

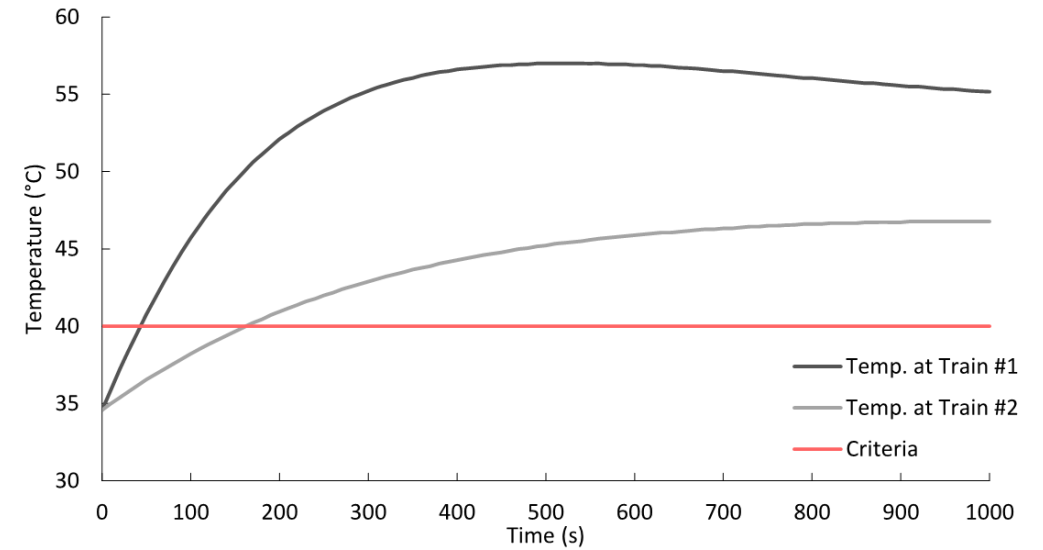


Figure 5-21: Example SES results for temperature in tunnel section between Shaul Hamelech and Arlosoroff Stations during congested operations without fan operation.

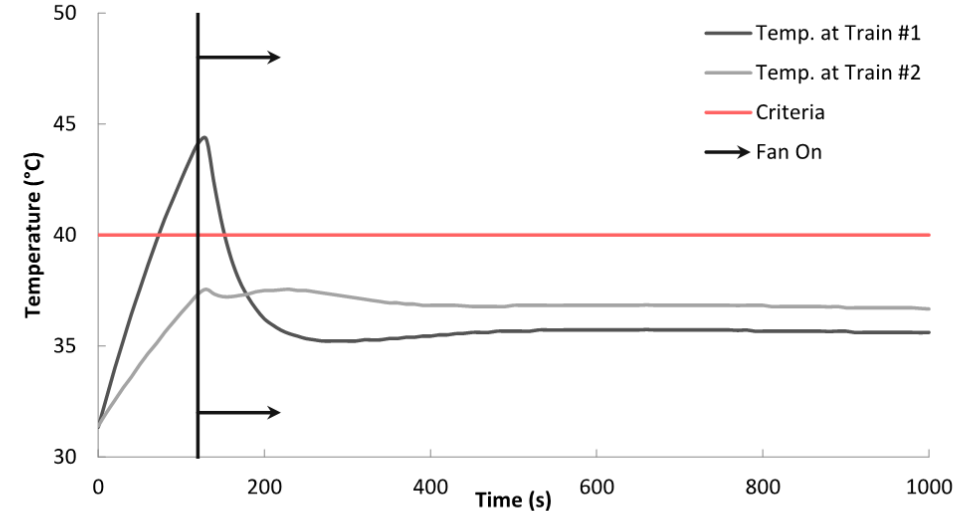


Figure 5-22: Example SES results for temperature in tunnel section between Shaul Hamelech and Arlosoroff Stations during congested operations with fan operation.

TVS: SES Analysis

Congested operation modes for TVF:

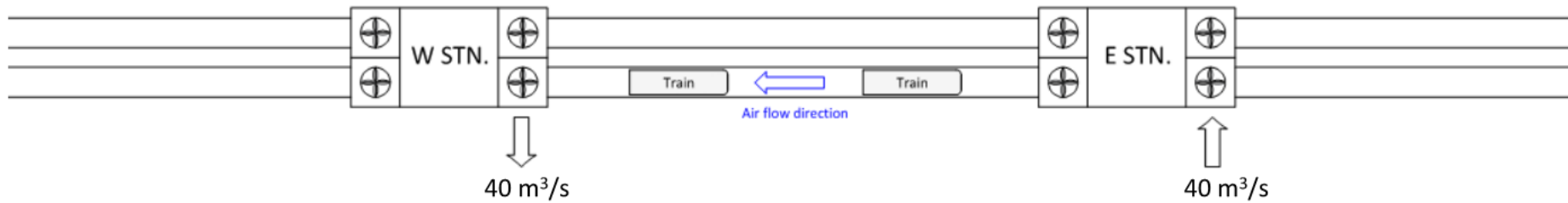


Figure 4-3: Operation mode for typical congested operation between stations.



Figure 4-4: Schematic of extended congested mode operation SES model setup.

TVS: SES Analysis

SES results: Emergency mode of operation

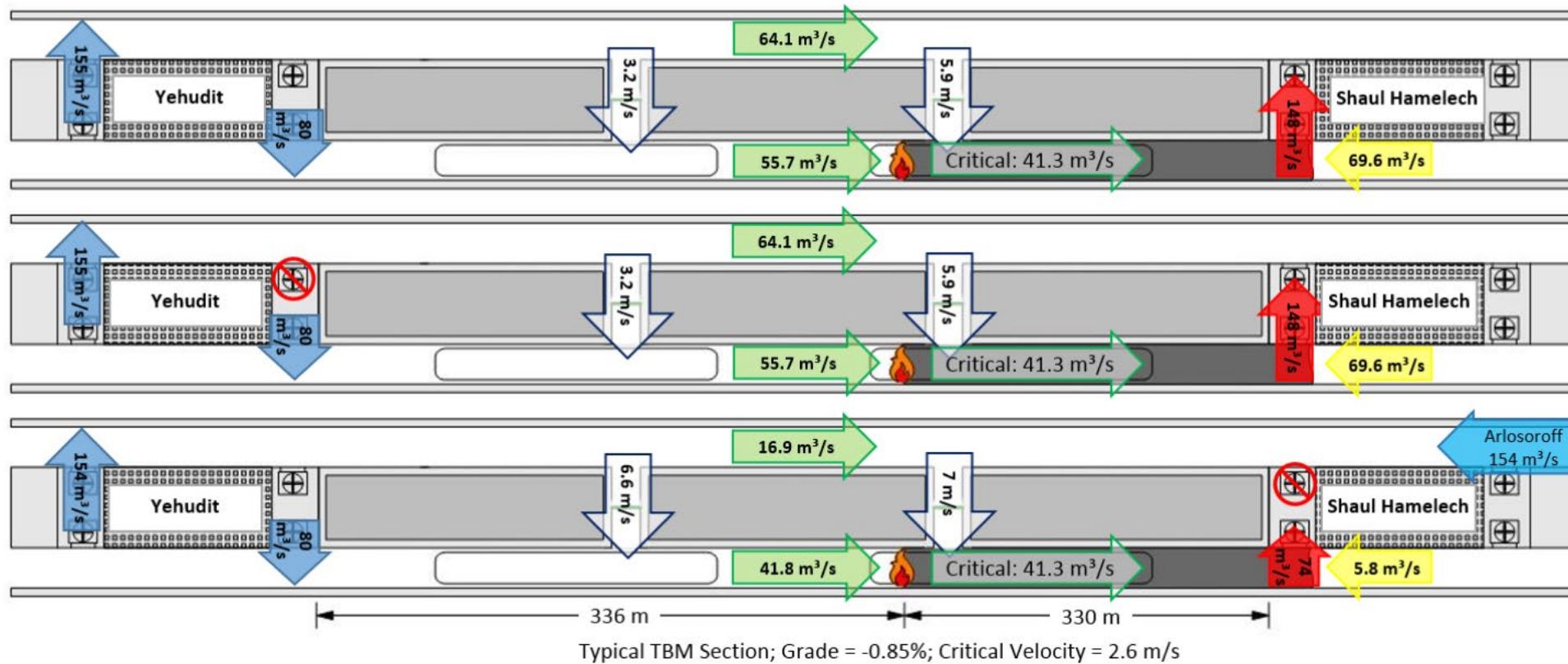


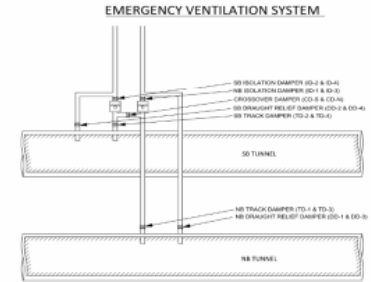
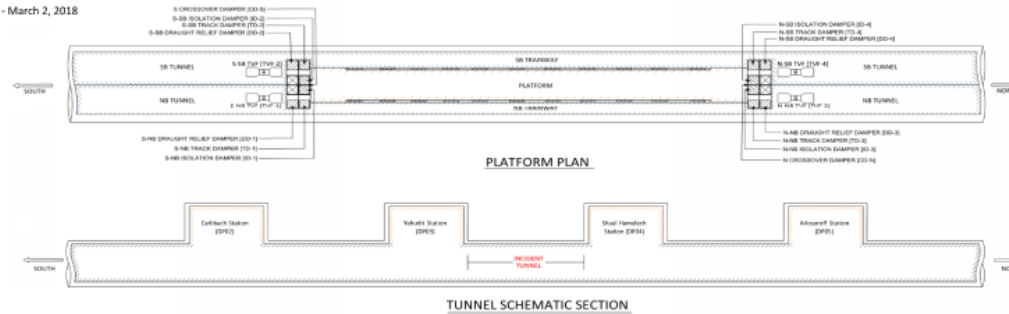
Figure 5-45: SES model results schematic for Yehudit Tunnel with supply from Yehudit Station.

TVS: SES

SES results: Emergency “mode tables”

Yehudit Tunnel Mode Table

Tunnel section between Yehudit Station (DP03) and Shaul Hamelech Station (DP04)
JENSEN HUGHES - Red Line SES Analysis Report Rev. 0: Section 5.6.4
Northbound Chainage 1-17168.6 to 1-17834.8
Southbound Chainage 2-17161.9 to 2-17825.9
Mode Table Rev. 0 - March 2, 2018



Legend
- TVF Off
E TVF In Exhaust
S TVF In Supply
x TVF Fan Failed
O Damper Open
C Damper Closed

Scenario			Carlsbad Station (DP02)										Yehudit Station (DP03)										Shaul Hamelech Station (DP04)										Arlossoff Station (DP05)									
			South TVF Plant										North TVF Plant										South TVF Plant										North TVF Plant									
Normal Train Operation	Ventilate towards Shaul Hamelech	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
	Ventilate towards Yehudit	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Fire in Northbound Tunnel (1-17168.6 to 1-17834.8)	Ventilate towards Shaul Hamelech	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
	Ventilate towards Yehudit	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Fire in Southbound Tunnel (2-17161.9 to 2-17825.9)	Ventilate towards Shaul Hamelech	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
	Ventilate towards Yehudit	Baseline - All Fans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-2 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP03-TV-3 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
		DP04-TV-1 Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				

TVS: CFD Analysis

- CFD analysis: Fire-Dynamics Simulator (FDS)

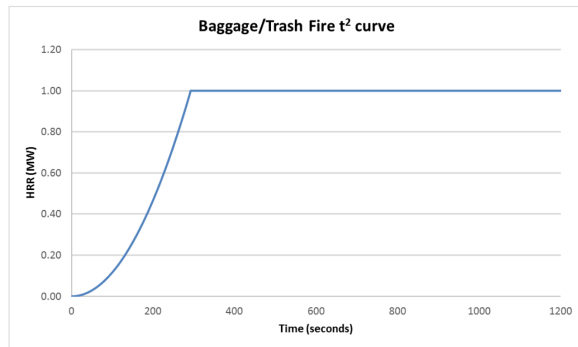


Figure 3-2: Design Fire Curve for the Platform and Concourse Public Areas

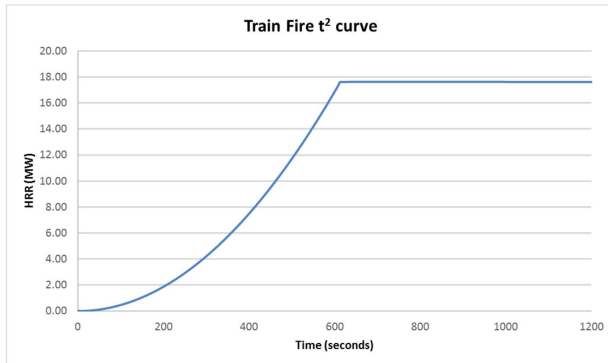


Figure 3-1: Train Design Fire Curve

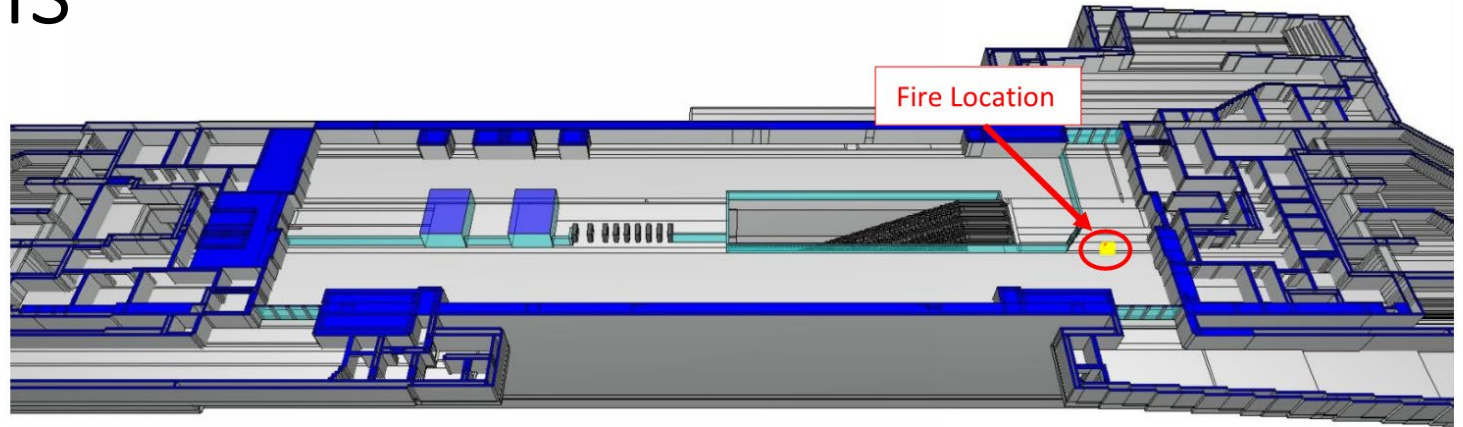


Figure 3-8: Concourse public fire location

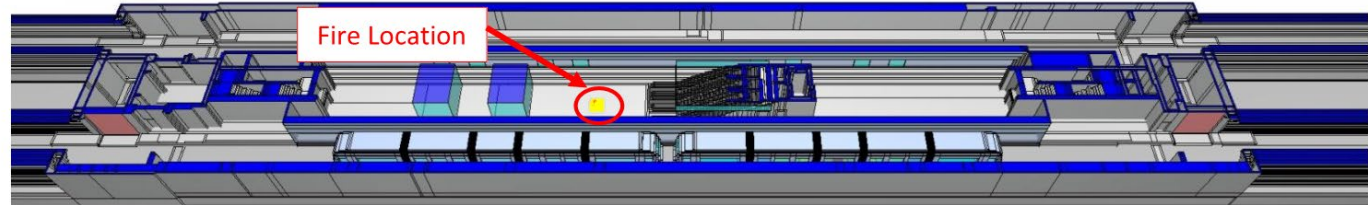


Figure 3-7: Platform public fire location

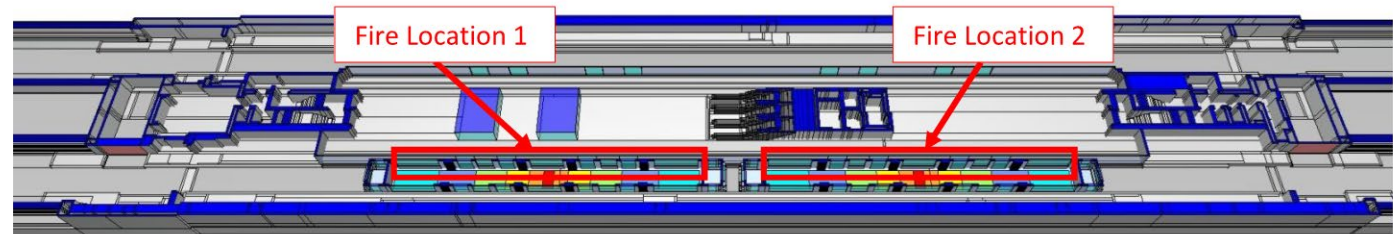


Figure 3-6: Train Fire Locations

TVS: CFD Analysis

- Train fire at platform: platform smoke vents and TVF response

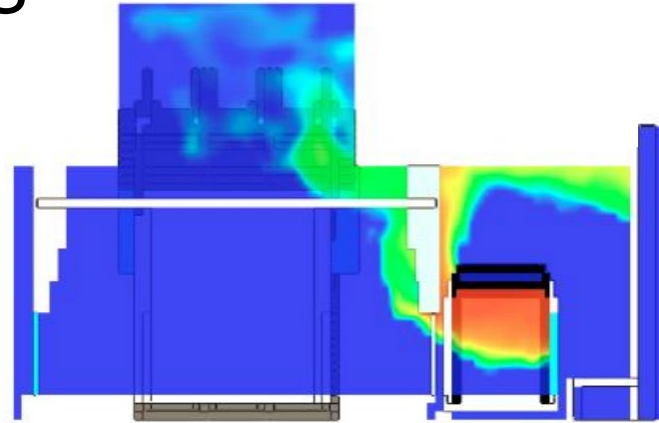


Figure 3-5: Section view through the open platform edge door showing visibility prior to fan activation

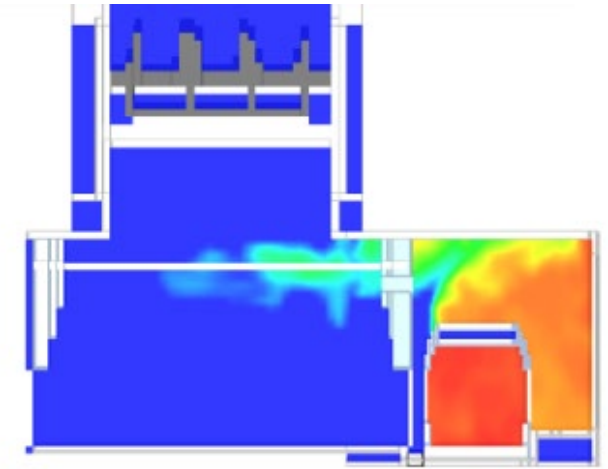


Figure 5-46: S3-Typical cross-section of the platform showing visibility at 4 minutes

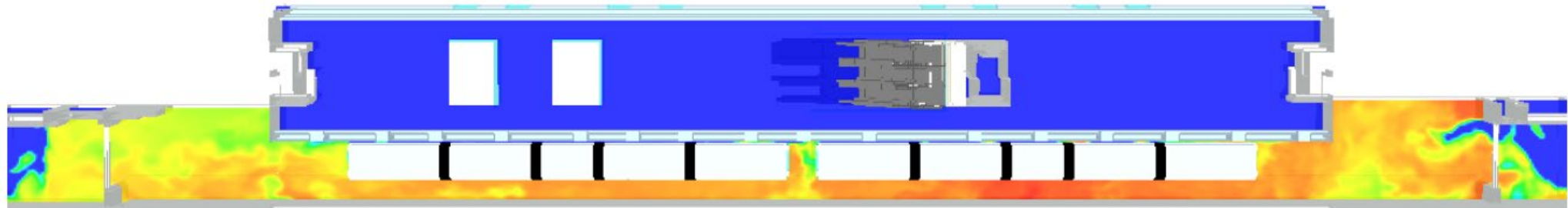


Figure 5-44: S3-Platform visibility at 4 minutes