EXHIBIT V

Route 34 Downtown Crossing Project
Air Rights Implementation Guidelines

New Haven, Connecticut

In Cooperation with

City of New Haven

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Table of Contents

Chapter 1 Table of Contents

Chapter 1 Introduction

1.1 GENERAL

These guidelines were developed by the City of New Haven to assist Downtown Crossing development proponents in understanding the complex issues involved in construction over and adjacent to the operating facilities located within the City of New Haven's right-of-way. The major point that must be understood in the preparation of a proposal for and/or design of facilities within this corridor is that the rights and safety of the roadway must be protected both during construction of any proposed facility and in its built condition. It should also be carefully noted that specific criteria identified are intended to be guidelines for preparation of design and construction documents. Current standards for each system must be verified with the City of New Haven's Authority Having Jurisdiction (AHJ). The AHJ could be the City Engineer, City Architect, Fire Chief/Marshal, Building Inspector, Commissioning Agent, and/or the City Engineer depending the element being discussed. For the purposes of this report, all below grade construction is considered and referred to a tunnel.

1.2 USE OF THE IMPLEMENTATION GUIDELINES

The function of the implementation guidelines is to identify basic criteria to be used in the planning and design of developments within and/or adjacent to the facilities located within the City of New Haven's right-of-way. These guidelines include minimum criteria for the planning, design, and implementation of the infrastructure systems required to support air rights development as they relate to the City of New Haven's existing facilities and operations.

The guidelines are based on pertinent federal, state, agency, and local standards, regulations, and codes. Agencies having authority over design criteria to be used in the planning and design of air rights projects along all or parts of the Downtown Corridor include the City of New Haven, the Federal Highway Administration (FHWA), and Connecticut Department of Transportation (CTDOT), and public and private utility agencies.

The implementation guidelines are intended to assist design professionals in determining the technical feasibility of development proposals within the corridor and in developing infrastructure systems that may be required to support either the proposed development or the operations of the City of New Haven facilities. The terminology used within each section of the guidelines is, or may be, specific to the infrastructure system(s) discussed in that section.

The implementation guidelines are presented in twelve distinct chapters. Each chapter addresses an infrastructure system that has its own separate

technical criteria. It should be understood that these systems must be planned and designed in concert and must be developed and presented to the City as an integrated package.

The implementation guidelines are intended to be guidelines only and are not expected to address all of the design problems that a development proponent will encounter. Each section of the corridor and each proposed development will present the designer with unique technical challenges. Designers are encouraged to develop and analyze alternative approaches to solving planning and design concerns as they relate to the specific proposal being developed. The implementation guidelines are intended, however, to establish the basic criteria for the evaluation of each alternative design solution proposed. The guidelines are also intended to establish consistent criteria for the design of elements that are constant throughout the length of the study area or can be anticipated to be constructed on adjacent air rights parcels and must be considered in the design of each proposal.

1.3 CODES, STANDARDS, POLICIES, REGULATIONS, AND BEST PRACTICES

The design shall be governed by all the latest standards, policies, and specifications listed below with all addenda, supplements, and revisions thereto. The designer is responsible for determining and using the latest version or the adopted version of all design and construction standards applicable to this work. This guidance document does not serve to freeze the version of codes that are to be used for the facility design and construction. The designer will be responsible for updates to meet current codes as they become available or are adopted and become applicable to the project.

Where the documents below do not provide minimum requirements, the design shall be in accordance with the design standards from other federal state, or local government agencies or from nationally known professional organizations as approved by the AHJ.

In the case of a conflict between any of the design codes, standards, policies regulations, or requirements the more stringent requirement should govern the design unless approved by the AHJ

Any exceptions to or interpretations of the design criteria/guidelines referenced or contained herein shall be submitted in writing in the form of a marked of version of this document explicitly noting the sections and how the language is proposed to be modified. This information shall be submitted to the AHJ for consideration.

Each chapter includes a statement of the applicable codes, jurisdictional requirements and design criteria and/or objectives where applicable. Reference is also made in each chapter to engineering design manuals that should be used in the design of specific infrastructure and building systems

associated with each development proposal.

As a general rule, all infrastructure systems must conform to the pertinent elements of the most current industry best practices, design codes and guidelines including but not limited to the following:

- American Association of State Highway and Transportation Officials (AASHTO)
  - A Policy on Geometric Design of Highways and Streets, latest edition
  - Technical Manual for Design and Construction of Road Tunnels – Civil Elements, latest edition
- U.S. Department of Transportation – Federal Highway Administration – Manual on Uniform Traffic Control Devices (MUTCD), latest edition
- The Connecticut State Building Code, latest edition
- The International Building Code, latest edition
- The International Plumbing Code, latest edition
- The Occupational Safety and Health Act (OSHA), latest edition
- The National Fire Protection Association (NFPA)
  - NFPA 502 Standard for Road Tunnels, Bridges, and Other Limited Access Highways, latest edition
  - NFPA 88 Standard for Parking Structures, latest edition
  - NFPA 70 National Electric Code along with applicable State and local electrical codes
- Connecticut Department of Transportation (CTDOT)
  - Highway Design Manual, latest edition
  - Drainage Manual, latest edition
- City of New Haven, Complete Streets Design Manual, latest edition

In the case of conflict between the above design codes, the more stringent requirement should govern the design.

1.4 CITY REVIEWS AND PROCEDURES

It should be anticipated that review submittals of drawings, specifications, and calculations commissioning documentation as well as supplemental information as may be requested will be required on the following schedule:

- Conceptual Design - 10% Complete
- Schematic Design - 30% Complete
- Design Development - 60% Complete
- Final Design - 90% Complete
- Contract Documents - 100% Complete
- Review of Commissioning Documents
- Shop Drawings (for confirmation purposes only)
- As Built Documentation

Developer shall obtain special permitting from the City of New Haven for all lane closures.

1.4.1 Conceptual Design (10%)

This shall be the initial submittal by the project proponent to the City of New Haven. The submittal shall include all materials necessary to allow the City Engineer or his designee to review all basic elements of the design as perceived and/or anticipated by the proponent. The submittal shall include, as a minimum, the following:

Site plan for the project at a scale not less than 1" = 40', indicating vehicular and pedestrian access to the proposed project and the relationship of the project to existing facilities within and adjacent to the City of New Haven right of way.

Longitudinal and perpendicular sections through the project indicating proposed structure locations, types and relationships to existing and proposed facilities and operations.

A discussion of the relationship to and impact of the proposed facility on each of the existing infrastructure systems within the area of the proposed project.

A discussion of the infrastructure systems required to be put in place in conjunction with the proposed project to maintain the existing, or desired, level of service of operations within the City of New Haven right of way.

An identification of structures and systems that are adjacent to the project that will be affected by the project. For example, the adjacent sections of the tunnel comprise a single long structure. Lighting, ITS, ventilation, control, and other systems in adjacent tunnel sections or under adjacent overpasses may require modifications or changes to operation for the new condition after construction.

The Developer shall provide a list identifying all permits and approvals other than those required by the City of New Haven.

Provide an outline of "Concept of Operations"

A preliminary schedule for implementation of the project identifying anticipated time frames for major design, permitting, approval and construction activities.

1.4.2 Schematic Design (30%)

The Schematic Design Submittal shall consist of the documentation required to indicate the layout and function of all major systems for the project as they impact City of New Haven facilities and operations. The submittal shall include:

Responses to comments received on the Conceptual Design submittal, including any additional information requested.

Plans and sections showing the graphic layout of all proposed structures and their relationships to existing facilities.

Geotechnical data and design reports adequate to understand the intent of proposed foundations and identifying major elements to be considered in design.

Preliminary layout plans for structures relative to horizontal and vertical clearance requirements as they impact existing operations and indicating allowances for proposed systems.

Plans and sections indicating relationship/impact of proposed facilities on adjacent utilities and streets.

Preliminary design reports for all systems impacting Power and Communication serving the City of New Haven operations including structures, foundations, lighting, drainage, ventilation, emergency systems (fire detection and fire suppression systems), and construction operations. These reports must discuss the design approach for proposed facilities, relationships to existing adjacent facilities and allowances for future facilities required to support both currently planned and potential adjacent projects by the City of New Haven or others.

Update list of all permits and approvals other than those required by the City of New Haven.

Project implementation schedule showing all principal elements of design, permitting, approvals, and construction activities.

Meet with the AHJ for the various project elements and key project stakeholders and provide meeting notes. Contents should include key features driving the design configuration including the following:

- Concept of Operations
- First Responder Activities
- Fire Apparatus Dispatch
- Fire Department Connection Locations
- Hydrant Locations
- Facility Exit Discharge Locations
- Preliminary design report documenting the engineering analysis as required by the latest standard of NFPA 502 Section 4.3.
- Preliminary design report documenting the emergency response plan as required by the latest standard of NFPA 502 Section 4.4.

1.4.3 Design Development (60%)

The Design Development submittal shall consist of design documentation adequate to precisely locate each design element and the interrelationships between elements. The submittal shall include:

Responses to comments received on the Schematic Design submittal including any additional information requested.

Plans adequate to define all work elements on systems impacting City of New Haven facilities and operations including adjacent existing facilities.

Copies of substantially complete design computations for all work elements (including equipment item and performance lists).

Draft technical specifications, special provisions and general conditions.

Update list of all permits and approvals other than those required by the City of New Haven.

A construction schedule and operations plan showing principal and secondary construction activities by stage with milestones identified. The schedule and plans shall identify all activities that may impact City of New Haven facilities and operations and will show how those facilities and operations are maintained and protected during each phase of construction.

An operations report detailing the anticipated means and methods to be used in construction of the proposed project as it relates to existing City of New Haven facilities and operations.

Written statements from all public and private agencies owning or operating facilities impacted by the proposed project stating that they agree to the concept(s) proposed for the interface between their systems and the proposed project.

Updated design report documenting the engineering analysis as required by the latest standard of NFPA 502 Section 4.3.

Updated design report documenting the emergency response plan as required by the latest standard of NFPA 502 Section 4.4.

1.4.4 Final Design (90%)

The Final Design Submittal shall consist of substantially complete contract documentation for all proposed facilities. The submittal shall include:

Responses to comments received on the Design Development submittal including any additional information requested.

Substantially complete contract drawings for the entire project.

Substantially complete technical specifications, general conditions and special provisions for the entire project.

Copies of complete design computations for all facilities located within the City of New Haven right of way.

Update list of all permits and approvals other than those required by the City of New Haven.

An updated construction schedule and detailed construction operations plans.

Written statements from all public and private agencies owning or operating facilities impacted by the proposed project stating their approval of the project as it relates to their facilities.

Written agreement by the proponents as to all operations, restrictions and requirements requested by the City of New Haven as they relate to construction of the proposed facility.

Updated design report documenting the engineering analysis as required by the latest standard of NFPA 502 Section 4.3.

Updated design report documenting the emergency response plan as required by the latest standard of NFPA 502 Section 4.4.

1.4.5 Contract Documents (100%)

The Contract Document submittal shall incorporate responses to all comments by the City of New Haven on previous submittals and shall consist of the complete contract documents as issued for

construction for all proposed facilities. The submittal shall include:

Responses to comments received on the Final Design submittal.

Copies of the specifications and contract drawings checked, stamped and signed by a Registered Engineer and/or Architect as appropriate.

Copies of all necessary approvals and permits required to build the facilities located within the City of New Haven right of way.

A final construction schedule and operations plan.

Review of Approved commissioning plan.

Final design report documenting the engineering analysis as required by the latest standard of NFPA 502 Section 4.3.

Final design report documenting the emergency response plan as required by the latest standard of NFPA 502 Section 4.4.

1.4.6 Shop Drawings

Copies of shop drawings, catalog cuts and other required contractor submittals as approved for fabrication for all facilities located within the City of New Haven right-of-way and for all facilities required to maintain the approved level of operation on City of New Haven facilities shall be submitted to the City of New Haven for review relative to conformance with approved design. Submission to the City of New Haven for final approval shall not occur until the Engineer of Record for the Developer has approved of the submission as submitted by the Contractor.

1.4.7 As Built Documents

As built documentation of all facilities constructed within the City of New Haven right of way and/or required to maintain adequate levels of operation upon facilities located within the right- of-way will be submitted to the City of New Haven upon completion of the project. The format of this submittal will be established by the City of New Haven prior to initiation of design.

A minimum of 30 days should be allowed for review by the City of each of the submittals identified above. If the proponent for construction contracting methodology, or other reasons, desires release from the submittal/review program identified, a request must be made to the City Engineer identifying the proposed submittal program and schedule at the time the Conceptual Design submittal is made to the City of New Haven.

Presentations of the design project to City of New Haven staff should be anticipated at each of the major submittals.

Supplemental information such as vehicular and traffic generation, shadow and light studies, etc. may be required by the City of New Haven depending on the scope and complexity of the proposal.

Chapter 2 Table of Contents

Chapter 2 Geometric Design

2.1 GENERAL

This section establishes the basic design criteria for geometric controls and clearance requirements for the access drives for use in the development of design for Downtown Crossing developments.

The intent of this design criteria is to provide guidance to the designer by referencing a required and recommended range of values for critical dimensions. Minimum values are given or implied by the lower value in a given range of values. These minimum design values represent the minimum requirements per codes, standards, and/or best practices. Therefore, it is important that these basic minimum requirements are met. Tunnel geometric design will depend on a number of factors including but not limited to roadway grade, sight distance, Average Daily Traffic (ADT), projected traffic use, availability of route bypass options.

Any exceptions to or interpretations of the design criteria contained herein shall be submitted to the City of New Haven's City Engineer for approval.

2.2 CODES AND STANDARDS

The geometric design shall be governed by the standards, policies, and specifications listed below with all addenda, supplements, and revisions thereto.

- American Association of State Highway and Transportation Officials design policies as stated in "A Policy on Geometric Design of Highways and Streets," latest edition
- American Association of State Highway and Transportation Officials, "Roadside Design Guide", latest edition
- U.S. Department of Transportation – Federal Highway Administration - "Manual on Uniform Traffic Control Devices for Streets and Highways", latest edition
- Connecticut Department of Transportation, Highway Design Manual, latest edition
- City of New Haven, Complete Streets Design Manual, latest edition

2.3 FUNCTIONAL CLASSIFICATION

The roadway is functionally classified as an Urban Local Street under the Department's Roadway Functional Classification System and is located in an Urban Built-up area.

2.4 DESIGN CONTROL

2.4.1 Design Vehicle

Design vehicle for the Access Drives is a WB-67 (Larger Tractor-Semitrailer). Width of traveled way on horizontal curves shall be designed to accommodate this class of vehicle. On two-lane roads, either one-way or two-way, width of traveled way shall be designed to accommodate two WB-67 side by side and in opposing directions at the same time. This shall be verified by the submission of Auto Turn turning movement diagrams to the City for their review and approval.

2.4.2 Design Speed

The design speed is either: maximum functional class speed or a speed based on the anticipated (post-construction) off-peak 85th percentile speed within the range of functional class speeds as shown below:

For roadways located in Urban Built-up area: 20 mph minimum, 25 mph maximum.

2.5 CROSS SECTION ELEMENTS

2.5.1 Travel Lane Width

10' minimum, 11' desirable.

2.5.2 Shoulder Width

2' minimum, 4' desirable.

2.5.3 Cross Slope

Travel Lane, 1.5% - 2.0% (1.5% - 3.0% with curbing)

Shoulder (width less than 4'), same as adjacent travel lane

Shoulder (width greater than or equal to 4'), 4% - 6%

2.5.4 Turn Lanes

Lane Width 10' minimum, 11' desirable.
Adjacent Shoulder Width 2' minimum, 4' desirable.

2.5.5 Bridge Width / Cross Slope

Meet Approach Roadway Width and Cross Slope

2.5.6 Underpass Width

Meet Approach Roadway width plus Clear Zones
Tunnel Section – See Section 2.7.4

2.5.7 Roadside Clear Zones

Per requirements of Highway Design Manual Section 13-2.0

2.6 ALIGNMENT ELEMENTS

Alignment elements below are based on 20 mph design speed.

2.6.1 Stopping Sight Distance

115' minimum.

2.6.2 Minimum Radius

80 feet.

2.6.3 Superelevation

4% maximum

2.6.4 Grade

0.5% minimum, 11% maximum.

2.6.5 Vertical Curvature (K-Value)

Crest Curve – 7, Sag Curve – 17.
With Minimum length of curve = 3 x V (design speed in mph).

2.6.6 Minimum Vertical Clearance

Local Street Under New Highway Bridge – 14'-6"

Local Street Under Existing Highway Bridge – 14'-3"

Local Street Over Railroad (Electrified) – 22'-6"

Local Street Over Railroad (Others) – 20'-6"

2.7 TUNNEL SECTIONS

The roadway design criteria for cross section elements and alignment elements indicated in the previous sections also apply to tunnels.

2.7.1 Roadway Width

For a two-lane tunnel, the overall roadway width should be a minimum 2 feet greater than the approach traveled way width, but not less than 24 feet.

The roadway cross section shall be suitable to accommodate two lanes of traffic. During maintenance operations in one tunnel or in the event of an incident that requires one tunnel to be closed, the other tunnel shall be converted to one lane of travel in each direction. Under these conditions the tunnel shall be designed to accommodate the design vehicle operating in opposing directions at the same time. This shall be verified by the submission of Auto Turn turning movement diagrams to the City for their review and approval.

2.7.2 Shoulder

Shoulders are not required in tunnels.

When provided, full left shoulder and right shoulder widths of the approach roadway desirably should be carried through the tunnel. The desirable width is a 10' right shoulder and a 5' left shoulder.

2.7.3 Sidewalk/Emergency Egress Walkway

Although pedestrians are typically not permitted in road tunnels, walkways for emergency egress are required in road tunnels. Walkways must be designed to be accessible to and usable by pedestrians with disabilities.

For short tunnels (less than 200 feet in length), 3.5 feet minimum (per AASHTO), 3.7 feet minimum (per NFPA). For design, a 3.7' minimum width shall be used.

For long tunnels (200 feet or more in length), 4 feet minimum (per AASHTO) with a 5 feet wide passing section every 200 feet.

Note that the width requirement under NFPA applies to all tunnel length which is 3.7' minimum.

2.7.4 Tunnel Width

Total clearance between walls of a tunnel:

33 feet minimum for short tunnels (less than 200 feet in length)

34.5 feet minimum for long tunnels (200 feet or more in length)

2.7.5 Minimum Vertical Clearance

16' minimum for freeways, a 6" allowance should be added for future repaving. 14'-6" minimum for other highways.

The height should not be less than the maximum legal height of load and should not be less than that on the approach roadway.

Any obstacles or proposed tunnel appurtenances such as signage, fire suppression, ventilation systems etc. should not encroach into the roadway envelope. Such elements, when installed above the roadway may require increasing the tunnel height to meet the minimum vertical clearance requirements.

2.8 NFPA 502, LATEST EDITION

Special attention shall be taken regarding the requirements for the Means of Egress, Section 7.16 under Chapter 7 Road Tunnels of NFPA 502.

Chapter 3 Table of Contents

Chapter 3 Drainage Design

3.1 GENERAL

Highway drainage shall be designed to keep the traveled ways usable and free from flooding during design storms and shall be adequate to accommodate water from firefighting and maintenance wash down operations.

The designer should be aware of and shall comply with federal, state and local legal requirements related to drainage design, and shall perform the design such that there will be no substantial adverse effects on adjacent properties or drainage systems.

The designer should be aware of and shall take into consideration in the design future land use plans, expected changes to existing water courses and drainage systems, and future federal, state and local actions affecting drainage.

The designer must also prepare and retain adequate documentation as part of the drainage design process.

The surface elevation and drainage inlets of the proposed driveway/roadway drainage system shall not be lower than the inlet in the existing Air Rights Garage

3.2 HYDROLOGY

3.2.1 Underground (Tunnel) Conditions

It is expected that firefighting water will be used to determine the peak discharge or runoff within enclosed facilities. Design frequency will be a minimum of two deluge zones operating simultaneously.

The water spread of gutter flow on the pavement during the design deluge event shall conform to the requirements outlined in Chapter 11 of the Connecticut Department of Transportation Drainage Manual for town roads.

All Hydrology and Drainage on portal roadways exposed to rain events shall comply with applicable federal, state, and local requirements and guidelines

3.3 STORM DRAIN SYSTEM

3.3.1 General

Storm drain systems shall be provided to convey runoff. A storm drain system shall consist of inlets, collector pipes, manholes, trunk

line, and outfall.

The storm drain system shall have sufficient capacity to accommodate the runoff flow during a design storm event from highway pavement, bridge decks, medians and/or air rights platforms.

3.3.2 Inlets

Inlet Types

Catch basins with grate inlet shall be used for paved area drainage.

Where the installation of catch basins would not be possible because of obstructions, gutter inlets, i.e., grate inlets without sumps, may be used.

Inlet Spacing

Inlets shall be spaced such that the flow in paved areas meets the design water spread specified herein.

Spacing between inlets or area drains should not exceed 200 feet Special attention shall be given to the following conditions in the location of inlets:

- Concentrated flows should not cross the roadway pavement.
- Flow concentrations should not outlet onto the roadway pavement.
- Where a gutter inlet is used, a catch basin with a manhole frame and cover should be installed between the inlet and the trunk line manhole.
- No more than two inlets should be connected together before outletting into a trunk line manhole.

3.3.3 Collector Pipes

The minimum diameter of collector pipes between inlets and the trunk line shall be 12 inches.

Other design criteria specified for trunk line pipes in Section 3.3.5 shall apply to the collector pipes.

3.3.4 Manholes

Manholes shall be provided at pipe junctions, at intermediate points on long tangent pipe runs, at changes in pipe size, and at changes in grade or alignment.

Manholes should be located outside of the vehicle wheel path in outside lanes.

Spacing between manholes should not exceed 200 feet.

3.3.5 Trunk Line

Discharge Criteria

The following discharge criteria shall apply to the design of a trunk line:

- The trunk line should have sufficient capacity to accommodate the runoff flow during the design deluge event.
- The trunk line pipe system should flow full for the calculated total flow.
- The hydraulic grade line (HGL) shall not rise to within one foot of any manhole cover or top of any inlet for the desired discharge.
- The hydraulics of the lateral pipes should not be influenced by the HGL of the trunk line.

Flow Velocity

The minimum desirable design flow velocity shall be 3 feet per second (3 ft/sec.). The maximum desirable design velocity should be 10 feet per second (10 ft/sec). In extreme cases, higher velocities may be permitted.

3.3.6 Discharge

Drainage retention vault may be required for flammable liquid or contaminate cargo drainage for pretreatment or offsite disposal. The underground drainage system shall only be connected to existing sanitary sewer systems or existing combination sanitary sewer storm drain systems. Pumping facilities may be required to facilitate drainage where gravity flow cannot be achieved.

The location where the proposed drainage/sewer system is to be connected into the existing sanitary sewer shall be coordinated with the Greater New Haven Water Pollution Control Authority (GNHWPCA). The Developer shall also coordinate with GNHWPCA to confirm that the existing pipe has sufficient capacity to support the additional load. Any required upgrades to the existing sanitary sewer infrastructure or addition of support system such as pump stations etc. shall be as required by the GNHWPCA in conjunction with the City Engineer and shall be required to be completed by the Developer.

Chapter 4 Table of Contents

Chapter 4 Utility Systems Design

4.1 GENERAL

These criteria govern the design of projects that impact utilities in order to maintain, support, or relocate existing utility facilities that will be affected by the construction of projects within the Downtown Crossing corridor.

Utility facilities are defined as facilities belonging to state, city governmental agencies, and privately-owned companies for the provision of sanitary sewer, storm drain, water, gas, electric, telecommunication, telegraph, and cable television services; street lighting; traffic signalization; and fire, police and emergency alarm systems. The various services and systems may consist of transmission facilities, distribution facilities and service connections to adjacent properties as well as services to the proposed development.

In the performance of construction impacting on utility systems, due consideration shall be given to the needs of the requirements and obligations of the facility owners, traffic requirements and the service needs of adjoining properties.

Several utility facilities presently exist within the limits of, or cross, the roadways. Such utility facilities may pass above or beneath the roadway. The designer shall determine which facilities must be maintained in place during project construction.

Existing utilities that are in physical conflict with proposed facilities shall be relocated. Such relocations may cross the roadway at different locations, or in utility corridors where several utilities cross at one location.

Whenever practical, utility crossings shall be perpendicular to the roadway alignment or as nearly perpendicular as possible.

Utility services will be maintained at all times unless specific authorization by the City of New Haven and the facility owner is obtained for a shutdown of service.

Design for the maintenance and protection of existing utility facilities shall be performed by using one of the following alternative procedures:

- Support the existing facility in place and maintain it during construction.
- Replace the existing facility, support the replacement in place and maintain It during construction.
- Permanently replace the existing facility beyond the construction impact limits.
- Permanently relocate the facility within the construction impact

limits with the new facility being supported and maintained in place during construction.

- Temporarily relocate the facility beyond the construction impact limits and maintain service. Upon completion of construction, restore the existing facility or replace it with a new facility at its original location.

All facilities must be accessible to the facility owner to the fullest extent feasible during and after construction.

Utility services to adjoining properties shall not be interrupted without permission from the facility owner and notification to the customer.

4.2 STORM DRAINS

The storm drain facilities affected by air rights construction may be owned and maintained by any one of the following agencies:

- City of New Haven
- Connecticut Department of Transportation

When no additional flow is added to an existing storm drain, conditions downstream and upstream of the manhole at the end of the modification need not be studied. Where increase in flow or reduction in system capacity takes place as a result of the construction, conditions downstream and upstream shall be evaluated. The extent of this evaluation shall be determined on an individual basis by the City Engineer.

The pipe sizes for storm drains shall be determined by calculating the discharge from the upstream contributory area considering the future development trends of the area. The resulting flows shall be used to size the storm drains.

The design of storm drains shall be in accordance with Chapter III of the Requirements, and the current standards and criteria of the facility owners.

4.3 SANITARY SEWERS

Sanitary and combined sewers affected by the construction may be owned and maintained by one of the following Agencies:

- City of New Haven
- Greater New Haven Water Pollution Control Authority (GNHWPCA)

The size and materials of new facilities shall be selected to give best service under local conditions and the requirements of the design. Both size and materials selected shall meet or exceed those of existing sewer pipes. Special consideration shall be given to the character of industrial wastes, possibilities of septicity, exceptionally heavy external loads, abrasion, infiltration and exfiltration, soil conditions and pipe bedding, and similar

problems.

Pipe materials for City of New Haven sewers shall be either reinforced concrete pipe or polyvinylchloride (PVC) pipe. Pipes 18 inches inside diameter or larger shall be reinforced concrete pipe; pipes 12 inches and 15 inches inside diameter shall be either reinforced concrete pipe or PVC pipe; pipes 10 inches inside diameter shall either be non-reinforced concrete pipe or PVC pipe; pipes less than 10 inches inside diameter shall be PVC pipe. Pipe having less than five (5) feet of cover shall be ductile iron pipe meeting the class requirements set by the City of New Haven for their sizes.

Pipe materials for GNHWPCA sewers shall be as required by the GNHWPCA.

Where sewers must be permanently replaced and surcharge conditions are known to exist, consideration shall be given to increasing the size of the proposed conduit to improve hydraulic capacity, if requested by facility owner.

The minimum diameter for sewers shall be 10-inches, except for individual building connections required by the facility owner.

Wherever possible, sewers shall be designed with sufficient slope to give mean velocities of not less than 2.0 feet per second based on Manning's formula with pipe flowing full or half full.

Sewers with a diameter of 24 inches or less shall be laid with straight alignment between manholes.

For larger sizes, curved alignments, if proposed, shall be reviewed and accepted by the City of New Haven or GNHWPCA before completion of the design.

Unless otherwise approved by the facility owner, manholes shall be installed at the end of each sewer line; at all changes in grade, pipe size, junctions, and intersections; and at changes in alignment, except where an approved curved alignment is involved. Manhole spacing shall not be greater than 300 feet, unless approved by the facility owner.

Manholes shall preferably be precast concrete units with a minimum diameter of 48 inches conforming to ASTM C478. The internal diameter of the base section shall be at least 1 foot larger than the outside diameter of the largest pipe connected to the structure. A minimum wall space of 1 foot for precast units and 6-inches for brick units, measured circumferential on the internal surface of the riser, shall be provided between the outside diameters of each pair of pipes connecting to a manhole. When the above design criteria cannot be met by using precast concrete sections, a cast-in-place reinforced concrete junction box shall be used unless otherwise required by the facility owner.

Water-tight manhole covers shall be used wherever the manhole tops may be flooded by street runoff or high water. Manhole joints shall be waterproofed on the exterior with coal tar epoxy where ground water

conditions are unfavorable, or as required by facility owner.

Manhole covers shall conform to street grade and cross-slope. The elevation shall be given for the center of the cover or for the rim, in accordance with the facility owner's requirements.

Manhole covers shall have centered pick holes.

The flow channel through manholes shall conform in shape and slope to that of the connecting sewers.

Force mains shall normally be constructed of ductile iron pipe with mechanical or other approved joints. If approved or required by owner other materials such as prestressed concrete cylinder pipe, steel pipe, or PVC pipe may be used.

Water pipe and sewer lines shall not be laid in the same trench. A lateral separation of at least 10 feet and, in the case of crossings, a vertical separation of at least 18 inches shall be maintained between the bottom of the water pipe and the top of the sewer line. Where these separations are impossible, consideration shall be given to relocating the water main, reconstructing it with mechanical joint pipe for a distance of 10 feet on each side of the sewer, or encasing a portion of either the sewer or the water main in concrete.

4.4 WATER MAINS

The water facilities affected by air rights construction owned and maintained by one of the following agencies:

- City of New Haven
- Southern Connecticut Regional Water Authority (RWA)

All replacements and relocations of sections of any water distribution systems are subject to approval by the City of New Haven or RWA and shall be in conformance with the current standards and practices of the facility owner.

Temporary piping or other methods of temporary supply shall be used to provide water service during construction, as required by the facility owner.

The following design standards shall apply to all replacement and relocations of the City of New Haven water distribution system, unless otherwise directed by the City of New Haven Fire Chief/Marshal.

4.4.1 Minimum Pipe Sizes

Minimum Domestic Service Connection	2-inch
Minimum Fire Protection Service Connection	6-inch
Minimum Hydrant Connection	6-inch

Minimum Local Distribution Main	8-inch

4.4.2 Pipes and Fittings

Unless otherwise required by special design considerations or by facility owner, replacement of piping in the existing and relocated municipal waterworks distribution systems shall be made using mechanical joint type pipe.

Ductile iron pipe and fittings shall conform to the following specific requirements and exceptions to the aforementioned standards insofar as they apply:

- The minimum thickness class for ductile iron pipe shall be Class 52 for pipe sizes 4-inch through 16-inch and Class 53 for pipe sizes 18-inch through 48-inch, except as noted herein.
- The minimum thickness class for flanged joint ductile iron pipe shall be Class 55.
- Fittings for pipe sizes 4-inch through 12-inch shall be gray cast iron having a minimum working pressure rating of 250 psi. Fittings for pipe size 16-inch through 48-inch shall be ductile iron having a minimum working pressure rating of 250 psi.

The pipe thickness design for standard conditions of new ductile iron pipe, required for alterations to, or relocations of the existing pipe systems, shall be based on the design system used in ANSI Standard A21.50. The design for pipe thickness shall be based on a working pressure of 200 psi with an allowance of 100 psi for water hammer.

The pipe thickness design for pipe supported at intervals above ground or underground shall be based the latest version of the International Plumbing code. The design shall be based on the working pressure and water hammer as stated above.

In general, the top of all water main, branches, and service connections shall be at least five feet below the finished street grade or other surfaces.

Accessibility shall be provided for in the design for the purpose of repair and maintenance of water mains and appurtenances located within easements and in or on structures.

Fire hydrant installation shall comply with the City of New Haven standards and requirements. The following is a list of major requirements to consider in the design of fire hydrants.

- Hydrants shall be located at street intersections for

visibility and accessibility, with intermediate hydrants spaced at approximately equal distance along the streets at intervals of from 200 to 300 feet. Hydrants shall be located off the traveled way, on the side of the street nearest to the main.

- Hydrants shall be installed on hydrant tees with a six-inch lateral and shall have a six- inch gate valve attached to the hydrant tee and located between the hydrant and the main.
- Hydrants shall be anchored in accordance with City of New Haven.
- In general, all mains shall have valves at points of intersections. Each main shall have valves on each side of the intersection.
- Intermediate valves shall be located along local distribution mains at intervals of approximately 500 feet. Each hydrant branch and building service larger than 2-inch in size shall be controlled by a gate valve the same size as the branch. A valve shall be located on either side of the Tunnel at a crossing.
- Unbalanced forces in water mains (as occur at horizontal or vertical elbows, tees, and dead ends) shall be counterbalanced by means of the following:
- Concrete thrust blocks shall bear against undisturbed earth and shall be designed for a main pressure of 200 psi.

Relocations and replacements of existing service connections required by construction shall be as required by facility owner.

All pipe joints and fittings which are to be aerially supported over or under a bridge or similar structure shall be thoroughly restrained against both longitudinal and lateral movement through the use of NFPA approved restraining devices. Each crossing shall have a valve on each side located in proximity to the crossing.

When a new water main installation is designed, particular attention shall be paid to high and low spots in the profile of the proposed water main. All drainage branches, blow offs, air vents, and appurtenances shall be provided with gate valves.

Provision shall be made at high points in the system for the release of air to prevent reduction of capacity and for the intake of air to prevent a vacuum from forming. Pitometer cocks shall be used as air vents on the. water mains. Pitometer cocks are required at high spots,

if there are any, and at points determined by the City during the design of the water main. Venting arrangements shall be subject to the approval of the facility owner.

Drainage branches or blow-offs shall not be connected to any sewer, submerged in any stream, or installed in any other manner which will permit backward flow into the distribution system.

Whenever possible, hydrants shall be the principal means of providing the necessary air relief at high spots on the main, and either drainage branches or hydrants shall be utilized at the low spots for drainage of water from the water main.

Blow-off connections shall be provided at low points in the system for removing accumulated sediments, for flushing lines, and for dewatering the lines.

Water pipes with less than five feet of cover shall be insulated, and exposed water pipes shall have insulation jackets as well as insulation.

In no case shall publicly owned water facilities be placed upon private property. Should the area within the public right-of-way be insufficient for facility installation, sufficient right-of-way or an easement shall be provided.

4.4.3 Sanitization

All new pipe systems, temporary bypass or permanent, shall be sanitized as required by the owner. Sanitization procedures performed by the proposer shall be subject to the approval of the facility owner

4.5 GAS FACILITIES

The design and relocation of gas facilities shall be approved by facility owner and shall be in accordance with the following criteria and standards (Laterals only shall be Double Walled Piping):

- Natural Gas Pipeline Safety Act, U.S. Department of Transportation, Code of Federal Regulation, Minimum Federal Safety Standards Part 192 - Title 49, Transportation of Natural and Other Gas by Pipelines.
- A.N.S.I. B31.8 - Standard for Gas Transmission and Distribution Piping System, including supplement B31.8b.
- American Petroleum Institute Standards for Welding Pipelines and Related Facilities,
- A.P.I. Standard 1104.
- Williams-Steigler Occupational Safety and Health Act of 1970,

O.S.H.A., U.S. Department of Labor.

4.6 UNDERGROUND FUEL STORAGE

Fuel storage and flammable gas storage shall not be allowed under any tunnel areas or any special use areas that are directly connected to the tunnel with no 2-hour separation. No fueling procedures shall be allowed within the tunnel or special use areas.

4.7 TELECOMMUNICATION FACILITIES

The following types of telecommunication facilities may be encountered:

- Aerial wires and cables mounted on wood or metal poles operated and maintained by one of the previously listed agencies.
- Underground conduit and manhole systems containing copper cables, long line copper cables and fiber optics belonging to one of the previously listed agencies.

The designer shall design and prepare contract documents subject to the review and approval by the City of New Haven and the facility owner for the layout of the conduit and manhole systems. The remaining design related to the installation of copper cables and fiber optics facilities will be performed by the facility owners subject to reimbursement by the developer.

The construction of the conduit and manholes will normally be by the proponent contractors subject to approval by the owner. The installation of new copper cables and fiber optics and the splicing of these new facilities to existing facilities will be performed by the facility owners subject to reimbursement by the developer.

The design shall be in accordance with the relevant criteria and standards of the facility owners.

The following are some general guidelines for material to be used and other design information related to conduits and manholes for telecommunications installations.

4.7.1 Conduits and Manholes

- Conduits shall be a minimum of four inches in diameter and shall be constructed of one of the following materials:
- Galvanized Rigid Steel
- Fiberglass rigid epoxy (FRE)
- Buried conduit shall generally be encased in concrete.
- Except where other alignments are approved by the agencies, conduit banks shall be straight between

manholes. Large-radius changes in the profile may be used where necessary.

- Maximum length of conduit between manholes shall be 600 feet unless otherwise approved by the facility owner.
- Conduits beneath the roadway shall be Galvanized Rigid Steel conduits encased in concrete.
- Manholes shall be of reinforced concrete and, wherever possible, standard types will be used. Manholes shall meet the loading requirements of the Latest Edition of the "Standard Specifications for Highway Bridges" of the American Association of State Highway and Transportation Officials (AASHTO).
- Conduits supported on bridges shall be Fiberglass Rigid Epoxy (FRE) conduit.

4.8 ELECTRIC FACILITIES

Electrical power transmission and distribution facilities may be located within the limits of impact of air rights construction. The owner of electrical facilities is listed below:

- United Illuminating Company (UI)

The types of facilities may include, but not be limited to the following:

- Aerial wires and cables, which may be mounted on wood or metal poles.
- Underground conduit and manhole systems containing electrical power transmission and distribution cables.

The designer shall design and prepare contract documents subject to the review and approval by the City of New Haven and the facility owner for the layout of the conduit and manhole systems. The remaining design effort related to cable sizing and circuit layouts will be done by the facility owners.

The construction of the conduit and manholes will be by the proponent's contractors subject to approval by the owner. The installation and splicing of new cables will be performed by the facility owners subject to reimbursement by the developer.

United Illuminating Company (UI) owned electrical power facility relocations will be designed to comply with the standard details and specifications of the company.

The following are some general guidelines for materials and other design information related to conduits and manholes for electrical power installations.

4.8.1 Conduits and Manholes

- Conduits shall be a minimum of five inches in diameter and shall be constructed of one of the following materials:
- Galvanized Rigid Steel
- Fiberglass Reinforced Epoxy (FRE).
- Buried conduit shall generally be encased in concrete.
- Conduits shall normally be straight between manholes. Where curvature of conduits in plan or profile is necessary to avoid obstructions, such alignments shall be approved by the facility owner.
- Maximum length of conduit between manholes shall be 600 feet, or as required by the facility owner.
- Conduits encased in concrete installed beneath the roadway shall be Galvanized Rigid Steel conduits
- Manholes shall be of reinforced concrete and, wherever possible, shall be of the configuration shown on the United Illuminating Company (UI) Standards, or as required by the facility owner.
- Conduits hung from the decks shall be Fiberglass reinforced epoxy.

4.9 HIGHWAY/STREET LIGHT FACILITIES

Highway and/or street lighting will be affected by the air rights construction. Ownership of lighting facilities is by one of the following agencies:

- United Illuminating Company (UI)
- City of New Haven

In general, all lighting fixtures will be supplied by cables located in underground conduits, with the possible exception of temporary lighting, which may be fed overhead.

The design of all lighting systems will be in accordance with the Lighting Design Criteria: Chapter 9, and the relevant criteria and standards of the various facility owners.

4.10 TRAFFIC SIGNALIZATION FACILITIES

Traffic signalization and other traffic-related facilities will be affected by air rights construction. Ownership of the traffic-related facilities is by the City of New Haven.

Traffic signalization facilities may be interconnected by cables attached to the traffic signal system installed in conduits located under the sidewalk or under the roadway connecting traffic signals. Where signals are interconnected, a master controller may be provided in addition to the individual controller at each set of signals. Intersection signal installations shall be connected to an intersection control mechanism, with the necessary auxiliary equipment, by means of an underground circuit.

All traffic signal design shall be in accordance with the City of New Haven standards and the Manual on Uniform Traffic Control Devices, latest edition.

4.11 FIRE, POLICE AND EMERGENCY ALARM FACILITIES

Fire, Police and Emergency alarm facilities operated and maintained by the City of New Haven Fire and Police Departments may be affected by construction of the Project.

The facilities consist of fire, police and emergency alarm boxes connected in circuits to various monitoring stations. Fire, police and emergency alarm circuits must be maintained in service at all times.

4.12 CABLE TELEVISION FACILITIES

Cable television facilities owned and maintained by the Comcast Communications may be affected by the air rights construction. These facilities will be located in below ground duct banks. The cable company will be responsible for the design and construction of any relocation of their facilities that conflict with the air rights construction.

4.13 TRAFFIC SIGN FACILITIES

Variable message and other guidance and traffic control signing owned and maintained by the City of New Haven will be affected by air rights construction. These facilities may include the message board, its structural support, foundation, a power supply system and a communications system.

All existing message boards may be maintained in place, replaced in kind or relocated to an alternative location approved by the City Engineer and/or the Director of Transportation, Traffic, and Parking. All facilities including communications must be maintained at all times during air rights construction.

All variable message sign systems shall be in accordance with the City of New Haven design requirements or as approved by the City Engineer and/or the Director of Transportation, Traffic, and Parking.

Chapter 5 Table of Contents

Chapter 5 Geotechnical Design

5.1 GENERAL

This section describes some of the major geotechnical design and construction issues associated with potential air-rights development. All geotechnical design parameters shall be provided by a Professional Engineer licensed in the State of Connecticut. Geotechnical design recommendations shall be in accordance with the latest edition of AASHTO for bridge foundations and the Connecticut State Building Code for Building Foundations.

5.2 GENERAL SOIL CONDITIONS AND SUBSURFACE EXPLORATION

A general subsurface profile shall be developed based on site-specific subsurface investigation program to ascertain existing subsurface conditions including groundwater levels.

5.3 EXISTING FACILITIES

Major existing facilities considered to be at risk during air rights construction include the following:

- Bridge Abutments and Piers (Generally pile supported; typically, timber piles)
- Retaining Walls
- Utilities
- Adjacent Buildings

Prior to any construction, a comprehensive inventory of existing adjacent structures and an in-depth study of the existing foundations must be conducted. This data will be used as input for subsequent assessment performed under Section 5.6 Construction Impacts. The foundations of all existing facilities, which are considered to be within the zone of influence of the proposed construction must be researched. The zone of influence could vary significantly based on proposed construction procedures, sub-surface conditions and existing facilities; therefore, it is necessary that a Professional Engineer, licensed in the State of Connecticut, estimate the zone of influence based on standard engineering practices, including empirical estimates of settlement and lateral strain as well as more sophisticated numerical modeling techniques as required. Should the monitoring program indicate that the zone of influence is greater than anticipated, additional instrumentation and foundation research may be required. Based on construction impact assessment, develop a structure-specific instrumentation and monitoring plan including threshold values of

displacement and lateral strain requiring modification of construction procedures up to and including stoppage of work.

In addition to fully researching the type and condition of existing facilities, a detailed analysis and explanation of the types of subsurface changes that the existing facilities are sensitive to must be provided. The Developer shall be aware of and account for the potential sensitive nature of the testing, research, imaging, and procedures being performed within the project area. The land use and building uses associated with the area surrounding the development shall be included in the vibration mitigation plan to be submitted to the City for review and approval.

5.4 PROPOSED FOUNDATIONS

It is likely that air-rights foundation loads will typically be supported on a deep foundation system bearing on the soil and/or bedrock. Low displacement foundation systems such as drilled shafts or load bearing elements appear reasonable. H-piles end bearing piles may also be feasible at specific locations where existing facilities are not at risk from vibrations and/or ground heave.

Drilled shafts and/or load bearing elements may assume friction in soil and rock in addition to end bearing, with the exception that no end bearing will be allowed in soil when visual inspection of the bottom of foundation is not possible. Site specific geotechnical design parameters must be determined based on code requirements and/or lab and field testing performed under the direction of a Geotechnical Engineer licensed in the state of Connecticut.

Where applicable, shallower foundations may be founded in sand and gravel stratum or the stiff clay stratum, provided a detailed analysis of the effects of construction dewatering on existing structures is performed and accepted by the City of New Haven. Acceptable bearing pressure for the sand and gravel or stiff clay are typically as the range of 2 TSF. Shallow foundations shall include an analysis of calculated settlements and the effects the settlements, if any, will have on existing facilities. Provide all applicable geotechnical design parameters for analysis and design of foundation and ground-retaining structures.

Foundation design shall include a seismic analysis for every proposed structure, including but not limited to:

- Liquification analysis
- Providing dynamic lateral earth pressure and water pressure coefficients
- Providing appropriate seismic design coefficients for all structural design.

5.5 GROUNDWATER

Maintaining groundwater levels at acceptable elevations is an important consideration of many construction procedures. Water levels will generally be required to be maintained at their existing levels in the vicinity of existing structures founded on timber piles. Where construction procedures require a temporary lowering of the existing groundwater levels, the dewatering procedure shall be as localized as possible and limit drawdown to within tolerances per settlement analysis to lessen the risks of damage to existing facilities. Upon completion of construction, groundwater levels must be returned to, and maintained at, existing levels.

All existing groundwater removed as part of the temporary lowering of the groundwater levels shall be subject to all handling and disposal requirements as set forth by the appropriate federal, state, or local agency or as required by the environmental permits obtained for the project.

5.6 CONSTRUCTION IMPACTS

Prior to any construction, a complete and detailed analysis will be made, which will explain the methodology of the construction procedures, the risks associated with the proposed construction procedures, and an analysis of the impacts the proposed construction might have on existing facilities. The analysis may be required to include the following:

- Anticipated groundwater drawdown
- Anticipated soil deformations
- Anticipated deformations of existing facilities
- Anticipated vibratory impacts and proposed monitoring plan

In addition, a detailed explanation of mitigative measures will be implemented if the actual effects of construction are different or are more severely impacting the existing facilities than originally anticipated.

5.7 MONITORING

Prior to any construction, an instrumentation monitoring program will be submitted to and approved by the City of New Haven. The monitoring programs should be tailored to the proposed construction procedures. Possible instrumentation may include but not be limited to the following:

- Utility, Building and ground surface settlement points
- Observation wells and piezometers
- Inclinometers
- Extensometers

Data shall be collected and submitted to the City of New Haven and any

others designated by the City of New Haven on a regular basis as agreed to by the City of New Haven during active construction. All survey data must be collected and stamped by a registered land surveyor licensed in the state of Connecticut.

Instrumentation data will also be provided to adjacent property owners on a regular basis if requested.

Video condition surveys should be performed of adjacent facilities within the zone of influence prior to and following construction. Copies of the survey must be submitted to the City of New Haven and to the adjacent property owners.

A program should be put in place prior to construction commencing that identifies methodologies and procedures for implementing remedial actions if required to correct unacceptable impacts. This program shall identify the monitoring process, the key elements determining 'acceptable' measurements, the person or persons responsible for interpretation of field data, and the person or persons responsible for implementation of remedial actions. The program will also identify specific remedial actions that will be taken in the case of unacceptable reactions to construction activity.

Chapter 6 Table of Contents

Chapter 6 Structural Design

6.1 GENERAL

This section describes the structural design requirements for improvements to be constructed in conjunction with air rights development over the Route 34 and/or City Row, comprising cut-and-cover tunnels, U-walls (Boat Structures), retaining walls and bridges.

The proposed alignment is to integrate the future development's platform with a segment of Route 34 by a combination of at-grade roadways, earth-retaining structures and tunnels. Because of the relatively short lengths and shallow profiles of the tunnel structures, cut-and-cover construction is identified as the appropriate solution.

All structural elements shall be designed to comply with fire durability design requirements set forth by NFPA 502, latest edition, American Society of Civil Engineers (ASCE), American Society for Testing and Materials (ASTM) and/or American Concrete Institute (ACI).

6.2 SYSTEM COMPONENTS

The dominant structure related to this project will be the platforms and below platform structures and foundation. These platforms will support proposed air rights developments including but not limited to roadways, open space parks, parking garages, and buildings for various uses. It is anticipated that the platforms will be designed to span over the City Row structures roadway and adjacent structures. Substructure units will be located between these and will support the platform superstructure. Crash barriers will be constructed to provide protection for the substructure units that are adjacent to visitors operations.

The proposed development over the platform may also involve changes in highway vertical and horizontal alignments. Substantial modification to existing retaining walls, culverts, and bridge superstructures and substructures may be associated with this work.

Other structural improvements covered by these criteria include the construction of tunnels, underground structures, new retaining walls, culverts, bridges, temporary construction structures, and other miscellaneous structures.

The design of a structure that is owned or maintained by an agency other than the City of New Haven shall be in accordance with standards and specifications utilized by that agency and as approved by City of New Haven, except that highway facilities shall be designed according to AASHTO specifications, and building facilities shall be designed in accordance with applicable specifications (see below).

6.3 CODES, STANDARDS AND REGULATIONS

Unless otherwise specified, the structural design of the various structure types shall be performed in accordance with the latest edition of the codes, standards, and specifications listed below including all addenda, supplements, interim specifications, and revisions thereto. Where requirements differ among the listed codes, standards, and specifications, the more restrictive requirement shall govern unless otherwise specified in these criteria.

- State of Connecticut "State Building Code" (State Code) and all applicable supplements.
- American Institute of Steel Construction (AISC), "Specification for Structural Steel Buildings" load and resistance factor design" (AISC Specification)
- American Concrete Institute (ACI) "Building Code Requirements for Reinforced Concrete," ACI 318.
- American Welding Society, "Structural Welding Code," AWS D1.1. (AWS)
- American Welding Society, "Bridge Welding Code," AWS D1.5. (AASHTO Welding) CTDOT
- American Association of State Highway and Transportation Officials (AASHTO), "LRFD Bridge Design Specifications." (AASHTO Bridges)
- AASHTO, "LRFD Road Tunnel Design and Construction Guide Specifications"
- AASHTO, "Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals." (AASHTO Signs)
- AASHTO "Standard Specifications for Transportation Materials and Methods of Sampling and Testing" (AASHTO Materials) and Part 11, (AASHTO Testing).
- AASHTO, Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members." (AASHTO Fracture Critical).
- AASHTO, "Guide Specifications for Horizontally Curved Highway Bridges." (AASHTO Curved Bridges).
- AASHTO, "Guide Specifications for Fatigue Design of Steel Bridges." (AASHTO Fatigue Design).
- AASHTO, "Guide Specifications for Bridge Railings." (AASHTO Bridge Railings).
- AASHTO, "Guide Specifications for Structural Design of Sound Barriers." (AASHTO Sound Barriers).

- ACI 201.2R "Guide to Durable Concrete".
- ACI 224R "Control of Cracking in Concrete Structures".
- American Society for Testing and Materials (ASTM), "Annual Book of ASTM Standards."
- American Institute of Timber Construction (AITC) Timber Construction Manual."
- National Fire Protection Association NFPA 101, latest edition
- National Fire Protection Association NFPA 502, "Standard for Road Tunnels, Bridges and Other Limited Access Highways"
- Precast Concrete Institute (PCI).
- International Building code as dictated by the latest Connecticut Building Code
- U.S. Green Building Council "Sustainable Design"
- U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA) – "Technical Manual for Design and Construction of Road Tunnels – Civil Elements", Publication No. FHWA-NH-10-034.
- Research Council on Structural connections - "Specifications for Structural Joints Using ASTM A325 or A490 Bolts"
- Concrete Reinforcing Steel Institute (CRSI)
- National Concrete Masonry Association (NCMA)
- American Society of Civil Engineers (ASCE)
- ASCE/SEI Minimum Design Loads for Buildings and Other Structures
- ASCE, and ASTM requirements for fire durability

6.4 CLEARANCE DIAGRAMS

Internal dimensions for U-wall and tunnels structures shall be established in accordance with Section 2.3 "Travel Clearance" and Section 2.4.3 "Sidewalk/Emergency Walkway" of the USDOT-FHWA Publication No. FHWA-NH-10-034, as described in Chapter 2 "Geometric design" and modified for the current roadway application.

Additionally, adequate spaces for utilities, and MEP equipment shall be provided.

6.5 DURABILITY

General durability requirements as described in ACI 201.2R shall be met.

6.5.1 Fire Protection

All structural steel members shall be protected from direct fire exposure. If steel members are protected by concrete encasement, the minimum concrete cover shall be as indicated in Table 6-1 below.

Table 6-1 Minimum Thickness of Concrete Cover for Structural Steel

Element	Cast-in-Place Concrete	Precast Concrete
Encased Steel	3 inches	2 $^{1}/_{2}$ inch
Ties or Wiremesh in Encasement	1 $^{1}/_{2}$ inch	N/A

For reinforced concrete walls and slabs of tunnels, where concrete cover to reinforcing steel necessary to meet the fire protection requirements of NFPA 502, Section 7.3.4 exceeds the concrete covers specified in ACI 344, Section 20.6.1, such greater cover shall govern.

The thickness of reinforced concrete walls and slabs separating tunnel structures from structures owned by other parties shall be at least 8 inches.

6.5.2 Watertightness

The following waterproofing requirements apply to tunnels and earth retaining structures:

- The structures shall be provided with membrane waterproofing, and nonmetallic waterstops and hydrophilic seals at construction joints. Waterproofing membranes shall be required to be protected at their interface with ground and backfill materials and shall be detailed on structural drawings.
- Drainage system for relieving groundwater pressure shall not be allowed for tunnel structures, the walls and slabs of tunnels shall be designed to withstand full hydrostatic pressure and uplift in addition to earth pressures.
- Cantilever stems of retaining walls and U-structures may be designed with drainage systems with provision of suitable well-draining backfill, and a geocomposite lining and perforated drainage pipe installed behind the walls. Weep holes shall not be allowed, drained water shall be collected in adequately sized pipes at the bottom of the

backfill and directed to sumps for discharge. Reduced hydrostatic pressure distribution for design shall be provided by the Geotechnical Engineer.

- The waterproofing membrane shall be discounted in assessing durability; the design of reinforced concrete walls and slabs that are in contact with the ground shall comply with the ACI 224R crack width limitations for the condition designated as "exposure to deicing chemicals".

6.6 MATERIALS

6.6.1 General

Unless otherwise approved, materials shall conform to the applicable specifications and codes listed in this Section. If, in the opinion of the designer, savings can be achieved by the use of different materials than those specified in this Section, while providing the same or a better level of performance and durability, the designer may substitute alternate material standards after receiving written approval from the City of New Haven.

6.6.2 Structural Steel

Bridges: Unless otherwise specified, structural steel shall conform to ASTM A709 (AASHTO M270), Grade 50. High Strength bolts for structural steel connections shall conform to ASTM A325 (AASHTO M1 64), Hardened Washers ASTM F436, Nuts ASTM A563. Anchor bolts shall conform to ASTM F1554, Grade 50 or higher.

Buildings: Unless otherwise specified, structural steel shall conform to ASTM A992, Grade 50 for W-Shapes. ASTM A572, Grade 50 for HP-Shapes, M-Shapes, S-Shapes, Channels and Angles. Rectangular and Square HSS (Hollow Structural Sections) Shapes shall conform to ASTM A500 Grade C. Steel Pipes shall conform to ASTM A53, Grade B. Structural steel connections shall conform to ASTM A325, or ASTM A490, Hardened Washers ASTM F436 and Nuts ASTM A563.

6.6.3 Reinforced Concrete

Unless otherwise specified, concrete shall have a minimum specified compressive strength (f'c) of 4,000 psi at 28 days. And shall conform to the requirements of the American Concrete Institute.

6.6.4 Prestressed Concrete

Unless otherwise specified, concrete for prestressed members shall

have a minimum specified compressive strength (f'c) of 6,000 psi at 28 days and a minimum compressive strength at time of initial prestress (f'ci) of 4,000 psi.

Prestressing reinforcement shall be high-strength steel wire, high-strength seven-wire strand, or high strength alloy bars.

- High-strength steel wire shall conform to AASHTO M204 (ASTM A421).
- High-strength seven-wire strand shall conform to the requirements of AASHTO M203 (ASTM A416), grade 270, including supplement for low relaxation strand.
- High-strength alloy bars shall conform to the requirements of ASTM A799. Bars with greater minimum ultimate strength but otherwise produced and tested in accordance with ASTM A722 may be used provided they have no properties that make them less satisfactory than the specified material and are approved by the City of New Haven.

6.6.5 Timber

Timber for bridges and temporary structures shall be in accordance with the provisions of Section 8 of the "AASHTO Bridges," using the appropriate allowable stresses. Timber for buildings shall be in accordance with the provisions of AITC.

Timber for buildings shall be in accordance with the provisions of AITC (American Institute of Timber Construction) and NDS (National Design Specifications).

6.7 LOADS AND FORCES

6.7.1 General

Unless noted otherwise, the general loads contained in this chapter refer to the loads and forces for the purpose of designing the structures included in this project in accordance with Section 3 of AASHTO LRFD Bridge Design Specifications.

Loads that concern specific structures are further defined in the applicable sections.

6.7.2 Dead Loads (D)

The dead load shall consist of the estimated weight of the entire structure such as pavement, walls, building components, foundations, soil, water, partitions, signs, safety walks, parapet walls, pipes,

conduits, cables, and other utility services.

Calculation of dead loads shall be in accordance with the International Building Code (IBC)" State Code," "AASHTO Bridges," "AISC/SEI," as applicable.

6.7.3 Live Loads (LL)

Live loads shall consist of any non-permanent loads including the weight of machinery, equipment, stored materials, pedestrians, motor vehicles, elevators, escalators or other moving objects, construction loads, and loads due to maintenance operations.

Unless otherwise noted, roadway live loads on bridge structures shall be based on a HL-93 loading system consisting of the Design Truck, Design tandem and Design Lane Load defined in Articles 3.6.1.2.2, 3.6.1.2.3 and 3.6.1.2.4 of "AASHTO Bridges", respectively.

Building live loads shall be calculated as specified in the International Building Code (IBC), Connecticut "State Code", and "AISC/SEI," as applicable for the building's intended use.

6.7.4 Impact (IM)

Impact loads are statically equivalent dynamic loads resulting from vertical acceleration of the live loads.

- Impact considerations for bridges shall be in accordance with Article 3.6.2 "Dynamic Load Allowance: IM", Table 3.6.2.2-1 of the "AASHTO Bridges."
- Design of the top slab of underground structures supporting roadway loading shall include impact according to the AASHTO Bridge Specifications equation 3.6.2.2-1.
- Structures supporting other moving equipment or dynamic loadings that would cause significant impact shall conform to the International Building Code (IBC), Connecticut "State Code.", and "AISC/SEI" Minimum Design Loads for Buildings and Other Structures, as applicable. For unspecified conditions, independent analysis shall be carried out to determine the extent of the loading.

6.7.5 Vehicular Collision Force

All tunnel and building structural elements exposed to vehicular traffic shall be designed for or protected against vehicular collision forces (CT) as specified in AASHTO LRFD Bridge Design Specifications Article

3.6.5.

6.7.6 Live Load Surcharge (LS)

Highway live load surcharge, as well as surface live load imposed by heavy equipment loads based on permitted construction methods shall be determined analytically considering the depth of soil cover, the weight distribution, extent and intensity of loading, soil type and the assumed construction staging. Unbalanced loading shall be analyzed for the staged construction condition specified in the design documents

6.7.7 Earth Pressures (E)

Earth pressures used in design shall be established by the Geotechnical Engineer using accepted engineering practice based on geotechnical data obtained from subsurface investigations. Symmetrically and if applicable, unsymmetrically applied earth pressures conditions shall be included in design loading combinations.

6.7.8 Hydrostatic Load (WA)

- Site-specific groundwater conditions shall be considered for determining hydrostatic loading on tunnel and U-structure walls and slabs, and on retaining walls. These effects shall consider recorded as well as site-specific geotechnical investigation data. Unsymmetrical water pressure on side walls, if present shall be added to unbalanced earth pressure described above.
- Buoyancy forces shall be computed for 62.4 psf/ft of depth below the water table as determined by the Geotechnical Baseline Report (GBR). Adequate resistance to floatation shall be ensured for the maximum probable height of water table. For the completed structure, resistance to uplift will consist of dead weight of the structure and for tunnels, the weight of backfill above it bound by the width of the structure. A factor of safety of 1.10 shall be required for this condition. The weight of street pavement and interior walls, pavement and finishes shall be excluded from the dead weight computations. For the condition of backfill removal, a factor of safety of 1.06 shall be required with the dead weight including interior walls, sidewalks and pavement.
- Live load and side wall friction shall be ignored in computing resistance to uplift.

- Unit weight of backfill shall be obtained from the GBR.
- Hydrostatic loading for strength and resistance to uplift shall be checked as stated above for 100-year and 500-year flood predictions of groundwater levels, with redundancy factors η_R of 1.10 and 1.05, respectively. Flood condition shall be considered an extreme loading condition.

6.7.9 Seismic Loads (EQ)

The earthquake loading (EQ) criteria shall be based on a site-specific seismic hazard assessment which establishes design acceleration response spectra (ARS) representative of local rock outcrop and ground surface motions. The seismic design shall be performed using site-specific ground motion for two performance levels: Safety Evaluation Earthquake (SEE) with a return period of 2500 years (2% probability of exceedance in 50 years) and Functionality Evaluation Earthquake (FEE) with a return period of 500 years (10% probability of exceedance in 50 years).

Seismic loads for buildings and other above-ground structures shall be determined in accordance with IBC and Connecticut State Code and shall take into account the combined structural systems consisting of air rights buildings and the platform.

Seismic loads for retaining walls and bridges shall be determined in accordance with "AASHTO Bridges."

Tunnel segments lying outside of the building envelope shall be analyzed considering soil-structure interaction.

6.7.10 Other Loads and Forces

Other loads and forces to be considered, including wind loads and snow loads, shall be in accordance with the appropriate provisions of "AASHTO Bridges," the (IBC) and Connecticut "State Code."

- Expansion and contraction strains and stresses due to thermal variations, shrinkage, creep and differential settlement shall be considered per AASHTO LRFD requirements. Uniform temperature variations causing axial strains and stresses in the longitudinal direction, as well as thermal gradients causing flexural strains and stresses through the thickness of walls and slabs of box structures (tunnels) shall be considered based on construction and site conditions. Recorded average temperatures for the project site range from 85° to 30°. Thermal gradients across the thickness of walls and slabs

are given in Table 6-2.

Table 6-2 Thermal Gradients

Location	Construction Phase	Completed Structure	
		Summer	Winter
Outer Surface	55°	60°	40°
Middle Surface	55°	75°	35°
Inner surface	55°	85°	30°

- The effect of extreme thermal loading on the tunnel structures due to the design fire specified in Chapter 7 – Ventilation shall be analyzed. The thermal analysis shall be performed for a typical cross section of the tunnels subjected to a steady-state thermal gradient through the thickness of the tunnel walls, and invert and roof slabs as determined by the appropriate heat transfer analyses. The structural analysis shall be conducted to ascertain the stability of the tunnel structure.

All structural elements shall be designed to account for forces caused by vehicular fuel tank explosions.

- Fire and explosion loads shall be considered non-concurrent extreme loading conditions.

6.8 REINFORCED CONCRETE STRUCTURES

Unless otherwise noted, reinforced concrete bridge structures subject to highway loadings shall be designed in accordance with "AASHTO Bridges," Strength Design Method (Load Factor Design).

Reinforced concrete culvert structures shall be designed in accordance with "AASHTO Bridges."

Reinforced concrete retaining walls which are independent from transition structures shall be designed in accordance with "AASHTO Bridges."

Reinforced concrete transition (boat) structures and tunnel structures subject to highway loadings shall be designed in accordance with "AASHTO Bridges."

Reinforced concrete structures not subject to highway loadings (including parking structures and buildings) shall be designed in accordance with "ACI

318" and with the requirements of (IBC) and Connecticut "State Code."

Where required, corrosion protection measures shall be provided for reinforced concrete structures. These measures may include corrosion-inhibiting admixtures low-permeability concrete, epoxy-coated rebars, silane surface treatment, cathodic protection of selected rebars, and Monitoring facilities.

6.9 PRESTRESSED CONCRETE STRUCTURES

Prestressed concrete structures subjected to highway loadings shall be designed in accordance with "AASHTO Bridges.

Prestressed concrete structures not subjected to highway or railroad loadings (including parking structures and buildings) shall be designed in accordance with IBC, ACI and PCI.

Where required, corrosion protection measures shall be provided for prestressed concrete structures as described for reinforced concrete structures.

6.10 STEEL STRUCTURES

Unless otherwise noted, steel bridge structures and other structures subject to highway loadings shall be designed in accordance with "AASHTO Bridges," Strength Design Method (Load Factor Design).

Steel structures not subject to highway or railroad loadings (including parking structures and buildings) shall be designed in accordance with "LRFD Specifications," Load and Resistance factor designing and with the requirements of CT "State Code."

6.11 BRIDGE STRUCTURES

6.11.1 General

Except as indicated herein, highway and pedestrian bridges shall be designed in accordance with "AASHTO Bridges"

6.11.2 Materials

Concrete

Concrete for Bridge deck shall have a minimum specified compressive strength (f'c) of 4,500 psi at 28 days. Concrete for other cast-in-place members shall have a minimum specified compressive strength (f'c) of 4,000 psi at 28 days. Higher strength concrete may be used if approved by the City of New Haven.

Reinforced Concrete

Reinforcing steel, including ties and spirals, shall conform to

AASHTO-M31 (ASTM A615) Grade 60 requirements. All highway bridge superstructure reinforcement and all backwall, beam seat and pier cap reinforcement shall be epoxy coated in accordance with AASHTO-M284 (ASTM A775). Bars in exposed faces of substructure members within 30 feet of a traveled way, or where steel reinforcement may be subject to a corrosive environment due to salt or deicing agents, shall also be epoxy coated.

Prestressed Concrete

Precast, prestressed concrete members shall conform to "AASHTO Bridge" Unbonded and ungrouted prestressing strands shall not be. Prestressing strands shall be coated for corrosion protection as per AASHTO Bridges." Non-corrosive or corrosion-resistant ducts and post-tensioning anchorage hardware should be used for post-tensioned concrete elements.

Steel

Structural Steel

Generally, AASHTO M270 (ASTM A709) Steel, Grade 50, shall be used for bridge structures on this project.

Connections

In addition to the provisions of Sections 10.18 and 10.19 of "AASHTO Bridges," the following shall also apply:

- Shop connections shall be designed for welding, and field connections shall be designed for high-strength bolts, unless otherwise approved by the City of New Haven.
- High strength bolts shall be a minimum of 7/8 inch diameter AASHTO M164 (ASTM A325) bolts.
- All connections shall be designed and detailed by the project designer.

Timber

Timber structures shall be designed in accordance with "AASHTO Bridges," Section 13, for highway loadings, and "AREA," Chapter 7, for railroad loadings, using the appropriate allowable stresses.

6.11.3 Loads and Forces

Components in the bridge structures shall be proportioned to withstand applicable loads and forces as specified in Section 3 of "AASHTO Bridges" for highway loadings.

6.11.4 Design

The design of bridge structures subjected to highway loadings shall comply with the following provisions.

Strength Design Method

Bridge structure elements subject to highway loadings shall be designed using the Strength Design Method (Load Factor Design).

Seismic Design

Seismic design for highway bridges shall be in accordance with "AASHTO Bridges."

Deflections

Deflection limitations for highway bridges shall be in accordance with "AASHTO Bridges."

Bridge Railings

Bridge railings shall be designed in accordance with "AASHTO Bridge Railings."

6.11.5 Horizontally Curved Bridges

The design of horizontally curved bridges shall conform to "AASHTO Curved Bridges."

6.11.6 Substructure

In addition to the requirements stated in Section 7 - Substructures of "AASHTO Bridges," the following provisions shall apply.

Approach Slabs

Except where the abutting at-grade structure includes a structural roadway slab, an approach slab shall be provided at each abutment to insure a smooth transition from the at-grade section to the bridge structure. The approach slab shall have a length of not less than 10 feet measured perpendicular to the abutment and shall be designed in accordance with "AASHTO Bridges."

Abutments and Wingwalls

Abutments and wingwalls founded on spread footings shall be so designed that the resultant load falls within the middle third of the base of a footing resting on rock or the middle half of the base of a footing resting on rock. These structures shall be designed with the following factors of safety:

- Overturning about the toe of footing resting on soil: 2.0
- Overturning about the toe of footing resting on Roc R: 1.75
- Sliding on the footing base: 1.50, assuming no passive resistance from the soil in front of the structure.

Crash Barriers

Crash barriers shall be incorporated into substructures abutting railroad and adjacent facilities. The design and construction of the barriers shall conform to the requirements specified in AASHTO Bridge.

6.12 RETAINING WALLS

6.12.1 General

The retaining walls shall be designed in accordance with section 11 of AASHTO LRFD Bridge Design Specifications.

6.12.2 Loads and Forces

Lateral Earth Pressure (EH)

Earth pressures for retaining wall design shall be determined by the Geotechnical Engineer based on subsurface investigations, as provided by the Geotechnical Baseline Report (GBR).

Conventional retaining walls founded on soils are structures which are free to yield to earth pressure in an amount sufficient to develop the active pressure condition. Retaining walls founded on rock and/or piles foundation including battered piles are considered rigid and designed for at-rest earth pressures. Retaining walls shall be designed with the procedures outlined in AASHTO, or as recommended by the project Geotechnical Engineer.

If a situation arises where the use of mechanically stabilized earth walls is considered appropriate, the design criteria will be provided by City of New Haven.

Loads from Adjacent Structures (ES)

The retaining walls shall be designed to support lateral earth surcharge load from adjacent buildings or other structures, including both existing structures and future construction as allowed under current zoning and land-use regulations.

Live Loads (LL, IM)

Live loads may be roadway traffic, but also other non-permanent loading conditions, including construction loads.

Live loads due to roadway traffic shall be based on the HL-93 loading as defined in Article 6.5.3 of these criteria.

Live load surcharge shall not include the effects of impact.

Live loads for building air-right development and from adjacent structures or other sources shall be analyzed on a case-by-case basis and applied as uniform surcharge, point load, or line load, depending on the specific circumstances.

6.12.3 Base Pressure

Base pressures shall not exceed the allowable soil bearing capacity determined by the Geotechnical Engineer based on data obtained from the projects site geotechnical investigation and provided in the GBR. In order to minimize differential settlement, walls on spread footings shall be proportioned so that the resultant of all forces will fall within the middle third of the base.

6.12.4 Stability

Overturning

Retaining walls constructed on spread footings shall be designed with the following factors of safety:

- Overturning about the toe of footing resting on soil: 2.0
- Overturning about the toe of footing resting on rock: 1.75

Sliding

Safety against sliding for walls on spread footings shall be achieved by providing a factor of safety of at least 1.50, assuming no passive resistance from the soil in front of the wall.

6.12.5 Walls on Deep Foundations

Design Philosophy

It is common practice to design retaining walls to resist the vertical dead and live loads supported by them, plus a single horizontal pressure produced by the retained earth. While this combination of loads usually defines the critical design condition and is usually satisfactory for spread footing design, it may not be satisfactory for the design of walls on deep foundations. Variations of horizontal earth pressures significantly affect the load resultant location and consequently cause an adverse redistribution of foundation loadings. The designer shall investigate various horizontal loading conditions to satisfy structural compatibility. A critical condition can exist if the total assumed horizontal pressure is not realized. A horizontal load

reduction to two-thirds of the active condition shall be assumed to represent such a contingency. Also, if the retaining wall system is relatively unyielding, horizontal earth pressures in excess of the active pressure condition can act on the wall. The design shall consider such variations in lateral wall pressures based upon the wall structural configuration.

Pile Foundation Design

Pile foundations shall be designed in accordance with Section 10 of "AASHTO Bridges."

6.12.6 Deep-Seated Failure Investigation

For both spread footings and deep foundations, investigations shall be made of the possibility of deep-seated failures in soft soils.

6.12.7 Seismic Design

Seismic design of retaining walls shall be in accordance with Section 11 of AASHTO LRFD Specifications. Seismic pressures may be estimated by the Mononobe-Okabe method.

6.12.8 Construction Details

Expansion Joints

Expansion joints extending the full height of the wall stem shall be provided in all walls over 72 feet long. Reinforcing steel shall not extend through the joints. Waterstops extending the full height of the wall stem shall be provided in all expansion joints. Spacing of expansion joints in retaining walls shall not exceed 90 feet. Joints in counterfort walls should be located between counterforts such that the wall moments at the exterior and interior supports are equal. Expansion joints shall be provided for the footing.

Contraction Joints

Cantilever walls shall have contraction joints extending the full height of the wall stem at a maximum spacing of 30 feet. Contraction joints shall be unbonded. Reinforcing steel shall not be continuous through contraction joints. Contraction joints shall not be provided for the footing. Waterstops extending the full height or the wall stem shall be provided in all contraction joints.

Construction Joints

Construction joints may be provided to divide the walls into convenient working units for concrete placement. Construction joints shall be bonded joints. Reinforcement shall be continuous through the joint. Construction joints, where provided in the face slab of

counterfort walls, shall be located at quarter points between counterforts. Waterstops extending the full height of the wall stem shall be provided in all construction joints.

BaseKey

Walls other than those supported on rock, piles, or drilled-piers may have a base key. Base keys may be unreinforced and cast monolithically with the base slab. They shall be poured against undisturbed soil and shall not exceed a depth of two-thirds of the footing thickness. Key width at the base slab shall not be less than twice the key depth, nor less than 16 inches. Keys shall be located in the heel between the midpoint of the base and the third point of the base measured from the heel, except that in no instance shall the key be closer to the toe than the back of the stem.

WallStem

Stem thickness at the top of the wall shall not be less than one foot. The exposed face of all walls shall be inclined back from the vertical at a slope of not less than 1/4 inch per foot of wall height to compensate for any outward deflection at the top of the wall. The inner face of all gravity and cantilever wall stems shall be battered as required to provide sufficient thickness at the base of the stem. The difference in elevation between the top of the wall and the top of the retained material behind the wall shall not be less than one foot for walls with level or sloping backfill.

Footings

Footing thickness shall not be less than two feet for spread footings. Minimum cover above the top of footings shall be one foot. The bottom of footings shall be at least one foot below the frost line and shall be placed against undisturbed compacted earth, compacted fill, or non-structural concrete. For design purpose, the frost line shall be assumed at a depth of four feet below proposed finished ground in all project areas.

Footing Steps

Where the wall footing is stepped more than two feet, the wall stem or face slab shall have an expansion joint from the top of the wall to the top of the lower footing.

6.13 U-WALL STRUCTURES

U-wall structures shall be designed by the same principles as the retaining walls, with the following exceptions.

- Stability against overturning does not apply.
- Stability against sliding shall apply for unsymmetrical earth fill condition.

- Stability against uplift (floatation) shall be ascertained by achieving a factor of safety of 1.10, considering dead weight of the structure and no skin friction.

6.14 CUT-AND-COVER TUNNEL STRUCTURES

The permanent and transient design loads, limit states, load factors and resistance factors required for LRFD of the cut-and-cover tunnels shall be taken in accordance with Sections 1 and 3 of AASHTO LRFD Bridge Design Specifications, and as specified in paragraphs below.

Permanent Vertical Loading (DC, EV, ES, DD)

- Dead Load (DC) – The dead load to be used for the design of cut-and-cover tunnel structures shall consist of the weight of base structure slabs and walls, the weight of elements permanently supported by the structure, including weight of utilities, system equipment, and weight of earth cover above the tunnel roof.

The analysis shall include the maximum dead load described above, and the minimum dead load that may result from future removal of the earth cover.

The design unit weight of backfill material shall not be less than 140 pcf for the analysis of the structural frame, unless specified by the GBR and Landscape specifications. For verifying stability against floatation, the unit weight used for backfill shall not be greater than 120 pcf.

- Minimum Earth Cover (EV) – The cut-and-cover tunnel shall be designed for the deepest actual cover. The depth of cover used for design shall not be less than 4 feet at the highest point of the structure. The design checks for construction stage and stability against uplift (floatation) shall consider the condition of no backfill cover.

- Loads from Adjacent Structures (ES) – The tunnels shall be designed to support lateral earth surcharge load from adjacent buildings or other structures, including both existing structures and future construction as allowed under current zoning and land-use regulations.

- Design loads on the tunnels and underpinning loads from existing structures shall be based on the actual weight, and the maximum occupancy for which the building is suitable in accordance with the State of Connecticut Building Code. The greater of the occupancy loads specified by the State Code or as specified in the ASCE/SEI Minimum Design loads for Buildings and Other Structures shall be

used.

Live Load (LL, IM, CT, PL)

- Design live load shall consist of non-permanent load placed on or in the tunnels. Where vehicles can gain access above the tunnels and depth of fill over the tunnel roof is less than 10 feet, the tunnel roof shall be designed for the AASHTO HL-93 truck loading, as well as a live load of 300 psf, taken non-concurrently. Vehicular live load applied to the tunnel invert shall correspond to HL-93 loading. The possibility of access by State Special Permit vehicles shall be investigated, and used for design live load, as applicable.

- The minimum live load applied to the roof of the tunnels shall meet the requirements for wheel load distribution provided in Table 6-2.

Table 6-2 Live Load Distribution

Soil Cover Thickness d (ft)	Distribution on Roof Area
Less than 2	Per Article 4.6.2.10 of AASHTO LRFD Bridge Design Specifications
Between 2 and 10	Over a square area of width equal to 1.75d
Greater than 10	300 psf

Where the distribution areas overlap, the total load shall be uniformly distributed over an area defined by the outside limits of the aggregate areas.

- Impact Allowance (IM) for traffic loading on tunnels shall be provided in accordance with AASHTO LRFD Bridge Design Specifications Article 3.6.2.2 as:

$$IM=33(1-0.125D_E)\%,$$

where D_E represents the minimum earth cover above the structure (ft). Impact is ignored for depths of earth cover exceeding 8 feet.

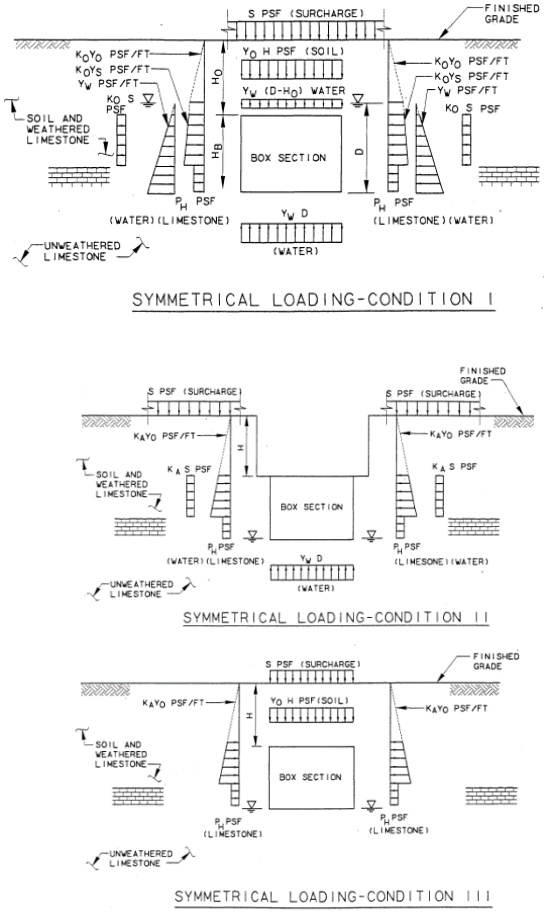
- Building columns exposed to vehicular traffic shall be designed for or protected against collision impact forces (CT) as specified in AASHTO LRFD Bridge Design Specifications Article 3.6.5.

- Pedestrian live load (PL) shall be taken as 100 psf.

Lateral Earth Pressure (EH)

- The cut-and-cover tunnels shall be designed for lateral pressure imposed by the earth abutting against the sides of the structures. The structures shall be designed for long-term symmetrical as well as short-term unsymmetrical (unbalanced) loading conditions, as illustrated in Figure 6-1 and Figure 6-2.

- To account for the influence of rigid support-of-excavation elements such as slurry diaphragm walls and secant pile walls in resisting lateral earth pressures, and for the behavior of the tunnel structures during tunnel excavation, soil-structure interaction modeling analysis methods may be used.

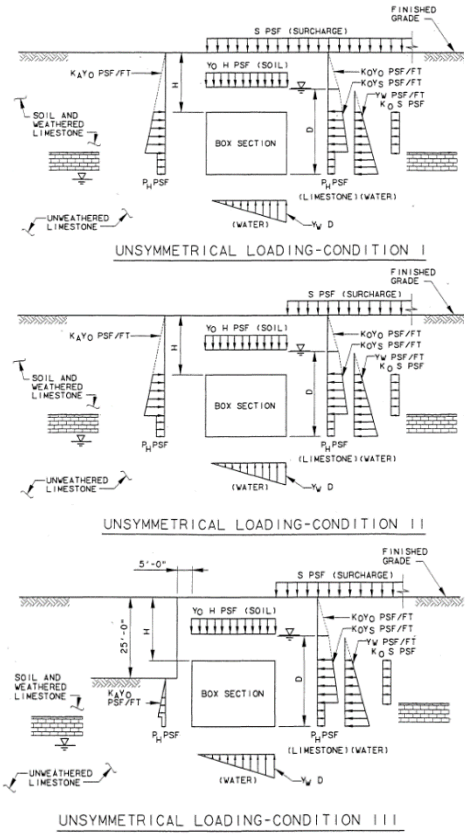


NOTE: DEAD LOAD AND LIVE LOAD ARE NOT INCLUDED IN THE DIAGRAMS.

LEGEND:

γ_O	UNIT WT OF SOIL
γ_S	UNIT WT OF SUBMERGED SOIL
γ_W	UNIT WT OF WATER
K_O	COEFFICIENT OF LATERAL EARTH PRESSURE AT REST
K_A	COEFFICIENT OF ACTIVE LATERAL EARTH PRESSURE
S	VERTICAL INTENSITY OF SURCHARGE
H_O	DEPTH OF OVERBURDEN
H_B	HEIGHT OF OVERBURDEN
P_H	LATERAL PRESSURE OF UNWEATHERED LIMESTONE
D	DEPTH OF WATER LEVEL TO THE BOTTOM OF BOX SECTION

Figure 6-1 Symmetrical Loading Conditions for Cut-and-Cover Tunnels



NOTE: DEAD LOAD AND LIVE LOAD ARE NOT INCLUDED IN THE DIAGRAMS.

LEGEND:

Y_O	UNIT WT OF SOIL
Y_S	UNIT WT OF SUBMERGED SOIL
Y_W	UNIT WT OF WATER
K_O	COEFFICIENT OF LATERAL EARTH PRESSURE AT REST
K_A	COEFFICIENT OF ACTIVE LATERAL EARTH PRESSURE
S	VERTICAL INTENSITY OF SURCHARGE
H_O	DEPTH OF OVERBURDEN
H_B	HEIGHT OF OVERBURDEN
P_H	LATERAL PRESSURE OF UNWEATHERED LIMESTONE
D	DEPTH OF WATER LEVEL TO THE BOTTOM OF BOX SECTION

Figure 6-2 Unsymmetrical Loading Conditions for Cut-and-Cover Tunnels

Hydrostatic Load (WA) as defined in Paragraph 6.7.7.

Seismic loads (EQ)

The seismic design of the tunnel structures shall be conducted for the two performance levels defined in Paragraph 6.7.8 conforming to the deformation-based racking analysis design approach as outlined in Chapter 10 of AASHTO LRFD Road Tunnel Design and Construction Guide Specifications.
The general seismic performance parameters that govern the design are

defined as follows:

FEE: Repairable damage with or without traffic restrictions, and immediate access to emergency vehicles following inspection.

SEE: Significant damage without collapse, limited service.

These conditions shall be ascertained by satisfying the Limits of concrete and reinforcement strain corresponding to these respective performance levels specified in Table C10.4.2-1 of the aforementioned AASHTO Guide Specifications.

6.15 ABOVE GROUND STRUCTURES

6.15.1 General

Except as indicated herein, above ground structures other than bridge structures shall be designed in accordance with the International Building Code and Connecticut "State Code"

6.15.2 Loads and Forces

Above ground structures shall be designed to withstand, the loads and forces, and the combinations thereof as required by the IBC and Connecticut "State Code."

6.15.3 Foundation Design

The design of foundations for above ground structures, when independent from roadway structures will be in accordance with the site-specific geotechnical parameters.

6.15.4 Construction Details

Expansion Joints

Provisions for expansion shall be made in all above-ground structures. Where a structural element is partially underground and partially above-ground, particular care shall be taken in detailing to accommodate differential thermal movements.

Expansion joints shall be designed to transmit the forces that may occur under any design condition. Reinforcing steel shall not be continuous through the joint. Shear forces shall be transferred across the joint by a key.

Contraction Joints

To control shrinkage stresses in concrete slabs and walls and to minimize cracking, contraction joints shall be provided in all structures at intervals of not greater than 32 feet. They shall also be provided at locations of major change in structural section. A closer spacing shall be used if appropriate to the framing system.

Contraction joints shall be unbonded joints, designed not to transmit the forces perpendicular to the joint that may occur under any design condition. Reinforcing steel shall not be continuous through the joint. Shear forces shall be transferred across the contraction joints by a key.

Construction Joints

Construction joint locations may be indicated by the designer to divide the structure into convenient working units for concrete placement. Such joints shall be detailed on the plans, together with an indication of whether they are optional or mandatory. They shall be designed to transmit all the forces that may occur under any design condition.

Construction joints through which moment is transferred shall be bonded joints, i.e., prior to placing concrete in the adjacent pour, the 'joint shall be cleaned in accordance with "ACI 318" requirements. Reinforcement shall be continuous through the joint.

All tunnel and foundation joint shall be waterproofed.

Joints in Steel Frames

Provisions shall be made in structural steel frameworks of aboveground structures for the temporary accommodation of fabrication and erection tolerances without introducing significant distortions in the frame. Temporary joints, if required, shall be permanently connected after the entire framework has been plumbed and aligned. They shall be designed to accommodate all design loads.

Crash barriers

Crash barriers shall be incorporated into substructures abutting other structure. The design and construction of the barriers shall conform to the requirements specified in AASHTO.

6.16 PROTECTION OF CITY OF NEW HAVEN PROPERTY

6.16.1 Bracing

Construction of air rights improvements shall be performed such that City of New Haven property is protected during all phases of design and construction. Shoring and bracing of existing structures shall be

utilized as necessary, and protective shields shall be installed to provide positive protection from all demolition and construction operations.

6.16.2 Surveys

Topographic surveys, settlement platforms, inclinometers, and other such methods shall be implemented during construction to monitor settlement, or other movement of City of New Haven structures, as approved by the City. Photographic pre-construction and post-construction surveys must be completed to document the condition of City of New Haven facilities to remain.

6.16.3 Drilled or Excavated Deep Foundations

Deep foundations located adjacent to sensitive City of New Haven facilities for buildings, bridges, or platforms shall be drilled or excavated under necessary to limit vibrations to minimize risk to existing facilities from construction vibrations.

6.16.4 Excavation Bracing and Support

Excavation support systems shall be provided for the protection of existing buildings, streets, walks, utilities, and other improvements. The contractor shall retain the services of an engineer licensed in the State of Connecticut to design the excavation supports, which shall include soldier piles and lagging, interlocking sheet piles, slurry walls, or other structured supports systems as may be necessary. The design shall be submitted for review by the City of New haven. Construction may not proceed before final approval by the City of New Haven.

6.16.5 Survey of Existing Conditions

The contractor shall retain the services of a land surveyor registered in the State of Connecticut to survey existing conditions prior to excavation and installation of excavation support systems and to monitor any movement in existing conditions during construction activities. The surveyor shall establish horizontal and vertical benchmarks on the excavation support structure, as well as on adjacent buildings, walks, and other structures as required. The surveyor shall monitor these benchmarks on a weekly basis and promptly report the findings to the City of New Haven and the contractor. Excavation support systems, and anchorage, shall not extend beyond the limits of work unless approved by the City of New Haven. Prior to the installation of such approved systems, the contractor's surveyor shall verify the location of all subsurface utility

lines indicated on the drawings or documented by the utility companies to protect these utilities from interruption or damage. The design of the excavation support system shall be submitted for review by the City of New Haven. Construction may not proceed before final approval by the City of New Haven. At the completion of work requiring excavation support, all components of the excavation support system shall be removed unless the contractor has received prior approval from the City of New Haven to wholly or partially abandon these systems, or selected components, in place.

6.16.6 Instrumentation and Monitoring

Requirements concerning monitoring of existing buildings in proximity of the Project are stated in Section 5.7. Damage criteria with related deformation thresholds to be complied with during construction and dewatering activities shall be included in the instrumentation monitoring program.

Chapter 7 Table of Contents

Chapter 7 Ventilation Design

7.1 GENERAL

This chapter establishes the basic criteria to be used for the design of roadway tunnel ventilation systems in conjunction with development of Air Rights over the Route 34 Corridor.

The roadway tunnel ventilation system shall be designed to provide a safe environment within the tunnel. For normal operating conditions, the ventilation system must be able to limit the concentration of vehicle emitted pollutants such as carbon monoxide (CO) and oxides of nitrogen (NOx) to acceptable levels. The system must also be able to maintain visibility by controlling the accumulation of smoke particulates (haze). However, modern car fleets with motor management, hybrid cars and electrical cars do not have relevant CO emissions. It is advised to use visibility additionally which covers dust as well from tires (the most important particle sources in modern tunnels).

During an emergency condition involving fire, the system must be able to mitigate the effects of smoke and heat to facilitate the evacuation of people and to allow for fire-fighting operations. In the event of a total electrical power failure, adequate supply and exhaust within each zone shall be operated on standby power.

In order to meet these requirements, the ventilation system shall be able to distribute supply air along the length of the roadway in accordance with acceptable design practices appropriate to site-specific conditions. System design/operations shall be evaluated to mitigate dispersion of pollutant concentrations for remote sensitive receptors adjacent to tunnel exit portals. The ventilation system shall also be capable of exhausting smoke in the event of a vehicle fire along the roadway.

The developer shall propose a reliable ventilation concept with the minimum impact on capital costs and maintenance costs. Ventilation system capacity and configuration shall be designed to manage pollutant concentration emissions at exit and entrance portals. National standards for acceptable concentration conditions for emissions shall be utilized for evaluating conditions for sensitive receptors in close proximity of portals. Evaluation shall include differentiation between commercial and residential occupancies in sensitive receptor conditions.

The developer shall provide for an easement for access within the building for all roadway ventilation systems for the City of New Haven. No other building systems shall be allowed within the easement.

7.2 CODES, STANDARDS AND REGULATIONS

The road tunnel ventilation system design shall be governed by the latest editions of the codes, standards, and regulations of the agencies listed below.

National Standards:

- United States Environmental Protection Agency (USEPA)
- American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE)
- National Fire Protection Association (NFPA -502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways, latest edition
- Federal Highway Administration (FHWA) Design Guidelines for Carbon Monoxide Levels in Tunnels
- Federal Highway Administration (FHWA) Technical Manual for Design and Construction of Road Tunnels – Civil Elements

Internationally Recognized Technical Rules for Information Purposes Only

- World Road Association / PIARC 2019R02RN: Road Tunnels: Vehicle Emissions and Air Demands for Ventilation
- World Road Association / PIARC 2011R202: Road Tunnels: Operational Strategies for Emergency Ventilation

7.3 LAYOUT OF TUNNEL VENTILATION SYSTEM

The layout of the tunnel ventilation system shall be based on an engineering process, considering:

- The traffic concept (uni-directional / bi-directional traffic)
- The traffic forecast
- A Traffic control system
- A reasonable design fire based on the traffic assumptions
- Emission rates of cars (actual and forecast)
- Wind pressure on the portals (95 % percentiles)
- Egress distances and time required for self-evacuation

7.4 SYSTEM COMPONENTS

7.4.1 System Components

System components depends on the chosen ventilation system. The

minimum road tunnel ventilation system includes the following:

- Jet Fans, vibration isolation devices and transmission drive systems
- Fan motors and fan starters
- CO monitors
- Visibility detectors
- Conduit and wiring
- Variable Speed Drive
- Anemometers
- Redundant power supply
- Control concept
- However, if longitudinal ventilation is not enough, then the following elements are required additionally: Axial fans with inlet nozzles, diffusors and sound attenuators
- Ductwork
- Fan dampers
- Damper operators

7.4.2 Revisions to Codes, Standards and Regulations

System design requirements necessary to accommodate the latest revisions, modifications, supplements, etc., to any of the publications listed in this chapter which are effective at the time of the design of each development shall be submitted for approval.

7.5 BASIS OF DESIGN

7.5.1 Normal Conditions

The exhaust products of vehicle engines are a mixture of carbon monoxide, carbon dioxide, oxides of nitrogen, sulfur dioxides, and unburned hydrocarbons. In order to maintain a satisfactory atmosphere and adequate visibility within the tunnel, the concentrations of these contaminants shall be diluted to acceptable levels in the case of reaching or exceeding threshold values.

The ventilation system performance for normal operation shall be determined based on vehicular emissions either by an appropriate computer program, e.g. USEPA's MOBILE6 computer program, latest edition or an adequate engineering analysis using other methods

acceptable to the City.

Carbon Monoxide (CO)

Although CO is not the only toxic constituent in vehicular exhaust gases, it is historically the dominant toxic gas and is usually the controlling factor in establishing the supply air requirements for normal operation. The following CO levels and exposure times shall serve as the basis for establishing the capacity and operation of the ventilation system to meet CO dilution requirements:

Maximum Average Concentration and Exposure Time for	
Parts per Million (ppm)	Time (minutes)
120	15
65	30
45	45
35	60

The above requirements are applicable during normal peak hour traffic operations. Given the potential for changing characteristics of the extension tunnel segments and traffic profiles (i.e., lengths of tunnels, and delays in the tunnels corresponding to design normal peak-hour traffic), the ventilation supply of air capacity should be designed to dilute the concentration of CO to 120 ppm with bumper-to-bumper congested traffic in the tunnel. The ventilation system operation should be designed to meet the time exposure criteria noted above and to mitigate the effects of congestion due to any cause. In general, under free-flowing normal traffic operations, the system should be operated to maintain an average CO level of 50 ppm.

The developer is also required to identify any incident management techniques which can or must be used to assure that CO exposure levels of the traveling public are kept to a minimum during accidents and breakdowns.

Oxides of Nitrogen (NOx)

The primary pollutants emitted by diesel engines are oxides of nitrogen. The main constituents of NOx are nitric oxide (NO) and nitrogen dioxide (NO2). Using a breakdown of all NOx by weight as 90% and NO and 10% NO2, the maximum concentrations which shall not be exceeded are:

Maximum Concentration of Oxides of	
NO	25 pm
NO2	3 ppm

Haze

Exhaust emissions, principally from diesel-powered vehicles, can severely limit visibility within a tunnel. Visibility can be measured in terms of the amount that a beam of light is attenuated over a given distance. The amount of attenuation is given in terms of an extinction coefficient.

Visibility shall not be less than that given using an extinction coefficient of $5x10^{-3}$ per meter.

Exterior sensitive receptor location concentrations shall be limited to criteria listed in CT legislation Title 22a (10/31/95 edition listed below for reference)

Maximum Average Concentration and Exposure Time for Carbon Monoxide	
Parts per Million (ppm)	Time Period for Average Exposure (hrs)
35	1
9	8

Maximum Concentration of Oxides of Nitrogen	
NO2	53 ppm

7.5.2 Emergency Conditions

During congested or emergency conditions, the ventilation system will establish airflows in roadway enclosure to mitigate the spread of pollutants and to control the spread of smoke and heat in the event of a fire. Design configuration of the system will account for potential for future construction and modification to enclosed roadway. Most likely maximum ventilation demand flows for the system will be determined from ventilation operations to mitigate fire hazards developed from emergency incident. Identification and quantification of design fire scenario is a key parameter for determining ventilation system sizing. Once the fire scenario is known, the appropriate ventilation concept shall be designed with respect to minimize capital costs and maintenance costs.

7.5.3 Interface to Underground Parking Lot

The interface to the adjacent underground parking lot shall be

considered for the tunnel ventilation layout. Smoke penetration from the parking lot to the tunnel and vice versa should be avoided by mechanical means (smoke / heat barrier) and by ventilation means (ventilation / pressurizing).

7.5.4 System Operation

The ventilation system shall be capable of being controlled either automatically or remote manually from an Operations Control Center (OCC) or local manually from within a ventilation room. Two automatic modes of operation shall be available: preprogrammed daily histogram and CO monitoring. Under the histogram mode, fan operation in a particular zone will be controlled as a function of the time of day. Under the CO monitoring mode, the fans in a particular zone are to be controlled to maintain a maximum CO concentration of approximately 50 ppm during normal traffic conditions. An operator at the OCC shall be given the capability of overriding either of the automatic modes as circumstances require.

7.5.5 Duct Systems

If ducts are required for the ventilation concept, the ducts shall be sized so that the maximum air velocity does not exceed 4,000 feet per minute (fpm) (20 m/s). Duct shapes and changes in duct sizes shall be designed to minimize the aerodynamic resistance of the ventilation system.

7.5.6 Temperature Rating

Normally the temperature of the exhaust air from the roadways is effectively the temperature of the outside air that is supplied to the roadways. In a fire emergency mode of operation, the exhaust air (hot gas/air mixture) can be several hundred degrees higher. Therefore, the fire rating for the tunnel ventilation equipment shall be assessed with regard to the volume flow rates, maximum ambient air temperatures and the convective Heat Release Rate (MW) of the design fire. The fastening (anchoring) of the tunnel equipment such as jet fans shall withstand 840 degrees Fahrenheit (450 degrees Celsius) for 2 hours.

7.6 DESIGN OF SPECIAL COMPONENTS

The road tunnel ventilation system includes the design of special components which are site- specific for a particular development.

7.7 DUCTWORK

Provisions shall be incorporated in the design of the metal ductwork to

facilitate the installation and removal of the ventilation system components. Access doors and panels shall be located to service, inspect, and maintain the equipment. Access doors for maintenance of the interior of any ductwork system shall be provided. Changes in duct sizes shall be gradual was stated in Section 7.4.5.

7.8 SUPPLY/EXHAUST OPENINGS

If ducts are required, the designer shall determine the spacing of the ventilation openings based upon the total air quantities established. A minimum static duct pressure of 0.5 inches w.g. is required at the most remote opening.

7.9 AXIAL FANS (if required)

It is recommended that tunnel ventilation fans are controlled by variable speed drive units. Fan plants (if required) shall be designed to facilitate removal of large components of fans for equipment replacement or repair activities. System design shall include some measures for equipment redundancy to allow tunnel/parking facility to remain operational during periods when components are replaced or repaired.

7.10 MONITORING DEVICES

7.10.1 Fans and Motors

The fans and motors of the road tunnel ventilation system shall be provided with monitoring devices to detect alert and shutdown conditions and to transmit them in the form of general or specific alarms to the Operations Control Room. Conditions to be monitored shall include:

- Fan Vibration - Alert (on each bearing)
- Fan Vibration - Shutdown (on each bearing)
- Fan Bearing Deterioration - Alert (on each bearing)
- Fan Bearing High Temperature - Shutdown (on each bearing)
- Motor Vibration - Alert (on each bearing)
- Motor Vibration - Shutdown (on each bearing)
- Motor Bearing High Temperature - Shutdown (on each bearing)
- Motor Winding High Temperature - Alert (on each winding)

Under an emergency condition involving a fire, the Operations

Control Room will output an emergency mode indication to the exhaust fans serving the ventilation zone containing the fire. The indication shall serve to preclude fan shutdown due to normal shutdown conditions and allow the fans to operate to destruction.

7.10.2 Carbon Monoxide

The road tunnel ventilation system shall include devices for monitoring CO levels and visibility levels in the roadways and for transmitting these levels to the Operations Control Room for continuous recording and for controlling the ventilation system. The monitoring system shall be as approved by the City Engineer.

7.11 TESTING

All testing shall be in harmony with the commissioning chapter. Additionally, the designer shall develop and specify the following tests for approval:

- Factory Acceptance Tests
- Site Acceptance Tests
- Site Integration Tests
- Fire and Smoke Tests with smoke extraction (if applicable)

Additionally, testing of the tunnel ventilation equipment shall be performed regularly during normal operation (e.g. ramp up of fans, opening / closing dampers, etc.). The anemometers shall perform plausibility tests during normal operation to identify mismatching values.

Chapter 8 Table of Contents

Chapter 8 Emergency Systems Design

8.1 GENERAL

Emergency systems will be identified through an engineering analysis in accordance with NFPA 502, latest edition Section 4.3. The following list is comprised of additional design requirements that will need to be considered while developing the performance requirements of the emergency systems in the engineering analysis.

- Review pertinent codes, specifications, regulations, design handbooks, and other sources of design guidance for applicability to the design of the system. Most recent edition of the following codes to be referenced: NFPA 13, NFPA 14, NFPA 72, NFPA 510 and NFPA 2001.
- Eliminate or control hazards identified by analyses or related engineering efforts through design solution, material selection, or substitution. Potentially hazardous material (e.g., hydraulic fluids, solvents, lubricants, or fuels) shall be selected to provide optimum safety characteristics.
- Isolate hazardous substances, components, and operations from other activities, areas, personnel, and incompatible materials.
- Locate equipment so that access during operations, maintenance, repair or adjustment minimizes exposure to hazards (e.g., hazardous chemicals, high voltage, cutting edges, or sharp points.
- Minimize hazards resulting from excessive environmental conditions (e.g., temperature, noise, acceleration, and vibration).
- Design to minimize human error in the operation and support of all systems.
- Consider alternative approaches to minimize hazards that cannot be eliminated. Such approaches include interlocks, redundancy, failsafe design, system protection, fire suppression, and protective clothing, equipment, and devices.
- Protect the power sources, controls, and critical components for redundant subsystems by physical separation or shielding.
- Provide suitable warning and caution notes in assembly, operations, maintenance, and repair instructions, and distinctive markings on hazardous components, equipment, or facilities to ensure personnel and equipment protection.
- Review individual system design criteria for. requirements

regarding safety. Recommendations should be made for new design criteria supported by study, analyses, or test data.

- Operations Control Center room shall be provided. This room shall be set up to hold a representative of all over-build entities (Approximately 5 people). This room shall be (approximately) 25 feet by 25 feet inside dimensions.

8.2 FIRE PROTECTION

All systems shall be designed and constructed in conformance with pertinent requirements of the City of New Haven Fire Department. Express, written approval of all systems shall be obtained prior to construction being allowed to commence.

The following systems represent industry standard level of care configuration when considering design fire load of a heavy goods vehicle (HGV) (i.e. WB67 semi-truck with cargo predominantly containing cellulosic materials (i.e. wood, paper, and other man-made solid materials).

Designer shall develop a complete evaluation of ventilation and fire life safety systems to identify how the following fire protection systems may be incorporated into system design to optimize installation and operations and maintenance costs. Project shall also identify required confidence testing intervals for proposed system.

8.2.1 Deluge Sprinkler System

The developer shall provide an engineering assessment about the need of a Deluge Sprinkler System. If the outcome is, that such a system is required, then the developer shall provide a fully functional manual deluge system to protect the roadway areas. This system shall comply with NFPA 13 –Standard for the Installation of Sprinkler Systems and shall comply with the requirements of NFPA 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways. The design for this system shall provide sufficient length zones (typically 100 feet long) and each zone shall have its own on/off deluge valve. The operation of the system shall be semi-manual with positive alarm sequence operation and according to the City of New Haven Fire Chief/Marshal direction. Complete design of the systems shall be developed including calculated water supply (based on 100-foot-long zone this may be close to 1250 gpm). The calculation area shall consist of two deluge sprinkler zones plus 750 gpm for a hose stream. The designer shall identify fire load criteria used for selection of overhead fixed fire spray system and confirm with AHJ (typical design be based on system density of 0.25 gpm per square foot). All Hydraulic calculations shall be based on the stated criteria and shall be approved by the City of New Haven Fire Department.

Typical on/off deluge zone control would include the following however the designer shall verify the system configuration, performance, and sizing; Each Deluge Valve shall be electrically actuated by a push button located in the designated fire command center for the development. NFPA 502 allows for a delivery time of up to 10 minutes; however, this is the delivery time to a hose valve. For this reason, the Authority Having Jurisdiction has requested that the Roadway Dry Manual Deluge system shall be calculated in an approved method to provide water to the most remote zone from the Fire Department Storz connection in a projected time of 5 minutes.

Roadway Alarm Systems shall be robust enough in their design to allow for expansion in the future. All calculations shall be approved by the New Haven Fire Department

Developer shall also be responsible for providing a fully automatic deluge system for any area the New Haven Fire Department, the New Haven Police Department or other Stakeholder deems as a special use area. Examples include but are not limited to areas similar to truck dock turn-around areas, parking areas where the area is directly attached to the roadway and where no rated separation is provided. The water application densities for these systems shall be consistent with the roadway densities. These systems shall be operated and maintained by the developer.

Deluge sprinkler distribution systems shall be securely and adequately supported according to local and national codes and standards and shall be of sufficient strength to withstand the pressure to which they may be subjected including transient water hammer and surge developed during deluge system activation and filling operations.

8.2.2 Standpipe and Hose System

Standpipes for Class I service, as described in the latest editions of NFPA 14 – Standard for the Installation of Standpipe and Hose Systems and NFPA 502 shall be installed in all covered sections of the roadway. Standpipes shall be of the dry type having no permanent water supply connections.

Standpipe lines shall be of a minimum size of 6 inches in diameter.

Identification shall be provided at each surface Storz connection and at each hose valve. Such identification shall be on conspicuous, durable and legible signs affixed to, or immediately adjacent to, ground level Storz connections. In tunnels, identifying signs shall be affixed to tunnel walls at each hose outlet valve or painted directly on the standpipe in white letters next to each hose outlet valve. Exposed tunnel standpipe lines shall be painted.

Dual dry standpipe valves shall be spaced 150 feet apart along the length of the covered roadway. Each covered development parcel shall have a separate standpipe system.

The ends of mains shall have a manual air vent and drain. A drain shall also be supplied at the bottom of each riser and low point.

Standpipes shall be securely and adequately supported according to local and national codes and standards and shall be of sufficient strength to withstand the pressure to which they may be subjected including transient water hammer and surge developed during dry pipe charging operations.

Street level Storz connections shall be provided at each crossing roadway and within 150 feet of an active hydrant. "NO PARKING" signs shall be provided next to these connections. Signing may be required to identify these connections to fire and other emergency personnel.

8.2.3 Standpipe Installation in Areas under Construction

A standpipe system, either temporary or permanent in nature, shall be installed in segments of the covered roadway where air rights platforms are under construction, before the platform has exceeded a length of 250 feet beyond any access point and shall be extended as the platform construction progresses.

Temporary standpipes, which may be used by contractors to furnish water for construction purposes, shall be equipped with hose outlets and valves with 2-1/2-inch hose thread conforming to local Fire Department hose thread, and may have suitable reducers or adapters attached for connection of contractor's hose. Such reducers or adapters shall be readily removable by use of firefighters' hose spanner wrenches.

Permanent standpipes; or temporary standpipes installed in the roadway during construction shall be provided with easily accessible risers to the ground surface level.

Both permanent and temporary standpipes installed during the construction phase shall be securely and adequately supported and shall be of sufficient strength to withstand the pressure to which they may be subjected including transient water hammer and surge developed during dry pipe charging operations.

Temporary standpipes shall remain in service until the permanent standpipe installation is operational.

8.2.4 Portable Fire Extinguishers

Portable fire extinguishers shall be provided in such numbers, sizes and types, and at such locations as determined by the City during the design approval process.

8.2.5 Fire Proofing

All structural systems subject to exposure to a fire occurring within the over-build shall be constructed in a manner conforming to a minimum of a three (3) hour fire rating. The Engineer shall develop sufficient analysis and design to demonstrate design fire load peak heat release and expected duration will not initiate progressive collapse. In addition, the evaluation shall include thermo-mechanical structural response analysis sufficient for identifying structural service factor post fire incident event.

8.3 COMMUNICATIONS

The emergency telecommunications system located within the City of New Haven's right of way shall be maintained at all times. The system shall be expanded within any tunnels created by air rights development with communication points located in well-marked accessible locations within the tunnel area.

Any proposed modifications to the existing system shall be approved by the City of New Haven prior to project initiation.

The following first responder frequencies are required to be available within the new tunnels, either through an active rebroadcast and antenna system within the tunnel area, or via open air through free space demonstrated by an RF study within the new tunnel areas. All these frequencies are "conventional analog radio systems" (both mobile and portable programming):

New Haven Fire Department 1 311	814.5625 MHz	859.5625 MHz
New Haven Fire Department 2 311	809.4875 MHz	854.4875 MHz
New Haven Police Department 1 110.9	465.100 MHz	460.100 MHz
New Haven Police Department 2 110.9	465.450 MHz	460.450 MHz

New Haven Police Department 3 110.9	465.500 MHz	460.500 MHz
New Haven Public Works Dept 110.9	458.750 MHz	453.750 MHz
Medical Dispatch (CMED) 167.9	467.975 MHz	462.975 MHz

8.4 SURVEILLANCE AND TRAFFIC CONTROL

Emergency surveillance, tunnel closure and traffic control systems will be identified through an engineering analysis in accordance with NFPA Section 4.3. and an Emergency Response Plan in accordance with NFPA 502 Section 4.4. The emergency systems owned, maintained and operated by the City of New Haven shall follow National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) standards, equipment cabinet manufacturers standards (NEMA, TEES, ATC), NEC 502, NEC 70, AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, and the MUTCD. Tunnel traffic control systems may need to interface with fire alarm control panel meeting NFPA 72 National Fire Alarm and Signaling Code standards. These systems must also be compatible with the City of New Haven's traffic management center software and meet all applicable design and construction standards.

8.5 TUNNEL FIRE DETECTION AND FIRE ALARMS

Tunnel Fire Detection and Manual Fire Alarm Boxes shall be provided in the tunnel roadway areas.

Manual fire alarm boxes shall be located linearly along the tunnel roadway area at intervals not to exceed 300 feet, and at cross passages and other means of egress from the tunnel. Locations of boxes shall be accessible to the public and tunnel personnel. Alarms shall indicate the location of the fire alarm boxes at the monitoring station.

Linear Heat Detectors (LHD) have been used for many years in U.S. tunnels and have demonstrated that they do not have the sensitivity to provide an early warning of a road tunnel fire, however, do provide alarms for major fire events. Tests performed by tunnel agencies within the U.S. and in Europe have confirmed this conclusion. LHD system performance during actual fires and field tests were not reliable due to normal air velocities in the tunnels caused by large vehicles (piston effect) and mechanical ventilation systems. LHD systems using new type sensors such as fiber optic and continuous thermocouple have been installed in European tunnels. Operational performance data for these type systems during fire emergencies is currently being reviewed by various operating tunnel facilities, especially for

early detection and warning capabilities.

There are essentially four types of LHD systems that may be applied for the tunnel roadway area for automatic detection. There is an analog type, fiber optic type, thermocouple type and digital type.

The analog type has generally not been used in tunnel roadway applications recently as it requires a high alarm temperature requirement, since most fire conditions start as localized events, affecting only a small portion of the overall zone length of the sensor cable to temperature rise. This high alarm temperature requirement usually is above the destruction temperature of the sensor cable, since the calibration for the zone must be over the total length of cable in the zone. Since the alarm temperature set point is over the entire length of the cable in the zone, for a much shorter section of cable in the zone that experiences a fire condition, the temperature at that point must be much higher in proportion to the alarm set point over the entire length of cable to activate the alarm early into the fire event. Generally, the cable is not recoverable after an event and must be replaced and alarm calibration and sensitivity cannot be adjusted without altering the installed cable length. Special tooling is required for the sensor cable splicing and terminations utilizing a heat shrink sleeve or cap, and care must be taking during the process to not to apply too much heat that would damage or destroy the sensor cable, nor too little heat such that proper sealing is not achieved that would then result in faults or false alarms.

The fiber optic type has been used in roadway tunnels recently, and essentially uses the scatter characteristics of light in the glass fiber medium to determine if a fire condition exists. The characteristics typically used are Stokes and Anti Stokes light intensities. Anti-Stokes intensities are temperature dependent while Stokes intensities are temperature independent. Local point temperature along the sensor cable is derived from the ratio of the Anti-Stokes and Stokes light intensities. The controller contains an algorithm that records temperatures along the sensor cable as a continuous profile, and reliably indicates temperature changes within 1 or 2 degrees centigrade per minute for up to 2.5 miles of sensor cable. The sensor cable is typically a stainless-steel tube with two independent quartz type fibers. This type of system can detect early stages of a fire event and its location within the zone. The portion of the cable exposed to a major fire event is not recoverable and that particular section must be replaced with a spliced in portion. Multiple zones may be established off of a common cable instead of the application of different multiple cables for different zones. More precise and different alarm points may be set. The amount of false alarms is dependent upon how finely tuned the set points are to ambient temperature conditions, as well as the type and quantity of alarm set points programmed,

The thermocouple type has been used in roadway tunnels recently and uses a pair of type K thermocouple wires with negative temperature coefficient

insulation between them forming a continuous thermocouple. Essentially, each cable has an infinite number of potential temperatures measuring junctions along its entire length. Each cable will continuously measure and report ambient temperature existing in large areas and detect differential temperatures, or hot spots, when they occur. Available alarm configurations are early warning, pre-alarm and rate of rise alarms. Cables are self-restoring for most events and return to normal configuration after temperature excursions. The amount of false alarms is dependent upon how finely tuned the set points are to ambient temperature conditions.

The digital type has been used in roadway tunnels recently as well as in the past and are the most tried and tested of all the types. The sensor cable is comprised of two metallic conductors, each individually insulated with a heat sensitive polymer. There is usually a twist to the conductors imposing a spring pressure and then wrapped with a protective tape and outer jacket material. When the cable is exposed to the heat of a fire, the insulating polymer melts allowing the two metallic conductors to come in contact and complete an electrical circuit. The sensor cable is a fixed temperature device, not adjustable, with the set point being the melting point of the polymer insulating material of the conductors. Accordingly, there is no calibration required for the sensor cable. There is only one set point for alarm and that is the temperature rating of the sensor cable selected. This sensor cable is the least sensitive of those described and activates primarily for major fire events producing spot temperatures above the temperature rating of the cable, and not for low temperature, smoldering types of fire events. It is also the least prone to false alarms for these same reasons. This type of system can detect a fire event's location within the zone. The portion of the cable exposed to a major fire event is not recoverable and that particular section must be replaced with a spliced in portion. Multiple zones may only be established off of different cables, each as its own zone.

The digital type of linear heat detection is proposed for this roadway tunnel application. This type of linear heat detection is the least prone to false alarms and activates in the event of a major event. It is proposed also due to its scalability and modular approach for expansion as additional developers build out air rights along the right of way. As subsequent sections are built out, new sensor cable zones may be added to existing controllers, or these new sensor cable zones added to new controllers as needed.

Zone layout for the sensor cables shall follow the zone layout for the deluge sprinklers that will be located along the tunnel roadway, such that there shall be a "one to one" layout for coverage for any particular section of the roadway. Sensor cable shall be placed over the centerline of each travel and breakdown lane. Sensor cables shall be routed back to controllers that establish set points and calibration as applicable as well as alarm interface to other systems.

All of these systems should have more than one source of electrical power

and communications to ensure continuous operation. The surveillance and traffic control systems shall be connected to the Operation Control Center via their fiber optics communication line.

Additionally, the visibility detectors, required for normal operation and congested mode SHALL be used for fire detection purposes as well. They shall be used as a second independent fire (smoke) detection method.

Chapter 9 Table of Contents

Chapter 9 Lighting Design

9.1 GENERAL

The lighting for this project consists of two tasks; Roadway Lighting and Parking Garage Lighting. Both with different illumination methodologies, but with same objective of providing the appropriate visual environment to ensure the operator of a vehicle can safely move through the facility. For the roadway entering the structure, the entry is considered a Vehicular Tunnel and will be illuminated using the ANSI/IES-RP-RP8-18 (Chapter 14, Tunnels), American National Standard for Tunnel Lighting. Once inside the parking structure, the illumination levels are then defined in ANSI/IES-RP-8-18 (Chapter 17 Parking Lots and Parking Garages. As the structures are developed over the roadway, the roadway lighting will require a review to ensure the approaching motorist has adequate contrast to perceive hazards within the entry of roadway tunnel or garage. Thus, depending on adjacent buildouts, the entrance could serve as a tunnel or the lower level entrance to the parking structure above. In either case, for the roadway and ramps that are considered a tunnel, during daylight hours a driver's adapted state is such that the interior can appear like a "black hole", and hence, obstructions within the entry can effectively become invisible. High levels of artificial lighting are typically required to compensate for these ambient daytime threshold conditions and the driver's adapted state. In order to minimize the costs associated with installing and maintaining these systems, careful analysis is required of the physical features, orientation, construction, and operational requirements for each structure. There are various approaches for providing the required illumination which need to be evaluated, with due consideration for visual performance, driver safety, and both initial capital and life cycle costs. For Emergency Lighting mode use reference National Fire Protection Association NFPA 502, latest edition.

9.2 CODES AND REGULATIONS

Several design recommendations are available for tunnel lighting. These include but not be limited to the latest editions of the following documents:

- ANSI/IESNA RP-8-18, *American National Standard Institute/Illuminating Engineering Society*, Recommended Practice for Tunnel Lighting in Chapter 14, Tunnels.
- ANSI/IESNA, RP-8-18 American National Standard Institute/Illuminating Engineering Society, Recommended Practice for Roadway Lighting in Chapters 10 though Chapter 12.
- CIE 88, International Commission on Illumination, Guide for the Lighting of Road Tunnels
- IESNA, RP-8-18 Roadway sign lighting *Illuminating Engineering*

Society, Lighting for Parking Facilities in Chapter 18 Roadway Sign Lighting,

- AASHTO, latest edition American Association of State Highway and Transportation Officials, Informational Guide for Roadway Lighting
- ANSI/NFPA-502, *American National Standard Institute/National Fire Protection Association*, Standard for Road Tunnels, Bridges, and Other Limited Access Highways, latest edition.

9.3 TUNNEL LIGHTING DESIGN

ANSI/IES RP-8-18 divides a complete tunnel lighting design into adaptation zones. The length of each zone and the associated lighting requirements vary with the safe sight stopping distance (SSSD), design speed, the exterior daylight and environmental conditions, and the driver's current adapted state. The required pavement luminance in each zone also depends on the reflectance of the materials used for both the road and tunnel.

Figure 1. Layout of Tunnel Zones

The geometry of these zones and their associated lighting levels are based on the design criteria and reference the dark adaptation rate of the human eye. These zones are the Approach, Threshold, Transitions, Interior, and Exit Zones. There is one additional Zone which is called the Nighttime Zone. This Zone extends from portal to portal and operates during the evening hours.

A graphical representation of the recommended luminance reduction steps for these zones, showing % Luminance versus Time in seconds, is in Figure 2.

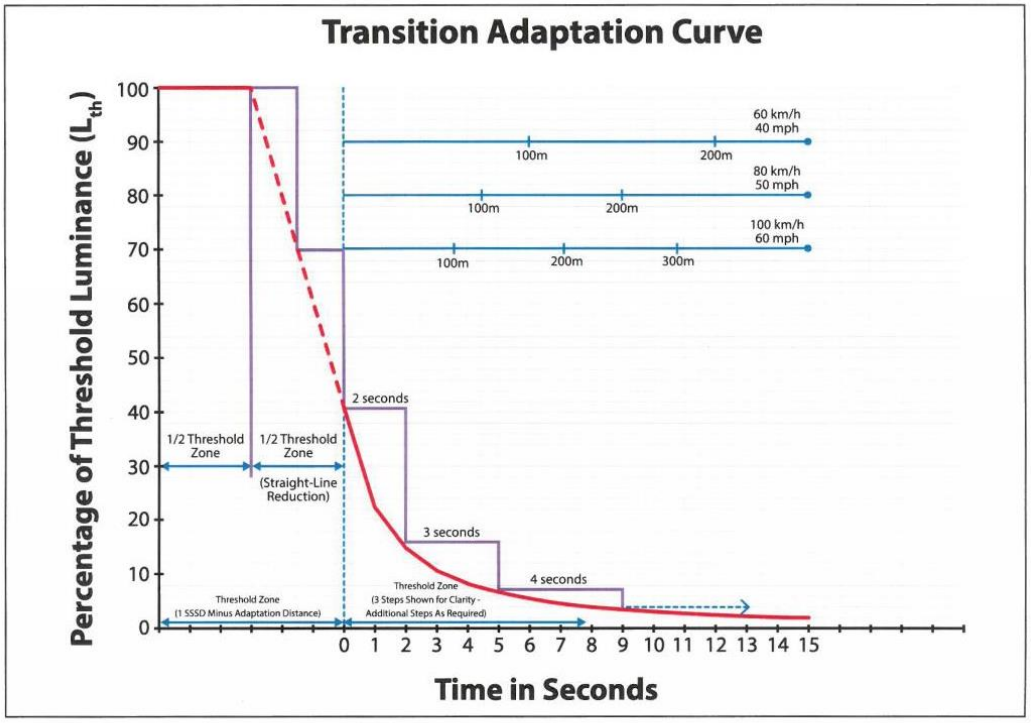


Figure 14-12. Recommended luminance reduction for threshold and transition zones. (Adapted from CIE-88 (2004), Figure 6.6.[2])

Figure 2. L_{th} Reduction Curve

Since human adaptation to higher brightness is all but instantaneous, and adaptation to lower levels is time dependent, standard practice does not require increases in luminance levels at the Exit portal. On the other hand, transitional nighttime roadway lighting is required, for both the Approach and Exit Zones, for a distance of nominally one SSSD.

Most importantly with Air Rights parcels, the location of various lighting zones may be altered thus causing the level of lighting required within the limits of each parcel to change. The lighting system installed under each parcel shall be flexible enough to accommodate all anticipated shifts in zones due to adjacent development.

9.4 TUNNEL ILLUMINATION REQUIREMENTS

9.4.1 Approach and Exit Zones

The Approach Zone is the area of open road immediately prior to the tunnel entry portal. Conversely, the section of roadway immediately following the exit portal is called the Exit Zone. The length of these zones is nominally one Safe Sight Stopping Distance (SSSD).

Most importantly, in the Approach Zone, the phenomenon of pre-adaptation begins. As the portal increasingly fills more of the field of

view, the driver's eye begins to adapt from the luminance of the wider general view to the significantly lower luminance within the approaching threshold.

For nighttime conditions, RP-8-18 the pavement luminance shall be at least one-third of the pavement luminance level within the tunnel. For example; based on an interior tunnel lighting level of 2.5 cd/m^2 both roadways should be illuminated to a minimum average pavement luminance of 0.83 cd/m^2. Since these are exterior roadways, it is also recommended they meet the uniformity and glare recommendations of ANSI/IES RP-8-18, latest edition Chapter 10 and Chapter 11.

9.4.2 Threshold Zone

The point, at which the portal structure completely fills the field of view, is called the Adaptation Point and is considered the start of the Threshold Zone. At this stage of the project, assumptions to geometric adjustments may be accounted for in the approach zone, which tends to modestly reduce the number of fixtures in the threshold zone.

The required values for pavement luminance (Lth) in the Threshold Zone(s) are dependent on the design speed, orientation of the tunnel, the ambient daylight conditions, and most importantly, the visual environment immediately surrounding the tunnel portal.

The current standard practice, RP-8-18, provides that the Luminance in the Threshold (Lth) is determined by completing an Equivalent Veiling Luminance evaluation also known as a Lseq evaluation of the portal. This method accounts for the complete visual field surrounding the portal. Using the luminance's within the visual field the Lth is developed based purely on the visual environment. In situations such as in preliminary or conceptual design, the Lth can be calculated using typical surface luminance values found in RP-8-18.

9.4.3 Transition Zone(s)

The Transition Zones immediately follow the Threshold Zone and extend in segments of time. During this time the drivers' eye adaptation continues, while allowing for the roadway luminance requirement to decrease from the bright threshold zone to relatively darker conditions in the interior zone.

- The numbers and lengths of each Transition Zone shall be determined based on the design vehicle speed.
- The value of the lighting levels in the Transition Zone shall be determined based on the Threshold Zone lighting level

and Figure 14-12 from RP-8-18.

- The values of Transition Zones length and lighting level of each Transition Zone shall be determined so that the designer can utilize the tunnel lighting criteria for the tunnel lighting system.

9.4.4 Interior Zone

The value of the lighting levels in the Interior zone shall be determined based on the design vehicle speed and Table 14-8 from RP-8-18. As the last zone within the tunnel, the Interior Zone runs from the end of the Transition Zone all the way to the Exit Portal. The roadway luminance level of the interior zone is based upon the speed and volume of traffic within the tunnel. RP-8-18 indicates the daytime interior level recommendations based on design speed and vehicle traffic flow.

The nighttime luminance level shall be uniform throughout the entire length of the tunnel. A luminance level of 2.5 cd/m^2 is recommended. This level is lower than the daytime interior zone level, thus the circuits that supply power to the interior zone daytime lighting system will either be equipped with dimming equipment that will dim the daytime lighting level to obtain the nighttime lighting level or designed using step dimming. In the threshold and transition zone only those circuits that supply power to the luminaires intended for nighttime operation shall also be similarly equipped to those found in the Interior zone.

The recommended maintained illuminance values for a tunnel approach roadway, per ANSI/IES RP-8-00, Section 14.3.1 shall be no less than 1/3 of the nighttime lighting level in the tunnel.

For the first phase of this project, the transition zone will lead directly into the parking facility; thus, at this point the illumination levels will follow the criteria for a parking garage. However, as the project progresses, the tunnel entry will have a transition leading to the interior zone.

9.5 TUNNEL LIGHTING CONSIDERATIONS

Considerations used in determining the appropriate source and configuration of lighting includes both initial and life cycle lighting cost, ease of construction, maintenance characteristics, photometric performance, traffic volume, and roadway use patterns.

Guidance and Architectural Considerations – The factors that make up these broad categories, which were followed in our evaluation, are as follows:

System Cost:

- Initial Installation Cost of Lighting System
- Controls Cost
- Cost of Spares
- Re-lamping Costs
- Energy Cost Including Demand Charges
- Maintenance Costs over the Life of the System
- Hazardous Waste Costs
- Replacement System Costs at End of Life (Typ. 25 years)

Construction:

- Fixtures' Ability to Withstand the Environment
- Impact Resistance
- Ease of Installation
- Relationship to Wireway and Branch Circuit Distribution

Maintenance:

- Ease of Maintaining System,
- Availability of Spare Parts
- Ease of Cleaning
- Tunnel Cleaning

Photometrics:

- Available Configurations and Wattages
- Beam Type
- System Efficacy (Lumens/Watt)
- System's Ability to Achieve Lighting Design Criteria

Traffic:

- Design speed
- Tunnel Capacity (AADT)
- Civil Design and Road Geometry
- Physical Design of Tunnel

Optical Guidance:

- Visual Coordination with Civil and Physical Design

Architectural:

- Surface Materials
- Fixture Locations
- Portal and Landscaping for Luminance Control
- Physical Design of Tunnel

9.5.1 Lighting Sources

LED tunnel luminaires shall be utilized. The IES distribution type and tunnel luminaire wattage shall be determined for daytime and nighttime luminaries for each tunnel zone. The proposed luminaires shall be suitable for tunnel application.

The selection of sources is dependent on the following criteria:

- Efficacy, lumens/watt
- Lamp Lumen Output, wattages available
- Life, hours
- Lumen Maintenance
- Physical Characteristics, size, base type, durability
- Color, stability and consistency
- Cost

9.5.2 Luminaire Maintenance

A tunnel atmosphere is normally dirty, infrequently cleaned, and highly corrosive. The lenses of the photocell control system will be cleaned once a month. The walls and exterior lens of the tunnel luminaires are projected to be cleaned once every six-months to keep LLF above 60%. Cleaning the lenses will aid in controlling the luminaire dirt depreciation factor and light output as well as aid in maintaining fixture integrity. Repairs and maintenance occur at non-peak hours in a closed travel lane. Workers must labor for prolonged periods, working overhead and exposed to oncoming traffic. The facts outlined above require that not only should maintenance be factored for cost and light depreciation, but the design of the luminaire must be made as maintenance and environmentally friendly as possible.

In order to meet the requirements for luminaire maintenance utilize stainless steel fixture(s) with appropriate gasketing and properly applied finishes.

9.5.3 Light Loss Factor

Many of the above issues are factored into the design calculations in terms of a Light Loss Factor (LLF). The LLF, also known as maintenance factors, are adjustments that are made in order to adjust the lighting calculations to anticipated field conditions. The overall light loss factor is dependent on a series of recoverable and non-recoverable factors which will affect the lighting systems operation from the time the system is first turned on, through the life of the system. The LLF shall be utilized per the City requirements or calculated by the following formula as follows:

$$LLF = (LAT) \times (VF) \times (RSDD) \times (BO) \times (LLD) \times (LDD)$$

Where:

LAT	=	Luminaire Ambient Temperature Factor.
VF	=	Voltage Factor.
RSDD	=	Room Surface Dirt Depreciation Factor.
BO	=	Burn Out Factor.
LLD	=	Lamp Lumen Depreciation.
LDD	=	Luminaire Dirt Depreciation Factor.
EF	=	Equipment Factor.

9.5.4 Controls

The ambient light level varies day to day, and throughout the year; inclement weather and cloudy days are significantly darker than clear sunny ones. Proper control of the threshold lighting can take advantage of these lower adaptation requirements by reducing energy consumption. The most effective way to control the lighting within the tunnel is through use of luminance meters located outside the tunnel that views the portal area. This type of meter will give the best indication of driver's adaptation, and therefore more effectively

control the tunnel lighting.

The luminaires within the tunnel should be dimmed in steps, depending on the ambient levels. The lighting control system should have various controlled set points measuring cloud cover, hold-on and hold-off timers, to minimize frequent switching of lamps throughout the course of the day.

The tunnel lighting shall be designed with an automatic illumination level control system operated by ambient light level sensing devices. These controls shall maintain a predetermined ratio of outdoor luminance to threshold luminance under all weather conditions during daytime operating hours. The system shall prohibit response to sudden and short duration (less than 15 minutes) light level changes and shall respond only to steady and long duration (more than 15 minutes) changes. The changes shall be made in five stages as follows:

Control Level	Indoor Level (as a percentage)	Sensor Setting – cd/m^2	
		On Increasing Lt.	Off Decreasing Lt
1	1	0 – 60	40 – 0
2	2	60 – 120	100 – 40
3	7	120 – 350	330 – 100
4	55	350 – 5000	4800 – 330
5	100	5000 – UP	UP – 4800

9.5.5 Emergency Power

For those situations where the power fails, selected luminaires of the tunnel lighting system shall be supplied using an uninterruptible power supply (UPS) listed and labeled as meeting UL-924 requirements.

These luminaires are powered using dedicated branch circuit wiring extended from the UPS. If there is a power failure, these luminaires will remain illuminated and maintain the necessary illumination levels required in NFPA-502-2011. Emergency circuits and fixtures shall meet the NFPA 502 requirement to remain functional for the required time period during the anticipated fire conditions.

All Emergency Power systems, equipment, and design shall utilize

equipment listed for use on Emergency Power and all requirements of NEC 700 Emergency Power.

9.5.6 Luminaire Power Circuiting

Tunnel lighting fixtures shall be energized by a 277-volt, single phase connection to 480/277-volt, three phase, four wire branch circuits radiating from lighting panels located in buildings.

All overcurrent protective devices (OCPDs) shall be resettable circuit-breakers with protection coordination where required by the NEC (for example, NEC 700 Emergency Power) using settable trip units.

9.6 SIGN LIGHTING

All ceiling mounted signs located in tunnels and containing fixed messages shall be retroreflective sheeting meeting the Federal Highway Administration (FHWA) publication FHWA-SA-14-022 for type IV, IX and XI. The developer shall ensure that any mounted signs do not infringe with the minimum vertical clearance for the tunnel.

9.7 PARKING GARAGE LIGHTING

Parking garage lighting focuses on developing an orderly passage for motorists and pedestrians when using the garage facilities. The lighting is based on recommendations for vehicular and pedestrian illuminance on the roadway surface, while providing a factor of safety and security. The garage area of the tunnel will follow the requirements of the IES-RP-8-18 (Chapter 17 Parking Lots and Parking Garages). During the course of this project, a revised version of the document is scheduled to be issued and will replace the existing revision and be used as the illumination guideline. The current lighting requirements for the parking garage lighting is in RP-8-18, Table 17-3.

9.8 PARKING GARAGE LIGHTING CONSIDERATIONS

Similar to the Tunnel Lighting, considerations used in determining the appropriate source and configuration of lighting includes both Initial and life cycle lighting cost, ease of construction, maintenance characteristics, photometric performance, traffic volume and roadway use patterns.

Guidance and Architectural Considerations – The factors that make up these broad categories, which were followed in our evaluation, are as follows:

System Cost

- Initial Installation Cost of Lighting System
- Controls Cost

- Cost of Spares
- Re-lamping Costs
- Energy Cost Including Demand Charges
- Maintenance Costs over the Life of the System
- Hazardous Waste Costs

Construction

- Fixtures' Ability to Withstand the Environment
- Impact Resistance
- Ease of Installation
- Relationship to Wireway and Branch Circuit Distribution

Maintenance

- Ease of Maintaining System,
- Availability of Spare Parts
- Ease of Cleaning
- Facility Cleaning

Photometry

- Available Configurations and Wattages
- Beam Type
- System Efficacy (Lumens/Watt)

Optical Guidance

- Visual Coordination with Civil and Physical Design

Architectural

- Surface Materials
- Fixture Locations

9.8.1 Lighting Sources

Parking Garage lighting shall be LED light sources and system shall comply with all applicable requirements of the International Energy Conservation Code (IECC) with amendments as adopted in the Connecticut State Building Code.

The selection of sources is dependent on the following criteria:

- Efficacy, lumens/watt
- Lamp Lumen Output, wattages available
- Life, hours
- Lumen Maintenance
- Color, stability and consistency
- Cost

9.8.2 Luminaire Maintenance

A garage atmosphere is normally dirty, infrequently cleaned, and to some extent corrosive. Repairs and maintenance occur at non-peak hours, and workers again labor for prolonged periods, working overhead. These factors require that not only should maintenance be factored for cost and light depreciation, but the design of the luminaire must be made as maintenance friendly as possible.

Routine maintenance for burned out lamps and failed ballasts or drivers can be accounted for in readily accessible luminaire components. Tool-less entry, readily removable ballasts/drivers and lamp holders, printed circuit boards, quick release connections, and interchangeable housings are minimum requirements for maintenance. All electrical connections should be made at the maintenance shop, or via quick connect/disconnect plugs in the field. Suspension systems should accommodate the removal of damaged fixtures without interruption of lighting performance in other portions of the system.

In order to meet the requirements for luminaire maintenance we propose the use of appropriate gasketing and properly applied finishes.

9.8.3 Light Loss Factor

Many of the above issues are factored into the design calculations in terms of a Light Loss Factor (LLF). The LLF, also known as maintenance factors, are adjustments that are made in order to adjust the lighting calculations to anticipated field conditions. The overall light loss factor is dependent on a series of recoverable and non-recoverable factors which will affect the lighting systems operation from the time the system is first turned on, through the life of the system. The LLF shall be utilized per the City requirements or calculated by the following formula are as follows:

$$LLF = (LAT) \times (VF) \times (RSDD) \times (BO) \times (LLD) \times (LDD)$$

Where:

LAT	=	Luminaire Ambient Temperature Factor.
VF	=	Voltage Factor.
RSDD	=	Room Surface Dirt Depreciation Factor. BO = Burn Out Factor.
LLD	=	Lamp Lumen Depreciation.
LDD	=	Luminaire Dirt Depreciation Factor. EF = Equipment Factor.

9.8.4 Controls

As mentioned previously for the tunnel lighting, the ambient light level varies day to day, and throughout the year; inclement weather and cloudy days are significantly darker than clear sunny ones. The lighting the parking garage obviously is very important in those areas that do not see daylight or are in congested traffic areas. However, for those areas along the edges of the facility, there is often more daylight entering the area than the illumination being delivered by the luminaires. The most effective way to control the lighting is through use of daylight sensors located in those areas affected. The lighting controls shall meet applicable requirements of the International Energy Conservation Code (IECC) with amendments as adopted in the Connecticut State Building Code.

9.8.5 Emergency Power

For those situations where the power fails, selected luminaires shall be supplied using an uninterruptible power supply (UPS). If required by building codes, the lighting backup power source shall meet all requirements of NEC Article 700.

These luminaires are powered using dedicated branch circuit wiring extended from the UPS. If there is a power failure, these luminaires will remain illuminated and maintain he necessary illumination levels required in NFPA-101.

9.8.6 Luminaire Power Circuiting

Garage lighting fixtures shall be energized by a 277-volt, single phase connection to 480/277-volt, three phase, four wire branch circuits radiating from lighting panels.

Overcurrent Protective Devices (OCPDs) shall be circuit breakers. Where coordination of protection is required, the system shall include adjustable trip devices.

Chapter 10 Table of Contents

Chapter 10 Maintenance of Operations

10.1 GENERAL

Construction operations shall be planned and conducted so as to cause a minimum interference with traffic flow. The Access to the air-rights garage shall be kept open for the full number of travel lanes normally in operation at all times except as previously approved by the City of New Haven and YNHH Hospital.

Any temporary maintenance and protection of traffic or traffic control inside or on the approaches to the tunnel shall be designed to the requirements in the latest version of NFPA 502 as well as the MUTCD and the City of New Haven.

10.2 PROSECUTION OF WORK AND PROTECTION OF TRAFFIC

The closing of travel lanes carrying Air-Rights traffic will be permitted for construction, subject to the conditions contained herein. Lane closing will be permitted, if in the opinion YNHH service deliveries can be rescheduled per weekly or daily AM coordination meetings.

Two adjacent travel lanes of a minimum width of 22 feet of roadway shall be maintained available for traffic at all times except when the City of New Haven may approve the restriction of traffic as stated in the City of New Haven and/or Connecticut Department of Transportation Limitations of Operations and Prosecution and Progress.

Work, including set-up of traffic control devices and detours, will be allowed as stated in the City of New Haven and/or Connecticut Department of Transportation Limitations of Operations and Prosecution and Progress.

At the end of each working day, all construction equipment and materials shall be removed from the Route 34.

Work shall proceed in such a manner as to minimize delay to traffic and with maximum safety precautions at all times

Workers at the site shall wear suitable safety vests at all times. Workers shall not enter or cross an operating Route 34 lane. Workers who disregard safety regulations will be barred from the job site.

Trucks and construction 'equipment shall be equipped with such devices, flags, lights, and/or colored signs as are in standard use under the safety rules of the City of New Haven and shall be kept in good working order.

All vehicles involved with setting traffic control signs and equipment shall have installed and shall use two 8-inch diameter amber rotating beacons when performing traffic control work.

Operations shall be conducted so as to cause the least possible interference with traffic. Vehicles and equipment traveling in lanes open to traffic shall maintain traffic speed within normal safety limits until entering the area coned or barricaded off as a work area. When entering lanes open to traffic from the work area, vehicles and equipment shall accelerate when possible to normal and safe traffic speed.

Vehicles and equipment will not be permitted to cross the median to reverse direction but will be permitted to reverse direction at intersections in a manner approved by the City Engineer.

During the construction of foundations, extreme care shall be exercised to prevent mud, water, concrete, or any extraneous material from spilling onto the traveled way or passing vehicles or entering the drainage system of CTDOT/City.

The operations of erecting shielding, removing structural steel, lifting and placing concrete or steel beams which from the lowest working platform, or any other construction operations over the Tunnel that may endanger traffic, shall be performed during the early morning hours.

During these operations, the Route 34 traffic shall be detoured through crossovers around the site onto the opposite roadway from the work which shall be made two-directional. This will involve State Police details and the erection and removal of traffic protection devices.

The detour entailing two-directional traffic in one roadway is a concern from the point of safety and will be permitted as allowed by the City of New Haven and/or Connecticut Department of Transportation Limitations of Operations and Prosecution and Progress.

Any work to be performed above the Route 34 while traffic passes underneath will require safety nets and/or shielding of a design approved by the CTDOT/City. Vertical clearances over the City Row shall not be less than 14 feet 3 inches. Nets and shielding shall be in continuous use in the until the appropriate portion of the structure is completed.

The work shall be prosecuted in such a manner that all excavations in the safety walks of the median or along the walls of the City will be backfilled at the end of each day's work. Any excavations authorized to be left open overnight shall be protected with barricades and traffic control devices satisfactory to the City's Engineer.

All areas disturbed by construction shall be restored to their original condition in a manner satisfactory to the City's Engineer.

The City of New Haven shall be reimbursed for all reasonable expenses incurred in performing any work which the City of New Haven deems necessary or advisable to protect persons or property from injury or damage due to the performance of work hereunder and for any and all reasonable expenses incurred by the City of New Haven due to failure of the developer

to comply with all terms and conditions hereof.

10.3 BARRICADES AND WARNING SIGNS

The Contractor will furnish, install, remove, reinstall, and maintain at its expense warning signs, cones, drums, portable flashing arrows, and portable barricades with battery operated flashers as the City's Engineer may direct or approve to meet site conditions, control and direction of traffic and promote safety and convenience. Warning signs, barricades, flashing lights, and other protective devices shall be constructed and erected in accordance with the latest edition of the "Manual on Uniform Traffic Control Devices for Streets and Highways" - Part VI, prepared by the National Joint Committee on Uniform Control Devices, and approved by the CTDOT/City.

The Contractor shall install, erect, relocate, remove, reinstall, and maintain the signs, cones, and barricades required throughout the period they are needed. Signs, cones, barricades, and flashers that are missing, damaged, or destroyed for any reason whatsoever will be repaired or replaced as soon as possible.

Prior to starting work on any portion of the Project adjacent to or being used by the traveling public, the Contractor shall furnish or have available on the Project the signs, cones, and other devices as required by the attached traffic protection detail sheets.

All signs, cones, and drums shall be reflectorized. Cones shall be an approved type, equipped with a factory made weighted base adapter to resist wind.

10.4 TRAFFIC OFFICERS

The City and/or CTDOT, as it may determine necessary, will furnish uniformed State Police with appropriate supervision to direct and expedite traffic and to safeguard those using the Route 34. The City of New Haven shall be reimbursed directly, at current rates, for detail duty plus the cost of overhead and charges for the use of cruisers.

10.5 CITY OF NEW HAVEN REPRESENTATION

The City of New Haven may assign such assistants and representatives, as it deems necessary at the expense of the Developer and they shall be authorized to give directions with regard to the safety and convenience of the Tunnel motorist, the erection and maintenance of traffic protection devices, barricades and warning signs and related matters.

The right is reserved to suspend construction on any operation on any day at any time when, in the opinion of the City's Engineer, the volume of traffic or the weather is such as to result in inordinate delays in traffic movement.

10.6 SCHEDULE OF OPERATIONS

At least thirty days prior to the time the Contractor intends to start any operations affecting the Tunnel or any of its facilities, and from time to time thereafter as directed by the CTDOT/City, the Contractor shall submit to the City, for its approval, complete shop drawings and work schedule showing the method and sequence of operations. Complete details of any proposed shielding, bracing and shoring which it intends to provide shall also be submitted for approval of the City's Engineer.

In addition to the schedule as required hereinbefore, the Contractor shall submit to the City, not later than 12 noon on every Wednesday, a detailed plan of its operations for the following 2-week period. This plan shall show the kind of work to be done and the traffic lanes which are to be affected for each and every day of the week in which work is to be performed. The City of New Haven may revise the schedule, if necessary, and all work will be performed in strict compliance with the approved schedule. If weather or other conditions beyond the control of the Contractor render the schedule impractical, a revised schedule will be submitted for approval.

10.7 COORDINATION OF WORK

Work on other projects on CTDOT as well as City of New Haven maintenance operations may be in progress during the period of construction of this platform. It is the Contractor's responsibility to coordinate and schedule his operations with those of City of New Haven projects in order to minimize interference to both CTDOT and local traffic. Scheduling will be subject to the review and approval of the City's Engineer who may require revision of the schedule to best suit the proper coordination of the various projects.

10.8 PROSECUTION OF WORK

All structural members shall be adequately connected and secured prior to leaving the site at the end of the workday. Newly erected beams or stringers with diaphragms over roadways, including ramps, shall be adequately secured immediately after erection and before traffic flow resumes.

Any areas of the Tunnel envelope disturbed by construction will be restored according to City of New Haven standards, including tunnel painted finishes, fireproofing, existing conduit reserved for traffic control, and the above-mentioned appurtenances.

Chapter 11 Table of Contents

Chapter 11 Commissioning

11.1 GENERAL

Commissioning will begin during the conceptual design phase. The developer will hire a qualified third-party commissioning agent that is independent of the design and constructions teams and those firms to fulfill the requirements of this section.

11.2 SUMMARY OF THE COMMISSIONING PROCESS

11.2.1 Definitions

Commissioning – Commissioning is the process to certify to the City of New Haven that systems, equipment, mechanical and electrical controls, and special systems are functioning together in a composite manner as shown on the plans and as specified in the special provisions.

Commissioning Agent – The Commissioning Agent is a designated agency or person hired by the Developer for the commissioning process. The Commissioning Agent is an independent entity, not otherwise associated with the Contractor or design team members. The Commissioning Agent communicates, directs and coordinates the day-to-day commissioning activities, and does not take an oversight role in the construction.

The Commissioning Authority (PB) – is a designated agency or person to oversee the commissioning process and the work of the various commissioning agents for the RTE 34E corridor program filling a QC function for the City of New Haven.

11.2.2 Reference Documents

The following are accepted industry guidelines for the commissioning process. Proposed deviation from this specification shall be in accordance with one or more of these guidelines:

- GSA – General Service Administration Commissioning Guidelines
- ACG – Associated Commissioning Group Guidelines
- BCA – Building Commissioning Association Guidelines

11.2.3 Qualifications

The Commissioning Agent provided by the Contractor shall not be an employee of the Contractor. The Agent shall be independent of the installing personnel or equipment suppliers for this project. The Commissioning Agent must maintain an unbiased approach to problem solving and conflict resolution. In addition, the Commissioning Agent shall:

- Be certified as an independent Commissioning Agent by the AABC Commissioning Group (ACG), BCA or Certified Building Commissioning Professional (CBCP) by Association of Energy Engineers
- Possess knowledge of the systems, including the design, optimization, installation, operations, acceptance testing, training and maintenance.
- Possess experience in management, leadership, system technologies and the construction process.
- Have practical field construction background.
- Demonstrated ability to organize many specific activities into a coherent Commissioning Plan.
- Communication skills, both written and verbal.
- Proficiency in documentation.
- Experience in working with multidisciplinary teams.
- Experience in writing and directing functional performance tests.
- At least 5 years of commissioning experience with the types of building, HVAC, fire protection, and control systems included in this project.

11.2.4 Scheduling

The Commissioning Agent shall:

- Provide the initial schedule of primary commissioning events/milestones at the initial commissioning scoping meeting.
- Work with the Contractor according to established protocols to schedule and maintain the integrated schedule with the commissioning activities.
- Provide a minimum of two weeks' notice to the

Contractor for scheduling commissioning activities.

- Adjust the commissioning schedule as construction progresses and more detailed schedules are available from the Contractor. The Contractor shall integrate all commissioning activities into the master schedule. All parties shall address scheduling problems and make necessary notifications in a timely manner in order to expedite the commissioning process.

11.2.5 Commissioning Team and Coordination

The members of the Commissioning Team consist of the Commissioning Authority, Commissioning Agent, the Contractor's, Project Manager, appropriate subcontractors (Mechanical, Electrical, Fire-Protection, Security Systems, Controls, Communication Systems), and any other subcontractors or suppliers of equipment. In, City Engineer or appropriate representatives shall be members of the commissioning team. The Authority Having Jurisdiction (AHJ) shall participate in commissioning of fire protection and alarm systems. The Commissioning Agent shall prepare a Commissioning Plan to supplement the team, roles, responsibilities and communication protocols defined in this section.

Commissioning Agent Responsibilities

The Commissioning Agent plans, directs and coordinates the commissioning process and activities; writes the Commissioning Plan and documents performance testing results. All reports and findings are sent directly to Commissioning Authority with carbon copy to the Developer's Representative, and Contractor's representative.

Responsibilities include:

- Plan, organize and lead the commissioning team
- Provide Commissioning Plan
- Convene commissioning team meetings
- Provide Project-specific construction checklists and commissioning process test procedures
- Verify the execution of commissioning process activities using random sampling
- Prepare and maintain the Commissioning Issues Log (Cxlog) and tracking of issues resolution.
- Prepare and maintain completed Construction Commission Checklist Log.

- Provide input to the construction schedule on the commissioning activities and their sequence.
- Witness systems, assemblies, equipment, and component startup.
- Compile test data, inspection reports, and certificates, include them in the systems manual and Commissioning Report

Contractor's Responsibilities

All Contractor's team members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents.

Contractor's representatives shall participate in and perform commissioning process activities including, but not limited to, the following:

- Attend commissioning team meetings.
- Integrate, maintain, and coordinate commissioning process activities with construction schedule.
- Review and accept system verification checklists (SVC) checklists provided by the Commissioning Agent.
- Review and accept commissioning process test procedures provided by the Commissioning Agent.
- Statement of Readiness – The Contractor shall provide the Commissioning Agent a written statement of readiness, certifying that systems, sub-systems, equipment, and associated controls are ready for testing, manufacturer's checklists are completed, and SVCs are completed.
- Complete commissioning process test procedures.
- Complete seasonal testing and commissioning testing as deemed required by the Commissioning Agent.
- Evaluate performance deficiencies identified in test reports and, in collaboration with entity responsible for system and equipment installation, recommend corrective action.
- Cooperate with the Commissioning Agent for resolution of issues recorded in the Commissioning Issues Log (CxLog).
- Ensure cooperation and participation of sub-contractors

as applicable.

- Ensure participation of major equipment manufacturing in appropriate start-up, testing and training activities.
- Prior to start-up, inspect, check and confirm the correct and complete installation of all equipment and systems for which system verification checklists are included in the Commissioning Plan. Document the results of all inspections and checks on the checklists and sign them. If deficient or incomplete work is discovered, ensure corrective action is taken and re-check until the results are satisfactory, and the system is ready for safe start-up.

The Contractor's personnel along with designated representatives may witness activities and verify results, and these activities will be separate from the Commissioning Agent witnessed tests and resulting reports.

City Representative and O&M Contractor Responsibilities

City representatives (including operation and maintenance personnel) and the O&M Contractor responsible for operating the tunnel during Detour Phases shall participate in and perform commissioning process activities including, but not limited to, the following:

- Attend commissioning team meetings.
- Attend testing meetings.
- Participate in training in operation and maintenance of systems, subsystems, and equipment.
- Demonstration of operation of systems, subsystems, and equipment

Meetings

Commissioning Scoping Meeting

Within 60 Calendar Days before the completion of the conceptual phase, the Commissioning Agent shall schedule, plan, and conduct a commissioning scoping meeting with the entire commissioning team in attendance. The scoping meeting shall address the tunnel systems to be commissioned, commissioning requirements, and completion and start-up schedules. Information gathered from this meeting will allow the Commissioning Agent to prepare the Commissioning Plan.

Meeting Minutes

The Commissioning Agent shall distribute meeting minutes and the revised Commissioning Plan to all parties in attendance at the

commissioning scoping meeting, and all the commissioning team members.

Commissioning Review Meetings

During the design phase the Commissioning Agent will plan and conduct a commissioning review meeting at each of the follow milestones:

- Schematic design – 30% complete
- Design development – 60% complete
- Final design – 90% complete
- Contract Documents – 100% complete

The Commissioning Agent shall distribute meeting agenda to all parties. Prior to each of these meetings the Commissioning Agent (CxA) will review the Owners Project Requirements (OPR) and the compare it to the Basis of Design (BOD) and or drawings that have been progressed. The CxA will prepare a report of the difference and diary these in the CxLog for communications to all team members. These issues will remain on the CxLog until resolved.

Additional Meetings

Other meetings shall be planned and conducted by the Commissioning Agent as construction progresses. The purpose of these meeting is to cover coordination, monitor progress, identify issues and deficiencies, and resolve issues relating to the commissioning with the Contractor, its particular subcontractors and relevant manufacturer representatives.

The Commissioning Agent shall plan and chair these meetings. These meetings shall be held monthly, until the final 6 months of construction, when they will be held once per week. The Commissioning Agent shall distribute meeting minutes to all parties.

11.3 COMMISSIONING PLAN

The Commissioning Agent shall submit a Commissioning Plan to the Commissioning Authority for review and approval 12 months in advance of the first proposed test. The Commissioning Plan shall include the outline of the organization and accountabilities, activities to be performed, sequence, schedule, documentation, verification procedures, and acceptance criteria pertaining to the overall commissioning process.

The Commissioning Plan shall define the percent of each system the Commissioning Agent must witness. Some systems may require 100 percent sampling, but all systems will be sampled at a minimum rate of 20 percent.

System commissioning shall not begin until the completion and acceptance of all utilities at the Tunnel/roadways. The system acceptance period ends when all systems have been operational and meets or exceeds accuracy and availability requirements for 180 days.

The Commissioning Plan shall detail the implementation of the commissioning process. The Commissioning Plan, submitted to the Commissioning Authority for review and approval, shall include the following:

- Scope of Commissioning – This section describes the overall commissioning process, and lists all equipment, systems, and interfaces to be commissioned.
- The commissioning team – The plan lists all members of the commissioning team, identified by individual name and corporate identity or by functional identity (e.g., general contractor, mechanical contractor, etc.) and describes their roles and responsibilities.
- Reference documents – These shall include the drawings and specifications for the project. In addition, published standards or guidelines relevant to commissioning requirements will be referenced.
- Commissioning meetings – Describe the purpose and number of commissioning meetings.
- System-specific details – For each system to be commissioned, the Commissioning Plan shall include the details listed below. The plan shall also identify the required testing sequence, progressing logically from equipment, to sub-systems, to systems, to interactions between systems.
    - Equipment readiness – Describe the system verification checks to be carried out prior to start-up and include specific checklists.
    - Equipment and system start-ups – Describe the step-by-step start-up procedure for each system and piece of equipment. This information is contained in the same checklist as the system verification (or pre-start) checks. If the specification requires that the manufacturer's authorized technician perform the start-up, then the plan shall require that a copy of the completed and signed manufacturer start-up form be included with the start-up checklist in the final documentation.
    - Data on specific equipment being installed.

- Functional performance tests (FPTs) – Detail the tests needed to demonstrate correct operation under all modes of operation and include the applicable pass/fail criteria. The Commissioning Agent must witness all FPTs to verify results.
- Acceptance – List the criteria for completion of the commissioning process. These shall include verification of functional performance for all systems, submission of TAB reports and O&M manuals, as well as other project-specific criteria.

- Training – Describe the intended program for City O&M staff orientation, training and demonstration. Training sessions shall be videotaped.
- Documentation requirements – List all documentation required for the final commissioning report. The Commissioning Plan itself shall form the basis of this documentation, which shall include:
  - A document reference list
  - Descriptions of each system, including a sequence of operations
  - Completed and signed system verification, start-up and functional performance test checklists documenting, on a system-by-system basis, all checks and tests carried out, and the results.
  - Retests of all unacceptable results
  - Training documentation, including an agenda for each scheduled session, a list of attendees, and videotape requirements.
  - Comprehensive O&M data.
- Schedule – Shall consist of a sequence of events, with an elapsed time allowance for each activity. Typical schedule events include:
  - Site inspections
  - Site meetings
  - Commissioning Issues Log (Cxlog) resolution meetings
  - System Verification Checklists (SVCs)
  - System Start-ups
  - Functional Performance Tests (FPTs)

- Operations staff orientation, training and demonstration.

11.3.1 Non-Conformance to Performance Verification Requirements

Should equipment, system components, and associated controls be incorrectly installed or malfunction during any of the Commissioning activities: correct deficiencies, re-verify equipment and components within the nonfunctional system and, include related systems as deemed required by the Commissioning Agent or Engineer, to ensure effective performance.

In addition, nonconformance issues discovered by the Engineer and Commissioning Agent during any separated witnessing or testing shall be recorded in the Commissioning-log, corrected, and may be retested at the request of the Engineer or Commissioning Agent.

Costs for corrective work, additional tests, and additional inspections, to determine acceptability and proper performance of such items to be borne by Contractor

11.3.2 O&M Training

The Commissioning Agent coordinates and schedules O&M training with the Contractor, and the City Engineers. The Contractor notifies subcontractors, suppliers and manufacturer's representatives, and plans the training program according to project specifications. The Commissioning agent is responsible for scheduling the O&M personnel and the O&M Contractor personnel for planned orientation, training and demonstration sessions.

Responsibility for the actual training program is shared by the Commissioning Agent, the Contractor and major equipment suppliers.

The Commissioning Agent is responsible for the videotaping and documentation of O&M training and demonstration sessions. Videotape permits existing O&M staff to review training material, and new staff to receive the same information provided at the original sessions, including questions posed and answers given. Video offers consistency in training and represents a key value-added component of the commissioning process.

The O&M training program shall include:

- Design intent
- System limitations
- Start-up and shut-down procedures
- Modes of control and operation sequences

- Detailed review of the information and organization of the O&M manual
- Complete listing of contractors and manufacturer contact information
- Detailed instructions on the control system
- Recommended procedures for effective operational monitoring including trending and graphics features for SCADA systems
- Routine preventative maintenance procedures as specified by the designer or recommended by the manufacturer
- Provisions for safety shutdowns, emergency conditions, and interfaces with SCADA, and life-safety systems.

11.3.3 Testing

Factory Acceptance Test (FAT)

Factory Acceptance Test (FAT) is performed before delivery of equipment. The Contractor shall submit a detailed list of all tests and general descriptions of each of the tests indicating the way in which these shall be conducted, and the estimated testing time required for each of these tests.

The Contractor shall submit to the Commissioning Agent (CxA) and Engineer for review and approval all detailed test procedures and final schedules for the tests at least 12 weeks prior to the schedule commencement of FAT.

Should a defect be found during the tests, the nature of the defect shall be explained in detail to the CxA and Engineer who shall decide which portion of the test or tests shall be re-run after the fault has been rectified.

When the performance of the equipment is rejected, the Contractor shall submit alternative equipment for Engineer's review and approval.

The Engineer and the Commissioning Agent may, at their option, witness any or all tests. Observations made during the tests and all test results shall be recorded in a document form, certified by Contractor and submitted to the Engineer for review and approval.

Record all data and observations of the tests. The Contractor shall submit formal test certificates and charts for Engineer's review and approval within 14 days after completion of the tests.

Complete FAT reports shall be provided to the Commissioning Agent for their review and approval and to be included as an appendix to the Commissioning Report.

System Verification Checks (SVCs)

SVCs ensure that systems have been installed properly, conform to the specifications and are ready for safe start-up. The responsibility for carrying out these checks, as well as any corrective action, lies with the Contractor. Documentation of these checks depends on project specifications. The Commissioning Agent prepares SVCs as part of the Commissioning Plan.

Contractor shall commence with testing of the complete equipment with all ancillaries when properly installed and connected in its final working arrangement at site. The Contractor shall perform all the necessary tests to prove that equipment has been properly installed and adjusted. In the event of any part of the equipment failing these tests, conduct further tests after rectification of the fault, over at least two successive and separate periods with no further fault occurring.

The Contractor shall provide suitable and approved test equipment, instruments and layout for the purpose of the tests or rectification of faults found during testing.

The Contractor shall have all instruments calibrated before and after tests by an approved laboratory.

The Contractor shall provide all consumable parts, and replacement parts required during the tests.

At least 8 weeks in advance of any particular site testing, the Contractor shall submit to the Engineer details of the test equipment intended for the testing for approval.

The Contractor shall include all tests for statutory requirements and insurances including payment and arrangements for such tests, inspections by authorized bodies, persons or insurers, as may be necessary and the provision of certificates in the prescribed and approved forms necessary to enable systems and equipment to be put into service.

Functional Performance Tests (FPTs)

The Commissioning Agent shall direct, witness and document the results of the FPTs of all systems commissioned. The Contractor operates the systems as directed by the Commissioning Agent so that FPTs, as documented in the Commissioning Plan, can be completed. The applicable sub-contractors shall participate, along with other relevant commissioning team members. The Contractor may have to

override normal control operation or parameters to simulate specific test conditions and set up trend-logs to provide a record of system responses to test actions. FPTs shall progress from individual items of equipment and sub-systems, to complete systems, to interfaces between systems, depending on the scope of the Commissioning Plan. This test progression helps to isolate the cause of problems while confirming correct operation of smaller portions of the installation, before moving on to tests involving larger systems or interfaces between systems.

Testing, Adjusting, and Balancing (TAB)

The Contractor shall perform HVAC testing, adjusting, and balancing (TAB), as shown on the plans and as specified in the commissioning plan in the presence of the Engineer, prior to the start of the Final Systems Integration Test.

Commissioning Agent witnessed tests

The Commissioning Agent shall witness the following procedures:

- Verification that systems and equipment have been cleaned and prepared for startup.
- Verification of systems for proper installation, adjustment, calibration, and readiness to function.
- Adjustment and verification of proper operation of all discrete elements and sub- systems. Each system shall be operated through all modes of system operation including every individual interlock and conditional control logic, all control sequences, both full- and part-load conditions, and simulation of all abnormal conditions for which there is a specified system or controls response.

The Contractor shall be responsible for operating systems and equipment throughout this testing and verification process.

Final System Integration Test

The Final System Integration Test requires the integrated simultaneous operation of all subsystems for a 24-hour period before the tunnel and roadways are opened to public traffic and before the system can enter the 180-day System Acceptance Test (SAT).

System Acceptance Test (SAT)

The System Acceptance Test (SAT) consists of a pre-installation test and a post installation test after a 180 test-day period of operations without a major failure of the Contractor furnished equipment.

The Contractor shall demonstrate that systems consisting of

hardware, software, materials and construction is properly installed, is free from identified problems, exhibits stable and reliable performance, and conforms to the requirements of the commissioning plan and this chapter.

The SAT shall be conducted with the actual traffic conditions when the tunnel and roadways are opened to public traffic.

The Contractor shall ensure that all equipment is maintained in operable condition during the SAT and shall troubleshoot, diagnose, identify, isolate, and resolve all hardware, software, SCADA and firmware problems and inconsistencies. The Contractor shall correct all problems and inconsistencies with Contractor installed equipment.

The Contractor shall correct all system documentation errors and changes discovered and resulting from the SAT and previous testing. System acceptance shall not be complete until corrected documentation is submitted.

Severity of faults and failures depend upon the accuracy and availability of data and control and the potential or actual results on the safety and convenience of the traveling public.

The following conditions shall result in suspension of the SAT:

- Interference with project operations due to vandalism, traffic accident, power failure, or natural disasters.
- Failure to complete the objective of any test scenario due to lack of complete documentation for equipment supplied by the Contractor.
- Intermittent hardware, SCADA, communication, or operation control malfunctions.

After satisfactory remedial action, the SAT shall be resumed and extended one day for each restart.

Any one of the following conditions is considered to be a major failure:

- Failure of any hardware, SCADA, or performance item to meet the operational requirements of the SAT for 72 consecutive hours.
- Failure of 5 percent of all field devices or communication equipment within a 14-day period.
- Failure to correct any problem that has an adverse impact on the safety of the traveling public within 4 hours of notification by the Engineer.

The SAT test clock shall be restarted at zero after a major failure is corrected.

The Commissioning Agent shall notify the Contractor in writing of the start of the System Acceptance Test work period and shall furnish statements regarding days credited to the tunnel systems and equipment commissioning work after the notification.

The time required for SAT work shall be considered as included in the total time limit specified for the contract.

Upon successful completion and acceptance of the SAT, the warranty period shall commence.

Upon successful completion of the SAT, the Commissioning Agent shall provide the Commissioning Authority with a statement of acceptable performance with the complete commissioning records and manuals.

11.3.4 Reports Submittal

The Commissioning Agent shall compile, organize and index the following commissioning data for each system and equipment into labeled, indexed and tabbed, three-ring binder manuals and submit to the Commissioning Authority, to be included with the Operation and Maintenance (O&M) manuals. Three copies of the manuals shall be submitted.

The Commissioning Report shall include a narrative description of systems, equipment, and components for each division of the specifications commissioned.

In addition, the commissioning report shall include, but will not be limited to:

- Executive Summary
- Manufacturer's checklists.
- Cx Issues Log (log of commissioning findings and resolution).
- System Verification Checklists.
- Functional Performance Tests.
- Functional Performance Test summaries
- Site Observation Reports
- Submittal Reviews
- O&M Manuals Reviews organized by systems

- As-Built Drawings Reviews
- O&M Training Documentation
- Start-Up Documentation
- TAB Report Review and Verification
- Commissioning Plan
- Commissioning Progress Reports
- System Acceptance Test Report
- FAT Reports
- List of Acronyms and Abbreviations

11.4 SAMPLE COMMISSIONING SCHEDULE

The Contractor will furnish, install, remove, reinstall, and maintain at its expense warning signs, cones, drums, portable flashing arrows, and portable barricades with battery operated flashers as the RTE 34E Engineer may direct or approve to meet site conditions, control and direction of traffic and promote safety and convenience. Warning signs, barricades, flashing lights, and other protective devices shall be constructed and erected in accordance with the latest edition of the "Manual on Uniform Traffic Control Devices for Streets and Highways" – Part VI, prepared by the National Joint Committee on Uniform Control Devices, and approved by the City Engineer

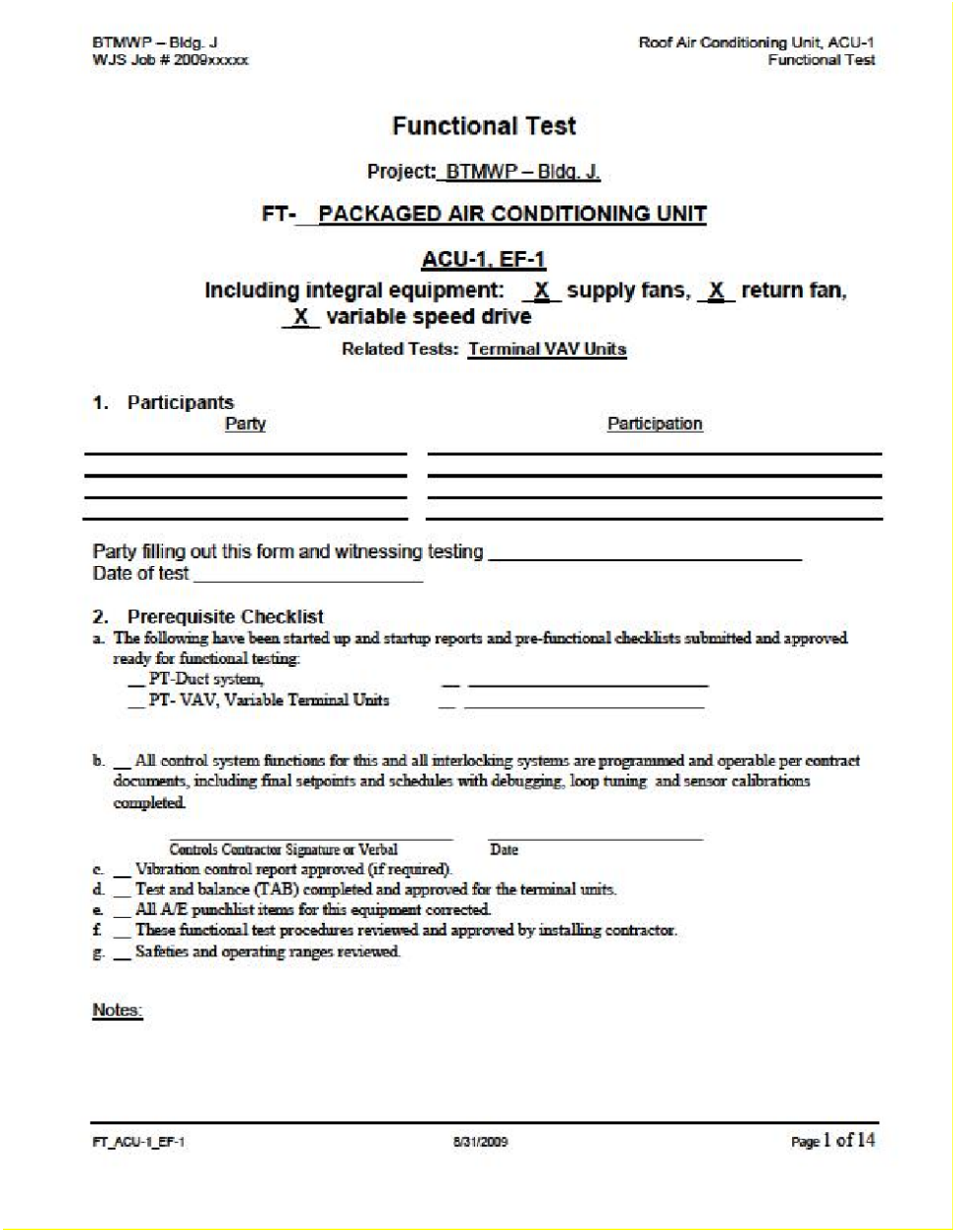
The appendix contains a sample schedule showing how the construction activities and commissioning activities will be linked in an integrated commissioning schedule.

Date: 3-May-10				SYSTEM START-UP AND COMMISSIONING SCHEDULE (Preliminary)												
Systems		Flush & Clean Meeting	Physical Installation Complete	Air/Hydro Testing	System Start-up Meeting	Pipe Flushing & Cleaning	Lock-out/Tag-out Review Meeting	Pre-functional checksheets completed -by Subs	Predecessors for Equipment Start-up	Equipment Start-up	CxA verifies Pre-functional Checklists	Predecessors in Cx Functional Checksheets	Cx Functional Performance Checklists Completed by Subs	Pre-Functional Test Meeting	Cx Functional Performance Checklists Verified By CxA	Start IAQ OA Flush
DDC Control system	DDC		7-May-11							8-May-11	7-Jun-11		7-Jul-11		7-Aug-11	
Supply Air Distribution System	A											L,O.R,J,H,C,B	1-Aug-11	6-Aug-11	10-Aug-11	16-Aug-11
AHU-1 & AHU-2	B	15-Jun-11		25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
Lab Exhaust System	C											D,E	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
EF-1,2 & 3	D	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
ERU	E	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
Atrium Smoke Exhaust System	F											A. G	1-Aug-11	6-Aug-11	11-Aug-11	16-Aug-11
SMF-1	G	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	10-Aug-11	16-Aug-11
HEPA Exhaust Systems	H											I	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
HEF-1 & 2	I	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
XEL Relief Fans	J											K	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
REF-1 ,2,3,4,5 & 6	K	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
Chilled Water System	L											M,N	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
CHWP-1 & 2	M	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
CHXX-1 & 2	N	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
Hot Water System	O											P.Q	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
HHWP-1 & 2	P	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
HHHX-1 & 2	Q	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
Energy Recovery System	R											S, O, L, C	1-Aug-11	6-Aug-11	9-Aug-11	16-Aug-11
ERWP-1&2	S	15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	8-Aug-11	16-Aug-11
Lighting Controls		15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11		1-Aug-11	6-Aug-11	11-Aug-11	16-Aug-11
Refrigeration Systems		15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	11-Aug-11	16-Aug-11
Domestic Hot Water		15-Jun-11	20-Jun-11	25-Jun-11	1-Jul-11	5-Jul-11	10-Jul-11	15-Jul-11	Electrical	20-Jul-11	25-Jul-11	DDC	1-Aug-11	6-Aug-11	11-Aug-11	16-Aug-11
NOTE:			When possible, Meeting Dates will change to co inside with Project Meetings. Dates to be adjusted as construction progresses.													

REVISED BY:

11.5 SAMPLE COMMISSIONING FORMS

Following is a sample commissioning forms to show how the rigor and depth of the testing activities.



BTMWP – Bldg. J
WJS Job # 2009xxxxx

Roof Air Conditioning Unit, ACU-1
Functional Test

Functional Test

Project: BTMWP – Bldg. J.

FT- PACKAGED AIR CONDITIONING UNIT

ACU-1, EF-1

Including integral equipment: _X_ supply fans, _X_ return fan, _X_ variable speed drive

Related Tests: Terminal VAV Units

1. Participants

Party	Participation

Party filling out this form and witnessing testing _____
Date of test _____

2. Prerequisite Checklist

a. The following have been started up and startup reports and pre-functional checklists submitted and approved ready for functional testing:
__ PT-Duct system, __ _____
__ PT- VAV, Variable Terminal Units __ _____

b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

_____ _____
Controls Contractor Signature or Verbal Date

c. __ Vibration control report approved (if required).
d. __ Test and balance (TAB) completed and approved for the terminal units.
e. __ All A/E punchlist items for this equipment corrected.
f. __ These functional test procedures reviewed and approved by installing contractor.
g. __ Safeties and operating ranges reviewed.

Notes:

FT_ACU-1_EF-1 8/31/2009 Page 1 of 14

BTMWP - Bldg J
WJS Job # 2009xxxxx

Air Conditioning Unit Prefunctional Checklist

Prefunctional Checklist - Packaged Air Conditioning Units ACU-1				
Check appropriate box if OK. Enter comment or note number if deficient.				
Requested documentation submitted				
	Specified	Shop Dr	Installed	Contr.
Manufacturer	Trane	Trane		
Model #	SFHFF20	SFHFF20E		
	Check	Comments		Contr.
Manufacturer's cut sheets				
Performance data (fan curves, coil data, etc.)				
Installation and startup manual and plan				
Sequences and control strategies				
O&M manuals				
Installation Checks				
Cabinet and General Installation				
Permanent labels affixed, including for fans				
Casing condition good: no dents, leaks, door gaskets installed				
Stainless steel drain pans				
Access doors close tightly - no leaks				
Boot between duct and unit tight and in good condition				
Vibration isolation equipment installed & released from shipping locks				
Maintenance access acceptable for unit and components				
Sound attenuation installed				
Thermal insulation properly installed and according to specification				
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)				
Clean up of equipment completed per contract documents				
Construction filters removed —— Filters installed. 30% Prefilters (MERV 70 and 85% final filters (MERV 13) and replacement type and efficiency permanently affixed to housing.				
Valves, Piping and Coils (see full piping checklists)				
Pipe fittings complete and pipes properly supported				
Condensate piping w/trap and extended to roof drain				
Pipes properly labeled				
Pipes properly insulated				
Strainers in place and clean				
Piping system properly flushed				
No leaking apparent around fittings				
All coils are clean and fins are in good condition				
All SS condensate drain pans clean and slope to drain, per spec				
Valves properly labeled				
Valves installed in proper direction				

PC_ACU 8/31/2009 Page 1 of 4

11.6 SYSTEMS TO BE COMMISSIONED

The City of New Haven may assign such assistants and representatives, as it deems necessary at the expense of the Developer and they shall be authorized to give directions with regard to the safety and convenience of the Tunnel motorist, the erection and maintenance of traffic protection devices, barricades and warning signs and related matters.

The right is reserved to suspend construction on any operation on any day at any time when, in the opinion of the Cities Engineer, the volume of traffic or the weather is such as to result in inordinate delays in traffic movement.

11.6.1 General

The Contractor shall perform systems and equipment commissioning in the presence of the Commissioning Agent. The commissioning process shall verify systems and equipment are fully functioning in conformance with the details shown on the plans and the requirements specified in this chapter.

The systems and equipment to be commissioned shall at a minimum include the following for tunnel, and roadways systems:

- Mechanical systems, including:
    - HVAC and ventilation systems
    - CO2 detection and control
    - Utilities – Drainage and Stormwater
- Fire protection systems, including:
    - Fixed fire protection system – stand-pipe system.
    - Manual fire alarm boxes (pull stations)
    - Fire alarm control panels
    - Fire alarm control panel remote annunciators
    - Fire department hose connections
    - Linear heat detectors
- Electrical systems, including:
    - Lighting systems.
    - Medium voltage switchgear.
    - Electrical metering, monitoring, and control systems.

- Motors.
- Medium voltage automatic transfer switches.
- Medium voltage transformers.
- Low voltage transformers.
- Primary power system cabling.
- Secondary power system cabling.
- Breaker trip sequencing coordination.
- Ground fault systems.
- Service switchboard.
- Circuit breaker panelboards.
- Motor control centers.
- UPS systems and battery capacity test.
- SCADA system

- Special systems, including:
  - Security and access system.
  - Carbon Monoxide (CO) monitoring, calibration and control systems.
  - Tunnel drainage system
- Traffic Operations System (TOS) / Tunnel Traffic Control System (TTCS), including:
  - Variable message signs.
  - Changeable message signs.
  - Extinguishable message signs.
  - Closed circuit television (CCTV) systems.
  - Vehicle detection stations
  - Traffic signals
- Communications systems, including:
  - Telephone systems.
  - Data systems.
  - Fiber optic systems.

- Radio rebroadcast systems.
- Call Box
- Communication link for the Operations control from and with all development parcels associated with the air rights program over the roadway.

After installation and testing of all elements of the tunnel and roadway systems, the systems shall be tested and integrated into a complete system. The testing and integration of all systems shall follow the test plan and procedures (Cx Plan) prepared by the Commissioning Agent and Contractor and approved by the Commissioning Authority.

11.7 COORDINATION WITH OTHER WORK

Work on other projects on the Tunnel as well as City of New Haven maintenance operations may be in progress during the period of construction of this platform. It is the Contractor's responsibility to coordinate and schedule his operations with those of City of New Haven projects in order to minimize interference to both Tunnel and local traffic. Scheduling will be subject to the review and approval of the RT 34E's Engineer who may require revision of the schedule to best suit the proper coordination of the various projects.

11.8 OPERATIONAL CONTROL

The commissioning Agent of this project working for this parcel's developer shall make himself aware and familiar with the previous air right development projects completed and underway.

This commissioning plan shall include the testing of the communication and controls of the scope of work performed under this project with the present Operations control center.

This commissioning plan shall include an integrated acceptance test, all pre-tests, and the preparation of the forms and schedules required for this test.

All systems included in this commissioning plan that communicate with the Operations Control center will be included in the integrated acceptance test of this section.

Chapter 12 Table of Contents

Chapter 12 Emergency Response Plan

12.1 GENERAL

Emergency response plans shall be developed in accordance with the latest edition of NFPA 502 Chapter 4.4 and approved by the AHJ. The Developer shall assume responsibility for coordinating meetings between all identified stakeholders in the fire life safety engineering analysis.

12.2 PLAN REQUIREMENTS

DRAFT emergency response plans shall be submitted with every design deliverable prepared in accordance with Chapter 4.4 of the latest edition of the NFPA 502. A final draft of the emergency response plan shall be submitted to the AHJ upon completion of the Project.

The emergency response plans shall be developed to work in conjunction/coordination with existing emergency response plans already in place for adjoining tunnel sections. Should modifications be required to the emergency response plan for the adjoining tunnel section the Developer shall be responsible the coordination with all appropriate stakeholders in order to update the emergency response plan.

12.3 MEANS OF EGRESS/ACCESS

The emergency response plan shall include the means of egress requirements in accordance with the latest edition of NFPA 502 Chapter 7 and Chapter 8. Routes used by emergency response units to access the covered roadway shall not be impeded at any time. Safe and well documented egress routes from the covered roadway shall be maintained at all times.

Egress paths shall be incorporated in the design at any air rights development. These paths shall allow egress from the site of an emergency to an unobstructed means of egress. Where roadways are segmented by continuous structures meeting separation requirements for fire and ventilation, egress from one segment (tunnel) to another shall be accommodated via well- marked accessible exit ways. These exit ways shall be located at a maximum of 500 feet on center.

This section needs additional language added to discuss the design of fire doors within traffic areas to allow safe pedestrian use and clearance for conventional swing door operation (e.g. curb or guiderail design in door threshold areas). Sliding doors are an option for confined locations.