ORIGINATION FORM
Proposed Revisions to the Specifications
(Please provide all information - incomplete forms will be returned)

Date: 5/26/16

Specification Section: 462

Originator: Charles Boyd

Articles/Subarticles: Various

Telephone: 414-4275

email: charles.boyd@dot.state.fl.us

Will the proposed revision involve Design Standard Index changes? **Yes** ◉ **No** ○

Roadway Design staff contacted (name): Gevin McDaniel

Structures Design staff contacted (name): Steve Nolan

Will the proposed revision involve PPM changes? **Yes** ○ **No** ◉

Roadway Design staff contacted (name): Gevin McDaniel

Will the proposed revision involve CPAM changes? **Yes** ○ **No** ◉

Construction staff contacted (name): Dan Hurtado

Will the proposed revision involve Pay Item changes? **Yes** ○ **No** ◉

Estimates staff contacted (name): na

Will the proposed revision involve SDG changes? **Yes** ◉ **No** ○

Structures staff contacted (name): me

Will the proposed revision involve APL changes? **Yes** ○ **No** ◉

Product Evaluation staff contacted (name): na

Will the proposed revision involve Material Manual changes? **Yes** ○ **No** ◉

State Materials Office staff contacted (name): na

Will this revision necessitate any of the following:

Design Bulletin ☑ **Construction Bulletin** ☐ **Estimates Bulletin** ☐ **Materials Bulletin** ☐

Are all references to external publications current? **Yes** ◉ **No** ○

If not, what references need to be updated? (Please include changes in the redline document.)

Why does the existing language need to be changed?

Various revisions are needed to improve language mainly related to flexible filler injection.

Summary of the changes:

Flexible filler injection requirements have been revised.

Are these changes applicable to all Department jobs? **Yes** ○ **No** ◉
If not, what are the restrictions?

Only projects with post-tensioning.

Contact the State Specifications Office for assistance in completing this form.
Dan Hurtado 850-414-4130 dan.hurtado@dot.state.fl.us Debbie Toole 850-414-4114 deborah.toole@dot.state.fl.us
Frances Thomas 850-414-4101 frances.thomas@dot.state.fl.us Olivia Townsend 850-414-4303 olivia.townsend@dot.state.fl.us

Florida Department of Transportation

RICK SCOTT
GOVERNOR

605 Suwannee Street
Tallahassee, FL 32399-0450

JIM BOXOLD
SECRETARY

M E M O R A N D U M

DATE: June 20, 2016

TO: Specification Review Distribution List

FROM: Dan Hurtado, P.E., State Specifications Engineer

SUBJECT: Proposed Specification: **4620100 Post-Tensioning.**

In accordance with Specification Development Procedures, we are sending you a copy of a proposed specification change.

The changes are proposed by Charles Boyd of the State Structures Design Office to revise the flexible filler injection requirements.

Please share this proposal with others within your responsibility. Review comments are due within four weeks and should be sent to Mail Station 75 or online at http://www2.dot.state.fl.us/ProgramManagement/Development/IndustryReview.aspx . Comments received after **July 18, 2016,** may not be considered. Your input is encouraged.

DH/ot
Attachment

POST-TENSIONING.
(REV ~~5-27~~*6-~~3~~6*-16)

ARTICLE 462-1 is deleted and the following substituted:

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 *and extradosed bridges* 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. Submit 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.

SUBARTICLE 462-2.3.1 is deleted and the following substituted:

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.

3. Do not combine different grout products.

SUBARTICLE 462-2.3.2 is deleted and the following substituted:

462-2.3.2 Flexible Filler: Prepare *flexible* filler for installation in accordance with the manufacturer's instructions. *Do not combine different flexible filler products.*

SUBARTICLE 426-2.4 is deleted and the following substituted:

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).

SUBARTICLE 462-2.5.3 is deleted and the following substituted:

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 *quantity of material from 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.

ARTICLE 462-3 is deleted and the following substituted:

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 *the design requirements*, 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.

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.

SUBARTICLE 462-6.4 is deleted and the following substituted:

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 *of grout filler* 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.

SUBARTICLE 462-7.2.1 is deleted and the following substituted:

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 *or sealing* 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 of larger members	±1/4	±1/2
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

Table 7.2.1.1-1 Duct Installation Tolerances		
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.

SUBARTICLE 462-7.2.3 is deleted and the following substituted:

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 2~~' 0"~~ ~~inches~~*feet*;

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

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.

SUBARTICLE 462-7.3.2.2 is deleted and the following substituted:

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 *at anchorages and 74% of GUTS at all other locations between anchorages*.

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.

SUBARTICLE 462-7.3.2.8 is deleted and the following substituted:

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 *at the pump and at the inlet*;
l. Elongations (theoretical and actual);
m. Anchor sets (anticipated and actual);
n. Stressing sequence (i.e., sequential order of tendon stressing by number);
o. Stressing mode (single-end, dual-end, simultaneous);
p. Witnesses to stressing operations (Contractor and Inspector);
q. Any other relevant information.

2. Submit to the Engineer a complete set of stressing operation records within five days of completed tendon installation.

SUBARTICLE 462-7.3.3.2 is deleted and the following substituted:

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~~*3*,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 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.

SUBARTICLE 462-7.4.1.1 is deleted and the following substituted:

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*s* by constructing ~~a~~ full-scale mockup*s* with all associated PT system components ~~of a typical longitudinal~~*using the mockup* tendon profile*s shown in the Plans* ~~on the project~~. Utilize 'clear' duct for the mockup*s* to facilitate visual inspection and verification that no voids or bleed are present in the tendon mockup*s* after grouting. Place a non-stressed PT ~~strand~~ *tendon* equivalent to the ~~typical longitudinal~~ tendon size inside the duct to simulate in-place PT ~~strand~~*tendon*.

SUBARTICLE 462-7.4.1.4.2 is deleted and the following substituted:

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

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

SUBARTICLE 462-7.4.1.5.4 is deleted and the following substituted:

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~~ *a* pumping pressure of 145 psi *anywhere within the system. Do not exceed a pumping pressure of 75 psi* at *the* 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.

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.

SUBARTICLE 462-7.4.1.5.6 is deleted and the following substituted:

462-7.4.1.5.6 Grouting Operations Report:

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

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. pressure gauge readings at the pump and at the inlet;
~~f~~*g*. ratio of actual to theoretical grout quantity;
~~g~~*h*. number of grout bags mixed;
~~h~~*i*. total quantity of water used to mix grout;
~~i~~*j*. summary of any problems encountered; and,
~~j~~*k*. corrective action taken,
~~k~~*l*. description and results of the post grouting operations and inspection.

SUBARTICLE 462-7.4.2 is deleted and the following substituted:

462-7.4.2 Flexible Filler Operations:

1. Inject flexible filler with or without using vacuum assistance for tendons with vertical or predominately vertical profiles as shown on Design Standards, Index No. 21801.

2. Inject flexible filler using vacuum assistance for all other tendon profiles shown on Design Standards, Index No. 21801.

462-7.4.2.1 Microcrystalline Wax: Conduct all wax injection operations, repairs, and inspections in the presence of the ~~Wax~~ *Filler* Injection Foreman, ~~Wax~~ *Filler* 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. Location and sequence of ducts to be injected;

e. Calculation of temporary elongation of tendons due to wax injection temperature;

~~d~~*f*. General wax injection procedure for all duct geometries and types;

~~e~~*g*. Duct pressure test and repair procedures;

~~f~~*h*. Method to be used to control rate of flow within ducts and anchorage assembly;

~~g~~*i*. Theoretical wax volume calculations;

~~h~~*j*. Injection rate;

~~i~~*k*. Maximum injection pressure during injection and locking pressure;

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

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

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

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

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

~~o~~*q*. Procedures for handling blockages;

~~p~~*r*. Procedure for sealing duct after wax injection;

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

~~r~~*t*. Procedures for possible post injection repair;

~~s~~*u*. 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~~*v*. 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*s* with all associated PT system components ~~of a typical duct profile on the project~~*using the mockup tendon profiles shown in the Plans*. Utilize the same type of duct and wax injection equipment as used on project. Place a non-stressed PT ~~strand~~ *tendon* equivalent to the typical ~~longitudinal~~ tendon size inside the duct to simulate *an* in-place PT ~~strand~~*tendon*. 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 *including rags and buckets of cold water*.

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 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.

8. Provide standby pumping and vacuum equipment on the project site during injection operations.

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.

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~~ *300* psi at *pump and* duct inlet*s*. ~~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 *(free air)* 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 *and within the limits of this Section*.

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

3. Inject *hot wax into specified* duct *inlet*.

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 pressure~~s~~ limited to 75~~-~~ psi *at the duct inlet and 145~~-~~ psi at the pump*. ~~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 *tendons in which* vacuum assisted injection *is used*, provide a minimum of 90% vacuum in the duct prior to injection. *After the vacuum is established, lock off the air supply to the duct and monitor the vacuum for 1~~-~~ minute. If the loss of vacuum after 1~~-~~ minute exceeds 10%, repair leaks as directed by the Engineer and retest the duct. If the results are acceptable, reestablish and maintain a minimum 90% vacuum using the outlet at the higher end anchorage shown on Design Standards, Index No.~~- *21801 while* ~~I~~inject*ing*~~ion of filler~~ *wax using* ~~at~~ *the inlet at the lower end anchorage shown on the same* ~~s~~*Standard*~~locations and provide required vacuum at the outlet locations shown on Design Standards, Index No. 21801.~~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.~~ *Close* ~~A~~*a*ll outlets, inlets, and vents other than *at injection and* vacuum locations ~~and injection location must be closed~~ during injection procedure. Pump *wax*~~filler~~ into inlet and continuously vacuum air *at the outlet* until duct is fully injected with ~~filler~~*wax*. Close outlet valve at anchorage ~~cap~~ when filled with ~~filler~~*wax*. Close inlet valve with locking pressure between 30 psi and 45 psi. *Do not reuse discharged wax.*

8. For *tendons in which vacuum assisted injection is not used, inject wax under pressure at locations shown on Design Standards, Index No. 21801.* ~~vented filler injection, a~~*A*llow 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 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. Submit the 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. ~~p~~Pressure gauge readings at the pump and at the inlet;
~~f~~*g*. Final locking pressure of wax in PT system;
~~g~~*h*. Reservoir temperature at time of initiation of wax injection;
~~h~~*i*. Theoretical volume of wax required to completely fill the duct;
~~i~~*j*. Volume of wax injected into duct;
~~j~~*k*. Volume of wax collected at discharge points;
~~k~~*l*. Injection rate including timing of duct inlet opening and closing;
~~l~~*m*. Ambient temperature;
~~m~~*n*. Summary of any problems encountered and any deviations from the Wax Injection Operations Plan;
~~n~~*o*. Corrective action taken;
~~o~~*p*. Description and results of the post wax injection operations and inspection;
~~p~~*q*. 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. Submit all daily reports to the Engineer on a weekly basis or 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 submit written certification to the Engineer that the Contractor's installation process is in conformance with the approved Wax Injection Operations Plan.

SUBARTICLE 462-7.5.3 is deleted and following substituted:

462-7.5.3 Duct:

1. *Repair the following ducts using h*~~H~~eat-shrink wrap material designed for duct repair*:* ~~may be used with approval of the Engineer in writing.~~

a. Smooth plastic ducts that will be encased in concrete;

b. Corrugated plastic ducts;

c. External smooth plastic ducts after the flexible filler injection procedure has been completed.

Install heat-shrink wrap in accordance with manufacturer's instructions.

2. *Repair external smooth plastic ducts before the flexible filler injection procedure has been completed using elastomer sleeves and stainless steel band clamps.*~~Use approved heat-shrink sleeve material to repair ducts. Install in accordance with manufacturer's instructions~~.

SUBARTICLE 462-8.2.1 is deleted and the following substituted:

462-8.2.1 Prior to Concrete Placement:

462-8.2.1.1 All Tendons Except as Noted:

1. *Test* ~~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 columns~~*, except those used for internal*~~.~~ ~~Longitudinal~~ *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~~7.5 psi and lock-off outside air source.

~~b.~~ Record pressure loss for one minute.

~~c.~~ If pressure loss exceeds 0.~~15~~ *75* psi, or 10%, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

462-8.2.1.2 Tendons For Which Vacuum Assisted Filler Injection Will Be Used:

1. Test all PT system components utilized on the project except those used for internal longitudinal tendons in box-girder segments.

2. In the formwork, perform a vacuum test for 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 the 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 a vacuum in accordance with this Section to determine if assembly connections are pressure tight.

~~a.~~ In presence of the Engineer, apply a 90% vacuum and lock-off outside air source.

~~b.~~ Record vacuum loss for five minutes.

~~c.~~ If vacuum loss exceeds 10%, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

SUBARTICLE 462-8.3.2.2.1 is deleted and the following substituted:

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,

c. If *a* void~~s greater than 12 cubic inches are~~ *is* detected *and the void is deeper than 1/2 inch or if the strands are exposed and uncoated*, address

the void~~s~~ 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.

ARTICLE 462-9 is deleted and the following substituted:

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
5/8 inch high strength deformed bar	*0.98*
3/4 inch high strength deformed bar	*1.49*
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~~*10*
2-1/2 inch high strength deformed bar	*18.20*
3 inch high strength deformed bar	*24.09*

Note: Weight per unit length of high strength deformed bars is based on values given in ASTM A722.