SECTION 610
MEDIAN COVER MATERIAL

DESCRIPTION

610.01 This work consists of the construction of median cover over the median area, or over other areas designated, in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

610.02 Bituminous median cover material shall conform to the requirements of Section 403 and as shown on the plans.

Concrete shall be of the class designated and shall conform to Section 601. Coloring agent, if required, shall be as shown on the plans or specified.

Aggregate for median cover shall conform to the requirements of subsection 703.10.

Plastic sheeting shall be black polyethylene with a minimum thickness of 10 mils or approved equal.

Herbicides shall conform to the requirements of Section 217.

CONSTRUCTION REQUIREMENTS

610.03 Median cover operations shall not be started until the underlying surface has been compacted, smoothed and, if required, treated with herbicides. Other requirements are as follows:

(a) *Bituminous Median Cover Material.* Bituminous median cover material shall be placed in conformance with the requirements of subsection 608.04(c).

(b) *Concrete.* Construction requirements shall conform to the requirements of subsection 608.03. The surface finish or pattern shall be as shown on the plans or in accordance with the recommendations of the supplier of the median cover material.

(c) *Stone.* Areas to receive stone median cover shall be treated, if required, with an approved herbicide treatment in accordance with Section 217 or as directed. Immediately after the placement of the herbicides, the plastic sheeting and stones shall be placed in accordance with details shown on the plans, or as specified.

METHOD OF MEASUREMENT

610.04 Bituminous median cover material will be measured by the number of tons of bituminous material placed and accepted.

Concrete median cover material will be measured by the square foot of surface placed and accepted.

Stone median cover material will be measured by the number of tons of aggregate placed and accepted.

BASIS OF PAYMENT

610.05 The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Median Cover Material (Bituminous)	Ton
Median Cover Material (Concrete)	Square Foot
Median Cover Material (Patterned Concrete)	Square Foot
Median Cover Material (Stone)	Ton

Herbicide treatment will be measured and paid for in accordance with Section 217.

Subgrade compaction and plastic sheeting will not be measured and paid for separately but shall be included in the work.

SECTION 611
CATTLE GUARDS

DESCRIPTION

611.01 This work consists of the construction of cattle guards in accordance with these specifications and in conformity with the lines, grades, and details shown on the plans or established.

MATERIALS

611.02 Concrete shall conform to the requirements of Section 601. Reinforcing steel shall conform to the requirements of Section 602. Structural steel shall conform to the requirements of Section 509. Timber shall conform to the requirements of Section 508. Fencing items shall conform to the requirements of Section 607.

CONSTRUCTION REQUIREMENTS

611.03 Cattle guards shall be constructed in accordance with the details shown on the plans. All work shall be done in accordance with the applicable construction methods contained in these specifications.

METHOD OF MEASUREMENT

611.04 Cattle guards will be measured by the number of units of the various sizes installed and accepted.

BASIS OF PAYMENT

611.05 The accepted quantities of cattle guards of the various sizes will be paid for at the contract unit price each when included in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
_____Cattle Guard	Each

SECTION 612
DELINEATORS AND REFLECTORS

DESCRIPTION

612.01 This work consists of the installation and furnishing of delineators and reflectors in accordance with these specifications and in conformity with the lines, grades and details shown on the plans or established.

MATERIALS

612.02 Materials for the various types of delineators and reflectors shall be as follows:

(a) *Delineators.*

1. Steel Posts. Details for each type of delineator are shown on the plans. Posts shall conform to the requirements shown on the plans and reflectors shall conform to the requirements in subsection 713.07.

2. Flexible Posts. Flexible posts shall be manufactured from an impact resistant flexible material and shall conform to the following requirements:

   A. Workmanship. The posts shall exhibit good workmanship and shall be free of burrs, discoloration, contamination, and other objectionable marks or defects which affect appearance or serviceability.

   B. Base Anchoring. The posts shall be designed to facilitate a permanent installation that resists overturning, twisting, and displacement from wind and impact forces. The post shall be designed for an anchoring depth of 18 to 24 inches. Detailed installation instructions shall be provided by the manufacturer.

      The posts or below-ground anchors shall be capable of being driven into an earth shoulder or roadside with or without a pilot hole. Installation shall be accomplished with typical maintenance equipment.

   C. Reflective Elements. Posts shall be shaped to accommodate the installation of reflective elements. Reflective elements shall be 3 inches square for Type I, 3 inches by 6 inches for Type II, and 3 inches by 9 inches for Type III (hazard marker) delineators. Reflective material shall be Type III reflective sheeting meeting the requirements of subsection 713.10.

      The top of the reflective element shall be mounted no more than 2 inches from the top of the post, with the reflective element facing in the direction of the oncoming traffic. The reflective element shall be mounted in accordance with the manufacturer's recommendations to prevent loss of the reflective element during the life of the post.

The reflective element shall be protected from scratches, abrasions, and other physical damage during shipping and driving by an easily removable "masking" sheet.

D. Marking. The tops of the posts on the side away from traffic shall be date-stamped showing the month and year of fabrication. The numerals shall be at least ¼ inch in height and shall be either die-stamped, or legibly stamped with permanent ink. In addition, each post shall be marked with a black horizontal stripe to denote an 18 inch embedment depth.

E. Dimensions.

(1) Width. The post shall have a minimum width of 3 inches and a maximum width of 4½ inches facing traffic.

(2) Length. The post shall be of such length to provide a height of 48 inches above the edge of the pavement and to provide the required anchoring depth.

F. Physical Properties and Performance Requirements. Flexible posts shall conform to the following physical properties and performance requirements.

(1) Heat Resistance: The post shall be conditioned a minimum of two hours in an oven at 140 °F ±3 °F. The conditioned post shall be capable of straightening itself within five minutes when bent 90 degrees at the midpoint for each of four bends. The conditioning temperature shall be maintained while the test on each post is completed.

(2) Cold Resistance: The post shall be conditioned a minimum of two hours at -5 °F ±3 °F in an environmentally controlled test chamber. Testing shall be performed in the environmental chamber.

(i) The post shall not be adversely affected when a person, standing approximately at the center of the post, bends the free half of the post to a 90 degree angle with the remaining section being stood upon. The post shall return to its original shape within 60 seconds for each of four separate bends.

(ii) A steel ball weighing 2 pounds shall be dropped a distance of 5 feet through a virtually frictionless vertical guide to impact the surface of the post. The surface of the post being struck by the steel ball shall be in a horizontal position, with the post supported and held in position at both ends. The

post shall be subjected to five impact tests concentrated near the middle of the post. Fracturing, cracking, or splitting of the post shall constitute failure.

(3) Colorfastness: Post shall be exposed for 500 hours in a Carbon-Arc Type weatherometer (ASTM G23, Method 1). The post shall show no signs of delamination, distress, or discoloration, and the reflective sheeting shall not be removable from the post without damage.

(4) Impact Resistance: The post shall be manufactured from an impact resistant material and be so designed that an installed post is capable of self erecting and remaining serviceable after being subjected to a series of direct impacts by a typical passenger sedan at temperatures of 40 °F or above. The posts to be tested shall be installed in accordance with the recommendations of the manufacturer. The posts shall be furnished complete with attached reflectors proposed for use. Posts shall be capable of withstanding a series of ten impacts head on (90 degrees) into traffic face of the post at a speed of 35 mph. Posts shall also be capable of withstanding a series of five impacts at an angle of 75 degrees to the traffic face of the post at speeds of 55 mph. The impacting vehicle shall suffer little or no damage during the impact test series. After each impact, the post shall:

(i) Remain intact and securely anchored.

(ii) Return to its original vertical orientation within an angle of 10 degrees from vertical.

(iii) Show minimal signs of distress (cracking, loss of rigidity).

(iv) Retain a minimum of 50 percent of its original amount of reflective sheeting.

(5) Each post, prior to and after installation, shall be visibly free of bends or twists.

(6) The posts shall have a minimum tensile strength of 1,100 pounds per square inch, as determined in accordance with ASTM D 638.

(7) The color of the posts shall be Interstate Green in accordance with Federal Standard No. 595B, Color Number 14109, unless otherwise specified.

G. Sampling and Acceptance. Prior to shipment of the posts, the manufacturer shall submit certified test reports and test data,

developed by an approved testing laboratory which attests to the fact that their marker post complies in all respects with requirements covered in the specifications.

(b) *Median Barrier Reflector.* Details for the median barrier reflector are shown on the plans. Reflectivity shall conform to the requirements in subsection 713.10.

CONSTRUCTION REQUIREMENTS

612.03 Spacing, location, color of reflectors and placement of delineator posts shall be as shown on the plans.

METHOD OF MEASUREMENT

612.04 Delineators and reflectors for median barrier will be measured by the actual number of the various types installed and accepted.

BASIS OF PAYMENT

612.05 The accepted quantities will be paid for at the contract unit price each for the pay items listed below that are included in the bid schedule.

Payment will be made under:

Pay Item	**Pay Unit**
Delineator (Type_____)	Each
Delineator (Flexible) (Type___)	Each
Reflector (Median Barrier)	Each

SECTION 613
LIGHTING

DESCRIPTION

613.01 This work consists of furnishing and installing foundations, light standards, luminaires, lamps, conduit, cable, wiring and incidental materials for highway lighting and for traffic signal installations in accordance with these specifications and in conformance with the details, lines, grades and locations shown on the plans or established.

MATERIALS

613.02 Highway lighting materials shall conform to the requirements of Section 715, and shall be compatible with the requirements of the local utility company.

Electrical conduit for traffic signal installations shall conform to subsection 715.06.

At the preconstruction conference the Contractor shall submit three copies of a list of all materials and equipment to be incorporated into the work, to the Engineer for review and approval (including type of metal pole - either steel or aluminum). Also included shall be detail plans, drawings, photographs, photometric charts, templates, manufacturer's specifications and recommendations, and all other available information pertinent to this work. The Contractor shall not order materials or equipment until the Engineer approves the materials and equipment list. Approval of the above required submission shall not relieve the Contractor of responsibility for the proper functioning of the completed installation.

Materials shall conform to the applicable requirements of the National Electrical Code and shall be a type currently recommended and approved by Underwriters' Laboratories, Inc.

CONSTRUCTION REQUIREMENTS

613.03 General. All installations shall be in accordance with these specifications and the National Electrical Code, and shall conform to subsection 107.01.

Each system shall conform as to voltage, cycles and type as shown on the plans or as designated. The Contractor shall furnish and install all incidentals necessary to provide a complete working unit or system, as called for on the plans.

Secondary service pedestal shall be constructed as shown on the plans.

613.04 Foundation Pads. Light standard foundations may be precast concrete, cast-in-place concrete, or screw-in galvanized steel foundations.

Screw-in foundations shall be of a type and manufacture previously approved by the Department. Screw-in foundations shall have a minimum auger helix pitch of 3 inches and be galvanized according to ASTM A 153. Screw-in foundations may be used only where soil testing shows aggregate sizes less than 3 inches in diameter. The

Contractor shall be responsible for testing and reporting soil conditions to the Engineer as necessary to ensure proper installation of screw-in foundations. The following minimum screw-in foundation sizes are required for 40-foot light standard:

No. of Mast Arms	Foundation Inside Diameter and Length	Outside Diameter of Helix
1	6 inch by 7 foot	12 inch
2	8 inch by 7 foot	14 inch

The cableway openings in the screw-in foundation shall be 2.5 inches by 12 inches. The openings shall have rounded ends and run vertically with the top 12 inches below the base plate. The baseplate shall have a pole mounting surface free from curvature or other deformity induced by the manufacturing process. The baseplate is to be machine smooth flame cut on the external edges and on the inner hole providing access to the foundation interior. The baseplate shall be of adequate size to provide actual contact support at outer corners and edges of the lighting structure or breakaway mounting device. The baseplate shall be permanently marked to indicate the locations of the cableway openings and shall have a thickness as required by the manufacturer's design based on shape of plate and number of mast arms. Bolt holes shall be provided through the baseplate to allow for the attachment of a breakaway device or light structure as specified in the plans. If tapped holes are used they shall be center tapped perpendicular to the baseplate plus or minus one degree, and the threads shall be fully cleaned after hot dip galvanizing so a bolt may be hand turned in the threads. Baseplate material shall conform to the requirements of ASTM A 709 Grade 36.

The screw-in foundation shaft shall be flame cut to length, 90 degrees square on top and true helical on the bottom. Cableway openings shall be smooth cut on both sides of the shaft 180 degrees apart unless otherwise specified. The sides of the cableway openings shall be parallel to the axis of the shaft plus or minus ½ degree as measured along their full length. Round shaft material shall be new, unused and mill traceable. The edges are to be mechanically cleaned before welding operation. The shaft shall be fabricated from standard weight pipe meeting the requirements of ASTM A 53, Type E or S, Grade B or ASTM 252, Grade 2.

The helix on screw-in foundations shall be of true helical form and shall be produced with a matching metal dye from formable weldable $^{3}/_{8}$ inch thick steel meeting the requirements of ASTM A29, Grade M 1010. The preformed helix is to be tumbleblasted to remove scale and contaminants before welding.

Screw-in foundation pilot point shall be sheared on a 45 degree angle from 1.25 inch diameter round bar steel meeting the requirements of ASTM A 575. It shall project a minimum of 6 inches below the leading edge of the helix and shall be tumbleblasted prior to welding.

Screw-in foundations shall be supplied with lighting standard to base plate connection hardware consisting of 1 inch by 10 UNC, 4 inch long Grade 8 hex head bolts, nuts, and washers galvanized in accordance with ASTM A 153.

All welding for construction of screw-in foundations shall be in accordance with Sections 1 through 8 of AWS D1.1.

Completed screw-in foundations shall be hot dip galvanized in accordance with ASTM A 153 after fabrication. Minor damage to the coating may be field repaired by thoroughly cleaning the damaged area with a wire brush and removing all damaged and loose coating. The cleaned areas shall be painted with two coats of zinc rich paint meeting the requirements of Federal Specification TT-P-641 or MIL-P-21035.

The lot or piece number identifying each screw-in foundation shall be clearly stamped or painted on the foundation where not visible after installation. The foundation will be accepted on the basis of visual examination at the project site and the manufacturer's Certificate of Compliance. When requested by the Engineer, the Contractor shall furnish the manufacturer's Quality Control Inspection Reports and shall demonstrate the ability to provide certification with regard to:

(1) Material Application
(2) Welder Certification
(3) Weld Quality
(4) Coating Requirements

Screw-in foundation shall be installed according to the manufacturer's recommended procedures and accomplished by either a boom type or a bed-mounted type digger truck. The maximum torque used shall not exceed the manufacturer's recommended limits. In the case of extremely difficult soils that cause the torque capacity of the installation equipment or mechanical limit of the foundation to be exceeded, the foundation may be installed, as approved by the Engineer, in a predrilled hole that is not larger than the foundation shaft diameter. When the foundation is installed in a predrilled hole, minimum recommended torque requirements shall be followed. The installation torque may be measured by a torque-measuring device or by calibrating the hydraulic system of the installing equipment.

All anchor bolts shall be positioned by means of templates, the center of which shall coincide with the center of the base.

Conduits shall be properly positioned and anchored before placing concrete.

Ground wiring cast in the foundation shall have 3 foot minimum extension at both ends.

613.05 Light Standards. A light standard shall consist of a metal light pole, bracket arm or arms, transformer base or approved breakaway device, and connector bolts. In special cases, mountings may be made on the base flange, without transformer base, in which case the pole will require a handhole at the base.

(a) Pole and bracket arm or arms shall be of the specified type and size shown on the plans.

Poles shall be set plumb on the foundation pad by means of non-corrosive metal shims and the mounting grouted with a non-shrinkable grout.

Defects or scratches on galvanized poles shall be given two coats of acceptable zinc-rich paint as directed.

(b) Transformer base shall be of a frangible breakaway type as shown on the plans and shall accommodate the anchorage and base flange of the light pole supplied.

Each transformer base shall have a ½ inch bolt or lug fastened inside the base, visible from the door opening, for grounding purposes; also a wire hole for outside grounding, if required.

(c) Connector bolts and anchor bolts shall accommodate the anchorage of the light pole from its base flange to the transformer base, and from the transformer base to the foundation pad.

613.06 Luminaires and Lamps. Luminaires shall be mounted on the mast arm by a slipfitter clamp or other approved method, and shall be adjusted vertically and horizontally to provide the required mounting height and maximum light distribution on the roadway.

Each luminaire shall be controlled by an individual photoelectric cell. The photoelectric control shall be positioned northward to minimize sun interference.

After installation and prior to acceptance, refractors shall be cleaned to provide maximum lumen output.

Lamps of the specified type and size shall be installed in the luminaires. Luminaire or pole shall be marked for the type and size of lamp. Tags will be furnished by the local utility company or the Department, if required.

Wall type luminaires for use under overpass structures shall be mounted as shown on the plans. Beam angle setting shall be adjusted to meet illumination requirements.

613.07 Conduit and Direct Burial Cable. Electrical conduit, including conduit for traffic signals, shall be installed in accordance with the applicable requirements described in the Department of Transportation's, "A Policy on the Accommodation of Utilities on Colorado Highways Rights-of-way," as amended, and to the following:

Conduit runs on structures or underground are shown on the plans only for information. Locations will be established during construction. Conduit and cable shall be so located as to avoid any interference with known present or known future construction installations. All underground conduit runs and conduit risers on poles shall be installed as needed even though they may not be shown on the plans.

All conduit, including conduit for traffic signals, installed under the roadway shall be 2 inch minimum diameter (ID), unless otherwise designated on the plans. The

Contractor may, at no expense to the Department, use conduit of larger size than specified. If larger conduit is used, it shall be for the entire length of the run from outlet to outlet. Reducer couplings shall not be used. All conduit runs shall be sloped a minimum of 3 inches per 100 feet for drainage.

Existing underground conduit to be incorporated into a new system shall be cleaned with a mandrel or cylindrical wire brush and blown out with compressed air.

Where new conductors are to be added to existing conductors in a conduit, all conductors shall be removed and the conduit cleaned as provided above. Both old and new conductors shall be pulled into the conduit as a unit.

Conduit terminating in standards or pedestals shall extend approximately 2 inches vertically above the foundations and shall be sloped towards the handhole opening. Conduit, including conduit for traffic signals, entering pull boxes shall terminate 2 inches inside the box wall and 2 to 5 inches above the bottom, and shall be sloped toward top of box to facilitate pulling of conductors. Conduit entering through the bottom of a pull box shall be located near the end walls to leave the major portion of the box clear. At all outlets, conduits shall enter from the direction of the run.

The ends of all conduits, whether shop or field cut, shall be reamed to remove burrs and rough edges. Cuts shall be made square and true so that the ends will butt or come together for the full circumference thereof. Slip joints or running threads will not be permitted for coupling conduit. When a standard coupling cannot be used for coupling metal type conduit, an approved threaded union coupling shall be used. All threads on all ferrous metal conduit, not previously treated with a corrosion preventative, shall be painted with rust preventive paint before couplings are made up. All couplings for metal type conduit shall be tightened until the ends of the conduit are brought together, providing a continuous electrical connection throughout the entire length of the conduit run. Where the coating on ferrous metal conduit has been damaged in handling or installing, such damaged places shall be painted with rust preventive paint. Non-metallic type conduit shall be cut with a hacksaw or other approved tool. Non-metallic type conduit connections shall be of the solvent weld type.

All metal type conduit ends shall be threaded and shall be capped until wiring is started. When caps are removed, the threaded ends shall be provided with conduit bushings. Non-metallic type conduit ends shall be capped until wiring is started.

Conduit connections at junction boxes shall be tightly secured and water proofed. Conduit entering controller cabinets shall be sealed by the use of paraffin or other sealing compound as approved by the Engineer.

When specified, conduit shall be installed under existing pavement by jacking or drilling operations. Where plans show that existing pavement is to be removed, jacking the conduit will not be required. Jacking or drilling pits shall be kept a minimum of 2 feet clear of the edge of pavement whenever possible. Water will not be permitted as an aid in the jacking or drilling operations.

When trenching is specified to place conduit under existing pavement that is not to be removed, the trench shall not be wider than 4 inches for 2 inch conduit or 5 inches for 3 inch conduit. Trenches shall be filled to within 2 inches of the existing grade with Class B concrete, or as directed. The remaining 2 inches shall be filled to match existing grade and surfacing materials with concrete or hot asphalt mix within 48 hours after cutting roadway.

Underground conduit or cable shall be buried a minimum of 2 feet without sag between boxes. Conductor, regardless of type, shall be placed in conduit when crossing under roadway. Conduit placed under roadways shall be located at a depth of not less than 30 inches.

Rigid metallic conduits on bridges shall have an expansion fitting at every expansion joint of the bridge.

Pull boxes shall be constructed as shown on the plans. With either direct burial cable or wiring in conduit, pull boxes shall be installed at all wiring splices, all conduit ends, all conduit angle points, and at all other locations which are shown on the plans. Pull box locations which are shown on the plans are approximate.

It shall be the option of the Contractor, at no expense to the Department, to install additional pull boxes to facilitate the work.

Where practical, pull boxes shown in the vicinity of curbs shall be placed adjacent to the back of curb, and pull boxes adjacent to standards shall be placed along the side of foundations as shown on the plans.

Unless otherwise shown on the plans, pull boxes shall be installed so that the covers are level with curb or sidewalk grade or level with the surrounding ground when no grade is established. The bottoms of pull boxes installed in the ground or sidewalk areas shall be bedded in crushed rock.

Where a “stub out” is called for on the plans, a sweeping ell shall be installed in the direction indicated and properly capped. The locations of ends of all conduits in structures or terminating at curbs shall be marked by a “Y” at least 3 inches high cut into the face of curb, gutter or wall directly above the conduit.

613.08 Wiring. Unless otherwise authorized, the multiple system of electrical distribution shall be used. Conductors of the size and material required either single or in cable shall include but not be limited to: control wiring, luminaire wiring, main circuit wiring, ground wiring and service entrance wiring.

Each metal light standard shall be wired with a breakaway fused connector of proper capacity rating. The fused connector shall be located in the transformer base, or, if the pole has no transformer base, in the pole at the hand hole.

Luminaires may be selected which operate at either 120 volts 60 Hz or 240 volts 60

Hz. Selection, however, must be consistent with utility company requirements. When 120 volt luminaires are utilized, 120/240 volts shall be brought to the base of each light standard and individual luminaires shall be connected to one leg or the other in such a manner as to minimize overall voltage drop.

A complete grounding system shall be provided for the entire lighting installation. Grounding shall consist of: ground cables, conduits, ground rods, wire or strap, and ground fittings, as required by the National Electrical Code.

613.09 Testing. Prior to final acceptance, the Contractor shall demonstrate to the Engineer's satisfaction that all electrical and lighting equipment installations are in proper condition. Temporary power and all required cable connections, for purpose of testing, shall be provided by the Contractor at no expense to the Department.

The Contractor shall operate the lighting system from sunset to sunrise for ten consecutive days. If lamps, ballast or photoelectric cells fail, they shall be replaced immediately. However, this will not require a restart of the test.

The records of all testing shall be submitted to the Engineer for approval.

METHOD OF MEASUREMENT

613.10 Light standard foundations including anchor bolts, whether concrete or screw-in type, will be measured by the actual number installed and accepted.

Light standards including pole, mast arm or arms, transformer base or approved breakaway device, and connector bolts will be measured by the number of light standards installed. Whenever Light Standard "Metal" is designated as a bid item, the Contractor will be permitted to furnish either steel or aluminum.

Luminaires including lamp, ballast and photoelectric cell will be measured by the number of installed luminaires of the specified wattage.

Secondary service pedestals will be measured by the number of units installed.

Conduit on structures or underground shall include junction boxes, pull boxes, 90 degree sweep ells, pull wire, weatherheads, adaptors, and condulets. Conduit will be measured by the linear foot in place and shall include all saw cutting, excavation, backfill, jacking and drilling pits. It shall also include removal of pavement, sidewalks, gutters, and curbs and their replacement in kind to match existing grade and all other work necessary to complete the item.

Direct burial cable, including junction boxes, will be measured by the linear foot along the cable.

Wiring will not be measured. The lump sum price bid for wiring shall include all the electrical circuitry necessary for the complete lighting installation as shown on the plans except for the conductors contained within the direct burial cable.

The Contractor may elect to use direct burial cable in conduit. However, all conductors in conduit, regardless of type, shall be considered as part of the wiring item and will not be measured and paid for separately.

BASIS OF PAYMENT

613.11 The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Concrete Foundation Pad	Each
Light Standard Foundation	Each
Light Standard_____ (_____Foot) (Furnish Only) (Install Only)	Each
Luminaire High Pressure Sodium (_____Watt)	Each
Luminaire High Pressure Sodium (Wall Type) (_____ Watt)	Each
Luminaire (____) (____Watt) (Furnish Only) (Install Only)	Each
Luminaire (Wall Type) (_____)(_____Watt) (Furnish Only) (Install Only)	Each
Secondary Service Pedestal	Each
___Inch Electrical Conduit (Furnish Only) (Install Only)	Linear Foot
___Inch Electrical Conduit (Plastic) (Furnish Only) (Install Only)	Linear Foot
___Inch Electrical Conduit (Jacked) (Furnish Only) (Install Only)	Linear Foot
Direct Burial Cable	Linear Foot
Wiring	Lump Sum

The Light Standard item, Luminaire Items and Electrical Conduit items will be furnish and install unless the Summary of Approximate Quantities indicates whether it is to be (Furnish Only) or (Install Only).

Soil testing for screw-in light standard foundations will not be measured and paid for separately, but shall be included in the work.

SECTION 614
TRAFFIC CONTROL DEVICES

DESCRIPTION

614.01 This work consists of the construction of traffic signs and sign structures, traffic signals and systems, barricades, rumble strips, masking sign legends on new sign panels, providing and installing multi-directional steel sign break-away assemblies, and modification of sign posts and legends. This work shall be done in accordance with these specifications, the latest revision of the *Manual on Uniform Traffic Control Devices for Streets and Highways* published by the FHWA and adopted by CDOT, the latest revision of the Colorado Supplement thereto, and in conformity with the details shown on the plans or established.

MATERIALS

614.02 Sign Posts and Sign Structures. Concrete shall conform to the requirements of Section 601. Reinforcing steel shall conform to the requirements of Section 602. Steel for Sign Posts and Sign Structures shall conform to the material grade and type specified in the Contract. Steel plates, shapes, and bars shall conform to the requirements of Section 509. Tubular steel shall conform to the requirements of ANSI/AWS D1.1. Timber sign posts shall conform to the following:

(1) Species: Douglas Fir South or Douglas Fir Larch, Grade No.1
(2) Finish: S4S
(3) Moisture content: 19 percent or less
(4) 80 percent Free of Heart Center

Prior to use all timber shall be stored, banded and kept dry.

All lumber shall be manufactured in accordance with Product Standard 20-70 as published by the Department of Commerce, and shall be grade marked by a grading agency or have an accompanying certificate from the grading agency. The grading agency shall be certified by the Board of Review of the American Lumber Standards Committee.

Underground portions of timber sign posts, plus at least 6 inches above ground line, shall be painted with one of the preservatives listed in AASHTO M 133.

Timber sign posts size 6 inches by 6 inches shall be provided with two 2 inch diameter holes through the neutral axis at right angles to the roadway for induced breakaway function, one drilled at 4 inches and one at 18 inches above the ground level.

Structure backfill around concrete footings shall be Class 2, in accordance with Section 206.

614.03 Overpass Mounted Sign Bracket. Material for overpass mounted sign bracket shall conform to the structural steel requirements of Section 509.

614.04 Sign Panels. Sign panel materials shall conform to Section 713 and to the details shown on the plans. Retroreflective sheeting shall be type III and shall conform to subsections 713.04 and 713.06 when applicable.

Retroreflective sheeting for all signs requiring a yellow background shall be fluorescent.

All exposed lockbolt fastener heads on the faces of sign panels shall be covered with material matching the background of the panel.

The Contractor shall provide sign panel legends for standard signs in accordance with the *Standard Highway Signs* published by the FHWA and the Colorado Supplement thereto, and sign panel legends for special signs in accordance with the detailed sign layouts provided by the Engineer.

All sign panels shall be identified with the month and year that the sign was manufactured. The date shall be located on the lower right side of the back of the sign panel and shall be approximately ¼ inch high. The date shall be stamped or adhered onto the sign panel material for a permanent record. This work will be paid for as part of the Item.

614.05 Sign Illumination and Illuminated Signs. Electrical work shall conform to Section 613. Lens and reflectors for flashing beacons shall be of a type as described in the November 1998 edition of the ITE Equipment Material Standards Chapter 2 Section 8.00, Traffic Signal Lenses, and Section 10, Reflectors.

LED modules shall meet the requirements described in the November 1998 edition of the ITE Equipment Material Standards Chapter 2a, Sections 1 through 7.2.2.

614.06 (unused)

614.07 Barricades. Wood used in barricades shall be untreated S4S and shall conform to the applicable portions of subsections 710.07 and 710.08. Retroreflective sheeting shall be type III and shall conform to subsection 713.04.

Underground portions of timber barricade posts, plus at least 6 inches above ground line, shall be painted with any preservative listed in AASHTO M 133. Any portion of a timber barricade not covered with reflective sheeting or treated shall be painted white in accordance with subsection 508.08 and the plan details.

614.08 Traffic Signal Materials.

(a) *General.* At the preconstruction conference, the Contractor shall submit, for approval, a list of equipment and materials which will be installed. Each item shall be identified by trade name, size, and number. Materials shall conform to the requirements of Section 713, to the requirements shown on the plans or as designated, and to the following:

All electrical equipment shall conform to the standards of ITE, IEEE, UL, or EIA, wherever applicable. In addition to the requirements of the plans, these

specifications, and the special provisions, all materials and workmanship shall conform to the requirements of the National Electrical Code (NEC), Rules for Overhead Electrical Line Construction of the Colorado Public Utilities Commission; standards of ASTM, ANSI, and all local ordinances which may apply.

Wherever reference is made to any of the standards mentioned above, the reference shall be construed to mean the code, order, or standard that is in effect on the date of advertisement for bids.

Materials and equipment for traffic signal installations and modifications within existing traffic signal systems shall be compatible and the equipment interchangeable with the existing equipment.

All traffic signal equipment which is supplied shall be of models which are currently manufactured by the suppliers of such equipment.

The locations of signals, standards, controllers, services and appurtenances shown on the plans are approximate and the exact locations will be established by the Engineer in the field.

Upon completion of the work, the Contractor shall submit record drawings or corrected plans or any additional data required by the Engineer showing in detail all construction changes, including but not limited to wiring, cable, and location and depth of conduit.

The Contractor shall submit two sets of schematic wiring diagrams for the traffic signal controller, the signal installation's light circuits and all auxiliary equipment including units and values for each component used to the Engineer. These diagrams shall show in detail all circuits and parts. Such parts shown thereon shall be identified by name or number and in such manner as to be readily interpreted.

All diagrams, plans and drawings shall be prepared using graphic symbols shown in ANSI Y32.2, "Graphic Symbols for Electrical and Electronic Diagrams." The cabinet drawings shall be non fading prints using the xerography method. Blue line drawings will not be accepted.

One copy of the controller cabinet diagram and the intersection and phase diagram as approved by the Engineer shall be placed in a heavy duty plastic envelope with side opening, and attached to the inside of the door of each controller cabinet.

Manufacturer guarantees furnished with installed equipment shall be furnished to the Engineer. The extent of such guarantee will not be a factor in selecting the successful bidder.

Steel incorporated into Traffic Signals shall conform to the material grade and type specified in the Standard Plans. Steel plates, shapes, and bars shall conform

to the requirements of Section 509. Tubular steel shall conform to the requirements of ANSI/AWS D1.1.

(b) *Traffic Signal Controllers-General.* The traffic signal controller shall be a Type 170E constructed in accordance with the FHWA-IP-78-16 specification except as revised in 614.08(b)1.,2., and 3. below. The controller assembly shall consist of a controller unit, cabinet and all necessary auxiliary equipment to provide the operation as shown on the plans. The output file shall have eight "flash programming jumper blocks," one for each of the eight phases.

The power distribution assembly shall be the PDA No. 2. The PDA No. 2 shall have field circuit breakers 1-6 to provide 15 amperes of operating AC current to the field load switches. If one of the field breakers is set off, the indicating switch shall place power on the MC coil and FTR coils causing a flashing operation.

The Prom Module shall be a 412B System Memory Module.

The module shall comply with details and connections shown on the plans for the Model 170E Traffic prom Module.

All electrical connections in and out of the module shall be through a printed circuit connector having two rows of 36 independent bifurcated contacts on 0.10 inch centers.

The module shall be designed so that persons inserting or removing the assembly shall not be required to insert hands or fingers within the microprocessor unit housing this modular assembly. A handle or gripping device protruding no more than 1 ¼ inches from the front panel shall be attached to the front of the assembly. The front panel shall be connected to ground.

All Inputs and Outputs shall be Tri State Buffered enabling them to drive a load consisting of 10 TTL gates and 200 picofarads. When this module is not being addressed, the data inputs and outputs shall be disabled into a high impedance state and the data I/O lines shall not source or sink more than 100 micro amperes. All address inputs shall not load the bus by more than one TTL gate load and 100 picofarads.

There shall be provided a positive method to prevent this module from being inserted upside down in the prom slot with the front panel of the 170E closed.

The memory module shall consist of a minimum of three 28-pin sockets, for JDEC pin compatible memory devices ranging in sizes from 4K X 8 (2732) to 32K X 8 (27356).

The selection of address and backup power shall be made via soldered wire jumper options.

One 28-pin socket shall be designed to house only EPROM memory devices. The remaining two 28-pin sockets shall be designed to house RAM, NOVRAM or EPROM memory devices. Solder jumper options shall route the optional battery backup power to each of these two sockets, when specified. When specified, the backup battery power shall enable volatile memory devices to retain the data in their memory in the event of a power failure or when the module has been removed from the 170E controller for a period of at least one year.

The entire memory map address map shall be user definable such that each socket can be addressed independently. The decode shall be provided by bipolar prom. When the bipolar prom recognizes an address within the range of the prom module, the appropriate decode output shall become active thereby enabling the appropriate memory device. Resistors shall be used to pull up the memory select lines to the +5 Volt power bus if the device is selected for battery back up power. This shall provide data detention in the event of a controller power failure.

There shall be provided on the 412B SYSTEM MEMORY MODULE a regulated 5 volts power supply, derived from the 12 volt supply available on the Prom Module. This supply shall provide a minimum of 500 milliamperes on the assembly. This 5 volt supply shall power only the module address bus, the data bus and the bus buffers.

There shall be a wire protect circuit to write protect the memory devices when power has been removed, and to delay writing for a short time after power has been restored.

The 412B shall have provisions for an optional battery backup supply voltage for RAM devices when the power is removed from the module. This optional battery, when called for, shall be an AA size lithium battery. All modules shall be provided with a battery disconnect switch and battery holder clip devices for the AA battery.

The assembly shall operate and mate with all Model 170E Controller Units.

The following configurations are required for the operation of Wapiti software used by CDOT.

The 412B Prom Module shall be configured for a 27256 EPROM at address 8000-FFFF and NOVRAMs at 1000-4FFF and 7000-7FFF unless otherwise specified.

When specified that the 412B Prom Module will be used for a master controller a 27256 EPROM shall be used a address A000-FFFF, a RAM shall be used at 8000-9FFF and NOVRAM configured for 0800-4FFF and 7000-7FFF.

The 170 PROM module shall be on the Colorado Qualified Products list.

1. 170E traffic Signal Controller. Each controller shall be a Type 170E with 4 ACIA connectors and 2 modem slots per FHWA-IP-78-16 specifications except as noted below.

In addition to the manual (as specified in the FHWA-IP-78-16 specifications) two "D" size (24 inch x 34.5 inch) drawings of all schematics and assembly prints contained in the manual shall be supplied for each twenty controllers or revision change.

The 170E Controller shall come with a blank panel to cover the Prom Module opening if the CDOT chooses to use a Prom Module. This panel will have all the necessary hardware to be attached to the Front panel.

FHWA-IP-78-16 Specifications Vendor's Testing Certification shall be modified to read "The Vendor shall supply with each shipment a full test report of the quality control and final test conducted on each item." In addition, the Contractor shall supply a statement with each 170E controller that the unit was tested in accordance with Section 1.8.5.3.3 as modified below.

1.8.5.3.3 shall be modified to read "A minimum 100-hour burn-in of all modules. This burn-in shall include 48 hours of monitored testing at the high and low temperatures as described in 1.8.3.7.1 and 1.8.3.7.2."

2. Training. The Contractor shall provide 16 hours of training at a site designated by CDOT. This training shall include but not be limited to Diagnostic Software and circuit theory and operation of the 170E controller. The training will be provided by a person knowledgeable in the operation and repair of the 170E controller, 332 and 336 cabinets, and associated diagnostic software.

3. Prom Module. The Prom Module shall be a separate item that shall be provided only when requested. The Prom Module shall be a 412B type Prom Module unless otherwise specified. When the equipment is supplied for a project the Contractor shall contact the Regional Supervisor to obtain the Traffic Program Revision that is to be provided.

(c) *Controller Cabinets.* The controller cabinet shall be either a Model 332 or 336S as specified in the Contract. The 336S cabinet shall include a base extension assembly. Each cabinet shall be natural aluminum with anchor bolts in accordance with the FHWA-IP-78-16 specification. The imput files shall meet the requirements of the split input file below. Unless Otherwise specified in the Contract, the cabinet shall include the following:

Quantity	Item
2	Internal (front/back) fluorescent lamps
4	Model 430 Transfer Relays
2	Model 204 2-Circuit Flasher (cube type, 25 AMP output)
12	Model 200 Load Switches (cube type, 25 AMP output)

Quantity (cont.)	Item (cont.)
3	Model 242 DC Isolators
6	Model 222 Loop Amplifiers
1	Model 210 Monitor with absence of red monitoring
1	New York 330 Pull-out Drawer Assembly
1	Auxiliary Detector Termination Panel Assembly
1	Transient Voltage Surge Suppression System

A 20 conductor cable assembly for monitoring the red outputs of all signal load switches shall be provided and mounted to the back panel assembly. The cable shall be routed to the front of the assembly and be plugged into the connector on the front of the conflict monitor.

A means of selecting the active red monitor channel shall be provided on the rear of the monitor panel. Selection shall be accomplished by means of a two position jumper (shunt) with the center position wired to a red monitor input and select of 115V AC to the right and red load switch output to the left. Moving the jumper to the right will provide continuous red input and override, while moving a jumper to the left will attach the monitor channel to the corresponding load switch output.

This jumper assembly shall be accessible while the intersection is in operation. Means shall be provided to prevent shock to personnel operating jumper selection devices.

A minimum of 12 selections are required, eight phase selections and four overlap selections shall be provided with jumper selections.

Red monitoring disable control shall be provided within the red monitor cable assembly. Pin six on TB02 shall connect to a 24V DC relay coil. This relay is designated RM control relay. The normally closed contacts shall provide 115V AC to the red monitor select line and pin 17 on the monitor cable. When a logic ground signal is applied to TB02-6 the RM relay shall energize and open the cable. The relay power will be derived from the cabinet 24V DC cabinet power supply.

Electrical characteristics of the device that will be used for series transient protection on the 332 and 336S cabinet system shall include tests run using a Velonex 587 surge generator and Tektronix oscilloscope type 2430 or equivalent hardware. Using ANSI/IEEE 062.41-1980 waveforms for normal mode and common mode ring wave and impulse tests, each unit shall comply to the following minimum characteristics:

(1) Clamping level 400V peak normal mode and 500V peak common mode. Trace photos and other test related information will be available upon request.

(2) EMI/EFI noise rejection derived via standardized 50 ohm insertion loss tests shall have amplitude of at least -20db over a minimum spectrum from 50 kHz with a -40db being the most desirable.

(3) Diagnostics indicators shall clearly display the status of the suppression circuit. The indication shall warn of the loss of protection.

(4) Transient energy suppression shall be in excess of 250 Joules.

(5) Rated voltage is 120V AC with rated output current minimum 10 amperes single phase operation.

All of the above components provided on the project, excluding the signal monitor unit, shall be on the Colorado Qualified Products listing.

Split input file shall be an SF 170 that will operate in the 332/336S cabinets.

The Split Input File shall use the same form factors as the present (older) input file and shall be completely interchangeable with these older input files except as follows.

The input file shall use a split 22 pin connector (2 rows of 22 pins) which provide for 44 unique contacts, rather than the 22 double contacts as provided by the former input file. This design shall interface electrically with the older 2 and 4 channel devices available under the 170 and NEMA TS1 specification as well as the newer 2 and 4 channel devices as specified in the TS2 NEMA specification.

The input file shall be divided into two partitions. The first partition shall include the first eight slots from the left; the second partition shall include the next six slots. All 14 slots shall be able to be tied to one common communication drop if desired.

The serial/TTL Transmit and receive pairs shall be wired across the back panel. TXO, DXO, and Ground0 serve the first eight slots; TX1, DX1 and Ground1 serve the next six slots. Black plane addressing is automatically assigned in the rear of the input file, such that:

Slot 1 = Address 0
Slot 2 = Address 1....Slot 8 = Address 7 (all three line low)

Addressing from the front of any input device shall override the back plane addressing.

Serial connections shall use a standard quick lock connection.

(d) *Magnetic Detectors.* Magnetic vehicle detectors shall have a moisture-proof housing and shall be capable of withstanding all types of soil conditions. The

magnetic vehicle detector shall be designed for underground operation and installed in a nonmetallic conduit housing.

Magnetic detector amplifiers shall have a continuously adjustable sensitivity level control which shall be adjustable over the full range of amplification of the unit.

Each magnetic detector shall be capable of being activated by a voltage induced in the coil of the sensing element by the passage of a vehicle at any speed from 3 to 80 miles per hour. Any vehicle passing within 18 inches of either end of the sensing element shall provide an output signal.

Each amplifier shall be provided with an integral power supply.

Each amplifier shall be designed to provide ease of maintenance with all electronic components readily accessible.

All input and output circuits for each amplifier shall enter via a single MS connector, circuitry for which shall be as shown in the following table:

Connector Circuitry
For Magnetic Detector Amplifiers

MS Connector Circuit	18-8 Pin
Magnetic Detector(-)	A
Magnetic Detector(+)	B
AC+, 120 volts	C
Chassis Ground	D
Detector Common	E
Output N.O.	F
Output N.C.	G
AC-, Grounded Conductor	H

All controls, indicator lights, fuseholders,and connectors shall be mounted on the front panel of the amplifier.

The magnetic detector sensing element casing shall be constructed of nonferrous materials suitable for use in the environment in which it will operate, and shall be sealed to prevent the entrance of moisture. The sensing element shall be designed to facilitate easy installation, repositioning and removal.

(e) *Micro Loop Detectors.* Micro loop detectors shall conform to the following and to the details shown on the plans.

The sensing element shall be no larger than 2 inches in diameter by 4 inches high and shall contain no moving parts.

The unit shall be a passive transducer which converts magnetic field intensity into inductance for use with conventional inductive loop detector units for the passage detection of vehicles. The operating field shall be 0.2 to 1.0 oersted; inductance: 20uH and DC resistance of 0.5 ohms plus 20uH and 3.2 ohms per 100 feet of probe cable.

Each micro loop detector shall be capable of being activated by a change in magnetic field caused by the passage of a vehicle within the lane of required detection at any speed from 3 to 80 miles per hour.

The probe shall operate at temperatures from -35 to 165 °F and at a relative humidity of 0 to 100 percent including submersion in solutions of chemicals typical of roadway run-off.

Lead-in cable shall be factory assembled, polyurethane jacketed four conductor No. 22 AWG, and shall be of a length specified on the plans.

(f) *Pedestrian Push Buttons.* Pedestrian push buttons shall be of the direct push button contact type. They shall operate on a voltage not to exceed 32 volts DC. They shall be of tamper-proof design and equipped with a push button instruction sign.

The assembly shall be weatherproof and so constructed that it will be impossible to receive any electrical shock under any weather conditions.

The housing shall be shaped to fit the curvature of the pole to which it is attached to provide a rigid installation. Saddles shall be provided to make a neat fit when required.

(g) *Traffic Signal Poles.* All traffic signal poles, mast arms, concrete foundations, and necessary hardware shall conform to the appropriate requirements of Sections 601, 613, 713, and 715, these specifications, and the details shown on the plans.

All traffic signal poles and mast arms shall be of like manufacture. Workmanship and finish shall be equal to the best general practice of metal fabrications shops.

Pole shafts shall be straight, with a permissive variation not to exceed 1 inch measured at the midpoint of a 30 foot or longer pole and not to exceed ¾ inch measured at the midpoint of a pole shorter than 30 feet.

Plumbing the pole shall be accomplished by adjusting the nuts before the foundation is finished to final grade. Shims or other similar devices for plumbing or raking will be permitted only when approved.

Span wire poles may be seamless or may be fabricated as one piece without transverse joints or welds and with only one longitudinal seam which shall be continuously welded and ground, or rolled flush.

(h) *Traffic Signal Faces.* All pedestrian signal faces and all vehicle signal faces shall conform to the requirements of subsection 713.11, the plans, and the following:

All vehicle signal faces shall be of the adjustable, vertical type with the number and type of sections detailed herein and as shown on the plans. They shall provide a light indication in one direction only and shall be adjustable through three hundred and sixty degrees about a vertical axis. They shall be mounted at the location and in the manner shown on the plans. Unless otherwise shown on the plans, all signal faces shall be standard and shall contain three sections arranged vertically; red-top; yellow-center; green-bottom.

All vehicle signal faces shall be focused to allow maximum visibility to approaching motorists. All new faces installed, at any one intersection, shall be of the same make and type.

When specified on the plans, the optical units of all vehicle signal faces and all pedestrian signal faces shall be an LED Traffic Signal Section Optical Unit conforming to the requirements of subsection 713.11. The LED optical units shall be installed in accordance with the manufacturer's instructions.

(i) *Backplates.* Where shown on the plans backplates shall be furnished and installed on signal faces. No background light shall show between the backplates and the signal face or between sections.

(j) *Programmed Visibility Vehicle Signal Faces.* All programmed visibility vehicle signal faces shall conform to the requirements of subsection 713.11, the plans, and the following:

Each programmed visibility signal section shall provide a nominal 12 inch diameter circular or arrow indication. Color and arrow configuration shall conform to ANSI D-10.1.

Each section shall be provided with a sun visor.

Each signal section shall be provided with an adjustable connection that permits incremental tilting from 0 to 10 degrees above or below the horizontal while maintaining a common vertical axis through couplers and mountings. Terminal connection shall permit external adjustment about the mounting axis in five degree increments.

The signal shall be mountable with ordinary tools and capable of being serviced without tools. Adjustment shall be preset at four degrees below the horizontal, unless otherwise specified.

Prior to programming, each signal section with a yellow indication shall provide a minimum luminous intensity of 3,000 candela on the optical axis, and a maximum intensity of 30 candela at 15 degrees horizontal from the axis. Each

such signal section shall be capable of having its visibility programmed to achieve the following luminous intensities: a minimum of 3,000 candela on the optical axis, a maximum of 100 candela at from ½ to 2 degrees horizontal from the axis and a maximum of 10 candela at from 2 to 15 degrees horizontal from the axis. Under the same conditions, the intensities of the red indication and the green indication shall be at least 19 and 38 percent respectively of the yellow indication.

The Contractor shall program the head as recommended by the manufacturer or as directed.

The visibility of each programmed visibility signal face shall be capable of adjustment or programming within the face. When programmed, each signal face's indication shall be visible only in those areas or lanes to be controlled, except that during dusk and darkness a faint glow to each side will be permissible.

(k) *Traffic Signal Electrical Conductors and Control Cable.* Conductors and cables shall conform to subsection 713.11.

A $^{1}/_{8}$ inch nylon rope shall be installed in all new conduit and all existing conduit where a cable is added or an existing cable is replaced. At least 2 feet of pull wire or rope shall be doubled back into the conduit at each termination.

Signal light conductors shall conform to the Red-Yellow-Green color sequencing with different colored tracers for each phase provided.

Sufficient signal light conductors shall be provided to perform the functional operation of the signal system. Additional conductors for service, interconnect, etc. shall be provided as noted on the plans.

A separate set of three spare conductors shall be provided from the controller cabinet to the base of each pole.

Conductors shall be permanently identified as to function. Identification shall be placed on each conductor, or each group of conductors comprising a signal phase, in each pull box and near the end of terminated conductors.

Identification shall be by bands fastened to the conductors in such a manner that they will not move along the conductors.

Loop detector wire shall consist of specified loopwire encased in ¼ inch OD, $^{3}/_{16}$ inch ID vinyl or polyethylene tubing.

All inductive loop detector harness cables shall be shielded.

All detector and pedestrian push-button circuits shall consist of separate two conductor wire systems.

All signal light cable conductors shall have individual terminal lugs for connection to terminal strips.

All detector lead-in cable shall consist of two No. 14 copper conductors with each conductor insulated with high molecular weight, heat-stabilized, colored polyethylene. The conductors shall be twisted and the twisted pair shall be protected with a shield of tinned copper-brass or aluminum-polyester. A No. 16 minimum, stranded tinned copper ground drain wire shall be provided. The cable shall be provided with a chrome vinyl outer jacket with a minimum thickness of 37 mils, suitable for use in conduit or for direct burial when used in conjunction with magnetic or magnetometer detectors.

(l) *Traffic Signal Vehicle Detector Amplifier*.

1. General System Requirements. Vehicle detector amplifier shall consist of high performance, multiple channel inductive loop vehicle detector units and data acquisition software that can provide binned traffic data and real-time traffic measurements on a vehicle-by-vehicle basis. The system shall provide current measurements and vehicle detection information on the last vehicle for use in local control, incident detection and advanced traffic management systems.

   A communication link shall provide remote access to the detector for reading unit configuration settings, for fault identification and verification, for real-time system monitoring and data collection on up to four channels of detection. It shall include password security to the detector to change configuration settings. The communication link shall provide for party line communication on up to eight units using 4-bit hardwired addresses to the card edge connector and/or 127 software programmable addresses in EEPROM memory.

   The interface and data acquisition software shall be organized by application and facilitate setup, real-time traffic monitoring and collection of binned count and occupancy data. A vehicle log shall provide a means for logging of vehicle speed, vehicle length, loop-to-loop travel time and detection duration. Optional modes of operation shall include a vehicle travel direction detection setup capability using overlapped 6 foot by 6 foot loops, a long-loop count mode to provide turning movement counts and a microloop mode selection when channels are connected to microloop sensors.

   The Contractor shall supply data acquisition and interface software and vehicle detectors that meet all the operational and functional performance requirements in accordance with the terms and conditions of this specification.

   The Contractor shall obtain the manufacturer's standard warranty and surrender it to the Engineer.

2. General Hardware - Standards and Performance Requirements. The inductive loop detector units shall be fully interchangeable, whether used for system counting, occupancy measurement, speed and length measurement, directional detection, binned data collection, remote data acquisition in advanced traffic management systems or for local intersection control (including long-loop counting).

   Detector configuration data shall be entered using special interface and data acquisition software. A communication interface shall provide for remote connection and configuration of detectors, real-time activity monitoring and data acquisition via modem to remote devices.

   Inductive loop detector units shall meet the latest edition of the National Electrical Manufacturers Association(NEMA) Standard TS2-1992 for Type 2 controller and cabinet assemblies plus the functional and performance requirements of this specification. The detectors shall be configured as plug-in devices which meet the requirements for NEMA TS2-1992 section 3.2, actuated Type 2 A2 operation and Type I Al operation in 44-pin input files.

   Detectors shall comply with NEMA TS2-1992 Section 6.5.2.2.1, Table 6.5-1 for four-channel rack mount type units, NEMA designation “D,” except that Delay and Extension Timing shall be provided on all four channels in lieu of NEMA TS2-1992 section 6.5.2.24 requirements.

   Detectors shall also be suitable for use in California/New York TYPE 170/179 and ATC cabinets with 22-pin input files. Detectors shall detect and hold the presence of all licensable motor vehicles (including small motorcycles). This shall be accomplished, without detecting traffic in the adjacent lane (beyond 3 feet from the loops except as noted below), on the following loop configurations with from 100 feet up to 1000 feet of home-run cable.

   One to six series connected, 6 foot by 6 foot square loops with three turns of #14 AWG wire or with four turns of #14 AWG wire.

   A 6 foot wide by 30 foot long loop with two or three turns of #14 AWG wire (when set to detect small motorcycles, may detect adjacent lane traffic).

   A 6 foot wide by 20 foot to 60 foot long quadruple loop with a winding of two-four-two turns of #14 AWG wire. When sensitivity is set to detect small motorcycles, adjacent lane traffic shall not be detected.

   Single, double and triple microloop probe sets.

   Each channel shall automatically self tune with full sensitivity, to any loop and lead-in combination resulting in a total inductance of 20 to 2500 micro henries with a Q factor of five or greater, within four seconds after application of power.

3. Special Features and Performance Requirements.

Detectors shall be microprocessor controlled and be capable of being configured with manual switch settings and via software settings in EEPROM memory.

Detectors shall include eight sensitivity settings (thresholds) in 2:1 steps. Threshold settings shall directly relate to nanohenries of inductance change (ΔL). Each increase in Presence or Pulse mode settings shall double the sensitivity (reduce the threshold) from the previous setting. The highest sensitivity (smallest change) setting shall have a ΔL threshold value of eight nanohenries while the lowest sensitivity setting shall have a ΔL threshold of 1024 nanohenries.

Each detector shall have a single, switched oscillator system to sequentially excite and measure each channel.

Each detector shall have a three-position toggle switch to manually select one of three operating frequencies. These three frequencies shall also be software selectable.

Each detector shall have two serial ports; a front panel RS232 port and transmit/receive pins on the card edge connector for serial communication.

Each serial port shall have a multi-drop mode and be capable of party line communication with up to eight detectors on the party line.

The detector unit shall be designed to accommodate the addition of either an optional plug-in memory module or a plug-in communication module.

The communication module shall allow expansion of the multi-drop capability to 32 devices on a common serial port bus and convert the rear port into an independent port. With the optional module installed, communication with a PC through the front port shall not interfere with system communication on the rear serial port, and the baud rates shall be independently settable for the front and rear serial ports.

Baud rates shall be selectable at 1200, 2400, 4800, 9600, or 19200 BPS using the interface software.

The memory module shall expand the memory used for on-board count and occupancy binning.

The front panel serial port shall have EIA-232 electrical characteristics and shall terminate with a front panel 6-pin circular Mini-DIN connector.

A communication cable with a DB-9 female connector (for a computer serial port connection) and a 6-pin Mini-DIN male connector (for the front panel serial port connection) shall be provided for direct communication with a remote reporting device or a PC running the interface and data acquisition software.

Units shall have software settable addresses from 128 to 254. Address 255 shall be assigned as a "wildcard" to be used only when connected to the front panel port to establish connection and read the correct address from the device.

Units shall have 4-bit back panel hardwired addressing capability to allow selection of one of 16 hard-wired addresses. Backpanel addressing shall be enabled via the interface software.

An external 24VDC Green control input shall be provided to control the output timing. If True (ground level = 0 to +8VDC), the Green input shall disable Delay and enable Extension Timing. If False (+16 to +30VDC or Open), the Green input shall disable Extension and enable Delay Timing. Software shall provide for an option to disable Green Gating so that Delay or Extension Timing is provided unconditionally.

Detector units shall have a Presence or Pulse mode output option. Selection shall be via front panel switches or software settable options.

Each channel shall have a pushwheel sensitivity switch to enable manual selection of one of seven Presence mode or eight Pulse mode settings or an OFF position.

Presence output shall hold vehicle detection for at least four minutes minimum for small licensed motor vehicles (100cc. motorcycles) and for at least 60 minutes for automobiles before tuning-out vehicles (dropping recognition of vehicle presence) over a 6 foot by 6 foot square loop with three or four turns of wire. The Presence output shall not tune out when vehicle motion exists (defined as vehicle entry and departures continue every few minutes and vehicles remain present in the sensing zone) for at least 60 minutes.

In Fast Recovery mode the channel shall recover to full sensitivity within 750 milliseconds after all vehicles leave the inductive loop sensing zone.

Pulse mode shall provide a single, output pulse of 118 ±5 milliseconds in response to an 18 foot long vehicle traveling over a 6 foot by 6 foot loop at 8 mph, and for successive vehicles traveling over the same loop at speeds ranging from 10 to 100 mph, with a one-second headway. Pulse width shall be programmable from interface software. If a vehicle remains over the loop, further detection shall be inhibited for a 1.9-second rephase delay and then full sensitivity shall return immediately regardless of continued presence of the vehicle. Pulse rephase shall be programmable from interface software.

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Detector units shall have optically-isolated FET outputs to provide fail-safe solid state operation.

Loop detector channels shall continue to function with a single point short to ground on the loop/lead-in system.

Each channel shall be capable of detecting and displaying current and historical faults (a short to ground, an open circuit or an inductance change P 25 percent) in the inductive loop or lead-in system.

Each channel shall have two LED indicator lights on the front panel; a green "Detect" LED and a red "Fault" LED.

The green "Detect" indicator shall indicate detection output status and output timing in process.

The green "Detect" indicator shall indicate an Extend flash while the call output is actuated following a directional detection unless fail-safe for a particular condition is disabled using the interface software.

The green "Detect" indicator shall flash during Delay and Extension Timing to provide a visual indication of timed output. Delay and Extension flash rates shall differ by at least four times the other's rate. Delay shall be four flashes per second and Extension shall be 16 flashes per second.

The green "Detect" indicator shall be ON continuously during a fault condition. During a fault condition on a channel, the channel shall display a continuous call indication on its green "Detect" LED and generate a continuous, fail-safe output on the primary output, regardless of the pulse or presence operating mode selected.

A status output shall provide a serial coded message to external devices (controllers) that are capable of using the serial information in accordance with NEMA conventions described in TS2-1992.

A red "Fault" LED shall indicate current or historical channel fault condition (status) and type. The Fault indicator shall flash a coded message during an open loop condition, a shorted loop system condition and a $\geq$ 25 percent change of inductance condition. The associated channel's red "Fault" LED shall provide visual indication of fault type and current or historical status with a unique flash code.

A fault indication shall be enabled for as long as the fault remains, except by turning the channel OFF in software or by selecting the "X" setting on the sensitivity switch.

If the fault heals or is corrected, the affected channel shall immediately retune and be capable of normal detection. The visual fault indication shall remain active until reset by a momentary change in the mode or sensitivity setting, a momentary interruption of power or by pressing a reset switch.

Primary output of each detector channel shall provide accurate detect duration in response to an automobile over a three or four turn 6 foot by 6 foot square inductive loop to enable accurate speed, length and occupancy measurements by external devices. The detector channel, with a 100 micro henry loop/lead-in attached to each channel, shall for any negative inductive change which exceeds its sensitivity threshold generate a ground true logic level output response within 13 milliseconds for a sensitivity setting of 128 nanohenries and within 20 milliseconds for a sensitivity setting of 64 nanohenries.

Loop detectors shall have a multi-position switch to Reset all channels and to provide Normal and Fast Recovery modes of operation. The Fast Recovery setting shall cause the detector to adapt instantly to large changes of apparent inductance in the non-call direction. The Normal Recovery mode shall cause the detector to adapt, at a default rate of 0.5 thresholds per second, to apparent changes of inductance in both directions.

Loop detectors shall have a Remote Reset input pin on the card edge connector. The unit shall reset and establish a new reference for each loop that is turned ON, when voltage on Pin C is less than 8 volts DC for a period of greater than 17 milliseconds.

Delay Timing shall be adjustable from zero to 31 seconds, minimum, in increments of 1.0 seconds in lieu of NEMA TS2-1992 section 6.5.2.24.1 increments. Delay timing shall occur if the green input is false.

Extension Timing shall be adjustable from zero to 7.75 seconds, minimum, in increments of 0.25 seconds in lieu of NEMA TS2-1992 section 6.5.2.24.2 increments. Extension timing shall occur if the green input is true.

Each channel shall be capable of being configured for Long-loop Count mode for counting each individual vehicle moving onto or over a single inductive loop which has a length greater than 20 feet, regardless of previous vehicles being stationary on, moving over or leaving the detection zone. The call output in the Long-loop Count mode shall be a presence output. The configuration of the channel and the retrieval of the long loop count shall be accomplished via the serial ports using the software.

Two channels (channels 1 and 2 or 3 and 4) shall be capable of being assigned to directional detection mode for detecting the direction of travel of a vehicle over two overlapping 6 foot by 6 foot loops with leading-edge

to leading edge spacing of 3 feet. A call output shall be generated and stored as a directional count by the second channel that detects the vehicle in the direction of the vehicle's travel. The configuration of the detector for directional detection and the retrieval of the directional count shall be accomplished via the serial ports using the software.

Each channel of the vehicle detector shall be capable of collecting and storing counts and occupancy in time bins. The detector memory shall allow storing count and occupancy in 15 minute time bins for a duration of 36 hours and with the optional memory module for a duration of 335 hours. The configuration of the time bin intervals and the retrieval of the stored counts and occupancy shall be accomplished via the serial ports using the software.

4. Interface Software Requirements.

The detector unit shall be capable of remote configuration, system diagnostic measurements and real-time data collection. A communication link shall provide remote access to the detector for reading its configuration, for fault identification and verification, for real-time monitoring and data collection on up to four channels. The link shall provide optional password protection to change unit configuration settings. Interface software shall display and report current loop inductance measurements, current or last (historical) fault information, and information specific to the last vehicle detected and vehicle counts. Vehicle information shall include vehicle change of inductance, speed, length and time over loop.

A Windows™ based interface and data acquisition software program shall be provided to perform these functions via a remote reporting device running under at least a Windows™ 95 or Windows™ NT 4.0 operating system.

The software shall establish and maintain the communication link to a remote reporting device via a field modem or by direct connection to one of the serial ports on the detector

The software shall be organized by application to simplify setup and monitoring of channel activity measurements, traffic counting, long-loop count, logging of vehicle speed and vehicle length, loop to loop travel time, detect duration, binning of count and occupancy, and sensing of vehicle travel direction with directional detection and call duration.

The software shall allow selection of the PC's communication port and baud rate.

The software shall include a phone book and dialing utility.

The interface and data acquisition software shall provide a Read from Device command on the File menu. The Read from Device shall allow the

selection of an address to establish remote communication with a detector unit.

The initial screen shall open with a Settings icon, a Real-Time Vehicle Logging icon and a Traffic Data Binning icon. After communications have been established with a detector, other icons shall appear. These shall include the Real-Time Activity Monitoring icon, Force ALL Outputs and LEDs icon, a Reset icon and a Scan-Time Utility icon.

A Settings window shall be divided into nine tabs to organize the settings by application.

A General tab shall allow selection of the configuration source to be either from EEPROM or switches, the oscillator frequency for the unit, the vehicle count period and channel sensitivity and mode.

A Communications tab shall provide for the setting of a field modem command string, transmit delay, selection of the communication baud rates on the front and rear ports, for setting a programmable address and to enable a backpanel address. There shall be provisions to establish, cancel and change a password.

If password protection is set up in a detector, the unit shall not respond to any requests to perform a reset or change settings until the correct password has been issued. After a verified password has been issued the detector shall respond to all requests for reset or settings changes for 60 minutes. After 60 minutes the unit shall revert back to password protected mode until the password has been issued. Reset shall cause immediate reinstatement of password protection.

A Timing tab shall provide for setting the Delay or Extend Time options and the timing increments for each channel. There shall be an option to select “Enable” Green Gating to condition the timing functions to green inputs.

A Microloop tab shall provide for selecting microloop mode of operation and setting some of the parameters that are unique to the performance of microloop sensors in special applications.

A Long Loop tab shall provide for selecting the option to count vehicles over long loops set to operate in Presence mode. Setup options shall be included to allow for calibrating the algorithm to improve count accuracy on loops 20 to 60 feet long. Vehicle counts shall be available over the serial communication ports.

A Directional tab shall provide the option of setting up travel direction sensing on channel pairs I & 2 and 3 & 4. With the paired channels connected to 6 foot by 6 foot loops that are overlapped by 3 feet, vehicles

shall be counted in both directions. The directional detection call output shall be assigned to the last loop a vehicle crosses when traveling in the direction that is to be detected. Call Duration shall be selectable for the directional output on the trailing channel of the paired sets.

An Output tab shall provide for the option to enable the Status Output for NEMA TS2 Type controllers. Software provision shall also exist to disable the “fail-safe” Call Output.

A Noise Immunity tab shall provide for selecting several noise options including a power line filter which can be enabled.

An Adapt tab shall provide for selecting the adaptation parameters for the detector unit to modify default operation.

A Real-Time Vehicle Logging icon shall provide for setting up channels to monitor vehicle speed and length measurements. Facilities shall be provided to insert a loop description (ID label), a loop type (configuration) and a calibration utility to select effective magnetic field loop sizes to improve measurement accuracy. The utility shall also provide for setting up loop assignments and leading edge distances from loop to loop to calculate vehicle speeds. Facilities shall be included to activate and view the log with channel ID, loop descriptions, dates, times, speeds, lengths, durations, loop to loop times displayed in real-time. Provisions shall be made to save the log to a file and print the log.

A Traffic Data Binning icon shall open a window to setup and collect binned count and occupancy data from the detector. A tab shall provide for setting up the channels to be binned, the start date and time, the end date and time and the binning intervals. Software shall be included to inform the user when the detector will run out of memory based on the setup information provided. If continuous binning is selected the data shall “wrap-around” so that the oldest data will be overwritten with the latest entries.

A Real-Time Activity window shall be provided to display all current detection information pertaining to each channel, including current measurements (loop inductance, loop frequency, reference frequency, green input state and loop status), last fault (or historical fault) information (fault type, time and date), plus information specific to the last vehicle detected (DL in nanohenries, detect duration, detect time, and detect date) and traffic counts (count, directional count and the count period remaining).

The Activity window shall include a freeze capability to capture the current activity information while the unit continues to display the most recent changes.

A window shall be included to verify the operation of a detector’s outputs

and LEDs and confirm the wiring of a control cabinet to issue the call output to a device or controller. This utility shall allow selection of specific Detect LEDs, Call Outputs, Fault LEDs, and channel Status Outputs to be "forced" ON or OFF for testing the system.

A window shall be included to remotely reset a detector. It shall be possible to select specific channels, all channels or the entire unit.

A window shall be included to provide a real-time view of the detector's self-measured scan-time. This interactive utility shall continuously read and display the detector's scan-time and display the theoretical detection performance based on user-selectable parameters.

The software shall allow printing of settings, activity measurements, and binned and logged vehicle data.

A comprehensive ON-LINE Help utility shall be included with detailed descriptions of unit features and setup information. The Help text shall include hyperlinks to all subjects related to applications or setup sequences. Help screens shall include a print function to print the page.

CONSTRUCTION REQUIREMENTS

614.09 Highway Signs and Traffic Signals. Aluminum shall be heliarc welded and conform to the AWS requirements for welding aluminum. Portions to be welded shall be cleaned and prepared to assure 100 percent penetration butt weld. Oxygen cutting will not be permitted. Preheating, if used, shall not exceed 400 °F for 30 minutes. Defective welds shall be removed and rewelded. Acceptable aluminum welds shall be in accordance with AWS with 17 ksi the minimum tensile strength for reduced section specimens.

Welding and fabrication of Traffic Control Devices shall conform to ANSI/AWS D1.1, as amended herein.

Fillet welds connecting tubular steel to a shape or plate shall be qualified in accordance with ANSI/AWS D1.1, section 4.11.1.

The fillet weld Procedure Qualification Record (PQR), all Welding Procedure Specifications (WPSs) and Welder Qualification Records (WQRs), Inspection, and Nondestructive Testing Reports shall be submitted to the CDOT Staff Bridge Fabrication Inspectors, 4201 East Arkansas Avenue, Denver, CO 80222 for approval prior to fabrication. CDOT acceptance of submitted PQRs, WPSs, and WQRs establishes prequalification to fabricate Traffic Control Devices.

All ungusseted traffic signal mast to pole bracket, pole bracket to pole, and pole to base plate attachment welds shall conform to ANSI/AWS D1.1, Section 2.36.6.6.

Prior to welding, base metal surfaces shall be blasted or ground to eliminate mill scale, visible rust, oil, or debris.

Welding shall be performed prior to galvanizing, metallizing, or application of zinc coatings to the piece.

The fabricator shall submit a Written Practice for the Administration of Personnel Qualification and Certification Program in accordance with the American Society for Nondestructive Testing (ASNT) SNTTC1A for approval. Personnel performing the weld evaluations shall be certified as ASNT Level I or II. Certification of Level I and Level II individuals shall be performed by a Level III individual who has been certified by (1) The American Society for Nondestructive Testing, or (2) has the education, training, experience, and has successfully passed the written examination prescribed in SNT-TC-1A.

All welds shall be visually inspected by the fabricator. All welds shall meet the acceptance criteria specified in ANSI/AWS D1.1, Table 6.1, Tubular Connections (All Loads).

The arm simplex plate, pole simplex plate to gusset, gusset to pole, pole to base plate, and all sign bridge beam to pole clamp welds shall be magnetic particle tested (MT). The alternating current (a.c.) yoke method shall be performed. The yoke spacing shall be 4 inches. The yoke shall be calibrated each day in accordance with ASTM E709. Daily calibration records shall be maintained and made available for review upon request. The acceptance criteria shall be as specified in ANSI/AWS D1.1, Table 6.1, Tubular Connections (All Loads).

Structural steel shall be galvanized in accordance with ASTM A 123. Pole hardware shall be galvanized in accordance with ASTM A 153. All signs must be clean prior to erection. Installation shall be of such sequence as to result in maximum traffic safety. Signs shall be erected in conformity with the plans. Prior to final positioning, the sign shall be inspected at night by the Engineer and adjustments will be made, if necessary, to eliminate specular reflection.

Footings for ground signs and overhead sign structures shall be in accordance with the Contract. The tops of drilled caissons used for overhead sign structure footings shall be formed to at least 6 inches below ground line in accordance with Section 601.

Timber sign posts shall be set in drilled or excavated holes and tamped firm and plumb. U-2 posts and steel tubing posts may be driven plumb or set in the same manner as timber posts.

The sequence of erection of new and reset sign installations shall be correlated with the removal of the existing traffic controls. The decision regarding the sequence shall be worked out with the Engineer prior to starting the work.

Longitudinal and lateral adjustments of sign locations to fit field conditions shall be as directed.

Electrical service for all sign illumination shall consist of all the electrical circuitry necessary from the power source to the switch box at the structure. This includes

grounding, fusing, direct burial cable or conductor in conduit. Electrical service shall be 110-115 volt AC, 15 amp. fused circuit, and shall be installed underground unless otherwise shown on the plans or permitted.

Electrical work including photoelectric control, shall conform to Section 613 and to the details shown on the plans.

Mask sign legend shall consist of providing a separate removable aluminum panel at least 0.040 inches thick and of sufficient dimensions to completely mask the legend. This panel shall be furnished with reflective sheeting conforming to Section 713 and shall be the same color as the background of the sign. Panels shall be securely fastened to the main panel by mechanical means using a minimum number of fasteners. Adhesives, glues or tapes shall not be used.

Modifications shall be as follows:

(1) Steel Sign Posts. This work shall consist of providing breakaway devices as shown on the plans for existing steel posts and shall include shortening and repainting the posts.

(2) Timber Sign Posts. This work shall consist of providing breakaway devices as shown on the plans for existing 6 inch by 6 inch timber posts.

(3) Sign Legend. This work shall consist of modifying the legend on existing signs as shown on the plans and shall include all work necessary to remove and respace existing legend; to furnish and install new legend and border as required.

614.10 Traffic Signal Systems - Construction.

(a) *General.* The Contractor shall submit an "As Built" plan, showing in detail all construction changes including: wiring, cabling, locations and depth of conduit. The "As Built" plan shall include a sketch identifying the cables by numbers and a code describing the function and color of each conductor contained within the cables.

(b) *Traffic Signal Electrical Conductors and Control Cable.* All cables and conductors not shown on the plans as aerial cable or imbedded loop detector shall be installed in conduit unless installed in poles, pedestals or mast arms.

Each mast arm mounted signal face shall be wired separately back to the pole base. The signal face position farthest from the pole shall be wired from the face to the controller to accept a five-section left-turn signal face, whether such a signal face is called for or not.

Aerial cable shall be installed where specified on the plans and secured to messenger cable with rings. Self-supported cable shall not be installed unless that cable is specifically designed for this purpose. Drip loops shall be provided on all conductors where they enter pole weatherheads or signal heads.

Wiring and splices shall conform to NEC practices. Wiring within cabinets, junction boxes, etc., shall be neatly arranged and within cabinets shall be laced.

Splicing of cable will not be permitted in the conduit or outside of pull boxes, standards, or pedestals at the handhole locations.

Powdered soapstone, talc, or other approved lubricant shall be used in placing conductors in conduit.

When splices are made, soldered splices or approved solderless connectors shall be individually taped with an approved polyvinyl chloride tape with a rubber-based pressure sensitive adhesive. The outside sheath shall be replaced by a minimum of two layers of this approved tape. Shellac compounds shall not be used.

All overhead splices shall be "T-tapped" and either soldered or connected by an approved copper compression ring. If a compression ring connector is used, the ring shall be applied by a ratchet tool which will not release until the proper crimping force is applied to the connector.

All splices in detector sensing circuits shall be soldered and taped to exclude moisture.

All splices done in cables containing solid wire shall be soldered. Splices in underground systems shall be waterproofed. All underground splices shall be capable of satisfactory operation under continuous submersion in water.

Conductors between detectors and the controller cabinet shall not be contained in the same cable with any other signal control circuits but may be carried in the same duct or conduit as other signal circuits with not more than one splice in each detector sensing circuit.

At least 5 feet of slack shall be left for each conductor at each support pole and at least 3 feet of slack at each pull box containing cable connections.

A minimum of 6 inches of slack shall be left at each splice except within handholes where 12 inches shall be left.

When conductors and cables are pulled into the conduit, ends of all these conductors and cables shall be taped to exclude moisture and shall be so kept until the splices are made or terminal appliances attached. Ends of spare conductors shall be taped.

Multi-conductor cables shall be spliced and insulated to provide a watertight joint and to prevent absorption of moisture by the cable.

(c) *Bonding and Grounding.* Metallic cable sheaths, conduit, metal poles and pedestals shall be made mechanically and electrically secure to form a

continuous system and shall be effectively grounded. Bonding and grounding jumpers shall be a bare copper wire or copper strap of the same cross sectional area. Sheath for detectors shall be grounded in control cabinet only. The other end of the sheath shall be taped and left ungrounded.

A ground electrode shall be installed at each pole, pedestal, and control box. Each ground electrode shall be one-piece copper-weld rod of $^{5}/_{8}$ inch diameter and 8 feet in length, driven to a depth of at least 8 feet below the surface of the ground.

Bonding of poles and pedestals shall be by means of connecting to the ground rod a bonding strap attached to an anchor bolt or a $^{3}/_{16}$ inch diameter or larger brass or bronze bolt installed in the lower portion of the shaft.

(d) *Excavation and Backfilling.* Excavation and backfilling shall be performed in accordance with the requirements of Section 206 and to the following:

All excavation and backfilling shall be made before other improvements are completed so as to not require the repair or replacement of new sidewalks, pavement or landscaping.

Excavation for the installation of conduit, foundations and other appurtenances shall be performed in such a manner as to cause the least possible damage to the streets, sidewalks, landscaping and other improvements. The trenches shall not be excavated wider than necessary for the proper installation of the electrical appurtenances and foundations. Excavation shall not be performed until immediately before installation of conduit and other appurtenances. The material from the excavation shall be placed in a position that will not cause damage or obstruction to vehicular and pedestrian traffic or interfere with surface drainage.

Excavations, after backfilling, shall be kept well filled and maintained in a smooth and well drained condition until permanent repairs are made.

Excavations in the street or highway shall be performed in such a manner that not more than one lane of traffic in each direction is restricted at any time unless otherwise approved by the Engineer or in the special provisions.

Improvements such as sidewalks, curbs, gutters, portland cement concrete and asphalt concrete pavement, underlying material, lawns and plants, and any other improvements removed, broken or damaged by the Contractor's operations, shall be replaced or reconstructed at the Contractor's expense with the same kind of material as found on the work or with materials of equal quality.

(e) *Foundations.* All foundations shall be portland cement concrete conforming to the applicable requirements of Section 601.

The bottom of concrete foundations shall rest on firm ground. Foundations shall be poured monolithically where practicable. For poles and pedestals the top 2 inches

shall be poured after the pole or pedestal is in proper position. The exposed portions shall be formed to present a neat appearance.

Forms shall be true to line and grade. Tops of foundations except as noted on the plans, shall be finished to curb or sidewalk grade or as ordered. Forms shall be rigid and securely braced in place. Conduit ends and anchor bolts shall be placed in proper position and to proper height and shall be held in place by means of a template until the concrete sets.

Both forms and ground which will be in contact with the concrete shall be thoroughly moistened before placing concrete.

Where obstructions prevent construction of a planned foundation, the Contractor shall construct an effective foundation as directed.

Strain and mast arm poles shall be installed with the proper rake as recommended by the manufacturer of the poles so as to assure a substantially vertical set when the specified signal and lighting equipment is installed,

(f) *Loop Detector Installation.* Loop detectors shall be installed in the configuration shown on the plans, A complete installation consists of a conductor loop or group of loops installed in a saw cut in the roadway, lead-in cable and a sensor unit with power supply installed in a traffic signal controller cabinet.

The saw cut shall be made $^{3}/_{8}$ inch wide and a minimum of 3 inches deep. The slot shall be as straight as possible and shall not vary more than ½ inch when checked with a 10 foot straightedge.

Saw cuts shall be hydroblasted with a mixture of water and air and then blown free of water and debris with compressed air only. The cuts shall be as dry as possible prior to placement of wire. All corners shall be rounded to full depth as directed to prevent angle bends in the loop wire.

After saw cut is cleaned of debris, the wire shall be placed for the loop by pushing it into the slot with a blunt non-metallic object. A screwdriver or other sharp tool shall not be used. Care shall be used to avoid abrading or damaging the insulation.

After the loops are properly seated and tested for continuity and proper loop inductance, the slots shall be filled with an approved two-part self curing, self bonding weatherproof epoxy, or an approved alternative material.

One continuous length of wire shall be used for each loop from the signal base or pull box around the loop with the specified number of turns and back to the signal base or pull box. Detector lead-in pairs shall be symmetrically twisted, five turns per 1 foot.

Two inch conduit shall be placed under the curb and into a signal base or pull box

to accommodate detector loop wires. Conduit may be "pushed" or trench-laid, depending on conditions at project site and upon approval from the Engineer.

Conductors of all loops to be operated by each sensor unit shall be run continuously to the nearest signal base or pull box. The loops shall be joined in the signal base or pull box in combination of series and parallel as shown on the plans so that optimum sensitivity is obtained at the sensor unit. Final splices between loops and lead-in cable shall not be made until the operation of the loops under actual traffic conditions is approved by the Engineer.

The loop detector wires shall be spliced to the shielded lead-in cable in the signal base or pull box and then pulled into the controller cabinet via the shortest possible distance using other existing conduit or messenger cable. A minimum of 3 feet of slack shall be provided in the controller cabinet for attachment to the detector amplifier. Each detector cable shall be clearly labeled in the control cabinet identifying phase relationship and approach leg.

(g) *Magnetic Detector Installation.* Magnetic detector sensing elements shall be installed within 3 inch, UL approved, Schedule 40 PVC conduit, as directed.

Conduit shall extend across the traveled way as shown on the plans. Bottom of conduit shall be placed 12 inches below top of pavement.

(h) *Painting.* All paint shall conform to Section 708. The painting of all electrical equipment requiring paint shall be done in accordance with Section 509.

The painting of all electrical equipment specified to be painted may be required at any time as directed. All metal parts of poles, pedestals, standards, and fittings shall be cleaned of all rust, scale, grease, and dirt prior to applying paint.

If an approved prime coat has been applied by the manufacturer and it is in good condition, an application of primer by the Contractor other than for repairs, will not be required.

All exterior surfaces shall be examined for damaged paint and all such damage shall be given a spot coat of primer and the entire exterior surface repainted. Factory finish on new equipment will be acceptable if of proper color and if equal in quality to the specified finish.

Paint shall not be applied to aluminum controller cabinets or to aluminum or galvanized poles, pedestals, standards, hardware, conduit, etc. unless specified. All steel poles shall be painted aluminum, unless otherwise shown on the plans. Controller cabinets (including inside door surface) shall be wire brushed or sanded to reduce reflectivity.

All paint coats may be applied either by hand brushing or by approved spraying machine in the hands of skilled operators. The work shall be done in a neat and

workmanlike manner. The Engineer reserves the right to require the use of brushes for the application of paint should the work done by the paint-spraying machine prove unsatisfactory or objectionable as determined by the Engineer.

Conduit and conduit fittings above ground shall be given one coat of primer and one coat of enamel conforming to the color of the adjacent standard or pedestal.

(i) *Maintaining Existing and Temporary Electrical Systems.* The existing traffic signals shall be kept in effective operation for the benefit of the traveling public.

Where power to all signals must be turned off, the Contractor shall provide an off duty police officer or other qualified person to direct traffic during the period the signals are off.

The local traffic enforcement agency shall be notified prior to any operational shutdown of a traffic signal.

The above does not apply to intersections which are completely closed to all traffic due to construction.

The Contractor shall maintain at all times a minimum of two, three-section (red, yellow, green) traffic signal heads for each approach. In the event that temporary signals are necessary to maintain the minimum signal display, the Contractor shall be responsible for furnishing all materials, equipment, tools, and labor necessary to install and maintain the temporary signals.

The State or local agency will continue operation and maintenance of existing electrical facilities. The State or local agency will furnish electrical energy for operation and will repair or replace facilities damaged by public traffic.

Where damage is caused by the Contractor's operations, the Contractor shall, at his expense, repair or replace damaged facilities promptly in accordance with these specifications.

Signal faces which are installed prior to turning on shall be covered or directed away from traffic to clearly indicate that the signal is not in operation.

(j) *Field Tests and Turn On.* Prior to completion of the work, the Contractor shall make the following tests on all traffic signal circuits in the presence of the Engineer:

1. Each circuit shall be tested for continuity.
2. Each circuit shall be tested for grounds.
3. An insulation resistance test shall be made on each circuit between the circuit and a ground. The insulation resistance shall not be less than the values specified in the provisions of the NEC.
4. A functional test shall be made in which it is demonstrated that each and every part of the system functions as specified or intended herein. The

functional test for each traffic signal system shall consist of not less than five days of continuous satisfactory operation. If unsatisfactory performance of the system develops, the condition shall be corrected and the test shall be repeated until the five days of continuous, satisfactory operation is obtained.

Functional tests shall start on any working day except Friday, or the day preceding a legal holiday.

Turn on of new or modified signal systems shall be made only after all traffic signal circuits have been thoroughly tested as specified.

The initial turn-on shall be made between 9:00 A.M. and 2:00 P.M. unless specified otherwise. Prior to turn-on, all equipment as shown on the plans shall be installed and operable. This includes pedestrian signals, pedestrian push buttons and vehicle detectors.

All louvers, hoods and signal heads shall be directed to provide maximum visibility.

During the test period, the State or local agency will provide the electrical energy and repair any damage caused by public traffic. All other maintenance will be the responsibility of the Contractor.

All systems shall be complete and in operation to the satisfaction of the Engineer.

614.11 Barricades. Construction shall conform to the requirements of Section 508.

614.12 Rumble Strips. Rumble strips shall conform to the details and locations shown on the plans.

METHOD OF MEASUREMENT

614.13 Overhead sign structures (Sign Bridge Structures, Butterfly Structures, Sign Bridge Cantilever Structures and Cantilever Structures) will be measured by the number of units of the various types and sizes installed and shall include structural frame members, mounting brackets, posts, excavation and backfill, and when called for on the plans, safety walkways and light fixtures including all electrical equipment as required. Drilled caissons used for overhead sign structure footings will be measured and paid for in accordance with Section 503.

Installing only of sign structures will be measured by the number of units installed and shall include all hauling, concrete footings, removing existing sign panels, respacing and adding walkway brackets, adding walkways, repainting, excavation and backfill and furnishing and installing light fixtures including all electrical equipment as required.

Overpass mounted sign brackets will be measured by the number furnished and installed and shall include all structural members required to install sign panels on overpass structures as shown on the plans and all light fixtures including all electrical

equipment as required. Sign panels shall be furnished and installed under the appropriate item.

Ground signs will be measured as follows: Concrete footings by the number used, sign posts by the length in linear feet of the various types used, and sign panels by the square feet of facing. For signs other than rectangular or triangular shape, the area in square feet will be computed from dimensions of the smallest rectangular shape from which a panel can be fabricated. Sign panels shall include all mounting and backing angles required.

Mask sign legend will be measured by the actual number of signs masked and shall include panel, reflective sheeting, and fastening the panel to the sign.

Steel sign post extensions, if required, will be measured and paid for as "Steel Sign Post" of the type shown on the plans.

Sign panels shall include background, message, backing zees (Classes 2 and 3), date of manufacture, and all necessary hardware.

Multi-directional break-away assemblies will not be measured and paid for separately, but will be paid for under the appropriate item: e.g., all brackets, nuts, bolts, shims, hinge plates, and couplings will be paid for as Steel Sign Post of the appropriate size; anchors and concrete footings will be paid for as Concrete Footing of the appropriate size.

Light fixtures shall include lamps, switch boxes, photoelectric controls, electrical conduit, electrical conduit in foundations, and all necessary wiring in the structure only.

Illuminated signs will be measured by the actual number installed including switch box, footing, electrical conduit in the footing, post, and shall also include the wiring from the light to the switch box.

Barricades will be measured by the number used.

Flashing beacon will be measured as a unit complete in place (including sign panel) and shall include all work necessary to complete the item.

Traffic signal poles shall include mast arms and all necessary hardware required to complete the item in place. Drilled caissons used as foundations for traffic signal poles will be measured and paid for in accordance with Section 503.

Cabinets shall include pedestals and concrete foundations as required.

Span wire poles shall include span wire cable, jaw deadends, cable rings, concrete footings and all necessary hardware. Pole height shall be as indicated on the plans.

Traffic signal controllers (Type 170E) shall include the cabinet, pedestrian detectors, and all auxiliary equipment required on the plans and shall include all work necessary to provide and install a complete system.

Loop detector wire will be measured by the linear foot and shall include loop wire, pavement sawing, slot sealant, lead-in conduit as shown on the plans, excavation, backfill and all other work necessary to complete the item.

Traffic signal magnetic detectors shall include all shielded lead-in wire and non-metallic conduit housing and all wiring necessary for the operation of the system.

Traffic signal loop detector amplifiers will be measured by the number of two channel units or four channel units and shall include all incidental materials and wiring necessary for the operation of the item.

All costs for making electrical service connections from the power source to the service switch will be paid for in accordance with subsection 109.04.

Rumble strips will be measured by the actual number of linear feet that are placed and accepted adjacent to or on the roadway surface, excluding gaps. Measurement of length for payment will be parallel to the roadway centerline or shoulder stripe.

BASIS OF PAYMENT

614.14 The accepted quantities will be paid for at the contract price per unit of measurement for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	**Pay Unit**
Sign Bridge Structure (_____) (size)	Each
Sign Bridge Structure (Install Only)	Each
Sign Bridge-Cantilever Structure (_____) (size)	Each
Cantilever Structure (_____) (size)	Each
Overpass Mounted Sign Bracket	Each
Concrete Footing (_____)	Each
Steel Sign Post (_____)	Linear Foot
Timber Sign Post (_____)	Linear Foot
Sign Panel (Class)	Square Foot
Mask Sign Legend	Each
Illuminated Sign	Each
Barricade (Type _____)	Each
Flashing Beacon	Each
Modification of Steel Sign Post	Each
Modification of Timber Sign Post	Each
Modification of Sign Legend	Each, Lump Sum
Pedestrian Signal Face (Type_____) (Furnish Only) (Install Only)	Each
Traffic Signal Face (Type_____) (Furnish Only) (Install Only)	Each

Pay Item (continued)	Pay Unit (continued)
Traffic Signal Controller Cabinet (Furnish Only) (Install Only)	Each
Traffic Signal Controller (Type_____) (Furnish Only) (Install Only)	Each
Loop Detector Wire (Furnish Only) (Install Only)	Linear Foot
Traffic Signal Vehicle Detector Amplifier (Type_____) (Furnish Only) (Install Only)	Each
Traffic Signal Vehicle Detector (Type_____) (Furnish Only) (Install Only)	Each
Traffic Signal-Light Pole (Type_____) (Furnish Only)(Install Only)	Each
Traffic Signal Pole (Type_____) (Furnish Only) (Install Only)	Each
Traffic Signal Pedestal Pole (Type_____) (Furnish Only) (Install Only)	Each
Traffic Signal Span Wire Pole (Type_____) (Furnish Only) (Install Only)	Each
Rumble Strip	Linear Foot

The traffic signal component item will be Furnish and Install unless the Summary of Approximate Quantities indicates whether it is to be (Furnish Only) or (Install Only) as appropriate.

The LED optical units will not be paid for separately but shall be included in the cost of the Traffic Signal Face. The pedestrian LED optical units will not be paid for separately but shall be included in the cost of the Pedestrian Signal Face.

SECTION 615
WATER CONTROL DEVICES

DESCRIPTION

615.01 This work consists of the construction of water and erosion control devices in accordance with these specifications, details shown on the plans and to the lines and grades established.

MATERIALS

615.02 Slide headgates and automatic drain gates shall be of the sizes designated and shall be approved by the Engineer.

Parshall measuring flumes including wings shall be made of galvanized sheet steel material. Galvanize coating shall be "light commercial" minimum. Thickness of material and fabrication method shall be as approved. Measuring flumes shall have reinforced edges and an inlet throat of the dimensions designated on the plans.

Embankment protectors shall be made from material conforming to the applicable sections of these specifications.

CONSTRUCTION REQUIREMENTS

615.03 Construction methods shall conform to the requirements of Section 603.

METHOD OF MEASUREMENT

615.04 Automatic drain gates, Parshall measuring flumes and embankment protectors will be measured by the number of units of the various sizes installed. Slide headgates will be measured by the number of units of the various sizes and frame heights installed.

BASIS OF PAYMENT

615.05 The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	**Pay Unit**
_____Inch Slide Headgate (_____Foot Frame)	Each
_____Inch Automatic Drain Gate	Each
_____Inch x _____Inch Parshall Measuring Flume	Each
Embankment Protector (Type_____)	Each

Pipe, concrete, or other material used with any of the above items will be bid under the appropriate Section.

SECTION 616
SIPHONS

DESCRIPTION

616.01 This work consists of the construction of invert siphons in accordance with these specifications and in conformity with the lines, grades and details shown on the plans or established.

MATERIALS

616.02 Concrete Pipe. Concrete pipe shall conform to the requirements of subsection 706.02 except that pipe and gaskets shall be of a type that will insure a watertight structure. Joints shall be self-centering. Gaskets shall meet the requirements of subsection 705.03.

616.03 Trash Guards. Steel shall conform to the requirements of subsection 712.06 and to the details shown on the plans. Trash guards shall be given one shop coat of primer and two field coats of aluminum paint in conformity with Section 509.

616.04 Drain Valves and Valve Boxes. Drain valves shall be gate type with flanged iron body, brass trim and brass fittings. Size will be as designated on the plans.

Valve boxes shall be the adjustable cast iron type with a 5½ inch minimum inside diameter. Drain valves and valve boxes shall be approved prior to use.

616.05 Drain Pipe. Pipe for the drain shall conform to Section 605. Concrete shall conform to Section 601 and reinforcing steel to Section 602.

The pipe attached to the siphon and leading to the drain valve may be non-perforated corrugated steel pipe conforming to AASHTO M 36 or of standard galvanized pipe conforming to the requirements of ASTM A 53 (Schedule 40). This pipe, when attached to steel siphon pipe, shall be bituminous dipped along with the siphon pipe. Flanges for attaching the drain valve may be galvanized or asphalt dipped.

Any damaged spelter shall be repaired in accordance with subsection 707.09 both inside and outside the pipe.

CONSTRUCTION REQUIREMENTS

616.06 Siphon pipe including drains shall be installed in accordance with the requirements of Section 603. Siphons shall show no leakage when filled with water and allowed to stand full for 24 hours. This test shall be performed before backfilling.

METHOD OF MEASUREMENT

616.07 Siphon pipe, of the designated type, will not be measured but will be the net length of pipe called for on the plans, except when field changes are ordered or when there are errors on the plans. In case of exceptions, the quantity to be measured shall

be the actual net length of conduit measured along the bottom centerline of the installed pipe. Trash guards, drain valves and valve boxes will be measured by the number installed and accepted. Drain pipe will be measured and paid for in accordance with Section 605. Concrete will be measured and paid for in accordance with Section 601. Reinforcing steel will be measured and paid for in accordance with Section 602. Structure excavation and structure backfill will be measured and paid for in accordance with Section 206.

Drain valves shall include the pipe for connecting the valve to the siphon, together with all necessary fittings and gaskets used therewith.

BASIS OF PAYMENT

616.08 The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
_____Inch Concrete Siphon Pipe	Linear Foot
_____Inch Trash Guard	Each
_____Inch Valve and Valve Box	Each

SECTION 617
CULVERT PIPE

DESCRIPTION

617.01 This work consists of furnishing and installing culvert pipe in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

617.02 Materials shall meet the requirements shown on the plans and specified in the following subsections for the type of culvert pipe furnished.

Corrugated Steel Pipe and Pipe Arches	707.02
Corrugated Aluminum Pipe	707.06
Reinforced Concrete Pipe	706.02
Plastic Pipe	712.13
Gaskets	705.03
Pipe Joint Sealing Compounds	705.04

Any type of culvert pipe meeting the above specifications may be used. The Contractor shall state, at the preconstruction conference, the type of culvert pipe to be furnished.

Plastic end sections shall not be used. When plastic pipe is to be installed with end sections, steel end sections conforming to Standard Plan M-603-10 shall be used.

CONSTRUCTION REQUIREMENTS

617.03 Installation shall conform to the requirements of Section 603.

METHOD OF MEASUREMENT

617.04 Culvert pipe will not be measured but will be the net length of pipe called for on the plans, except when field changes are ordered or when there are errors on the plans. In case of exceptions, the quantity to be measured shall be the actual net length of conduit measured along the bottom centerline of the installed pipe. The net length shall include end sections when required.

BASIS OF PAYMENT

617.05 The accepted quantities of culvert pipe will be paid for at the contract unit price per linear foot for the specified size.

Payment will be made under:

Pay Item	**Pay Unit**
_____Inch Culvert Pipe	Linear Foot

Structure excavation and structure backfill will be measured and paid for in accordance with Section 206.

SECTION 618
PRESTRESSED CONCRETE

DESCRIPTION

618.01 This work consists of fabricating, furnishing and installing prestressed concrete members in accordance with the requirements of the Contract.

This work includes the furnishing and installation of all appurtenant items necessary for the particular prestressing systems to be used, including but not limited to ducts, anchorage assemblies and grout used for pressure grouting ducts.

For cast-in-place prestressed concrete, the term "member" as used herein shall be considered to mean the concrete which is to be prestressed.

The term "tendon" as referenced herein shall be considered to mean the prestressing steel within a duct.

MATERIALS

618.02 Materials shall conform to the following:

Anchorage devices shall meet the requirements of subsection 714.02. Prestressing steel shall meet the requirements of subsection 714.01.

Elastomeric bearing pads shall meet the requirements of subsection 512.

All reinforcing and embedment item supports, bolsters, chairs, and spacers shall be CDOT approved. These items shall be plastic, rubber, or epoxy coated at all areas that will contact external concrete surfaces, unless otherwise shown on the plans.

(a) *Grout for Post-tensioned Ducts.*

1. Portland Cement. Portland cement shall conform to subsection 701.01. Cement used for grouting shall be fresh and shall not contain any lumps or other indication of hydration or "pack set."

2. Water. The water used in the grout shall conform to subsection 712.01.

3. Admixtures. An expansive admixture, approved by the Engineer, shall be used.

   Admixtures containing chlorides in excess of 0.005 percent by weight of admixture, fluorides, sulfites or nitrates shall not be used.

   Chemical admixtures shall conform to the requirements of subsection 711.03. Admixtures shall be used in accordance with the manufacturer's recommendations for proportioning and construction requirements.

(b) *Steel and Metal for Prestress Members.* All steel and metal products incorporated into the work shall meet the requirements of Section 106. The Contractor shall keep Certified Mill Test Reports (CMTR's) on file for all steel and metal products used, and shall furnish copies of CMTR's when requested.

Galvanizing and metallizing of steel products shall be done in accordance with the product applicable ASTM method. The product shall be galvanized after welding and fabrication is complete. Minor repair of galvanizing shall be brush coated with an approved zinc-rich compound that is acceptable to the QA Representative.

Materials and fabrication procedures shall conform to ASTM or ANSI / AWS requirements. The materials and work shall conform to the following requirements and specifications, unless otherwise indicated in the Contract.

1. Reinforcing Bars. All reinforcing bar material shall be Grade 60 minimum and shall conform to ASTM A 615, or ASTM A 706; epoxy coated bars shall also meet ASTM D 3963. Reinforcing bars that require welding shall conform to ASTM A 706. Welding of A 706 bars shall be done in accordance with ANSI /AWS D.1.4.

2. Welded Wire Fabric. Steel welded wire fabric for concrete reinforcement shall conform to ASTM A 185, or ASTM A 497.

3. Plate Steel. All plate steel shall conform to ASTM A 709 Grade 36 specifications. Fabrication and welding of plate steel products shall be done according to ANSI / AWS D.1.1.

4. Steel and metal products shall be free of loose rust and foreign substances before incorporation into the cast product.

(c) *Concrete for Pretensioned and Combination Tensioned Products.* Materials for Concrete class PS shall meet the requirements specified in the following subsections:

Portland Cement	701.01
Fly Ash	701.02
Fine Aggregate	703.01
Coarse Aggregate	703.02
Curing Materials	711.01
Air Entraining Admixtures	711.02
Chemical Admixtures	711.03
Water	712.01

(d) *Concrete and Steel for Other Members.* Concrete for other members shall conform to the requirements of Section 601 and the plans. Reinforcing steel for other members shall conform to the requirements of Section 602.

CONSTRUCTION REQUIREMENTS

618.03 Prestressed Members. Members may be pretensioned, post-tensioned, or a combination of pretensioned and post-tensioned. Members shall be fabricated and finished as shown in the Contract.

Minimum cover for prestressing steel shall be 1½ inches, unless otherwise shown in the Contract. Minimum clearance for reinforcing steel shall be 1 inch unless otherwise shown in the Contract.

If the plans show only pretensioning details, use of a post-tensioning system will be allowed only if complete details of all necessary modifications are approved by the Engineer.

Cast-in-place members shall be post-tensioned unless otherwise shown on the plans. All falsework for cast-in-place members shall remain in place until all post-tensioning and grouting has been completed and accepted by the Engineer.

618.04 Shop Drawings.

(a) *General.* The Contractor shall furnish shop drawings in conformity with subsection 105.02 for all prestressed components. When the Contractor's Engineer completes or revises design details or engineering drawings, then those engineering drawings and details that are submitted to the Engineer shall contain the endorsement seal of a Professional Engineer registered in the State of Colorado. CDOT review of the shop drawings does not relieve the Contractor of the responsibility for the adequacy of the prestressed members. Minor changes to design details or engineering drawings that do not represent a significant change to the original design will not require a Professional Engineer seal. The Contractor shall submit supporting calculations for these changes along with the shop drawings

(b) *Pretensioned and Combination Tensioned Members.* The shop drawings shall include the following:

(1) All unit dimensions.
(2) Location and arrangement of prestressing strands.
(3) Initial and final jacking forces.
(4) Location, description, and detail of structural reinforcing items, excluding minor items used for field erection.
(5) Location of all hold-down devices.
(6) Location and description of all plates.
(7) Provisions for diaphragm connections.
(8) Blockout and keyway dimensions, if any.
(9) Location and detail of debonded strands.

(c) *Post-tensioned Members.* The shop drawings for post-tensioned members shall show the following:

(1) Strand and bar properties, including material type, modulus of elasticity, ultimate strength, diameter, and cross-sectional area assumed in the design.
(2) Duct properties, including material type, and minimum inside and maximum outside diameters, and friction coefficients of the duct-strand system if different from shown on the plans.
(3) The position and profile of the ducts and tendons along the length of the member. Each duct position shall be defined at tenth points along the length of the member. The minimum clearance from the edge of concrete to the edge of a duct shall be shown.
(4) The maximum offset between the center of the duct and the center of force in the duct for each unique strand and bar and duct combination. The resultant force of all permanent tendons in the member shall match the profile indicated on the plans.
(5) The initial and final force at each anchorage. The initial force is defined as the largest force at each anchorage before anchor set. The final force is defined as the residual force remaining after anchor set and long term losses.
(6) Complete dimensions and properties necessary to fabricate and install each unique anchorage device, including the type of materials, yield strengths, distribution plates, wedges, trumpets, anchorage blocks, and other appurtenant items. Adjacent reinforcement shall be detailed showing how it will coordinate with the anchorage device and its reinforcement.
(7) The dimensions and properties necessary to fabricate and install the bursting, splitting, and other reinforcement required by the prestressing system, as shown on the plans or as proposed by the Contractor. Included shall be cross-sectional areas, yield strength, the location of the reinforcement, and the diameter and pitch of the spirals. If no additional bursting steel is required, it shall be so stated on the shop drawings.
(8) The minimum length of strand or bar projection at the live ends and accessible dead ends.
(9) The preload force for each unique tendon. The preload force is defined as 20 percent of the jacking force.
(10) The required total jacking force for each unique tendon.
(11) The total final elongation, after dead and live end anchor sets, and the measurable elongation for each tendon. The measurable elongation is defined as the total elongation at the live end after preload while the stressing equipment is tensioning the tendon to the total jacking force. The tendon length used for calculations shall include the full length of strand that is being stressed.
(12) The sequence of stressing.
(13) Blockout or buildout concrete dimensions and reinforcement details.
(14) If the Contractor elects to submit an alternative system, as defined in subsection 618.07(c), the Contractor shall also provide the following, as appropriate.

If the anchorage device will differ from what is shown on the plans, the Contractor shall submit calculations or manufacturer test certification

consistent with the Contract. The calculations shall show the complete design of the anchorage device, including splitting steel, bursting reinforcement, the distribution plate, and the bearing stresses transmitted to the concrete by the anchorage device. The manufacturer's test certification shall certify the adequacy of the anchorage device. The shop drawings shall reflect the anchorage device design.

If the flare of the tendons is different from what is shown on the plans, the Contractor shall submit design and details of appropriate reinforcement and concrete dimensions to accommodate the flare.

Along with the shop drawing details, six copies of computations for friction losses, calculated measurable elongations, the maximum offset between the center of force and center of duct for each unique tendon, and the stressing sequence shall be submitted for review. The friction losses shall be determined in accordance with the plans and as provided for in the AASHTO *Standard Specifications for Highway Bridges*.

618.05 Notification of Fabrication for Pretensioned and Combination Tensioned Members.

(a) *Start of Work.* Prior to beginning the work, the Contractor shall provide written notice to the Engineer and the Quality Assurance (QA) Representative, as defined in subsection 618.06(a), so that QA services may be provided. The written notice shall be received at least seven days before fabrication begins.

The anticipated production schedule, including the start of work, phase work and shipment dates shall be submitted in writing to the QA Representative before any work begins. Fabrication shall not be started until the shop drawings have been returned with the Engineer's review stamp, indicating Reviewed, no exception taken; or Reviewed, revise as noted; or Resubmit, revise as noted in accordance with subsection 105.02, and delivered to the Contractor's site of fabrication.

(b) *Production Schedule Changes.* Accelerated changes to the proposed production schedule, including start of work, phase work, and shipment dates, shall require advance written notification be provided to the Engineer and the QA Representative. The written notice of change shall be received at least 48 hours before fabrication begins, unless otherwise approved in writing by the Engineer or the QA Representative.

(c) *Notice of Shipment.* The QA Representative shall be notified in writing, at least 72 hours before shipment of prestressed members to the job site.

(d) *Notification.* Failure to notify the Engineer or the designated QA Representative as described in this section may be cause for rejection.

618.06 Inspection of Pretensioned and Combination Tensioned Members.

(a) *Quality Control and Quality Assurance*. Quality Control (QC) of prestressed

concrete fabrication is the responsibility of the Contractor. The Contractor shall designate a QC Manager who shall be responsible for product quality requirements as defined in the specifications and the Contractor's approved QC plan (QCP). The QC Manager shall possess and maintain certification at Level II minimum, from the Prestressed Concrete Institute (PCI), and shall have one year minimum of construction related experience. The QC Manager shall not be supervised by the Contractor's production section.

Quality Assurance and product acceptance are the prerogatives of the Engineer. The QA Representative acts for and in behalf of the Engineer on all matters within the scope of the contract documents, as delegated by the Engineer. QA administration will be performed to the extent necessary to assure contract compliance.

Repeated out of tolerance work, including dimensional non-conformance, shall be considered as recurring deficiencies. Recurring deficiencies shall be considered as evidence that required QC is not being provided. When the QA Representative determines that fabrication operations are producing recurring defects that do not conform to the Contract and the QCP requirements, the Contractor will be notified that the present work is unacceptable. Work shall not continue until the QC Manager has submitted a written proposal addressing corrective procedures that the Contractor will take to prevent recurrence of the non-conforming work. Fabrication shall not resume until the proposal has been reviewed and accepted in writing by the QA Representative.

(b) *Quality Control Plan (QCP)*. The Contractor shall submit a written QCP to the QA Representative prior to the beginning of fabrication. The QCP shall be reviewed and approved in writing by the Contractor's QC Manager. The QCP shall list all methods utilized by the Contractor to ensure that the work conforms to contract requirements. The QC section is responsible for establishing the QCP, as well as conformance to the QCP. Fabrication shall not begin until the QCP has been reviewed and accepted in writing by the QA Representative.

If work methods for a specific project or product are not listed in the original QCP, the Contractor shall submit written addenda addressing the proposed methods that are necessary to meet contract requirements. Fabrication shall not begin until the addenda have been reviewed and accepted in writing by the QA Representative.

The QCP shall address the following:

(1) Names and qualifications of the QC Manager and personnel conducting inspection and testing. This list shall be updated when changes in personnel occur.
(2) List of material suppliers and certified testing agencies used; the list shall be updated when vendors change.
(3) Materials sampling and testing schedule, showing testing methods and frequencies.

(4) QC inspection methods and procedures for all stages of fabrication operations.
(5) Methods for curing products and test specimens.
(6) Method and sequence for tensioning strands, including methods used for verifying equal distribution of jacking forces.
(7) Method and sequence of detensioning strands.
(8) Written report format for materials sampling, testing, and inspection for all phases of the work.
(9) Copies of all concrete mix designs to be used, including mix design computations and test data.
(10) Provisions for fabrication operations during cold, windy, or hot weather conditions.
(11) Procedures for patching small production holes and holes left by strand hold-down devices.
(12) Procedures for identifying, evaluating and reporting defects, including dimensional non-conformance, discovered during QC/QA inspections and testing.
(13) Procedures for notifying the QA Representative of structural defects, and submittal of written proposal for repairs.

(c) *Frequency.* QC inspection and testing at all intervals of forming, tensioning, steel and concrete placement, curing, and storage operations shall be performed in accordance with the accepted QCP. The QCP shall contain provisions for increased frequencies of inspection and testing when operations or products do not conform to the Contract.

(d) *Written Records and Reports*. The QC Manager shall review and submit the following completed records and reports to the QA Representative before the product receives acceptance by the QC section:

1. Prestressing Steel - Tensioning reports for each setup, showing the jacking force calculations; initial and final jacking force used; calculated and final net measured elongation; applicable stressing corrections for seating, slippage, shortening, rotation movement, and temperature; Certified Mill Test Reports for prestressing steel used.

2. Concrete - A daily report of each mix design used, showing the fresh concrete slump, temperature, unit weight, and air content (if specified). The daily report shall also include the following data:
   (1) date and time of casting
   (2) bed and setup location
   (3) ambient conditions
   (4) total cubic yards placed
   (5) girder mark and unique sub-mark identifications
   (6) actual product curing temperature charts or graphs
   (7) actual curing enclosure humidity charts or graphs
   (8) average release strength in psi

(9) date and time of release strength
(10) copies of individual batch tickets when requested by the QA Representative

3. Pre-pour Inspection Records shall include the items to be checked as listed in the QCP.

4. Post-pour Inspection Records shall include the items to be checked as listed in the QCP. These records shall include all discovered variances from product dimensional tolerances.

5. Report of minor repairs made to each individual product.

6. The following written records shall be submitted to the QA Representative before product shipment:

   (1) Elastomeric Bearing Pads - Product manufacturer's certification and supplier's letter of compliance.

   (2) Length measurement of beams within three days prior to shipping.

   (3) Product camber measurement within seven days prior to shipping.

7. Steel and Metal. For reinforcing bars, welded wire fabric, plate steel, and miscellaneous steel and metal products incorporated into the work, QC Manager shall review and maintain all certified mill test reports (CMTRs). QC Manager shall certify in writing that all steel and metal products comply with the Contract. When requested, QC Manager shall furnish copies of CMTRs to the QA Representative.

618.07 Fabrication.

(a) *Pretensioning - General.* Prestressing shall be done with calibrated jacking equipment that conforms to the requirements of subsection 618.10. Strands shall be tensioned in accordance with the approved sequence as indicated in the QCP. All indicating dials shall be at least 6 inches in diameter; calibrated digital display equipment is also acceptable.

The stressing sheet shall show the measurements, factors and computations for tension and elongation, including all stressing corrections; if these factors are not shown on the stressing sheet, they must be submitted with the shop drawing and calculation index. The applicable stressing corrections shall be applied at the time of final stressing. Before using any stressing correction for friction, the need for corrections shall be proven by load cell or dynamometer checks at both ends of the setup. Temporary overstressing shall not exceed 80 percent of the minimum ultimate tensile strength of the prestressing steel. Tensioned strands shall not be seated during temporary overstressing.

Tensioned strands shall maintain vertical and horizontal position, within allowable tolerances, as specified in subsection 618.14(b), throughout the entire length of the member; intermediate strand supports shall be used if the tolerances cannot be maintained. Tensioned strands shall not be entangled or intertwined with other strands, except for draped strands in the bundled area between hold down devices.

A QC employee shall witness and verify final tensioning operations and record the jacking forces and the net measured elongations. Jacking force shall be recorded to the nearest 100 pound increment used. Net elongation shall be measured to the nearest $^{1}/_{8}$ inch. Tensioning operations shall also meet the following requirements:

1. Initial tensioning shall not exceed 20 percent of the jacking force.

2. Tension load readings shall be taken from pressure gages, dynamometers or load cells. If pressure gages or dynamometers are used, the applied load shall register between 20 and 80 percent of the total reading capacity of the system. If load cells are used, the applied load shall register between 10 and 90 percent of the total load cell capacity. If a master gage system is used, a current certified calibrated graph or table correlating actual loads with the master gage readings, shall be given to the QA Representative.

3. The jacking force applied shall be within plus or minus 5 percent of the design jacking force. The net measured elongation shall be within plus or minus 5 percent of the calculated elongation; if net measured elongation is not within tolerance, the strand shall be stressed from both ends. The algebraic comparison of the variation between the jacking force and the net measured elongation shall agree within plus or minus 7 percent. If these three tolerances are not achieved, tensioning operations shall cease; all stressing deficiencies shall be corrected before regular tensioning operations resume.

4. If any wire in a 7-wire strand breaks, that strand shall be removed and replaced.

5. Strand or spliced strand that exhibits unraveling after stressing, shall be removed and replaced with a sound strand. Strand splices shall not fall within the member to be cast.

6. Strands that have received final tension shall be protected from temperature fluctuations greater than 40 °F until the time of concrete placement. The Contractor may apply stress corrections at the rate of 1 percent per 11 °F, for temperature variation between final tensioning and concrete placement. This requirement does not apply to self-stressing bed setups. The total stressing force applied shall not exceed 80 percent of the minimum ultimate tensile strength of the prestressing steel.

7. Tensioned prestressing steel shall be free from dirt, mud, ice, snow build up, oil, grease, paint, loose rust, and all other bond inhibiting substances prior to concrete placement. Visibly pitted strand shall not be used.

8. Draped Strand - Final stressing shall be accomplished by any of the methods described below:

   A. Jacking in Draped Position. Final stressing shall begin at one end of the bed. Strands that do not meet the tension vs. elongation tolerances shall be jacked from the other end so that all tolerances are achieved. If all draped strands conform to tolerances after jacking at one end, the jacking force shall be verified on at least two strands at the opposite end.

   B. Partial Stressing and Subsequent Strain. Initial and partial stress may be induced from either end of the bed. Final stress shall be attained by lifting or depressing the strands to the design location. Final stress and strain shall be applied in such a manner that uniform distribution of jacking force is attained throughout the bed setup and, all tension vs. elongation tolerances have been achieved. The distribution of force shall be verified on at least two strands at the opposite end.

   C. Stage Tensioning. Initial tensioning shall be done from one end. Partial tensioning may then be performed from either end. When final stressing is completed, the sum of the partial elongations shall be used to verify that all tension vs. elongation tolerances have been achieved. This method may also be used for tensioning of straight strands.

9. Hold-down devices shall be placed within a plus or minus 20 inch horizontal tolerance from the locations shown on the contract drawings; if minimum or maximum placement locations are shown on the contract drawings, the placement tolerances shall not encroach beyond these locations.

   The hold-down device shall not encumber or displace adjacent straight strands out of tolerance; and shall not produce nicking of any drape or bundled strands. The device shall secure the draped or bundled stands in the positions shown on the shop drawings, within all tolerances required by subsection 618.14(b).

(b) *Combination Tensioned Members*. Pretensioning of combination members shall be performed in accordance with subsection 618.07(a). All post-tensioning operations shall conform to subsection 618.07(c)

(c) *Post-tensioning Method.*

1. Post-tensioning and Grouting Systems Review. Upon review of the shop drawings, the Engineer will schedule a meeting with the Contractor to review

the post-tensioning and grouting procedures to be used on the project. The following individuals shall be in attendance at this meeting:

(1) The Engineer.
(2) The Contractor's Superintendent.
(3) A responsible representative of the post-tensioning system supplier. This individual shall have the following qualifications:

(i) Professional Engineer Registered in the State of Colorado.
(ii) Knowledgeable in the analysis of post-tensioned structures, the design required for shop drawing development, field calculations for revising tendon elongations from the assumed parameters to the actual strand area and modulus used on the project as determined by tests conducted on the strand by CDOT, and stressing of tendons.
(iii) A holder of a current Grouting Training Certificate from the American Segmental Bridge Institute.
(iv) Able to be present during all tendon stressing and grouting to keep written records of these operations for submittal to the Engineer for review.

(4) A grout manufacturer's field representative who will provide technical assistance to the grouting crew, and will be present during all grouting operations.
(5) The Contractor's designee who will be in direct charge of the post-tensioning and grouting crews. This individual shall have the following qualifications:

(i) Be skilled in the use of the post-tensioning and grouting equipment.
(ii) Have at least three years experience on previous projects supervising the post-tensioning and grouting of structures of similar type and magnitude.
(iii) Present on the project during the installation of the post-tensioning system, stressing operations, and grouting operations.

(6) Other individuals as deemed necessary by the Contractor or Engineer.

Ten days prior to the Post-Tensioning and Grouting System Review meeting, the Contractor shall submit a written plan for grouting the ducts. Grouting shall not begin until the Engineer has provided written approval of the grouting plan. The grouting plan shall provide at least the following information:

(1) The name, training, and experience records of the person supervising the grouting operations.
(2) Name of the grout material and the required certifications and test results.

(3) Manufacturer and type of grout mixer and pump to be used, including provisions for back-up equipment and spare parts.
(4) Grouting procedure and the role of each person on the crew.
(5) Theoretical grout volume calculations.
(6) Method for closing all duct orifices as grouting progresses.
(7) Grout mixing and pumping procedures.
(8) Location of grout inlet and direction of pumping.
(9) Procedures for handling blockages.
(10) Methods to inspect behind anchorages, grout inlets and outlets, and vents for voids.
(11) Procedures for post grouting repair of all grout voids detected.

2. Alternative Post-tensioning Systems. The Contractor may choose to supply the design and details of the prestressing system shown on the plans or submit an alternative for approval. Items considered as acceptable alternatives are:

(1) Alternative anchorage systems.
(2) Alternative number or sizes of ducts. The duct pattern must conform to an acceptable pattern as indicated on the plans.
(3) Alternative jacking ends.
(4) Alternative number of strands, provided the minimum area of steel and the center of force matches that indicated on the plans.
(5) Alternative duct type, friction coefficients, or anchor set.

The stressing sequence, details, or procedures shall not differ from what is called for on the plans, such that it would cause a change in the jacking force times initial stress ratios at the critical points identified on the plans, beyond an acceptable tolerance of 0 to +5 percent.

If the Contractor elects to submit alternative details, the alternative details shall conform to the following:

(1) The final center of force shall match that as indicated on the plans.
(2) If the plans call for a tendon to be composed of a certain number of strands, the Contractor's alternative shall have that same tendon composed of the same number of strands.
(3) If the plans call for a tendon to be composed of bars, the Contractor's alternative shall have that same tendon composed of bars.
(4) If the plans call for ducts and tendons internal to the member, the Contractor's alternative shall also have internal ducts. Similarly, if the plans call for ducts and tendons external to the member, then the Contractor's alternative shall also have external ducts.
(5) The alternative shall include details or calculations supporting the adequacy of the Contractor's alternative as specified in the shop drawing and calculation requirements of this specification.

(6) Bridge cross-sectional geometries, dimensions, and clearances shall match those indicated on the plans, with the exception of girder flares near anchorages.

3. Duct Fabrication and Placement. Duct enclosures for prestressing steel shall be either rigid corrugated plastic or galvanized, corrugated, rigid ferrous metal.

Metal ducts shall be fabricated with either welded or interlocked seams. Galvanizing of the welded seams for metal ducts will not be required.

The ducts shall be mortar tight and accurately placed within ½ inch of the positions shown on the approved shop drawings. Ducts shall be securely fastened to maintain their correct alignment during placing of concrete. Joints between sections of duct shall be positive rigid connections which do not result in angle changes at the joints. Waterproof tape shall be used at the connections. Ducts shall be bent without crimping or flattening. Transition couplings connecting ducts to anchoring devices need not be galvanized. Ducts shall be free of kinks. All changes of direction shall have a radius of 20 feet, unless otherwise shown on the plans.

The duct area shall be at least twice the net area of the prestressing steel for tendons composed of multiple wires, bars, or strands.

The duct diameter shall be at least ¼ inch larger than the nominal diameter of the wire, bar, or strand for tendons made up of a single wire, bar, or strand.

All ducts shall have grout openings at each end. Grout vents shall be provided at all high points and low points of draped tendons. In addition, at draped tendon high points, secondary high point gout vents shall be located three feet beyond all high points in the direction that the grout will be pumped.

Grout openings and vents shall be securely fastened to the ducts and forms or reinforcing steel to prevent displacement while placing concrete. The vents shall be mortar tight, taped as necessary and shall provide means for injection of grout. Ends of grout vents shall be removed to 1 inch inside the face of concrete surface after the grouting has been completed and the holes filled with an approved epoxy or non-shrink grout and finished smooth.

Once installed, the ends of the ducts shall be covered as necessary to prevent the entry of water or debris.

Prior to installation of the prestressing steel, the Contractor shall show that the ducts are free from debris and water. For ducts which are internal

to the member, the Contractor shall show that the ducts are free from any blockage or damage from the concrete placing operations. The Contractor shall do this immediately after the concrete encasing the duct has achieved initial set.

Once installed, the ducts (including the ends of the ducts at the anchorages, grout ports, and duct vents) shall be sealed immediately to prevent the entry of water or other debris until the tendons are grouted.

The use of water soluble oil, corrosion inhibitors, or a combination thereof in the ducts and flushing the ducts with water will not be allowed.

4. Post-tensioning Equipment and Procedure. Tensioning shall be done with approved jacking equipment. Hydraulic jacks shall be equipped with accurate pressure gauges at least 6 inches in diameter. The combination of jack and gauge shall have been calibrated within the last 12 months, in accordance with subsection 618.10(a). A certified calibration chart, graph, or table showing this calibration of the jack and gauge combination shall be furnished to the Engineer. The range of calibrations shall encompass the range of required forces indicated on the shop plans. The jacking equipment shall be capable of simultaneously stressing all wires, strands, or bars for each individual tendon.

   Tendons shall be stressed in accordance with the sequence as indicated on the reviewed shop drawings. If the Contractor chooses to deviate from the sequence, the Contractor shall resubmit the shop drawings for review. The sequence shall not cause stresses in excess of the maximum allowable stresses shown on the plans.

   Tendons shall be preloaded to 20 percent of their total jacking force, before measuring elongations.

   Measured elongations shall be within ± 7 percent of the calculated values, unless otherwise approved by the Engineer.

   A broken or damaged strand is cause for rejection of the tendon. If a strand is rejected, the remaining strands in the tendon will be evaluated by the Engineer for reuse.

   Where dead end anchorages and tendons are accessible, the anchorage system and length of projecting prestressing steel shall permit jacking with the same jacking equipment that was used on the live end.

   Tendon projections at the live end and accessible dead ends shall not be cut off until all post-tensioning is completed and accepted.

The representative of the post-tensioning system supplier shall keep a record of the following items for each tendon installed and provide a copy to the Engineer the day stressing is completed:

(1) Project name and number.
(2) Contractor and subcontractor.
(3) Tendon location, strand diameter, and number of strands.
(4) Date strand was first installed in the ducts.
(5) Heat number of the strands.
(6) Assumed and actual strand cross-sectional area and modulus of elasticity.
(7) Date stressed.
(8) Date of calibration of the jack and pressure gauge combination with their identification numbers.
(9) Required initial and final jacking force and the gauge pressure.
(10) Anticipated and actual elongations and anchor set.
(11) All deviations from the plans, specifications, and approved shop drawings shall be brought to the attention of the Engineer for immediate resolution.

618.08 Post-Tensioning Anchorages and Distribution. Prestressing steel shall be secured at the ends by means of approved permanent type anchoring devices.

Anchorages and couplers shall develop at least 95 percent of the minimum specified ultimate strength of the prestressing steel. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Couplers and coupler components shall be enclosed in housings long enough to permit necessary movements. Couplers for tendons shall be used only at locations specifically indicated or approved by the Engineer.

Couplers shall not be used at points of sharp tendon curvature.

Anchorage devices shall have a minimum clear concrete or grout coverage of 2 inches in every direction. Alternative corrosion protection methods for anchorages shall be shown on the shop drawings submitted by the Contractor.

The prestressing force shall be effectively distributed to the concrete by means of an approved anchoring device. Such devices shall conform to the following requirements:

(1) The average concrete bearing stresses on the concrete-created anchorage distribution plates shall not exceed the values allowed by the following equations:

During jacking:

$$f_{cp} = 0.8 f'_{ci} \sqrt{\frac{A'_b}{A_b} - 0.2} \leq 1.25 f'_{ci}$$

After jacking:

$$f_{cp} = 0.6 f'_{ci} \sqrt{\frac{A'_b}{A_b} - 0.2} \leq 1.25 f'_{c}$$

Where:

f_{cp}	=	permissible compressive concrete stress
f'_{ci}	=	compressive strength of concrete at time of jacking
f'_{c}	=	compressive strength of concrete
A'_b	=	maximum area of the portion of the concrete anchorage surface that is geometrically similar to and concentric with the area of the anchorage
A_b	=	bearing of the anchorage

If bursting steel is not used, the peak bearing pressure on the concrete at the time of jacking from the distribution plate shall not exceed 0.90 f'_{ci}. If the distribution plate or anchorage device is within 4 inches of any concrete edge or corner or another distribution plate or anchorage device, the pressure on the concrete shall not exceed 0.70 f'_{ci}. Construction joints shall not pass under distribution plates or anchors.

(2) Bending moments in the plates or assemblies induced by the pull of the prestressing steel shall not exceed the plastic strength of the material or cause visible distortion of the distribution plate when 100 percent of the ultimate prestress load is applied as determined by the Engineer.

(3) Distribution plates may be omitted if the anchorage device distributes the stresses in the concrete consistent with these specifications, and provided that this anchorage device is used in conjunction with embedded bursting and splitting reinforcement.

618.09 Bonding and Grouting.

(a) *General.* Post-tensioned prestressing steel shall be bonded by completely filling the void space within a duct with grout. Prestressing steel to be bonded shall be free of dirt, loose rust, or other deleterious substances. The ducts shall be kept free of water, dirt, or other deleterious foreign materials that will inhibit bond until the tendons are grouted.

When all ducts in a girder web have been stressed, the ducts shall be grouted within seven days. The exception to the seven day grouting requirement is during

cold weather when heating would be required to allow the ducts to be grouted in accordance with (e) below. If the Contractor chooses not to heat the structure, the ducts shall be grouted within 30 days after weather permits grouting in accordance with (e) below.

(b) *Grout.* Grout shall be prepackaged in bags.

The following information shall be printed on the grout bags: product name, name of the producer, date of packaging, lot number, and mixing instructions.

Grout shall not contain any lumps or other evidence of hydration.

The grout shall not contain aluminum powder or compounds, which will produce hydrogen gas, carbon dioxide, or oxygen. In addition, the grout shall not contain fluorides, sulphites, nitrates, calcium carbonate fillers, or acid-soluble chloride ions which exceed 0.08 percent by weight of the cementitious materials. The Contractor shall provide the Engineer with written certification from the grout manufacturer that the grout does not contain or produce these elements or compounds with the grouting plan.

The grout shall conform to the following Standard and Modified ASTM Tests in Table 618-1 when mixed in accordance with the manufacturer's instructions:

Table 618-1

Property	Test Value	Test Method
Total Chloride Ions	Max. 0.08% by weight of Cementitious material	ASTM C 1152
Fine Aggregate (If utilized)	Max. Size: 300 µm (No. 50 Sieve)	ASTM C 33
Volume Change at 24 hours and 28 days	0.0% to + 0.3%	ASTM C 1090 [1]
Expansion	2.0% for up to 3 hours	ASTM C 940
Compressive Strength at 28 days (Average of 3 cubes)	7,000 psi minimum	ASTM C 942
Initial set of the grout	3 hours minimum 12 hours maximum	ASTM C 953
Bleeding at 3 hours	Maximum 0.0 %	ASTM C 940 [4]
Permeability at 28 days	Maximum 2500 coulombs At 30 Volts for 6 hours	ASTM C 1202
FLUIDITY TEST [2]		
	Efflux Time from Flow Cone	**ASTM Method**
(a) Immediately after mixing	20 Seconds Minimum 30 Seconds Maximum OR 9 Seconds Minimum 20 Seconds Maximum	ASTM C 939 ASTM C 939 [3]
(b) 30 minutes after mixing with remixing for 30 seconds	30 Seconds Maximum OR 30 Seconds Maximum	ASTM C939 ASTM C 939 [3]

Footnotes for Table 618-1

[1] ASTM C 1090 shall be modified to include verification at both 24 hours and 28 days.

[2] Adjustments to flow rates shall be achieved by strict compliance with the manufacturer's recommendations.

[3] Grout fluidity shall meet either the Standard ASTM C 939 flow cone test or the Modified Test described herein. Modify the ASTM C 939 Test by filling the cone to the top instead of to the standard level. The efflux time is the time to fill a one liter container placed directly under the flow cone.

[4] ASTM C 940 shall be modified to conform with the wick induced bleed test as follows:

(i) Use a wick made of a 20 inch length of ASTM A 416 seven wire 0.5 inch diameter strand. Wrap the strand with 2 inch wide duct or electrical tape at each end prior to cutting to avoid splaying to the wires when it is cut. Degrease (with acetone or hexane solvent) and wire brush to remove any surface rust on the strand before temperature conditioning.

Footnotes for Table 618-1(continued)

(ii) Condition the dry ingredients, mixing water, prestressing strand and test apparatus overnight to 65 to 75 °F.

(iii) Mix the conditioned dry ingredients with the conditioned mixing water and place 800 ml of the resulting grout into the 1,000 ml cylinder. Measure and record the level of the top of the grout.

(iv) Completely insert the strand into the graduated cylinder. Center and fasten the strand so it remains essentially parallel to the vertical axis of the cylinder. Measure and record the level of the top of the grout.

(v) Store the mixed grout at the temperature range listed in (ii).

(vi) Measure the level of the bleed water every 15 minutes for the first hour and hourly for two successive readings thereafter.

(vii) Calculate the bleed water, if any, at the end of the three hour test period and the resulting expansion In accordance with the procedures outlined in ASTM C 940, with the quantity of bleed water expressed as a percent of the initial grout volume. Note if the bleed water remains above or below the top of the original grout height. Note if any bleed water is absorbed into the specimen during the test.

Each lot of grout used on the project shall have been sampled and tested within the last six months in accordance with the above referenced test procedures. The Contractor shall provide certified test reports for each lot of grout from an independently certified Cement Concrete Research Laboratory (For a listing of facilities contact NIST, Gaithersburg, Maryland, 20899) with the plan for grouting the ducts. Lots which do not meet the above requirements will be rejected.

(c) *Mixing of Grout.* All grout shall be mixed with a high speed shear (colloidal) mixer.

(d) *Grouting.* All grouting operations shall be performed under the immediate control of a person who has completed the American Segmental Bridge Institute (ASBI) Grouting Certification Training Program.

The Contractor shall perform the following tests and report the results to the Engineer:

(1) One pressure bleed test per day per lot in accordance with the requirements of Appendix C of the "Specification for Grouting of Post-Tensioned Structures" by the Post-Tensioning Institute. The Gelman filtration funnel shall be pressurized to 50 psi and the maximum percent bleed shall be zero.

(2) Two mud balance tests per day or when there is a visual or apparent change in the characteristics of the grout in accordance with the API Recommended Practice 13B-1 "Standard Procedure for Field Testing Water-Based Drilling Fluids".

(3) Minimum of one strength test per day per lot in accordance with ASTM C942 and the minimum 28 day compressive strength shall be 7000 psi.
(4) Minimum of two fluidity tests (flow cone) – one at the mixer and one at the duct outlet in accordance with ASTM C939, "Standard Tests Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)". The efflux time shall be between 11 and 30 seconds.

Grout shall be injected from the lowest end of a tendon to the highest end in an uphill direction. A continuous, one-way flow of grout shall be maintained for each duct.

All grout vent openings shall be open when grouting starts. Grout shall be allowed to flow to the first vent from the inlet pipe until residual slugs of water or entrapped air have been eliminated and the grout has the same consistency as that of the grout being injected. The vent shall then be capped or otherwise closed. Remaining vents shall be capped or closed in sequence in the same manner except that at draped tendon high points, the secondary vents placed a short distance downstream from the high point vent shall be closed before the highpoint vent.

The Contractor shall inspect the interiors of box girders during grouting operations for grout leakage. Leaks shall be sealed before grouting is continued.

Grout shall be pumped through the duct and continuously wasted at the outlet pipe until all visible slugs of water or air are ejected. To insure that the tendon remains filled with grout, the outlet shall be closed and the pumping pressure allowed to build to a minimum of 150 psi and held for one minute before the inlet vent is closed.

For all vertical tendons that are 20 feet and taller, a standpipe shall be provided at the upper end of the tendon to collect bleed water and allow it to be removed from the grout. This device shall be designed with commercial steel plumbing fittings so that the grout level will not drop below the elevation at the highest point in the upper anchorage device due to bleeding. If the level of the grout drops below the highest point in the upper anchorage device, additional grout shall immediately be added to the standpipe. After the grout has hardened, the standpipe shall be removed.

For vertical internal tendons, if the grouting pressure exceeds the maximum recommended pumping pressure, the grout shall be injected at increasingly higher outlets (which become inlets) that have been or are ready to be closed as long as one-way flow of grout is maintained. Grout shall be allowed to flow from each outlet until all slugs of air and water have been purged prior to using that outlet for injection.

Plugs, caps, and valves thus required shall not be removed or opened until the grout has set.

The Contractor shall monitor all anchorages, grout ports and vents periodically until the grout sets. The Engineer shall be notified if bleed water is dripping from these locations. Bleed water may be an indication of voids and will require investigation by the Contractor after the grout sets.

After the grout has set, anchorage grout caps and the grout port and vent plugs shall be removed. The Contractor shall inspect the tendon anchorages, grout ports and vents for voids or other evidence of incomplete grouting. If evidence is found of voids in these areas, the Contractor shall submit a plan for regrouting the voids to the Engineer for approval. All costs for remedial grouting will not be measured and paid for separately but shall be included in the work.

(e) *Temperature Considerations.*

The temperature of the concrete adjacent to the ducts shall be 40 °F or higher from the time of grouting until site cured 2-inch grout cubes, tested in accordance with AASHTO T 106, reach a minimum compressive strength of 800 psi.

Grout shall be between 40 and 90 °F during mixing and pumping. If necessary, the mixing water shall be heated or cooled.

618.10 Equipment. Equipment used for fabrication of pretensioned and combination tensioned members shall conform to the following requirements:

(a) *Jacking Equipment and Load Cells.* All equipment shall be calibrated as a system that represents actual use. Jacks, gage and pump systems, and load cells shall be calibrated at intervals not longer than 12 months, or whenever the tensioning system yields erratic results. Master gage systems shall be calibrated at intervals not longer than six months, or whenever the tensioning system yields erratic results. If load, sensor or indicator components are replaced or repaired, the system shall be recalibrated before resuming jacking operations. System error shall not exceed plus or minus 1 percent of the applied loads.

Calibration shall be performed by an agency or service that uses equipment certified by the National Institute for Standards and Technology (NIST). Accuracy of the calibration equipment shall be traceable to the NIST records. The calibration procedures used shall conform to ASTM Standard Practices E 4 and E 74. Each time that calibration verification is performed, a copy of the certified test report shall be furnished to the QA representative or the Engineer.

(b) *Concrete Batching Equipment.* The weighing system shall be calibrated at intervals no longer than 12 months. If disassembly, replacement, damage or repair of scales or balance indicators should occur, the weighing system shall be recalibrated before resumption of mix operations. Scale calibrations shall be performed in conformance with the State of Colorado - Department of Agriculture requirements. Current calibration labels shall be visibly displayed on the equipment.

The batching system shall record the weights of all concrete mix ingredients for each batch. Ingredient weights shall meet the requirements of ASTM C 94, Section 8, Measuring Materials.

The batching system shall be equipped with a flow meter which measures the weight or volume of the added mixing water within plus or minus 1 percent of the total water added to each batch.

(c) *Concrete Load Testing Machine.* The test machine shall be calibrated at intervals no longer than 12 months, or whenever the machine ram, sensor, or indicator components are replaced or repaired. Machine error shall not exceed plus or minus 1 percent of the applied load.

The machine calibration shall be performed according to the requirements of subsection 618.10(a), second paragraph. Current calibration labels shall be visibly displayed on the test machine.

(d) *Concrete Cylinder Molds.* 4 inch by 8 inch molds, (nominal diameter to length) shall be used to produce hardened test specimens free of deformation and distortion. The molds shall produce specimen diameters ranging from 3.96 to 4.04 inches ; with uniform lengths ranging from 7.92 to 8.08 inches. No diameter of an individual specimen shall differ from any other diameter on the same specimen by more than 2 percent. Molds shall be made of nonabsorptive materials that do not promote chemical reaction with cementitious products.

(e) *Forms.* Forms shall be sufficiently mortar tight to minimize fresh mortar paste leakage, and sufficiently rigid to prevent product distortion due to concrete pressure or consolidation operations. Form joints shall be kept clean, smooth and adjusted to minimize form finish irregularities.

Forms shall be constructed and erected to produce units that conform to the product dimensional tolerances required by subsection 618.14(b); the forms shall also meet smoothness tolerances required by this subsection.

Forms shall be treated with a form release agent that does not adhere to or significantly discolor the final concrete product.

Forms that have known deviations from the typical sections shown in the contract drawings, shall be approved by the Engineer before use. The deviations shall be submitted on working or shop drawings.

(f) *Miscellaneous Test Equipment*. All miscellaneous test equipment used during fabrication shall be kept in a condition such that accurate test results are obtained. Proper equipment maintenance and calibration shall be the responsibility of the Contractor’s QC section.

618.11 Concrete for Pretensioned and Combination Tensioned Products. The Contractor shall furnish and place concrete according to this subsection.

(a) *Classification.* Concrete shall be designated as class PS. The Contractor shall be responsible for the actual mix proportions and adjustments necessary to produce the specified strength. The specified strengths and air content shall be as stated on the plans. Fly ash material may be substituted for portland cement, up to a maximum of 25 percent by weight. If fly ash material is used in the mix, the total cementitious content shall be the sum of the weight of the portland cement and the weight of the fly ash material.

When voluntary use of fly ash by the Contractor results in delays, changes in mix quantities or materials sources, or unsatisfactory work, the costs of such delays, changes or corrective actions shall be borne by the Contractor.

(b) *Concrete Mix Components.* Materials sources shall be listed in the Contractor's QCP. The QC Manager must notify the QA representative in writing before changing the sources as listed in the QCP. For new sources, the Contractor must submit certified data for review and acceptance by the Engineer, at least 30 days before the sources can be used for production. Materials shall conform to the requirements of subsection 618.02(c).

(c) *Proportioning.* The minimum total cementitious content shall be 610 pounds per cubic yard of concrete. Fine aggregates shall not exceed 45 percent of the total aggregate volume. Aggregates from different sources and of different gradings shall not be stockpiled together.

(d) *Batching and Mixing.* Concrete shall be batched and mixed according to ASTM C 94.

(e) *Placing Concrete.* Forms shall be free of dirt, mortar, debris, and foreign substances before depositing the fresh concrete. Rust areas shall be cleaned to prevent rust staining of the finished products.

The concrete shall be consolidated with suitable mechanical vibrating equipment. Vibration time shall be of sufficient duration to accomplish adequate consolidation throughout the entire product, but shall not be prolonged to the point that segregation of the fresh concrete occurs.

The Contractor shall use the procedures listed in the QCP, to protect the freshly deposited concrete from rapid drying and surface moisture loss due to extreme ambient or climatic conditions.

Temperature limitations are as follows:

1. The temperature of the plastic concrete during placement operations shall not be lower than 50 °F.

2. Mixed concrete that has a temperature in excess of 90 °F shall not be placed.

3. The concrete shall be deposited in place within 90 minutes after batching; any load or portion of a load shall not be placed after the 90 minute limit.

4. Inner form temperature shall be within 40 °F of the fresh concrete temperature at time of concrete placement.

5. Minimum inner form temperature shall be 40 °F at the time of concrete placement.

6. Maximum inner form temperature shall be 130 °F at the time of concrete placement.

(f) *Finishing Fresh Concrete*. Open surfaces of fresh concrete shall be worked as little as possible to obtain the finish shown on the plans. Water shall not be added to the surfaces to ease finishing. Excessive water or laitence brought to the surface through vibration shall be removed before the surface is final finished.

Monomolecular film coatings or fogging systems, as approved by the QA Representative, may be used to retard evaporation during extreme ambient conditions. Application methods shall deposit a fine mist spray over the concrete surface. Streaming, puddling, or droplet application of coatings shall not be permitted. The concrete surfaces shall not be reworked after application of mist.

(g) *Concrete Testing*. The Contractor's QC section shall make representative cylinder test specimens for QC/QA testing. The Contractor shall forward test cylinders to the QA representative, for 28-day strength tests, and for shipping strength tests as required by subsection 618.15. Concrete tests shall be performed in accordance with the following requirements:

1. Test cylinder specimens shall be made in accordance with ASTM C 31, except that 4 inch by 8 inch size specimens shall be made and vibration consolidation shall not be allowed. Specimens shall be cured as listed in the accepted QCP.

2. Cylinders shall be tested in accordance with ASTM C 39. The average strength of at least two test cylinders shall be greater than the minimum required strength. No individual strength test shall be more than 7 percent below the minimum required strength.

3. Cylinder test specimens shall be made to verify stress transfer strength and to verify 28-day design strength. If the products will be shipped prior to 28-day testing, additional test specimens shall be available to verify product strength prior to shipment.

4. Representative cylinders shall be molded for each 50 cubic yards or portion thereof, for each different concrete mix design used per day per product line.

5. Air Content, when specified, shall be determined in accordance with either ASTM C 173 or ASTM C 231. Air entrained mixes shall be tested a minimum of once per day to assure specified air entrainment.

6. Slump of fresh concrete shall be determined in accordance with ASTM C 143. The slump shall be tested whenever test cylinder sets are made.

7. Unit Weight of fresh concrete shall be determined in accordance with ASTM C 138. Unit weight shall be tested a minimum of once per day for each different concrete mix design used.

8. Temperature of fresh concrete shall be taken as needed, to assure compliance with the temperature requirements.

618.12 Curing.

(a) *Pretensioned and Combination Tensioned Members.* Members shall be uniformly cured from the time of concrete placement until at least two representative product test specimens achieve an average strength that meets or exceeds 0.7 f'_c or the specified release strength, f'_{ci} whichever is higher.

Where:
f'_c = 28 Day Compressive Strength of Concrete
f'_{ci} = Required Concrete Strength at Release of Prestress Force

Additional curing requirements shall be maintained until the above strength requirements are achieved, and are as follows:

1. Exposed concrete surfaces shall be kept moist from the time of concrete placement until the freshly finished concrete is covered with an enclosure that retains heat and moisture. After enclosure, moist curing shall be maintained at a minimum 70 percent relative humidity.

   The Contractor shall monitor the temperature and humidity conditions from the initial curing period through the end of the accelerated curing stage.

2. Temperature of the concrete shall be maintained above 50 °F.

3. The internal and surface temperature of the concrete shall not exceed 160 ° F.

4. Concrete shall attain initial set prior to application of the accelerated curing cycle. If initial set was not determined in accordance with ASTM C 403, accelerated curing shall not be induced for 4 hours, or 6 hours if retarding admixtures are used.

While waiting for the initial set period, low cycle heat may be applied to maintain the curing chamber temperature, however, the temperature rise shall not exceed 10 °F per hour during the waiting period.

5. The rise in temperature in the curing chamber during accelerated curing cycle shall not exceed 40 °F per hour.

(b) *Cast-in-Place Members.* The curing of cast-in-place members shall conform to the requirements of subsection 601.13. The concrete shall not be exposed to temperatures below freezing for six days after casting, or until it has reached the strength required for applying the prestressing force. The minimum strength of the concrete shall be at least, 3500 psi for post-tensioned members, or as given on the plans whichever is greater, before prestressing.

(c) *Other Precast Members.* Precast members that do not contain pretensioned steel shall meet curing requirements as follows:

1. Exposed surfaces of freshly finished concrete shall be covered with moisture retaining material, or shall be treated with a concrete curing compound approved by the QA representative.

2. Temperature of the concrete shall be maintained above 50 °F from the time of concrete placement until the curing is complete.

3. Uniform curing shall continue until at least two representative product test specimens achieve an average strength that meets or exceeds 0.7 f'_c or the specified release strength f'_{ci} whichever is higher.

4. The internal and surface temperature of the concrete shall not exceed 150 ° F.

618.13 Repairs of Pretensioned and Combination Tensioned Members. Repairable product defects discovered during QC or QA inspection, shall be corrected at the Contractor's expense prior to shipping. Damage incurred during handling, storage, shipment and erection shall be repaired or replaced at the Contractor's expense.

Defects shall be categorized as minor, structural, or rejectable. The QC section shall examine and record all defects. The QC section shall submit a written proposal for minor repairs to the QA Representative for review and acceptance prior to correcting the minor defects. The proposal shall also address the measures the Contractor will take to prevent recurring defects in future members. The QA Representative will approve, or reject, the finished repair work in writing.

Small production holes that are less than ½ inch in depth and less than 1 square inch in surface area, shall not be considered defects. Larger production holes shall be repaired according to the procedures listed in the QCP.

Structural and rejectable defects shall be examined by the Contractor's Engineer. A written proposal for repair of structural or rejectable defects shall be submitted to the QA Representative for review and acceptance prior to correcting any defects. The proposal shall include a detailed description and sketch of the defects, detailed repair procedures, description of repair materials, and the methods the Contractor will use to evaluate the finished repair work. The proposal shall also include the measures the Contractor will take to prevent recurring defects in future members.

Completed repairs shall be cured as needed to ensure soundness of the reworked area.

The defect categories and repair requirements are defined as follows:

(a) *Minor Defects*. Minor defects are those which do not affect the ability of the product to withstand service or construction loads. Minor defects include superficial discontinuities such as cracks; small spalls, voids and honeycombed areas; and defects that do not extend beyond the centerline of any reinforcing steel or into any elements of the tensioning system. Minor defects of other types may also be designated by the QA Representative.

Repair methods shall not affect the structural integrity of the product. The finished repair work shall meet the approval of the QA Representative and the Engineer.

(b) *Structural Defects*. Structural defects, as determined by the QA Representative or the Engineer, include defects which may impair the ability of the product to adequately withstand construction or service loads. Defects that extend beyond the centerline of any reinforcing steel or into any element of the tensioning system are classified as structural defects. Such defects also include cracks, spalls, honeycombed areas, voided areas, significant concrete breakage areas, cold joints, and segregated concrete areas. Structural defects of other types may also be designated by the QA Representative or the Engineer.

Repair methods shall adequately restore structural integrity of the product. When repairs have been completed, the Contractor's Engineer shall examine and analyze the product for construction and service load ability, and certify in writing that the repair work is structurally adequate. Evaluation and test data shall be submitted along with the written certification. The finished repair work, including aesthetic acceptability, shall meet the approval of the Engineer.

(c) *Rejectable Defects*. Rejectable defects or damages, as determined by the QA Representative or the Engineer, are those which impair the ability of the product to adequately withstand construction or service loads, and which cannot be successfully repaired to structural and architectural acceptability. Structurally defective or rejected products shall not be incorporated into the work but shall be replaced with acceptable products supplied at the Contractor's expense.

Damaged and defective products will also be rejected by the QA Representative for the following reasons:

1. Failure by the Contractor's Engineer to approve and submit proposed repair procedures in writing before repair work begins.

2. Failure by the Contractor to execute the repair work according to QA approved procedures.

3. Failure by the Contractor to provide written certification of acceptable structural repair, along with submittal of evaluation and test data, if applicable.

4. Failure by the Contractor to correct recurring defects.

5. Determination by the QA Representative that the work, or materials used in the work, does not meet all contract requirements.

618.14 Other Fabrication Requirements for Pretensioned and Combination Tensioned Members.

(a) *Finishing Hardened Concrete Products.* Finished and repaired areas shall reasonably match the coloration and profile characteristics of the adjacent concrete. Loose concretious laitence shall be removed from the product before storage.

Each finished product shall clearly display legible identification markings that show the cast date, piece mark and unique sub-mark. The marking shall also identify the setup location where the product was cast.

Finishing operations shall also conform to the following requirements:

1. Excessive laitence and unsound rubble shall be removed from surfaces to be bonded.

2. Fins and irregular projections shall be removed from the formed surfaces.

3. Bulges or offsets on the formed surfaces greater than ¼ inch shall be smoothed by stoning, sawing, or grinding.

4. Dented and inset surfaces greater than 4 square inches in area and deeper than ½ inch shall require a written repair proposal before repair or finish work begins.

5. Patches in areas of exposed steel or prestressing strand shall be bonded with an approved bonding agent and patched with an approved non-shrink grout.

6. If liquid membrane curing compounds are used on the concrete surfaces which are to be bonded, they shall be removed by sandblasting, prior to shipping the product.

(b) *Product Dimensional Tolerances*. Tolerances for prestressed concrete products shall meet the unit tabulations listed in the PCI Manual MNL-116, unless otherwise stated in the Contract. The PCI tolerance figures and tabulations shall be specification requirements. Out-of-dimensional-tolerance variations shall be considered defects and shall be examined and evaluated by the Contractor's Engineer. The evaluation shall be submitted to the QA Representative in writing and shall contain written opinion of structural adequacy as determined by the Contractor's Engineer. The submittal shall meet the approval of the Engineer. Failure to submit the written evaluation and opinion will be cause for rejection.

The following work or products shall meet the specific PCI tolerance requirements described as follows, unless otherwise specified in the plans:

(1) Bulb-Tee Sections shall conform to Division VI, I-Beams.
(2) G-Series Sections shall conform to Division VI, I-Beams.
(3) Box Girders shall conform to Division VI, Box Beams.
(4) Deck Panels shall conform to the dimensional tolerances as listed in the PCI Special Report JR-343-88, Chapter 4, or the updated published edition thereof.

(c) *Handling, Storage, Shipment and Erection*. The Contractor shall handle the product in such a manner as to prevent cracking or damage. Cracked or damaged products shall be inspected by the QC section and repaired in accordance with subsection 618.13, or replaced at the Contractor's expense.

Braces, trusses, chains, cables, or other metal devices used for handling, storing, shipping, or erecting shall be adequately padded at points in contact with the concrete, to prevent chipping of the finished product.

Beam sections shall be handled, stored, shipped and erected with supports and devices that maintain the product in an upright position. Deck panels shall be lifted as directed in the Contract unless alternative lifting methods are allowed by the Engineer. Lifting of more than one panel at a time shall not cause panel cracking. Methods for multiple lifting of panels shall be shown on the working or shop drawings. Panel products shall be stacked in such a manner that damage does not occur.

Pre-cast concrete members shall be erected in a manner that will provide safety to the Contractor's forces, inspectors and the traveling public. Pre-cast concrete members shall be erected in a manner to prevent damage to all elements of the structure. The primary members such as beams and girders shall be temporarily anchored and braced as they are erected to preclude detrimental movement in any direction, and to prevent overturning and buckling. Struts, bracing, tie cables, and other devices used for temporary restraint shall be designed to resist all loads imposed during each stage of construction until completion of the deck concrete.

At least four weeks prior to erection, the Contractor shall approve, sign and submit a proposed plan of erection to the Engineer for record purposes only. The Erection Plan shall be approved by, and contain the seal and signature of, the Contractor's Professional Engineer registered in the State of Colorado. The Erection Plan will not be approved by the Engineer. If falsework drawings are required, they shall be submitted in accordance with subsection 601.11.

The Erection Plan and procedure shall provide complete details of the erection process including but not limited to:

(1) Temporary falsework support, bracing, guys, deadmen, connection details and attachments to other structure components or objects
(2) Procedure and sequence of operation including a detailed schedule that shall comply with the working hour limitations
(3) Cranes: make and model, weight, geometry, lift capacity, outrigger size and reactions
(4) Girder weights, lift points, lifting devices, spreaders, and angle of lifting cables
(5) Assumed loads and girder stresses during progressive stages of lifting and erection to substantiate the structural integrity and stability of the girders prior to completion of the entire structure
(6) Girder launcher or trolley details and capacity (if intended for use);
(7) Locations of cranes, trucks delivering girders, and the location of cranes and outriggers relative to other structures, including retaining walls, wing walls and utilities
(8) Material properties and specifications for temporary works
(9) Drawings, notes, catalog data showing the manufacturer's recommendations or performance tests, and calculations clearly showing the above listed details, assumptions, and dimensions

A Pre-Erection Conference will be held at least two weeks prior to the beginning of erection. The Contractor and the Contractor's Professional Engineer shall attend the meeting.

The Contractor's Professional Engineer shall inspect and provide written approval of each phase of the installation prior to allowing vehicles or pedestrians on or below the structure. The Contractor's Professional Engineer shall approve all changes to the Erection Plan. The Contractor shall submit all changes to the Erection Plan to the Engineer for record purposes only. The Contractor shall demonstrate his knowledge and familiarity with the location of the piece marks and the piece mark convention used by the girder fabricator at the Pre-Erection Conference. This is required to assure the structural components are assembled in accordance with the reviewed shop drawings.

The Contractor shall perform daily inspections of the erected girders until completion of the deck concrete. The Contractor shall provide the Engineer with written documentation of these inspections within 24 hours.

All temporary struts, bracing, tie cables, other devices and extra material required shall be removed upon completion of the structure.

618.15 Product Shipping Strength for Pretensioned and Combination Tensioned Members. Products shall not be shipped before concrete strength meets or exceeds 0.95 f'_c. The average of at least two representative test specimens shall meet or exceed 0.95 f'_c. No individual specimen strength shall be more than 7 percent below 0.95 f'_c. The shipping strength test specimens shall be cured in the same environment as the actual product until the time of testing. The QC section shall test the specimens for actual shipping strength. The QA Representative may independently verify any shipping strength tests.

The Contractor may elect to take concrete cores from the actual product in lieu of curing cylinder test specimens with the product. If the Contractor chooses this test option, the QC Manager shall submit written request to the QA Representative. Core extraction shall not begin until the request has been accepted in writing by the QA Representative. The written request shall include the proposed location and time schedule for core extraction and testing.

The cores shall be delivered in a wrapped and moist condition to the certified test laboratory as listed in the QCP. The QA Representative may witness any or all stages of the core testing operations. The test laboratory shall provide a copy of the formal test report to the QA Representative.

The Contractor shall bear all expenses associated with the optional core testing requirements. Sampling and testing of the concrete core specimens shall conform to ASTM C 42 with the following addenda:

(1) Samples may be removed at any age at the Contractor's sole risk of damage.
(2) Test cores shall not contain embedded reinforcement.
(3) A minimum of three core samples shall be taken from the product casting in question. Three specimens shall be tested for compressive strength. The average compressive strength of the three tests shall meet or exceed product f(c). If the compressive test result of any specimen differs from the average strength by more than 15 percent, those results shall be disregarded, and the compressive strength shall be determined from at least two remaining valid test results.
(4) If end capping of test specimens is necessary, the capping shall be done with sulfur mortar in accordance with ASTM C 617. Specimens shall be kept moist until end capping preparation begins.

    Ends shall be trimmed or prepped as required, wiped with absorbent cloth and air-dried or fan-dried to prepare for end capping. The drying period shall not exceed 20 minutes before capping is completed.

    Specimens shall be air-dried for 10 to 20 minutes after capping, then wrapped with a double layer of wet, thick cloth or burlap. Compressive testing shall not be

started for at least one hour after wet-wrapping. The wrapped specimens shall be kept moist until compressive testing begins.

The Contractor shall submit a written repair proposal to the QA Representative for patching the core holes. Repair work shall not begin until the proposal is accepted in writing by the Engineer.

METHOD OF MEASUREMENT

618.16 Prestressed units will be measured by one of the following methods as indicated in the Contract.

(1) Prestressed girders will be measured by the linear foot from end to end or by the square foot, based on the plan length multiplied by the plan width, whichever is specified on the plans.

(2) Prestressed concrete box girders and prestressed concrete slabs will be measured by the square foot based on the plan length multiplied by the plan width.

(3) When measured by component materials, concrete and reinforcing steel will be measured and paid for in accordance with Sections 601 and 602 respectively.

The quantities of prestressing steel will not be measured but shall be the quantities shown on the plans, completed and accepted. MKFT equals the jacking force, in thousands of KIPS, times the length in feet.

Precast panel deck forms that are required by the plans will be measured by the square foot. The quantity will not be remeasured, but will be the quantity shown on the plans, except when a plan change is ordered or when it is determined that there are discrepancies in an amount of plus or minus 2 percent of the plan quantity.

BASIS OF PAYMENT

618.17 The accepted quantities of prestressed units and prestressing steel will be paid for at the contract unit price per unit of measurement for each of the pay items listed below that is included in the bid schedule. Precast panel deck forms required by the plans will be paid for at the contract unit price for the area shown on the plans.

Payment will be made under:

Pay Item	**Pay Unit**
Prestressing Steel Bar	Pound or MKFT
Prestressing Steel Strand	Pound or MKFT
Prestressed Concrete _____(_____)	Linear Foot or Square Foot
Prestressed Concrete Box (_____)	Square Foot
Prestressed Concrete Slab (Depth _____)	Square Foot

Payment will be full compensation for all work necessary to complete the designated pay item.

Prestressing steel bar and prestressing steel strand shall include but not be limited to all anchorage devices, prestressing steel, ducts, grout, and miscellaneous hardware. Elastomeric leveling pads, and galvanized steel diaphragms and connectors will not be paid for separately, but shall be included in the work. Concrete and reinforcing steel not shown on the plans but required by the Contractor's alternative will not be paid for separately but shall be included in the work.

Concrete quantities will not be reduced for the volume occupied by the ducts, prestressing steel, anchorages, blockouts for tensioning, etc., and will not include web flares, projections, warts, etc., required to accommodate the prestressing system used.

All costs associated with implementing the Erection Plan will not be paid for separately but shall be included in the work.

Concrete, reinforcing steel, and prestressing steel for permanent steel bridge deck forms will not be measured and paid for separately, but shall be included in the work.

SECTION 619
WATER LINES

DESCRIPTION

619.01 This work consists of the construction of water lines in accordance with these specifications, the latest revision of the American Water Works Association Standards and in conformity with the lines and grades shown on the plans or established.

This work also includes furnishing welded steel pipe and installing it by jacking it into place at the location and in conformity with the lines and grades shown on the plans.

MATERIALS

619.02 Materials shall meet the requirements specified in the following subsections:

Cast Iron Pipe	716.01
Welded Steel Pipe	716.02
Galvanized Pipe	716.03
Copper Pipe	716.04
Plastic Pipe	716.05
Valves and Valve Boxes	716.07

Specific type of material, when required, will be shown on the plans or as designated.

The maximum working water pressure will be shown on the plans.

Welded steel pipe, when used as a casing and not as a carrier pipe, will not require full depth welds or welds from both sides, and will not require coatings. Sections of the casing shall be welded firmly together on the inside to prevent separation. Certification of the welder/operator will not be required.

CONSTRUCTION REQUIREMENTS

619.03 Trench shall be excavated to a width sufficient to allow for proper jointing of the water line and thorough compaction of the backfill material in accordance with Section 206.

Where ground water occurs, the bottom of the trench shall be kept free of water during pipe laying and until backfilled.

Backfilling shall consist of suitable materials uniformly distributed in layers of not more than 8 inches.

Each layer shall be thoroughly compacted as required. All joints, connections, valves and fittings shall be watertight.

(a) *Jacked Pipe.* The term “jacking” as used herein shall mean jacking, boring, or other approved construction methods. Method of installing pipe other than jacking may be used only with written approval from the Engineer. Trenching,

jetting, or any other method that may cause damage to the embankment or highway area, or be hazardous to the traveling public will not be permitted. When jacking is specified, the pipe must be jacked without disrupting highway traffic.

The sides of the jacking pit shall be supported in such a manner as to prevent any movement or slippage of the earth during the jacking operations.

A jacking frame shall be constructed of guide timbers or rails to the exact line and grade of the casing and shall be capable of maintaining the desired alignment and gradient throughout the jacking operation.

Depending upon the soil conditions, the excavation operation inside the pipe shall proceed approximately 1 foot ahead of the lead pipe. The excavation around the pipe shall be cut accurately to line and grade and as reasonably close to the outside diameter of the pipe as possible.

Each section of pipe in its final position shall be straight and true in alignment and grade. Deviation in alignment and grade from beginning to end of the jacked pipe shall not exceed plus or minus 0.3 foot per 100 feet of length.

METHOD OF MEASUREMENT

619.04 Water lines of the various types and sizes will be measured by the linear foot in place and shall include all fittings. Valves including valve boxes will be measured by the actual number of the specified type and size used in the completed water lines, and accepted.

The quantity of jacked pipe will be measured by the linear foot complete in place and accepted.

BASIS OF PAYMENT

619.05 The accepted quantities of water line will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	**Pay Unit**
_____ Inch Cast Iron Pipe	Linear Foot
_____ Inch Welded Steel Pipe	Linear Foot
_____ Inch Galvanized Pipe	Linear Foot
_____ Inch Copper Pipe	Linear Foot
_____ Inch Plastic Pipe	Linear Foot
_____ Inch (Type) Valve and Valve Box	Each
_____ Inch Welded Steel Pipe (Jacked)	Linear Foot

Structure excavation and structure backfill for lines 12 inch and less will not be measured and paid for separately but shall be included in the work. Structure excavation and structure backfill for lines larger than 12 inch will be measured and paid for in accordance with Section 206.

All work incidental to installing jacked pipe will not be measured and paid for separately but shall be included in the work.

SECTION 620
FIELD FACILITIES

DESCRIPTION

620.01 The Contractor shall furnish field offices, sanitary facilities and field laboratories when called for on the plans or as directed. These units are to be maintained by the Contractor and shall be removed when the project is completed unless released earlier by the Engineer.

MATERIALS

620.02 Field Offices. Field offices, either Class 1 or Class 2 as designated on the plans, shall substantially conform to the details shown on the plans and to the requirements of this section.

The minimum inside height for a field office shall be 7 feet if the facility is certified as having been manufactured prior to November 1, 1992.

The field office shall be equipped with a facsimile machine, copy machine, and telephone service that conform to the following:

(1) Facsimile Machine. The facsimile machine shall print on plain paper and shall be capable of sending 8 ½ x 11 inch and 8 ½ x 14 inch documents. The Contractor shall install and maintain the fax machine in the Engineer's field office. Should the fax require repair and be out of service for more than 24 hours, a replacement machine shall be supplied within 24 hours. The Contractor shall supply all necessary supplies, except paper, and a rollaround stand. Paper will be provided by the Department.

(2) Copy Machine. The Contractor shall provide a self feeding plain paper photo copying machine, which is capable of making at least eight copies per minute. Copier shall also be capable of reproducing copies at standard sizes up to and including 11 x 17 inches. The copier shall be capable of reducing 11 x 17 plan sheets to 8 ½ x 14 legal size and to 8 ½ x 11 letter size. The Contractor shall supply all necessary supplies, except paper, and a roll around stand. Paper will be provided by the Department. The Contractor shall maintain all furnished equipment in good working condition and shall provide replacement equipment due to breakage, damage, or theft within five working days.

(3) Telephone Service. The Contractor shall provide telephone service as required by standard plans. This service shall include a long distance carrier. The Department will be responsible for actual long distance toll charges.

620.03 Field Laboratories. Field laboratories, either Class 1 or Class 2 as designated on the plans, shall substantially conform to the details shown on the plans and to the requirements of this section.

Each laboratory shall be qualified in accordance with CP 10.

The minimum inside height for a field laboratory shall be 7 feet if the facility is certified as having been manufactured prior to November 1, 1992.

620.04 Commercial Plant Laboratory. The plant laboratory at the site of the commercial hot mix plant shall consist of weatherproof, insulated, mobile housetype trailer or other approved structure having equipment meeting the following minimum requirements.

Each laboratory shall be qualified in accordance with CP 10.

(1) Outside Dimensions: 28 feet long x 12 feet wide if a separate facility is provided, or inside area of 175 square feet with a minimum width of 7 feet when not a separate facility

(2) Drinking Water Supply: Dispensed from an acceptable water cooling device

(3) Testing Water Supply: 100 gallons, insulated and pressurized by pump, minimum 30 psi delivery pressure

(4) Shelving: 24 linear feet

(5) Sink: One, with faucet

(6) Fire Extinguisher: One, non-toxic, dry chemical, meeting Underwriters Laboratories, Inc. approval for 10 pound class ABC with 20 BC rating.

(7) Work Bench: 19 feet x 30 inches x 36 inches high.

(8) Lighting: Adequate fluorescent lighting directly over all work bench and desk areas

(9) Range: One, 30 inch free standing, oven with reinforced racks, and four surface burners

(10) Sieve Shaker: One, motor-driven, standard portable, capable of handling a set of 8 inch US standard sieves, mounted 24 inches above floor in a sound-proof, insulated enclosure having hinged openings

(11) Heating: Furnace, 200 BTU per square foot, minimum, forced air type

(12) Telephone: Minimum flat rate service from nearest exchange

(13) Air Conditioner: Adequate for laboratory size

(14) Furniture: Desk with at least one drawer. One desk chair with rollers. One stool with height compatible with work bench

(15) Balance: Balance or scale capable of weighing 20,000 grams to an accuracy of one gram

(16) Microwave Oven: One, 1.5 cubic foot, with at least five power levels, and revolving floor or rotating power source

620.05 Sanitary Facilities. Sanitary facilities shall consist of a portable chemical toilet fabricated from steel, fiberglass or wood, meeting the following minimum requirements:

Each facility shall be well ventilated, shall conform to State law, shall have a vented chemical tank and a separate urinal.

CONSTRUCTION REQUIREMENTS

620.06 The Contractor shall furnish a suitable site for field facilities. The site may be located within the right of way with approval of the Engineer. If located within the right of way, the Contractor shall be responsible for restoring the area.

Facilities shall be on the project, leveled and ready for use prior to the start of any operations. Facilities shall be for the exclusive use of Department personnel.

The Contractor shall provide replacement equipment due to breakdown, damage, or theft within five working days.

620.07 Maintenance, Service and Utilities. The Contractor shall furnish the following:

Fuel:	Adequate supply for heating and testing operations.
Electricity:	A 3000 watt, 115-125 volt AC facility for each field office and field laboratory. Independent generators shall be provided where commercial power is not available.
Telephone:	Minimum flat rate service from nearest exchange for each field office and field laboratory as directed.
Sanitary:	Sanitary facilities shall be serviced and maintained in a sanitary condition.
Trash:	The Contractor shall provide and maintain suitable containers and shall haul away as necessary.

METHOD OF MEASUREMENT AND BASIS OF PAYMENT

620.08 The various facilities complete with utilities, will be measured and paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

620.08

Payment will be made under:

Pay Item	Pay Unit
Field Office (Class_____)	Each
Sanitary Facility	Each
Field Laboratory (Class_____)	Each

Payment will be full compensation for Field Laboratory (Class1) or (Class 2), including all appurtenant items specified in the Contract.

Restoration of the field facility areas will not be paid for separately, but shall be included in the cost of the item.