ILC CFS BASELINE TECHNICAL REVIEW

AMERICAS REGION LIFE SAFETY

CONVENTIONAL FACILITIES AND SITING

V. Kuchler, J. Niehoff

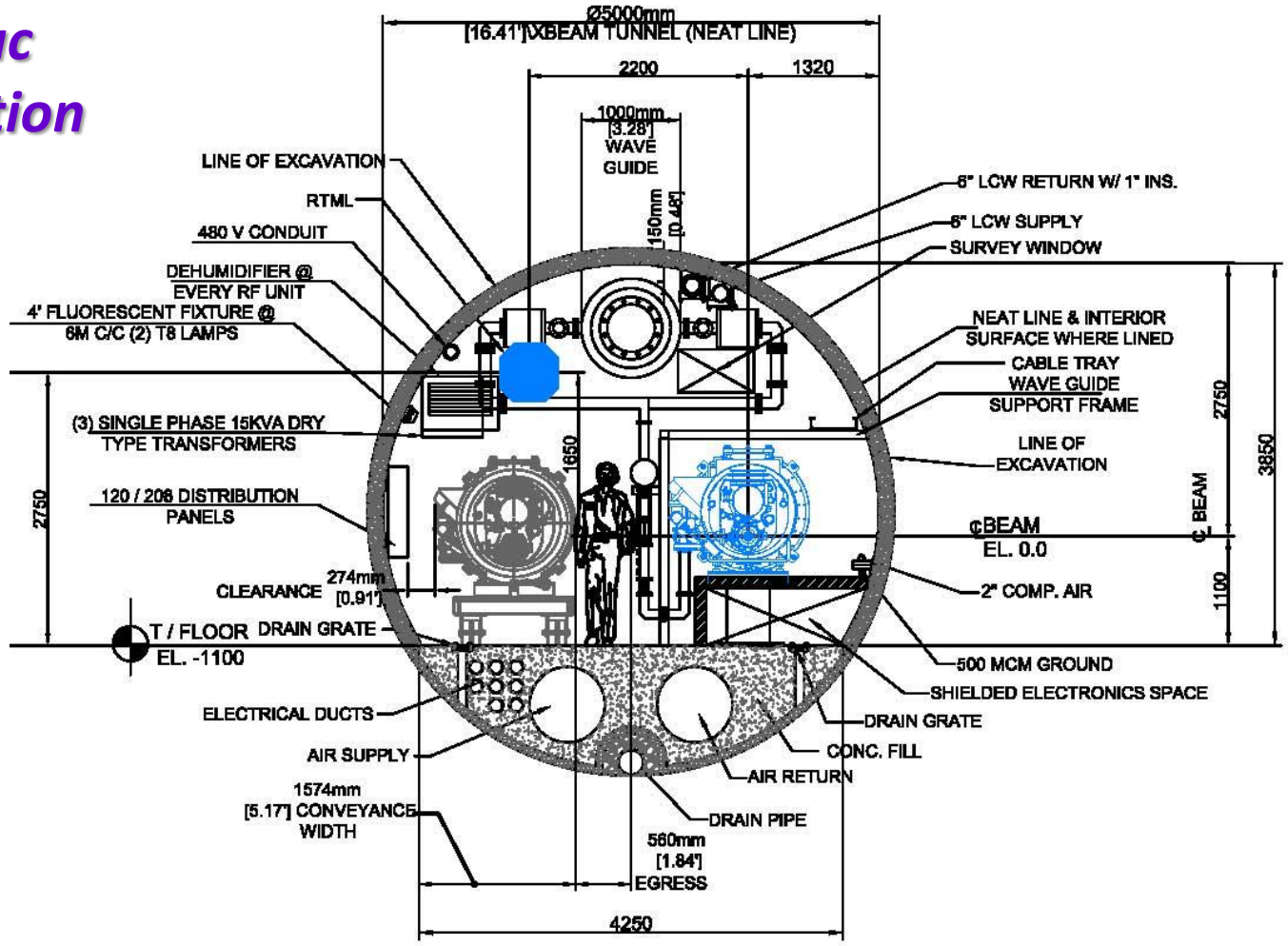
Basis of Design and Analysis

- National Fire Protection Association
  - Key Elements
    - Building portion within a subterranean space, NFPA 101 Life Safety Code.
    - Subterranean space, NFPA 520, Standard for Subterranean Spaces

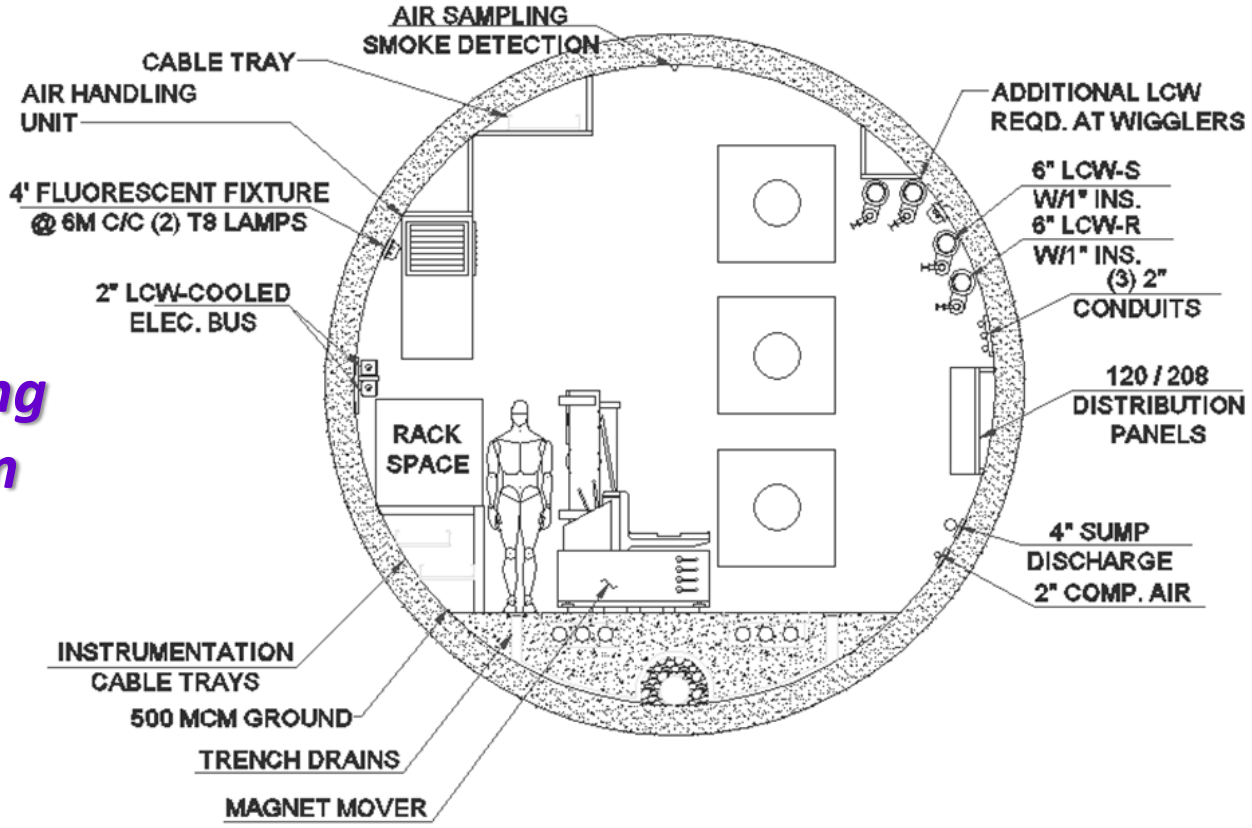
Key Components of NFPA 520

- Defines common space as the area of the developed subterranean space other than buildings; Hughes Engineering has defined the tunnel space as the common space
- Travel distance through common space to a portal, or refuge area, or exit shall not be more than 610 m (2,000 ft)
- Width of an exit not less than 112 cm (44 in) except with magnet mover or non-fixed equipment can be reduced to 56 cm (22 in)
- Two paths of egress required at all locations

Main Linac Cross Section



Damping Ring Cross Section



Analysis

- Hughes Engineering prepared a Life Safety/Fire Protection Requirements Report based on NFPA 520
- Hughes Engineering developed Fire Models to verify NFPA 520 and their Report requirements
- Fire modeling was conducted using a computational fluid dynamics, known as Fire Dynamics Simulator (FDS) developed by NIST

LIFE SAFETY/FIRE PROTECTION ANALYSYS

for

THE INTERNATIONAL LINEAR COLLIDER
Single Deep or Near Surface Tunnel Options

Prepared by

HUGHES ASSOCIATES, INC
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CODE CONSULTANTS

September 18, 2009
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FIRE AND EGRESS ANALYSIS FOR THE

INTERNATIONAL LINEAR COLLIDER

(DRAFT)

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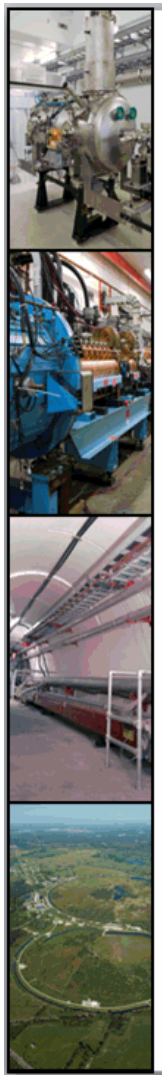
December 9, 2011

Rev 0

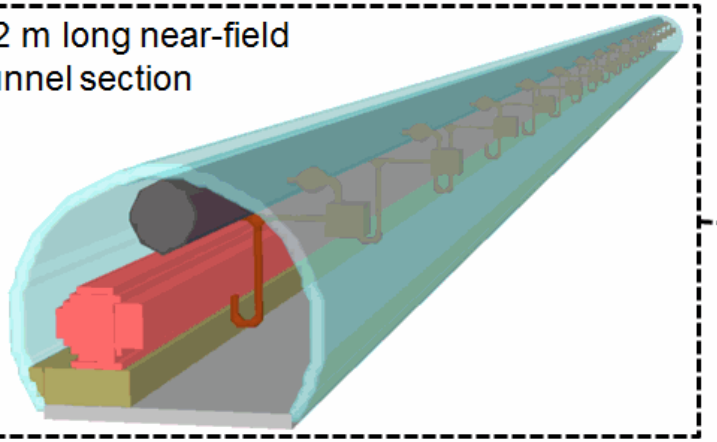


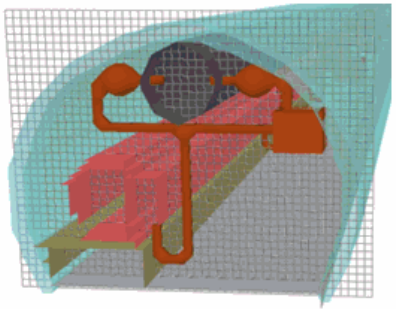
Approach

- Research tunnel fire dynamics
- Model representative tunnel fire scenarios using (FDS) to analyze the effects of:
  - Smoke movement
  - Fire size
  - Fire location (tunnel or base cavern)
  - Sprinklers
- Determine the time required for occupants to evacuate
- Determine the maximum fire size that will allow occupants to evacuate safely

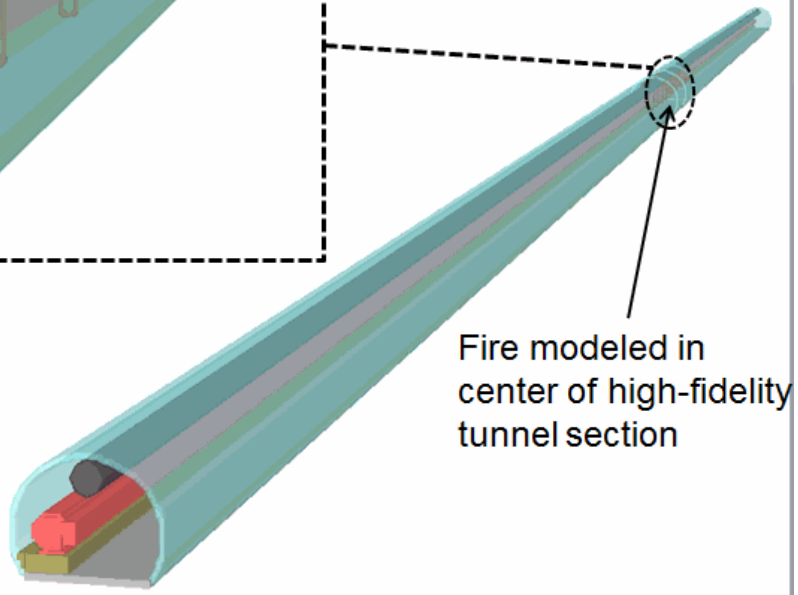
Main LINAC Tunnel Geometry

22 m long near-field tunnel section





5 inch cells – isometric view showing grid

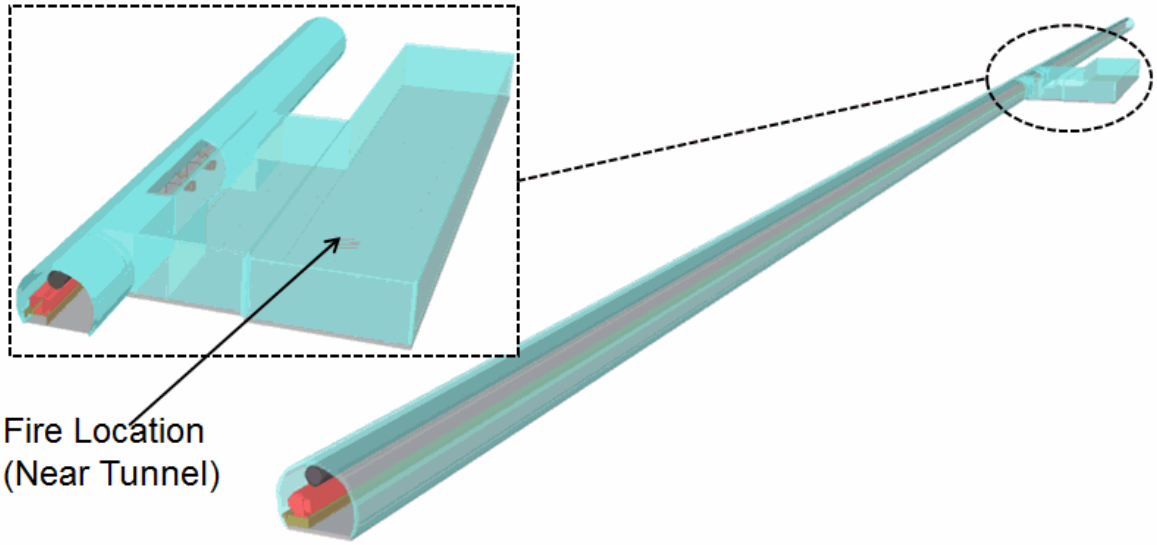


400 m long tunnel section.

Fire modeled in center of high-fidelity tunnel section

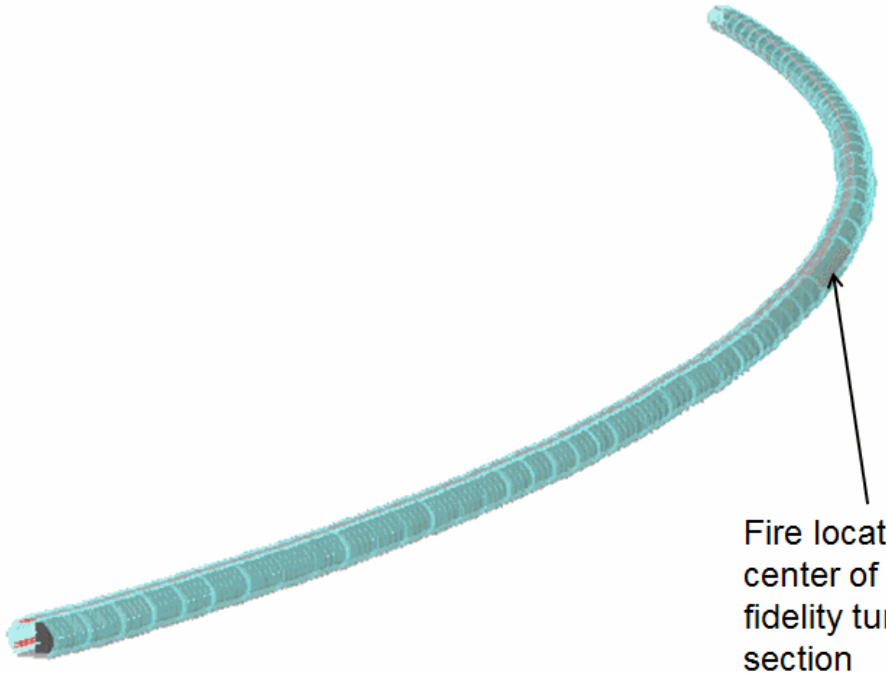
Base Cavern and Tunnel Geometry

- Base cavern modeled using 10 inch cells
  - Base cavern height assumed to be approximately the same height as tunnel



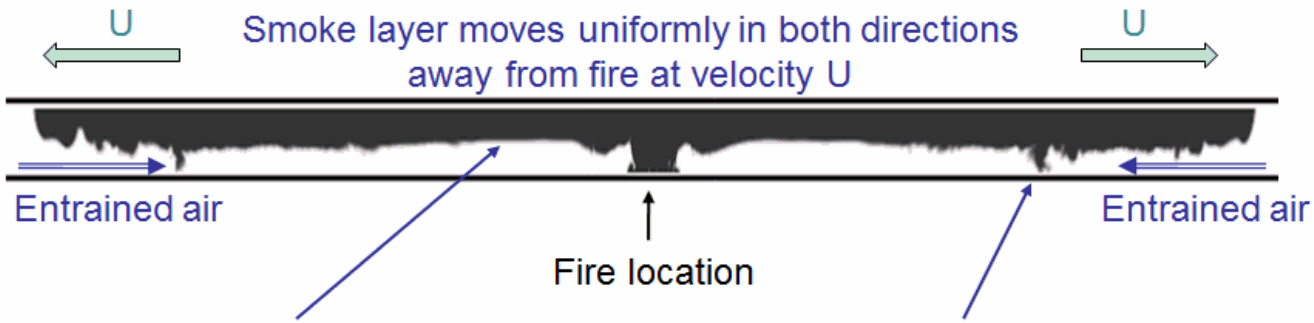
Curved Damping Ring Tunnel Geometry

- Curved and straight tunnel sections modeled



Tunnel Fire Dynamics

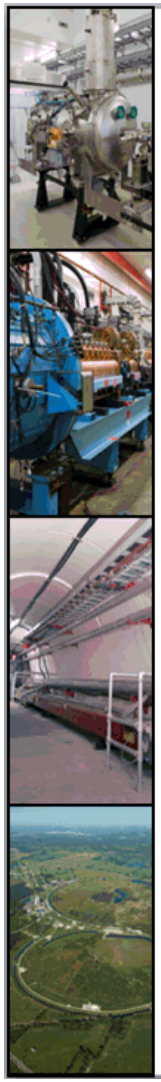
- Smoke movement in level, naturally ventilated tunnels



Near the fire, the smoke layer is hot (strong buoyancy) and remains close to the ceiling with little mixing.

As the smoke moves away from the fire, cooling occurs causing smoke to loose buoyancy. Descending smoke mixes with the entrained air and is drawn back towards the fire. This is referred to as “back-layering”

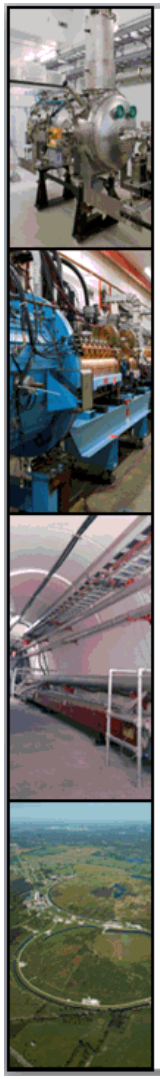
1MW fire modeling 5M Tunnel Section View



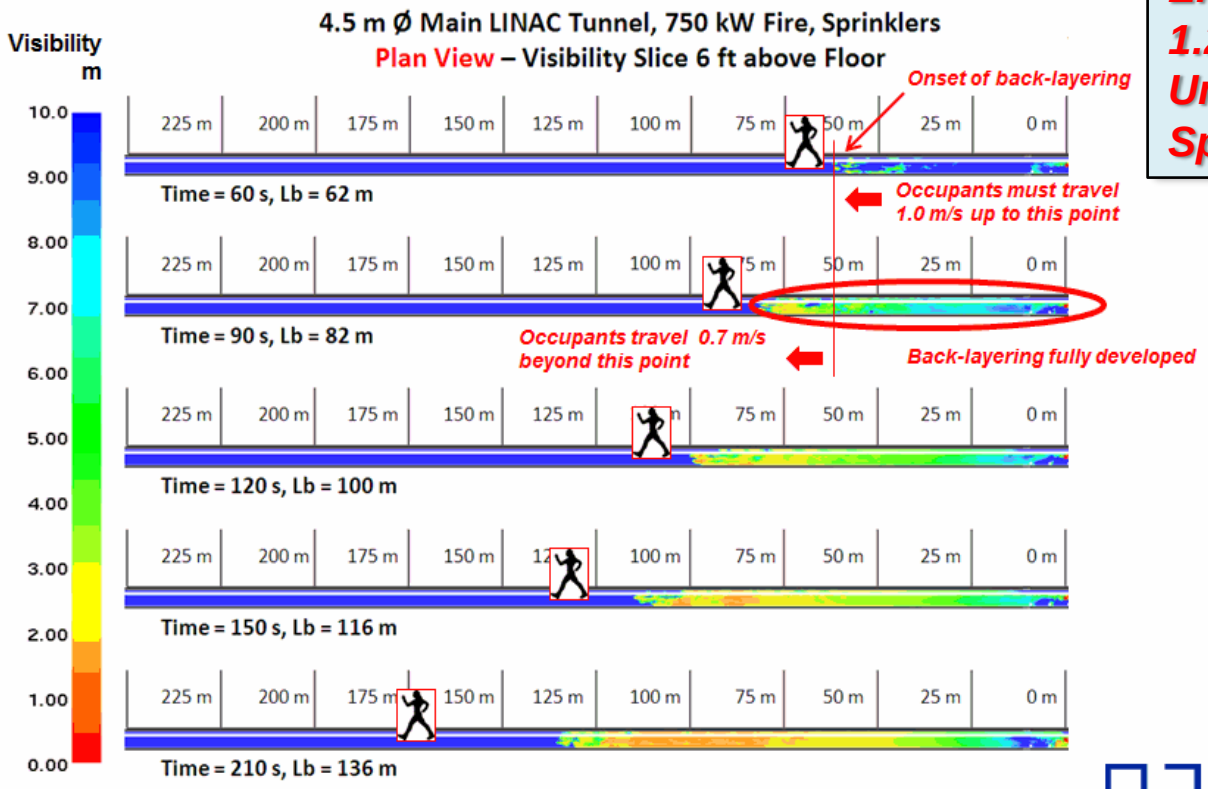
Summary of Main LINAC Tunnel Fire Results

Tunnel Diameter (m)	Limiting Fire Size (kW)	Maximum Fuel Spill Area (m^2)	Maximum Unconfined Spill Rate (L/min)
4.5	750	0.8	1.3
5.0	1,000	1.0	1.7
5.5	1,100	1.1	1.9
6.5	1,500	1.4	2.6

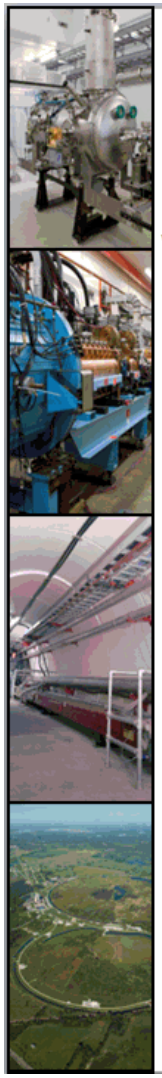
- **Results for Main LINAC apply to straight portions of damping ring tunnel**
  - Smoke movement is essentially the same in straight tunnels of the same diameter. The difference in obstructions between the Main LINAC and damping ring have a minimal effect.



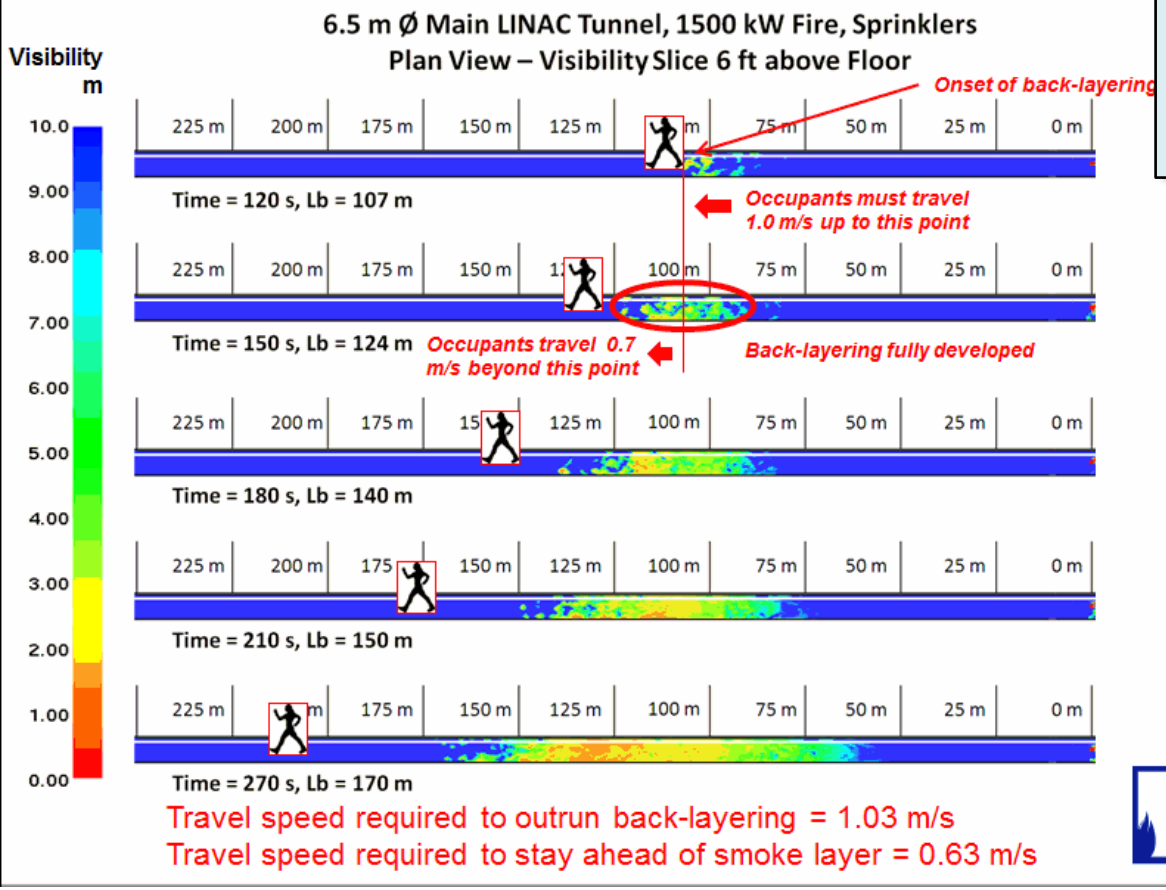
Main LINAC Tunnel Fire Results



SFPE Handbook for Fire Protection Engineering uses 1.25m/s as Average Unrestricted Walking Speed



Main LINAC Tunnel Fire Results

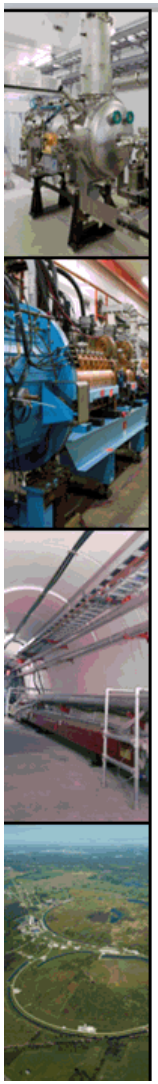


SFPE Handbook for Fire Protection Engineering uses 1.25m/s as Average Unrestricted Walking Speed

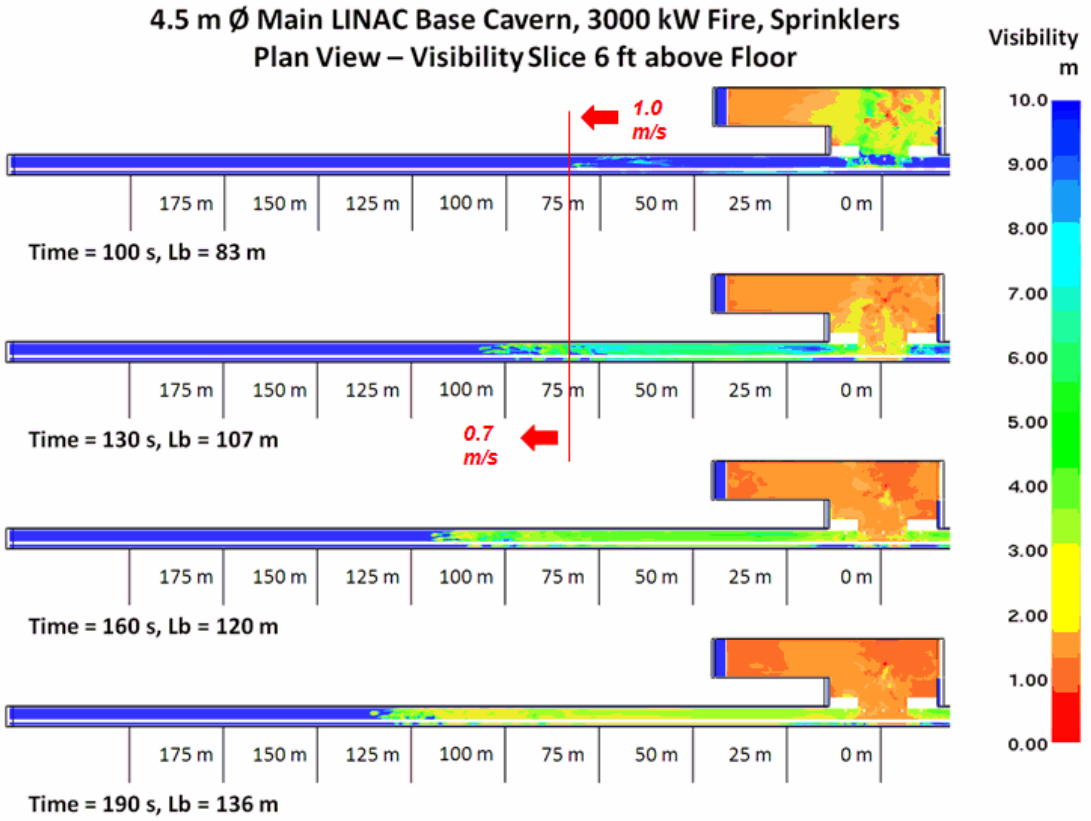
Summary of Base Cavern Fire Results

Tunnel Diameter (m)	Limiting Fire Size (kW)	Maximum Fuel Spill Area (m^2)	Maximum Unconfined Spill Rate (L/min)
4.5	3,000	2.4	5.1
5.0	4,000	3.0	6.8
5.5	4,500	3.3	7.7
6.5	6,000	3.6	10.2

- Limiting fire sizes in base cavern increase significantly over straight tunnel sections
  - Smoke spills out of the base cavern and impacts tunnel walls causing the ceiling jet velocity to decrease



Base Cavern Fire Results



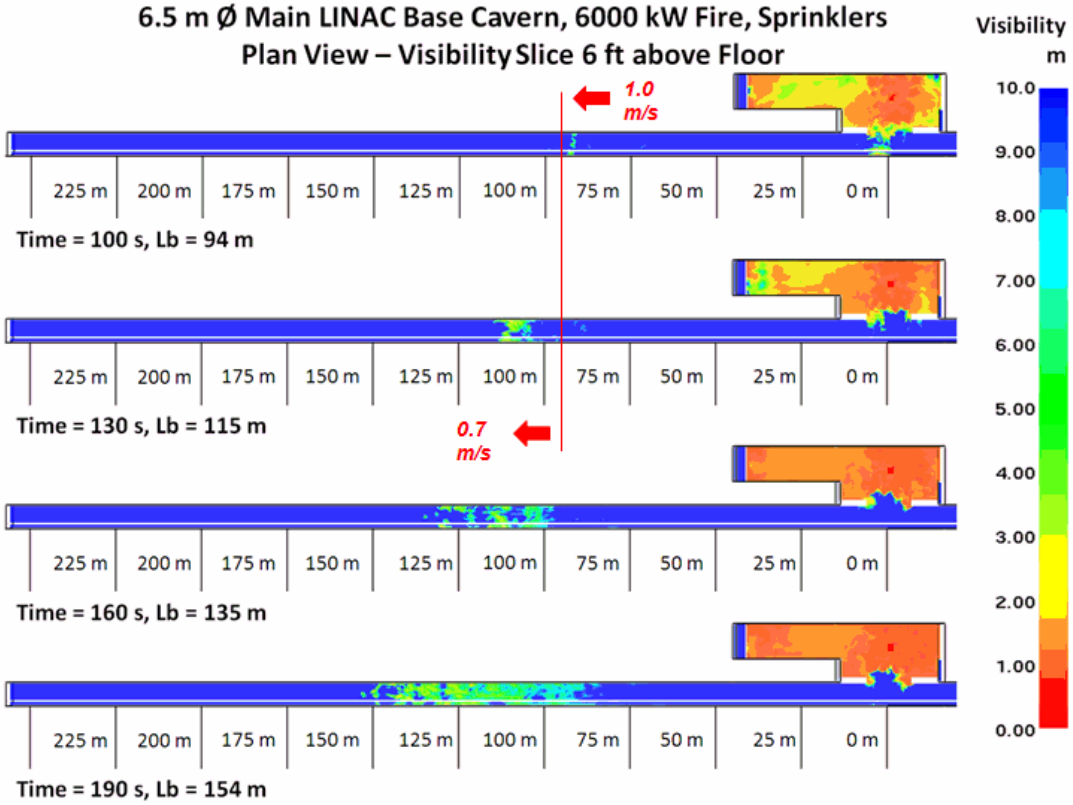
Travel speed required to outrun back-layering = 0.83 m/s

Travel speed required to stay ahead of smoke layer = 0.62 m/s

SFPE Handbook for Fire Protection Engineering uses 1.25m/s as Average Unrestricted Walking Speed



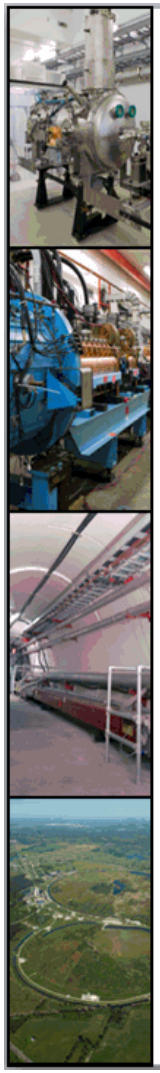

Base Cavern Fire Results



Travel speed required to outrun back-layering = 0.94 m/s

Travel speed required to stay ahead of smoke layer = 0.73 m/s

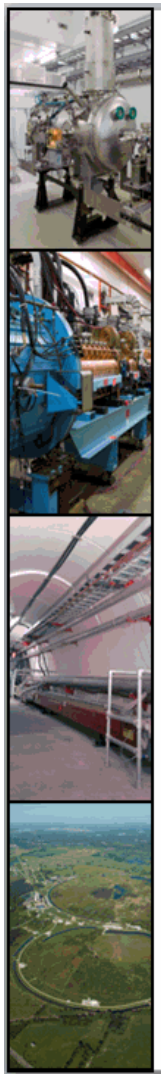
SFPE Handbook for Fire Protection Engineering uses 1.25m/s as Average Unrestricted Walking Speed



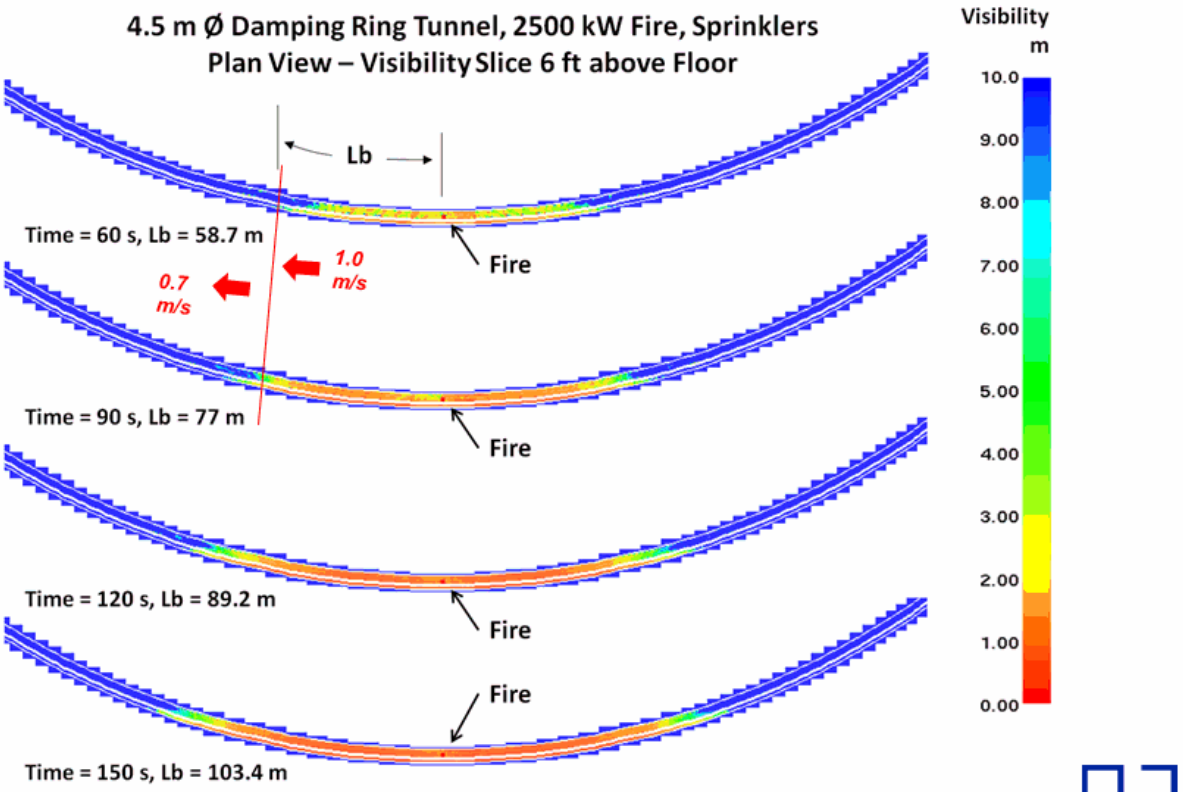
Summary of Damping Ring Fire Results

Tunnel Diameter (m)	Limiting Fire Size (kW)	Maximum Fuel Spill Area (m^2)	Maximum Unconfined Spill Rate (L/min)
4.5	2,500	2.0	4.3
5.0	3,250	2.5	5.5
5.5	4,000	3.0	6.8
6.5	5,000	3.6	8.5

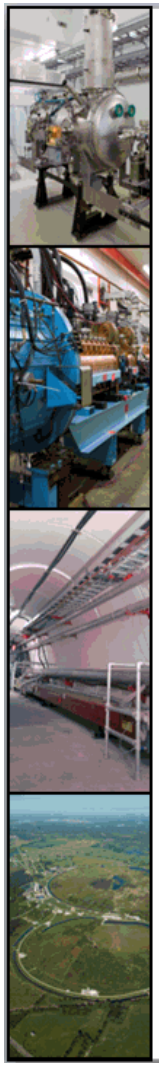
- Results apply to curved sections of damping ring
- Limiting fire sizes in curved section of tunnel increase over straight tunnel section
  - The speed at which smoke descends to head-level decreases due to the curvature of the tunnel
- The straight tunnel sections of the damping ring represent limiting fuel spill quantities for the damping ring



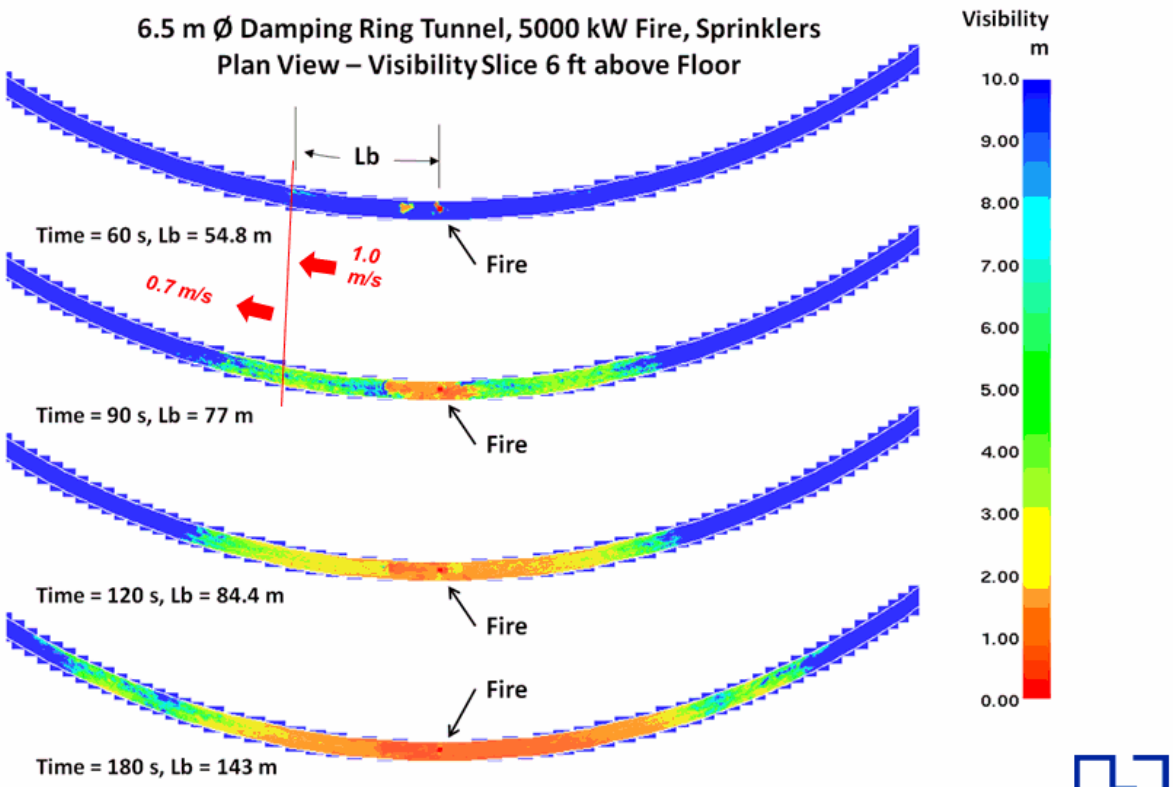
Damping Ring Tunnel Fire Results



Travel speed required to outrun back-layering = 0.98 m/s
Travel speed required to stay ahead of smoke layer = 0.5 m/s



Damping Ring Tunnel Fire Results



Travel speed required to outrun back-layering = 0.91 m/s

Travel speed required to stay ahead of smoke layer = 0.65 m/s

Fire Location	Tunnel Diameter (m)	Limiting Fire Size (kW)	Maximum Fuel Spill Area (m^2)	Maximum Unconfined Spill Rate (L/min)
LINAC / Straight Damping Ring Tunnel	4.5	750	0.8	1.3
	5.0	1,000	1.0	1.7
	5.5	1,100	1.1	1.9
	6.5	1,500	1.4	2.6
Base Cavern	4.5	3,000	2.4	5.1
	5.0	4,000	3.0	6.8
	5.5	4,500	3.3	7.7
	6.5	6,000	3.6	10.2
Curved Damping Ring Tunnel	4.5	2,500	2.0	4.3
	5.0	3,250	2.5	5.5
	5.5	4,000	3.0	6.8
	6.5	5,000	3.6	8.5

Ventilation

- Each exit passageway and access portal will be designed to provide positive air pressure not less than 12.5 N/m^2 (0.05 inch per water column)
- Each refuge are will be design to provide air quantity of 944 L/s (20 cfm) per person and positive air pressure not less than 12.5 N/m2 (0.05 inch per water column)
- Smoke control system is not required

Drawings Developed for Final Report

MULTIPURPOSE FIRE EXTINGUISHER

FIRE DEPARTMENT AUTOMATIC SPRINKLER CONNECTION - SIAMESE

FIRE HYDRANT

FIRE DEPARTMENT HOSE VALVE CONNECTION

EMERGENCY TELEPHONE

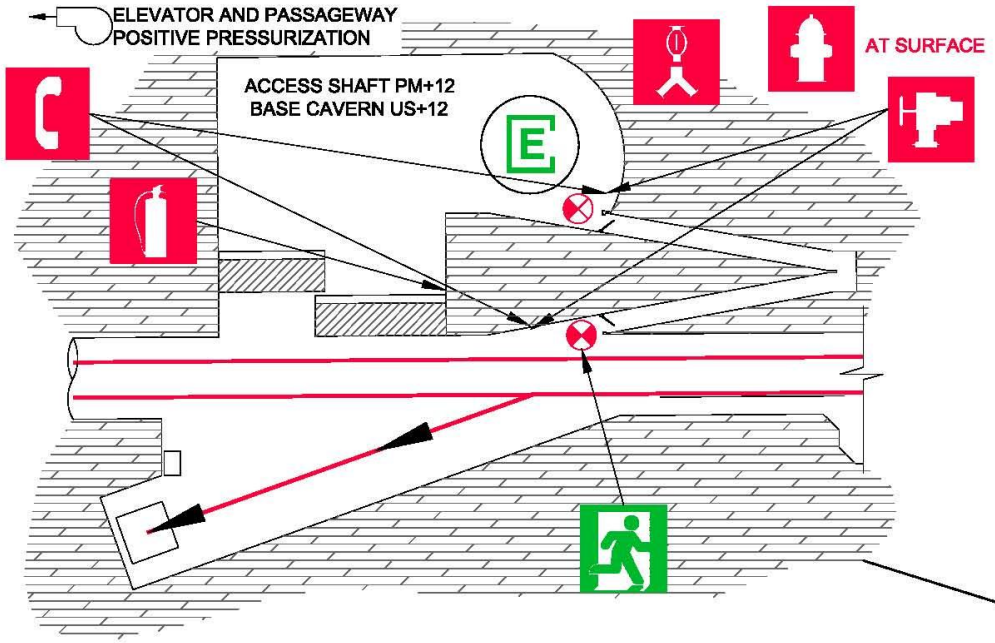
ACCESSIBLE EMERGENCY EXIT ROUTE

DIRECTIONAL ARROW

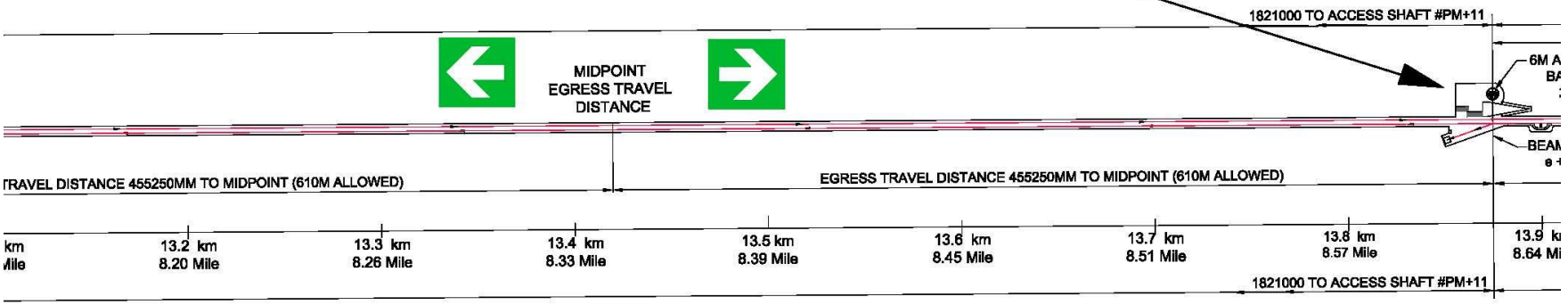
ILLUMINATED EXIT SIGN (2 SIDES)

ILLUMINATED EXIT SIGN (1 SIDE)

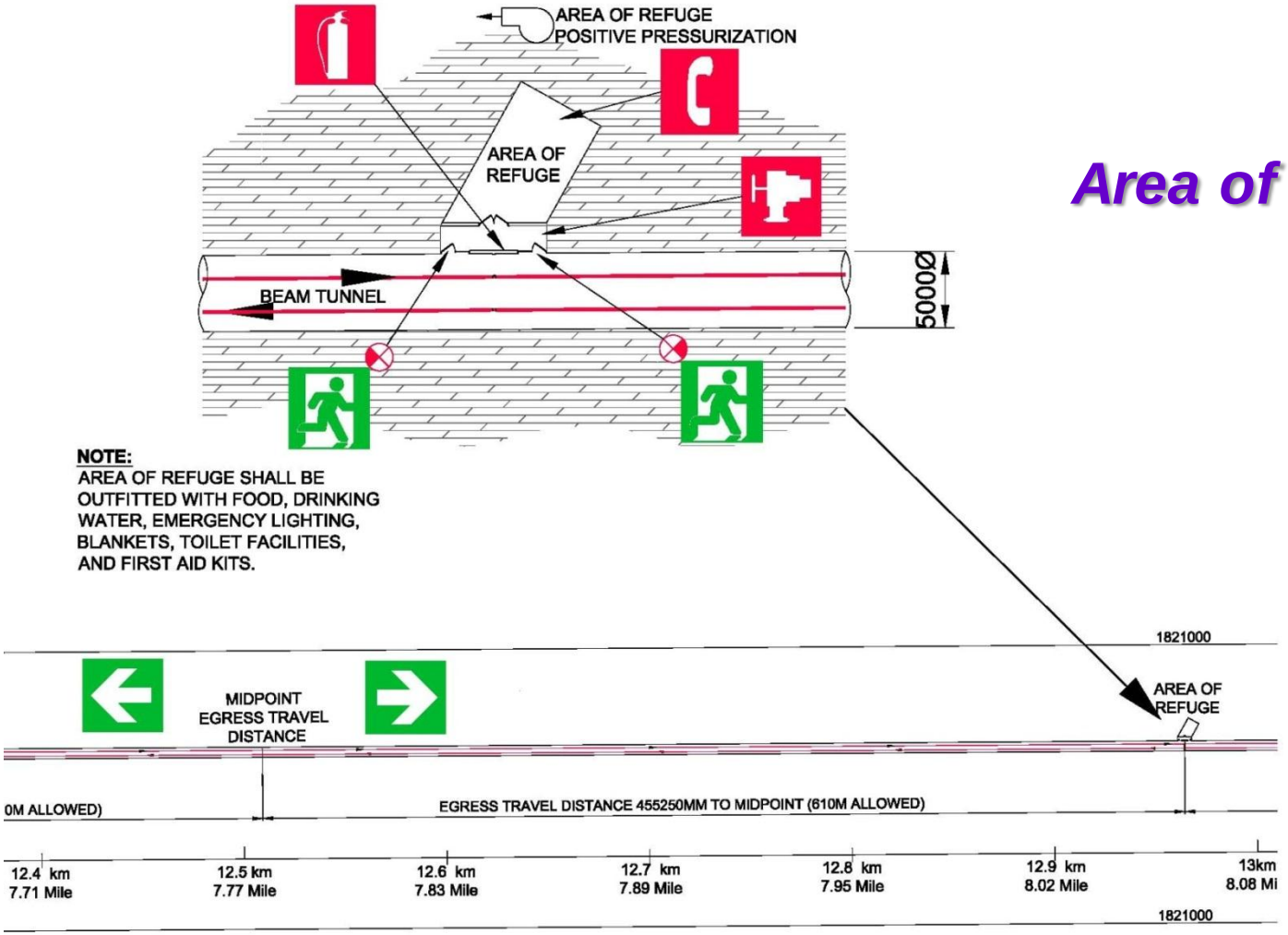
ELEVATOR



Access Portal at Shaft Base Cavern



Area of Refuge



Fire Protection Requirements

- Automatic sprinkler protection provided throughout the facility
- Class I standpipe, fire department hose valves throughout
- Fire extinguishers throughout the facility
- Fire hydrants provided at surface of Service Buildings/Access portals

Fire Detection/Alarm Requirements

- Two-way fire department communication system provided throughout the facility
- Emergency voice alarm system provided throughout the facility
- Smoke detection provided throughout tunnel and cavern
- Manual pull stations located at each access portal, exit gallery, spaced 122 m (400 ft) along tunnel

Fire Command Stations

- Located at service building(s)
- Two-way fire department communication controls
- Emergency voice alarm controls
- Heat, smoke, sprinkler water status
- Graphic annunciator of complex
- Status indicators of elevators, emergency and standby power systems