ITEM 426

PRESTRESSING

426.1. Description. Furnish, store, and handle prestressing materials and perform prestressing of precast members and cast-in-place structural units. For this Item, the following definitions apply:

- **Prestressing.** The introduction of internal stresses (pretensioning or post-tensioning) into a structural member by tensioning and anchoring strands, bars, or wires to counteract the stresses resulting from the applied load.
- **Pretensioning.** The application of prestressing force to the tensioning devices before casting concrete.
- **Post-Tensioning.** The application of prestressing force to the tensioning devices after concrete has hardened.
- **Tendon.** Any single unit used to apply prestressing force to the member. For post-tensioned units, a tendon is a bar, group of wires, or group of strands having common end anchorage.
- **Post-Tensioning System.** A complete tendon with couplers, end anchorage, and all other necessary hardware.

426.2. Materials. Furnish materials that meet requirements of the following Items:

- Item 420, “Concrete Structures”
- Item 421, “Hydraulic Cement Concrete”
- Item 434, “Elastomeric Bridge Bearings”
- Item 440, “Reinforcing Steel”
- Item 442, “Metal For Structures”
- DMS-4670, “Grouts for Post-Tensioning”
- DMS-6310, “Joint Sealants and Fillers.”

A. **Prestressing Hardware.** Furnish prestressing hardware that meets the manufacturer’s specifications.

B. **Concrete.** Furnish concrete of the class shown on the plans.

C. **Prestressing Steel.** Furnish prestressing steel conforming to one of the following types:

- 7-wire steel strand meeting DMS-4500, “Steel Strand, Uncoated Seven-Wire Stress Relieved and Low Relaxation for Prestressed Concrete,”
- alloy bars meeting ASTM A 722, or
- steel wire meeting ASTM A 421.

When shown on the plans or permitted by approval of optional design, use stress-relieved 7-wire strand.

Furnish a copy of the manufacturer’s certified Domestic Certification Form D-9-PS-1 for 7-wire steel strand. Use 7-wire steel strand produced by a prequalified manufacturer on the list maintained by the Construction Division. The Department may take samples in accordance with Tex-710-1 to verify compliance with specification requirements.

Test prestressing material per the applicable ASTM standards. Furnish project samples of prestressing bar and prestressing wire for testing in accordance with Section 426.4.B.1, “Prestressing Steel Bar and Wire Samples.”

Assign an individual lot number to all bars from each size and heat, all wire from each coil, and all strand from each reel, and tag the material for accurate identification at the jobsite. Identify each lot of anchorage assemblies and couplers in a similar manner. Unidentified prestressing steel, anchorage assemblies, or couplers received at the site will be rejected. Loss of positive identification of these items at any time will be cause for rejection.

D. **Post-Tensioning System.** Furnish a post-tensioning system as required by this Item and the plans. The system selected must provide the magnitude and distribution of prestressing force and ultimate strength required by the plans without exceeding allowable temporary stresses. Provide grouted or ungrouted post-tensioned tendons as shown on the plans. Use tendon couplers only at locations shown on the plans or approved by the Engineer.
Post-tensioning systems must be pre-qualified before use on the project. Prequalification will consist of tests on the complete tendons for compliance with the requirements of this Section for grouted tendons and ungrouted tendons. Have these tests performed by an approved testing laboratory. For post-tensioning systems previously tested and approved on Department projects, complete tendon samples are not required if there is no change in material, design, or details previously approved. Identify on shop drawings or prestressing details the project where approval was obtained. Perform prequalification testing at the Contractor’s expense, and provide written certified results.

1. **Grouted Tendons.** Provide post-tensioning systems with grouted tendons that develop at least 95% of the required ultimate strength of the tendon with a minimum elongation of 2% of the gauge length when tested in the unbonded condition. Include tendon couplers, when permitted, in the test.

Ducts and all connections must be capable of withstanding the pressures required for the grouting operation and the test pressures specified in Section 426.4.D.1, “Internal Duct Pressure Test,” and Section 426.4.D.3, “Duct Connection Pressure Field Test.” Ducts must be watertight and strong enough to withstand concrete placement and grouting without damage or excessive deformation. Size the ducts so that the nominal internal area of the duct is at least 2.5 times the area of the prestressing steel for multiple strand and wire tendons. The minimum inside duct diameter must be at least 3/8 in. larger than the outside diameter of a single-bar or single-strand tendon.

Provide connections of couplers and transition fittings that are adaptable to various duct materials, air tight, water tight, and strong enough to prevent distortion or displacement of the ducts during concrete placement or tendon grouting. Equip ducts with:
- fittings at each end of the tendon for injection of grout and
- ports for venting or grouting at high points and for draining at intermediate low points.

Vents and drains must be at least:
- 3/4 in. in diameter for strand tendons in round ducts and
- 1/2 in. in diameter for single-bar tendons, single-strand tendons, and strand tendons in flat ducts.

Vents and drains must have a positive shutoff to allow injection of grout through the vents and sealing to prevent grout leakage.

Equip all grouted tendon anchorages with permanent fiber reinforced plastic grout caps that are vented and bolted to the anchorage. Grout caps must completely cover and seal all exposed metal parts of the anchorage. Seal the cap with neoprene “O” ring seals against the bearing plate, and place a grout vent on the top of the cap. Ensure that permanent grout caps have sufficient antioxidant additives. Certify the cap material for environmental stress cracking per ASTM D 1693, Condition C. Caps must have an endurance rating of 192 hr. and be rated for a minimum pressure rating of 150 psi. Use ASTM F 593 Alloy 316 stainless steel bolts to attach the cap to the anchorage.

a. **Plastic Ducts.** Do not use plastic ducts made from recycled material. Plastic duct material must not have an adverse chemical reaction with concrete, prestressing steel, or grout. Use seamless fabrication methods to produce plastic ducts. Provide a manufacturer’s certification stating that the plastic ducts and connections meet the material requirements of this Item.

   (1) **Internal Plastic Ducts.** Plastic ducts for tendons completely embedded in concrete must be semi-rigid, corrugated, and made of unfilled polypropylene meeting the requirements of ASTM D 4101, cell classification range PP0346B44544 to PP0346B65884. Certify that the polypropylene contains 0.2% hindered amine light stabilizer, non-yellowing type, and that the environmental stress cracking will not be less than 192 hr. as determined by ASTM D 1693, Condition C. Provide corrugated duct with a minimum wall thickness of 0.08 in.

   Provide a manufacturer’s certification that the internal plastic duct can be bent to the radii shown on the plans. Have the manufacturer test the duct to determine the minimum bending radius. Provide a 1/2 in. diameter 270 ksi strand stressed to 75% guaranteed ultimate tensile strength (GUTS) bearing on an ungrouted duct for a length range of 2 to
4 ft. for the testing. Perform the test for a 7-day period. After test completion, remove the duct and measure the wall thickness along the strand path. The wall must be at least 0.06 in. thick in this area.

Provide connections from materials containing antioxidant stabilizers and having an environmental stress cracking not less than 192 hr. as determined by ASTM D 1693, Condition C. Make all connections with devices or methods that produce a smooth interior alignment and an airtight sealed connection with no lips or kinks. Do not use duct tape to join or repair connections.

(2) **External Plastic Ducts.** Plastic ducts for tendons not embedded in concrete must be smooth and made of polyethylene material meeting the requirements of ASTM D 3350 with a minimum cell class of 344464C. Provide smooth duct manufactured to ASTM D 3035 or ASTM F 714, with a dimension ratio (DR) of 17.0.

Make all connections using heat-welding techniques in accordance with the duct manufacturer’s recommendations or by other methods. Ensure all connections have a pressure rating of 100 psi, producing a smooth interior alignment and an airtight sealed connection with no lips or kinks. Connections with plastic couplers must meet the material requirements of external plastic ducts.

b. **Steel Ducts.** Steel pipe must conform to ASTM A 53, Grade B, Schedule 40 and be galvanized per Item 445, “Galvanizing.”

c. **Grout.** Grout must be prepackaged and meet the requirements of DMS-4670, “Grouts for Post-Tensioning.” Prepackage grout in plastic lined or coated bags. Grout bags must indicate brand name, date of manufacture, lot number, and mixing instructions. Do not use material more than 12 mo. old. Furnish a copy of the manufacturer’s quality control data sheet for each lot number and shipment of grout. Use grout produced by a prequalified manufacturer on the list maintained by the Construction Division. Furnish project samples of grout for testing in accordance with Section 426.4.B.2, “Grout Samples.”

Have the prepackaged grout materials delivered in bags and stored in a building, bin, or other location that is both waterproof and convenient to the work location. Open storage may be permitted if a raised platform and suitable waterproof covering is used. Use prepackaged grout materials within 30 days of receipt.

2. **Ungrooved Tendons.** Provide post-tensioning systems with ungrooved tendons that develop at least 95% of the required ultimate strength of the tendon with a minimum elongation of 2% of the gauge length, and that withstand 500,000 cycles in a stress range of 0.6 to 0.7 F_s, where F_s is the guaranteed ultimate tensile strength of the tendon, without failure or slippage. Include tendon couplers when permitted in the test.

Coat ungrooved tendons with a nonvolatile, low-friction mineral oil-base grease having a rust-preventing additive of relatively uniform viscosity at temperature ranges of 20°F to 120°F. Provide a protective sheathing around the tendon consisting of a waterproof material capable of maintaining the tendon tightly bundled and containing the lubricant.

426.3. Equipment.

A. **Prestressing Equipment.** Furnish hydraulic jacks with sufficient capacity for prestressing the steel. Equip the jacks with instruments for monitoring the hydraulic pressure. Provide gauges at least 6 in. in diameter and with means to prevent the gauge pointer from fluctuating. Electronic pressure transducers with digital indicators may be used. Pressure gauges or electronic pressure indicators must indicate the load directly to 1% of the maximum gauge or sensor/indicator capacity or 2% of the maximum load applied, whichever is smaller.

Calibrate each jack and its gauge with the cylinder extension in the approximate position at final jacking force. Jacks and gauges for post-tensioning and single-strand pretensioning must be calibrated as a unit. Have certified calibration charts furnished by an independent laboratory and with each jack and gauge used on the project. Provide certified calibration of each ram before starting stressing operations on the project and:
• every 6 mo. thereafter for post-tensioning operations,
• every 12 mo. thereafter for pretensioning operations, and
• as requested by the Engineer.

The calibration frequency for multiple-strand pretensioning equipment may be extended to every 24 mo. thereafter if an approved master gauge system monitors it. The master gauge must check this equipment when suspect results occur and at least every 6 mo. Calibrate the master gauge per the manufacturer’s recommendations and at least every 12 mo.

Recalibrate jacks and gauges when a malfunction occurs, when repairs such as replacing the seals, changing the length of the hydraulic lines, or changing the pump occur, or when using gauges that have not been calibrated with the jack. Extra compensation will not be allowed for the initial or subsequent calibrations.

For post-tensioning, the jacks must have provisions for measuring tendon elongation directly on the strand, bar, or wire. The jacks must be capable of slow release of force to properly seat the tendon anchors.

For pretensioning, multiple-strand stressing jacks must have sufficient capacity to provide the required stressing force and to permit simultaneous release of all straight strands if multiple-strand detensioning is performed. Single-strand stressing jacks for pretensioning must have provisions for measuring the elongation directly on the strand.

B. Grouting Equipment. Use a high-speed shear or colloidal mechanical mixer, capable of continuous mixing that meets the grout manufacturer’s recommendations and that will produce a grout free of lumps and undispersed cement. Provide equipment that will accurately measure solid and liquid contents to batch all materials.

Use grouting equipment with gravity feed to the pump inlet from a hopper attached to and directly over it. Use a screen with clear openings of 1/8 in. or less for screening the grout before entering the pump.

Use a positive-displacement pump that can provide an outlet pressure of 150 psi. The pump must have a system for continuous agitation of the grout and be fitted with a valve that can be locked off without loss of pressure in the duct and hoses. Attach a pressure gauge that can read up to 300 psi to the grout line between the pump outlet and the duct inlet.

Under normal conditions, the grouting equipment must be able to continuously grout the longest tendon on the project in less than 20 min. Provide standby grout mixer and pump.

426.4. Construction. The requirements of Item 420, “Concrete Structures,” will govern for cast-in-place construction, and Item 424, “Precast Concrete Structures (Fabrication),” will govern for precast concrete units or members.

Before stressing, furnish certified copies of load calibration curves on all jacks and gauge systems to be used in the work.

A. Required Submittals. Submit information required in this Section for cast-in-place prestressed units, in addition to forming and falsework plans required by Item 420, “Concrete Structures.” Include all necessary construction information in these submittals for cast-in-place and precast construction including but not limited to the information required in this Section.

Submit the post-tensioning details and grouting plan on 11 in. × 17 in. sheets. Design calculations may be on standard letter-size sheets. Submit 7 sets of the post-tensioning details and grouting plan and 3 sets of design calculations for approval. Submit 1 additional copy of each if the owner is a non-Department entity such as a railroad or a municipal or turnpike authority, and another copy if the designer is a private consultant.

1. Design Calculations. Provide design procedures, coefficients, allowable stresses, and tendon spacing and clearances in accordance with the AASHTO Standard Specifications for Highway Bridges or AASHTO LRFD Bridge Design Specifications unless otherwise shown on the plans. Submit sufficient calculations to support the proposed system and method of prestressing including friction loss diagrams. When the required jacking force for a particular type of tendon, duct, and configuration is furnished as shown on the plans, do not submit design calculations except to adjust for conditions different from those shown on the plans.
2. **Post-Tensioning Details.** Provide drawings with details of type, size, and number of strand, bar, or wire per tendon; tendon location and identity mark; jacking forces; lubricated tendons; seating loss; end anchorage systems; tendon profile; total elongation; measurable elongation; and other information necessary to complete the work. Adjust calculations for elongation based on the modulus of elasticity given for the strands or, when a bench test is specified, the apparent modulus derived from the bench test.

Submit a numbered layout and a step-by-step stressing sequence for the tendons that prevents overstressing the member in vertical or lateral bending. Identify members to be partially post-tensioned, including the stressing amount and the stressing sequence for partial post-tensioning. Make complete provisions for each stressing operation beginning with prestressing steel installation and ending with excess strand removal at the anchors. Furnish all tendon stressing data for each structure in tabular form.

Include in the post-tensioning details the location and support method for the duct to ensure proper position of the enclosed steel center of gravity. Show:
- the offsets from the bottom of the duct relative to the position of the prestressing steel within the duct and
- the distance from the face of the member to the nearest part of the duct.

Submit post-tensioning details reflecting the following general tensioning procedure, modified for each particular installation:
- Do not allow the modulus of elasticity to vary by more than 1% for any 2 strands within a tendon.
- Tension the tendons in the sequence designated in the approved post-tensioning details.
- Apply initial tension, to take the slack out of the tendons, between 10% and 20% of the final load.
- Reference-mark the tendons to determine elongation after the initial tensioning.
- Measure the elongations to determine tendon acceptance after tensioning to the specified jacking force. Seat tendon anchors after tendon acceptance.
- Trim projecting tendon strand tails as required in Section 426.4.D.2, “Prestressing Steel Installation for Post-Tensioning,” immediately after stressing and anchoring all tendons. Install grout caps immediately after trimming the tendons.

3. **Grouting Plan.** Submit for approval written grouting procedures at least 4 weeks before starting grouting operations. Include:
- type, quantity, and brand of materials to be used including all required certifications and laboratory test results on the grout materials;
- type of equipment needed including provisions for backup equipment;
- types and locations of grout inlets, outlets, and vents;
- duct cleaning methods before grouting (water flushing of tendon is not permitted);
- internal duct repair procedures due to pressure test failures;
- duct connection repair procedures for external tendons due to pressure test failures;
- mixing and pumping procedures;
- direction of grouting;
- sequence of use of the inlets and outlets;
- procedures for handling blockages due to grouting interruptions, etc. (water flushing of tendon is not permitted);
- procedures for possible secondary grouting (vacuum-grouting process); and
- names of people responsible for grouting operations including their relevant experience and a certification that they have attended an American Segmental Bridge Institute (ASBI) Grouting Certification Seminar.

B. **Project Samples.**

1. **Prestressing Steel Bar and Wire Samples.** For post-tensioning applications only and unless otherwise shown on the plans, the Department will sample and test bar and wire for ultimate strength. These samples will be taken according to Tex-710-I. Submit a certification stating the manufacturer’s guaranteed ultimate tensile strength and modulus of elasticity with each
prestressing steel bar or wire sample. If the test results indicate the need for check tests, furnish additional samples without cost to the Department. For prefabricated tendons, notify the Engineer to arrange sampling and testing at least 10 days before installing end fittings or heading wires.

2. **Grout Samples.** The Department will sample and test each brand of grout furnished at the project site. Testing will be performed by the Construction Division to verify compliance with the material requirements of DMS-4670, “Grouts for Post-Tensioning.”

C. **Packaging, Storing, and Handling of Prestressing Steel.** Protect prestressing steel against physical damage and rust or other results of corrosion, from manufacture to grouting or encasing in concrete. Prestressing steel with physical damage will be rejected. Replace any reel containing broken wires. Provide wire that is bright and uniformly colored, without foreign matter or pitting on the surface. Package prestressing steel in containers or shipping forms for protection from physical damage and corrosion during shipping and storage. A corrosion inhibitor must be:

- placed in the package or form,
- incorporated in a corrosion inhibitor carrier type packaging material, or
- applied directly to the steel when permitted.

The corrosion inhibitor must not have deleterious effect on the steel, concrete, or bond strength of steel to concrete. Inhibitor carrier-type packaging material must conform to the provisions of federal specification MIL-PRF-3420G. Immediately replace damaged packaging or forms, or restore them to original condition.

Have the shipping package or form clearly marked with the corrosion inhibitor type, packaging date, and a statement that the package contains high-strength prestressing steel.

Handle prestressing steel carefully to avoid abrading, nicking, or kinking the strand, bar, or wire. Protect prestressing steel from damage and corrosion by storing it above the ground on platforms, skids, or other approved supports. Any pitting or tightly adhering rust on prestressing steel will be cause for rejection of the steel. Do not weld or torch-cut near any prestressing steel, so that it is not exposed to weld spatter, direct heat, or short-circuited current flow.

When prestressing steel for post-tensioning is installed in the ducts, any rust that forms during the first 14 days after installation will not be cause for rejection of the steel.

D. **Duct and Prestressing Steel Installation for Post-Tensioning.** Securely tie ducts in position, and carefully inspect and repair as necessary before placing concrete. Exercise care during concrete placement to avoid damaging or displacing the ducts. Support ducts at maximum 24-in. intervals. Provide method and spacing of supports per the approved post-tensioning details. Position tendons to a vertical and horizontal tolerance of ±1/4 in. After installing the forms, seal the duct ends to prevent entry of water, debris, and concrete. If conflict exists between the reinforcement and the post-tensioning ducts, the position of the post-tensioning ducts take precedence over the reinforcing steel. Adjust conflicting reinforcing steel as approved. Do not flush ducts with water at any time.

1. **Internal Duct Pressure Test.** Before installing the prestressing steel inside internal ducts and casting concrete, seal or plug the ducts and pressurize them to 5 psi from the inlet pipe. Hold this pressure for at least 5 min. If there is a pressure loss exceeding 2 psi, repair the leaks according to the approved grouting plan and retest before casting concrete. The internal duct pressure test is not required for internal longitudinal ducts of segmental units.

2. **Prestressing Steel Installation for Post-Tensioning.** Open low point duct vents to drain any moisture before installation of prestressing steel. Blow the ducts with oil-free compressed air or other approved methods to remove water and debris.

Push or pull the strands into the duct to make up a tendon using methods that will not snag on any lips or joints in the ducts. Strands may also be pre-assembled into tendons and pulled into the duct using a special steel wire sock (“Chinese finger”) or other device attached to the end. Do not weld the strands together for this purpose. Cut excess strands using an abrasive saw or equal. Do not flame-cut strands. Close all duct vents after installing prestressing steel.
Stress the tendons within 1 day (24 hr.) after installing the steel in the ducts. Follow the tensioning procedure noted in the approved post-tensioning details. Tension the post-tensioning steel with hydraulic jacks so the force of the steel will not be less than the value shown on the approved working drawings. The maximum temporary tensile stress (jacking stress) in the post-tensioning steel must not exceed 80% of the specified ultimate tensile strength of the steel. Size tendons based on the jacking stress shown on the plans. Anchor post-tensioning steel at stresses (initial stresses) that provide long-term retention of permanent forces not less than those shown on the approved working drawings. The initial stress after anchor set must not exceed 70% of the specified ultimate tensile strength of the steel. Permanent force and stress are the force and stress remaining in the tendon after all losses, including creep, shrinkage, and elastic shortening of the concrete; relaxation of the steel; and losses due to sequence of stressing, friction and take-up of anchorages.

For stressing and staged loading of post-tensioned structural elements, verify that concrete strength requirements on the plans are met by testing in accordance with Article 420.4, “Construction,” for cast-in-place construction and by testing in accordance with Tex-704-I for precast construction.

Provide suitable means for measuring the elongation of the steel to the nearest 1/16 in. Elongations for determining tendon acceptance must be made before anchor seating and must compensate for:
- dead end anchor loss,
- anchor set, and
- elongation of strand in the jack.

For the required jacking force, the measured elongation must agree within 5% of the calculated elongation. In the event of discrepancies, suspend stressing operations until the problem has been identified and corrected.

Check actual anchor set for agreement with the anticipated value used in the stress calculations. Adjustments to the jacking force may be required to compensate for anchor set greater than anticipated.

Failure of individual wires of a 7-wire strand or of wires in a parallel-wire tendon is acceptable provided the total number of wire failures is not more than 2% of the total number of wires in the tendon group. Failure of an entire strand will be cause for rejection of the tendon. Slippage of anchor wedges will be cause for a structural review for tendon acceptance.

After the tendons have been stressed and the elongations have been approved, immediately cut off the tendon strand tails using an abrasive saw or equal. Do not flame-cut strands. Install the permanent grout cap and close all vent tubes to prohibit moisture accumulation inside the ungrouted duct. Keep grout caps in place until the tendons are grouted.

3. **Duct Connection Pressure Field Test.** Test external tendons with compressed air before grouting to determine if duct connections require repair. Pressurize each tendon to 100 psi and lock off the outside air source. Hold this pressure for at least 5 min. If there is a pressure loss exceeding 10 psi, repair the leaking duct connections according to the approved grouting plan and retest before grouting.

**E. Grouting.** Provide ASBI-certified grouting personnel at the project site during all grouting operations. At least 1 week before starting grouting operations, make a trial batch using the same materials, equipment, and personnel to be used for the actual grouting operations to verify that all equipment is properly operating. Perform this trial batch in the presence of the grout manufacturer’s technical representative. Field-test the grout produced for the trial batch in accordance with Table 1. For actual grouting operations, correct problems encountered during trial batching.
Table 1

Requirements for Field Testing of Grout

<table>
<thead>
<tr>
<th>Test</th>
<th>Frequency</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleed test (Tex-441-A)</td>
<td>1 per day</td>
<td>per DMS-4670</td>
</tr>
<tr>
<td>Fluidity test (Tex-437-A, Method 2)</td>
<td>1 every 2 hr., 2 min. per day</td>
<td>per DMS-4670</td>
</tr>
<tr>
<td>Strength test (Tex-442-A)</td>
<td>1 per day</td>
<td>per DMS-4670</td>
</tr>
</tbody>
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Unless otherwise noted, grout within 14 days of tendon stressing. Immediately before grouting, remove the grout cap, coat the inside surfaces of the cap with grease, then re-install.

Do not allow the grout temperature to be above 90°F during mixing and pumping. Do not grout when the ambient temperature is less than 35°F. Field test the grout in accordance with Table 1 during grout installation. Perform field testing by trained personnel at the Contractor’s expense while witnessed by the Engineer.

Add water to the mixer first, followed by the prepackaged grout. Mix the grout according to the manufacturer’s recommendations and following the procedures outlined in the grouting plan and used for the trial batch. Mix long enough to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of properties of the mixture. Continuously agitate the grout until it is pumped. Do not add water after mixing to increase the flowability of grout. Pump grout within 30 min. of the first addition of the mix components. Keep the hopper at least partially full of grout to prevent air from being drawn into the ducts.

Open all grout vents before grouting. Allow grout to flow from the first vent. Do not close this vent until all visible slugs of grout and air have been ejected and the consistency of the grout flowing from the vent is equivalent to the injected grout. Close all other outlets in the same manner, one after another in the direction of flow except at intermediate crests. Close outlets placed a short distance past the crest before closing the crest outlet. Provide pumping pressure at the inlet no higher than:
- 150 psi for internal plastic ducts and
- 250 psi for internal steel pipe ducts.

For tendons not embedded in concrete, provide pumping pressure no higher than 150 psi. Grout typically at 75 psi pressure for normal grouting operations. If the grouting pressure exceeds the maximum allowed, close the inlet and inject grout at the next vent, which now becomes the inlet, if one-way flow of the grout is maintained. Do not inject grout into a succeeding outlet or vent if grout has not yet flowed from it. When blockage occurs where one-way flow of the grout cannot be maintained, follow the procedures for handling blockages in the approved grouting plan. Do not flush a blocked tendon with water.

To ensure that the duct remains filled with grout, close the outlet first and then the inlet after holding the pressure for 1 min. The inlet must then be sealed off under pressure. Do not open or remove valves, caps, or pipes at the inlet and outlets until the grout has set. Do not subject filled ducts to shock or movement within 24 hr. after grouting.

Investigate the ducts for voids between 24 hr. and 7 days after grouting completion. Remove grout caps in the presence of the Engineer to determine if the cap was completely filled with grout. Inspect inlet and outlet ports for voids. Completely fill any observed voids with grout by secondary grouting of the duct with a vacuum-grouting process that determines the size of the void and the measure of filling the void with grout. Perform this process according to the approved grouting plan.

Clean exposed end anchorages and other metal accessories of rust, misplaced mortar, grout, and other materials shortly after all post-grouting inspections. Install tight-fitting forms around the anchor assembly immediately after this cleaning and hold it securely in place. Apply a heavy, unbroken coating of epoxy conforming to DMS-6100, “Epoxies and Adhesives,” Type V or VII, along the entire surface to be covered by the pourback concrete. Place the pourback concrete with an approved chloride-free non-shrink grout mix while the epoxy is still tacky.

F. Pretensioning. Pretension all strands to a uniform initial load between 5% and 25% of the final load. Apply the load within a tolerance of:
- ±100 lb. per strand if the designated initial load is less than or equal to 10% of the final load or
• ±200 lb. per strand if the designated initial load is greater than 10% of the final load.

Measure the initial load with a calibrated dynamometer or other suitable equipment.

Do not allow the modulus of elasticity of individual strands to vary more than 1% from each other when multiple-strand tensioned. Use a weighted average modulus of elasticity of strands to calculate elongation for multiple-strand tensioning operations.

After initial tensioning, establish reference marks on the strand for measuring elongation. Provide means for measuring the elongation of the strand to an accuracy of 1% of the theoretical elongation or 1/8 in., whichever is smaller. Establish independent references on the strand adjacent to each anchorage, to indicate slippage that may occur between the time of initial stressing and final release of the strands.

Do not allow the stress in the strand to exceed 80% of the specified ultimate tensile strength of the strand at any time.

Do not use any portion of the strand that has been previously gripped with chucks in the length of strand to be tensioned.

Strand chucks designed with spring caps must be used with the spring caps. Visually inspect strand chucks that are not equipped with spring caps to ensure that all wedges are evenly seated after applying initial load. Correct unevenly seated wedges by releasing the stress, repositioning wedges, and reapplying the initial load.

1. **Strand Splicing.** Do not splice draped strands. One splice per straight strand will be permitted subject to the following:
   - Locate splices outside the members.
   - Splice strands with the lay or twist in the same direction to avoid unraveling.
   - Splice all straight strands in a multiple-strand tensioning operation so that an adjustment can be made for the average seating loss.
   - Cut strand ends to be spliced with shears, abrasive saws, or grinders to remove regions where chucks were previously seated. Cut in the same manner at least 12 in. from strand ends to be spliced that were previously flame cut.

2. **Single and Multiple Straight Strand Tensioning.** After initial tensioning, apply the required load to the strands as shown on the plans by means of single-strand or multiple-strand hydraulic jacks equipped with calibrated gauges. Verify the final load in the strands by observing either the gauge pressure or elongation and independently checking the other. The final load and elongation must agree within 5% of the computed theoretical values. Additionally, the final load and elongation must agree algebraically with each other within 5%. In the event of discrepancies greater than these tolerances, suspend tensioning operations until the problem has been identified and corrected.

   Verify uniform application of load to strands for multiple-strand-tensioning systems by measuring the movement on opposite sides of the anchorage.

3. **Draped Strand Tensioning.** When draped strands are tensioned in a straight or partially draped position before application of final load, verify the intermediate load by observing either the gauge pressure or elongation and independently checking the other. The intermediate load and elongation must agree within 5% of the computed theoretical values. Additionally, the intermediate load and elongation must agree algebraically with each other within 5%. In the event of discrepancies greater than these tolerances, suspend tensioning operations until the problem has been determined and corrected.

   After application of final load, measurements on individual draped strands to establish differential stresses at selected points on the member will be averaged at a cross-section of the member, and the averages must be within 5% of the theoretical elongation. The measured elongation of any individual draped strand must not vary from the theoretical elongation by more than 10% at any measured cross-section. In the event of discrepancies greater than these tolerances, suspend tensioning operations until the problem has been identified and corrected.
Other methods to measure the intermediate load and final load in the draped strands may be submitted for approval.

4. **Strand Debonding.** When shown on the plans, encase strands in plastic sheathing along the entire debonded length, and seal the ends with waterproof tape. Split plastic sheathing may be used provided the seam is sufficiently sealed with waterproof tape to prohibit grout infiltration. Do not use sheathing that will permanently alter the physical or chemical properties of the surrounding concrete.

Full-length debonding of straight strands will be approved on an individual basis. Full-length debonding, when permitted, must be symmetrical about the vertical centerline of the beam and limited to 10% of the total number of straight strands or 6 straight strands, whichever is less. Do not debond draped strands full length.

5. **Detensioning.** After concrete strength requirements are met, release the tension in the strands using a sequence to minimize premature wire breakage and shock and damage to the concrete members. Release strands by multiple-strand detensioning or single-strand flame detensioning. Do not release strands individually with single-strand jacks.

If strands are released individually, flame-release each strand simultaneously at both ends of the casting bed, using a symmetrical sequence prepared by a licensed professional engineer. When flame detensioning, heat the strands so that the metal gradually loses strength. Include the flame-release sequence on the shop drawings for each strand pattern involved. For products that do not require shop drawings, submit the flame-release sequence for approval. Approval of flame-release sequences does not relieve the Contractor from responsibility for meeting the product workmanship requirements of Section 424.3.C, “Workmanship.”

When draped strands are used, release the tension in the strand hold-down anchor slowly to minimize shock and damage to the concrete member. If heat is used to release the hold-down anchor, heat the anchor until the metal gradually loses strength. Provide positive external hold-downs to offset the vertical forces in the members when the sum of the hold-down forces is greater than half the weight of the member.

G. **Combined Pretensioning and Post-Tensioning.** When the plans call for a combination of pretensioning and post-tensioning, all of the requirements for both pretensioning and post-tensioning apply.

426.5. **Measurement.** Where indicated on the plans, the post-tensioning system for cast-in-place structural units required and the work involved in prestressing cast-in-place structures will be measured by the product of the required final prestress force and the horizontal length over which the prestressing is applied, expressed in thousands of kip-feet (MKF). Unless otherwise shown on the plans, the required final prestress force used will be the maximum value required within a unit, and the length of prestressing will be taken as the overall dimensions of the unit. No deductions will be made for the clearance distance between the ends of tendons and the ends of the unit.

The post-tensioning system for cast-in-place structural units is a plans quantity measurement item. The quantity to be paid is the quantity shown in the proposal unless modified by Article 9.2, “Plans Quantity Measurement.” Additional measurements or calculations will be made if adjustments of quantities are required. The maximum percent variance from the plans quantity for which no adjustment will be made will be as shown in Table 2.

<table>
<thead>
<tr>
<th>Plans Quantity</th>
<th>Percent Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 5,000 MKF</td>
<td>1/2</td>
</tr>
<tr>
<td>1,000 MKF–5,000 MKF</td>
<td>1</td>
</tr>
<tr>
<td>&lt; 1,000 MKF</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

426.6. **Payment.** The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Post-Tensioning (Grouted)” or
“Post-Tensioning (Ungrouted).” This price is full compensation for prestressing steel, fabrication, transportation, erection, post-tensioning, encasing ducts, grout fittings, grout, end anchorages, bearing plates, equipment, labor, materials, tools, and incidentals. Materials furnished for testing will not be paid for directly.

Post-tensioning of precast concrete members and all pretensioning will be measured and paid for as specified in Item 425, “Precast Prestressed Concrete Structural Members,” unless noted otherwise.