

4620000 Post-Tensioning  
COMMENTS FROM INTERNAL/INDUSTRY REVIEW

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Steven Plotkin, P.E.  
[steven.plotkin@dot.state.fl.us](mailto:steven.plotkin@dot.state.fl.us)

Comments: (5-8-12)

I have begun reviewing these specs and I have observed that the word “the” is not used as it normally would be. In fact, it has obviously been deliberately left out of the text wherever possible. As far as I know, this is not the spec writing convention that all other specs conform to and it is not a standard contact language convention. In order to continue to provide specifications that are written with consistent usage conventions, please consult with your supervisors regarding this unilateral change by the authors of the attached specifications. Do we want to start writing all revisions and new specs with this convention or not? My personal opinion is that eliminating “the” is inconsequential considering that it disrupts the flow of the text and with the advent of electronic specifications just around the corner the savings is even less consequential since the amount of electronic storage saved is minuscule.

Response: It was not the author’s intent to enact a unilateral change regarding language convention but was rather a matter of style. The word “the” has been selectively added where deemed appropriate.

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Jeffrey A. Pouliotte  
[jeffrey.pouliotte@dot.state.fl.us](mailto:jeffrey.pouliotte@dot.state.fl.us)

Comments: (5-21-12)

1. Under 462-1,(b),1, it refers to the approved systems on the website. In light of all the problems we’re having with voids and segregated grout in our existing bridges, consideration should be given to requiring clear duct for external post-tensioning.

Response: The development of 960 and the associated proposed revisions to 462 and 933 are for the most part only a reorganization of existing spec requirements and not a rewrite for technical content. We will take these comments under advisement for future consideration. No changes to the proposed 462, 933 and 960 are required at this time based on the comments. No changes made.

2. Under 462-6.3, it indicates the PT steel is protected by corrosion inhibitor, which must have no deleterious effect on steel or concrete or bond strength of steel to concrete. Despite this requirement, does the corrosion inhibitor need to be wiped off prior to placing it in the ducts? The reason I’m asking the question is that I’m wondering whether the corrosion inhibitor can become dispersed in the grout and affect the functioning of the grout. I know that using corrosion inhibitor is an old practice, but in light of problems we’re having with grout, I’m asking the question.

Response: See response to #1, above.

3. Under 462-6.5, it states “if contamination is discovered, immediately flush duct with potable water per 462-7.2.4 before use.” Recent inspection of PT ducts have revealed sand trapped in the ducts, and there has been some question of whether water can get trapped in the ducts and promote the formation of soft grout that doesn’t set-up. Sub-article 462-7.2.4 states” blow oil-free compressed air through duct to remove any excess water in duct,” but does not address how to confirm that the ducts are indeed dry and clean. It is unclear to me how to confirm the presence of contamination, how to remove the contamination and how to confirm it has been removed. This may be more of a question for the State Construction Office rather than a specification question, or maybe the specification needs to require the Contractor to submit a plan to deal with these issues.

Response: See response to #1, above.

4. Under 462-7.4.5.1, it states “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.” The State Materials Office has found that several of the grout systems formally on the QPL (there are currently no approved grouts on the QPL) start to experience problems (development of trapped air and grout starting to set-up) at grout temperatures of around 90°F. The specification goes on to say “condition grout material to maintain mixed grout temperature below maximum limit,” which is a cryptic way of staying keep grout temperatures at or below 90°F. I think this portion of the specification needs to be strengthened and consideration needs to be give to requiring lower grout temperatures, and requiring the Contractor to submit a plan to control these temperatures.

Response: See response to #1, above.

5. Under 462-7.4.5.4 indicates discharging “a minimum of two gallons of grout from anchorage cap” and there appear to be no volume requirement of grout discharge at other outlets. In light of all the problems we’re having with voids and segregated grout in our existing bridges, consideration needs to be given to adopting European grout procedures that I understand require the discharge of more grout at these locations. Also grout pressure tests and required pressures before and during grouting operations needs to be reconsidered. In general this specification seems to be less prescriptive than the previous specification, which appears to be current Department philosophy. Therefore, it would seem prudent to require the Contractor to submit specific quality control plans to control and inspect the quality of the work.

Response: Response: See response to #1, above.

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Previte, John

Comments: (5-23-12)

This looks like a late change that comes off as a little naïve given the current range of media. Signed and sealed already connotes non-verbal or hard copy communication. At best delete “in

writing” At worst say “Submit written signed and sealed... Or do we mean ...”Engineer for review and written approval”? (ec) Submit signed and sealed project specific local zone reinforcement details to the Engineer for review and approval *in writing*.

**462-2.2.2 Prestressing:**

Response: Agreed. Change incorporated as shown here.

(ec) Submit signed and sealed project specific local zone reinforcement details to the Engineer for review and *written* approval ~~*in writing*~~.

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Karen Byram  
[karen.byram@dot.state.fl.us](mailto:karen.byram@dot.state.fl.us)

Comments: (5-24-12)

I am requesting that the reference to “Epoxy Grout” in the section 462-2.3 Other Material References to be modified. The correct reference is “Epoxy Compounds “(not grout). Not only is this consistent with the QPL listing but it will help to eliminate confusion with the post-tensioning grout references throughout the specification. Additionally, throughout the document, changes need to be made in the wording from ‘epoxy’, ‘epoxy grout’ and ‘epoxy material’ to ‘epoxy compound’ for the same reasons.

Response: Clarification has been added to call for "epoxy grout" for use in anchorage protection and repairs of lifting and access holes where Type Q is required with its aggregate load. Elsewhere, the term "epoxy compound" is used where Types E, F or Q (without aggregate load) are required. This is because for anchorage protection and repair of lifting and access holes which require large volumes of material, Type Q can only be used with the aggregate load and cannot be used neat. For repairing smaller volumes such as inlets and outlets, Type Q could be used neat.

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Richard Kerr  
(850) 410-5808

Comments: (5-30-12)

It appears that Garcon Point may have been the exception to use tie wires around the PT strands for external tendons. Since currently magnetic flux and magnetic leakage appear to be the best NDE technology and the use of tie wires appears to defeat this technology, perhaps the post tensioning specifications should be changed to prohibit the use of tie wires in at least external tendons if not all tendons.

Response: Added the following sentence to 462-7.2.4(n) to remove ties (wire or nylon) prior to stressing. (n) Strand installation aids (i.e. wire/nylon ties around strand bundle, strand spacers, etc.) must be removed prior to stressing.

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Womble, Steve

Comments: (5-31-12)

Here are my review comments on Section 462, Post-Tensioning, as requested.

1. In 462-1(a), I suggest modifying the updated final statement to read as follows: "...for protecting components, as determined by the engineer, from damage..."

Response: Agreed. Change incorporated as shown here –

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. In 462-1(b) there is a lined-thru item, ~~Approved Post-Tensioning~~, that is simply restated in red. This occurs at various points in the update, and I'm curious as to why.

Response: Agreed. No changes required. Strike-throughs are cleaned up in final version.

3. Same section, subgroup (b)(2), suggest replacing the word "appropriate" with "specific."

Response: The word "appropriate" conveys the intent here.

4. In 462-3(j), the existing wording is "Contractor's Specialty Engineer," but the update says "Engineer of Record," but this is referring to a change in the contract documents. Wouldn't such a change have been designed by the contractor's specialty engineer, and later approved by the EOR? The same question is applicable elsewhere.

Response: Agreed. No change required. Per Spec 1-3 Definitions, "The Contractor's Engineer of Record may also serve as the Specialty Engineer."

5. In 462-6.5, item I is a sentence (has subject and verb), but item (f) is not a sentence if the words "must be" are removed. Same thing elsewhere.

Response: Agreed. Changed to Active Voice, Imperative Mood.

6. In 462.7.2.3, item I(2) now reads "top of anchorage cap," but aren't there grout inlets/outlets at other locations than just anchorages?

Response: No change required. Items (1) thru (7) do not constitute an exhaustive list. Subparagraph (c) above states: "...and those shown in Design Standard Index No. 21801."

7. In 462-7.3.3.2(a), the word "tendon" is replaced with "strand," but in other locations this change was not made. So, why is this change proposed here?

Response: No change required. The word “tendon” is used in the context of this Section as a general term for all post-tensioning steel; whereas, strand is specific to wire-type PT steel to distinguish from PT bars.

8. Same section, item I, within 28 days of what?

Response: Agreed. Change incorporated as shown here –

(cd) Construct anchorage pour-backs ~~as required~~ Use with a Type Q epoxy grout ~~compound~~ per Section 926 ~~within twenty-eight (28) days of permanently affixing all anchorage caps within each individual pour-back to construct all pour-backs located at anchorages.~~

9. In 462-7.4.4.2(d), the item should read “...to maintain the optimal specified grouting rate.”

Response: Agreed. Change incorporated as proposed.

10. In 462-7.4.5.1I, the third line should read “...below 40D F or is expected to...”

Response: Agreed. Change incorporated as proposed.

11. In 462-7.4.5.3(f), the last line should read “...operations have ceased...”

Response: Agreed. Change incorporated as proposed.

12. In 462-7.4.5.5 (b), insert a comma between the words “drop” and “potentially.”

Response: Agreed. Change incorporated as proposed.

13. In 462-8.3.2(d), the item should read “...if drilling of inlets or outlets is not feasible...”

Response: Agreed. Change incorporated as proposed.

14. I would expect that both the Structures Office and the Materials Lab have reviewed these proposed changes. If not, they are highly recommended for such a review. Another good review source would be the District Level Construction offices.

Response: Agreed. All appropriate FDOT offices are included in the Industry Review.

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Todd Schille  
[TLSchille@pcl.com](mailto:TLSchille@pcl.com)

Comments: (6-21-12)

In general my comment to this entire system is;

A. This continues to specify a “grouted” PT system only, which is not fully understood other

than when something goes wrong the grout may rapidly corrode the strand.

B. This specifies using corrugated duct on the interior tendons and continues to mention “flushing” in several sections of the spec. You cannot economically get ALL the water out of these corrugated ducts if you flush and I like to think we know that **any excess water** is a bad thing in a tendon being grouted.

C. Not having the comments back on vacuum grouting, the sentiments are, that no one in the Industry, that we are aware of, can comply with that specification. Not DSI, VSL or PCL.

Responses:

A. This rewrite of 462 and the introduction of the new 960 is primarily just reorganization of existing spec language to improve their usability. As a separate effort, the SDO is also in the process of writing a developmental spec for the potential use of greased and sheathed tendons on future projects.

B. See proposed change to spec language, specifically the **highlighted** portion below:

**462-7.12.4 Tendons:**

(a) For tendon *ducts* subjected to contamination with chlorides (i.e.e.g.[s1], *uncapped ducts that have been subjected to salt spray construction location in an aggressive environment*), flush duct with potable water containing slack lime (i.e., calcium hydroxide) or quicklime (i.e., calcium oxide) in the amount of ~~seventeen hundredths~~ *0.17 lb/gal* pounds per gallon (0.17 lb/gal).

~~(b)~~ 1. Test for presence of chlorides and oils in discharged water before placing prestressing strands.

~~(c)~~ 2. ~~Limit chlorides in flush water outflow to less than six hundred parts per million (600 ppm).~~

~~(d)~~ If chloride levels *in flush water outflow* exceed ~~six hundred parts per million (600 ppm)~~, continue to flush duct until chloride level in flush water outflow is below ~~two hundred and fifty parts per million (250 ppm)~~.

~~(e)~~ 3. **Blow oil-free compressed air through duct to remove any excess water in duct. 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 boroscope or other visual inspection means, at no additional cost to the Department, to ensure duct interior is water free.**

C. This provision has been in the Standard Specifications for many years now. The development of 960 and the associated proposed revisions to 462 and 933 are for the most part only a reorganization of existing spec requirements and not a rewrite for technical content. We will take these comments under advisement for future consideration. No changes to the proposed 462, 933 and 960 are required at this time based on the comments.

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Cheryl Hudson

Comment: (7-2-12) All Cheryl’s comments are incorporated into the spec change following this comment page.

Response: All responses are also incorporated into the same document.

**POST-TENSIONING.**  
**(REV 5-147-12)**

SECTION 462 (of the Supplemental Specification) is deleted and the following substituted:

**SECTION 462**  
**POST-TENSIONING**

**462-1 Description.**

(a) Furnish, transport, store, handle, and install Post-Tensioning (PT) Systems, all constituent components of PT systems, as well as, all other related items, *according to requirements of this Section and component manufacturer's recommendations, that are* [s2] required for successful installation of the *particular* [s3] PT application *required by defined in* [s4] the Contract Documents. Constituent components of PT systems include, but are not necessarily limited to, anchorage assembly, grout containment assembly, and related steel reinforcement. *Of the requirements of this Section or the component manufacturer's recommendations, use whichever specifies the most stringent requirements. Use the most stringent requirements, as determined by the Engineer, of those specified in this Section or the component manufacturer's recommendations* [s5] *for protecting components from damage due to environmental exposure, improper handling, or improper installation.*

(b) Furnish all PT system components, including steel pipes, from a single supplier. *Obtain* Pp [s6] prestressing steel and local zone mild reinforcement *may be obtained* [s7] from any supplier.

*(1) 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* ~~Approved Post-Tensioning Systems~~.

*(2) Use only PT Systems of appropriate type and size required* [s8] *to construct tendons shown in the Contract Documents.*

*(3) Substitution, modification, or deletion of components of approved* [s9] *PT systems on the SDO website for Approved Post-Tensioning Systems* ~~Approved Post-Tensioning Systems~~ [s10], *excluding local zone reinforcement, is not permitted. Inclusion of all possible sub* [s11] *components 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.* ~~(e) Transport, store, handle, and install all PT system components and related items according to requirements of this Section and component manufacturer's recommendations. Of the two, use whichever specifies the most stringent requirements for protecting components from damage due to environmental exposure, improper handling, or improper installation.~~

~~(d)~~ (c) Install PT steel (e.g., strands or bars) through ducts, either embedded in concrete, referred to as internal, or external to the concrete member. Stress PT steel to a predetermined load and anchor end [s12] directly against hardened concrete. After anchoring PT steel, grout ducts to completely fill voids, and install protection at end anchorages.

~~(e)~~ (d) ~~Submit all~~ Submit all required ~~Plans, Shop and Working Drawings, and manuals~~ *documents* in accordance with this Section and Section 5 to the ~~SDO Engineer~~ *for*

review and written approval. ~~Provide all PT related Shop Drawings signed and sealed by a Specialty Engineer.~~

*(e) Cable stays are not covered by this Specification.*

## 462-2 Materials.

### 462-2.1 General:

*Approval of any material by the Engineer will not preclude subsequent rejection if material is damaged ~~in transit or later damaged~~ [s13] or otherwise found to not meet the requirements of this Section or Section 960.* ~~462-2.1 Post Tensioning Components:~~

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

~~\_\_\_\_\_ (b) Use only PT Systems of appropriate type and size to construct tendons shown in the Contract Documents.~~

~~\_\_\_\_\_ (c) Substitution, modification, or deletion of components of PT systems on the SDO website for Approved Post Tensioning Systems. Approved Post Tensioning Systems, excluding local zone reinforcement, is not permitted. Inclusion of all possible components 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.~~

~~\_\_\_\_\_ (d) Use only PT systems utilizing tendons completely encapsulated in grout filled anchorages and ducts. Systems transferring prestress force by bonding prestress steel strand directly to concrete are not permitted.~~

### 462-2.2 Steel Reinforcing:

#### 462-2.2.1 Mild:

(a) Provide reinforcing steel per Section ~~415~~ 931.

~~\_\_\_\_\_ (b) Final design and details of local zone reinforcement are project specific and are the responsibility of PT system supplier.~~

~~\_\_\_\_\_ (c) Use either typical local zone reinforcement shown on approved system drawings or design project specific reinforcement. Final design and details of local zone reinforcement are project specific and are the responsibility of PT system supplier.~~

~~\_\_\_\_\_ (d) 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 ~~same~~ ~~the~~ [s14] number of strands *a particular used for* approved PT system *can accommodate at maximum allowable strand force;* ~~Do not~~ design project specific local zone reinforcement for a reduced system capacity.

~~\_\_\_\_\_ (e) Submit signed and sealed project specific local zone reinforcement details to the Engineer for review and *written* approval ~~in writing~~ [s15], [s16]~~

#### 462-2.2.2 Prestressing:

##### 462-2.2.2.1 Strand:

(a) ~~Unless otherwise noted in the Contract Documents, use uncoated~~ *Provide prestressing* strands per Section 93360: ~~Grade 270, low relaxation 7 wire strand conforming to ASTM A416.~~

(b) Strand couplers are not permitted.

**462-2.2.2.2 Bar:**

~~(a) Unless otherwise noted in the Contract Documents, use uncoated Provide prestressing Grade 150, high strength, coarse thread bars conforming to ASTM A722, Type II per Section 93360.~~

~~(b) Use spherical nuts to anchor bars at bearing plates.~~

~~(eb) For permanent applications, use and location of bar couplers is subject to written approval by the Engineer.~~

**462-2.3.3 Grout:**

(a) Use only approved grouts *meeting requirements of Section 938* [s17] found on Department's Qualified Products List (QPL) *meeting requirements of Section 938* [s18].

(b) Select grout for use in PT system by *proper* [s19] application: repair, horizontal, or vertical.

(c) Mix grout per manufacturer's instructions with potable water meeting requirements of Section 923.

**462-2.4.4 Other Material References:**

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

<del>Class V</del> <i>Class 5</i> Applied Coating.....	Section 975
Elastomeric Coating System.....	Section 975
Epoxy <i>Grout Compound</i> [s20].....	Section 926
Magnesium Ammonium Phosphate Concrete .....	Section 930
Methacrylate .....	Section 413
Water.....	Section 923

**462-2.5.5 Component Samples:**

~~Consider jobsite as location where prestressing steel is to be installed, whether at bridge site or casting yard.~~

**462-2.5.5.1 Prestressing Steel:**

(a) Furnish samples *per Section 933 for testing as described herein* from each manufacturer of prestressing strand and bar to be used on project.

~~(b) Submit certification stating the manufacturer's minimum GUTS for each prestressing strand or bar sample furnished for testing.~~

~~(eb) The Engineer will collect sample materials from prestressing steel used for PT operations at plant or jobsite on the~~ [s21] *Project*, as indicated:

~~(1) Strands — three randomly selected samples, five feet (5 ft) long, per manufacturer, per strand size, per shipment, with a minimum of one sample for every ten reels delivered;~~

~~(2) Bars — three randomly selected samples, five feet (5 ft) long, per manufacturer, per bar size, per heat of steel, with a minimum of one sample per shipment.~~

~~(dc) One of each of the samples furnished to represent a Lot will be tested. Remaining s~~ Samples, properly identified and tagged per *Subarticle 462-46.2*, will be stored by the Engineer ~~for future testing. In event of loss or failure of the component, the stored sample will be utilized to evaluate for minimum strength requirements. Test results must show 100% of GUTS for acceptance of the Lot represented.~~

**462-2.5.5.2 Grout:**

~~(a) The Engineer may sample grout packages at random, not to exceed a total quantity of one bag per LOT (see 462-6.2) or shipment.~~

*(b) 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.*

*(c) 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:

(a) PT system ~~is a~~<sup>[s22]</sup> type and size ~~described in, and meeting meets~~<sup>[s23]</sup> all requirements of this Section.

(b) Net compressive stress in ~~the~~<sup>[s24]</sup> concrete after all prestress losses is ~~at least as large equivalent to or greater than~~<sup>[s25]</sup> that provided by ~~the~~<sup>[s26]</sup> PT scheme shown in original Contract Documents.

(c) Distribution of individual tendons at each cross section generally conform~~s~~<sup>[s27]</sup> to ~~the~~<sup>[s28]</sup> distribution shown in original Contract Documents.

(d) ~~Ultimate strength of structure with pP~~<sup>[s29]</sup> proposed PT scheme meets ~~the ultimate strength~~<sup>[s30]</sup> 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.

(e) 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.

(f) All Design Criteria provisions noted in original Contract Documents are satisfied.

(g) ~~The Contractor~~<sup>[s31]</sup> ~~fully show complete~~<sup>[s31]</sup> designs and details ~~of all~~<sup>[s32]</sup> elements ~~where for proposed locations of~~<sup>[s32]</sup> alternate PT scheme, ~~is proposed for use.~~<sup>[s33]</sup>

(h) ~~The Contractor~~<sup>[s34]</sup> submit: (1) design calculations including short and long term prestress losses and (2) complete Shop Drawings including PT scheme and system, reinforcing steel, and concrete cover, for the Engineer's approval.

(i) 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~~<sup>[s34]</sup> (1) quantity actually used and accepted or original Plan quantity, whichever is less, and (2) 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.

(j) ~~Submit alternate PT scheme signed and sealed by the Contractor's Engineer of Record. Responsible Contractor's Specialty Engineer of Record signs and seals alternate PT scheme.~~<sup>[s35]</sup>

### 462-4 Qualifications.

Provide all project personnel and crew foreman per Section 105.

~~Conduct all stressing and grouting operations in the presence of the Engineer.~~

#### ~~462-4.1 Post-Tensioning Operations:~~

~~Perform all PT stressing operations under direct supervision of a crew foreman who is a qualified post-tensioning technician.~~

~~462-4.2 Grouting Operations:~~~~Perform all PT grouting operations under direct supervision of a crew foreman who is a qualified grouting technician.~~**462-5 Submittals.****462-5.1 Shop and Working Drawings:**

(a) Submit to the ~~SDO Engineer~~ all necessary information, ~~material and component samples,~~ Plans, Shop and Working Drawings, and manuals in accordance with this Section and Section 5. ~~Include all~~ *Submit to the Engineer* signed and sealed PT-related Shop Drawings designed by the ~~Specialty Contractor's~~ *Engineer of Record*.

(b) Prepare Shop Drawings ~~to~~<sup>[s36]</sup> address ~~ing~~<sup>[s37]</sup> 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 ~~in~~<sup>[s38]</sup> detail ~~s~~<sup>[s39]</sup> of tendon geometry and locations complying with the Contract Documents and limitations of selected PT system. ~~Show~~ *Include*<sup>[s40]</sup> all inlets, outlets, high point outlet inspection details, anchorage inspection details, permanent ~~grout~~ *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.

**462-6.1-2 Lot/LOT Identification:**

(a) Assign an individual ~~Lot/LOT~~ number and tag items ~~to be~~ shipped to ~~jobsite project~~ in ~~such~~<sup>[s41]</sup> a manner that ~~allows~~<sup>[s42]</sup> each ~~Lot/LOT~~ ~~can to~~<sup>[s43]</sup> be clearly identified at project site for all *PT system components, grouting materials,* bars of each size from each mill heat of steel, and all strands from each manufactured reel.

(b) Submit records to the Engineer identifying assigned ~~Lot/LOT~~ numbers with heat or reel of material represented *if applicable*.

(c) All unidentified prestressing *components,* strands, ~~or~~ bars, *or grouting material* received at *the* site will be rejected.

(d) Loss of positive identification of these items at any time will be cause for rejection.

(e) Provide a copy of grout Quality Control Data Sheet, ~~received~~<sup>[s44]</sup> from manufacturer<sup>[s45]</sup> to the Engineer for each ~~Lot/LOT~~ ~~number and shipment~~<sup>[s46]</sup> ~~sent to jobsite.~~ ~~received for use~~<sup>[s47]</sup> *on the*<sup>[s48]</sup> *Project.*

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

~~(g) Consider jobsite as location where the prestressing steel is to be installed, whether at bridge site or casting yard.~~

**462-6.2-3 Prestressing Steel:**~~462-6.2.1 Jobsite:~~

(a) Protect all prestressing steel against physical damage and corrosion at all times, ~~from manufacturer to final grouting or encasing in concrete.~~

*(1) Package prestressing steel in containers for protection against physical damage and corrosion during shipping and storage.*

*(2) Place a corrosion inhibitor, which prevents rust, in package or incorporate it into a corrosion inhibitor carrier type packaging material.*

*(3) Corrosion inhibitor must have no deleterious effect on steel or concrete or bond strength of steel to concrete.*

*(4) Inhibitor carrier type packaging material must conform to provisions of Federal Specification MIL-P-3420.*

*(5) Immediately replace or restore damaged packaging to original condition.*

*(6) Clearly mark shipping package with a statement that package contains high-strength prestressing steel, care to be used in handling, ~~and include~~ [s49] type, kind, and amount of corrosion inhibitor used, ~~including~~ [s50] date when placed, safety orders, and instructions for use.*

(b) The Engineer will reject prestressing steel that has sustained physical damage.

(c) ~~Remove and discard lengths of strand~~ Carefully inspect any reel ~~that is~~ [s51] found to contain broken wires during use and remove and discard lengths of strand containing broken wires: wires.

(d) Wire must be bright and uniformly colored, ~~having with~~ [s52] no foreign matter or pitting on its surface.

~~(e) Package prestressing steel in containers for protection against physical damage and corrosion during shipping and storage.~~

~~(f) Place a corrosion inhibitor, which prevents rust, in package or incorporate it into a corrosion inhibitor carrier type packaging material.~~

~~(g) Corrosion inhibitor must have no deleterious effect on steel or concrete or bond strength of steel to concrete.~~

~~(h) Inhibitor carrier type packaging material must conform to provisions of Federal Specification MIL-P-3420.~~

~~(i) Immediately replace or restore damaged packaging to original condition.~~

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

~~(k) Specifically designate low-relaxation (stabilized) strands on packaging per requirements of ASTM A416. Strands not so designated will be rejected.~~

#### **462-6.2.2 Installation:**

~~(a) Do not exceed fourteen (14) calendar days between first installation of prestressing steel within duct and completion of stressing and grouting operation for PT bars located in superstructure and all strands regardless of location.~~

~~(b) Do not exceed twenty one (21) calendar days between the first installation of prestressing steel within duct and completion of stressing and grouting operations for PT bars located in substructure.~~

~~(c) Any light surface corrosion forming during period of time described in (a) or (b) will not be cause for rejection of prestressing steel.~~

~~(d) Failure to grout tendons within number of calendar days specified will result in stoppage of work in accordance with Article 8-6, except when waived by the Engineer in writing.~~

~~(e) Flushing of grout is not permitted unless approved by the Engineer in writing. Flushing of ducts is only permitted as defined in Subarticle 462-4.5.5.~~

~~(f) Vacuum grouting is required to repair all voids and blockages as subject to provisions of Subarticle 462-4.8.5.7.~~

#### **462-6.3-4 Grout:**

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

~~(b) Store grout in a location that is both dry and convenient to the work.~~

~~(e) Storage in the open must be on a raised platform and with adequate waterproof covering to protect the material.~~

~~(d) On site storage is limited to a maximum period of one (1) month.~~

#### **462-6.4-5 Duct and Pipe:**

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

~~(b) Furnish ducts [s53] with end caps to seal duct prevent interior from contamination inside duct. Do not remove duct [s54] end caps supplied with duct [s55] until duct [s56] is incorporated into the bridge component.~~

~~(c) Ship capped [s57] duct in bundles which are capped and that are [s58] covered during transport and storage.~~

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

~~(d) Do not remove end caps supplied with duct until it is incorporated into the bridge component.~~

~~(e) Store duct in a location that is dry and protected from sun exposure.~~

~~(f) Storage [s59] must be on a raised platform and completely covered [s60] to prevent contamination.~~

~~(g) If contamination is discovered, Flush immediately flush duct with potable water per Subarticle 462-74.52.54 before use to remove any contamination, if necessary.~~

#### **462-7 Construction.**

##### **462-7.1 General:**

(a) 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.

~~(b) Along with the certification, provide a list of PT system components and reference drawings to the Engineer.~~

*(c) 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.*

*(d) Conduct all stressing and grouting operations in the presence of the Engineer.*

#### **462-7.1.2 System Installation:**

Accurately and securely fasten all PT anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other ~~embedments~~ *embedded items* at locations shown in the Contract Documents or on approved Shop or Working Drawings or as otherwise approved by the Engineer *in writing*.

##### **462-7.1.2.1 Ducts:**

(a) Construct tendon ducts using ~~the~~ *the* minimum number of splices possible.

(b) Accurately ~~position and~~ *position and* align ducts ~~and position~~ *and position* at locations shown in the Contract Documents, ~~or~~ *or* according to approved Shop or Working Drawings, ~~or as otherwise~~ *or as otherwise* approved *in writing* by the Engineer *in writing*.

(c) Securely fasten all internal ducts ~~in position~~ *in position* at regular intervals not exceeding ~~thirty~~ *30* inches (~~30 in~~) for steel pipes, ~~twenty four~~ *24* inches (~~24 in~~) for round plastic ducts, and ~~twelve~~ *12* inches (~~12 in~~) for flat ducts to prevent movement, displacement, or damage from concrete placement and consolidation operations.

(d) Show method and spacing of duct supports on appropriate Shop Drawings.

(e) Ensure ~~external tendon~~ *external tendon* ducts ~~for external tendons~~ *for external tendons* 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.

(f) 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.

(g) ~~Carefully check~~ *Check* and repair all ducts *in accordance with 462-7.5* as necessary before placing any concrete.

(h) Ensure ~~all ends of~~ *all ends of* ducts, ~~at end~~ *at end* connections to anchorages, splices, inlets, outlets, and all other duct openings are sealed at all times after installing ducts and until ~~grouting tendon installation is complete;~~ *open low point outlets just prior to strand installation.*

(i) Provide an absolute seal of anchorage and duct termination locations *per the pre-approved system drawings. by using plumber's plugs or equal.*

~~(j) Install grout inlets and outlets with plugs or valves in closed position. Leave low point outlets open.~~

~~(k) Use of duct tape is not permitted to join or repair duct connections, or make connections for any other reason. Use only approved shrink sleeve material to repair duct and install using procedures and methods in accordance with manufacturer's instructions. Special wrap designed for duct repair may be used with approval of the Engineer in writing.~~

~~(k) 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 or other mechanical duct couplers meeting material requirements of ~~this~~ *Section 960 and approved system drawings.*

~~(m) When connecting steel pipe to plastic pipe with a boot, Use a three-eighths~~ *3/8 inch (3/8")* wide power seated band and clamps *in accordance with 960-2.2*

~~constructed from stainless steel~~ on each end of ~~the~~-a duct boot to seal against grout leakage. Install band ~~with an eighty to one hundred and twenty pounds (80-120 lbs) seating force~~ per manufacturer's instructions.

(~~h~~m) Ducts for prestressing ~~bars~~ used exclusively for temporary erection ~~PT to where PT will~~ [s77] be removed from structure are not required to be coupled across segment joints.

#### 462-7.12.1.1 Installation Tolerances.

(a) Ensure ~~final position of~~ PT ducts ~~in their final position are is~~ [s78] within the tolerances in the following table:

**Table 7.12.1.1-1 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
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

(b) Ensure entrance and exit angles of tendon paths at anchorages, ~~duct joints~~, and/or at faces of concrete are within plus or minus ~~three-3~~ degrees (~~±3 deg~~) of desired angle measured in any direction.

(c) Accomplish any deviations in alignment with smooth ~~unkinked~~ transitions ~~without kinks~~ [s79].

~~(d) Angle changes at duct joints must not be greater than plus or minus three degrees (±3 deg) in any direction and must be accomplished with smooth transitions without any kinks.~~

(~~e~~d) Locate anchorages within plus or minus ~~one-quarter~~ 1/4 inch (~~±1/4 in~~) of desired position laterally and plus or minus ~~one-1~~ inch (~~±1 in~~) along tendon except that minimum cover requirements must be maintained.

(~~f~~e) Position anchorage confinement reinforcement in the form of spirals, multiple U-shaped bars, or links ~~to be properly~~ [s80] centered around duct and ~~to starting~~ [s81] within ~~one-half~~ 1/2 inch (~~1/2 in~~) of the back of the main anchor plate.

(~~g~~f) If conflicts exist between reinforcement and ~~a~~ [s82] PT duct, position of duct prevails.- Adjust ~~local~~ [s83] reinforcement ~~locally~~ [s84] with the Engineer's ~~written~~ [s85] approval ~~in writing~~ [s86].

**462-7.12.2 Splices and Joints:**

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

~~(b) Approved shrink sleeve material may be used to repair duct.~~

~~(c) Use of any tape to repair or seal duct is not permitted.~~

~~(d) Special wrap designed for duct repair may be used with approval of the Engineer in writing.~~

(~~e~~b) Fabricate all duct splices to prevent duct kinks during concrete placement.

(~~f~~c) Use mandrels as needed to maintain duct alignment and shape.

**462-7.12.3 Inlets and Outlets:**

(a) Place grout inlets/outlets at locations shown in the Contract Documents including approved Shop Drawings.

(b) Equip all grout inlets/outlets with *approved* positive shut-off devices (e.g., valves).

(c) At a minimum, place grout inlets/outlets in *these following* [s87] positions *and those shown in Design Standard Index No. 21801:*

(1) Top of tendon anchorage;

(2) Top of *grout anchorage* cap;

(3) At high points of duct when vertical distance between highest and lowest point is more than ~~twenty 20~~ inches (~~20 in~~);

(4) At location three feet (~~3 ft~~) past high points of duct on downstream side opposite direction of grouting;

(5) At all low points;

(6) At major change in duct cross section; and,

(7) At other locations required by the Engineer.

(d) Extend grout tubes a sufficient distance out of concrete member to allow for proper closing of valve.

**462-7.12.4 Tendons:**

*(a) Do not exceed 14 calendar days between first installation of prestressing steel within duct and completion of the [s88] stressing and grouting operation for PT bars located in superstructure and all strands regardless of location.*

*(b) Do not exceed 21 calendar days between the first installation of prestressing steel within duct and completion of the [s89] stressing and grouting operations for PT bars located in substructure.*

*(c) Any light surface corrosion forming during the [s90] period of time described in (a) or (b) will not be cause for rejection of prestressing steel.*

*(d) Failure to grout tendons within the number of calendar days specified, will result in stoppage of work, except when waived by the Engineer in writing.*

*(e) Flushing of grout is not permitted unless without written approval by of the Engineer in writing. Flushing of ducts and [s91] is only permitted as defined in this Article.*

*(f) Vacuum grouting is required to repair all voids and blockages as subject to provisions of 462-8.3.2.*

(~~a~~g) For tendon *ducts* subjected to contamination with chlorides (*i.e.e.g.* [s92], *uncapped ducts that have been subjected to salt spray construction location in an aggressive environment*), flush duct with potable water containing slack lime (i.e., calcium

hydroxide) or quicklime (i.e., calcium oxide) in the amount of ~~seventeen hundredths~~ *0.17 lb/gal* pounds per gallon (0.17 lb/gal).

~~(b)~~ 1. Test for presence of chlorides and oils in discharged water before placing prestressing strands.

~~(c)~~ 2. ~~Limit chlorides in flush water outflow to less than six hundred parts per million (600 ppm).~~

~~(d)~~ If chloride levels *in flush water outflow* exceed ~~six hundred parts per million (600 ppm)~~, continue to flush duct until chloride level in flush water outflow is below ~~two hundred and fifty parts per million (250 ppm)~~.

~~(e)~~ 3. ~~Blow oil-free compressed air through duct to remove any excess water in duct. 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 boroscope or other visual inspection means, at no additional cost to the Department, to ensure duct interior is water free.~~<sup>[s93]</sup>

~~(f)~~ Push or pull PT strands through ducts to make up a tendon using methods that will not snag on any lips or joints in ducts.

~~(g)~~ Round off end of strands that are pushed or fit advancing end with smooth protective cap.

~~(h)~~ Do not intentionally rotate strand by any mechanical means during installation of PT strand into duct.

~~(i)~~ Provide sufficient strand length beyond dead end anchorages to allow for second end stressing as needed for reconciliation of jacking force versus measured elongation.

~~(j)~~ Alternatively, tendons may be pulled through duct using a special steel wire sock (~~“Chinese Finger”~~) or other device attached to advancing end. *Strands may be brazed together for pulling as long as one foot (1-ft) of strand from the brazed end is removed by cutting after installation.* Do not electric arc weld strand ends together for this purpose.

~~(k)~~ ~~Strands may be brazed together for pulling as long as one foot (1-ft) of strand from brazed end is removed by cutting after installation.~~

~~(l)~~ ~~Cut strands using an abrasive saw or equal. Flame cutting is not permitted in accordance with 462-7.3.~~

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

~~(n)~~ Do not install permanent tendons before completion of testing as required by this Section or the Contract Documents. The only two ~~(2)~~ exceptions ~~to this requirement~~ are:

(1) Tendon to be tested by “Theoretical Elongation Verification” may be installed for test; and,

(2) Transverse tendons may be pre-installed in precast segmental boxes prior to concrete casting ~~as described in such that they meet Subarticle 462-78.63.21.~~

~~(p)~~ Time limit between initial strand placement and grouting of stressed tendon, as defined in ~~Subarticle 462-76.32.1.2,~~ begins when strand is first placed in duct.

~~(q)~~ ~~The Engineer will reject ducts or any part of the work found to be deficient.~~

~~(r)~~ ~~Perform no remedial or repair work without the Engineer’s approval in writing.~~

#### **462-7.1.4.1 Placing Concrete:**

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

#### **462-7.2.3 Post-Tensioning Operations:**

(a) Do not apply PT forces until concrete has attained ~~specified~~ compressive strength *specified as determined by cylinder tests in the Contract Documents.*

(b) Conduct all stressing operations in presence of the Engineer.

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

#### **462-7.2.3.1 Stressing Equipment:**

Only use equipment furnished by supplier of PT system.

##### **462-7.2.3.1.1 Jacks and Gauges:**

~~(a) Equip each jack with pressure gauge for determining jacking pressure that has a-~~

~~(b) Pressure gauge must have an accurate reading with minimum dial diameter of at least six inches (6 in) in diameter.~~

##### **462-7.2.3.1.2 Calibration:**

(a) Calibrate each jack and its gauge(s) as a unit.

(b) Calibration must consist of three ~~(3)~~ test cycles with cylinder extension of jack in various positions (e.g., two inch ~~(2 in)~~, four inch ~~(4 in)~~, eight inch ~~(8 in)~~ stroke).

(c) At each pressure increment, average forces from each test cycle to obtain an average force.

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

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

(f) Use load cells calibrated within *the* past ~~twelve months~~ *(12 months)* to calibrate stressing equipment.

~~(g) Furnish certified calibration charts and curves to the Engineer prior to stressing for each jack and gauge unit used on project.~~

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

*(i) 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 ~~(6 mos)~~ thereafter or as requested by the Engineer.

*(j) 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.*

(~~k~~) Any jack repair, such as replacing seals or changing length of hydraulic lines, ~~is cause for~~ *requires* [s94] recalibration using a load cell.

(~~k~~) No extra compensation will be allowed for initial or any subsequent calibrations or use of master gauge *required by the Engineer*.

#### **462-7.23.2 Stressing Tendons:**

(a) Tension all PT steel ~~with hydraulic jacks~~ so PT force is not less than that required by the Contract Documents or as otherwise approved by the Engineer *in writing*.

(b) Do not use monostrand jacks to stress tendons with five ~~(5)~~ or more strands.

(c) Use of curved stressing noses or chairs is not permitted.

#### **462-7.23.2.1 Jacking Maximum Stress:**

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

~~(b) Do not overstress tendons to achieve expected elongation.~~

#### **462-7.23.2.2 Initial and Permanent Stresses:**

(a) 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.

(b) Unless otherwise approved by the Engineer *in writing*, initial stress after anchor set must not exceed ~~seventy percent (70%)~~ of GUTS.

(c) 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 ~~peculiar~~ *particular* to *the* specific PT system.

#### **462-7.23.2.3 Stressing Sequence:**

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

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

~~(c) Single end stressing is permitted when these conditions exist:~~

~~(1) Space limitations prohibit double end stressing;~~

~~(2) Calculated elongation of PT steel at second end is one-half inch (1/2 in) or less and wedges are power seated; or,~~

~~(3) Single end stressing applied at alternate ends of paired adjacent PT tendons is required to produce a symmetrical force distribution in agreement with design in the Contract Documents.~~

~~(d) For construction in stages, where some tendons are required to be stressed before others, install and stress in accordance with the Contract Documents or as otherwise approved by the Engineer in writing.~~

#### **462-7.23.2.4 Elongation:**

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

(b) Measure elongations to nearest ~~one sixteenth~~ *1/16* inch (*1/16 in*).

(c) For required tendon force, observed elongation must agree within ~~seven percent (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 ~~further~~.

(d) Do not overstress tendon to achieve theoretical elongation.

(e) In event that agreement between observed and theoretical elongations at required force falls outside acceptable tolerances, the Engineer may, at his discretion and without additional compensation to the Contractor, require additional tests for "Tendon Modulus of Elasticity" and/or "~~In Place Friction~~*In Place Wobble and Friction Test*" ~~in accordance with Subarticle 462-7.1.1 Subarticle 462-7.1.1 and Subarticle 4.1.2, respectively.~~

#### **462-7.23.2.5 Friction:**

~~(a) The Contract Documents were prepared based on assumed friction and wobble coefficients and anchor set so stated in the Contract Documents.~~

~~(ba) 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 ~~, after friction, wobble, and anchor set losses,~~ based upon expected actual coefficients and values for *the* PT system to be used.

~~(c) Provide expected actual coefficients and values in the Shop Drawings.~~

~~(d) Revise PT operations so final tendon force is in agreement with the Contract Documents if, in opinion of the Engineer, actual friction significantly varies from expected friction.~~

~~(eb) Graphite may be used as a lubricant when friction must be reduced, subject to written approval of the Engineer in writing.~~

#### **462-7.23.2.6 Tendon Wire Failure:**

(a) Multi-strand PT tendons ~~having with [s95]~~wires which fail by breaking or slipping during stressing may be accepted provided these conditions are met:

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

(2) 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 ~~erection~~ *erection 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 ~~erection~~ *erection construction*; and,

(3) Any single tendon must have no more than a ~~five percent (5%)~~ reduction in cross-sectional area of PT steel due to wire failure.

(b) 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.

#### **462-7.23.2.7 Cutting of PT Steel:**

(a) Cut PT steel using an abrasive saw or plasma torch within ~~three-quarters inch (3/4 inch)~~ to ~~one and a half inch (1-1/2 inch)~~ away from anchoring device.

(b) Flame cutting of PT steel is not permitted.

(c) Do not cut tendon to final length ~~until it has been prior to being~~ ~~accepted~~ *ance* ~~[s96]~~.

#### **462-7.23.2.8 Stressing *Post-Tensioning* Operations Record:**

(a) Keep a record of these PT operations for each tendon installed:

- (1) Project name, Financial Project ID (FPID);
- (2) Contractor and/or subcontractor;
- (3) Tendon location, size, and type;
- (4) Date tendon was first installed in duct;
- (5) Reel number for strands and heat number for bars;
- (6) Tendon cross-sectional area;
- (7) Modulus of elasticity;
- (8) Date stressed;
- (9) Jack and Gauge numbers per tendon end;
- (10) Required jacking force;
- (11) Gauge pressures;
- (12) Elongations (theoretical and actual);
- (13) Anchor sets (anticipated and actual);
- (14) Stressing sequence (i.e., sequential order of tendon stressing by number);
- (15) Stressing mode (single-end, dual-end, simultaneous);
- (16) Witnesses to stressing operations (Contractor and

Inspector);

~~(17) Date Grouted; and~~

(17) Any other relevant information.

(b) Provide the Engineer with a complete copy of all stressing ~~and grouting~~ operation ~~procedures~~ records within five (5) days of completed [s97] tendon installation.

#### **462-7.23.3 System Protection:**

##### **462-7.23.3.1 Tendon:**

(a) Install ~~grout~~ anchorage caps and seal all other duct openings within four- hours ~~(4 hrs)~~ after stressing.

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

(c) If tendon contamination occurs *and if directed by the Engineer*, remove tendon, flush duct with potable water per ~~Subarticle~~ 462-7.52.54, and replace with new tendon.

##### **462-7.23.3.2 Anchorage:**

(a) Protect PT bar and ~~tendon-strand~~ anchorages as indicated in the Contract Documents within seven ~~(7)~~ days of completing grouting operations (see ~~Subarticle~~ 462-7.84 for grouting operations).

~~(b) Application of elastomeric coating may be delayed up to ninety (90) days after grouting, as permitted by the Engineer in writing.~~

~~(c) Cap all grout inlets/outlets with plugs meeting the requirements of Section Subarticle 960-2.2.2.2.~~

~~(cd) Construct anchorage pour-backs as required Use [s98] with a Type Q epoxy grout compound [s99] per Section 926 within twenty-eight (28) days of permanently affixing all anchorage caps within each individual pour-back [s100] to construct all pour-backs located at anchorages.~~

~~(e) (1) Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting using a minimum ten thousand~~

~~pounds per square inch (10,000 psi) nozzle pressure~~<sup>[s101]</sup>. Flush surface with water and blow dry. Surfaces must be clean, sound, and without any standing water. ~~In case of dispute, use Test substrate at all pour-back locations using~~<sup>[s102]</sup> ACI 503 ~~for substrate testing~~<sup>[s103]</sup> and develop a minimum of ~~one hundred and seventy five pounds per square inch (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 results of the ACI 503 test.~~<sup>[s104]</sup>

(f2) Mix and apply epoxy ~~grout compound~~<sup>[s105]</sup> ~~as per in accordance with the~~<sup>[s106]</sup> manufacturer's current standard technical guidelines. Construct all pour-backs in leak proof forms creating neat lines. Epoxy ~~grout compound~~<sup>[s107]</sup> 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.

(dg) Coat exposed surfaces of all pour-backs and ~~grout anchorage~~ caps with an elastomeric coating system meeting requirements of Section 975 and having a thickness of ~~thirty (30) to forty five (45)~~ mils. Assure concrete, ~~grout anchorage~~ caps, or other substrates are structurally sound, clean, and dry. Concrete must be a minimum of ~~twenty eight (28)~~ days old. Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting using a minimum ~~ten thousand pounds per square inch (10,000 psi) nozzle pressure to establish anchor pattern~~. Blow surface with compressed air to remove dust or water. ~~Apply the elastomeric coating within 90 days of tendon grouting.~~<sup>[s108]</sup> Apply a manufacturer's approved primer over ~~the~~<sup>[s109]</sup> elastomeric coating before applying ~~Class V Class-5~~ coating, if required. ~~Apply the elastomeric coating within ninety (90) days of tendon grouting.~~<sup>[s110]</sup>

(eh) ~~Prior to application of elastomeric coating,~~ ~~Construct a two foot (2 ft) x four foot (4 ft) concrete test block with a similar surface texture to surfaces to be coated.~~ ~~and e~~ Coat a vertical face with ~~chosen~~ elastomeric coating system ~~chosen~~. Determine number of coats required to achieve ~~a coating thickness between thirty (30) to forty five (45) mils~~ ~~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 ~~(3 yrs)~~ experience applying similar polyurethane systems. Submit credentials of these persons to the Engineer for review and consideration for approval.

#### **462-7.3-4 Grouting Operations:**

*Conduct all grouting operations in the presence of the Engineer.*

##### **462-7.3.4.1 Plan:**

- (a) Submit a Grouting Operations Plan *to the Engineer* for approval at least six ~~(6)~~ weeks in advance of any scheduled grouting operation.
- (b) Written approval of Grouting Operations Plan by the Engineer is required before any grouting of permanent structure takes place.
- (c) At minimum, Grouting Operations Plan will address and provide:

- (1) Names and proof of training for grouting crew and crew supervisor in conformance with this Specification;
- (2) Type, quantity, and brand of materials to be used in grouting *that conform to Section 938* including all required certifications;
- (3) Type of equipment to be used, including capacity in relation to demand and working conditions, as well as, standby equipment and spare parts;
- (4) General grouting procedure;
- (5) Duct pressure test and repair procedures;
- (6) Method to be used to control rate of flow within ducts;
- (7) Theoretical grout volume calculations;
- (8) Mixing and pumping procedures *in accordance with the manufacturer's recommendations*;
- (9) Direction of grouting;
- (10) Sequence of inlet and outlet pipes use;
- (11) Procedures for handling blockages;
- (12) Procedures for possible post grouting repair.

(d) 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.

*(e) Demonstrate<sup>[s111]</sup> to the Engineer's satisfaction<sup>[s112]</sup> grouting of a longitudinal tendon by constructing a full-scale mockup<sup>[s113]</sup> with all associated PT system components<sup>[s114]</sup> of a typical longitudinal tendon profile on the project, as specified by the Engineer<sup>[s115]</sup>. 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~~<sup>[s116]</sup> on-stressed PT strand equivalent to the typical longitudinal tendon size ~~will be placed~~<sup>[s117]</sup> inside the duct to simulate in-place PT strand.*

#### **462-7.34.2 Inlets and Outlets:**

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

#### **462-7.34.3 Supplies:**

- ~~(a) 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.~~
- ~~(b) Provide a water storage tank of sufficient capacity where water is not supplied through public water supply system.~~

#### **462-7.34.4 Equipment:**

- (a) 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.
- (b) Provide pumping equipment with sufficient capacity to ensure PT ducts can be filled and vented in not more than ~~thirty minutes (30- minutes)~~ without interruption.
- (c) Provide an air compressor and hoses with sufficient output to perform required functions.
- (d) ~~Provide~~ *Have available* vacuum grouting equipment (i.e., volumetric measuring type) and experienced operators within ~~forty eight hours (48 hrs)~~ notice.

#### **462-7.34.4.1 Mixer and Storage Hopper:**

~~(a) Provide a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and un-dispersed cement.~~

~~(ba)~~ 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 ~~partially~~ 10% full at all times during pumping operations to prevent air from being drawn into duct.

~~(eb)~~ Add water during ~~initial~~ *primary* mixing *phase in the colloidal mixer* by use of a flow meter or calibrated water reservoir with measuring accuracy equal to ~~one percent~~ (1%) of total water volume.

#### **462-7.34.4.2 Pumps:**

(a) Provide pumping equipment capable of (1) continuous operation which includes a system for circulating *and agitating* -grout when actual grouting is not in progress and (2) maintaining pressure on ~~completely~~ grouted ducts and (3) fitted with a valve that can be closed off without loss or pressure in duct.

(b) Grout pumps will (1) be positive displacement type, (2) provide a continuous grout flow, and (3) be able to maintain a discharge pressure of at least ~~one hundred forty five pounds per square inch~~ (145 psi).

(c) Use pumps constructed with seals ~~adequate~~ to prevent oil, air, or other foreign substances from contaminating grout and prevent loss of grout or water.

(d) Specify pump capacity adequate to maintain ~~an~~ *the* <sup>[s118]</sup> ~~optimal~~ *specified* grouting rate.

(e) Place pressure gauge ~~having a~~ <sup>[s119]</sup> ~~with~~ full scale reading of no more than ~~three hundred pounds per square inch~~ (300 psi) at duct inlet. If long hoses (i.e., in excess of ~~one hundred feet~~ (100 *feet*)) are used, provide two gauges:- one at pump and one at inlet.

(f) ~~Size diameter and rated pressure capacity of grout~~ *Grout* hose(s) to be compatible with pump output (*diameter and pressure rating*).

#### **462-7.34.4.3 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 ~~(10 cfm)~~ and equipped with flow-meter capable of measuring amount of grout being injected.

(3) Manual colloidal mixers and/or dissolvers (e.g., manual high speed shear mixers) for voids less than five- ~~and twenty eight hundredths~~ gallons ~~(5.280 gal)~~ in volume;

(4) Standard colloidal mixers for voids five ~~and twenty eight hundredths~~ gallons ~~(5.280 gal)~~ and greater in volume.

#### **462-7.34.4.4 Standby Equipment:**

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

#### **462-7.34.5 Grouting:**

(a) Maintain grout fluidity in strict compliance with grout manufacturer's recommendations ~~and test with flow cone.~~

(b) *In the presence of the Engineer, P*perform test to confirm accuracy of grouting equipment volume-measuring components each day of use before performing any grouting operations.

~~(c) Use either water or grout for testing using standard testing devices with volumes of one-half gallon (0.5 gal) and six-and-a-half gallons (6.5 gal) and an accuracy of equal to or less than four- ounces (4 oz). Perform one (1) test with each device. Results must verify accuracy of grouting equipment void volume-measuring component within one percent (1%) of test device volume and must verify accuracy of grouting equipment grout volume component within five percent (5%) of test device volume.~~

~~(d) Ensure the Engineer is present when any tests are performed.~~

*(c) Do not use grout which<sup>[s120]</sup> tests outside allowable flow rates.*

~~(e) Perform Grout grouting tendons~~ in accordance with procedures set forth in approved Grouting Operations Plan.

~~(f) Grout all empty ducts.~~

#### **462-7.34.5.1 Temperature:**

(a) *At inlet end of grout hose, the M*maximum limit for grout temperature is ~~ninety degrees Fahrenheit (90°F) at grout inlet for normal grouting procedures and eighty five degrees Fahrenheit (85°F) when performing repair operations with vacuum grouting.~~

(b) ~~Use chilled water and/or pre-cooling of bagged~~ *Condition grout* material to maintain mixed grout temperature below maximum limit.

~~(c) Grouting operations are not permitted when ambient temperature is below forty degrees Fahrenheit (40°F) or is~~ *(c) Grouting operations are not permitted when ambient temperature is below forty degrees Fahrenheit (40°F) or <sup>[s121]</sup> are expected to fall below forty degrees Fahrenheit (40°F) and falling within one (1) day subsequent to grouting.*

(d) Postpone grouting operations if freezing temperatures are forecasted within ~~next two (2) days~~ *subsequent to grouting. and it is expected concrete temperature surrounding duct will fall below forty degrees Fahrenheit (40°F).*

#### **462-7.34.5.2 Mixing and Pumping:**

(a) Mix grout with a metered amount of water.  
 (b) Mix materials to produce a homogeneous grout.  
 (c) Continuously agitate grout until grouting operations are complete.

(d) Reject bags of grout containing clumps.

#### **462-7.34.5.3 Production Test:**

(a) ~~Maintain~~ *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.

(b) Determine grout fluidity ~~by use of either test method found in~~ *accordance with* Section 938.

*(1) Perform a fluidity test using flow cone on grout discharged from grout anchorage cap outlet immediately after uncontaminated uniform*

*consistency discharge begins for each tendon greater than ~~fifty feet (50 ft)~~ in length. For tendons ~~fifty feet (50 ft)~~ 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.*

*(2) 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.*

~~(c) Perform fluidity test for each tendon to be grouted and maintain correct~~ *without modifying* water-cementitious ratio.

~~(d) Do not use grout which tests outside allowable flow rates.~~

~~(e) Condition grout materials as required to limit grout temperature at inlet end of grout hose to ninety degrees Fahrenheit (90°F) prior to grouting empty ducts.~~

~~(f) Condition grout materials to limit grout temperature at inlet end of grout hose to eighty five degrees Fahrenheit (85°F) prior to performing repair operations with vacuum grouting.~~

~~(g) Check temperature of grout at inlet end of grout hose hourly to verify conformance to this Section.~~

~~(h) Obtain a representative 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.~~

~~(i) Begin grouting operations after sample is obtained.~~

~~(j) 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 are have ceased due to non-compliance of the wick induced bleed test.~~

~~(k) Do not re-start grouting operations until they have been such time that adjusted and testing shows grout meets specified requirements.~~

~~(l) Immediately inform the Engineer when grouting operations are stopped due to wick induced bleed test non-compliance.~~

#### **462-7.34.5.4 Operations:**

(a) Open all grout outlets before starting grouting operation.

(b) Grout tendons in accordance with *approved* Grouting

Operations Plan.

~~(c) Pump grout at a rate of sixteen feet (16 ft) to fifty feet (50 ft) of duct per minute unless otherwise approved by the Engineer in writing the lowest possible pressure practical.~~

~~(d) Conduct normal grouting operations at a pressure range of ten pounds per square inch (10 psi) to fifty pounds per square inch (50 psi) measured at grout inlet.~~

(e) Do not exceed maximum pumping pressure of ~~one hundred forty five pounds per square inch (145 psi)~~ at grout inlet for round ducts and ~~seventy five pounds per square inch (75 psi)~~ for flat ducts ~~in deck slabs~~.

(f) Use grout pumping methods that ensure complete filling of ducts and complete encasement of steel.

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

(h) Pump grout through duct and continuously discharge it at anchorage and ~~grout~~*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 (~~2 gal~~) of grout from ~~grout~~*anchorage* cap into a clean receptacle. Close ~~grout~~*anchorage* cap outlet.

~~(i) Perform a fluidity test using flow cone on grout discharged from grout cap outlet immediately after uncontaminated uniform discharge begins for each tendon greater than fifty feet (50 ft) in length. For tendons fifty feet (50 ft) 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 house into holding tank. Ensure measured grout efflux time is not less than efflux time measured at injection end of grout hose.~~

~~(j) Alternately, check grout fluidity using Wet Density method contained in Section 938. Density at final outlet must not be less than grout density at inlet. Discharge additional grout from anchorage outlet and test grout fluidity if fluidity is not acceptable. Continue this cycle until an acceptable grout fluidity is achieved. Discard grout used for testing fluidity.~~

(*ki*) Elevate grout pressure to ~~plus or minus~~*the equivalent realized pumping pressure while grouting the tendon* ~~seventy five pounds per square inch ( $\pm 75$  psi)~~, seal inlet valve, and wait two- minutes (~~2 min~~) to determine if any leaks exist after all outlets have been bled and sealed. *If leaks are present* ~~Fix-repair~~ all identified leaks using methods pre-approved by the Engineer ~~if leaks are present~~ and repeat ~~above~~ steps until no leaks are present. Bleed pressure to ~~five pounds per square inch (5 psi)~~ and wait a minimum of ten- minutes (~~10 min~~) for any entrapped air to flow to high points if no leaks are present. Increase ~~pressure~~*pumping pressure not to exceed actual realized pumping pressure of tendon as needed* and discharge grout at each high point outlet to eliminate any entrapped air or water after specified ten- minute (~~10 min~~) period has expired. Complete process by locking a pressure of ~~thirty pounds per square inch (30 psi)~~ into tendon duct.

(*lj*) 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.

(*mk*) Stop grouting operation if complete grouting of tendon cannot be achieved by the steps stated ~~in this Subarticle~~ and in compliance with the *approved Grouting Operations Plan*. *After waiting forty eight hours (48 hrs), vacuum grout duct in accordance with this Section.*

~~Fill tendon duct with grout in accordance with procedure outlined in Subarticle 462-7.8.5.7 Subarticle 462-7.8.5.7 after waiting forty eight hours (48 hrs).~~

~~\_\_\_\_\_~~  
**462-7.34.5.5 Vertical Grouting:**

~~(a) Grouting of cable stays is not covered by this Specification.~~

~~(b) Provide a standpipe 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; and maintain grout level above level of prestressing plate and anchorage for all vertical tendons. Design and size this device to maintain level of grout at an elevation that as ensurings potential bleeding will at no time cause level of grout to not drop below the highest point of upper anchorage device. Design standpipe reservoir to allow all bleed water, if any, to rise into standpipe reservoir, not into uppermost part of tendon and anchorage device.~~

~~(b) Discharge grout and check grout fluidity as described in Subarticle 462-7. this Section Article 8.5.4. Fill standpipe with grout to a level assuring grout level will not drop below highest point in upper anchorage device as settlement of grout occurs. Immediately add grout to standpipe if level of grout begins to drop, [s123] potentially allowing bleed water into the upper anchorage device and tendon ducts below highest point in anchorage device. Remove standpipe reservoir after grout has hardened. Visually inspect for voids using an endoscope or probe in presence of the Engineer. Fill all voids found in duct using volumetric measuring vacuum grouting process in accordance with this Section.~~

~~(c) 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. in excess of one hundred (100 ft) or if the grouting pressure exceeds maximum recommended pumping pressure. Allow grout to flow from each outlet until all air and water have been purged prior to using outlet for pumping.~~

~~\_\_\_\_\_~~  
**462-7.3.5.6 Vibrations:**

~~\_\_\_\_\_~~  
~~During grouting and for a period of four hours (4 hrs) upon completion of grouting, eliminate vibrations from all sources such as moving vehicles, jackhammers, compressors, generators, pile driving operations, soil compaction, etc., that are operating within three hundred (300 ft) downstation and three hundred feet (300 ft) upstation of ends of span in which grouting is taking place.~~

~~\_\_\_\_\_~~  
**462-7.34.5.7-6 Grouting Operations Report:**

~~(a) Provide grouting report signed by the grouting Contractor and/or the Subcontractor within seventy two hours five (5) days (72 hrs) of following each grouting operation for review by the Engineer.~~

~~(b) Report Record [s124] theoretical quantity of grout anticipated as compared to actual quantity of grout used to fill duct. Notify the Engineer immediately of shortages or overages.~~

~~(c) Information to be noted in this report must include at a minimum, but not necessarily be limited to: (1) identification of tendon; (2) date grouted; (3) number of days from tendon installation to grouting; (4) type of grout; (5) injection end and applied grouting pressure; (6) ratio of actual to theoretical grout quantity; (7) number of bags of grout bags mixed; (8) total quantity of water used to mix grout; (9) summary of any problems encountered; and, (10) corrective action taken, (11) description and results of the post grouting operations and inspection.~~

#### **462-7.4.5 Repair:**

*Perform no remedial or repair work without the Engineer's approval in writing.*

##### **462-7.4.5.1 Lifting and Access Holes:**

(a) 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 ~~twenty-four hours~~ (24 hrs)), 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 ~~ten-thousand-pounds-per-square-inch~~ (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.

(b) Coat repaired holes, block-outs, and an area extending six- inches (~~6 in~~) outside perimeter of repair with a High Molecular Weight Methacrylate (HMWM) listed on the QPL upon completion of deck grooving. Prepare surface to be coated and apply HMWM in accordance with Section- 413. Friction (i.e., skid) test per Section- 413 are not required.

~~(c) Alternately, a Type Q Epoxy grout meeting requirements of Section 926 may be used for repair material.~~

##### **462-7.4.5.2 Inlets and Outlets:**

(a) Place threaded plastic plugs in all inlet/outlet locations required in the Contract Documents.

(b) Repair inlets/outlets as shown in the Contract Documents using an *Type Q* epoxy ~~compound~~<sup>[s125]</sup>, Type E epoxy ~~compound~~<sup>[s126]</sup>, or Type F-1 ~~epoxy~~ ~~compound~~<sup>[s127]</sup> meeting requirements of Section 926.

(c) Prepare surface to receive epoxy ~~material-compounds~~ <sup>[s128]</sup> in strict compliance with manufacturer's recommendations.

##### **462-7.5.3 Duct:**

~~(a) Heat-shrink wrap material designed for duct repair may be used with approval of the Engineer in writing.~~<sup>[s129]</sup>

~~(a) Use only~~ <sup>[s130]</sup> *approved heat-shrink sleeve material to repair ducts. and it*<sup>[s131]</sup> ~~install using procedures and methods~~ <sup>[s132]</sup> *in accordance with manufacturer's instructions.*

~~(b) Heat-shrink wrap material designed for duct repair may be used with approval of the Engineer in writing.~~<sup>[s133]</sup>

#### **462-8 Acceptance and Testing.**

##### **462-8.1 Contractor Material Testing:**

(a) 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.

(b) 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.

(a) Bench test two (~~2~~) samples of each size tendon prior to stressing tendons to determine modulus of elasticity for purpose of accurately determining tendon elongations while stressing.

(b) Bench length between anchorages must be at least ~~forty feet (40 feet)~~ and tendon duct at least two- inches (~~2 in~~) clear of tendon all around for purpose of this test.

(c) Test procedure must consist of stressing tendon at an anchor assembly with a load cell at dead end.

(d) Tension test specimen ~~eighty percent (80%)~~ of GUTS in ten (~~10~~) increments and then detention from ~~eighty percent (80%)~~ of GUTS to zero in ten (~~10~~) decrements.

(e) Record gauge pressure, elongations, and load cell forces for each increment and decrement.

(f) Note elongations of tendon for both ends and the central ~~thirty feet (30 feet)~~, measured to an accuracy of plus or minus ~~one-thirty-second inch ( $\pm 1/32$  inch)~~.

(g) Correct elongations for actual anchorage set of dead end.

(h) 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 ~~thirty feet (30 feet)~~ of tendon

A = cross sectional area of tendon ~~based on nominal area?~~  
~~diameter~~

dl = strand elongation within length, L, for load, P;

(i) 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 ~~one percent (1%)~~.

(j) 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 satisfaction of the Engineer.

(k) Additional test series of substantiation from previous projects, not to exceed two (~~2~~) per source, will be required if source of prestressing steel changes during project.

(l) Apparatus and methods used to perform the test must be submitted to the Engineer for approval *in writing*.

(m) Tests must be conducted in the Engineer's presence.

#### 462-8.1.2 ~~Theoretical Elongation Verification~~ *In-Place Wobble and Friction*

##### *Test:*

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

(b) Functional tendon groups are cantilever tendons, continuity tendons, draped external tendons, or continuous profiled tendons passing through one (~~1~~) or more spans.

(c) Selected tendon will represent the size and length of tendon group being tested.

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

(e) Test procedure consists of stressing tendon at an anchor assembly with a load cell or a second certified jack at dead end.

(f) Stress test specimen to ~~eighty percent (80%)~~ of GUTS in eight (~~8~~) equal increments.

(g) For each increment, record gauge pressure, elongations, and load cell force.

(h) 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 through these assemblies.

(i) 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.

(j) If elongations fall outside the plus or minus ~~five-seven percent ( $\pm 57\%$ )~~ range compared to anticipate elongations, investigate reason ~~why~~ and make detailed calculations confirming final tendon forces are in agreement with requirements of the approved Contract Documents.

(k) Do not vary value of expected friction and wobble coefficients by more than plus or minus ~~ten percent ( $\pm 10\%$ )~~ in reconciling theoretical and actual elongations.

(l) ~~A significant shortfall in elongations is indicative of poor duct alignments and/or obstructions. Submit for written approval by the Engineer a plan to C~~correct or compensate for ~~such~~ elongation ~~discrepancies if necessary, in a manner proposed by the Contractor and reviewed and approved by the Engineer in writing at no additional cost to the Department.~~

(m) The Engineer will require one ~~(1)~~ successful ~~friction~~ test for each tendon group for the project.

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

(o) Submit apparatus and methods used to perform test to the Engineer for approval in writing.

(p) Conduct all in-place ~~friction~~ tests in the Engineer's presence.

#### **462-8.1.3 Required Reports:**

(a) Submit two ~~(2)~~ copies of the test report for "Tendon Modulus of Elasticity Test" to the Engineer at least ~~thirty (30)~~ days before installing tendon.

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

#### **462-8.1.4 Test Results Application:**

(a) 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* ~~Theoretical Elongation Verification~~," as appropriate, and correct calculations as necessary.

(b) Submit revisions to theoretical elongations to the Engineer for approval in writing.

#### **462-8.2 Contractor Field Tests:**

##### **462-8.2.1 ~~Before~~ *Prior to* Concrete Placement:**

(a) *Types of systems to be tested include all system PT 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. Longitudinal tendons in box-girder segments (internal tendons) are exempt from this testing.*

~~Pressure test each different type and size of duct assembly before its first use on project.~~

(b) ~~In the formwork, P~~ 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, ~~and thereafter, in groups of not more than fifty (50) components.~~

(c) One ~~(1) component-system~~ per group, but not less than a total of two ~~(2)~~ per project, will be randomly chosen by the Engineer for testing.

~~Types of components to be tested include all PT components including but not limited to transversely post tensioned slabs, longitudinally post tensioned girders, post tensioned box girder segments, pier and bent caps, and columns. Longitudinal tendons in box segments are exempt from this testing.~~

(e) ~~When required by the Engineer, T~~ 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 Article* to determine if assembly connections are pressure tight.

(f) ~~In presence of the Engineer, P~~ressurize ~~pressurize~~ duct to ~~one and five tenths pounds per square inch (1.5 psi)~~ and lock-off outside air source.

(2) ~~Then~~ record pressure loss for a ~~duration of~~ one minute ~~(1 min))~~ in presence of the Engineer.

(3) ~~If~~ pressure loss exceeds ~~fifteen hundredths pounds per square inch (0.15 psi)~~, or ~~ten percent (10%)~~, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

#### **462-8.2.2 After Post Concrete Placement:**

(a) After stressing and before grouting internal or external tendons, install all ~~grout~~ *anchorage* caps, inlets and outlets and test the tendon with compressed air *in accordance with this Section* to determine if duct connections require repair.

(b) In the presence of the Engineer, pressurize tendon to ~~fifty pounds per square inch (50 psi)~~ and lock-off outside air source. Record pressure loss for one- minute ~~(1 min)~~. A pressure loss of ~~not to exceed less than~~ <sup>[s134]</sup> ~~twenty five pounds per square inch (25 psi)~~, or ~~fifty percent (50%)~~, is acceptable for tendons ~~having with~~ <sup>[s135]</sup> a length of equal to or less than ~~one hundred and fifty feet (150 ft)~~ and a pressure loss ~~not to exceed less than~~ <sup>[s136]</sup> ~~of fifteen pounds per square inch (15 psi)~~ is acceptable for tendons longer than ~~one hundred and fifty feet (150 feet)~~.

(c) 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 After Post Concrete Placement / Before Prior to Grouting**

##### **Operations:**

(a) Upon completion of concrete placement and except as otherwise described ~~below in this Subarticle~~, 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.

(b) Use a torpedo having same cross-sectional shape as duct that is ~~one quarter inch (1/4 inch)~~ 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 ~~(2 ft)~~ long. For curved ducts, determine length so that when both ends touch outermost wall of duct, torpedo is ~~one quarter inch~~

(1/4 inch) 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.

(c) Alternatively, four (4) strand tendons in flat ducts used for transverse PT of precast 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 (1 ft) in each direction. Move strands easily, by hand, without resorting to excessive effort or mechanical assistance.

#### 462-8.3.2 After Post Grouting Operations:

(a) *Inspect all tendons.*

(ab) Do not open or remove inlets and outlets until grout has cured for a minimum of twenty four hours (24 hours).

(bc) *Perform inspections within one hour after removal of all inlets/outlets.* Remove all inlets/outlets located at anchorages and high points along the tendon. ~~to facilitate inspection and perform inspections within one hour (1 hr) after removal of inlets/outlets.~~ [s137]

(ed) Drill into existing grout ports at and inspect all high points along tendon as well as inlets or outlets located at anchorages for inspection. Drilling through hardened grout may be required to penetrate full-length of grout port access piping to top to inner surface of trumpet or duct depending on geometry of grout inlets. *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 grout anchorage cap unless grout anchorage caps are determined to have voids by sounding.

(de) Perform all inspections using endoscopes or probes and in presence of the Engineer.

(ef) Fill voids using volumetric measuring vacuum grouting process within forty eight hours (48 hrs) if voids are detected in tendon ducts or anchorages during inspection.

(g) Seal and repair all anchorage and inlet/outlet voids that are produced by drilling for inspection purposes as specified in Subarticle 462-7.4.2 Subarticle 462-7.4.2 within four hours (4 hrs) of completion of inspections if no additional voids are detected in tendon ducts or anchorages.

(h) Remove inlet/outlet to a minimum depth of two inches (2 in) 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 drilled holes for backfilling with epoxy compound [s139].

~~(f) Seal and repair all anchorage and inlet/outlet voids that are produced by drilling for inspection purposes as specified in Subarticle 462-7.4.2 Subarticle 462-7.4.2. Remove inlet/outlet to a minimum depth of two inches (2 in). Use an injection tube to extend to bottom of drilled holes for backfilling with epoxy.~~

~~(g) Post grouting inspection of tendons having a length of less than one hundred fifty feet (150 ft) may utilize following statistical frequency for inspection:~~

~~(1) Inspect all outlets located at anchors and tendon high points by drilling and probing with endoscope probe. Continue testing all tendons until the first twenty (20) consecutive tendons have been inspected and no voids found.~~

~~(2) Frequency of inspection can be reduced to inspect every other tendon (i.e., fifty percent (50%)) when no defects are detected as defined in number one (1) above. Inspect last five (5) tendons grouted if a defect is found. Return to step one (1) above and renew cycle of one hundred percent (100%) tendon inspection.~~

(h) Drill into duct and explore voided areas with an endoscope if tendon grouting operation were prematurely terminated prior to completely filling tendon. Probing is not allowed. Determine location and extent of all voided areas. ~~Install grout inlets as needed~~ and fill voids using volumetric measuring vacuum grouting equipment *in accordance with this Section.*

#### 462-9 Method of Measurement.

(a) 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.

(b) 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.

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

(d) Use these unit weights for quantity determination:

**Table 6.1-1 PT Strand 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:**

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

(b) Payment will be full compensation for furnishing, installing, stressing, and grouting of all temporary and permanent, internal and external PT tendons. 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, all testing ~~including Tendon Modulus of Elasticity Test and In-Place Wobble and Friction Test~~<sup>[s140]</sup>, 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.

(c) 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.

(d) 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.

(e) Permanent PT strand 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.

(f) Payment for PT will be made following successful placement, stressing, grouting, inspection, repair, protection, and *written* approval by the Engineer.

(g) 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 grouted and anchorage protection system applied and the segmental unit otherwise approved *in writing* for placement by the Engineer.

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**462-10.1-2 Pay Items:**

Payment will be made under:

- (a) ~~Pay~~-Item No. 462- 2      Post-tensioning Tendons - Per Pound