19.0 Tunnel Enhanced Fire Safety System

19.1 General

This Section identifies the requirements for mechanical, electrical, and supervisory systems that comprise the Fixed Fire Suppression System (FFSS) and its ancillary components. All elements of these systems shall be designed, furnished, and installed in accordance with the requirements of the Contract, Governmental Approvals, and applicable Standards and Laws.

The Contractor shall be responsible for all analyses, reports, designs, drawings, detailing, clearances, tolerances, and specifications of the FFSS and the procurement, fabrication, installation, testing, and commissioning of components to provide a fully functional system that meets the Project requirements.

19.2 Concept of Operations

The objective of the Eisenhower/Johnson Memorial Tunnel (EJMT) Enhanced Fire Safety System is to provide an integrated mechanical/electrical system that reduces the maximum heat release rate from the design fire in the tunnel. The Tunnel Enhanced Fire Safety System is intended to enhance tenability in the EJMT by limiting the maximum heat release rate from the design fire to 35 Megawatts (MW). This will permit the existing tunnel ventilation system to control the generation of smoke and heated gases from the design fire in the tunnel so as to maintain a stream of noncontaminated air to motorists in the path of egress away from a fire.

The EJMT Enhanced Fire Safety System shall include an FFSS and associated water supply systems, fire detection systems, and mechanical, electrical, and control systems required for system operation, monitoring, and control. The activation of the FFSS shall limit the design fire to the maximum heat release rate. The design fire has a growth rate of 20 MW per minute.

Contractor shall design, procure, install, and test an integrated FFSS for control of fires in the EJMT. The FFSS consists of the following subsystems:

- Water storage and supply subsystem
- Water distribution subsystem in both bores
- FFSS operation, control, and monitoring subsystem
- FFSS communication subsystem to support operation, control, and monitoring functions
- Closed Circuit Television (CCTV) subsystem
- Power supply system

In addition, modifications shall be made to the existing Control Room located in the East Ventilation Building. Modifications include installation of a raised floor and replacement of the existing operator console. Equipment shall be added to the Control Room, as described herein.

The Contractor shall design, procure, install, and test an integrated Fire Detection System for detection of fires in the EJMT and for the activation of the FFSS. The Fire Detection System consists of the following subsystems:

- Linear Heat Detector (LHD) subsystem
- Low Light Level CCTV subsystem
- Fire Alarm Control Panel (FACP)
- Operator Interface Subsystem (OIS)
- Fire Detection Communication subsystem to support Fire Detection System monitoring functions
- Power supply system

The LHD subsystem shall provide fire detection in the EJMT. The FACP monitors the status of the LHD and provides alerts when a fire has been detected. The FACP also provides control, monitoring, and alerts for the FFSS pumps, valves, and devices.

The OIS processes data streams from the FACP and video from the CCTV subsystem and displays the status of all monitored subsystems at workstations located in the EJMT Control Room.

The Tunnel Enhanced Fire Safety System shall be designed based on 24/7 monitored operations.

It is the intent to integrate the proposed FFSS with the existing ventilation system by tunnel operator action. Any proposed modifications to the existing ventilation equipment or controls shall require CDOT Approval.

19.3 Design Criteria

The FFSS shall be designed to provide redundant, fault-tolerant management and control of system devices. Data paths, network devices, power supply and distribution, and servers shall include means to assure high system availability.

The primary elements of the FFSS are required to be designed and constructed for a service life of 30 years, with no system outages required for system rehabilitations during the 30-year life. Elements not specifically required to be designed to a 30-year service life shall be designed to applicable and appropriate codes, guidelines, and the Contract.

Elements of the Tunnel Enhanced Fire Safety System shall be designed for protection and survivability from the design fire condition. This shall include design of signal, communication, and power supply wiring to minimize exposure to fire conditions. Materials exposed to a tunnel fire shall include shielding and coverings to improve fire resistance. Systems design shall include modular segmentation to enhance replacement and quick recovery following a tunnel fire.

19.4 Codes and Standards

The Contractor shall perform engineering analyses and classify all subsurface configurations as road tunnel, in accordance with NFPA 502, or other appropriate standards, and apply other applicable Standards of the Industry. In all cases, the Contractor shall design and provide the necessary mechanical, electrical, and supervisory features to provide an appropriate environment during all emergency and non-emergency operating modes.

The Contractor shall develop and submit for Approval to CDOT within 60 days after NTP1, the list of codes and standards proposed for the design and construction of the Tunnel Enhanced Fire Safety System.

19.5 Requirements Management

The Contractor shall develop and implement a comprehensive Requirements Management (RM) process, defining how the Technical Contract Requirements are parsed, captured, documented, derived, apportioned, traced, managed, verified, and validated.

The Contractor shall develop and manage a requirements database for the management and reporting of the RM process. The requirements database shall include all requirements in these specifications and the requirements that may be added or modified during contract scope modifications.

The Contractor shall furnish a conventional, off-the-shelf (COTS) product for a Requirements Management tool, which makes use of a spreadsheet or relational database for the management of Contract requirements. The Contractor shall submit the preliminary Requirements Traceability Matrix (RTM) to CDOT for Approval within 60 days after NTP1.

The Contractor shall provide updates to the RTM during all phases of the Project.

The Contractor shall keep CDOT's version of the RTM synchronized with the Contractor's requirements database by performing a monthly synchronization.

Each requirement within the requirements database shall have a unique identifier, be unambiguous, and non-repetitive. Each requirement within the RTM shall be assigned a functional allocation, which allocates the requirements into the functional areas including the FFSS, LHD subsystem, CCTV subsystem, OIS, Supervisory Control and Data Acquisition (SCADA) system, power supply system, water supply system, and the Emergency Response Plan (ERP). Each requirement within the RTM shall be mapped to the associated Contract deliverable where the requirement is addressed and to the specifications.

The functional allocation shall be submitted to CDOT for review and Approval in conjunction with the RTM submittals.

The Contractor shall produce RTM reports. The RTM reports shall list each Project requirement from the Project specifications and provide traceability to each test procedure in which this requirement will be tested.

For each submittal of a Project deliverable, the Contractor shall submit an RTM report that lists only those requirements addressed within the deliverable and the associated mapping of each requirement to the section where the requirement is addressed.

The Contractor shall be responsible for testing every requirement listed in the RTM against pass/fail criteria stated in the commissioning test plan and schedule as reviewed and Approved by CDOT.

19.6 Design Baseline Report

The Contractor shall prepare and submit a Design Baseline Report to CDOT for Approval within 90 days after NTP1. The Design Baseline Report shall provide a system description that includes at a minimum the following elements:

- System block diagrams for the FFSS, fire detection, FACP, power supply, water supply, and data communication systems
- Proposed FFSS type, LHD model and supplier, and CCTV camera model
- Operator interface system
- Monitoring and control system
- Proposed system operation
- CFD analysis process, model, cases and assumptions
- Proposed modifications to existing tunnels and buildings
- Proposed modifications to the Control Room
- Proposed approach to performing the FFSS Design Configuration Acceptance Test

19.7 Emergency Response Plan

An ERP will be prepared as part of the Contract, as described in NFPA 502, by CDOT. The Contractor shall attend ERP coordination meetings to discuss the details of the FFSS operation and tunnel emergency procedures.

19.8 Existing Tunnel Systems

The Work includes coordination (and in some cases interconnection) with all existing tunnel facilities and equipment, including the following:

- Tunnel ventilation system
- Carbon Monoxide (CO) monitoring system
- Power supply and distribution system
- Tunnel lighting
- Drainage and water treatment
- Fire- and life-safety systems (radio communications)
- Programmable Logic Controllers (PLCs)
- Tunnel CCTV traffic surveillance and ITS
- Tunnel signage, signals, and control
- Tunnel communications and control (including tunnel Control Room)
- Tunnel washing machine and procedures

19.8.1 Ventilation System

The EJMT has an existing tunnel ventilation system that operates in a transverse configuration. There are existing centrifugal ventilation fans located above both the east and west portals. Fresh air is supplied to the tunnel from an air duct located above the roadway. In the north tunnel, fresh air is conducted to the roadway level from air ducts located at the sidewall. In the south tunnel, fresh air is supplied to the roadway level via air ports in the floor of the fresh air duct. In both north and south tunnels, vitiated air is removed from the roadway level via ducts located in the floor of the exhaust air duct.

The capacity of the existing tunnel ceiling support system is limited by critical connections at the ceiling hangers embedded in the center divider wall. Service loads applied to the duct floor during construction shall not result in loading on the critical connections that would exceed loading from a uniform load over the plenum floor area

equivalent to 62 pounds per square foot divided by a 1.7 load factor. The determination of equivalent uniform loading shall consider the exhaust and supply sides of the plenum separately. The Contractor shall submit a Construction Sequencing Plan that provides details of service loads applied to the plenum floor during all phases of construction including stockpiling of materials, tools, equipment, labor, and all other loads.

The Construction Sequencing Plan shall be submitted to CDOT, for Approval, a minimum of 30 days prior to NTP2. Particular care shall be taken that the loads established in the Approved Construction Sequencing Plan are not exceeded. The Construction Sequencing Plan shall indicate the procedures that the Contractor will follow to ensure that loadings are not exceeded. Service point loads on the plenum floor are also limited to the punching shear capacity of the plenum floor section reduced by a 1.7 load factor; maximum anticipated construction and final point loads shall be determined and provided in the Construction Sequencing Plan.

The total dead load applied to the plenum floor (and to the ceiling in the plenum transition areas) by the finished system shall be limited to two pounds per square foot over the surface area of the entire floor (for exhaust and supply side, considered separately). Weight of water in piping shall not be included in the calculation of the system dead load.

The existing ventilation system maintains CO concentrations below the maximum acceptable levels during all non-emergency traffic conditions, including congested, stopped, and normal flowing traffic. During these traffic conditions, the EJMT ventilation system maintains the CO level below 50 parts per million. When work parties are present, CO levels are maintained at or below 35 parts per million.

19.8.2 Ventilation Control

The capability to monitor and operate the EJMT ventilation system fans, motors, and dampers is provided at the tunnel Control Room through the existing ventilation control system. The existing ventilation system is manually operated by tunnel operators from a control panel in the tunnel Control Room. Fan operation for emergency response is based on ventilation zones. Zoning of the FFSS shall consider the limits of ventilation zones to ensure coordinated response by the ventilation system to fire conditions.

The EJMT is equipped with monitoring equipment/sensors to monitor and control the tunnel atmosphere/environment for CO and visibility.

The Contractor shall maintain the existing ventilation control system and operating modes as necessary to maintain the aforementioned tunnel environment under congested, stopped, and normal flowing traffic.

The current method for operation and control of the existing tunnel ventilation system will not be changed as part of the Tunnel Enhanced Fire Safety System. Tunnel operators will manually control fan operation as required following an alert of the fire detection system.

19.8.3 Cross Passages

Tunnel cross passages connect the existing tunnels. Tunnel cross passageways and, as applicable, other spaces within the roadway, may be used for FFSS equipment. Emergency ingress/egress capability shall be maintained. Any use of the cross passages and any equipment location requires CDOT Approval.

19.8.4 Water Supply System

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The existing tunnel standpipe system at the EJMT is charged from a 120,000 gallon storage tank located above the west portal. This storage tank is filled with water collected from a diversion dam on Straight Creek. CDOT has existing water rights on Straight Creek of 0.03 cubic feet per second.

19.8.5 Electric Power System

Electrical power is provided to the EJMT at the East and West Ventilation Buildings by independent primary feeders operating at 24.9 kilovolt (kV). A 24.9 kV tie runs through the tunnel between the east and west portals to provide power in the event of loss of one of the primary feeders. Power is provided to tunnel equipment through 2.4 kV and 480 volt (V) switchgear located in the electrical rooms at the East and West Ventilation Buildings.

The 2.4 kV switchgear powers a portion of the ventilation fans and other loads.

The 480 V switchgear is divided into two sections, with a tie between sections. Normal loads are powered through the normal switchgear; emergency loads are powered through the emergency switchgear. The emergency switchgear is backed up with emergency generators. The existing emergency generators do not have any spare capacity beyond the loads currently supported.

The existing 24.9 kV switchgear is scheduled to be replaced in 2014. After the replacement work is complete, physical space will be available to accommodate an additional enclosure to the new 24.9 kV lineup for a breaker dedicated to FFSS needs. Physical space is also available to add an additional enclosure to the existing 2.4 kV switchgear lineup for a breaker dedicated to FFSS needs. Enclosures and switchgear added to existing equipment shall match existing.

One existing 480 V breaker rated at 1600 amps (A) is available at each of the east and west electrical switchgear lineups for use by the FFSS project. These breakers are part of the normal switchgear lineup and are not supported on existing generators.

Each of the three tunnel cross passages has two 480V transformers, powered through two separate 2.4 kV feeders from the portals. One of the 2.4 kV feeders is connected through the 480 V normal power switchgear. This feeder provides power to the 480 V panel connected to normal loads. The other 2.4 kV feeder is connected to the emergency portion of the 480 V switchgear, connected to the existing generators. This feeder provides power to the cross passage 480 V panel connected to critical loads. Physical space is limited in the cross passage electrical rooms for additional electrical equipment.

19.9 Fixed Fire Suppression System

An FFSS shall be designed, supplied, installed, tested, and commissioned in the north and south tunnels at the EJMT. The FFSS shall reduce the maximum magnitude of a design fire with a growth rate of 20 MW per minute to a maximum heat release rate of 35 MW. The design fire types considered for the FFSS shall be an open fuel fire and an enclosed heavy goods vehicle fire.

At a minimum, the FFSS shall include the following elements:

- Piping and valves for the FFSS through the tunnel
- Control and isolation valves
- Distribution valves, piping, and nozzles
- Power supply
- Control and monitoring system

19.9.1 System Requirements

The FFSS piping system shall be in a loop configuration. The FFSS shall include provisions for freeze protection as required to maintain full functioning of the FFSS at all ambient weather conditions. Dry valves and piping do not require consideration of heat tracing. Antifreeze shall not be considered for freeze protection.

The FFSS nozzles and appurtenances installed in the tunnel roadway compartment shall be designed and installed to resist mechanical tunnel washing.

The FFSS system shall be monitored and controlled through the FACP.

The performance of the FFSS proposed shall limit the maximum heat release rate to 35 MW under the following cases:

- Fuel tanker fire, assuming rupture of the tanker and a liquid fuel spill on the roadway. The unconstrained maximum heat release rate growth shall be 20 MW per minute.
- Heavy goods truck with a fire occurring in an enclosed trailer. The unconstrained maximum heat release rate growth shall be 20 MW per minute.

For the purpose of the FFSS design, the following operational assumptions shall be made:

- The time from fire ignition to fire detection shall be based on the performance characteristics of the LHD subsystem. Performance characteristics of the LHD subsystem shall be validated through full scale testing. Published results of prior tests shall be submitted to satisfy the full scale test requirement.
- As part of the design, the ventilation system shall be operated in an optimal manner based on fire location.
- It shall be assumed that tunnel operators will initiate the start of the tunnel ventilation system immediately upon alarm from the LHD subsystem.
- It shall be assumed that the FFSS is initiated 60 seconds after the receipt of the alarm from the LHD subsystem. Fill times shall be considered in the analysis of the FFSS operation.
- As part of the design, the existing traffic signal system shall be integrated with the FFSS to allow traffic signal control in the event of activation of the FFSS.

The entire tunnel area shall be covered by the FFSS spray and shall be divided into sections. Minimum section length shall be 80 feet to a maximum of 100 feet; each section shall cover the tunnel from wall to wall. The capacity of the FFSS shall be based on activation of a minimum of two adjacent sections.

Operation of the combined FFSS and existing tunnel ventilation system shall be validated through a Computational Fluid Dynamics (CFD) model. The CFD model shall be calibrated to the performance of the existing tunnel ventilation system and to the performance of the proposed FFSS system. Model calibration shall be validated through field measurement of air speeds in the existing supply and exhaust air ducts, air speeds through a representative selection of air ducts, and air speeds through the tunnel when the ventilation system is functioning. CFD model calibration to the proposed FFSS shall be based on prior full scale tests of the proposed FFSS system. The Contractor shall provide notification to CDOT 14 days before for any model calibration validation testing.

The CFD analysis shall be performed using the design fires and determine the controlling fire condition for the proposed FFSS. The model shall include consideration of worst case outside ambient air temperatures between -30^{o}F and 90^{o}F, adverse wind flow of 30 mph at the portal, and fire location.

Any proposed water supply lines for the FFSS located in the air ducts in the north and south tunnels shall be considered in assessing ventilation system performance in the CFD model.

Information obtained shall be placed in the CFD Analysis Report, which shall be submitted for CDOT Acceptance within 120 days of NTP1.

19.9.2 Design Criteria

The FFSS piping and valves shall satisfy the applicable requirements of NFPA 13 and 502.

System components shall be protected against damage from earthquakes.

No system element shall be attached to the plenum divider walls. Penetrations through the plenum walls, floors, and ductwork shall be sealed air tight.

19.10 Water Supply System

19.10.1 System Requirements

A water supply system shall be developed to provide water to the FFSS. The water supply for the FFSS can be derived from the existing water storage tank, from a new water storage tank, or from a combination of both. Total installed tank capacity shall include consideration of the water supply required for simultaneous operation of the tunnel standpipe system and the FFSS.

The determination of water supply volume required for the existing tunnel standpipe system shall be based on the requirements of NFPA 13, 14, and 502, for a Class I standpipe system, assuming no tank refill is occurring during a fire event. The Contractor shall provide code analysis to support recommendations for system criteria.

The water supply volume for the FFSS shall be sized based upon a minimum of one hour operation of two sections of the FFSS, assuming no tank refill is occurring during a fire event.

Any new water storage tank shall be coated to avoid contamination of the contained water. The water tank shall be monitored for water level and water temperature. The tank shall include a drain valve and overflow outlet, connected to Straight Creek. Venting shall be provided.

At a minimum, the FFSS water supply system shall include the following elements:

- Inspection, cleaning, and application of concrete coating to the interior surfaces of the existing water storage tank
- Inspection, cleaning, and lining of the water line from the existing water tank to the West Ventilation Building
- Filtration equipment and water pumps as required to supply water to any new water storage tank
- Road-level connection to a water supply pump, to permit refilling the water storage tank(s) from trucked water
- Required piping, valves, isolation valves, backflow preventers, pressure-regulating devices, air release valves, and all other appurtenances required for a fully functioning water supply system to the FFSS in compliance with applicable codes and standards for an FFSS
- Flow and level sensors required to monitor, control, and alarm the existing storage tank, new FFSS water storage tank, if any, filtration equipment, pumps (if necessary), and valves

The concrete coating applied to the interior surfaces of the existing water storage tank shall be a flexible concrete waterproofing material suitable for drinking water applications. Surface preparation, priming, and application shall be completed in compliance with the requirements of the material(s) used. Cleaning and lining of the existing water line shall be in accordance with AWWA M28 Class I requirements and the requirements of the material(s) used. Provision for a minimum water supply of 30,000 gallons shall be made during the time the existing water supply system is unavailable.

The FFSS water supply system shall include provisions for freeze protection as required to maintain full functionality of the FFSS water supply system at all ambient weather conditions. Antifreeze shall not be considered for freeze protection.

Filtration shall be provided as required for the operation of the FFSS components.

19.10.2 Design Criteria

The water supply pressure shall be adequate to provide water at the minimum working pressure at two adjacent sections simultaneously. Under dynamic full fire flow conditions, all locations within the system shall be demonstrated to have adequate pressure for the proposed FFSS. Operation of the FFSS shall not reduce the operating pressure or flow rate of the existing tunnel standpipe system.

Pumps, piping, and equipment shall be designed to minimize downtime during repair and maintenance operations.

The FFSS shall be configured to permit testing with water being discharged to the tunnel drainage system. Means shall be provided to permit venting and clearing residual water from the FFSS nozzles following system activation.

19.11 Fire Detection and Control System

The Contractor shall design, supply, install, and test systems for detection of fires in the EJMT for the activation of the FFSS. The Fire Detection and Control System consists of the following subsystems:

- Linear Heat Detector subsystem
- Closed Circuit Television subsystem
- Fire Alarm Control Panel
- Operator Interface System

The LHD subsystem provides fire detection in the EJMT. The FACP monitors the status of the LHD subsystem and provides alerts when a fire has been detected. The FACP also provides monitoring and alerts for the FFSS valves and devices.

The LHD and FACP shall conform to the requirements of NFPA 502.

The OIS processes data streams from the FACP and from the CCTV subsystem and displays the status of all monitored subsystems at workstations located in the EJMT Control Room.

The Fire Detection and Control System shall be designed based on 24/7 monitored operations. Fire detection accuracy shall be sufficient to identify a fire location to within 25 percent of the FFSS section length.

19.11.1 Linear Heat Detector Subsystem

19.11.1.1 System Requirements

An LHD subsystem shall be installed in both bores of the EJMT. The LHD subsystem shall consist of a detector cable and control unit.

The LHD control panel shall provide the same system power supply, supervision, and alarm features as specified for the FACP. The LHD control panel shall be mounted in the EJMT Control Room and at the west portal at locations determined by CDOT.

19.11.1.2 Design Criteria

The LHD subsystem shall be designed and installed by a certified representative of the FACP manufacturer.

The LHD subsystem shall be installed in compliance with NFPA 72. All subsystem components shall be UL listed.

The LHD cable shall comply with UL 521. The cable rating for ambient and alarm temperatures shall be based on numerical modelling (CFD) of the design fires used in the analysis of the FFSS.

Any type of local system trouble for the LHD shall be reported to the FACP as a composite "trouble" signal. Alarms on each detection zone shall be individually reported to the FACP as separately identified zones.

Integral addressable modules shall be arranged to communicate detector status (normal, alarm, or trouble) to the FACP.

The LHD alarm circuits shall be installed in their own dedicated conduit, separated from any open conductors of power, lighting, or Class 1 circuits, and shall not be placed in conduit, junction boxes, or raceways containing such conductors. Detector wiring and control circuits shall be Class A, Style 7 in accordance with NFPA 72.

19.11.2 Closed Circuit Television Subsystem

19.11.2.1 System Requirements

The Contractor shall provide a fully functional low light level CCTV subsystem for surveillance in the EJMT. The CCTV subsystem shall include cameras, Pan-Tilt-Zoom units, encoders/decoders, communication network, network video recorders, and video servers. The CCTV subsystem shall provide continuous overlapping coverage of the entire EJMT with the ability to detect fire conditions.

The CCTV camera images shall be viewable at the Operator Interface Workstations (OIW).

Cameras shall provide continuous overlapping visual coverage through the tunnels. To the extent feasible, CCTV cameras shall be positioned between the existing CCTV cameras in the tunnels.

The Contractor shall furnish, install, and configure a Network Management System (NMS) consisting of a computer workstation and network management software application. The NMS shall provide the ability for a System Administrator to configure, manage, and monitor all devices on the OIS and CCTV communication networks.

19.11.2.2 Design Criteria

The CCTV cameras shall be dome units with full pan-tilt-zoom capabilities. The CCTV cameras shall be IP66-rated sealed units, suitable for installation in the tunnel environment, and have an allowable ambient temperature range of -50°C to 55°C. Cameras shall provide full 1080p image quality at 15 frames per second. Cameras shall be capable of low light level viewing, with minimum light levels of: 0.5 lux (Color), 0.06 lux (Black & White) at F1.6.

A minimum of two dedicated network video recorders shall be provided to record video images from the CCTV cameras. Recording capability for each network video recorder shall be up to 12 simultaneous cameras at 15 frames per second and minimum 4CIF resolution. Video storage capacity for each network video recorder shall be adequate for 72 hours of video recording for 12 cameras at 100% activity, at the frame rate and resolution specified. Playback capability shall be a minimum of four simultaneous playback streams.

The video communications network shall provide adequate bandwidth to support transmission of full-motion video from all CCTV cameras installed in the EJMT. The communication network shall be based on non-proprietary switching equipment that provide self-healing ring capability so in the event of a failure of the ring connected to one switch port, the network shall automatically recover and handle data from the ring connected through another switch uplink port. The ring fault recovery time shall be 600 milliseconds or less.

19.11.3 Fire Alarm Control Panel

19.11.3.1 System Requirements

The FFSS and the LHD shall be controlled by the FACP. The FACP shall automatically detect and report open circuits, shorts, and grounds of wiring for initiating devices. The FACP shall be redundant per NFPA 502 with the primary FACP located at the East Ventilation Building Control Room and the backup FACP located at a CDOT-identified location in the West Ventilation Building.

Automatic alarm response functions resulting from an alarm signal from one device shall not be altered by subsequent alarm, supervisory, or trouble signals. An alarm signal shall have the highest priority. Supervisory and trouble signals shall have second and third level priority. Higher priority signals shall take precedence over signals of lower priority, even when the lower priority condition occurs first. The system shall annunciate and display all alarm, supervisory, and trouble signals regardless of priority or order received. A signal from one device shall not prevent the receipt of other signals.

All signals shall be manually resettable from the FACP after initiating devices are restored to normal. The system shall automatically route alarm, supervisory, and trouble signals to the OIS.

Loss of primary power at the FACP shall initiate a trouble signal at the FACP. The FACP shall indicate when the fire alarm system is operating on the secondary power supply.

Automatic alarm operation of an LHD shall initiate the following:

- Identification at the FACP of the origin of the alarm.
- Transmission of fire alarm signal(s) to the OIS.
- Recording of the event in the system memory.

Alarm silencing, system reset and indication shall be controlled by switches in the FACP. The FACP shall include provisions for manual operation of the FFSS by the tunnel operator at the OIW. Allowed manual operations include activation of the FFSS by section, place an FFSS activation on suspense, override an FFSS initiation, and cancel active operation of the FFSS.

19.11.3.2 Design Criteria

Removal of an alarm-initiating device shall initiate the following:

- A "trouble" signal indication at the FACP for the device involved.
- Recording of the event by the system memory.

The FACP shall be mounted in a lockable, steel enclosure. Interior components shall be arranged so operations required for testing or for normal maintenance of the system are performed from the front of the enclosure.

Individual components and modules within cabinets shall be identified with permanent labels. The FACP enclosure shall be surface-mounted. Local visible and audible signals shall announce alarm, supervisory, and trouble conditions. Each type of audible alarm shall have a different sound.

Individual Light Emitting Diode (LED) devices shall identify transmitting signals. Lights shall distinguish between alarm and trouble signals, and indicate the type of device originating the signal. Manual switches and push-to-test buttons shall not require a key to operate. Controls shall include the following:

- Alarm acknowledge switch
- Alarm silence switch
- System reset switch
- LED test switch

The system shall prevent the resetting of alarm, supervisory, or trouble signals while the alarm or trouble condition still exists.

Alphanumeric display and system controls shall be arranged for interface between human operator at the FACP and addressable system components, including annunciation and supervision, and shall display alarm, supervisory, and component status messages, time and date, and the programming and control menu.

Wiring for the fire alarm system shall be kept physically and electrically separate from all other power and signal system wiring.

Detector wiring and control circuits shall be Class A, Style 7 in accordance with NFPA 72.

19.11.4 Operator Interface System

The OIS shall provide the means for tunnel operators to:

- Examine the status of the devices monitored by the FACP.
- Activate the FFSS through the FACP in the event of a fire in the tunnel.
- View CCTV subsystem camera images.
- Process alarms from interfaced systems and display alarms at the operator workstations.
- Monitor the status of electrical and mechanical systems that are provided as part of the Tunnel Enhanced Fire Safety System.

The OIS shall include the following elements:

- OIS servers running software required to provide specified functions.
- Communication network connecting the OIS servers, the OIW, the CCTV servers, and the FACP.

- OIW that provide an interface between the tunnel operators and the subsystems comprising the Tunnel Enhanced Fire Safety System.

The OIS shall operate through software that processes data from the FACP, and provides for display of CCTV video images at the OIW. OIS software shall run on a minimum of two redundant servers. The servers in the redundant configuration shall operate independently of each other, but shall work as a redundant pair with an infallible tie between them. The primary and secondary servers shall be mirror images of each other, which shall be achieved by utilizing a COTS software product.

The OIS software shall provide a means to log system events and operator actions with time stamp data. Capability shall be provided at the OIW for the operator to format, prepare, and download to a USB device, system activity reports, listing events collected by the OIS software. Standard report formats shall be included in the OIS software based on reporting requirements provided by CDOT. Report formats shall be compatible with Microsoft Office software (Excel or Access).

Initially, the secondary server shall be in stand-by mode; however, throughout the life of the OIS, the two servers shall alternate roles of primary and secondary on demand. In the event of a primary server failure, the secondary server shall automatically take control. When the failed server is brought back on-line, the servers shall reconcile any file inconsistencies between the two and both servers again have full function capabilities. If a primary server fails, or any of the data connections fail, the secondary server shall take over with no loss of data and no functional lapse within 1.0 seconds after the primary server failure.

The OIS shall include a communication network providing data communication between OIS servers, the FACP and the CCTV video image servers. The communication network shall be based on non-proprietary switching equipment that provides self-healing ring capability so in the event of a failure of the ring connected to one switch port, the network shall automatically recover and handle data from the ring connected through another switch uplink port. The ring fault recovery time shall be 600 milliseconds or less.

19.11.5 Operator Interface Workstations

The Contractor shall furnish and install three OIW: one in the East Ventilation Building Control Room, one in the West Ventilation Building at a location to be determined by CDOT, and one in the tunnel superintendent's office at a location to be determined by CDOT. Each of the OIW shall include a central processing unit (CPU), twin LED monitors, keyboard, two USB ports and mouse. Each of the OIW shall include the current Microsoft Office suite in use by CDOT.

Using a graphical user interface (GUI), the OIW shall inform the operator of device events and alarms, allow the operator to log additional event data, enable the operator to examine historical and current alarms and operation, suggest courses of action on alarm, and enable the operator to take control actions.

Operators at the OIW will view and respond to alarms sent to the workstations from the FACP. On alarm, a data logger will track alarms and responses with date and time stamping. The alarms and status provided at the OIW include alarms from the LHD subsystem, alarms from valve tamper and operation switches as part of the FFSS, alarms and operation status from the fire pump control panel (if necessary).

The OIW shall provide a GUI, based on a graphic of the tunnel bores, with icons indicating monitored devices. Alarms and alerts shall be displayed on the monitors for operator viewing and query. On receipt of alarms from field devices, the GUI shall indicate the CCTV cameras that are in range of the alarm location, for operator

selection and image viewing. The OIW shall provide a means to identify the location of a fire, as it relates to the ventilation zones, so the tunnel operator can start the appropriate ventilation fans.

The OIW shall provide the interface that allows tunnel operators to manage response to alarm or fault conditions for equipment monitored and controlled by the FACP. The OIW interface also provides means to manually activate the FFSS by zone.

19.11.6 Operator Interface Subsystem Minimum Functional Requirements

The OIS shall provide the functions described in the ERP. At a minimum, the ERP shall include a strategy for tunnel operator response to an LHD alarm. The LHD response strategy shall include the following:

Upon activation of an LHD, the FACP forwards the alarm notification to the OIS and prepares to activate the FFSS in the zones corresponding to the location of the fire alarm. The OIS issues a 60 second hold to the FACP, inhibiting activation of the FFSS while the hold is in effect. After the hold expires, the OIS releases the hold, causing the FACP to activate the FFSS.

Upon notification of an LHD alarm, the tunnel operator reviews images from the existing tunnel CCTV cameras and the FFSS CCTV cameras to determine if a fire condition exists. The tunnel operator can do any of the following based on the review of conditions in the tunnel:

- Permit the hold to expire, thereby allowing the FACP to activate the FFSS.
- Actuate the FFSS at the OIW by cancelling the hold.
- Place the alarm on suspense for 120 minutes, if there is no fire occurring.
- Activate other FFSS section(s).

If a fire alarm is made and the operator sees there is no fire condition in the tunnel, the alarm may be caused by a fault, rather than by an actual fire condition. On receipt of a fire alarm, the operator views CCTV camera images of the scene; if the operator can conclude the alarm is incorrect, the operator can override the alarm at the OIW. The alarm override function is activated by the operator selecting the OVERRIDE 120 MINUTES button on the OIW. The override function will apply only to the fire zone of the faulty detector and all other tunnel fire zones and detectors will remain active.

Selecting the OVERRIDE 120 MINUTES button while an alarm is active causes a hold command to be sent to the FACP. Upon receipt of the hold command, the FACP subsystem stops the operation of the FFSS.

Selecting the OVERRIDE 120 MINUTES button while the alarm is active also causes the OIS to set a false alarm countdown timer to permit the operator to defer the alarm and complete maintenance on the faulty detector unit. Cancelling an alarm can only be performed at the FACP.

If the operator later determines that a fire is in fact occurring, the operator can run the FFSS by selecting the ALARM RESPONSE RESET button on the OIW. This cancels the false alarm and FFSS hold command.

The tunnel operator can stop the operation of active FFSS sector(s).

19.11.7 Operator Interface Subsystem Video Display Creation and Editing Software Interface

The OIS shall be furnished with a completely installed and tested version of a commercially available COTS video display creation and editing software.

The software shall allow creation and editing of a customized video display. The software shall include full color capability. The software shall allow development and previewing of the screens.

19.12 Electrical System

19.12.1 System Requirements

The Contractor shall design a complete electrical system for all equipment supplied and installed, including but not limited to the water supply system, FFSS, LHD subsystem, CCTV subsystem, and OIS. The Contractor shall coordinate the design and construction of the electrical system with existing tunnel architectural, structural, civil, and mechanical installations.

The architectural, mechanical, and electrical designs shall be integrated to provide adequate space to install and maintain all electrical equipment. No electrical equipment subject to failure shall be installed in any location that would require excavation or tunnel modification to replace such equipment.

Working clearances around electrical equipment shall, at a minimum, meet the requirements of the National Electrical Code, National Electrical Safety Code, and Approved State Building Codes.

The electrical design shall remediate the negative effects of harmonic currents.

The electrical design shall incorporate energy-saving practices.

The electrical design shall use existing operational primary and secondary voltage distribution sources to serve the electrical and control requirements of the new systems. In addition, the electrical design shall verify existing sources consisting of all necessary and required components to form a complete and operational electrical distribution system that provides safety, reliability, and durability for the new systems.

Electrical systems shall support the Tunnel Enhanced Fire Safety System equipment under all normal and emergency modes. Electrical systems supporting the Tunnel Enhanced Fire Safety System elements shall be connected to an emergency power supply system, as defined in NFPA 110 and 502, that is separate from the existing electrical systems. The emergency power supply system shall include a generator capable of powering the Tunnel Enhanced Fire Safety System equipment for a minimum of two hours without refueling.

Uninterruptable Power Source (UPS) backup shall be provided for electronic equipment including servers and workstations. The UPS shall have sufficient capacity to power connected loads for a time period adequate to permit the generator to come up to speed and energize the emergency circuits.

The maximum voltage drop on both feeder and branch circuit loads to the farthest load shall be designed not to exceed the limits specified by regulatory requirements, and in any event, the voltage at each load shall not be less than its minimum rated voltage.

All electrical systems shall be designed for conditions suitable for operation in an environment where adverse conditions (high temperature, adverse winds, gases, soot and smoke, explosives, and highly corrosive atmospheres) are anticipated.

19.12.2 Design Criteria

The Contractor shall design the electrical systems required to provide power for new systems at a suitable voltage for all required loads. The design shall provide electrical power under all conditions to each load defined by the Contractor and as required by the applicable specification requirements. An emergency generator with automatic failover shall be identified and installed to ensure the continuity of power in the event that the primary power

source becomes unavailable. The Contractor shall provide uninterruptable sources of power, in accordance with the requirements of NFPA 502 at all times for the new systems.

Exposed PVC conduit is prohibited from being used.

Conduits mounted in the tunnel air duct:

- All new conduit shall be attached to the tunnel arch structure in the air ducts. All prestressing strands shall remain intact when penetrating the plenum floor/roadway ceiling. No conduit shall be attached to the plenum divider wall.
- Exposed conduit runs shall be neatly installed parallel or at right angles to the walls. Use straps, clamps, or hangers of an approved type made of stainless steel or galvanized malleable iron. Space the attachments as required.

Submit calculations stamped by a Colorado Licensed Professional Engineer with design submittals to verify the conduit supports are capable of supporting the conduit loads.

19.13 Existing Building Modifications

19.13.1 System Requirements

The Contractor shall design and install equipment and system elements in the existing East and West Ventilation Buildings. Equipment to be installed in the East Ventilation Building Control Room includes a replacement operator console, two new operator chairs, one of the OIW, the primary FACP, a low-profile raised floor, two new empty cabinets, and all required wiring and cabling.

Space is available on the East Ventilation Building fan deck for water and/or foam system piping, pumps, and ancillary equipment. Space is available in the East Ventilation Building electrical room for new switchgear as described above.

Space is available in the West Ventilation Building for water and/or foam system piping, pumps, and ancillary equipment. A space 20 foot by 22 foot has been identified in the West Ventilation Building for FFSS pumping equipment and tanks. Space is available in the West Ventilation Building electrical room for new switchgear as described above.

Space allocation and equipment configuration shall be coordinated with CDOT.

19.13.2 Design Criteria

The Contractor shall complete the following modifications to the existing EJMT Control Room.

1. Install low-profile raised flooring over the existing floor in the Control Room. The approximate nominal height of the raised floor shall be 1 inch to 2 inches. Actual height shall be determined from equipment wiring needs and coordinated with CDOT. An ADA-compliant ramp shall be provided inside the Control Room to transition from the existing floor surface to the top of the raised floor. Raised flooring shall be installed at the faces of existing equipment cabinets that are to remain.

2. Remove existing operator’s console and install a new two-person operator console at approximately the same location as the existing. New operating console shall accommodate new FFSS workstations,

monitors and keyboards and relocated equipment from the existing operator's console. Equipment to be relocated to the new console includes the following:

- Camera Chameleon Personal Computer (PC) with shared dual monitors
- Business PC with shared dual monitors
- Video Intercom
- West Portal Control Panel
- Digital Trunking Radio PC
- 3 Video Joystick Controllers
- 2 Tunnel Radio Tone Remotes
- 1 Mutual Aid Channel Tone Remote
- East Portal Control Panel
- 1 receptionist-style telephone
- 1 telephone
- Tunnel Message Board System PC Client
- Vehicle Counting PC Client

Two printers, files, binders, Operation Plans, logbooks, etc. shall be accommodated adjacent to the new console.

3. Provide two new operator chairs as described below.

4. Provide a temporary operator's console and move existing equipment to temporary console during construction to permit continuous tunnel operations.

5. Provide and install a new North Tunnel fan control cabinet. The cabinet shall have space for fan operation switches and indicator lights. The new FFSS controls shall also be in the new control cabinet. The new FACP will either go in the new control cabinet or in another location to be determined by CDOT. This cabinet shall be located adjacent to the existing power control cabinet. All connections made to existing devices at the new cabinet will be completed by CDOT.

6. Provide and install a new South Tunnel fan control cabinet. This cabinet shall have space for fan operation switches and indicator lights and the existing traffic counter device. This cabinet shall be located adjacent to the existing power control cabinet, on the opposite side of the power control panel from the new North Tunnel cabinet. All connections made to existing devices at the new cabinet will be completed by CDOT.

7. Provide power circuits (120 V ac and 125 V dc) to new fan control cabinets. Provide coax and CAT 6 connections as required from the new cabinets to the existing PLC cabinet in the Control Room. Power and communications wiring shall be run via the new raised floor.

8. Provide and install three new ceiling-mounted video display racks above the existing cabinets. Racks shall be secured to the structural ceiling above the existing suspended ceiling. Asbestos abatement shall be required during this Work. Each rack shall include four new 40 inch diagonal full High Definition LED video displays. Electrical and communications connections to the new monitors will be completed by CDOT.

The two new operator chairs shall meet the following requirements:

The chairs shall be fully adjustable (tilt position, forward-tilt control, seat height, back-angle position, back height, seat position, arms up and down, and arms in and out.).

The chairs shall be equipped with a pneumatic-lift mechanism, integral to the chair, to provide vertical adjustment to the backrest, seat and arms. The chair shall be vertically adjustable from 17 inches to 20 inches above the floor.

The chairs shall be equipped with hard rubber wheels and a base mounting with a minimum of 5 prongs.

The arms and seat shall be padded and shall not compress more than 1 inch. The seat shall have a width of approximately 18.5 inches and a depth of approximately 18 inches. Each chair shall have a backrest that is shoulder height.

The high quality chairs shall be designed and constructed for, and proven in, an extended use and industrial environment. The chair's material shall be able to withstand 24-hour heavy usage without deterioration or material break-down beyond normal wear and tear. The chair's material shall be stain-resistant. The cover material shall be a black-colored fabric.

19.14 Testing and Commissioning

19.14.1 Testing

Four tests are required to demonstrate the efficacy of the proposed FFSS system: the Feasibility Test, the Design Configuration Acceptance Test, Tunnel Washing Compatibility Test, and the Construction Acceptance Test.

19.14.1.1 Feasibility Test

The Feasibility Test shall be used to demonstrate the feasibility of a fixed fire suppression system, similar in nature to the proposed system, for effective control of both the heavy goods and liquid fuel type fires. Previously conducted tests can be used to satisfy this requirement; however, the tests must have results for both fuel types. Heat release rates to be controlled may be scaled down. Results from the Feasibility Test shall be included in the Proposal.

19.14.1.2 Design Configuration Acceptance Test

The Design Configuration Acceptance Test shall be designed and conducted following NTP1 and prior to construction of any FFSS elements to be tested. The test shall be a full-scale, cross-sectional mockup of the roadway space of one bore of the EJMT. The nozzle configuration for the test shall match the proposed design. Pressures and flow rates at the individual control valves and nozzles shall model those proposed for final construction. Any proposed additives shall also be used during this test. The length of the test section shall be appropriate to the nozzle spacing, but no less than 40 feet. Fans shall be used to provide a minimum air flow through the test section. Testing procedures shall be submitted to CDOT for Approval a minimum 30 days prior to the test. The test shall demonstrate achievement of the performance requirements by:

- Constraining the maximum magnitude of a design fire with an unconstrained growth rate of 20 MW per minute to a maximum heat release rate of 35 MW.
- Initiating the FFSS 60 seconds after the fire reaches the LHD trigger temperature.
- Testing both heavy goods and liquid fuel fire.

Thermocouples to simulate the readings of the LHD are acceptable.

The Design Configuration Acceptance Test shall not be performed in the EJMT.

The Design Configuration Acceptance Test shall be performed as many times as necessary to successfully demonstrate achievement of the performance requirements. Test results shall be submitted to CDOT for Acceptance, 14 days after successful test completion.

A previously completed test can substitute for the Design Configuration Acceptance Test. The previously completed test shall meet all the requirements of Section 19.14.1.2, including:

- The dimensions of the test space conforms to the roadway space of one bore of the EJMT
- The nozzle type and configuration matches the proposed design
- Pressures and flow rates match the proposed design
- Additives proposed in the design were used during the test
- Tests were performed on both heavy goods and liquid fuel fires with an unconstrained growth rate of 20 MW per minute
- The test FFSS was initiated 60 seconds after the test fires reached the trigger temperature of the LHD proposed in the design

19.14.1.3 Tunnel Washing Compatibility Test

At the beginning of nozzle installation, the Contractor shall coordinate testing of the initial nozzle placement and orientation for compatibility with the existing tunnel washing machine and operation. The test shall confirm compatibility between the nozzles and the existing tunnel washing machine and operation. The test is considered successful when no damage has occurred to the nozzles and the tunnel washing equipment. The test will be witnessed, and results Approved, by CDOT, prior to further nozzle installation. In the event of incompatibility, the Contractor shall propose a different nozzle installation or provide compatible tunnel washing equipment.

19.14.1.4 Construction Acceptance Test

The Construction Acceptance Test shall be performed using the constructed system in the EJMT, at least 30 days prior to the Interim Acceptance of the Project and initialization of the 5-year Maintenance and Operations period. This test is in addition to any tests needing to be performed under NFPA 13. The LHD system shall be tested using a controlled (non-fire) heat source. The automatic and manual actuation systems shall be tested. The system shall be actuated in the most hydraulically remote zone of the system in each tunnel. The flows and pressures shall be measured to ensure the design spray densities are satisfied. The test shall be conducted for a minimum of 10 minutes to demonstrate the capacity of the delivery network. Simultaneously, the standpipe system will be operating to ensure adequate pressures and flows are available to both sprinkler and stand pipe flows. No fires shall be started in the EJMT for this test. A test is considered successful when design spray densities are obtained.

19.14.2 Commissioning

All mechanical, electrical, and software systems shall be tested as part of a complete commissioning program. Commissioning testing shall be performed in accordance with NFPA 13 and 502.

Commissioning tests shall include at a minimum the following elements:

- Component and equipment
- Communication links
- Status, control, alerts, and alarms
- Interfaces between subsystems
- Integration among new and existing subsystems
- Failover on faults
- Functioning of redundant components

Commissioning shall be carried out by a commissioning agent with demonstrated experience in commissioning tunnel systems within the past five years. The Contractor shall complete commissioning of all systems for CDOT Acceptance prior to Interim Acceptance.

The commissioning agent shall prepare and submit a Commissioning Test Plan and Schedule for Approval to CDOT a minimum 90 days before the start of any testing. The test plan shall be based on the technical specifications and performance characteristics of all devices, equipment, parts, assemblies, systems, subsystems, software and devices supplied and installed under this contract. Testing shall be carried out by the Contractor and witnessed and documented by the commissioning agent.

All elements subject to testing shall be included in the testing schedule. Weekly commissioning meetings shall be held beginning 90 days prior to the scheduled start of testing to review the status of the testing and planning for future tests.

All commissioning documentation shall be submitted to CDOT for Acceptance following testing and prior to Interim Acceptance.

A Full Scale Test Program shall be prepared and submitted for Approval. The full-scale system test shall involve non-destructive testing of the all systems supplied and installed to demonstrate compliance with the functional performance requirements of the overall integrated system. The full-scale test shall involve CDOT tunnel operators at the OIW, as the final step in the training of CDOT operators and supervisors on the installed systems.

The scope, methods, and timing of the full-scale test shall be submitted in the Full Scale Test Program for Approval to CDOT 60 days prior to the proposed test date. A Full Scale Test Report shall be prepared and submitted to CDOT for Approval following the test and prior to Interim Acceptance.

19.15 Maintenance and Operations Training

The Contractor shall provide Maintenance and Operations training a minimum of 90 days prior to Interim Acceptance. The Contractor shall provide an EJMT Maintenance and Operations Training Plan and Syllabus 30 days prior to beginning training for review by CDOT. The training shall be conducted by the manufacturer's technical service personnel or factory authorized representatives for all of the systems installed in the EJMT. The Contractor shall provide a minimum of 80 hours of training for each Tunnel Enhanced Fire Safety System subsystem.

The Contractor shall include in the training; operation instructions, theory of operation, circuit description, preventive maintenance procedures, troubleshooting and repair of all equipment specified herein. The Contractor shall include with the training all material and manuals required for each participant. Dedicated systems training for CDOT system administrators shall cover computer systems, hardware, communication networks, and software systems.

19.16 Manuals and Documentation

The Contractor shall provide the draft fire safety system Maintenance and Operations Manual to CDOT for review and Approval 120 days prior to Interim Acceptance. The Contractor shall provide five printed and bound copies and one electronic copy in native editable format of the final Maintenance and Operations Manual within 90 days after CDOT Approval. The Maintenance and Operations Manual shall include catalog cuts, final as-built shop drawings, hardware and software instruction manuals for all systems supplied and installed, stored on USB memory, equipment maintenance, and recommended spare parts. Interim Acceptance of the Tunnel Enhanced Fire Safety System will not be provided until the Maintenance and Operations Manual has been Approved.

The Maintenance and Operations Manual shall include a complete parts list. The parts list shall include a list of all parts supplied under the Contract, down to the lowest level part or assembly that is user-replaceable. Commodity supplies such as conduits, conductors, and pipes do not need to be included. The parts list shall include part numbers, description, system application or use, manufacturer, and supplier. The parts list shall identify sole-source and propriety parts. For all sole-source and proprietary parts, compatible or alternative parts shall be identified. The estimated service life of parts that have a service life less than 30 years shall be identified.

The Maintenance and Operations Manual shall include a complete consumable supplies list. The supplies list shall include a list of all materials required for routine maintenance of the equipment supplied under the Contract. The supplies list shall include material name, description, function, application rate and frequency, manufacturer, and supplier.

19.17 FFSS Short-Term Operations Period

The Contractor shall provide a draft Short-Term Operations Plan (STOP) to CDOT for review and comment no less than 30 days before Interim Acceptance. The STOP shall describe the proposed means by which the Short-Term Operations requirements will be met. The STOP shall include:

- General description of Contractor's approach to maintenance of the Project;
- Maintenance scope and schedule for all equipment installed as part of the Project;
- Strategy for sourcing spare parts, special tools and consumables;
- Warrantees on equipment;
- A staff organization chart and staffing plan including all positions, qualifications, training and certification processes, work locations, and assignments required for the maintenance work;
- List of subcontractors employed to undertake maintenance work with associated scope of responsibility;
- Strategy for responding to fault conditions;
- Approach to performing annual system test;
- Safety Manual that includes staff training, safety procedures and protocols to address the hazardous conditions associated with the Maintenance work; and,
- The first year AMP.

The Contractor shall submit the final STOP to CDOT for Approval 21 days following receipt of comments on the draft version, from CDOT.

The Contractor shall prepare an AMP. The AMP shall describe all maintenance activities planned for completion during the following 12 months. The AMP shall include the expected dates, locations, times, and durations of each planned maintenance activity.

The AMP shall be submitted to CDOT for review and Approval at least 30 days prior to the commencement of the year scheduled.

The STOP shall include consideration of warranties included with the equipment provided. Warranties can be used to make necessary repairs, at the Contractor's option. A standard manufacturer's warranty shall be furnished for each major item which is furnished and installed or otherwise provided to CDOT. The warranty documentation shall be provided to CDOT and a copy shall be included in the Maintenance and Operations Manual.

A pay adjustment for Nonconforming Work will be assessed in conformance with Book 1, Section 5.7.2. Work is considered Nonconforming when performance falls outside the Performance Indicator parameter as shown in the table below.

Table 19-1: Maintenance Work Performance Requirements

Element Category	Required Task	ID	Performance Requirement	Performance Indicator
Annual Planned Maintenance Schedule	Annual Maintenance Plan	1	Beginning from NTP2, deliver the Annual Maintenance Plan to CDOT	30 days prior to the start of the Short-Term year
Equipment failures	Clear Emergency Failures	2	Clear Emergency Failures within stipulated time	Mean Time To Respond (MTTR) no greater than 8 hours
	Clear Priority Failures	3	Clear Priority Failures within stipulated time	MTTR no greater than 24 hours
	Clear Routine Failures	4	Clear Routine Failures within stipulated time	MTTR no greater than 72 hours
Routine Maintenance	Complete routine maintenance	5	Complete routine maintenance according to Annual Maintenance Plan	All maintenance tasks completed before end of Short-Term year
Emergency Response Drills	Conduct annual emergency response drills	6	Organize and conduct full system test at a minimum rate of once per year	Once during Short-Term year
Maintenance Reports	Annual Maintenance Report	7	Prepare and deliver the Annual Maintenance Report for the prior year to CDOT for review	30th day of the new Short-Term year

The Contractor shall perform an annual system test of the FFSS to validate system performance within specifications and operational parameters and shall repair and/or replace all system components that do not meet operational requirements.

The Contractor shall have no liability for repair or replacement of system elements that are damaged or destroyed in a tunnel fire or in a traffic accident in the tunnel.

The Contractor shall provide documentation of all testing, repairs, and maintenance service performed, including dates and results of tests, dates and description of service performed on equipment and systems, including replacement of parts and assemblies. The Maintenance and Operations Manual parts list shall be updated as parts and assemblies are replaced.

The Contractor shall perform repairs during the short-term operational period to achieve the reliability requirements specified herein.

Emergency Failures: An emergency failure is any failure that prevents the monitoring and control of equipment supplied and installed. The following conditions shall constitute emergency failures:

- Loss of the ability to control or monitor two or more devices.
- Loss of the ability of the CCTV subsystem to process video images, control or monitor video images from two or more cameras.
- Loss of the ability to control or monitor the LHD subsystem.
- Loss of functionality of all OIS operator console workstations. Loss of functionality shall include hardware and software failures of the CPU, monitor, keyboard, and mouse.
- Loss of both the primary and secondary servers comprising a redundant pair.
- Loading of computer resources including CPU, memory, and mass-storage media (e.g., disk) usage above 90 percent averaged over a 30-minute period for any server or workstation.
- Two or more priority failures, as defined herein, active at the same time.

Priority Failures: A priority failure is any failure that eliminates the redundancy of a subsystem or affects the information processing functions of the computer hardware and software. A priority failure also includes any failure that degrades performance so that the system capability is reduced, but not eliminated. The following conditions shall constitute priority failures:

- Loss of the ability to control or monitor one device.
- Loss of the ability of the CCTV subsystem to control or monitor video images from one CCTV camera.
- Loss of either the primary or secondary server comprising part of a redundant pair.
- Loss of functionality, as defined herein, of one OIS operator console workstation.
- Loss of information processing functions including, but not limited to, alarm management, graphics and video display management, and database logging and reporting.
- Loading of computer resources including CPU and mass-storage media (e.g. disk) usage above 60 percent averaged over a 30-minute period for any server or workstation.

Routine Failures: A routine failure is a failure that impairs system performance, but permits the system to perform its designed functional capabilities. The failure of any single system component that does not result in an emergency or priority failure shall be classified as a routine failure.

The Contractor shall respond to failures and complete repairs to restore system function so as to maintain the following Mean Time to Respond (MTTR) on a 12-month basis.

- Emergency Failures: MTTR less than or equal to 8 hours
- Priority Failures: MTTR less than or equal to 24 hours
- Routine Failures: MTTR less than or equal to 72 hours

Response time begins when CDOT notifies the Contractor of a failure condition and ends when the Contractor arrives on site. The Contractor shall maintain a 24-hour, 7 days per week service to receive and log failure condition notifications from CDOT.

19.18 Spare Parts

For sole-source and/or propriety parts, the Contractor shall provide the quantity of spare parts required to achieve the 30-year service life.

19.19 Deliverables

The Contractor shall submit the following to CDOT for Review, Approval, and/or Acceptance:

Table 19-2: Deliverables by the Contractor

Deliverable	Review, Acceptance, or Approval	Schedule
Codes and Standards List	Approval	60 days after NTP1
Preliminary Requirements Traceability Matrix	Approval	60 days after NTP1
Functional Allocation	Approval	With monthly RTM sychronization
Design Baseline Report	Approval	90 days after NTP1
Construction Sequencing Plan	Approval	Minimum 30 days prior to NTP2
CFD Analysis Report	Acceptance	120 days after NTP1
Design Configuration Acceptance Test procedures	Approval	Minimum 30 days prior to test
Design Configuration Acceptance Test results	Acceptance	14 days after successful test completion
Tunnel Washing Compatibility Test results	Approval	Prior to nozzle installation
Construction Acceptance Test	Acceptance	Minimum 30 days prior to Interim Acceptance
Commissioning	Acceptance	Prior to Interim Acceptance
Commissioning Test plan and schedule	Approval	90 days before start of testing
Commissioning Documentation	Acceptance	Following Testing and Prior to Interim Acceptance
Full Scale Test Program	Approval	60 days prior to proposed test date
Full scale test report	Approval	Prior to Interim Acceptance
Maintenance and Operations Training Plan and Syllabus	Review	30 days prior to beginning training
Draft Maintenance and Operations Manual	Approval	120 days prior to Interim Acceptance
Draft Short Term Operations Plan	Review	Minimum 30 days prior to Interim Acceptance
Final Short Term Operations Plan	Approval	21 days after CDOT comments received on draft version
Annual Maintenance Plan	Approval	30 days prior to the start of the Short-Term year
Annual Maintenance Report	Review	30th day of the new Short-Term year

All deliverables shall also conform to the requirements of Book 2, Section 3.