EXPECTED IMPLEMENTATION JANUARY 2016

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462 POST-TENSIONING.
(REV 8-18-15) (FA 8-19-15) (1-16)

SECTION 462
POST-TENSIONING

462-1 Description.

1. Furnish, transport, store, handle, and install all components of Post-Tensioning (PT) systems, in accordance with the requirements of this Section and the component manufacturer's recommendations. Constituent components of PT systems include, but are not limited to, anchorage assemblies, filler containment assemblies, filler material, and related steel reinforcement. Use the most stringent requirements, as determined by the Engineer, of those specified in this Section or the component manufacturer's recommendations for protecting components from damage due to environmental exposure, improper handling, or improper installation.

2. With the exception of mild reinforcing and prestressing steel, furnish all PT system components from a single supplier.

a. Use only approved PT systems meeting the requirements of Section 960 and selected from the Structures Design Office (SDO) website for Approved Post-Tensioning Systems.

b. Use only PT systems of appropriate type and size required to construct tendons shown in the Contract Documents.

c. With the exception of local zone reinforcement, do not substitute, modify, or delete any components of an approved PT system. Inclusion of all possible subcomponents is required for PT system and component testing; however, subcomponents of approved systems may be eliminated from final installations based on project-specific requirements, provided all component-to-component interface hardware are included as necessary to maintain connections and PT system integrity.

3. Install the PT tendon (e.g., strands, wires, or bars) in ducts. Stress the PT tendon to a predetermined load and anchor ends directly against hardened concrete. After anchoring the PT tendon, install permanent anchorage caps, inject ducts with filler to completely fill voids, and install protection at anchorages.

4. Submit all required documents in accordance with this Section and Section 5 to the Engineer for review and written approval.

5. Cable stays are not covered by this Specification.

6. Install duct filler in accordance with the requirements of this Section. Provide fully filled duct and anchorage assemblies free from leaks, blockages, and voids. Provide sufficient test data to the Engineer to verify that the work meets the requirements of this Section. Perform filler injection operations in accordance with 462-4.

462-2 Materials.

462-2.1 General:

Approval of any material by the Engineer will not preclude subsequent rejection if material is damaged or otherwise found to not meet the requirements of this Section or Section 960.

462-2.2 Steel Reinforcing:

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462-2.2.1 Mild:

1. Provide reinforcing steel per Section 931.
2. Final design and details of local zone reinforcement are project specific and are the responsibility of PT system supplier. Design project specific local zone reinforcement for the number of strands or wires a particular approved PT system can accommodate at maximum allowable strand or wire force; do not design project specific local zone reinforcement for a reduced system capacity.
3. Submit signed and sealed project specific local zone reinforcement details to the Engineer for review and written approval.

462-2.2.2 Prestressing:

462-2.2.2.1 Strand:

1. Provide prestressing strands per Section 960.
2. Strand couplers are not permitted.

462-2.2.2.2 Bar:

1. Provide prestressing bars per Section 960.
2. For permanent applications, use and location of bar couplers is subject to written approval by the Engineer.

462-2.2.2.3 Parallel Wire:

1. Provide prestressing parallel wire assemblies per Section 960.
2. Wire couplers are not permitted.

462-2.3 Duct Filler: Use only grout and flexible filler meeting the requirements of Section 938 and are listed on the Department's Approved Product List (APL).

462-2.3.1 Grout:

1. Select grout for use in PT system by application: repair, horizontal, or vertical.
2. Mix grout per manufacturer's instructions with potable water meeting requirements of Section 923.

462-2.3.2 Flexible Filler: Prepare filler for installation in accordance with the manufacturer's instructions.

462-2.4 Other Material References:

Meet the requirements of this Section, as well as the following:

Class 5 Applied Coating* .....Section 975
Elastomeric Coating System* .....Section 975
Epoxy Compound* .....Section 926
Magnesium Ammonium Phosphate Concrete* .....Section 930
Methacrylate* .....Section 413
Water Section 923
*Use products listed on the Department's Approved Product List (APL).

462-2.5 Component Samples:

462-2.5.1 Prestressing Steel:

1. Furnish samples per Section 933 from each manufacturer of prestressing strand, wire, and bar to be used on project.
2. The Engineer will collect sample materials from prestressing steel used for PT operations on the Project.
3. Samples, properly identified and tagged per 462-6, will be stored by the Engineer.

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462-2.5.2 Grout:

1. The Engineer may sample grout packages at random, not to exceed a total quantity of one bag per LOT or shipment.

2. Grout sample may be virgin package mix, liquefied state, or solid state; Engineer will determine at what frequency, interval, sample phase (powder, liquid or solid) and location those samples will be recovered from the project.

3. Sample, properly identified and tagged per 462-6, will be stored by the Engineer.

462-2.5.3 Flexible Filler:

1. The Engineer may sample flexible filler at random, not to exceed a total quantity of one gallon per LOT. A LOT is defined as a single production batch or shipment not to exceed 1,000 gallons.

2. Sample may be virgin product in liquefied state or solid state. The Engineer will determine at what frequency, interval, sample phase (liquid or solid) and location those samples will be recovered from the project.

3. Sample, properly identified and tagged per 462-6, will be stored by the Engineer.

462-3 Alternate PT System Designs.

Designs using a PT scheme different from that shown in the Contract Documents may be submitted for the Engineer's approval provided proposed scheme fulfills, and the Contractor demonstrates, compliance with these requirements:

1. PT system type and size meets all requirements of this Section.

2. Net compressive stress in the concrete after all prestress losses is equivalent to or greater than that provided by the PT scheme shown in original Contract Documents.

3. Distribution of individual tendons at each cross section generally conform to the distribution shown in original Contract Documents.

4. Proposed PT scheme meets the ultimate strength requirements of the American Association of State Highway and Transportation Officials Load and Resistance Factor Design, AASHTO LRFD Bridge Design Specifications Section 5, and is equivalent to or greater than service and strength limit states provided in original Contract Documents.

5. Stresses in concrete and PT steel at all sections and at all stages of construction meet requirements of the Design Criteria shown in original Contract Documents.

6. All Design Criteria provisions noted in original Contract Documents are satisfied.

7. Show complete design and detail of all elements for proposed locations of alternate PT scheme.

8. Submit the following for the Engineer's approval:

a. design calculations including short and long term prestress losses

b. complete shop drawings including PT scheme and system, reinforcing steel, and concrete cover

9. Any alternate PT system approved by the Engineer resulting in a change in quantity from that shown in the Contract Documents is paid based on comparison of the following:

a. quantity actually used and accepted or original plan quantity, whichever is less, and

b. unit bid price.

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If approved alternate PT scheme or system is under a Cost Savings Initiative Proposal (CSIP), method of payment will be in compliance with CSIP agreement.

10. Submit alternate PT scheme signed and sealed by the Contractor's Engineer of Record.

462-4 Qualifications.

Provide all project personnel and crew foreman in accordance with Section 105.

462-5 Submittals.

462-5.1 Shop and Working Drawings:

1. Submit to the Engineer all necessary information, Plans, shop and working drawings, and manuals in accordance with this Section and Section 5. Submit to the Engineer signed and sealed PT related shop drawings designed by the Contractor's Engineer of Record.

2. Prepare shop drawings addressing all requirements stated in the Contract Documents and requirements of this Section. Indicate pre-approved PT systems to be used as shown on the SDO website for Approved Post-Tensioning Systems. Show details of tendon geometry and locations complying with the Contract Documents and limitations of selected PT system. Include all inlets, outlets, high point outlet inspection details, anchorage inspection details, permanent anchorage caps, protection system materials, and application limits.

462-6 Transport, Handling and Storage.

462-6.1 General:

Store all materials in a weatherproof building, shed, covering, or container until time of use.

462-6.2 LOT Identification:

1. Assign an individual LOT number and tag items shipped to project in a manner that allows each LOT to be clearly identified at project site for all PT system components, filler, bars of each size from each mill heat of steel, and all strands from each manufactured reel.

2. Submit records to the Engineer identifying assigned LOT numbers with heat or reel of material represented if applicable.

3. All unidentified prestressing components, strands, wires, bars, or filler received at the site will be rejected.

4. Loss of positive identification of these items at any time will be cause for rejection.

5. Provide a copy of filler Quality Control Data Sheet received from the manufacturer, to the Engineer for each LOT on the project.

6. Material with a total time from manufacture in excess of six months must be retested and certified by supplier before use or be removed from project and replaced with new material.

462-6.3 Prestressing Steel:

1. Protect all prestressing steel against physical damage and corrosion at all times.

a. Package prestressing steel in containers for protection against physical damage and corrosion during shipping and storage.

b. Place a corrosion inhibitor, which prevents rust, in package or incorporate it into a corrosion inhibitor carrier type packaging material.

c. Corrosion inhibitor must have no deleterious effect on steel, filler, concrete, or bond strength of steel to concrete.

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d. Inhibitor carrier type packaging material must conform to provisions of Federal Specification MIL-P-3420.

e. Immediately replace or restore damaged packaging to original condition.

f. Clearly mark shipping package with a statement that package contains high-strength prestressing steel, care to be used in handling, include type, kind, and amount of corrosion inhibitor used, date when placed, safety orders, and instructions for use.

2. The Engineer will reject prestressing steel that has sustained physical damage.

3. Remove and discard lengths of strand found to contain broken wires.

4. Wire must be bright and uniformly colored, with no foreign matter or pitting on its surface.

462-6.4 Filler:

1. Maintain filler in environmental exposure conditions (e.g., temperature, humidity) in strict conformance with manufacturer's recommendations at all times from manufacture to installation.

2. Storage in the open must be on a raised platform and with adequate waterproof covering to protect the filler.

3. On site storage is limited to a maximum period of one month.

4. Do not use stored filler that has exceeded the manufacturer's recommended usage date. Remove all such filler from the jobsite.

462-6.5 Duct and Pipe:

1. Protect ducts against ultraviolet degradation, crushing, excessive bending, dirt contamination, corrosive elements, or any other damage or contamination during transport, storage, and handling.

2. Furnish ducts with end caps to prevent contamination inside duct. Do not remove duct end caps until duct is incorporated into the bridge component.

3. Ship capped duct in bundles that are covered during transport and storage.

4. Store on a raised platform and completely covered to prevent contamination.

5. If contamination is discovered, immediately flush duct with potable water per 462-7.2.4 before use.

462-7 Construction.

462-7.1 General:

1. Furnish the Engineer with written certification from PT supplier (vendor) that PT system chosen for the project meets requirement of this Section, Section 960, and is a Department approved PT system prior to installing any PT hardware.

2. Provide a list of PT system components and reference drawings to the Engineer.

3. Use methods to place and consolidate concrete that will not displace or damage any PT ducts, anchorage assemblies, splices and connections, reinforcement, or other embedded items.

4. Conduct all stressing and filler injection operations in the presence of the Engineer.

462-7.2 System Installation:

Accurately and securely fasten all PT anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other embedded items at locations shown in the

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Contract Documents or on approved shop or working drawings or as otherwise approved by the Engineer in writing.

462-7.2.1 Ducts:

1. Construct tendon ducts using the minimum number of splices as practical.

2. Accurately position and align ducts at locations shown in the Contract Documents, or according to approved shop or working drawings, or as approved in writing by the Engineer.

3. Securely fasten all internal ducts at regular intervals not exceeding 30 inches for steel pipes, 24 inches for round plastic ducts, and 12 inches for flat ducts to prevent movement, displacement, or damage from concrete placement and consolidation operations.

4. Show method and spacing of duct supports on appropriate shop drawings.

5. Ensure external tendon ducts are straight between connections to internal ducts at anchorages, diaphragms, and deviation saddles and are supported at intermediate locations according to the Contract Documents including approved shop drawings.

6. Ensure all alignments, including curves and straight portions, are smooth and continuous with no lips, kinks, or dents. This also applies to curves in pre-bent steel pipe.

7. Check and repair all ducts in accordance with 462-7.5 as necessary before placing any concrete.

8. Ensure ducts at end connections to anchorages, splices, inlets, outlets, drains, and all other duct openings are sealed at all times after installing ducts and until tendon installation is complete. Briefly open low point drains just prior to tendon installation and again just prior to filler injection to allow for drainage of any water that may be present within the duct.

9. Provide an absolute seal of anchorage and duct termination locations per the pre-approved system drawings.

10. Use of tape is not permitted to make connections for any reason.

11. Use heat welding techniques, in accordance with duct manufacturer's instructions, to make splices between sections of smooth plastic duct or make connection with electrofusion duct coupler meeting the material requirements of Section 960 and approved system drawings.

12. When connecting steel pipe to plastic pipe with a boot, use a 3/8 inches wide power seated band and clamps in accordance with 960-2.2 on each end of a duct boot to seal against filler leakage. Install band per manufacturer's instructions.

13. Ducts for prestressing used exclusively for temporary erection where PT will be removed from structure are not required to be coupled across segment joints.

462-7.2.1.1 Installation Tolerances:

1. Ensure final position of PT ducts is within the tolerances in the following table:

Table 7.2.1.1-1 Duct Installation Tolerances

Type	Vertical Position (inches)	Horizontal Position (inches)
Horizontal tendons in slabs or in slab regions	±1/4	±1/2

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of larger members		
Longitudinal draped superstructure tendons in webs: Tendon over supports or in middle third of span	±1/4	±1/4
Tendon in middle half of web depth	±1/2	±1/4
Longitudinal, generally horizontal, superstructure tendons usually in top or bottom of member	±1/4	±1/4
Horizontal tendons in substructures and foundations	±1/2	±1/2
Vertical tendons in web	Longitudinal Position ±1	Transverse Position ±1/4
Vertical tendons in pier shafts	±1/2	±1/4
All other cases	±1/4	±1/4

2. Ensure entrance and exit angles of tendon paths at anchorages, duct joints, and/or at faces of concrete are within plus or minus 3 degrees of desired angle measured in any direction.

3. Accomplish any deviations in alignment with smooth unkinked transitions.

4. Locate anchorages within plus or minus 1/4 inches of desired position laterally and plus or minus 1 inch along tendon except that minimum cover requirements must be maintained.

5. Position anchorage confinement reinforcement in the form of spirals, multiple U-shaped bars, or links centered around duct and starting within 1/2 inches of the back of the main anchorage plate.

6. If conflicts exist between reinforcement and a PT duct, position of duct prevails. Adjust local reinforcement with the Engineer's written approval.

462-7.2.2 Splices and Joints:

1. All splices, joints, couplings, connections (inlet and outlet), and valves are part of approved PT system.

2. Fabricate all duct splices to prevent duct kinks during concrete placement.

3. Use mandrels as needed to maintain duct alignment and shape.

462-7.2.3 Inlets, Outlets, and Drains:

1. Place filler inlets/outlets and drains at locations shown in the Contract Documents including approved shop drawings.

2. Equip all filler inlets/outlets and drains with approved positive shut-off devices (e.g., valves).

3. At a minimum, place filler inlets/outlets in the following positions and those shown in Design Standards, Index No. 21801:

a. Top of tendon anchorage;

b. Top of anchorage cap;

c. At high points of duct profile when vertical distance between highest and lowest point is more than 20 inches;

d. At major change in duct cross section; and,

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e. At other locations required by the Engineer.

4. For all tendons other than grouted top slab transverse tendons in box girders, place drains at the geometric low points of all duct profiles, or as close as is practical to the geometric low points of all duct profiles, except where an inlet, outlet or anchorage that can serve as a drain is located at a low point. Locate drains, and inlets and outlets serving as drains, at the bottom of the duct cross section.

5. Extend filler and drain tubes a sufficient distance out of concrete member to allow for proper closing of valves.

6. Direct inlets, outlets and drains exiting on vertical or predominantly vertical surfaces of box and I-girders toward the inside face of exterior I-girders or toward the interior of box girders.

462-7.2.4 Tendons:

1. Do not exceed 14 calendar days between first installation of prestressing steel within duct and completion of the stressing and filler injection operation for PT bars located in superstructure and all strands and wires regardless of location.

2. Do not exceed 21 calendar days between the first installation of prestressing steel within duct and completion of the stressing and filler injection operations for PT bars located in substructure.

3. Any light surface corrosion forming during the period of time described in (1) or (2) will not be cause for rejection of prestressing steel.

4. Failure to inject filler into duct within the number of calendar days specified, will result in stoppage of work, except when waived by the Engineer in writing.

5. Flushing of filler is not permitted without written approval of the Engineer and is only permitted as defined in this Article.

6. Vacuum injection is required to repair all voids and blockages as subject to provisions of 462-8.3.2.

7. For tendon ducts subjected to contamination with chlorides (e.g., uncapped ducts that have been subjected to salt spray), flush duct with potable water containing slack lime (i.e., calcium hydroxide) or quicklime (i.e., calcium oxide) in the amount of 0.17 pounds per gallon.

a. Test for presence of chlorides and oils in discharged water before placing tendon.

b. If chloride levels in flush water outflow exceed 300 ppm, continue to flush duct until chloride level in flush water outflow is below 250 ppm.

c. Dry duct interior by blowing oil-free compressed air, by vacuuming, or by other means deemed acceptable to the Engineer. Remove excess water trapped in duct corrugations. The Engineer may require use of a borescope or other visual inspection means, at no additional cost to the Department, to ensure duct interior is water free.

8. Push or pull strands and wires through ducts to make up a tendon using methods that will not snag on any lips or joints in ducts.

9. Round off end of strands and wires that are pushed or fit advancing end with smooth protective cap.

10. Do not intentionally rotate strands or wires by any mechanical means during installation of PT strand into duct.

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11. For superstructure tendons, provide sufficient strand and wire length beyond dead end anchorages to allow for second end stressing as needed for reconciliation of jacking force versus measured elongation.

12. Alternatively, tendons may be pulled through duct using a special steel wire sock or other device attached to advancing end. Strands may be brazed together for pulling as long as one foot of strand from the brazed end is removed by cutting after installation. Do not electric arc weld strand ends together for this purpose.

13. Cut tendons in accordance with 462-7.3.2.7.

14. Strand installation aids (i.e. wire/nylon ties around strand bundle, strand spacers, etc.) must be removed prior to stressing

15.Do not install permanent tendons before completion of testing as required by this Section or the Contract Documents. The only two exceptions are:

a. Tendon to be tested by “Theoretical Elongation Verification” may be installed for test; and,

b. Transverse tendons may be pre-installed in precast segmental boxes prior to concrete casting such that they meet 462-8.3.1.

462-7.3 Post-Tensioning Operations:

1. Do not apply PT forces until concrete has attained compressive strength specified in the Contract Documents.

2. Conduct all stressing operations in presence of the Engineer.

3. With the written approval of the Engineer, revise PT operations so final tendon force is in agreement with the Contract Documents.

462-7.3.1 Stressing Equipment:

Only use equipment furnished by supplier of PT system.

462-7.3.1.1 Jacks and Gauges:

Equip each jack with pressure gauge for determining jacking pressure that has a minimum dial diameter of six inches.

462-7.3.1.2 Calibration:

1. Calibrate each jack and its gauges as a unit.

2. Calibration must consist of three test cycles with cylinder extension of jack in various positions (e.g., two-inch, four-inch, eight-inch stroke).

3. At each pressure increment, average forces from each test cycle to obtain an average force.

4. Perform calibration with equipment (e.g., jack, pump, hoses, etc.) setup in same configuration intended for use on Project.

5. Jack and gauge calibration is to be initially performed by PT supplier or an independent laboratory.

6. Use load cells calibrated within the past 12 months to calibrate stressing equipment.

7. Supply documentation denoting the load cells calibration date and tractability to National Institute of Standards and Technology (NIST) along with jack/gauge calibration.

8. Provide the Engineer with certified calibration charts and curves for each jack and gauge unit used on the project prior to start of work and every six months thereafter or as requested by the Engineer.

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9. Calibrations subsequent to initial calibration with a load cell may be accomplished with use of a master gauge. Supply master gauge to the Engineer in a protective waterproof container capable of protecting calibration of gauge during shipment to a laboratory. Provide a quick-attach hydraulic manifold to enable quick and easy installation of master gauge to verify permanent readings. Master gauge will remain in the possession of the Engineer for duration of project and will be returned to the Contractor after final acceptance of project by the Engineer.

10. Any jack repair, such as replacing seals or changing length of hydraulic lines, requires recalibration using a load cell.

11. No extra compensation will be allowed for initial or any subsequent calibrations or use of master gauge required by the Engineer.

462-7.3.2 Stressing Tendons:

1. Tension all PT steel so PT force is not less than that required by the Contract Documents or as otherwise approved by the Engineer in writing.

2. Do not use monostrand jacks to stress tendons with five or more strands or wires.

3. Use of curved stressing noses or chairs is not permitted.

462-7.3.2.1 Jacking Maximum Stress:

Maximum temporary stress (i.e., jacking stress) in PT steel must not exceed 80% of Guaranteed Ultimate Tensile Strength (GUTS).

462-7.3.2.2 Initial and Permanent Stresses:

1. PT steel must be anchored at initial stresses resulting in long term retention of permanent stresses or forces of no less than those shown in the Contract Documents.

2. Unless otherwise approved by the Engineer in writing, initial stress after anchor set must not exceed 70% of GUTS.

3. Permanent stress and permanent force are stress and force remaining in PT steel after all losses, including long term creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, losses in PT steel from sequence of stressing, friction, and unintended wobble of ducts, anchor set, friction in anchorages, and all other losses particular to the specific PT system.

462-7.3.2.3 Stressing Sequence:

1. Permanent PT tendons must be stressed from both ends, except as noted in the Contract Documents.

2. Required force may be applied at one end and subsequently at other end or simultaneously at both ends.

462-7.3.2.4 Elongation:

1. Ensure forces being applied to tendon and resulting elongation of tendon can be measured at all times.

2. Measure elongations to nearest 1/16 inch.

3. For required tendon force, observed elongation must agree within 7% of theoretical elongation or entire operation must be halted, checked, and source of error determined and remedied to satisfaction of the Engineer before proceeding.

4. Do not overstress tendon to achieve theoretical elongation.

5. In event that agreement between observed and theoretical elongations at required force falls outside acceptable tolerances, the Engineer may, at his

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discretion and without additional compensation to the Contractor, require additional tests for Tendon Modulus of Elasticity and/or In Place Wobble and Friction Test.

462-7.3.2.5 Friction:

1. Provide actual expected friction and wobble coefficients and anchor set in the shop drawings; submit calculations and show a typical tendon force diagram on shop drawings based upon expected actual coefficients and values for the PT system to be used.

2. Graphite may be used as a lubricant when friction must be reduced, subject to written approval of the Engineer.

462-7.3.2.6 Tendon Wire Failure:

1. Multi-strand PT tendons with wires which fail by breaking or slipping during stressing may be accepted provided these conditions are met:

a. Completed structure has a final PT force of at least 98% of original total design PT force;

b. PT force across a mating joint is at least 98% of PT force required by the Contract Documents for that mating joint for that stage of construction for precast or cast-in-place segmental construction. This 98% minimum PT force requirement applies to segmental construction, or any similar construction, that has members post-tensioned together across a common joint face at any stage of construction; and,

c. Any single tendon must have no more than a 5% reduction in cross-sectional area of PT steel due to wire failure.

2. When conditions permit the Contractor to propose acceptable alternative means of restoring PT force lost due to wire failure, any of the above conditions may be waived at discretion of and with approval of the Engineer in writing.

462-7.3.2.7 Cutting of PT Steel:

1. Cut PT steel using an abrasive saw or plasma torch within 3/4 inches to 1-1/2 inches away from the anchorage.

2. Flame cutting of PT steel is not permitted.

3. Do not cut tendon to final length prior to acceptance.

462-7.3.2.8 Post-Tensioning Operations Record:

1. Keep a record of these PT operations for each tendon installed:

a. Project name, Financial Project ID (FPID);

b. Contractor and/or subcontractor;

c. Tendon location, size, and type;

d. Date tendon was first installed in duct;

e. Reel number for strands and wires and heat number for bars;

f. Tendon cross-sectional area;

g. Modulus of elasticity;

h. Date stressed;

i. Jack and Gauge numbers per tendon end;

j. Required jacking force;

k. Gauge pressures;

l. Elongations (theoretical and actual);

m. Anchor sets (anticipated and actual);

n. Stressing sequence (i.e., sequential order of tendon stressing by number);

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o. Stressing mode (single-end, dual-end, simultaneous);

p. Witnesses to stressing operations (Contractor and Inspector);

q. Any other relevant information.

2. Provide the Engineer with a complete copy of all stressing operation records within five days of completed tendon installation.

462-7.3.3 System Protection:

462-7.3.3.1 Tendon:

1. Install anchorage caps and seal all other duct openings within four hours after stressing.

2. Seal all openings and temporarily weatherproof open ends of anchorage if acceptance of tendon is delayed.

3. If tendon contamination occurs and if directed by the Engineer, remove tendon, flush duct with potable water per 462-7.2.4, and replace with new tendon.

462-7.3.3.2 Anchorage:

1. Protect PT strand, wire, and bar anchorages as indicated in the Contract Documents within seven days of completing filler injection operations (see 462-7.4 for filler injection operations).

2. Cap all filler inlets/outlets with plugs meeting the requirements of Section 960.

3. Construct anchorage pour-backs with a Type Q epoxy grout per Section 926 within 28 days of permanently affixing all anchorage caps within each individual pour-back.

a. Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting. Flush surface with water and blow dry. Surfaces must be clean, sound, and without any standing water. Test substrate at all pour-back locations using ACI 503 and develop a minimum of 175 psi tension (e.g., pull-off value). Testing frequency may be reduced, as determined by the Engineer, after the Contractor has demonstrated an ability to prepare substrate surfaces for bonding as indicated by the result of the ACI 503 test.

b. Mix and apply epoxy grout in accordance with the manufacturer's current standard technical guidelines. Construct all pour-backs in leak proof forms creating neat lines. Epoxy grout may require pumping for proper installation. Construct forms to maintain a liquid head to ensure intimate contact with concrete surface. Use vents as needed to provide for escape of air to ensure complete filling of forms.

4. Coat exposed surfaces of all pour-backs and anchorage caps with an elastomeric coating system meeting requirements of Section 975 and having a thickness of 30 mils to 45 mils. Assure concrete, anchorage caps, or other substrates are structurally sound, clean, and dry. Concrete must be a minimum of 28 days old. Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting using a minimum 10,000 psi nozzle pressure. Blow surface with compressed air to remove dust or water. Apply the elastomeric coating within 90 days of filler injection. Apply a manufacturer's approved primer over the elastomeric coating before applying Class 5 coating, if required.

5. Prior to application of elastomeric coating, construct a 2 foot x 4 foot concrete test block with a similar surface texture to surfaces to be coated. Coat a vertical face with chosen elastomeric coating system. Determine number of coats required to achieve the

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specified thickness without runs and drips. Mix and apply elastomeric coating as per manufacturer's current standard technical specifications. Spray application is preferred; roller application is permitted. Have coating manufacturer representative on site to supervise and comment on application of elastomeric coating onto test block. Apply coating using approved and experienced personnel with a minimum of three years experience applying similar polyurethane systems. Submit credentials of these persons to the Engineer for review and consideration for approval.

462-7.4 Filler Injection Operations:

462-7.4.1 Grouting Operations: Conduct all grouting operations in the presence of the Engineer.

462-7.4.1.1 Plan:

1. Submit a Grouting Operations Plan to the Engineer for approval at least six weeks in advance of any scheduled grouting operation.
2. Written approval of Grouting Operations Plan by the Engineer is required before any grouting of permanent structure takes place.
3. At minimum, Grouting Operations Plan will address and provide:
   a. Names and proof of training for grouting crew and crew supervisor in conformance with this Specification;
   b. Type, quantity, and brand of materials to be used in grouting, including all required certifications;
   c. Type of equipment to be used, including capacity in relation to demand and working conditions, as well as, standby equipment and spare parts;
   d. General grouting procedure;
   e. Duct pressure test and repair procedures;
   f. Method to be used to control rate of flow within ducts;
   g. Theoretical grout volume calculations;
   h. Mixing and pumping procedures in accordance with the manufacturer's recommendations;
   i. Direction of grouting accounting for grade and/or slope of tendon;
   j. Sequence of inlet and outlet pipes use;
   k. Procedures for handling blockages;
   l. Procedures for possible post grouting repair.
4. Conduct a joint meeting of the Contractor, grouting crew, and the Engineer before grouting operations begin. Discuss Grouting Operations Plan, required testing, corrective procedures, and any other relevant issues at the meeting.
5. Demonstrate, to the Engineer's satisfaction, grouting of a longitudinal tendon by constructing a full-scale mockup with all associated PT system components of a typical longitudinal tendon profile on the project. Utilize 'clear' duct for the mockup to facilitate visual inspection and verification that no voids or bleed are present in the tendon mockup after grouting. Place a non-stressed PT strand equivalent to the typical longitudinal tendon size inside the duct to simulate in-place PT strand.

462-7.4.1.2 Inlets and Outlets:

1. Ensure connections from grout pump hose to inlets are free of dirt and are air-tight.
2. Inspect valves to ensure they can open and close properly.

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462-7.4.1.3 Supplies:

Provide an adequate supply of water and compressed air for clearing and testing ducts, as well as, mixing and pumping grout before grouting operations start.

462-7.4.1.4 Equipment:

1. Provide grouting equipment consisting of measuring devices for water, a high-speed shear colloidal mixer, a storage hopper (e.g., holding reservoir) and pump with all necessary connecting hoses, valves, and pressure gauge.

2. Provide pumping equipment with sufficient capacity to ensure PT ducts can be filled and vented in not more than 30 minutes without interruption.

3. Provide an air compressor and hoses with sufficient output to perform required functions.

4. Have vacuum grouting equipment (i.e., volumetric measuring type) and experienced operators available not less than 48 hours prior to the maximum number of calendar days allowed in 462-7.2.4, between first installation of prestressing steel within the duct and completion of the stressing and grouting operation for PT. If the maximum number of days in 462-7.2.4 have been exceeded, have available vacuum grouting equipment and experienced operators available within 48 hours notice.

462-7.4.1.4.1 Mixer and Storage Hopper:

1. Provide colloidal grout machinery with a charging tank for blending and a holding tank. Blending tank must be equipped with a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and un-dispersed cement. Holding tank must be kept agitated and at least 10% full at all times during pumping operations to prevent air from being drawn into duct.

2. Add water during primary mixing phase in the colloidal mixer by use of a flow meter or calibrated water reservoir with measuring accuracy equal to 1% of total water volume.

462-7.4.1.4.2 Pumps:

1. Provide pumping equipment capable of:

a. continuous operation which includes a system for circulating and agitating grout when actual grouting is not in progress,

b. maintaining pressure on grouted ducts,

c. fitted with a valve that can be closed off without loss of pressure in duct.

2. Grout pumps will:

a. be positive displacement type,

b. provide a continuous grout flow

c. be able to maintain a discharge pressure of at least 145 psi.

3. Use pumps constructed with seals to prevent oil, air, or other foreign substances from contaminating grout and prevent loss of grout or water.

4. Specify pump capacity adequate to maintain the specified grouting rate.

5. Place pressure gauge with full scale reading of no more than 300 psi at duct inlet. If long hoses (in excess of 100 feet) are used, provide two gauges: one at pump and one at inlet.

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6. Grout hoses to be compatible with pump output (diameter and pressure rating).

462-7.4.1.4.3 Vacuum Grouting: Provide vacuum grouting equipment meeting these minimum requirements:

1. Volumeter for measurement of void volume;
2. Vacuum pump with a minimum capacity of ten cubic feet per minute and equipped with a flow-meter, graduated hopper, or other acceptable means approved by the Engineer capable of measuring the amount of grout being injected.
3. Manual colloidal mixers, manual high speed shear mixers, or other mixing methods recommended and approved by the grout manufacturer, in writing, for the specific project covered by this Section for voids less than 5.5 gallons in volume. However, mix a minimum of one full bag of grout regardless of the size void to be grouted.
4. Standard colloidal mixers for voids 5.5 gallons and greater in volume.

462-7.4.1.4.4 Standby Equipment:

Provide a standby colloidal grout mixer and pump during grouting operations.

462-7.4.1.5 Grouting:

1. Maintain grout fluidity in strict compliance with grout manufacturer's recommendations.
2. In the presence of the Engineer, perform a test to confirm accuracy of grouting equipment volume-measuring components each day of use before performing any grouting operations. Testing in a warehouse or similar condition is acceptable. Use either water or grout for testing using standard testing devices with volumes of 0.5 gallon and 6.5 gallon and an accuracy of equal to or less than four ounces. Perform one test with each device. Results must verify accuracy of grouting equipment void volume-measuring component within 5% of test device volume and must verify accuracy of grouting equipment grout volume component within 10% of test device volume for the 0.5 gallon test device. When testing the 6.5 gallon device, ensure an accuracy of 3% (test device volume) and 6% (grout volume).
3. Do not use grout that tests outside allowable flow rates.
4. Perform grouting in accordance with procedures set forth in approved Grouting Operations Plan.
5. Grout all ducts.

462-7.4.1.5.1 Temperature:

1. At inlet end of grout hose, the maximum limit for grout temperature is 90°F for normal grouting procedures and 85°F when performing repair operations with vacuum grouting.
2. Condition grout material to maintain mixed grout temperature below maximum limit.
3. Grouting operations are not permitted when ambient temperature is below 40°F or is expected to fall below 40°F within one day subsequent to grouting.
4. Postpone grouting operations if freezing temperatures are forecasted within two days subsequent to grouting.

462-7.4.1.5.2 Mixing and Pumping:

1. Mix grout with a metered amount of water.

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2. Mix materials to produce a homogeneous grout.

3. Continuously agitate grout until grouting operations are complete.

4. Reject bags of grout containing clumps.

462-7.4.1.5.3 Production Test:

1. Test grout fluidity to verify it is within limits established by grout manufacturer during grouting operations. Target fluidity rate is established by manufacturer's representative based on ambient weather conditions.

2. Determine grout fluidity in accordance with Section 938.

a. Perform a fluidity test using flow cone on grout discharged from anchorage cap outlet immediately after uncontaminated uniform consistency discharge begins for each tendon greater than 50 feet in length. For tendons 50 feet or less, perform a fluidity test on a per batch basis. For fluidity tests done on a per batch basis, perform test after new batch has been transferred from mixing tank to holding tank and thoroughly mixed with remains of the previous batch to produce a new homogenous mixture. During mixing process, continually re-circulate grout from hose into holding tank. Ensure measured grout efflux time is not less than efflux time measured at injection end of grout hose.

b. Alternately, check grout fluidity using Wet Density method contained in Section 938. Density at discharge outlet must not be less than grout density at inlet. Continuously discharge grout until density requirements are met. Discard grout used for testing fluidity.

3. Perform fluidity test for each tendon to be grouted without modifying water-cement ratio.

4. Check temperature of grout at inlet end of grout hose hourly to verify conformance to this Section.

5. Obtain a sample from first production batch of grout and perform a wick induced bleed test on this sample in accordance with Section 938 at beginning of each day's grouting operation. Begin grouting operations after sample is obtained.

6. Once grouting has begun, if zero bleed requirement is found to not have been achieved in the wick induced bleed test at any time during required test time period, complete grouting of any partially grouted tendons currently being grouted but do not begin grouting any new or additional tendons. Immediately inform the Engineer when grouting operations have ceased due to non-compliance of the wick induced bleed test.

7. Do not re-start grouting operations until such time that testing shows grout meets specified requirements.

462-7.4.1.5.4 Operations:

1. Open all grout outlets before starting grouting operation.

2. Inject grout into duct in accordance with approved Grouting Operations Plan.

3. Pump grout at the lowest possible pressure practical.

4. Conduct normal grouting operations at a pressure range of 10 psi to 50 psi measured at grout inlet.

5. Do not exceed maximum pumping pressure of 145 psi at grout inlet for round ducts and 75 psi for flat ducts.

6. Use grout pumping methods that ensure complete filling of ducts and complete encasement of steel.

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7. Grout must flow from first and subsequent outlets until any residual water or entrapped air has been removed prior to closing outlet.

8. Pump grout through duct and continuously discharge it at anchorage and anchorage cap outlets until all free water and air are discharged and consistency of grout is equivalent to that of grout being pumped into inlet. Close anchorage outlet and discharge a minimum of two gallons of grout from anchorage cap into a clean receptacle. Close anchorage cap outlet.

9. Elevate grout pressure to the equivalent realized pumping pressure while grouting the duct, seal inlet valve, and wait two minutes to determine if any leaks exist after all outlets have been bled and sealed. If leaks are present repair all identified leaks using methods pre-approved by the Engineer and repeat steps until no leaks are present. Bleed pressure to 5 psi and wait a minimum of ten minutes for any entrapped air to flow to high points if no leaks are present. Increase pumping pressure not to exceed actual realized pumping pressure of duct and discharge grout at each high point outlet to eliminate any entrapped air or water after specified ten minute period has expired. Complete process by locking a pressure of 30 psi into tendon duct.

10. If actual grouting pressure exceeds maximum allowed, close inlet and pump grout at next outlet which has just been closed or is ready to be closed as long as a one-way flow is maintained. Do not pump grout into a succeeding outlet from which grout has not yet flowed. Fit outlet/inlet to be used for pumping with a positive shut-off valve as shown in the approved system drawings and pressure gauge if this procedure is used.

11. Stop grouting operation if complete grouting of tendon cannot be achieved by the steps stated and in compliance with the approved Grouting Operations Plan. After waiting 48 hours, vacuum grout duct in accordance with this Section.

462-7.4.1.5.5 Vertical Grouting:

1. Provide a reservoir, equivalent to a minimum of 2% of the total anticipated grout volume used on a particular tendon, at upper end of tendon to store bleed water and grout; maintain grout level above level of prestressing plate and anchorage for all vertical tendons. Design and size this device to maintain level grout at an elevation that ensures potential bleed will not drop below the highest point of upper anchorage device. Design reservoir to allow all bleed water, if any, to rise into reservoir.

2. Discharge grout and check grout fluidity as described in this Section. Immediately add grout if level of grout begins to drop, potentially allowing bleed water into the upper anchorage device and tendon duct. Remove reservoir after grout has hardened. Visually inspect for voids using a borescope or probe in presence of the Engineer. Fill all voids found in duct using volumetric measuring vacuum grouting process in accordance with this Section.

3. Allow grout to flow from each outlet until all air and water have been purged prior to using a higher elevation outlet for pumping. Pump grout at increasingly higher outlets which have been or are ready to be closed, as long as one-way grout flow is maintained for vertical tendons within allowable grouting pressures.

462-7.4.1.5.6 Grouting Operations Report:

1. Provide grouting report signed by the grouting Contractor within five days of each grouting operation for review by the Engineer.

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2. Record theoretical quantity of grout anticipated as compared to actual quantity of grout used to fill duct. Notify the Engineer immediately of shortages or overages.

3. Information to be noted in this report must include at a minimum, but not necessarily be limited to:

a. identification of tendon;
b. date grouted;
c. number of days from tendon installation to grouting;
d. type of grout;
e. injection end and applied grouting pressure;
f. ratio of actual to theoretical grout quantity;
g. number of grout bags mixed;
h. total quantity of water used to mix grout;
i. summary of any problems encountered; and,
j. corrective action taken,
k. description and results of the post grouting operations and inspection.

462-7.4.2 Flexible Filler Operations:

462-7.4.2.1 Microcrystalline Wax: Conduct all wax injection operations, repairs, and inspections in the presence of the Wax Injection Foreman, Wax Injection QC Inspector and the Engineer.

462-7.4.2.1.1 Wax Injection Operations Plan:

1. Prepare a Wax Injection Operations Plan in cooperation with the PT system vendor and the PT wax manufacturer.

2. Submit the Wax Injection Operations Plan to the Engineer for approval at least six weeks in advance of any scheduled injection operation.

3. Written approval of the Wax Injection Operations Plan by the Engineer is required before any injection of permanent structure can begin.

4. At a minimum, the Wax Injection Operations Plan will address and provide the following:

a. .Names and qualifications for wax injection crew and crew supervisor in conformance with this Specification;
b. Type, quantity, and brand of materials to be used in wax injection including all required certifications;
c. Type of equipment to be used, including capacity in relation to demand and working conditions, as well as, standby equipment and spare parts;
d. General wax injection procedure for all duct geometries and types;
e. Duct pressure test and repair procedures;
f. Method to be used to control rate of flow within ducts and anchorage assembly;
g. Theoretical wax volume calculations;
h. Injection rate;
i. Maximum injection pressure during injection and locking pressure;

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j. Vacuum (gauge) pressure requirements, vacuum tests and repair procedures;

k. Heating, mixing and pumping procedures in accordance with the manufacturer's recommendations;

l. Direction of wax injection accounting for grade and/or slope of tendon;

m. Location of all high points and all low points accounting for grade and/or slope of tendon;

n. Sequence of valve operations at PT system inlets and outlets, including minimum wax discharge quantities;

o. Procedures for handling blockages;

p. Procedure for sealing duct after wax injection;

q. Procedure for inspecting the PT system after wax injection, filling voids created by inspection procedures, and sealing duct after PT system inspection;

r. Procedures for possible post injection repair;

s. Method(s) and material(s) that will be used to protect concrete surfaces from wax spills, leaks, etc. during wax injection, post injection inspection and post injection repair;

t. Safety and clean-up procedures;

5. Conduct a joint meeting of the Contractor, wax injection crew, and the Engineer before wax injection operations begin. Discuss Wax Injection Operations Plan, required testing, corrective procedures, and any other relevant issues at the meeting.

6. Demonstrate, to the Engineer's satisfaction, wax injection of a duct by constructing a full-scale mockup with all associated PT system components of a typical duct profile on the project. Utilize the same type of duct and wax injection equipment as used on project. Place a non-stressed PT strand equivalent to the typical longitudinal tendon size inside the duct to simulate in-place PT strand. Assist the Engineer in the inspection and disassembly of the PT system after wax has congealed.

462-7.4.2.1.2 Inlets and Outlets:

1. Ensure connections from wax pump hose to inlets are free of dirt and are air-tight.

2. Inspect valves to ensure they can open and close properly.

3. Provide clear hose and connections to outlet valves compatible with heated wax injection for discharging excess wax. Kinks and clogs in the vent hoses are not permitted during pumping operations.

462-7.4.2.1.3 Supplies:

1. Provide an adequate supply of compressed air for clearing and testing ducts before wax injection operations start.

2. Provide clean receptacles for collecting excess wax at outlet locations.

3. Provide supplies for stopping wax leaks.

462-7.4.2.1.4 Equipment:

1. Provide equipment consisting of measuring devices for wax, wax melting unit(s), wax mixer for maintaining uniform temperature, a storage holding

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reservoir, pump, and volumetric flow rate and displacement volumetric meters with all necessary connecting hoses, valves, pressure gauges, timer, and temperature gauge.

2. Provide pumping equipment with sufficient capacity to ensure PT ducts can be filled and vented in not more than time specified by the wax manufacturer and this Specification.

3. Provide an air compressor and hoses with sufficient output to perform required functions.

4. For filling of air voids in an incomplete wax injection, have vacuum wax injection equipment (i.e., volumetric measuring type) and experienced operators available not less than 48 hours prior to the maximum number of calendar days allowed in 462-7.2.4, between first installation of prestressing steel within the duct and completion of the stressing and wax injection operation for PT. If the maximum number of days in 462-7.2.4 have been exceeded, have available vacuum wax injection equipment and experienced operators available within 48 hours notice.

5. For vacuum assisted injection, provide vacuum pump equipment able to measure and have sufficient capacity to ensure a minimum of 90% vacuum in the PT system prior to filler injection. Provide continuously running vacuum pump or vacuum reservoir capable of maintaining vacuum during the wax injection process.

6. Ensure that all injection and inspection equipment is maintained in accordance with equipment manufacturer's instructions and is calibrated and in good working condition.

7. Provide equipment for dislodging congealed wax blockages.

462-7.4.2.1.4.1 Storage Reservoir and Mixing:

1. Provide heated holding tanks for wax injection.

a. Holding tanks must be equipped with a heating system capable of producing a melted wax free of lumps within the temperature limits specified by the manufacturer.

b. Holding tanks must be kept at least 10% full at all times during pumping operations to prevent clogs and air from being drawn into duct

c. Holding tanks must have at time of injection a quantity of heated wax required to inject the PT system. The quantity of heated wax required to inject the PT system is calculated as 25% more than the total quantity to fill the duct and anchorages, to discharge wax at outlets, to fill pumping equipment and hoses, and to maintain the minimum amount of wax in the holding tanks during pumping operations.

2. Provide equipment to ensure uniform temperature of heated wax, either by mixing or other methods.

462-7.4.2.1.4.2 Pumps:

1. Provide pumping equipment capable of the following:

a. continuous operation which includes a system for heating pump components when wax injection is not in progress;

b. maintaining pressure on wax injected ducts;

c. fitted with a valve that can be closed off without loss of pressure in duct.

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2. Wax pumps will:

a. be positive displacement type;

b. provide a continuous wax flow;

c. be able to maintain a discharge pressure of at least 75 psi;

d. provide an injection of filler into duct in a velocity range of 40-70 ft/min.

3. Use pumps constructed with seals to prevent oil, air, or other foreign substances from contaminating wax and prevent loss of wax.

4. Pumps with hoppers are not permitted.

5. Specify pump capacity adequate to maintain the wax injection rate.

6. Place pressure gauge with full scale reading of no more than 150 psi at duct inlet. If long hoses (in excess of 100 feet) are used, or if the duct injection port is more than 50 feet above the pump, provide two gauges: one at pump and one at inlet.

7. Wax injection hoses to be compatible with pump output (diameter, pressure rating and temperature).

462-7.4.2.1.4.3 Vacuum Wax Injection:

1. For filling voids in incomplete wax filling operations, provide vacuum wax injection equipment meeting these minimum requirements:

a. Volumeter for measurement of void volume;

b. Vacuum pump with a minimum capacity of ten cubic feet of air per minute and equipped with a flow-meter, graduated reservoir, or other acceptable means approved by the Engineer capable of measuring the amount of wax being injected.

c. Mixers and heaters, or other mixing and heating methods recommended and approved by the wax manufacturer, in writing, for the specific project covered by this Section.

2. For vacuum assisted injection, provide vacuum wax injection equipment meeting these minimum requirements:

a. Vacuum pump with a minimum capacity of ten cubic feet of air per minute with the capability of removing 90% of standard atmospheric pressure within the PT system and equipped with a vacuum pressure gauge;

b. Hoses, vacuum reservoirs, and connections required for attachment to the PT system.

462-7.4.2.1.4.4 Heaters: Use a heater and temperature monitoring system capable of liquefying the entire mass of PT wax to be used for a given injection operation within the temperature limits specified by the PT wax manufacturer. The heater systems must apply a uniform heat to the PT wax and avoid locally high temperatures that may damage the PT wax or container. Use a heater and temperature monitoring system which complies with the recommendations of the PT wax manufacturer.

462-7.4.2.1.5 Wax Injection:

1. Maintain wax temperature in strict compliance with the wax manufacturer's published product data sheet.

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2. Perform wax injection in accordance with procedures set forth in approved Wax Injection Operations Plan.

3. Inject duct.

462-7.4.2.1.5.1 Temperature:

1. Condition wax to maintain its temperature during injection between 212°F and 240°F unless proven acceptable otherwise.

2. Wax injection operations are not permitted when ambient temperature is below minimum temperatures specified by the wax manufacturer.

462-7.4.2.1.5.2 Production Test:

1. Check wax temperature to verify it is within established limits during operations.

2. Do not start operations until such time that testing shows wax meets specified requirements.

462-7.4.2.1.5.3 Operations:

1. Open all inlets, outlets and drains before beginning wax injection operation to remove standing water from duct.

2. Protect concrete surfaces from wax spills, leaks, etc.

3. Inject wax in accordance with approved Wax Injection Operations Plan.

4. Use pumping methods that ensure complete filling of ducts and anchorage assembly with wax.

5. Ensure the entire mass of wax is fully liquefied prior to and throughout injection operations. Establish a non-turbulent, laminar system circulation by continuously recirculating the wax between the pump and the storage container prior to injecting the wax into the duct. Pump components must be at wax injection temperature prior to wax injection into duct. Do not allow wax to free fall during recirculation or injection operations. Maintain a positive head of liquid wax above all withdrawal and recirculation ports and do not allow air intrusion into the pumping system. Do not pour liquid wax into an open pump or hopper.

6. Inject PT wax at a continuous and steady rate in accordance with the approved Wax Injection Operations Plan at a flow rate through duct at a velocity between 40 and 70 feet per minute and pressures limited to 75 psi. If pressure gauges are utilized at the pump and at the injection port, ensure that pressures at both locations are within the limits put forth in this Section.

7. For vacuum assisted injection, provide a minimum of 90% vacuum in the duct prior to injection. Injection of filler may occur at an anchorage port. Vacuum through anchorage cap outlet at opposite end of duct from the injection anchorage port. If injection location does not occur at anchorage port, provide required vacuum through both anchorage caps. All outlets, inlets, and vents other than vacuum locations and injection location must be closed during injection procedure. Pump filler into inlet and continuously vacuum air until duct is fully injected with filler. Close outlet valve at anchorage cap when filled with filler. Close inlet valve with locking pressure between 30 psi and 45 psi.

8. For vented filler injection, allow wax to flow from duct and anchorage discharge points until a steady flow of wax free from air is continuously discharged. Collect a minimum of two gallons of continuously flowing wax free

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from air at discharge point before closing outlet valve. Do not reuse discharged wax. After all outlets are closed, close the inlet valve at locking pressure between 30 and 45 psi. For tendon profiles with high point vents as labeled in Design Standards, Index No. 21801, continue with the following procedure:

a. Wait 30 to 60 seconds after outlet valves and inlet valve are closed.

b. Open high point outlet valves and inlet valve, and inject wax through duct.

c. Close each high point valve after wax flows through outlet continuously free from air. After all high point valves are closed, increase pressure to locking pressure between 30 and 45 psi and close inlet valve.

9. Record the total volume of wax injected into the system.

10. Upon completion of wax injection, seal the duct in accordance with the approved PT system drawings. Remove all excess wax from exposed surfaces.

462-7.4.2.1.5.4 Wax Injection Operations Report:

1. Provide wax injection report signed by the wax injection Contractor within five days of each wax injection operation for review by the Engineer.

2. Record theoretical quantity of wax anticipated as compared to actual quantity of wax used to fill duct. Notify the Engineer immediately of shortages or overages.

3. Information to be noted in this report must include at a minimum, but not necessarily be limited to:

a. Identification of duct;

b. Date of duct pressure test;

c. Date wax injected;

d. Number of days from tendon installation to wax injection;

e. Wax product identification;

f. Final locking pressure of wax in PT system;

g. Reservoir temperature at time of initiation of wax injection;

h. Theoretical volume of wax required to completely fill the duct;

i. Volume of wax injected into duct;

j. Volume of wax collected at discharge points;

k. Injection rate including timing of duct inlet opening and closing;

l. Ambient temperature;

m. Summary of any problems encountered and any deviations from the Wax Injection Operations Plan;

n. Corrective action taken;

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o. Description and results of the post wax injection operations and inspection;

p. Vacuum gauge pressure and percent vacuum in duct prior to injection.;

4. Maintain daily wax injection operations reports at the job site for review by the Engineer. Provide all daily reports to the Engineer on a weekly basis or more frequently as directed by the Engineer.

462-7.4.2.1.6 Manufacturer's Installation Technician: Provide for a PT system vendor installation technician, certified by the vendor as having sufficient knowledge and expertise to oversee the wax injection personnel. The vendor's technician shall be under the direct employ of the vendor and shall be present for all wax injection activities for a minimum of the first two days of wax injection for each of the Contractor's wax injection crews. The vendor's technician shall provide written certification to the Engineer that the Contractor's installation process is in conformance with the approved Wax Injection Operations Plan.

462-7.5 Repair: Perform no remedial or repair work without the Engineer's approval in writing.

462-7.5.1 Lifting and Access Holes:

1. Repair all holes with magnesium ammonium phosphate concrete meeting requirements of Section 930 or Type Q epoxy grout meeting requirements of Section 926. Immediately before casting concrete (i.e., within 24 hours), mechanically clean and roughen the mating concrete surfaces to remove any laitance and expose small aggregate. Use grit blasting or water blasting using a minimum 10,000 psi nozzle pressure. Flush surface with water and blow dry. Form, mix, place, and cure material in strict compliance with manufacturer's recommendations.

2. Coat repaired holes, block-outs, and an area extending six inches outside perimeter of repair with a high molecular weight methacrylate (HMWM) listed on the APL upon completion of deck grooving. Prepare surface to be coated and apply HMWM in accordance with Section 413. Friction (skid) tests per Section 413 are not required.

462-7.5.2 Inlets and Outlets:

1. Place threaded plastic plugs in all inlet/outlet locations required in the Contract Documents.

2. Fill inlet/outlet recesses as shown in the Contract Documents using a Type Q epoxy compound, Type E epoxy compound, or Type F-1 epoxy compound meeting requirements of Section 926.

3. Prepare surface to receive epoxy compounds in compliance with manufacturer's recommendations.

462-7.5.3 Duct:

1. Heat-shrink wrap material designed for duct repair may be used with approval of the Engineer in writing.

2. Use approved heat-shrink sleeve material to repair ducts. Install in accordance with manufacturer's instructions.

462-8 Acceptance and Testing.

462-8.1 Contractor Material Testing:

1. The following tests are not required on post-tensioned, precast flat slab bridges, and double-tee bridges, but are required on all other PT applications.

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2. Include cost for Contractor Tendon Modulus of Elasticity Test and In-Place Wobble and Friction Test in price of PT system.

462-8.1.1 Tendon Modulus of Elasticity Test:

Perform a tendon modulus of elasticity test in accordance with the following procedure if required in the Contract Documents or ordered by the Engineer.

1. Bench test two samples of each size tendon prior to stressing tendons to determine modulus of elasticity for purpose of accurately determining tendon elongations while stressing.

2. Bench length between anchorages must be at least 40 feet and tendon duct at least two inches clear of tendon all around for purpose of this test.

3. Test procedure must consist of stressing tendon at an anchorage assembly with a load cell at dead end.

4. Tension test specimen 80% of GUTS in ten increments and then detention from 80% of GUTS to zero in ten decrements.

5. Record gauge pressure, elongations, and load cell forces for each increment and decrement.

6. Note elongations of tendon for both ends and the central 30 feet, measured to an accuracy of plus or minus 1/32 inches.

7. Correct elongations for actual anchor set of dead end.

8. Calculate modulus of elasticity as follows:

$$E = PL/Adl$$

where,

P = force in tendon

L = distance between pulling wedges and dead end wedges or exact length in the center 30 feet of tendon

A = cross sectional area of tendon

dl = tendon elongation within length, L, for load, P

9. Submit revisions to theoretical elongations to the Engineer for approval if bench test varies from modulus of elasticity used for shop or working drawings by more than 1%.

10. Additional Tendon Modulus of Elasticity Tests may be required when observed tendon elongations in erected structure fall outside acceptable tolerances or to otherwise settle disputes to the satisfaction of the Engineer.

11. Additional test series of substantiation from previous projects, not to exceed two per source, will be required if source of prestressing steel changes during project.

12. Apparatus and methods used to perform the test must be submitted to the Engineer for approval in writing.

13. Tests must be conducted in the Engineer's presence.

462-8.1.2 In-Place Wobble and Friction Test:

1. Test in-place a minimum of one tendon per tendon group performing the same function for tendons in excess of 100 feet long.

2. Functional tendon groups are cantilever tendons, continuity tendons, draped external tendons, or continuous profiled tendons passing through one or more spans.

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3. Selected tendon will represent the size and length of tendon group being tested.

4. In-place test is not required on projects with straight tendons used in flat slabs or precast voided slabs.

5. Test procedure consists of stressing tendon at an anchorage assembly with a load cell or a second certified jack at dead end.

6. Stress test specimen to 80% of GUTS in eight equal increments.

7. For each increment, record gauge pressure, elongations, and load cell force (if a load cell is used).

8. Take into account any wedge seating in both live end (i.e., back of jack) and dead end (i.e., back of load cell) and any friction within anchorages, wedge plates, and jack as a result of slight deviations of strands or wires through these assemblies.

9. Keep an accurate account of elongation at jacking end allowing for intermediate wedge seating and slip of the jack's wedges for long tendons requiring multiple jack pulls with intermediate temporary anchoring.

10. If elongations fall outside the plus or minus 7% range compared to anticipated elongations, investigate reason and make detailed calculations confirming final tendon forces are in agreement with requirements of the approved Contract Documents.

11. Do not vary value of expected friction and wobble coefficients by more than plus or minus 10% in reconciling theoretical and actual elongations.

12. Submit for written approval by the Engineer a plan to correct or compensate for elongation discrepancies if necessary.

13. The Engineer will require one successful test for each tendon group for the project.

14. The Engineer may require additional in-place tests if there are irreconcilable differences between forces and elongations or other difficulties during the course of routine stressing operations.

15. Submit apparatus and methods used to perform test to the Engineer for approval in writing.

16. Conduct all in-place tests in the Engineer's presence.

462-8.1.3 Required Reports:

1. Submit two copies of the test report for "Tendon Modulus of Elasticity Test" to the Engineer at least 30 days before installing tendon.

2. Submit two copies of the test report for "In-Place Wobble and Friction Test" to the Engineer within two weeks after successful installation of tested tendon.

462-8.1.4 Test Results Application:

1. Reevaluate theoretical elongations shown on PT shop or working drawings using results of "Tendon Modulus of Elasticity Test" and "In-Place Wobble and Friction Test," as appropriate, and correct calculations as necessary.

2. Submit revisions to theoretical elongations to the Engineer for approval in writing.

462-8.2 Contractor Field Tests:

462-8.2.1 Prior to Concrete Placement:

1. Types of systems to be tested include all PT system components utilized on the project for, but not limited to, transversely post-tensioned slabs, longitudinally post-tensioned girders, transverse post-tensioning in box girder segments, pier and bent caps, and

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columns. Longitudinal tendons in box-girder segments (internal tendons) are exempt from this testing.

2. In the formwork, pressure test each different type and size of duct assemblies with all assemblies used in a single structural component (e.g. segment, beam, etc.) constructed for first time on project.

3. One system per group, but not less than a total of two per project, will be randomly chosen by the Engineer for testing.

4. When required by the Engineer, test assemblies in their final position just prior to concrete placement by sealing them at their anchorages or construction joint termini and then applying compressed air in accordance with this Section to determine if assembly connections are pressure tight.

a. In presence of the Engineer, pressurize duct to 1.5 psi and lock-off outside air source.

b. Record pressure loss for one minute.

c. If pressure loss exceeds 0.15 psi, or 10%, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

462-8.2.2 Post Concrete Placement:

1. After stressing and before injecting filler into duct, install all anchorage caps, inlets and outlets and test the duct with compressed air in accordance with this Section to determine if duct connections require repair.

2. In the presence of the Engineer, pressurize duct to 50 psi and lock-off outside air source. Record pressure loss for one minute. A pressure loss less than 25 psi, or 50%, is acceptable for ducts with a length of equal to or less than 150 feet and a pressure loss less than 15 psi is acceptable for ducts longer than 150 feet.

3. If the pressure loss exceeds allowable, repair leaking connections using methods approved by the Engineer and retest.

462-8.3 Contractor Inspections:

462-8.3.1 Post Concrete Placement/Prior to Filler Injection Operations:

1. Upon completion of concrete placement and except as otherwise described, prove PT ducts are free and clear of any obstructions or damage and are able to accept intended PT tendons by passing a torpedo through ducts.

2. Use a torpedo having same cross-sectional shape as duct that is 1/4 inches smaller all around than clear, nominal inside dimensions of duct. Make no deductions to torpedo section dimensions for tolerances allowed in manufacture or fixing of ducts. For straight ducts, use a torpedo at least two feet long. For curved ducts, determine length so that when both ends touch outermost wall of duct, torpedo is 1/4 inches clear of innermost wall. The Engineer will reject member if torpedo will not travel completely through duct and workable repair cannot be made to clear duct. Torpedo must pass through duct easily when pushed through by hand, without resorting to excessive effort or mechanical assistance.

3. Alternatively, four strand tendons in flat ducts used for transverse PT of segmental box-girders may be preplaced prior to concrete casting. Prove PT ducts are free and clear of any obstructions or damage by moving the group of strands back and forth in duct for a minimum distance of one foot in each direction. Move strands easily, by hand, without resorting to excessive effort or mechanical assistance.

462-8.3.2 Post Filler Injection Operations:

462-8.3.2.1 Post Grouting Operations:

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1. Inspect all tendons.

2. Do not open or remove inlets and outlets until grout has cured for a minimum of 24 hours and complete tendon inspections within 96 hours.

3. Perform inspections within one hour after removal of all inlets/outlets located at anchorages and high points along the tendon.

4. Drill into existing grout ports at all high points along tendon as well as inlets or outlets located at anchorages for inspection. Drill through hardened grout to penetrate full-length of grout port access piping to top of trumpet or duct. If drilling of inlets or outlets is not feasible with conventional equipment, propose an alternative method of tendon inspection for approval by the Engineer in writing. Use drilling equipment that will automatically shut-off when steel is encountered. Do not drill into anchorage cap unless anchorage caps are determined to have voids by sounding.

5. Perform all inspections using borescopes or probes and in presence of the Engineer.

6. Fill voids using volumetric measuring vacuum grouting process not less than 48 hours prior to the maximum number of calendar days in 462-7.2.4 allowed between first installation of prestressing steel within duct and completion of the stressing and grouting operation for PT. If the maximum number of days in 462-7.2.4 have been exceeded, have vacuum grouting equipment and experienced operators available within 48 hours notice.

7. Seal and repair all anchorage and inlet/outlet voids that are produced by drilling for inspection purposes as specified within four hours of completion of inspections if no additional voids are detected in tendon ducts or anchorages.

8. Remove inlet/outlet to a minimum depth of two inches below face of concrete and seal the surface as specified within 4 hours of inlet/outlet removal. Use an injection tube to extend to bottom of holes for backfilling with epoxy grout.

9. Drill into duct and explore voided areas with a borescope if grouting operations were prematurely terminated prior to completely filling duct. Probing is not allowed. Determine location and extent of all voided areas. Fill voids using volumetric measuring vacuum grouting equipment in accordance with this Section.

462-8.3.2.2 Post Flexible Filler Injection Operations:

462-8.3.2.2.1 Microcrystalline Wax:

1. Inspect PT system.

2. Do not open or remove inlets and outlets until wax has cooled for a minimum of 24 hours and complete tendon inspections within 96 hours.

3. Perform inspections within one hour after removal of all inlets/outlets located at anchorages and high points along the tendon.

4. Visually inspect existing ports at all high points along tendon as well as inlets or outlets located at anchorages. Repair wax leaks according to the Wax Injection Operations Plan.

5. Between 24 and 48 hours following wax injection, perform the following inspection operations for each tendon:

a. Sound external ducts with a rubber mallet to ensure the system is free from voids,

b. Remove all inspection port caps and visually inspect to ensure the system is free from voids,

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c. If voids greater than 12 cubic inches are detected, address voids using this section and methods described in the approved Wax Injection Operations Plan;

d. Fill voids created by inspection procedures and replace all inspection port caps and seal in accordance with the approved Wax Injection Operations Plan.

6. Fill voids greater than 12 cubic inches using volumetric measuring vacuum wax injection process not less than 48 hours prior to the maximum number of calendar days in 462-7.2.4 allowed between first installation of prestressing steel within duct and completion of the stressing and wax injection operation for PT. If the maximum number of days in 462-7.2.4 have been exceeded, have vacuum wax injection equipment and experienced operators available within 48 hours notice.

7. Seal and repair all anchorage and inlet/outlet voids that are produced for inspection purposes as described in the approved Wax Injection Operations Plan within four hours of completion of inspections if no additional voids are detected in tendon ducts or anchorages.

8. Inspect duct and explore voided areas with a borescope if wax injection operation was prematurely terminated prior to completely filling duct. Determine location and extent of all voided areas. Fill voids using volumetric measuring vacuum wax injection equipment in accordance with this Section.

462-9 Method of Measurement.

1. Quantity of PT tendons to be paid for under this Section will be computed weight, in pounds, of permanent PT steel tendons installed in the completed structure and accepted.

2. Quantity is determined by theoretical plan length measured from anchorage to anchorage (measured from front face of bearing plate) with no allowance made for waste or extension past bearing faces.

3. No measurement will be made for temporary PT which is considered incidental to Pay Item 462-2, Post Tensioning Tendons.

4. Use these unit weights for quantity determination:

Table 9-1 PT Strand and Bar Weight per Unit Length

Prestressing System	Weight per Unit Length, Lb/Ft
1/2 inch diameter 7-wire strand	0.52
0.6 inch diameter 7-wire strand	0.74
1 inch high strength deformed bar	3.01
1-1/4 inch high strength deformed bar	4.39
1-3/8 inch high strength deformed bar	5.56
1-3/4 inch high strength deformed bar	9.23

462-10 Basis of Payment.

462-10.1 General:

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1. PT tendons will be paid for at the Contract unit price per pound of steel tendon, completed and accepted.

2. Payment will be full compensation for furnishing, installing, stressing, and filler injection of all temporary and permanent, internal and external ducts. Payment also includes anchorage assemblies and associated supplemental reinforcing steel required by supplier, PT system hardware not embedded in concrete, ducts, grout and grouting operations, flexible filler and filler injection operations, all testing, including Tendon Modulus of Elasticity Test and In-Place Wobble and Friction Test, protection of PT anchorages, vents, inlets, outlets, and all labor, materials, tools, equipment, and incidentals necessary for completing the work in accordance with the Contract Documents. This payment also includes lubricants in tendon ducts for friction control and flushing lubricants or contaminants from ducts.

3. Anchorage components, ducts, and similar items of PT system hardware embedded within precast components or cast-in-place concrete will be deemed to be included in cost of precast component or cast-in-place concrete in which it is embedded.

4. Payment is based on unit price bid extended by either quantities shown in the Contract Documents or actual quantities used and accepted, whichever is less, if the Contractor constructs structure with an accepted alternate not detailed in the Contract Documents.

5. Permanent PT strand, wire, or bar tendons which are an integral part of individual precast concrete segments or units will be measured and paid for under this item and will not be considered incidental to cost of those precast concrete segments or units.

6. Payment for PT will be made following successful placement, stressing, filler injection, inspection, repair, protection, and written approval by the Engineer.

7. Full payment for PT tendons within precast segmental concrete structure units may occur prior to erection of segments into final position when ducts have been injected and anchorage protection system applied and the segmental unit otherwise approved in writing for placement by the Engineer.

462-10.2 Pay Items:

Payment will be made under:

Item No. 462- 2 Post-tensioning Tendons - Per Pound